Technical and Final Report: Application and Findings of the North Bay-Delta Transect Watershed Assessment Framework (WAF)

Application of the Watershed Assessment Framework (WAF) in the Napa River Watershed - County of Napa 460000793

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May 24, 2010

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Acknowledgements

The project team would like to thank the project's funders and contributors.

Most of the project's funding came from the Department of Water Resources, agreement number 4600007937. Thanks also to the Supervisors of the County of Napa, and to the Napa County Resource Conservation District, for providing matching funding.

The approach taken here owes a debt to the North Bay Watershed Association's work on indicators and performance measures, and to the Watershed Health Scorecard project led by the Sonoma Ecology Center and Napa County RCD.

Thanks for supporting this effort go to Hillary Gitelman, Director; Patrick Lowe, Deputy Director; and Lynsey Kelly, GIS/Planner, at Napa County's Conservation, Development, and Planning Department. Kathleen Wallis in Napa County Information Technology Services also provided volumes of necessary data.

A special thank you also to other WAF project teams throughout the state. Their willingness to share their understanding, their work products, and the challenges of the tasks at hand made this project go further along than it would have had we worked in isolation.

8. Appendices

8.1 Glossary of Watershed Assessment Framework terms

Glossary of Terms

This appendix provides a list of terms useful in communicating effectively and ensuring consistency among California based Watershed Assessment Framework (WAF) Valuation projects.[1] The terms and definitions provided below come from a combination of reports and background documents from both state and federal efforts towards developing ecological condition reporting frameworks for monitoring watershed condition and health.[2]

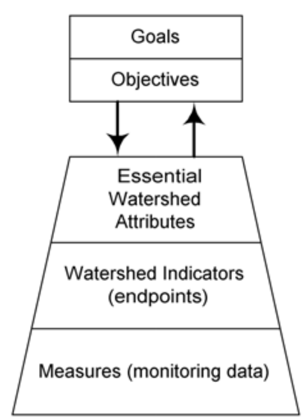
Watershed Assessment Framework

The Watershed Assessment Framework (WAF) is in an evaluation framework developed for use at the scale of identified watershed boundaries. The geographical scope of the assessment framework varies, and is based upon the washed area being evaluated. The concept and use of the WAF was developed by the USEPA's Science Advisory Board and has been adapted to meet watershed monitoring needs and performance measures identified in the California Watershed Management Strategic Action Plan.

The framework provides a scientifically defensible approach for aggregating and assessing a multitude of environmental, economic and social data. The framework can be used to assist in linking the condition of a watershed's air, water, land, biota, and social structures into a broad framework termed ecosystem condition — the sum total of the physical, chemical, social and biological components of the watershed and how they interact and change over time. The WAF includes evaluation of economic and social conditions at the watershed scale and is a way of integrating consideration of environment, economics, and social conditions in watersheds. The WAF acknowledges that humans and their activities are integral parts of watersheds and their ecosystems.

Goals & Objectives

"***Goals and Objectives***. *Ideally, environmental management programs begin with a process to develop goals and objectives that articulate the desired ecosystem conditions that will result from the program(s)*." (USEPA SAB Report)



[1] http://www.water.ca.gov/watersheds/framework.cfm

[2] Developed by Fraser Shilling (UC Davis) based on the index/indicator literature and feedback from Jeff Sharp (Napa County) and Mike Antos (Los Angeles San Gabriel Rivers Watershed Council).

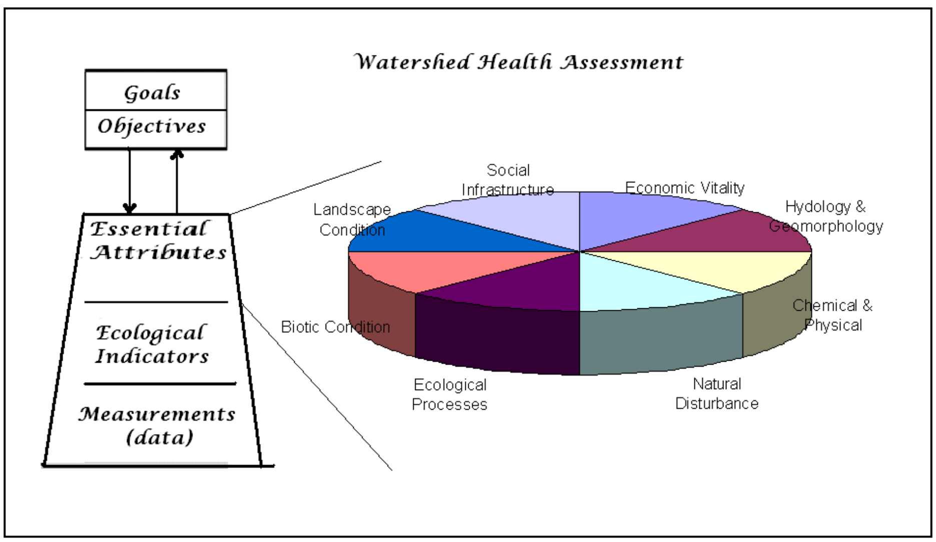
Goals describe desired outcomes for a watershed or similar place, through a particular project or program in a stated timeframe. In the case of the WAF, groups could set goals for the watershed, in which case they would be describing the desired outcomes for the watershed in some stated timeframe.
Objectives are the tactics to the goals' strategies. They describe actions that can be taken to implement or reach goals. Objectives for watersheds can be defined as actions that help reach desired outcomes for particular aspects of watershed condition.

Index

Sometimes organizations want to develop a comprehensive understanding of environmental or social health and express that as a single score, which is a composite of several or many indicators. This composite is usually called an index. In terms of the WAF, you could imagine scores for indicators within each essential attribute being composited into an overall attribute score for health assessment based upon a set of identified goals. In this case, the attribute is functioning as an index. The WAF is also an index, composed of the 8 attributes and component indicators, though a single index score for the WAF may be only generally meaningful.

Essential Watershed Attributes

"*The EEAs and their component categories and subcategories can be used as a checklist to help design environmental management and assessment programs and as a guide for aggregating and organizing information*." (USEPA SAB Report)



The essential watershed attributes (EWA) provide a way to categorize environmental and social processes to facilitate understanding and reporting of condition. The 8 essential attributes identified in the WAF valuation projects is a means to categorize various attributes that describe a watershed and are described below.
Landscape Condition The extent, composition, and pattern or structure of (non-human) habitats in a landscape.
Biotic Condition The condition or viability of communities, populations, and individual biota (i.e., at the scale of individual habitat types).

Ecological Processes Metabolic function of ecosystems - energy flow, element cycling, and the production, consumption, and decomposition of organic matter at the ecosystem or landscape level.
Social Condition The examination of the organization and development of human social life within the watershed, including measurements of community and social patterns, and behavior of individuals and groups.
Economic Condition Measures of the production, distribution, and consumption of goods and services within a watershed, including the valuation and of non-market resources that provide individual and community utility.
Chemical and Physical Characteristics Physical parameters and concentrations of chemical substances present in the environment/watershed (water, air, soil, sediment).
Hydrology/Geomorphology Characteristics that reflect the dynamic interplay of surface and groundwater flows and the land forms within the watershed.
Natural Disturbance The historical and/or contemporary function of discrete and usually recurrent disturbances, which may be physical, chemical, or biological in nature, that shape watershed ecosystems.

Categories

A category is a class of similar concepts, ideas, or things within in an organized and rule-based system to discriminate among classes where the discrimination is based on apparent differences among the categorized objects. EWAs are pseudo-categories in that they contain groups of similar indicators, but are not completely discreet and overlap each other. The EWAs often include sub-categories. Categories are one way to organize information in an overall condition index, like the WAF, where the categories and sub-categories are used to classify related indicators.

Indicators

***"Ecological Indicators** (also called ecological endpoints) are measurable characteristics related to the structure, composition, or functioning of ecological systems. Multiple indicators may be associated with each subcategory in the EEA hierarchy.*" (USEPA SAB Report)

Indicators (the backbone of the WAF process) provide a way to collect information about a condition and to report and compare condition over time. Indicators in the WAF are organized within EWAs and are based on metrics or measures of condition, though sometimes indicators and metrics are the same thing.

Metrics/measures

"***Measures.** The measures are the specific monitoring variables that are measured in the field and aggregated into one or more ecological indicators*." (USEPA SAB Report)
Metrics/Measures are the building blocks of indicators and thus the foundation of a condition assessment system (e.g., the WAF). Examples of metrics and measures

include dissolved oxygen concentration, proportion of successful nests (i.e., produce young) per season for a particular bird species, and fire return interval for a particular plant community within a study area. Each of these measures might fit into an indicator composed of one or more metrics (e.g., “fire dynamics”) that in turn is categorized into an EWA (e.g., natural disturbance) or EWA sub-attribute (e.g., fire).

Report Card

Category	Indicator	Metric	Score
Landscape Condition	Development	Impervious surface Fragmentation	65±13
Biotic Condition	Native fish	Out-migrants Habitat	43±22
Social Condition	Material relationship to watershed	Fishability	84±3
Economic Condition	Community well-being	School lunch program enrollment	71±15
Hydrology/Geomorphology	Erosion	TSS Bed-load movement	34±8
Ecological Processes	Exotic invasion	Extent Rate of spread	57±31
Natural Disturbance	Fire	Spread risk Succession/regeneration	35±16
Chemical/Physical Properties	Toxics	Metals Pesticides	52±9

Figure 1: Example use of Categories, Indicators and Metrics in a report card format

8.2 Report Card

Project Background

The Napa River is the largest river system that empties into the northern portion of San Francisco Bay. Relative to other watersheds in the North Bay, the Napa River watershed remains predominately rural, with about 34 mi^2 of urban development. The watershed supports an abundance of wildlife and a nearly intact community of more than 29 native fish species, including steelhead and fall-run Chinook salmon.

However, similar to the rest of the Bay-Delta region, the abundance and distribution of anadromous fish have diminished since the 1940s. In response to this and other water quality issues, the State Water Board listed the Napa River as impaired by sediment, nutrients and pathogens.

Fortunately, the Napa River watershed has strong community stakeholder involvement. This project grew out of local initiatives to understand ecological and community conditions in Napa Valley, such as the Watershed Information Center and Conservancy of Napa County, and out of regional and state-level efforts to standardize ecological reporting from watersheds.

Through various planning efforts, local stakeholders have expressed a suite of goals related to ecosystem protection and quality of life in the Napa River watershed. The project team consolidated these community goals and used them to select 14 meaningful indicators with readily available and reliable data. The project also identified challenges of conducting a large watershed scale assessment, data gaps, and recommendations to better understand and track progress towards community goals.

Learn More

Visit the project website to learn more!
http://sfcommons.org/scorecards/waf/napa

• The Report Card's final report, with details about the project's background, methods for selecting goals, objectives, and indicators, analyzing data, and interpreting results, and recommended next steps.

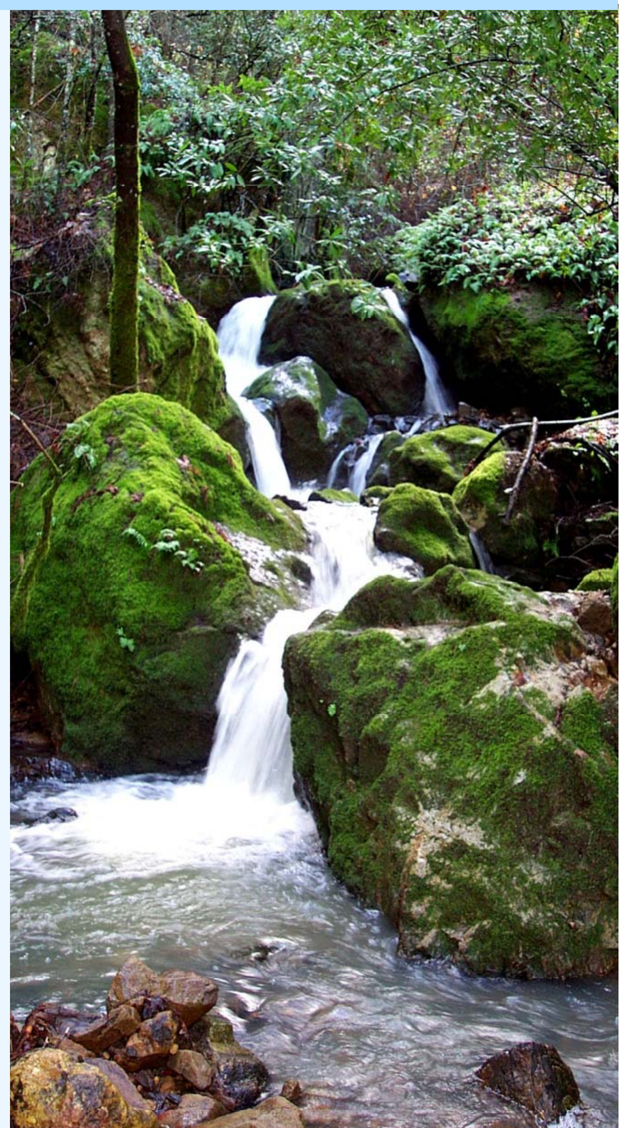
• Interactive display of watershed goals, indicators, and detailed indicator analysis results.

Project Contributors

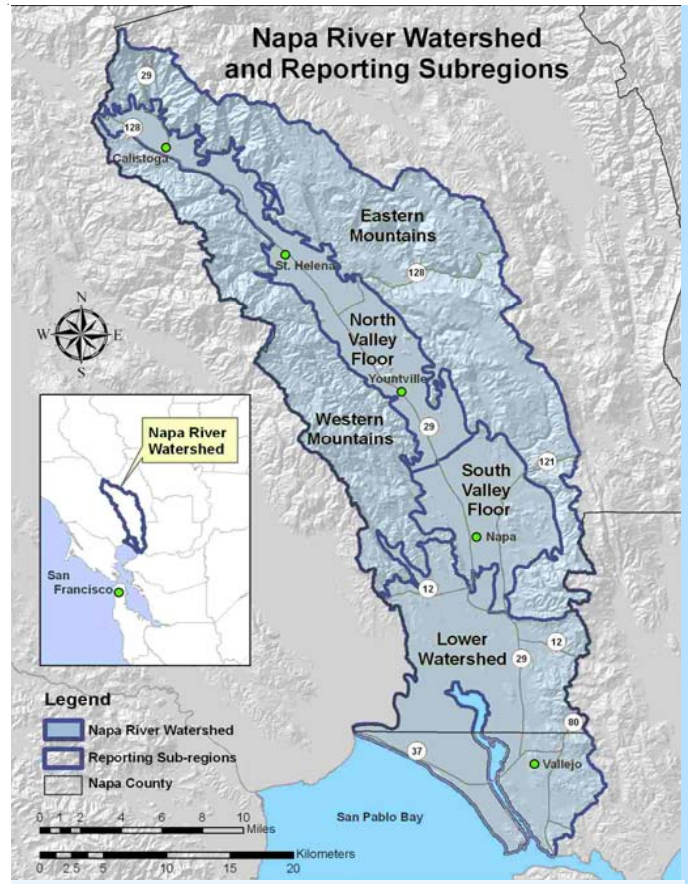
This project is a collaboration between the Napa County Conservation, Development, and Planning Department, the Napa County Resource Conservation District, Sonoma Ecology Center, University of California, Davis, and Oregon State University.

Funding was provided by the California Department of Water Resources, agreement 4600007937. The County of Napa and the Napa County Resource Conservation District provided matching funding.

The project benefitted directly from prior work conducted by the North Bay Watershed Association and the Watershed Health Scorecard project. Valuable input was also provided by the project's Technical Advisory Committee.



Napa River Watershed Report Card 2010



Watershed Goals and Indicators

A major objective of this project is to develop a system of indicators to track progress towards community watershed goals.

We surveyed stakeholders, examined planning documents, and consulted with our Technical Advisory Committee to come up with 6 overarching community watershed goals.

Indicators, which are measureable characteristics related to the structure, composition, or function of a watershed, were then compiled from local and regional planning documents, and other indicator projects throughout the world. We selected indicators for each community goal that met the following criteria:

- Availability of high-quality data
- Data affordability
- System representation
- Ability to detect change over time
- Independence from other indicators
- Support management decisions and actions
- Reportable and understandable

How Healthy is the Watershed?

The watershed condition scores across all 14 indicators are not extreme; based on these objective indicators, the overall health of the Napa River watershed is fair. There is considerable variation in health for most indicators across subregions. Some indicators in some subregions reflect very good watershed health. For example, terrestrial and aquatic conditions tend to be best in the less disturbed eastern and western mountains. For other indicators and subregions, conditions were poor. For example, aquatic and biological conditions in the developed valley floor tend to be worse than in the mountains.

What should be of most concern to the Napa River watershed community is that current conditions are only fair, and, for some indicators, there has been a measurable decline in condition over the past several years. None of the indicators show that watershed health is improving.

It is important to keep in mind that the reliability of these findings varies dramatically among the 14 indicators. A given indicator may have no score for a particular subregion because it does not apply there or because there are insufficient data to support a statistically significant scoring.

It is clear that the community needs more and better data, and deeper analysis, to understand the health of its watershed. Many basic conditions—such as the state of the streams during the driest time of year– cannot be understood until monitoring efforts are increased and improved.

Tracking watershed vital signs can help guide community decisions to turn declining trends around and encourage a trajectory toward a healthy and more sustainable watershed.

Napa River Watershed Health Report Card

Each watershed subregion was evaluated for its condition relative to targets for each indicator. Scores close to 100 reflect excellent watershed health. The subregions are: WM – Western Mountains, LW – Lower Watershed, EM – Eastern Mountains, SVF – South Valley Floor, NVF – North Valley Floor. Trend was evaluated from a combination of trend assessments from each subregion. Confidence refers to quantitative and professional assessment of confidence in the result. ND indicates that the score or trend was not determined because data were not available or sufficient. Go to http://sfcommons.org/scorecards/waf/napa for more detailed information.

Goals	Indicators	Watershed Subregion Condition Score					Watershed Condition Score	Trend	Confidence for Subregion Scores
		WM	LW	EM	SVF	NVF			
Improve and protect geomorphic and hydrologic processes	Impervious area	ND	ND	ND	ND	ND	75	Declining	Moderate
Promote watershed awareness and stewardship through improved education, recreational access, and community involvement in decision-making	Local media coverage of watershed topics	ND	ND	ND	ND	ND	46	No trend	High
	Access to public open space	2	22	1	74	58	38	ND	Low - High
Conserve, protect and improve native plant, wildlife and fish habitats and their communities	Fish community	ND	37	ND	78	ND	ND[1]	ND	Moderate
	Habitat fragmentation and connectivity	77	34	100	29	51	67	ND	High
	Sensitive bird species	64	77	82	88	60	74	No trend	Low
	Aquatic insects	59	33	53	39	41	45	ND	Moderate - High
	Fire recurrence	84	80	42	99	48	65	ND	Moderate
Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity	Groundwater	Spring: Main Basin = 100, MST Basin = 29; Fall: Main Basin = 67, MST Basin = 7					ND[1]	ND	Moderate
	Water conservation	ND	ND	ND	39	ND	ND[1]	ND	High
	Stream temperature	100	81	ND	87	54	82	No trend	Moderate
Reduce greenhouse gas emissions and adaptively manage watershed resources to address climate change	Carbon storage and net primary productivity	98	100	97	93	94	97	No trend	Moderate
Support community planning and management actions that further the goal of a healthy, happy, and economically just community	School lunch program enrollment	ND	45	55	70	61	58	Declining	Low – High
	Housing affordability	66	60	66	57	40	58	Declining	Moderate – High

[1] No watershed score was calculated for Fish Community, Groundwater and Water Conservation as data for these indicators was available for only for a few select subregions of the watershed.

8.3 Indicator Selection Criteria

Indicator Selection Criteria

The summary of selection criteria is that there is existing knowledge of indicators that are feasibly monitored, the indicators are representative of the social and ecological systems, and that there are and will continue to be data for the indicators.

- Availability of high-quality data

  One of the main obstacles many face when selecting indicators is the lack of available data. Frequently the data for an indicator that may be important are not available. Alternatively, the data might only be available for random points in time or for limited geographical areas. The data might have been collected for one purpose in a particular way that served the original purpose, but for your purposes, it may be inadequate. If new data are needed, the feasibility of collecting them might be limited by the amount of effort required to accurately make the measurement (e.g., actual salmon escapement). Alternate indicators may be considered that have significantly lower cost (e.g., remote-sensing based habitat assessment). For certain indicators, it may be very cost-effective to collect the required metrics (e.g., habitat assessment for a species of concern), but the indicator may not represent the process of concern compared to more expensive indicators (e.g., actual population trends in the species of concern).

  Data collection and analysis costs (further described as a separate criterion below) have to be evaluated in relation to the potential cost and societal implications of a proposed action or inaction, i.e., the greater the expected tradeoffs between societal goals, the greater the need for certainty in the environmental outcome. When choosing indicators, it is essential to carefully consider the current availability of data for the indicator, as well as how much data will be available in the future from our own collection and from the efforts of others. The availability of metadata is one criterion for selection of particular data for corresponding indicators. Finally, indicators will be useful and useable in the long-run if there is a process for updating the corresponding database, metadata, and data collection & QA/QC procedures.

- Data costs and benefits

  One factor to consider in evaluating indicators is the costs associated with collecting and analyzing data. One consideration in evaluation the costs and benefits is the usefulness of the information for evaluation of management and ecosystem condition. Indicators that are cost-effective, while accurately representing ecosystem characteristics are preferable. The primary guide is that the amount of data required to adequately report on condition and change in condition can be and are being collected with the resources available. The data should also be collected in a standardized way for which there are QA/QC procedures described. For critical indicators (those reflecting important system conditions for which there is no viable alternative), more resources may need to be made available if they are currently inadequate.

- System representation

Another factor to consider in indicator selection is how well the indicator reflects the issue for which it was selected. Frequently, certain indicators are widely recognized to be a useful measure for an issue. Selecting these indicators is usually a 'safe bet'. For example, % riparian canopy cover is considered a good indicator of riparian conditions because it has been extensively studied and shown to have a good relationship with stream temperature and the detection of changes can be made easily. Selecting indicators that have been carefully evaluated for their scientific validity means they usually have wider acceptance than those that haven't been studied very much, and they are more likely to allow you to make confident inferences about system condition.

Indicators that are representative of large aspects of system condition and trends are preferable for those that have narrower utility, all else being equal.,

Sometimes the condition is itself an important ecosystem driver. For example, surface water temperature is an important ecological variable for understanding the condition of aquatic ecosystems. It is also the target of management actions to benefit these ecosystems, which is another criterion described below. Indicators that can provide important information at both broad and fine spatial scales are likely to be more useful as they can help inform both strategic and site-specific decisions.

- Ability to detect change over time

The ability to report on trends over time is a key function of an indicator. The availability of a data set collected over a period of many years is ideal. Indicators that respond relatively quickly to management intervention and can effectively be used to measure change over time may be preferable to those that require data over long periods of time to observe changes due to management actions. This is especially useful in reference to short-term grants and contracts, or short-term program evaluation, which require performance measures to demonstrate the success or failure of the project. If possible, select indicators whose range of natural variation can be quantified and that permit change detection over short periods of time (2-3 years). At the same time, recognize that many of the processes that we try to improve with restoration programs take decades or longer to change or recover (e.g., salmon population recovery). Indicators for these projects and programs should be stable over these longer timeframes (i.e., decades).

- Independence of indicators from one another

Independence refers to how related indicators are to each other. Road density and %impervious surface are related indicators because roads are often impervious. Indicators that are relatively independent are preferable (e.g., rate of ground water use for irrigation and migration barriers), while recognizing that some critical indicators are related and somewhat dependent on each other (e.g., surface water temperature, flow, stream shading, hydraulic connectivity to groundwater, salmon rearing habitat suitability). The concern about independence is important for designing efficient indicator systems, but is secondary to choosing easily-measured and representative indicators. You may choose related indicators, but you would be constrained in your attempts to use them together to explain condition of a system. For example, if (a) surface water temperature, (b) flow, (c) stream shading, (d) amount of groundwater withdrawal, and (e) salmon rearing habitat were indicators of success for a restoration program, then you could not report changes in these indicators without acknowledging that (a) depends on (b), (c), and (d); (e) depends on (a), (b), (c), and possible indirectly on (d) through (b); and (c) may depend on (b) and (d). If restoration of riparian shade (c) was a goal in order to benefit salmon rearing (e), then the inter-dependence of some of the other parameters would need to be acknowledged and potentially controlled-for in order to measure the true effect of increased riparian shade on salmon rearing.

- Supports management decisions and actions

Measuring conditions in the environment and in communities can inform policy development and social/fiscal investments. Indicators should be informative in evaluating environmental/social/economic conditions, as well as the influences on these conditions. Another useful characteristics of indicators is that they can be used to evaluate the effects or effectiveness of management actions – be it a state or federal agency or the goals and objectives of a watershed council. Whatever the business of the organization is, indicators should provide information that can be used to assess the effectiveness of the work and efforts of the group. In the past, *activities* were seen as a measure of the effectiveness of an organization. The number of grants awarded, the number of pamphlets distributed, or similar “bean counting” has been used extensively to evaluate an organization’s productivity. Environmental performance measures, on the other hand, look at the environmental and social *outcomes* of these activities to determine an organization's effectiveness. This is the reason it is so important to select indicators that are closely linked to management actions and decisions.

- Can be reported and understood in public arenas

  The point of most indicators is to inform a wide audience about conditions in the environment and communities. Indicators should be science-based and easily understood by various kinds of decision-makers (e.g., scientists, public, elected officials). They should be equally presentable in summary form in newspapers and on web sites. Finally, indicators should be based upon reportable technical & scientific information and links easily made between summary presentations and the source data and knowledge.

Sources:

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Stalberg, H.C., Lauzier, R.B., MacIsaac, E.A., Porter, M., and Murray, C. 2009. Canada's policy for conservation of wild pacific salmon: Stream, lake, and estuarine habitat indicators. Can. Manuscr. Fish. Aquat. Sci. 2859: xiii + 135p.

8.4 Report on analytical approach

Knowledge Base for the North Bay-Delta Transect Watershed Assessment Framework

REPORT ON ANALYTICAL APPROACH – County of Napa 4600007937

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4/15/2010

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Executive Summary

The North Bay and Delta watersheds are home to unique human and natural systems; these include major cities, agriculture, fresh-water wetlands, salt and brackish water marshes, managed and natural waterways, and native upland habitats. Because of historic and contemporary interactions among these systems, as well as impacts from outside the region, many of the native ecosystems in the region are in decline. Watershed and ecosystem restoration has been a priority for Napa County and other administrative bodies for much of the last decade. To measure both the existing condition of these systems and to evaluate the success of restoration efforts, the California Department of Water Resources and CALFED have proposed the use of a Watershed Assessment Framework (WAF). The WAF uses categories of condition indicators to help organize restoration, monitoring and research information to better inform decision-making about land and water management.

This report describes a foundation to analyze and report on the WAF approach, through a region-wide application and a focus watershed assessment in the North Bay and Delta region of California. The geographic study area for conceptual development and testing of the WAF approach is an east-west transect across the North Bay watersheds in the West eastwards towards the Mokelumne and Cosumnes Rivers watersheds in the East. Watershed goals and objectives to develop and assess the WAF approach across the study area will be defined by stakeholders. Candidate indicators of watershed condition will be selected to correspond to the derived stakeholder goals and objectives. The focus watershed for data analysis using the WAF approach will be the Napa River watershed. In this focus watershed, a number of candidate indicators corresponding to the goals and objectives will be selected and assessed. These candidate indicators will then be refined to a shorter list for additional data analysis and report card development. The focus watershed is intended to be a representative example of the region, while recognizing that intra-regional differences in ecosystem properties will likely limit the direct application of the identical indicators elsewhere. The combination of the focus watershed and regional framework provides a foundation for a region-wide application of the WAF at the watershed scale, as well as serving as an example for the state.

Reporting indicators at appropriate spatial and temporal scales is critical for good management decision-making based on those indicators. Where appropriate and possible, individual indicators will be reported at a more detailed scale or at different levels of aggregation. Ultimately, indicators are useful when they inform the public about conditions and change. The reporting system developed in this project will provide guidance on scale issues and will provide summary assessments that people can understand.

Basis for approach

The WAF approach is founded on metrics and indicators (see *Appendix A: Glossary of Terms* for explanation of terms) that are organized into a hierarchical structure corresponding to aspects of natural and human systems that are termed system "attributes." The WAF is not the only way to organize these measures of environmental (both human and natural) condition. One of the functions of this knowledge base development was to examine other ways to organize information describing ecological, economic and social conditions.

In the past 15 years, a number of frameworks have been developed due to growing concerns about sustainability assessment. Our aim in reviewing these is not to provide a comprehensive review of existing frameworks, but rather to illustrate the conceptual variations among the different approaches to organizing indicators. Review of available literature on indicator frameworks suggests that framework selection varies depending on what is being measured and on the audience targeted. The National Research Council (NRC, 2000) identified two types of frameworks: those that measure the status or condition of the system, and those that seek to identify cause and effect relationships.

Noteworthy examples of other environmental assessment efforts include: the Pressure-State-Response, the State of the Environment Report of Western Australia (http://www.soe.wa.gov.au/report/about.html), the Millennium Ecosystem Assessment (http://www.millenniumassessment.org), and the Chesapeake Bay Health Report Card (http://www.eco-check.org). In the assessment of economic and social condition, in particular, the efforts of the World Health Organization (WHO) are noteworthy ((http://www.ncbi.nlm.gov/pubmed/8518769).

One of the most popular frameworks for sustainability evaluation is the Pressure-State-Response (PSR) framework (OECD, 1993). The PSR framework is based on the fact that human activities produce pressures on the environment, causing changes in its state, and specific responses from society can reduce or mitigate those pressures. Subsequent versions replaced pressure with driving forces, acknowledging that driving forces can be both positive and negative, unlike pressures which are always negative. A further modification was introduced by the European Environment Agency with the Driver-Pressure-State-Impact-Response framework (DPSIR; Smeets and Weterings, 1999). The idea behind the DPSIR is that driving forces like industry and transport produce pressures on the environment, such as polluting emissions, which then degrade the state of the environment. The resulting impacts on human health and ecosystems cause society to respond with various policy measures, such as regulations, information and taxes, which can be directed at any other part of the system (Segnestam, 2002). Overall, these frameworks are based on the concept of causality, whereby human activities exert pressures on the environment and change the state of natural resources.

The State of the Environment Report of Western Australia (SOE-WA) uses a modified version of the PSR: condition-pressure-response-implication. The justification for this modification is that it assists in environmental policy planning while retaining the benefits of an internationally agreed framework for environmental reporting. The reporting is organized around environmental themes, issues and indicators. Environmental themes refer to major groupings of the environment, including *Fundamental Pressures, Atmosphere, Land, Inland Waters, Biodiversity, Marine, Human Settlements, Heritage* and *Towards Sustainability*. Issues refer to environmental problems and are reported under each theme. Environmental indicators are used to provide a summary measure of the changes and/or trends in the environment or for environmental issues. The *Towards Sustainability* theme reviews the progress of Western Australia's economic sectors and reports on their sustainable management, use, protection and conservation of natural resources.

The Millennium Ecosystem Assessment (MEA) is based on a conceptual framework that explicitly connects ecosystems and human well-being by addressing a number of services that ecosystems provide, as well as including drivers which cause the reduction of these services (MEA, 2005). In some ways the MEA can be considered a causal framework that can be applied at any temporal or spatial scale. Essentially, changes in indirect drivers (population, energy, economic growth, governance) lead to changes in proximate forces on ecosystems (climate change, land use and cover change, factor inputs such as irrigation and fertilizers, pollution, resource use, nutrient release, species introductions) which alter ecological "stocks" and "flow/processes." This results in changes in both the goods and services directly provided by ecosystems such as food, fiber, water, pathogens, carbon sequestration, storm buffering, etc. These changes in goods and services have consequences for human development (e.g. food, security, health, vulnerability, employment, tourism, climate), which in turn influence the basic driving forces (Corvalan and Reid, 2001).

The Chesapeake Bay Health Report Card organizes the indicators into a hierarchy of detail based on the degree of synthesis and detail required. Based on this organization scheme, individual indicators are categorized into "reporting" and "diagnostic and detail" indicators. The reporting indicators represent a small number of indicators which effectively communicate the key messages of Chesapeake Bay health. These indicators are organized into categories (e.g., *Water Quality, Habitats and Lower Food Webs,* and *Fish and Shellfish*) and form the basis for two upper levels of indices: "Top Level Indices" and "Overarching Indices." The former represent a single value index for each indicator category (e.g. *Water Quality Index*) and serve as a mid-level of synthesis between the reporting indicators and the overarching indices. The overarching indices are derived from synthesis of respective top level indices and serve as the highest level of information synthesis enabling rapid communication and understanding of the 'big picture. ' Finally, diagnostic indicators are indicators that either facilitate the interpretation of the reporting indicators and the associated integrated indices or address topics of special interest that do not fit directly under the top level indices. Supporting indicators are not used in the generation of top level or overarching indices.[1]

Most contemporary indicator frameworks incorporate both condition indicators and indicators of pressures or influences. This combination allows for a condition assessment as well as an evaluation of what may be driving the condition. This dual approach reflects a trait common among these frameworks, in that they are practical and intended to support decision-making, usually management choices in support of restoration, regulatory, or sustainability goals. Our approach to the WAF and application of it in the North Bay and Delta watersheds will reflect these contemporary trends and will be based in current-day scientific understanding of ecosystem and human community conditions and the processes and actions that influence them. This combined approach of assessing both condition and influence indicators allows for more effective evaluation. It also helps report on human and natural system attributes that are important to the formation of regional and local watershed stakeholder goals.

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[1] http://archive.chesapeakebay.net/pubs/subcommittee/irw/indicator_framework_desc.doc

Watershed context

The project team spent a large amount of time finding agreement on fundamental scoping questions about the contextual relationships of social and economic goals in the framework of a "watershed."

The team's deliberations arose out of two possible meanings of the word "watershed" used in the SAB's Watershed Assessment Framework. In traditional application, a watershed is a geographic area defined by the movement of surface runoff draining to a common point or waterbody. A more expansive, or all-encompassing definition of a watershed is one which pertains to both natural resources (soil, water, rivers, erosion, vegetation, animal species) and human uses and conditions (land use, social structure and organization) within the traditionally defined area. The subtle difference in the latter, more expansive concept of a watershed is that it explicitly includes a relationship to people and how they utilize, manage, and are affected by their environment (e.g., watershed lands).

If the narrower, traditional definition of a watershed were chosen, the project team would be guided to assess the degree to which watershed goals are being achieved solely within the context of natural "watershed" conditions and processes. Although it is possible for the project to include some collection of economic and social goals using the traditional definition based on the movement of water; a solely natural conditions focus would make it difficult to associate the human aspect of the watershed. The project team decided that the traditional approach to defining a watershed was too narrow and missed opportunities to highlight the relationship between the biophysical watershed and its human communities.

The project team elected to use a more expansive or all-encompassing definition of a watershed, one that includes human social and economic elements. Although still geographically based in the traditional sense of a "watershed," the broader definition allows the team to assess the degree to which natural process and condition goals are being achieved, knowing that these "watershed" goals are affected by (and perhaps directly correlated with) human social and economic systems and conditions. In using a broader application of the term "watershed," the project team has greater ability to assess indicators that measure how physical watershed conditions affect economic and social goals (e.g. fishability of streams, fertility of farmlands, rate of development, recreational access), and conversely how economic and social systems and patterns affect watershed resource goals (e.g. species biodiversity, habitat connectivity, water quality). In summary, the project team has adopted a more expansive view of the term watershed, one that includes human elements as well as natural conditions. This expanded view provides the team the ability to assess the degree to which natural systems goals and the economic and social conditions affect overall watershed condition.

Bibliography

A total of 105 articles, mainly scientific publications and technical reports, were compiled into a bibliography to support the project. The majority of the documents have been published within the last 8 years. If a report is updated periodically (e.g. state of the environment, scorecard), the latest version was included in the database. Because there is a very large number of publications dealing with environmental and sustainability indicators, the literature review carried out for this project prioritized those articles and technical reports that have been published recently and that address issues related to developing, analyzing, reporting, and using environmental or sustainability indicators. Additionally, indicator initiatives that focus solely on one aspect of the system (e.g. agriculture, health, economy, forestry, community) were not included in the database, unless they tackle analytical or methodological issues (e.g. multi-criteria analysis, development of composite indices, etc.). The bibliography is available to project participants via secure online access.

Collection, organization, access, and composition

The compilation of the bibliography was as comprehensive as possible, including reports from indicator schemes around the world and at varying spatial scales (i.e. from creek or watershed scales to regional and national scales). The search for scientific articles was conducted through the on-line bibliographic data base the ISI Web of Knowledge using keyword searches such as “environmental indicators”, “ecological indicators”, “sustainability indicators”. Several specialized journals provide “early on-line publications” (i.e. published on the web before they are available as hardcopy), and such publications are not yet indexed in the ISI Web of Knowledge data base. Therefore, the latest issues of these journals (Ecological Indicators, EcoHealth, Environmental Management, and Ecological Economics) were browsed separately. In addition, internet searches were conducted using keywords such as “environmental indicators,” “watershed indicators,” “socio-economic indicators,” “sustainability indicators,” “state of the environment report,” “environmental scorecard,” etc. In general, most environmental indicator initiatives, either implemented by governmental or non-governmental organizations, have a web site with access to published documents such as technical reports, executive summaries, and scorecards.

The bibliography was organized in JabRef (http://jabref.sourceforge.net/), a free reference database manager. All metadata associated with each article (i.e. author(s), title, year of publication, organization, keywords, abstract, journal or book name, etc.) was imported into the reference manager. One of the advantages of JabRef is that the database can be exported in an HTML (hypertext markup language) table that can be opened with any web browser. The table contains the most common fields cited in a bibliography (i.e. author(s), title, year, journal name, and type of publication) plus URL links to the documents on line (usually as PDF files). Additionally, the table can be sorted by any of its fields and searched using authors’ names, keywords, publications’ names, etc. Where available, the table can display abstracts, reviews, and the complete citation in bibtex format (a tool and a file format used to describe and process lists of references). The HTML table and all associated documents have been uploaded to the Watershed Information Center & Conservancy of Napa County web site (http://www.napawatersheds.org) and can be accessed by all project participants that have a secure log-in account.

Example frameworks

Given the number of available indicator initiatives it is important to consider peer reviewed guidelines for indicator development and selection and the interpretation and communication of the results at the outset of the project. Accordingly, from the technical reports compiled, a set of 20 different indicator initiatives were selected for review and comparison with the WAF (see Appendix B – Example Indicator Frameworks). Each indicator initiative was evaluated considering the organization that developed the indicators, the goals and objectives proposed, the framework or scheme employed, the process of developing indicator sets (e.g. criteria for indicator selection, public involvement, etc.), examples of these indicators, and the arrangement of indicators within major attributes, categories or themes. A brief description of three relevant systems from different parts of the world is provided below.

The first example is the Atlantic Slope Consortium (ASC) (http://www.asc.psu.edu/default.asp) which is one of five projects funded nationally by the USEPA through its Estuarine and Great Lakes Indicator Research Program. The consortium is composed of 5 institutions, including universities, research institutes, and private organizations. The main goal of the ASC was to "develop and test a set of indicators in coastal systems that were ecologically appropriate, economically reasonable, and relevant to society" (Brooks et al. 2007). Within this goal, the specific objectives of the project were: a) to develop and test ecological and socioeconomic indicators of aquatic resource condition, construct models that use environmental, geographic, and stressor data to predict indicator responses, and use models to link upstream watersheds and downstream estuaries; b) to develop large scale measures for characterizing landscape attributes and land-use patterns to serve as predictors of a range of environmental conditions; and c) to deliver a nested suite of indicators to managers, in such manner that the implications of aggregating models at various scales are considered and the reliability of the indicators is known.

The ASC used a framework for the selection and use of the indicators based on three elements: the type of question being asked, the spatial and temporal scale of the issue being addressed, and the context of the question (Brooks et al. 2007). The type of question being asked is directly related to the type of indicator to be selected and used. Based on this, the ASC recognized four types of questions/indicators: a) condition assessment: snapshot of the current state of the system; b) stressor diagnosis: identification of causative factors of condition; c) communication to the public: encouraging comprehension of condition in its most elementary or integrated form; d) futures assessment: estimating the probable trajectory of condition, or assessing the vulnerability of any system to a stochastic event; e) performance evaluation: a subset of condition indicators that evaluate the effectiveness of management actions (Wardrop et al. 2007). The spatial and temporal scale of the issue (or question) being addressed by each indicator used is related to the scale for which each indicator is informative and valid. Finally, the context of the question implies using categories of surrounding land use as surrogates for social choices and management options. Using this framework, the ASC arranged the indicators under two main issues or attributes: estuarine indicators and watershed indicators. The former group contains 10 indicators, including examples such as bio-optical model of habitat suitability for submerged aquatic vegetation, index of marsh bird community integrity, and nitrate, total N and total P concentrations. The latter includes 21 watershed indicators including examples such as spot-sampled average stream nitrate concentration in watersheds, macro-invertebrate assemblage composition (e.g., indexes of biotic integrity (IBI)), and stream–wetland–riparian index.

The second example is the Ecosystem Health Monitoring Program (EHMP) (http://www.ehmp.org/) of South East Queensland, Australia. The EHMP study area represents 14 major river catchments and 18 estuaries over an extent of 22,672 km^2. The EHMP is led by the South East Queensland Healthy Waterways Partnership which includes the government, industry, researchers, and the community. The main goal of the EHMP is to assess the effectiveness of management and planning activities aimed at improving South East Queensland's waterways. The program assesses the ecosystem response to both natural pressures and human activities and is based on an adaptive management framework that links management actions to the achievement of management objectives.

The indicators are arranged into two major attributes or issues: freshwater and estuarine/marine. Freshwater indicators include: a) physical and chemical parameters, b) nutrient cycling, c) ecosystem processes, d) aquatic macroinvertebrates, and e) fish. Examples of metrics for each of these indicators are: conductivity, algal bioassay, gross primary production, number of macroinvertebrate taxa, and proportion of native fish expected. Estuarine/marine indicators include: a) ecosystem health index and b) biological index rating. For the estuarine environment, the ecosystem health index is a composite of 5 different metrics: total nitrogen, chlorophyll a, turbidity, total phosphorus, and dissolved oxygen. The biological index rating for estuaries is a composite of 4 different parameters: sea-grass distribution, nutrient plots, sewage plume mapping, and riparian assessment. Unfortunately, there is no information available at this time regarding the EHMP process and criteria for selecting indicator sets.

Finally, the third example is the State of the Sound Program (http://www.psp.wa.gov/) carried out by the Puget Sound Partnership. The partnership is made up of citizens, governments, tribes, scientists and businesses. The overall goal is "to make Puget Sound healthy again, and create a roadmap for how to get it done". Unfortunately, there is not much detailed information regarding the framework and process for the selection of indicators. The monitoring of key indicators is carried out by the Puget Sound Assessment and Monitoring Program, a network of regional scientists belonging to local, state, and federal agencies and universities. The indicators are arranged into four main attribute areas: water quality, habitat, species, and climate. Indicators under water quality include marine and freshwater quality, toxic contaminants, pollution from human and animal waste, and stormwater runoff. Habitat indicators include lowland habitat loss, eelgrass, and aquatic nuisance species. Examples of indicators for the species attribute include population status and trends of several key species such as orcas, salmon, groundfish, herring, pinto abalone, and marine birds. Finally, climate indicators address issues relevant to climate change. They describe status and trends in air and sea surface temperatures, sea level, stream flow, and snow pack.

Comparison among indicator frameworks

There are many ways to compare indicator frameworks, including assessments of coverage of ecosystem and human community issues, temporal and spatial scale, measurement of programmatic performance, and reporting mechanisms. For this comparison, the project team gathered information on 20 indicator frameworks from around the world, including the types of attributes covered, the types of indicators, and their coverage of spatial scales (Appendix B). The team compared them to each other based on their similarity to the Watershed Assessment Framework. It was found that the attribute categories of biotic condition, chemical/physical condition, hydrology/geomorphology, and social condition were well-represented among the compared frameworks. A majority of the indicators among all 20 frameworks analyzed were represented in 4 WAF attribute categories: chemical/physical condition, biotic condition, hydrology/geomorphology, and social condition. The indicator frameworks did not effectively cover the WAF attributes of ecological processes, natural disturbance, economic condition, or landscape condition. See the figure.

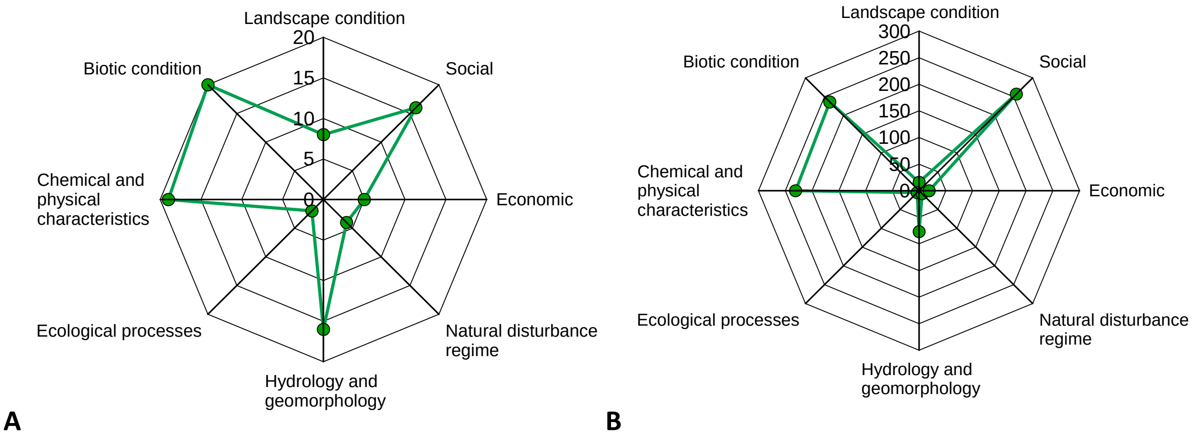

Figure. The indicators from all 20 frameworks reviewed were categorized within each of the EWAs of the WAF (e.g. Landscape Condition, Biotic Condition, Chemical and Physical Characteristics, etc.). This categorization allows for comparisons among the different approaches. (A) Number of frameworks with indicators in each WAF attribute category. (B) Number of indicators from all frameworks categorized within each WAF attribute category.

Watershed Assessment Framework

The recommendation to the USEPA from the agency's Science Advisory Board (SAB) was that environmental information be organized into categories corresponding to major environmental attributes and processes and that indicators used for evaluation be included that are based upon system goals and objectives. The environmental attributes recommended by the SAB were: landscape condition, biotic condition, physical/chemical condition, ecological processes, natural disturbance, and hydrology/geomorphology. The Watershed Assessment Framework (WAF) builds upon the SAB and includes social and economic categories – the things that make up what we call *quality of life* – as additional important environmental aspects of evaluating watershed condition. The WAF attributes are described below.

Central to the application of the WAF is the description of goals for the watershed or region being evaluated. From these goals, measurable objectives are crafted. Indicators are chosen that allow evaluation of the objectives and thus the goals. Indicators may or may not be actual metrics for which data are collected. For example, water temperature may be an indicator, which is also a metric. However, native fish populations may be an indicator, but metrics such as adult population size, reproduction rate, and population demographics may be the actual metrics, or things measured about native fish populations.

There are several overarching goals for indicator system development and application. One is to report on the condition of a single watershed (the Napa River watershed), another is to provide proposed watershed-scale goals and indicators (for the North Bay and Delta), and the third is to develop and test an assessment approach that can be used as an example for the creation of a future statewide watershed assessment system. These goals relating to the eventual application of the WAF are separate from the goals and objectives for the watershed (which are described in more detail below).

Attributes

The WAF approach is organized in terms of *essential watershed attributes* (EWAs). These may be thought of as different aspects or categories into which the overall picture may be subdivided. It is worth considering how the attributes relate to goals and objectives.

Goals and objectives are one way to understand how well a watershed or similar system is doing. You may have a goal that your cardiovascular system be capable of supporting a long life, which is linked to objectives you set for heart rate, ability to exercise, etc. In this context, attributes are the categories of health indicators that measure how well your body system is doing. Your cardiac system is an attribute or category of organ(s) within your body. Similarly, natural and human systems can be broken up into categories in order to understand how these sub-systems are doing within the context of a larger watershed. Landscape condition is one of the EWAs used in the WAF to include evaluation of the structural integrity of the terrestrial landscape of the watershed. The other EWAs are biotic condition, chemical/physical condition, hydrology/geomorphology, ecological processes, natural disturbance, social condition, and economic condition. These are the same as the US EPA approach (Figure 4), with the addition of consideration of social and economic conditions.

The attributes associated with social and economic conditions have unique definitional issues somewhat different from the other attributes considered here. Broad-based definitions of *quality of life* are provided in the UN Millennium Ecosystem Assessment (MEA) and in the WHO assessment. Broad categories of quality of life suggested in the MEA include *security, basic materials, health and social relations*. These general categories of human welfare suffer from a lack of specificity and measurability that minimizes their utility in the WAF. In actual application of the MEA framework, these attributes are typically transformed into more narrowly defined attributes (see for example, the Puget Sound Partnership Technical Memorandum on quality of life, Burke et al, 2008).

Consider *basic materials*, which is too broad to be measurable with anything other than highly aggregated indices. Not surprisingly, basic materials are typically redefined to include such localized and measurable indicators as per capita income, employment rates, property values, transportation systems, and other reported metrics of economic activity. In the WAF approach, social and economic attributes within the North Bay will be based on indicators identified by the stakeholders and from reviews of other, geographically and hydrologically similar settings, such as the Puget Sound.

Indicators and measures

In the USEPA Science Advisory Board's indicator framework, "ecological indicators are measurable characteristics related to the structure, composition, or functioning of ecological systems" (Young and Sanzone, 2002). In this framework, multiple indicators can be hierarchically arranged within subcategories, categories and essential ecological attributes (similar to the term "essential watershed attributes" used in the present study). In turn, indicators are the product of monitoring variables measured in the field. These measures or parameters can be used alone or aggregated into a single metric to provide a value for a particular indicator.

There follows a brief description of the categories within each essential watershed attribute (EWA), along with a few examples of possible indicators and measures. These are examples only, not intended as prescriptive for the current project. The specific indicators used in the current project will depend on the particulars of the subject watershed and on local goals and objectives.

According to the WAF guidelines, two other EWAs have been added to the SAB framework: Social Condition and Economic Condition. Again, the specific indicators shown are examples only. In the section which follows, we provide further background on these two EWAs.

Landscape condition: The extent, composition, and pattern or structure of (non-human) habitats in a landscape.

> *Extent*: it refers to the areal extent of each habitat type within a landscape. Example indicators or measures include: core area, perimeter-to-area ratio.
>
> *Landscape composition*: it refers to the aggregate of elements in a region or area, including vegetation, topography, landform, and land use. Example indicators or measures are: number of land cover/habitat types, number of patches of each habitat, and size of the largest patch.
>
> *Landscape pattern/structure*: it refers to the spatial pattern of habitat. Example indicators or measures include: dominance, contagion, fractal dimension, and distance between patches.

Biotic condition: The condition or viability of communities, populations, and individual biota (*individual* at the scale of individual habitat types).

> *Ecosystem or native community measures*: they refer to the condition of ecological communities. Five subcategories are distinguished: community extent, community composition, trophic structure, community dynamics, and physical structure. Example indicators of each of these subcategories are: extent of native ecological communities, species diversity, food web complexity, succession, and vertical stand structure, respectively.
>
> *Species or population level measures*: they refer to the condition or viability of populations of species of special interest (i.e. threatened, rare, sensitive) in an area. There are five subcategories within this category: population size, genetic diversity, population structure, population dynamics, and habitat suitability. Example indicators or measures within each of these subcategories include: size of breeding population, degree of heterozygosity within a population, population age structure, birth and death rates, measures of habitat attributes important to focal species.
>
> *Individual organism measures*: they refer to the health of individuals of focal species. There are three subcategories: physiological status, symptoms of disease or trauma, and signs of disease. Example indicators or measures within each of these subcategories are: hormone levels, gross morphology, and presence of parasites or pathogens.

Chemical and physical characteristics: Physical parameters and concentrations of chemical substances present in the environment/watershed (water, air, soil, sediment).

Nutrient concentrations: it refers to the concentration of nutrients that may be limiting the growth of autotroph organisms, either because they are scarce or in excessive amounts. Examples of indicators or measures include: phosphorus, nitrogen, potassium and micronutrients.

Trace inorganic and organic chemicals: it refers to baseline information about concentrations of metals and organic chemicals. Examples of indicators or measures are: copper and zinc in sediments and suspended particulates, and concentrations of selenium in waters, soils, and sediments.

Other chemical parameters: these parameters will vary depending on the environmental compartment (water, air, soil and/or sediment) being assessed. Examples of indicators or measures include: pH in surface waters and soil, dissolved oxygen in streams, conductivity, soil organic matter, and buffering capacity.

Physical parameters: they refer to physical measures of the soil, sediments, air or water such as temperature, concentrations of particulates, and turbidity.

Hydrology/Geomorphology: Characteristics that reflect the dynamic interplay of surface and groundwater flows and the land forms within the watershed.

Water flow: it refers to surface and groundwater flows which determine which habitats are wet or dry and when, as well as the transportation of nutrients, salts, sediments and contaminants. There are five subcategories within this category: pattern of surface flows, hydrodynamics, patterns of groundwater flows, spatial and temporal salinity patterns, and water storage. Example indicators or measures include: flow magnitude and variability, water movement, horizontal salinity gradients, and water level fluctuations for lakes and wetlands.

Dynamic structural characteristics: they refer to the maintenance of underlying processes involving variations in water flow, erosion and deposition of sediments and transport of other materials, and provide direct information about the quality and diversity of habitats. Subcategories within this category include: channel morphology and shoreline characteristics, channel complexity, distribution and extent of connected floodplain, and aquatic physical habitat complexity. Example indicators or measures are: stream braidedness, length of natural shoreline, area flooded by 2-year and 10-year floods, and aquatic shaded riparian habitat.

Sediment and other material transport: it refers to the pattern of sediment and debris movement that can maintain underwater and nearshore habitat, such as wetlands, and to which native species have adapted. There are three subcategories within this category: sediment supply and movement, particle size and distribution, and other material flux. Examples of indicators or measures are: sediment deposition, distribution patterns of different grain/particle sizes in aquatic or coastal environments, and transport of large woody debris in rivers.

Ecological processes: Metabolic function of ecosystems - energy flow, element cycling, and the production, consumption, and decomposition of organic matter at the ecosystem or landscape level.

Energy flow: it refers to the flow of energy between trophic levels from the autotrophic organisms to the heterotrophic ones. There are three subcategories: primary production, net ecosystem production, and growth efficiency. Example indicators or measures within these categories are: net primary production, net ecosystem organic carbon storage, and transfer of carbon through the food web.

Material flow: it refers to the flow of key materials in ecosystems. Examples of indicators or measures are the cycling of organic carbon, nitrogen, phosphorus, and other nutrients.

Natural disturbance regimes: The historical and/or contemporary function of discrete and usually recurrent disturbances, which may be physical, chemical, or biological in nature, that shape watershed ecosystems.

Frequency: it refers to the recurrence interval of a disturbance. Examples of indicators or measures are: recurrence of fires, floods, or pest infestations.

Intensity: it refers to the effects of the disturbance on the biota. Examples of indicators or measures include: occurrence of low intensity (forest litter fire) to high intensity (crown fire) fires, density (number per area) of insect pests in an area.

Extent: it refers to the spatial coverage of the disturbance event. Examples of indicators or measures are: spatial extent of the fire and spatial extent of the infested area.

Duration: it refers to the temporal scale of the disturbance event. Examples of indicators or measures include: length of fire events and length of infestation.

Social Condition: The examination of the organization and development of human social life within the watershed, including measurements of community and social patterns, and behavior of individuals and groups.

Population: it refers to the changes and trends in human population parameters. Examples of indicators or measures include: population growth, population density, migration, urban/rural population ration, and age structure.

Education: it refers to the level of education and literacy of the population. Example indicators or measures are: literacy rate, percentage of population with high school, college, or graduate diploma, and student/teacher ratio.

Stewardship: it refers to the engagement of the community in sustainable practices. Examples of indicators or measures include: number of landcare groups in the region, people’s environmental attitude, number of people participating in environmental workshops.

Economic Condition: Measures of the production, distribution, and consumption of goods and services within a watershed, including the valuation of non-market resources that provide individual and community utility.

> *Employment*: it refers to the status, trends and changes in the number or percent of people that are gainfully employed. Examples of indicators or measures include: employment and unemployment rates, net job growth, and total wage and salary jobs per employed resident.
>
> *Income*: it refers to the amount of money received during a period of time in exchange for labor or services, from the sale of goods or property, or as profit from financial investments. Example indicators or measures are: income distribution, personal income per capita, and median family income as percent of the US median.
>
> *Consumption*: it refers to the people's consumption of goods and services. Example indicators or measures are: per capita residential area energy consumption and per capita residential area water consumption.

Indicators can be aggregated, or organized, based upon WAF attributes or categories, or by the goals and objectives which have been identified for the watershed. Looking more broadly at the future application of the WAF across California, attribute categories should remain constant across watersheds for ease of comparison, as goals and objectives will be likely differ at various local levels. The project team will attempt to report findings using both aggregation approaches (organization via WAF attributes and via goals). Reporting on both attributes and goals allows for comparison of our findings with findings from other watersheds also using the WAF, while also answering to local goal assessment needs. This dual reporting capability is an inherent strength of the WAF.

More on Social and Economic Conditions

As noted above, several organizations provide definitions of quality of life or well-being that serve as useful starting points in any discussion of this topic. A broad definition is provided by the United Nations Millennium Ecosystem Assessment (MEA), which defines well-being as "A context- and situation- dependent state, comprising basic material for a good life: freedom and choice, and bodily well-being, good social relations, security, peace of mind, and spiritual experience."

Such general definitions are challenging in that what is described as an attribute is often immeasurable; further, attributes may in some cases have opposite effects on the well-being of different individuals or groups. Values and value systems determine quality of life and well being. Economic or commercial well being forms the foundation of one set of values in which improvements in human well-being often relate to material items, such as jobs or personal incomes. Alternatively, ecosystem-based concepts of well-being assume the environment has importance equal to or greater than human well being. A third, but equally important attribute list may be compiled based on a cultural, spiritual or religious value system, which attaches spiritual or cultural values to aspects of the environment. Tradeoffs between indicators in terms of their effects on human and ecological health are thus inherent in the use of such indicators in decision making.

The MEA definitions concerning quality of life are a useful starting point to discuss measurable indicators that would apply to economic and social indicators in the North Bay and Napa River watershed. As defined in the MEA, there are four general categories that are deemed important for quality of life: *Security, Basic Materials, Health, and Social Relations*. Within each of these broad categories are numerous indicators, many of which are important to the North Bay and Napa River watershed.

Security as envisioned in the MEA takes many forms. The one of most relevance to inhabitants of the North Bay is secure resource access including access to the resources (goods and services) that flow from ecosystems, such as agriculture, forests, parks and other natural areas, as well as homes, buildings, built roads and parking lots. Examples of attributes associated with access to the flows of ecosystem goods and services include:

- Open space (acres in agricultural/timber lands) [2]
- Ecological services
- Recreational services/opportunities (parks/park land per capita, number of park visits)
- Shelter
- Food, fiber, timber
- Community/cultural linkages/tribal land holdings
- Diversity of landscape types
- Access to shopping/commercial facilities

Each type of access to resources and the nature of its specific attributes can contribute to, or detract from, the quality of life through the various services provided. However, there is a tension, because sometimes landscapes have a negative impact on the ecosystem. Such negative effects are the basis for many of EPA's science-based water quality regulations, which in turn have led to classes of Best Management Practices (BMPs) related to various types of land use. For example, agricultural areas in the North Bay-Napa River Watershed not only provide food and wine but also may provide open space and wildlife habitat. Conversely, each landscape may also detract from quality of life, depending on individual perceptions. Using agriculture again as an example, runoff from fields may contain pesticides and sediments that are harmful to fish or other aquatic organisms. Similarly, runoff from built areas (roads, houses) may also contain pollutants that impact water quality. Adverse water quality impacts are regulated by EPA Total Maximum Daily Load (TMDL) requirements, some of which regulate urban run-off.

Basic Materials refers to economic measures of the quality of life, which typically, but not exclusively, pertain to the material well-being of individuals. Thus, common measures of quality of life include personal income, presence of jobs (well paying, rewarding), affordability of housing, access to food and energy resources at stable prices, adequate supplies of raw materials for industry and so forth. Quantifiable attribute measures include:

- Employment rates
- Personal (per capita) incomes
- Cost of living (e.g., CPI or similar indices)
- Business creation and capital flows

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[2] Definitions of open space vary across entities and reports. For this quality of life memorandum the definition of open space includes agricultural and timber lands

- Savings rates
- Property values
- Wage rates
- Transportation systems (miles of freeway, port facilities, bridges)

As with *Security*, increases in such economic measures can both add to well-being, as well as detract from the state of the environment, creating yet again a tension for competing uses of the resource, such as loss of privacy and isolation in the enjoyment of outdoor amenities due to crowding.

Social Relations and Institutions include a range of values and behaviors, including respect for others and cohesion among groups. This category may also be viewed as referring to culture and sense of place. For example, culture is a set of distinctive spiritual, material, intellectual and emotional features of a society or a social group. In addition to art and literature, it encompasses ways of living together, values systems, traditions and beliefs. Cultural diversity presupposes respect for fundamental freedoms, namely freedom of thought, conscience and religion, freedom of opinion and expression, and freedom to participate in the cultural life of one's choice (UNESCO). Culture within the North Bay-Napa River Watershed region takes many forms, including the values inherent in rural agricultural communities, coastal communities, and native American communities.

The attributes associated with these communities and the associated cultural diversity include:

- Sense of community
- Psychological health
- Social well-being/cohesion
- Better understanding of the natural world in which we live and operate
- Synergies arising from social and economic interaction

Social relations are facilitated by the institutions of a society. Broadly defined, social institutions consist of the rules (e.g. laws), procedures, government services and other items that societies observe for the benefit of all members of the group. In the North Bay-Napa River Watershed, these would include such common measures of quality as the performance of education (all levels), access to high quality and affordable health care, effectiveness of governments (all levels), including efficiency and equity of tax systems, and public safety (crime rate). Measurable attributes include:

- Level of educational achievement
- Life expectancy (human mortality and morbidity measures)
- Relative tax burdens
- Per capita governmental expenditures
- Voter participation
- Crime
- Access to public transportation

Higher levels of social institutions and services may be viewed as improving the quality of life. Again, however, tradeoffs occur because, for example, some may value improved education over investments in environmental enhancement, but with limited budgets, governments cannot satisfy all public wants.

Health has multiple dimensions, including physical and psychic well being. Physical health (human mortality and morbidity) is obviously dependent on such environmental attributes as clean air and water. These values are regulated by USEPA and other governmental agencies to minimize adverse human health consequences. A form of human health not regulated directly relates to psychic values, such as those derived from lifestyles. For example one lifestyle tends to revolve around the diverse environmental amenities associated with flora, fauna and topography of the region. As a result, outdoor recreation is an important attribute of quality of life and is cited as one reason companies and individuals migrate to a given region (there is a large literature on the role of amenities in determining migration patterns). These outdoor activities include fishing, hiking, boating, skiing, wildlife viewing and others. Quantifiable attribute measures for this lifestyle include:

- Recreational participation (e.g. angler days, license sales, wildlife viewing days)
- Access (e.g. number of boat ramps, length and location of hiking trails)
- Measures of ecosystem health (e.g. salmon and steelhead stocks)
- Environmental quality measures (e.g. ambient air quality, water quality)
- Environmental ethic (e.g. contributions to environmental organizations)

An alternative lifestyle may be more dependent on the built environment. In this case the Quality of Life may be far less dependent on the attributes listed above, and more dependent on the built environment (roads, homes, cars, etc) and attributes listed under the *Security* and *Basic Materials* categories.

As with all the categories discussed above, tradeoffs exists. For example, increases in access and improvements in quality of recreational activities would generally be seen as an improvement in some individuals' well-being. Improvements in water quality in the region's streams may adversely impact economic vitality of some entities (corporations/growers/Cities/Counties) that pay for infrastructure to improve water quality, but may increase the stock of fish, which in turn may enhance the enjoyment of anglers.

The list of possible social and economic indicators suggested by the notion of quality of life will be refined in the application of the WAF to the North Bay-Napa River Watershed. The resultant list of measures will be constrained by the general conditions imposed within the overall assessment framework (they must be measurable) as well as the scale and other features unique to this region. As noted earlier, the data on which these social and economic indicators will be based will reflect the availability of secondary data sources (Census, etc.) but will also reflect current or emerging literature on the role of non-marketed flows of goods and services from ecosystems. The use of such information has been demonstrated in the Chesapeake and Puget Sound studies.

Watershed goals and objectives

The watershed goals and objectives for the project were derived from a broad list of regional and local stakeholder goals and objectives. The project team compiled a comprehensive list of goals and objectives via three source methods to insure that goals pertaining to each watershed attribute (EWA) were represented (see Appendix C – Table 1: Identification of Stakeholder Watershed Goals). First, the team surveyed active watershed stakeholder groups by mail. 65 groups received a worksheet-formatted survey in which they were asked to write their goals and objectives for their watersheds. Ten groups responded to the survey with a list of their goals and objectives. Second, we extracted goals and objectives from planning documents and mission statements of 17 stakeholders that did not respond to the mailed survey. The team additionally searched online documents of state and federal agencies that are active in the region, and goals pertaining to the EWAs identified in the WAF were included in the comprehensive list. Third, the team presented the list of compiled goals to the project's Technical Advisory Committee (TAC) and requested that the TAC suggest additional goals that were important and missing from the list.

Draft Final Goals
Improve and protect watershed processes and functioning
Promote watershed awareness and stewardship through improved education, organizational capacity and recreational access
Improve and sustain watershed conditions and functions that advance human and environmental economies
Support social structures that encourage community engagement in watershed

To render a manageable list of goals and objectives to guide the project, team members integrated the comprehensive list of stakeholder goals into a shorter list of seven broad watershed goals. Indicators of watershed condition will be developed from this condensed set of goals (see Appendix C – Table 2: Condensed North Bay-Delta WAF goals, objectives and potential indicators). The project team purposefully phrased the condensed WAF goals to be inclusive of all specific stakeholder goals. The team then developed a set of objectives for each goal by summarizing stakeholder goals from the comprehensive list and consulting stakeholder documents.

These goals are broken down into measurable objectives. The measurable objectives in turn are linked to indicators, which are ways to evaluate both the condition of essential watershed attributes and progress toward goals. This is a critical linkage – between goals and attribute conditions – which allows the application of the WAF to evaluate progress toward regional and watershed goals.

Most goals and objectives pertain to more than one EWA. Because indicators will be designed to measure progress towards the WAF objectives, it is very likely that condition indicators will fit into multiple EWAs. This is a reflection of the fact that most stakeholders are active and concerned with more than one component of the watershed.

Linking goals & objectives to metrics: An Example

A critical and sometimes missing component of indicator system development is an explicit or transparent link between the goals for the system and the indicators chosen to represent the system condition. An example of a goal is to "Conserve, protect, and improve native plant, wildlife, and fish habitats and their communities". An example of an objective corresponding to this goal (taken from the Napa River Rutherford Reach Restoration Project) is to "*Improve aquatic habitat for salmonids and other native species*". This objective may have subsidiary objectives, each with a corresponding indicator or metric. See the table.

Table. Relationship between Goal, Objectives, Sub-objectives, and Indicators/Metrics

Goal: Conserve, protect, and improve native plant, wildlife, and fish habitats and their communities	
Objective: Improve aquatic habitat for salmonids and other native species	
Sub-objective	**Indicator/Metric**
Maintain or reduce stream temperature	Mean weekly average or maximum instream temperature
Improve stream cover and complexity	% Riparian cover and diversity
Maintain areas of clean gravel	Sediment grain size

The objectives are clearly understandable and each of the indicators is measurable.

For each draft goal chosen, draft objectives have been chosen that can be evaluated with either numeric or narrative approaches. For the indicators above, numeric evaluation is possible, assuming that thresholds or benchmarks are available with which to compare the numeric values.

Narrative approaches to evaluation have also been used by large science-based report-cards for regional environmental condition. The UCLA Institute of the Environment develops report cards about environmental, social, and economic conditions in Southern California to inform decision-makers and the public (http://www.ioe.ucla.edu/reportcard/). These report cards include grades, but are based on expert opinion (UCLA faculty) about conditions for various aspects of Southern California's environment. It is possible that we will use a similar approach in this project, if we find that a narrative evaluation makes more sense than an attempt at numeric analysis.

Criteria for selecting indicators

"*The essential elements for evaluating the suitability of an indicator are whether the indicator is measurable using available technology, is relevant and responds to the assessment question, and provides information for management decision-making. Additionally, the best indicators are able to quantify information so its significance is more readily apparent and simplify information about complex phenomena to improve communication between researchers, managers, and ultimately the public*." (USEPA, 2008)

In order to efficiently evaluate the natural and social systems within the project's study area, the criteria for selection of indicators of system condition should be made explicit. These criteria can include: data availability, data costs, representativeness, ability to detect change over time, independence of indicators from one another, and ability to support management decisions and actions (Shilling et al., 2007). These criteria can be complemented by the same and other criteria developed by the USEPA, the National Research Council, and the Environmental Monitoring and Assessment Program (USEPA). A good description of these criteria and challenges, as they apply to indicators of human welfare (social and economic) can be found in Schneider and Plummer, 2008. A synthesis of evaluation criteria or guidelines is shown in the table.

Table. Examples of various indicator evaluation guidelines[1].

General Criteria Group	EPA (2000b)	NRC (2000)	EMAP (1994)
Conceptual relevance or soundness	*Relevance to the assessment*	*General importance*	*Unambiguously interpretable*
	Relevance to ecological function	*Conceptual basis*	
Feasibility of implementation (current and future)	*Data collection methods*	*Necessary skills*	*Available method* *Minimal environmental impact*
	Logistics		*Amendable to synoptic survey*
	Information management	*Data archiving*	
	Quality assurance		
	Monetary costs	*Cost, benefits, and cost-effectiveness*	*Cost effective*
		Data requirements	
Response variability	Estimation of measurement error		
	Temporal variability – within the field season *Temporal variability – across years* *Spatial variability*	*Temporal and spatial scales of applicability*	*Index period stability*
	Discriminatory ability	*Robustness* *Statistical properties*	*High signal-to-noise ratio* *Ecologically responsive*
Interpretation and utility	*Data quality objectives*	*Data quality*	
	Assessment thresholds		*Nominal-subnominal criteria*
	Linkage to management action		
			Retrospective
			Anticipatory
		Reliability	*Historical record*
			New information
		International compatibility	

[1]Criteria that are common to more than one program are italicized.

This project proposes to use the following criteria to evaluate candidate indicators for selection, with the following caveats: 1) Indicators may be considered ideal to represent a system, but considered cost-prohibitive with current budgets (These indicators will be considered as future options); 2) Indicators will be chosen based on their understandability to decision-makers and the public; and 3) Indicators should be relatively independent of each other, with the recognition that some attributes being measured (e.g., native fish populations) may be correlated with other conditions measured (e.g., flows, temperature).

Project Challenges

Scale issues

Today it is widely acknowledged that ecological, social, and economic systems vary in space and time. Observations made on a single scale or observation level can, at best, capture only the patterns and processes relevant to that scale or level of observation (Zurlini and Girardin 2008). Hence, the value of environmental indicators greatly depends upon the spatial and temporal scale that they represent (Stein et al. 2001). It is essential then, to understand the spatial and temporal scale at which the environmental characteristics we want to measure exhibit variation (IMST, 2007). While some indicators can be appropriately applied at certain scales, they may not be relevant at other scales. Similarly, as the spatial and temporal scales change, their linkage to particular watershed stressors may be decoupled (Niemi et al., 2004). Without an understanding of the response variability in ecological indicators over space and time, it becomes impossible to differentiate measurement error from changing condition, or an anthropogenic signal from temporal and spatial background variation (Niemi et al., 2004).

It is important to state clearly and understand the nature of data at different scales, so that the information is correctly applied to different levels of reporting. If indicators are developed or interpreted at the wrong scale, incorrect messages to decision makers and management errors could result. To reduce this error, it is suggested that individual indicators be reported at a more detailed scale or at different levels of aggregation. If there is a mismatch among scales, changes in scales of assessment and reporting may be necessary. The two main components in changing scale are up-scaling and down-scaling. Up-scaling is aggregating information collected at a fine scale to a coarser scale. Down-scaling is taking information collected and disaggregating it towards a finer scale (Stein et al. 2001). Cross-scale mismatches may result also when dealing with sustainability indicators because ecosystem processes and societal dynamics do not necessarily operate at the same spatial and temporal scales (Cumming et al., 2006). As a result, new indicators are needed to be able to integrate phenomena across multiple scales of space, time, and organizational complexity to highlight cross-scale effects and mismatches (Zurlini and Girardin 2008).

In the following, we examine the challenges associated with both spatial (extent and resolution) and temporal (changes over time frames) scaling of environmental and social indicators of watershed health.

Spatial scale issues

Spatial scale in analysis consists of the extent or area of analysis and the grain or resolution. When evaluating conditions across a geographic area, it is essential that we know the relevant spatial scale, to ensure that the scale of management actions matches the scale of the phenomena being measured/monitored (Niemi et al., 2004). This is particularly important when dealing with environmental stressors. Several studies show that the response signal of indicators to disturbances may be difficult to differentiate from background variability/noise as we increase the spatial scale of our analysis. For example, in an assessment of the effect of human disturbances over 66 wetland indicators in the Great Lakes region, analyzed at multiple spatial scales (Brazner et al., 2007), macro-scale variables not associated with environmental stress accounted for a greater proportion of variance than stressors. Spatial variables such as watershed area and wetland area explained a significant proportion of the variance in most models, indicating that assessing the relative influence of different disturbance factors without considering spatial issues may produce misleading results. In a study of macroinvertebrate communities (Johnson and Goedkoop, 2002), 23% of the variance in taxonomic composition was associated with habitat factors, but greater spatial scales (riparian, catchment, ecoregion classification) accounted for 24% of the variance. Therefore, when developing new ecological indicators, it is critical to use experimental approaches that allow for the partitioning of the variance among different stress components and over a hierarchy of spatial scales (Niemi et al., 2004).

A desired feature when selecting indicators is that they can be scalable; that is, they are valid across different spatial and temporal scales. For instance, indicators reviewed on a larger (national) scale, can be also useful on the regional and local level. The Indicator Development for Estuaries Manual (US-EPA, 2008) suggests that, whenever possible, it is always best to try to align local and regional programs with programs at a higher (i.e., national) spatial scale because this allows for future comparisons with data collected over the larger area. The benthic index, which provides a quantification of the response of benthic communities to stress, is an example of a scalable indicator (Kurtz et al., 2001). Finding scalable indicators is a difficult task because many cost-effective methods to measure and summarize social, economic and ecological data are scale dependent (Hagan and Whitman, 2006). In the project's analysis of 20

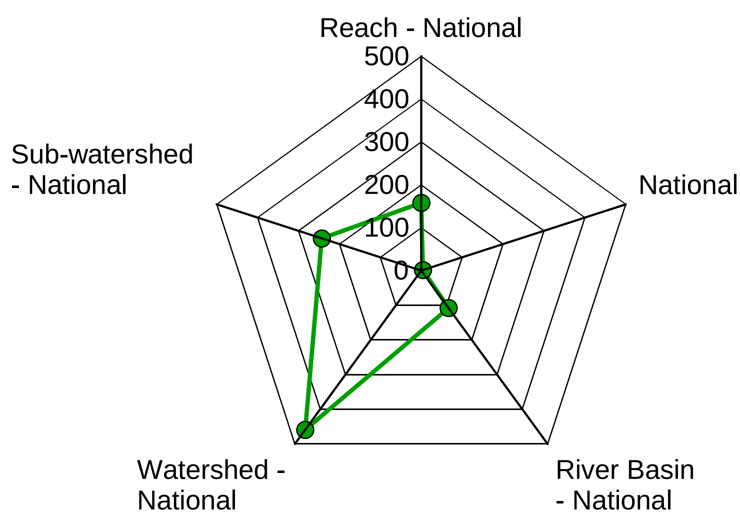

Figure. Scale-dependence of indicators among 20 indicator frameworks. The indicators reviewed from all 20 approaches were categorized depending upon the spatial scale at which they can be applied. The spatial scales in which indicators were categorized are: Reach or Patch (< 10 ha), Creek or Sub-watershed (10 - 2500 ha), Watershed, Municipality, or Small County (2500 - 250,000 ha), River basin, Region, or Large County (250,000 - 2.5M ha), and National or larger (> 2.5M ha). In most cases, indicators can be applied to more than one scale; therefore, the range of scales at which indicators can be used is shown.

indicator frameworks from around the world, most indicators were appropriate for a watershed to national scale range, while fewer spanned a range from reach or sub-watershed to national scale (see Figure).

Scalability of indicators may be more feasible in nested systems (e.g. sub-watershed-watershed-basin) than in non-nested ones. For nested systems the issues of sampling and data aggregation are more straightforward because of the direct spatial correlation from one scale to the next. Data can be sampled at one scale finer than the question of interest and then up-scaled. Sampling and data aggregation in non-nested systems proves more difficult because the emergent properties of the systems are different and simply aggregating data will overlook the synergistic effects of systems (US Forest Service, http://www.fs.fed.us/institute/monitoring/Scale_Overview.htm). In nested natural systems, cross-scale aggregation of environmental indicators may be more realistic than social or economic indicators. In contrast, social and economic indicators may be easier to aggregate when using nested political boundaries (e.g. municipality-county-state).

Spatial scale relates to another issue in the consideration of social and economic indicators. The links between human welfare and ecological health may be more apparent and manageable on a finer geographic scale, at the level of a tributary, for example, rather than the entire watershed. However, obtaining measures of these effects at finer scales is difficult, compared with larger scales, given that most reported data tend to be at the level of counties or regions. Thus, practitioners of the WAF or similar frameworks must trade off decision-making relevance against measurability.

In the particular case of the USEPA SAB reporting framework, the Essential Ecological Attributes (EEAs) were successfully mapped onto structural, functional, and compositional characteristics of ecological systems at a variety of scales in order to assure coverage of different aspects of natural systems (Young and Sanzone, 2002). Furthermore, the EEAs and their subcomponents were checked to determine whether they would be relevant at several geographic scales (ecoregion, 1000 km^2; regional landscape, 100 km^2; small watershed or ecosystem, 10 km^2; reach or stand, <1 km^2). Overall, it was found that all the components of the SAB reporting framework were relevant to each geographic scale (Young and Sanzone, 2002).

Temporal scale issues

Indicators and monitoring should be designed to detect changes in time frames and on the spatial scales that are relevant to policy objectives, goals, and decisions. Monitoring has a temporal component because it is intended to be repeated on a periodic basis to detect changes and trends (USFS, http://www.fs.fed.us/institute/monitoring/Scale_Overview.htm). However, natural sources of variability, such as within-season variation for biological indicators, should be taken into account in order to minimize erroneous conclusions (Jackson et al., 2000). Species distributions and abundances not only vary over spatial scales but also can show considerable temporal variation over time scales ranging from years to decades, even in the absence of major disturbances. This inherent random variability should be considered to determine the minimum sampling extent and interval (both spatial and temporal) required for characterizing an ecological indicator and detecting differences among sites (IMST, 2007). Indicators with high inherent variability may mask responses to stressors.

The use of pilot studies may help to determine this variability and also sensitivity to changing conditions or management activities (Andreasen et al., 2001).

In general, choices of temporal scales will be unique for each indicator. This is because the various issues targeted by indicators will have different natural dynamics, and a monitoring program to detect change will need to use a temporal scale appropriate to the natural scales of variation. For example, indicators that change slowly may need to be measured less frequently in order to detect change. However, if they respond to a small change, they may need to be measured frequently to ensure that such changes are not occurring (Ward, 2000). The figure shows how different biological indicators may vary across temporal and spatial scales in response to ecological drivers. For example, periphyton responds in a very short period of time and at a wide range of spatial scales, whereas crocodilians respond more slowly and only at large spatial scales (Doren et al., 2009).

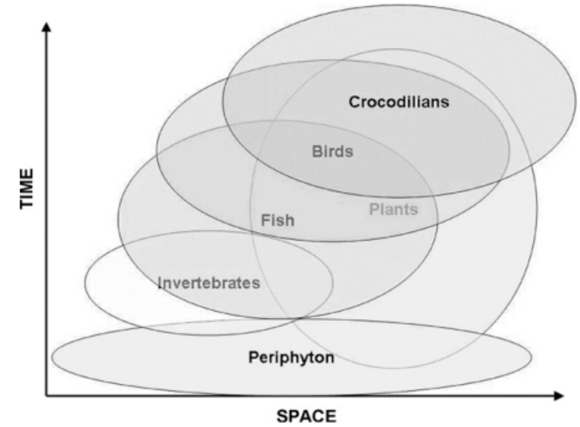

Figure. Temporal and spatial variation in the responses of ecological indicators to drivers. (From: *Doren et al. (2009) Ecological Indicators*)

The USEPA Science Advisory Board recommends surveying the temporal characteristics of the proposed indicator list to assure that some of them will respond in a reasonably short time frame and some will represent long-term dynamics. Some of the EEAs will exhibit change over several time scales (e.g., annual, decadal), but for each category there is generally a time scale over which to observe both natural variation and changes outside the normal range (Young and Sanzone, 2002).

Thresholds/criteria/benchmarks for indicators

A critical requirement for using indicators to inform condition assessments is that the indicator condition value is compared against a fixed/reference value. This fixed value could be a historical condition, a desired future condition, a legal threshold, or some other reference value. One of the criteria commonly used when selecting indicators is interpretability, which refers to the existence of a reference value for the indicator to which current status and trends can be compared. For instance, the question "Does an observation of more than 3% of water samples total coliform-positive in a month represent a health hazard?" can be answered only if there is a context for that number. Thus, the reference value is taken as a level of the parameter that reflects a desired goal or target, a historic or pristine condition, or some combination of these, as supported by available science (Jabusch et al., 2007). The selection of a reference value may be considered as important as the selection of the indicator itself because, without this baseline, it is difficult to assess the magnitude of change objectively, whether the magnitude of change is important, or if any efforts at amelioration are succeeding (National Research Council, 2000).

A reference value can take many forms and, consequently, is referred to with different names (standard, target, benchmark, and threshold). However, they all refer to a comparison by which an indicator can be examined or gauged. *Standards* may be legal or regulatory targets that must not be violated (e.g., water quality standards for a variety of uses). A *target* alludes explicitly to intention (i.e. a reference value to strive for). A target may also be a desired level to be achieved by an indicator. For example, air quality indicators usually involve air pollution targets such as particulate levels in parts per million. A *benchmark* is a point of reference with which measurements can be compared. It is the value for an indicator that has some defined environmental significance in the functioning of the natural system. In many cases, a benchmark represents the best-case documented performance related to the same variable in another site. In this case, the benchmark is represented by a *reference site*. In other cases, benchmarks can be represented by *reference conditions*. Finally, *thresholds* represent values beyond which a system undergoes significant and irreversible change. For example, a threshold can be the amount of habitat loss from fragmentation beyond which interior-dwelling species will not be able to survive (USFS, http://www.fs.fed.us/institute/monitoring/rv_factsheet.htm).

Establishing reference values for indicators is a challenging task. Unfortunately, information regarding criteria or best practices to select them is very scarce. However, the Forest Service Local Unit Criteria and Indicators Development (LUCID**)** project has put together a list of lessons learned and tips on using reference values (http://www.fs.fed.us/institute/monitoring/Reference_Values_TipSheet.htm). Below are the key suggestions proposed:

- Take time to clarify the rationale and implications of the reference value
- Document assumptions used
- Start early in the process, to clarify and revise indicators and measures
- Be specific
- Establish reference values using a collaborative, interdisciplinary approach rather than leaving these to individual specialists
- Discuss interrelationships between reference values, and use this information to help clarify systems relationships and tradeoffs between reference values
- Recognize that clarifying these tradeoffs will lead to some conflict
- Carefully assess the usability of legal standards, their underlying assumptions and scientific validity, and consider a second reference value if necessary
- Seek external expert judgment and input

The term *reference condition* also may have multiple meanings. Stoddard et al. (2006) suggest that the term is reserved for referring to the "naturalness" of the biota (structure and function) and that naturalness implies the absence of significant human disturbance or alteration. They further propose specific terms to characterize the expected condition to which current conditions are compared: ''minimally disturbed condition'' (MDC); ''historical condition'' (HC); ''least disturbed condition'' (LDC); and ''best attainable condition'' (BAC). A similar concept of reference conditions is considered in the EPA-SAB reporting framework (Young and Sanzone, 2002): "Reference conditions that attempt to define a 'healthy' ecological system are often derived from either the conditions that existed prior to anthropogenic disturbance or conditions in a relatively undisturbed but comparable system in the ecoregion. Alternatively, reference conditions can be inferred from a combination of historical data, a composite of best remaining regional conditions, and professional judgment."

Ideally, reference conditions will include sampling sites with little or no indication of stressors associated with human disturbance. However, this is not always the case and most landscapes have already been altered. Where undisturbed sites are absent, Stoddard et al. (2006) propose a combination of methods to determine reference conditions: (1) sampling biota from least disturbed sites (reference sites), (2) interpreting historical records to deduce which biological characteristics occurred at times with substantially less human disturbance, (3) developing models that incorporate the best ecological knowledge, and (4) using best professional judgment. These methods have been developed within the Mid-Atlantic streams bioassessment project and rely heavily on the concept of "naturalness". However, the concept of naturalness as scientifically derived reference condition for ecosystems has not been without controversy. Lele and Nogaard (1996) state that the use of naturalness as the benchmark is neither value free nor logically or practically usable.

Data availability

The availability of sufficient and sufficiently high quality data is one of the criteria for choosing and evaluating condition indicators. Although a good indicator will not be rejected based solely on data availability, the lack of data will inhibit its evaluation. Selected indicators for which there are no or few data will be attributed with a data gap notation.

Data for environmental, social, and economic conditions are available from many sources in the North Bay and Delta. The attached table (Appendix C, second item) is based upon one created by the North Bay Watershed Association and includes potential and actual data sources for the region. It is not exhaustive, but covers many of the main sources. These data sources have been coded by WAF attribute to facilitate their access for indicators within each attribute. In some cases, projects or databases were represented in more than one attribute.

Reporting strategies

One of the most critical functions of an indicator framework is reporting to the public, decision-makers, and technical/scientific peers. This range of audience requires that the framework and accompanying evaluation be both science-based and easily understood – the holy grail of indicator frameworks. We will be reviewing possible reporting strategies and mechanisms for the WAF indicator framework and proposing several to the regional technical advisory committee. The following sections provide some general approaches that we will consider.

Numeric reporting

For many of the quantitative evaluations, the output is a number that is compared or comparable to a reference or desired condition (e.g. regulatory standard or historic condition). The meaning of this number depends on that comparison. To effectively present numeric findings in an indicator framework depends upon effectively conveying the meaning of the indicator, the reasons for the types of analysis, and the relevance of the comparison to a reference.

Report Card

Category	Indicator	Metric	Score
Landscape Condition	Development	Impervious surface Fragmentation	65±13
Biotic Condition	Native fish	Out-migrants Habitat	43±22
Social Condition	Material relationship to watershed	Fishability	84±3
Economic Condition	Community well-being	School lunch program enrollment	71±15
Hydrology/Geomorphology	Erosion	TSS Bed-load movement	34±8
Ecological Processes	Exotic invasion	Extent Rate of spread	57±31
Natural Disturbance	Fire	Spread risk Succession/regeneration	35±16
Chemical/Physical Properties	Toxics	Metals Pesticides	52±9

Figure R-1. Example of a numeric report card based on WAF attributes and example indicators.

There are many examples around the world of the use of numeric reporting for indicator evaluation in frameworks. In most cases, a decimal system is used (e.g., 1-100), where 100 represents a "good" or reference-attained condition (e.g., Figure 3). A comparable system is the grading system, where numeric data ranges are given a corresponding letter grade, or a descriptive term like "poor", or "good".

Diagrammatic reporting

Numeric or grade reporting provides one way of conveying quantitative information about indicators. Another, related method is through diagrams representing proportions, levels, and/or trends in conditions. This strategy has the advantage of providing a more graphic representation of numeric information, which can be easier for some people to grasp. The graph shown here (Figure R-2) represents several indices of Chesapeake Bay condition over time, illustrating both the condition at any one time and the trend in condition.

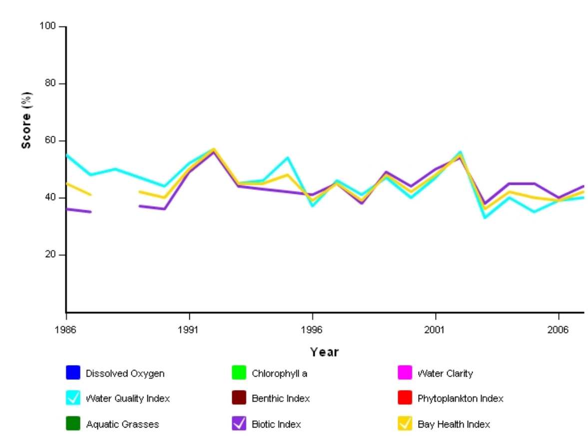

Figure R-2. Change in Chesapeake condition over 20 years.

Narrative reporting

Narrative reporting usually accompanies numeric and other forms of reporting, but it rarely stands alone as the sole form of reporting. The Southern California Environment Report (UCLA-Institute of the Environment; http://ioe.ucla.edu) is based on the narrative reporting approach (Figure R-3), where experts describe in several pages the status and trends in particular ecosystem attributes and processes (e.g., water supply). The advantage of this approach is the significant depth of information presented, including, in this case, the condition of the attribute, the influences on the system, and recommended courses of action. The disadvantages are the relative complexity of the material and the less-than-obvious conclusion about overall condition (in the case of the example shown – A).

The failure of the East Valley Water Reclamation Project has taught us that we need to better inform the public and politicians about the safety, risks and benefits of water reclamation.

Agencies like the West Basin Facility will be providing water even during the next serious drought. This is one example of environmental improvements creating a better climate for business—a sustainable water supply.

Another positive development is the experience we have gained with failed projects. The failure of the East Valley Water Reclamation Project has taught us we need to better inform the public and politicians about the safety, risks and benefits of water reclamation. The plan died when it became a political football, with candidates for City offices wooing voters with statements like "toilet to tap" (see RC 2002 to learn why water reclamation is not toilet to tap). Voters and candidates need to understand that our

THE GRADES

We give mixed grades for the various responsible parties.

- The wastewater treatment agencies receive an **A** for complying with the Clean Water Act, being proactive in building new treatment plants and committing to improvements without lengthy legal fights.
- Our regulatory agencies, such as the Los Angeles Regional Water Quality Board, receive an **A** for adopting far reaching strategies that are sustainable, and using newer, more scientific approaches to regulation.
- The public receives a mixed grade—an **A** for supporting environ-

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He teaches courses in water and wastewater treatment, mathematical modeling of environmental systems, and laboratory analysis. He has published over 200 papers in journals and conference proceedings. Stenstrom's most recent research focuses on stormwater management in highly urbanized environments such as Los Angeles.

Figure R-3. Narrative reporting style.

Graphic reporting

A commonly proposed and used mechanism for reporting indicator condition is through graphics, which are often combined with the other approaches shown above. One simple example is the glass of water, with partial filling with water corresponding to the degree to which goals for a particular attribute are being met (Figure R-4). Because water, an environmental resource, is used in this case, the graphic itself may determine how people interpret the condition evaluation being conveyed.

Figure R-4. Example of graphic reporting of condition relative to a goal (full glass of water).

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Appendix A – Example Indicator Frameworks

Example Indicator Frameworks

Each framework was analyzed for the indicators and metrics chosen, as well as the approximate scales at which the indicators were relevant

Framework Name	Source	Primary Scale(s)
Atlantic Slope Consortium	http://www.asc.psu.edu/publications.asp	Regional
Cascadia Scorecard 2007	http://www.sightline.org	Watershed
Catchment Condition Report 2007	http://www.vcmc.vic.gov.au/Web/vcmc-public.html#catchment	Watershed
Chesapeake Bay Program	http://www.chesapeakebay.net/	Regional
Credit Valley Watershed Report Card	http://www.creditvalleycons.com/bulletin/resources.htm#water	Watershed
Ecosystem Health Monitoring Program (Freshwater)	http://www.ehmp.org/freshwater_methods_and_indicators.html	Sub-Watershed - National
Environmental Performance Index	http://epi.yale.edu/Home	National
EPA - Report on the Environment	http://www.epa.gov/roe/	National/Regional
EPA - Science Advisory Board	http://yosemite.epa.gov/sab/sabpeople.nsf/WebCommittees/BOARD	Multiscale
Great Central Valley	http://www.greatvalley.org/indicators/index.aspx	Regional
Indicators for environmental performance of watersheds in Alberta	http://environment.gov.ab.ca/info/posting.asp?assetid=7945&categoryid=5	Regional
Long Island Sound Study	http://ww.longislandsoundstudy.net/monitoring/indicators/index.htm	Regional
Millenium Ecosystem Assessment	http://www.millenniumassessment.org/en/index.aspx	Multiscale (local to global scales)
Oregon Plan for Salmon and Watershed	http://www.oregon-plan.org/	Regional
State of the Environment Report Western Australia 2007	http://www.soe.wa.gov.au/report/overview.html	Regional
State of the Fraser Basin Report: Sustainability Snapshot 3	http://www.fraserbasin.bc.ca/publications/indicators.html	Basin
State of Our Environment City of Ann Arbor	http://www.a2gov.org/government/publicservices/systems_planning/Environment/soe07/Pages/ExecutiveSummary.aspx	Municipality
State of the (Puget) Sound	http://www.psp.wa.gov/	Regional
(Saskatchewan) State of the Watershed Reporting Framework	http://www.swa.ca	Watershed
Waikato Regional Council	http://www.ew.govt.nz/Environmental-information/Environmental-indicators/	Regional
White Clay Creek Watershed	http://whiteclay.org/	Watershed

Appendix B – Identification of Watershed Goals

Table 1: Identification of Stakeholder Watershed Goals

(LC=Landscape Condition, BC=Biological Condition, EP= Ecological Processes, SC=Social Condition, EC=Economic Condition, CP= Chemical and Physical Processes, HG=Hydrological and Geomorphological Processes, ND=Natural Disturbance)

Goal Category	**Identified Goals**	**Organization/ Agency**	Essential Ecological Attribute							
			LC	BC	EP	SC	EC	CP	HG	ND
Improve and protect watershed geomorphic and hydrologic processes and functioning	Reduce the mismatch between Delta water supplies, and current and projected beneficial uses dependent upon the Bay-Delta system	CALFED-Bay Delta: Water Supply Reliability Program	x	x	x			x	x	x
	Define a statewide watershed program.	CA Dept of Conservation	x	x	x	x	x	x	x	x
	Assist in implementation of policies and programs of CA Coastal Act- 1976, SF Bay Plan, & adopted plans of local governments & spc. dist.	Coastal Conservancy - SF Bay Area	x	x	x			x	x	
	Protect the California Delta as a unique and valued place.	Delta Vision	x	x	x	x	x	x	x	x
	Reduce risks to people, resources, and state interests in the Delta.	Delta Vision				x	x			
	Healthy Communities and Ecosystems	EPA Region 9	x	x	x	x	x	x	x	x
	Enhancement of River system to the fullest extent, without precluding or eliminating future restoration opportunities	Living River System	x	x	x	x	x	x	x	x
	Natural resources sustained, conserved, restored, & protected within landscape of productive agriculture, growing cities, & wild lands.	Napa Co RCD	x	x	x	x	x	x	x	x
	Maximize effective use of resources	NBWA	x	x	x	x	x	x	x	
	Be proactive on watershed based regulations	NBWA	x	x	x			x	x	
	Pursue integrated flood management solutions	Rutherford Dust Rest Team	x	x	x	x	x	x	x	x
	To promote, assist, and enhance projects for open space and natural areas - accessible to urban populations for recreation & educational purposes.	SF Bay Area Conservancy	x	x	x	x	x	x	x	
	To protect, restore, and enhance natural habitats and connecting corridors, watersheds, scenic areas, and other open-space resources of regional importance.	SF Bay Area Conservancy	x	x	x	x	x	x	x	x
	Improve & implement programs for protection, use, and restoration of Bay resources	SF Bay Conservation & Development Commission	x	x	x	x	x	x	x	

	Promote optimum and sustainable use/management of bay resources	SF Bay Cons & Dev Commission	x	x	x	x	x		x	
	Maintain sustainable river ecosystem	Wildlife Cons Com.	x	x	x	x	x	x	x	x
	Improve protection from fire	WAF Tech Advisory Committee								
	Decrease toxicity of buildings	WAF Tech Advisory Committee								
	Provide good water quality for all beneficial uses.	CALFED-Bay Delta: Water Quality						x	x	
	Improve River Water Quality within City Limits	City Calistoga Public Works						x	x	
	Establish Delta ecosystem & reliable water supply for CA as the primary, co-equal goals for sustainable management of the Delta.	Delta Vision					x		x	x
	Prevent environmental degradation that can affect water quality	Mokelumne River Forum	x					x	x	
	Decrease reliance on groundwater	Napa Sanitation District					x		x	
	Enhancement of Bay-Delta system by reducing dependence on North Bay Aqueduct	Napa Sanitation District					x		x	
	Increase availability of recycle water for irrigation	Napa Sanitation District							x	
	Restore and maintain hydrologic functions of river and streams:	Regional Water Quality Control Board							x	x
	Restore and maintain physical functions of rivers and streams	Regional Water Quality Control Board							x	
	Increase rate/amount of groundwater recharge	Rutherford Dust Rest Team							x	
	Maintain base flows	Rutherford Dust Rest Team							x	
	Prevent unnecessary bay fill and enlarge the Bay where appropriate	SF Bay Cons & Dev Committee	x						x	
	Improve quality of water in Napa River	The Land Trust of Napa Co						x	x	
Sustainability of water reliability for human consumption	Maintain and improve statewide water management systems to provide reliable water supplies, improve drought and flood management, and sustain the Delta	CA Water Plan				x	x		x	x
	Promote integrated regional water management to ensure sustainable water use, reliable supplies, better water quality, environmental stewardship, efficient urban dev, protection of agriculture, & a strong economy	CA Water Plan				x	x	x		
	Reduce the risk to land use and associated economic activities, water supply, agriculture and residential use, infrastructure, and the ecosystem from catastrophic breaching of Delta levees.	CALFED-Bay Delta: Levee Program	x			x	x		x	
	Consumer water conservation	City of Napa Water Div				x	x		x	

	Provide a safe and reliable supply of high-quality drinking water for residential, commercial, industrial, and institutional customers	City of Napa Water Division				x	x	x	x	
	Drive California's water policies through conservation, efficiency, and sustainable use.	Delta Vision				x	x		x	
	Build new facilities for water conveyance and storage, and manage all facilities to achieve the co-equal goals.	Delta Vision							x	
	Clean and Safe Water	EPA Region 9				x		x		
	Improve water reliability through regionally supported projects	Mokelumne River Forum				x	x		x	
	Avoid future water shortages for some Mokelumne interests and improve groundwater reliability	Mokelumne River Forum				x	x		x	
	Prevention or postponement of water supply projects	Napa Sanitation District				x	x		x	
	Assurance of high water quality	Napa Sanitation District				x		x		
Promote watershed awareness and stewardship through improved education, organizational capacity, and recreational access.	Cooperative approaches to resource stewardship and use	CA Dept of Fish & Game				x	x			
	Public service, outreach, education	CA Dept of Fish & Game				x	x			
	Lead the change in the value proposition for the conservation of agricultural and open space land in California.	CA Dept of Conservation	x			x	x			
	Promote, assist, enhance projects that provide open space and natural areas that are accessible to urban populations for recreational & educational purposes	Coastal Conservancy - SF Bay Area	x			x				
	To improve public access to, around the bay, coast, ridgetops, and urban open spaces consistent with rights of private property owners, and without having significant adverse impacts on agricultural operations, environmentally sensitive areas, wildlife.	Coastal Conservancy - SF Bay Area				x				
	Create an effective governance system with the authority, responsibility and secure funding to achieve the co-equal goals.	Delta Vision				x	x			
	Compliance and Environmental Stewardship	EPA Region 9				x				
	Educate public	Inst Cons Adv Research & Ed				x				
	Create long term, cooperative working relationships among Mokelumne water interests	Mokelumne River Forum				x	x			
	Useful and consistent data & information regarding education, government, economics, healthcare, housing, social services	Napa Community Indicators Report				x	x			
	Provide for District management and interagency partnerships.	Napa C Regional Parks & O S Dist				x				

	Provide historical, cultural and environmental educational programming opportunities.	Napa C Regional Parks & O S Dist	x			x				
	Provide opportunities for outdoor recreational through the development of a system of parks, trails, water resource activities, open space & facilities.	Napa C Regional Parks & O Spc Dist	x			x				
	Bring together local agencies to work on issues of common interest	NBWA				x				
	Enhance NBWA's influence on local, state, fed policies & programs	NBWA				x				
	Promote watershed stewardship	NBWA				x				
	Increase eligibility for watershed based funding	NBWA					x			
	Community participation	Rutherford Dust Restoration Team				x				
	Improve coordination & interaction with other orgs to improve bay	SF Bay Cons & Dev Committee				x				
	Improve public access to the Bay and Suisun Marsh	SF Bay Cons & Dev Committee				x				
	Improve public awareness of the Bay and Suisun Marsh	SF Bay Cons & Dev Committee				x				
	Maintain an active enforcement program	SF Bay Cons & Dev Committee				x				
	Maximize public access where compatible with resource protection	SF Bay Cons & Dev Committee				x				
	Play an integral role in developing and implementing a regional proactive strategy for dealing with climate change	SF Bay Cons & Dev Committee				x	x			x
	Maintain compatible land uses on lands adjacent to conserved areas	The Nature Conservancy	x			x				
	Educate/support community to maintain & improve health of Napa	WICC				x				
	Make it more difficult for people to ignore existing regulations; raise additional fine monies that can be used for habitat improvements	Wildlife Cons Com				x	x			
Improve and sustain watershed conditions and functions that advance human and environmental economies	Maintain and improve regional economic heath	Mokelumne River Forum					X			
	Build affordable homes for low and very low income workers	Napa Valley Committee Housing					X			
	Workers can afford to live in Napa	Napa Valley Committee Housing					X			
	Recognize the importance of the Bay in advancing the economic prosperity of the Bay region	SF Bay Cons & Dev Committee					X			

	Maintain and improve viability of agricultural	WAF Tech Advisory Committee					X			
Support social structures that encourage community engagement in watershed management and decision-making	Upkeep/repair/replacement of aging infrastructure (of all kinds).	WAF Tech Advisory Committee				X				
	Increase availability of healthcare	WAF Tech Advisory Committee				X				
	Increase economic self-sufficiency.	WAF Tech Advisory Committee				X				
	Enhance recreational, aesthetic values of Napa river & tributaries	Regional Water Q Control Board				X				
	Support environmental justice in Commission decisions	SF Bay Cons & Dev Committee				X				
	Improve transportation	WAF Tech Advisory Committee				X				
	Improve vineyard worker safety/health	WAF Tech Advisory Committee				X				
	Decrease noise & night lights	WAF Tech Advisory Committee				X				
	Increase environmental justice (poorer areas not exposed to more pollutants)	WAF Tech Advisory Committee				X				
	Improve happiness	WAF Tech Advisory Committee				X				
	Improve cultural resources	WAF Tech Advisory Committee				x				
Conserve, protect and improve native plants, wildlife and fish, their habitats and their communities	Manage wildlife from broad habitat perspective	CA Dept of Fish and Game	x	x	x					
	Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species.	CALFED-Bay Delta: Ecosystem Restoration Program		x	x					x
	Protect, restore, enhance natural habitats & corridors, watersheds, scenic areas, and other open-space resources of regional importance.	Coastal Conservancy - SF Bay Area	x	x	x					
	Revitalize the Delta ecosystem to function as an integral part of a healthy estuary supporting native and migratory species.	Delta Vision	x	x	x			x	x	x
	Land Preservation and Restoration	EPA Region 9	x	x						
	Long term biological monitoring	Inst Cons Adv Research & Ed		x	x					
	Restoration	Inst Cons Adv Research & Ed	x	x	x			x	x	
	Geomorphology, water quality, and habitat to be self sustaining	Living River System	x	x	x			x	x	x

	Preserve and enhance habitat, water quality, natural geomorphic characteristic of the Napa River system	Living River System	x	x	x			x	x	
	Contribute to ongoing efforts to preserve the river's fish, wildlife, and recreational resources	Mokelumne River Forum	x	x	x					
	Preserve, restore and protect open space lands, natural resources and special habitat areas.	Napa County Regional Park & Open Space Dist.	x	?	x					
	Determine viability of existing population and need to improve habitat, water flows, etc. (with AB 2121)	Napa River Steelhead		x	x				x	x
	Improve probability of successful spawning by salmon and steelhead	Napa River Steelhead		x	x				x	
	Enhance the overall health of the native fish community	Regional Water Q Control Board		x						
	Restore and maintain biological functions of rivers and streams	Regional Water Q Control Board		x	x					x
	Improve aquatic habitat for salmonids & other native spp.	Rutherford Dust Rest Team		x	x				x	
	Improve riparian habitat for birds & other wildlife	Rutherford Dust Rest Team	x	x	x					
	To assist in the implementation of the policies and programs of the California Coastal Act of 1976, the San Francisco Bay Plan, and the adopted plans of local governments and special districts.	SF Bay Area Conservancy	x	x	x			x	x	
	Improve health and species diversity of aquatic fauna	The Land Trust of Napa Co		x						
	Maintain adequate flow, water quality to protect aquatic habitats & species	The Nature Conservancy	x	x	x			x	x	x
	Protect remaining critical habitats	The Nature Conservancy	x	x						
	Build on existing protected areas	The Nature Conservancy	x							
Reduce greenhouse gas emissions and adaptively manage watershed resources to address changing climatic conditions.	Reduction of Greenhouse Gas Emissions	EPA Region 9						x		
	Improve air quality	WAF Tech Advisory Committee						x		

A. Condensed North Bay-Delta WAF goals, objectives, and potential indicators.

Goal	Objectives	Potential Indicators
Reduce greenhouse gas emissions and adaptively manage watershed resources to address changing climatic conditions.	Promote activities that contribute to the reduction of GHG emissions from the energy and industry sectors Promote the use of fuel-efficient vehicles Increase awareness of climate change issues Develop adaptation strategies for watershed managers and institutions to minimize risks and maximize opportunities associated with climate change Monitor and track changes in weather, hydrology and ecosystems Make ecosystems and resource systems more adaptable or resilient to climate change	Percentage of energy consumed that is 'green' Median MPG of vehicles in watershed Number of public education events -climate change Number of government climate change initiatives for watershed resource managers Number of weather monitoring sites
Conserve, protect and improve native plants, wildlife and fish, their habitats and their communities	Protect and improve riparian and wetland habitat quality Protect and improve native plant communities Protect and improve aquatic and terrestrial habitat connectivity Protect and improve native bird, amphibian, mammal, fish and invertebrate populations and communities, particularly sensitive and at-risk species Discourage and reduce invasive, non-native species Promote the creation of protected areas, conservation easements, etc. Encourage management activities in ranches and farms that improve wildlife habitats	Acreage of wetland habitat Acreage of native plants Acreage of connected habitat Percentage of at-risk species population in protected area Percentage of riparian corridor dominated by nonnative plants Number of new protected parcels in past year Number of private land owners participating in NRCS's EQIP or WHIP
Improve and sustain watershed conditions and functions that advance human and environmental economies	Improve personal income, employment rates, home ownership rates Improve productivity & sales of businesses, agriculture, and recreation Improve rate of economic self sufficiency Increase the availability of safe, decent affordable housing for low-income individuals and individuals with developmental disabilities.	Median income Yearly agricultural sales Percentage of population on welfare Percentage of homes priced affordably
Support social structures that encourage community engagement in watershed management and decision-making	Improve health and health care at work and home Decrease traffic and commuting times Improve child care availability & affordability Decrease crime rate Improve cultural resources Increase emergency preparedness Support community planning and management actions that protect	Percentage of population with health care Median duration of commute Percentage of childcare centers that are affordable Crime rate Number of cultural presentations Percentage of prepared households Yearly pending on infrastructure

	and improve adequate public facilities and infrastructure Support projects, programs, and policies that provide people equal access to safe energy, healthy food, clean air and water, open space, non-toxic communities, and equitable opportunities for education, employment, and access to decision making. Support programs that empower at-risk youth through environmental education, mentoring, civic activism, and hands-on work in conservation and restoration.	Percentage of population who go hungry Number of at-risk youth served by community programs
Promote watershed awareness and stewardship through improved education, organizational capacity, and recreational access.	Educate the public (students, funders, and public officials) about the ecological, recreational, scenic, aesthetic, and relaxation functions of their watershed. Create long term, cooperative working relationships among watershed interests. Provide training in interest-based negotiation and opportunities for watershed stakeholders to discover collaborative solutions to watershed needs. Provide historical, cultural and environmental educational programming opportunities. Provide opportunities for outdoor recreation through the development of a system of parks, trails, water resource activities, open space and related facilities, especially for urban populations. Improve public access consistent with the rights of private property owners, and without having a significant adverse impact on agricultural operations and environmentally sensitive areas and wildlife. Create and maintain systems for providing useful and consistent data and information on the watershed and watershed improvement efforts, to watershed stakeholders, including the general public, students, and public officials. Increase eligibility for watershed based funding Increase community participation (particularly among lower-income, lower-status groups) in natural resource issues. Promote watershed stewardship by landowners and residents by providing technical assistance, organizing assistance, and help obtaining funding.	Number of people participating annually in selected education and outreach efforts. Months of activity multiplied by number of durable collaborations; government dollars for collaborations. Number of years in the last 3 years in which at least one forum of at least 6 stakeholder groups was held. Number of people participating annually in selected education and outreach efforts. Miles of trails within 1/2 mile of urban areas; acreage of publicly accessible recreational and open space lands within 1/2 mile of urban areas [SCAPOSD has good metric.]. Frequency of complaints from private property owners or trustee agencies about public access. Usage statistics from 5 most relevant websites. Funding allocated annually to support such participation Number of interest groups multiplied by number of attendees per group who attended 10 most relevant

		events each year. Number of residents receiving such assistance annually; number of programs providing such assistance; acreage of land served; acreage of land or linear feet of stream revegetated or enhanced.
Improve and protect watershed geomorphic and hydrologic processes and functioning	Restore natural variability of hydrologic systems Maintain natural flow regimes in regulated waterways Reduce artificial sources of surface water from developed areas to waterways Conserve and restore natural erosion as a source of sediment Reduce artificial inputs of sediment to streams Increase the number of stream reaches with natural channel morphology Conserve natural variability in stream geomorphology and benthic composition	Number of waterways with natural flow regimes Volume of water from stormdrains entering main waterway Rate of erosion Sediment lode in river Number of stream reaches with natural channel morphology
Manage water quality and quantity to meet multiple needs for human and environmental use	Improve connections between native surface waters and groundwater basins Improve and protect flows to benefit aquatic communities and ecosystem processes Increased the reliability of water quality and yields from groundwater basins Reduced water demands and reliance on imports for the region Improved efficiency of water use within the watershed Protect and improve water quality for aquatic ecosystems	Number of streams with sufficient flow to promote aquatic community Volume of imported water per capita Volume of total water used per capita Dissolved oxygen content of river

8.5 Indicator Selection Process

Indicator Selection Process for the North Bay-Delta Transect Watershed Assessment Framework

INDICATOR DEVELOPMENT AND REPORTING PLAN – County of Napa 4600007937

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4/26/2010

Contents

Introduction

This report summarizes the process used by the project team to select a final set of indicators for assessment of environmental conditions in Napa County within the *Watershed Assessment Framework*. The analytical framework for this effort is described in the document *Knowledge Base for the North Bay-Delta Transect Watershed Assessment Framework: Report on Analytical Approach*, also prepared for this project. Included as appendices to this report, are two documents supplied by Fraser Shilling, which provided important support to the process (Appendix A: *Indicator Selection Criteria* & Appendix B: *Napa River WAF Indicator Descriptions*).

Goals and Objectives

The project team began by considering watershed goals to guide the indicator selection process. The project team used three approaches to develop the list of watershed goals. First, the team surveyed 65 active watershed stakeholder groups by mail using a worksheet on which they were asked to write their goals and objectives for their watersheds. Ten groups responded to the survey. Second, we extracted goals and objectives from planning documents and mission statements of 17 stakeholders that did not respond to the mailed survey. The team searched online documents of state and federal agencies that are active in the region, and goals pertaining to the watershed attributes identified in the WAF were included in the comprehensive list. Third, the team presented the list of compiled goals to the project's Technical Advisory Committee (TAC) and the TAC suggested additional goals that were added to the list.

The list of goals and objectives was subsequently refined, on the basis of the project team's investigation of relevant indicators likely to have sufficient data for evaluation. A broad list of potential indicators was then assembled, keyed to specific goals and objectives, on the basis of joint consideration of the indicator selection criteria, recommendations from project team members, and comparison with comparable systems in the global indicator literature. The goals and objectives are shown in the following Table 1. For the list of potential indicators and information on their sources, please see the first tab of the accompanying electronic spreadsheet (*Draft Final Indicators_4142010.xls*).

Table 1. Original Goals and Objectives

Goal	*Objective*
Improve and protect watershed geomorphic and hydrologic processes and functioning	Restore natural variability of hydrologic systems
	Maintain natural flow regimes in regulated waterways
	Reduce artificial sources of surface water from developed areas to waterways
	Conserve and restore natural erosion as a source of sediment
	Reduce artificial inputs of sediment to streams
	Increase the number of stream reaches with natural channel morphology
	Conserve natural variability in stream geomorphology and benthic composition
Promote watershed awareness and stewardship through improved education, organizational capacity and recreational access	
Improve and sustain watershed conditions and functions that advance human and environmental economies	
Support social structures that encourage community engagement in watershed management and decision-making	
Conserve, protect and improve native plant, wildlife and fish habitats and their communities	
Manage water quality and quantity to meet multiple needs for human and environmental use	Improve connections between native surface waters and groundwater basins
	Improve and protect flows to benefit aquatic communities and ecosystem processes
	Increased the reliability of water quality and yields from groundwater basins

	Reduced water demands and reliance on imports for the region
	Improved efficiency of water use within the watershed
	Protect and improve water quality for aquatic ecosystems
Reduce greenhouse gas emissions and adaptively manage watershed resources to address climate change	
Support community planning and management actions that protect and improve adequate public facilities and infrastructure, including affordable housing	
Support healthy, happy, and economically-just communities	

Winnowing Steps

This rather lengthy list of indicators was then subjected to a series of winnowing steps to produce a final set of indicators. Local resource agency staff first carried out an informal review of the list, selecting 21 indicators (approximately half) for closer analysis. This first-cut selection included at least one indicator for each of the 9 goals identified and also at least one for each of the 8 attributes in the California Watershed Assessment Framework (WAF attributes). The procedure for making the final cull may be summarized as follows:

1. *The first list of 9 goals and corresponding objectives was consolidated*. There were areas of overlap between different goals, so in order to make the results of our work more useful in the public arena we determined to shorten the list by combining related issues into single goals, reducing the degree of overlap. The resulting list included 6 goals, and for two of them a limited number of objectives were retained. The list of consolidated goals and objectives is shown in Table 2.

Table 2. Consolidated Goals and Objectives

Goal	*Objective*
1. Improve and protect watershed geomorphic and hydrologic processes and functioning	1a. Restore natural variability of hydrologic systems, including stream geomorphology and benthic composition
	1b. Reduce artificially increased inputs of sediment to streams, particularly those due to increases in runoff from developed areas
2. Promote watershed awareness and stewardship through improved education, recreational access, and community involvement in decision-making	
3. Conserve, protect and improve native plant, wildlife and fish habitats and their communities	
4. Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity	4a. Improve and protect flows to benefit aquatic communities and ecosystem processes
	4b. Reduce reliance on imports by reducing demand, improving the efficiency of water use, and increasing the reliability of water quality and yields from groundwater basins
	4c. Protect and improve water quality for aquatic ecosystems
5. Reduce greenhouse gas emissions and adaptively manage watershed resources to address climate change *could be subsumed under the previous goal*	
6. Support community planning and management actions that protect and improve adequate public facilities and infrastructure, including affordable housing, in order to further the goal of a healthy, happy, and economically just community	

2. *Indicators previously identified were organized into a table according to the new consolidated goal and WAF attribute with which each was most closely related.* Table column headings corresponded to WAF attributes and table rows corresponded to goals and objectives. This made it easier to ensure that "all bases were covered," as we considered the final selection.

3. *The indicators were evaluated using a set of 7 criteria developed and used by two other regional WAF projects – Sacramento River Watershed and Southern California*. Making use of short indicator descriptions supplied by UC Davis and our indicator selection criteria, we determined the degree to which each criterion appeared to be satisfied for each of the 21 indicators. For each of the 7 criteria, we judged whether the degree of satisfaction was high, medium or low, and we used these judgments to guide our selection of preferred indicators. Our aim was to select one indicator for each goal or objective. In doing this, the project team relied on both local knowledge and experience and the resources of our academic partners. The indicator selection criteria are summarized in a document headed *SR-WHIP: Indicator Selection Criteria*, which has been appended below.

4. After review of the results of the previous step by UC Davis project partners, the project team decided to retain all indicators on the final list, subject to review in light of the availability and suitability of data. The indicators were divided into two groups, distinguishing between a first tier and a second tier.

The final indicators are listed in Table 3 (first tier) and Table 4 (second tier). For more details on the selection process, see the accompanying electronic spreadsheet *Draft Final Indicators_4142010.xls.* A short narrative description of each can be found in Appendix B of this report.

Table 3. Final Indicators (first tier)

indicator	*related goal/objective*	*WAF category*
Natural flooding and connection with floodplain: proportion of river with floodplain access, proportion of floodplain accessible by 2, 10 yr floods and flood pattern	1a	Natural Disturbance
Impervious area runoff: % area impervious	1b	Landscape Condition
Pollutant reduction through TMDL: load reduction	1b	Physical/Chemical
Watersheds with citizen monitoring programs and/or watershed groups: # involved	2	Social Condition
Salmon population: smolt production, number of returning adults per run	3	Biotic Condition
Ground water storage: spring and fall water table depth	4b	Hydrology/Geomorphology
Water use and savings: per capita use, efficiency savings, re-use	4b	Economic Condition
Water quality: T, DO, DSS, Cond.	4c	Physical/Chemical
Net carbon storage in natural and agricultural landscapes	5	Ecological Processes
Free and reduced price meals programs	6	Economic Condition

Table 4. Final Indicators (second tier)

indicator	*related goal/objective*	*WAF category*
Embeddedness/ Permeability	1a	Hydrology/Geomorphology
Channel morphology, dynamicism	1a	Hydrology/Geomorphology
% residents that have positive view toward environment	2	Social Condition
sustainability policies index	not listed	not listed
Christmas Bird Count: # spp., total annual count; wading and tidal marsh birds	3	Biotic Condition
BMIs: various metrics; EPT, spp richness; Native fish counts, spp. Diversity, IBI	3	Biotic Condition
Recurrence intervals for fire in different plant communities	4	Natural Disturbance
% of un-developed watershed burned per year	4	Natural Disturbance
Instream base-flow: 7-day min average flow at gage	4a	Hydrology/Geomorphology
% new development in urban areas, housing density; annual change in average house price compared to state average	6	Economic Condition

Appendix A: Indicator Selection Criteria

The summary of selection criteria is that there is existing knowledge of indicators that are feasibly monitored, the indicators are representative of the social and ecological systems, and that there are and will continue to be data for the indicators.

- Availability of high-quality data

  One of the main obstacles many face when selecting indicators is the lack of available data. Frequently the data for an indicator that may be important are not available. Alternatively, the data might only be available for random points in time or for limited geographical areas. The data might have been collected for one purpose in a particular way that served the original purpose, but for your purposes, it may be inadequate. If new data are needed, the feasibility of collecting them might be limited by the amount of effort required to accurately make the measurement (e.g., actual salmon escapement). Alternate indicators may be considered that have significantly lower cost (e.g., remote-sensing based habitat assessment). For certain indicators, it may be very cost-effective to collect the required metrics (e.g., habitat assessment for a species of concern), but the indicator may not represent the process of concern compared to more expensive indicators (e.g., actual population trends in the species of concern).

  Data collection and analysis costs (further described as a separate criterion below) have to be evaluated in relation to the potential cost and societal implications of a proposed action or inaction, i.e., the greater the expected tradeoffs between societal goals, the greater the need for certainty in the environmental outcome. When choosing indicators, it is essential to carefully consider the current availability of data for the indicator, as well as how much data will be available in the future from our own collection and from the efforts of others. The availability of metadata is one criterion for selection of particular data for corresponding indicators. Finally, indicators will be useful and useable in the long-run if there is a process for updating the corresponding database, metadata, and data collection & QA/QC procedures.

- Data costs and benefits

  One factor to consider in evaluating indicators is the costs associated with collecting and analyzing data. One consideration in evaluation the costs and benefits is the usefulness of the information for evaluation of management and ecosystem condition. Indicators that are cost-effective, while accurately representing ecosystem characteristics are preferable. The primary guide is that the amount of data required to adequately report on condition and change in condition can be and are being collected with the resources available. The data should also be collected in a standardized way for which there are QA/QC procedures described. For critical indicators (those reflecting important system conditions for which there is no viable alternative), more resources may need to be made available if they are currently inadequate.

- System representation

Another factor to consider in indicator selection is how well the indicator reflects the issue for which it was selected. Frequently, certain indicators are widely recognized to be a useful measure for an issue. Selecting these indicators is usually a 'safe bet'. For example, % riparian canopy cover is considered a good indicator of riparian conditions because it has been extensively studied and shown to have a good relationship with stream temperature and the detection of changes can be made easily. Selecting indicators that have been carefully evaluated for their scientific validity means they usually have wider acceptance than those that haven't been studied very much, and they are more likely to allow you to make confident inferences about system condition.

Indicators that are representative of large aspects of system condition and trends are preferable for those that have narrower utility, all else being equal.,

Sometimes the condition is itself an important ecosystem driver. For example, surface water temperature is an important ecological variable for understanding the condition of aquatic ecosystems. It is also the target of management actions to benefit these ecosystems, which is another criterion described below. Indicators that can provide important information at both broad and fine spatial scales are likely to be more useful as they can help inform both strategic and site-specific decisions.

- Ability to detect change over time

The ability to report on trends over time is a key function of an indicator. The availability of a data set collected over a period of many years is ideal. Indicators that respond relatively quickly to management intervention and can effectively be used to measure change over time may be preferable to those that require data over long periods of time to observe changes due to management actions. This is especially useful in reference to short-term grants and contracts, or short-term program evaluation, which require performance measures to demonstrate the success or failure of the project. If possible, select indicators whose range of natural variation can be quantified and that permit change detection over short periods of time (2-3 years). At the same time, recognize that many of the processes that we try to improve with restoration programs take decades or longer to change or recover (e.g., salmon population recovery).

Indicators for these projects and programs should be stable over these longer timeframes (i.e., decades).

- Independence of indicators from one another

Independence refers to how related indicators are to each other. Road density and %impervious surface are related indicators because roads are often impervious. Indicators that are relatively independent are preferable (e.g., rate of ground water use for irrigation and migration barriers), while recognizing that some critical indicators are related and somewhat dependent on each other (e.g., surface water temperature, flow, stream shading, hydraulic connectivity to groundwater, salmon rearing habitat suitability). The concern about independence is important for designing efficient indicator systems, but is secondary to choosing easily-measured and representative indicators. You may choose related indicators, but you would be constrained in your attempts to use them together to explain condition of a system. For example, if (a) surface water temperature, (b) flow, (c) stream shading, (d) amount of groundwater withdrawal, and (e) salmon rearing habitat were indicators of success for a restoration program, then you could not report changes in these indicators without acknowledging that (a) depends on (b), (c), and (d); (e) depends on (a), (b), (c), and possible indirectly on (d) through (b); and (c) may depend on (b) and (d). If restoration of riparian shade (c) was a goal in order to benefit salmon rearing (e), then the inter-dependence of some of the other parameters would need to be acknowledged and potentially controlled-for in order to measure the true effect of increased riparian shade on salmon rearing.

- Supports management decisions and actions

Measuring conditions in the environment and in communities can inform policy development and social/fiscal investments. Indicators should be informative in evaluating environmental/social/economic conditions, as well as the influences on these conditions. Another useful characteristics of indicators is that they can be used to evaluate the effects or effectiveness of management actions – be it a state or federal agency or the goals and objectives of a watershed council. Whatever the business of the organization is, indicators should provide information that can be used to assess the effectiveness of the work and efforts of the group. In the past, *activities* were seen as a measure of the effectiveness of an organization. The number of grants awarded, the number of pamphlets distributed, or similar "bean counting" has been used extensively to evaluate an organization's productivity. Environmental performance measures, on the other hand, look at the environmental and social *outcomes* of these activities to determine an organization's effectiveness. This is the reason it is so important to select indicators that are closely linked to management actions and decisions.

- Can be reported and understood in public arenas

  The point of most indicators is to inform a wide audience about conditions in the environment and communities. Indicators should be science-based and easily understood by various kinds of decision-makers (e.g., scientists, public, elected officials). They should be equally presentable in summary form in newspapers and on web sites. Finally, indicators should be based upon reportable technical & scientific information and links easily made between summary presentations and the source data and knowledge.

Sources:

Shilling, F.M., S. Sommarstrom, R. Kattelmann, B. Washburn, J. Florsheim, and R. Henly. California Watershed Assessment Manual, Volume II (2007). Prepared for the California Resources Agency and CALFED (http://cwam.ucdavis.edu).

Stalberg, H.C., Lauzier, R.B., MacIsaac, E.A., Porter, M., and Murray, C. 2009. Canada's policy for conservation of wild pacific salmon: Stream, lake, and estuarine habitat indicators. Can. Manuscr. Fish. Aquat. Sci. 2859: xiii + 135p.

Appendix B: Napa River WAF Indicator Descriptions

In the first column, each goal, objective, WAF attribute, and indicator are coded and presented as follows: Goal.Objective.WAF.Indicator #

A.1.ND.i Proportion of river with floodplain access – For healthy rivers, flood-waters have contact with flood-plains. In developed areas, natural flood-plains have been replaced by agricultural and urban areas protected by levees. Levee setbacks and extensive bypasses provide an artificial and partial solution. Ideally, rivers would have access to the flood-plain along much of its length.

Proportion of floodplain accessible by 2 and 10 year floods and flood pattern – Similar in concept to the previous indicator. Could be measured by calculating the proportion of the 100-year flood-plain accessible by 2 and 10 year floods. Flood pattern refers to the combination of flood extent and frequency.

A.2.ND.i Integrated storm-water/flood management: volume storm-water retained/recharged

A.3.HGM.i Impervious area runoff: Paving and compaction prevents natural infiltration of precipitation into ground water. Instead, rain runs off directly into waterways, impacting stream physical conditions and habitat quality, or is collected in storm-water management systems and released from a pipe into waterways. Sub-watershed metric = % sub-watershed area impervious; Watershed metric = % of sub-watersheds with >10% impervious surface

A.3.HGM.ii Detention of urban storm-water for infiltration: Captured urban runoff can be diverted to ground-water through infiltration swales and basins. Metric = % of urban storm-water captured for infiltration to ground water.

A.4.HGM.i Annual sediment load (SEC)

A.4.PC.i Pollutant load reduction through TMDL: Effective TMDL implementation results in measurable reduction in pollutant loads. Metrics include change in specific pollutants covered by TMDLs relative to goals for these pollutants.

A.4.EC.i Capital valuation of properties at risk of water erosion: Water-erosion refers to flooding and other precipitation-caused wasting of land-surface to waterways and other land-surfaces. Property values are usually available in the County parcel database. Metric could be land-value in the watershed at risk of either or both flooding (100-year flood-plain) or mass-wasting.

A.5.HGM.i Floodplain protection: Protecting flood-plains and their connections to channels is a critical conservation activities protecting biodiversity, geomorphic processes, and human endeavors (e.g., urban areas). Metric could be acres of flood-plain in conservation easement or other protected status as a proportion of total flood-plain.

A.6.HGM.i Embeddedness/permeability: Coarse gravels and cobbles are essential spawning habitats and homes for benthic macroinvertebrates. Coarse benthic sediments can become embedded in finer sediments from excessive erosion, reducing the flow of oxygenated water and habitat value for fish and insect larvae. Metric could be distribution of sediments across size classes (fine to coarse) for particular stream reaches.

A.6.HGM.ii Channel morphology, dynamicism: Channels moving through relatively flat and low-slope alluvial plains will naturally tend to meander in response to changing flows, land-forms, and vegetation. This process re-works lands and is a critical geomorphic process for maintaining riparian vegetation and aquatic ecosystem structure and function. Metric could be sinuosity (how much a channel meanders), lateral movement of the channel over time, incision of the channel in the plain, reducing opportunities for meander.

B.1.LC.iRestoration projects to improve upland, riparian, and stream conditions: Knowledge of and support for restoration programs and organizations is an important indication of public education about and stewardship for watershed characteristics and processes. Metric could be number of projects per year supported or funded by local institutions.

B.1.SC.i Community involvement in watershed management/restoration: The more people involved in and supportive of watershed management and restoration, the more likely effective action will take place. Metric could be # of people involved, especially members of public, in decision-making and sponsored activities.

B.1.SC.ii Proportion of residents that have positive view towards environment: Most effective action for the environment follows a positive view toward the environment. Surveying by statewide polling organizations includes questions about the environment. Metrics could include proportion of people concerned about the environment and supportive of action to protect and restore the environment.

C.1.LC.iProportion of protected to developed lands: Protection of landscapes through voluntary stewardship actions, conservation easements and fee-title acquisition is a common practice to conserve watershed attributes and processes. Metric could be percent of sub-watershed composed of protected lands vs. developed lands (urban or intensive agriculture) and % of sub-watersheds with greater protection than development.

C.1.HGM.i Riparian, channel, and wetland restoration (miles, acres): In developed landscapes, restoration of natural characteristics (e.g., riparian vegetation) and processes (flood-plain connection) is a vital restoration activity for stream and wetland systems. Metric could be proportion of degraded historic riparian, flood-plain, and wetland areas that have been restored.

C.1.ND.i Recurrence intervals for fire in different plant communities: For certain vegetation types, the fire return interval has lengthened considerably due to fire suppression. This leads to greater threats of high intensity fires. The naturally-occurring fire regime for different vegetation types includes a range of return intervals, extents and durations. Un-natural conditions include those outside this range.

C.1.ND.ii Proportion of un-developed watershed burned per year: Fire is a natural disturbance in many Californian vegetation types. Natural, undeveloped parts of the landscape can be expected to burn at frequencies that depend upon the types of vegetation. Metric could be the % of each sub-watershed that has been burned each year.

D.1.SC.i Watersheds with citizen monitoring programs and/or watershed groups: Metric could be % of watershed with a watershed group, or % of sub-watersheds covered by watersheds.

E.1.LC.i% of historic vegetation types remaining undeveloped: Development of native and historic vegetation interferes with natural processes. Metric could be the % of historic/native vegetation in a sub-watershed that lacks any development. Watershed metric could be % of sub-watersheds that have less than XX% (25% ?) development.

E.1.LC.ii weed invasion: Invasion of native and non-native plants into ecosystems can disrupt habitat structure and ecosystem function. Weeds are poorly mapped in California, but for certain weeds, distributions are better understood (e.g., Arundo donax). Metrics could include -- % of each veg type invaded, % of sub-watersheds with significant invasions, etc.

E.1.LC.iii Landscape connectivity/fragmentation: This is very important attribute of landscape structure and ecosystem function. Fragmentation affects wildlife distribution and movement, water flows, aquatic system condition, and other attributes and processes. There are many possible fragmentation and connectivity metrics to choose among. Several that are independent from each other and comprehensive in their representation of fragmentation are patch shape, patch isolation from similar patches, relative distance of grid cells from disturbance, habitat integrity, and effective patch size.

E.1.HGM.i Stream physical habitat: the physical composition and structure of stream beds and associated woody material and banks partially determines aquatic habitat value. Metrics could include benthic sediment composition relative to expectations, availability and frequency of large wood, channel incision, and rate/extent of bank erosion.

E.1.HGM.ii Proportion of original tidal wetlands remaining: Tidal wetlands are a very important type of habitat for many marine, fresh-water, and terrestrial species. They provide a structural and functional interface between two very different worlds in the North Bay and Delta. They have also been highly developed and impacted by pollution and other disturbances. Metric could be % of original mapped tidal wetland remaining at the mouth of a watershed to the Bay or western Delta.

E.1.BC.i Salmon population: one of our most visible forms of fish and wildlife, salmon are iconic species in the Delta. The crash of anadromous salmonid populations is indicative of watershed impacts and distressing to those enjoying economic, dietary, and aesthetic benefits from healthy populations. Metrics could include smolt production per large sub-watershed or watershed and/or number of returning adults per sub-watershed or watershed.

E.1.BC.ii Bird count: Populations of individual birds and bird diversity are important indicators of terrestrial, riparian, and wetland condition. They are important in their own right because of peoples' appreciation of their presence. Metrics include # of species per sub-watershed or watershed, total annual count per sub-watershed or watershed, presence and # of wading and tidal marsh birds

E.1.BC.iii BMIs (benthic macroinvertebrates): these organisms are indicative of watershed disturbance and an important source of food for fish (larval forms), birds, and bats (adult forms). There are many possible metrics, including species richness; sensitive species richness; EPT richness – Ephemeroptera, Plecoptera, and Tricoptera are Orders of benthic macroinvertebrates that are sensitive to watershed and waterway disturbance by human activities; proportion of pollution tolerant to intolerant (sensitive) species, which varies with watershed disturbance.

F.2.HGM.i Instream base-flow: Flow is a critical variable both in terms of flooding flows to maintain ecosystem structure and minimum flows that are still adequate to maintain cool, wet conditions for fish and other aquatic animals. Metric could be 7-day minimum average flow at gage.

F.3.HGM.i Ground-water storage: Ground-water is largely un-regulated in California and in some places is declining in availability and quality. Metric could be spring and fall water table depth.

F.3.SC.i Proportion of population served by community water systems with no reported violations: this metric indicates how well our water supply systems are performing to meet peoples' drinking water quality needs.

F.5.EC.i Water use and savings: Water conservation is one way to meet the challenge of increasing populations and potentially decreasing, or less reliable, water supplies. Metrics include per capita use, efficiency savings, proportion of water re-used.

F.6.PC.i Water quality: temperature is a critical ecosystem condition that can determine habitat availability and quality for animals and plants. Dissolved oxygen concentrations in water vary with temperature, elevation, in-stream primary production, in-stream respiration (biological oxygen demand), chemical oxygen demand, and turbulence. Two common causes of insufficient dissolved oxygen for aquatic life are high temperatures and high in-stream plant biomass because of eutrophication. Total suspended sediments and conductivity are two other measures of water quality.

F.6.PC.ii Pollutant load reduction through TMDL

F.6.BC.i BMIs (benthic macroinvertebrates): these organisms are indicative of watershed disturbance and an important source of food for fish (larval forms), birds, and bats (adult forms). There are many possible metrics, including species richness; sensitive species richness; EPT richness – Ephemeroptera, Plecoptera, and Tricoptera are Orders of benthic macroinvertebrates that are sensitive to watershed and waterway disturbance by human activities; proportion of pollution tolerant to intolerant (sensitive) species, which varies with watershed disturbance.

F.6.EP.iNitrogen budget/constituents (e.g., ammonia): There are various possible nitrogen compounds to measure that indicate healthy nitrogen cycling and inputs and inputs from human activities. Excess ammonia indicates certain ag and urban wastewater inputs and can harm aquatic organisms. Excess nitrate/nitrites also indicates certain ag and urban wastewater inputs and can disrupt nitrogen cycling, cause excessive algal/periphyton growth, and degrade drinking water quality. The metrics will vary here, but ammonia and nitrate/nitrite are good initial choices.

G.1.HGM.i Precipitation: Climate change will cause changes in regional temperatures and precipitation amounts and timing. Metric could be annual rainfall departure from long-term average.

G.1.SC.i Transportation is a major contributor to greenhouse gases carbon dioxide and nitrous oxide. As people change transportation patterns, they change their greenhouse gas production. Meeting SB375 requirements requires that city and county governments pay attention to the combination of land-uses and transportation choices in their jurisdictions. Metrics include vehicle miles traveled (VMT) per capita, mode choice -- cars vs. biking, buses, etc

G.1.EP.i Net carbon storage in natural and agricultural landscapes. Carbon storage/flux – Carbon may be stored/sequestered in natural systems as plant biomass (above or below ground), or soil carbon as a result of partial decomposition. Flux refers to the exchange of carbon among soil, plant, water, and air compartments. From a climate change point of view, it would be best to have high carbon storage rates and negative net flux to the atmosphere of CO_2 and CH_4.

H.1.SC.i Community planning to improve public infrastructure and affordable housing: In-fill and other smart growth development patterns will tend to make provision of services easier and provide mechanisms to keep some housing affordable. Metrics include % new development in urban areas, housing density; annual change in average house price compared to state average, proportion of income devoted to mortgage or rent.

I.1.SC.i Prevalence of child-hood asthma: childhood asthma is increasing rapidly in urban and agricultural areas and is a good indicator of air quality and human health. Metrics could include the rate of childhood asthma (measured at the individual school scale).

I.1.EC.i Rate of public assistance – public assistance comes in various forms and indicates local or regional poverty rates. One of the best measures of this is enrollment of children in free and reduced cost meals programs (http://nces.ed.gov/programs/coe/2009/section4/indicator25.asp). These data are available for individual schools. Rates of enrollment are also available by ethnicity.

I.1.EC.iiEconomic disparities are often reported as a critical failing of economic systems to b provide somewhat equitable opportunities and resources. Metric could be income gap -- difference between top and bottom 20%.

Napa River & North-Bay/Delta Watershed Assessment Framework

Consolidated goals and objectives with first-cut selection of indicators RZ 2/4/2010		Indicators by WAF Category							
Goals (green identifiers refer to short indicator descriptions)	Objectives	Landscape Condition	Hydrology/ Geomorpholo	Physical/ Chemical	Biotic Condition	Social Condition	Economic Condition	Natural Disturbance	Ecological processes
A. Improve and protect watershed geomorphic and hydrologic processes and functioning	Restore natural variability of hydrologic systems, including stream geomorphology and benthic composition		1. Riparian condition as measured using CRAM					1. Natural flooding and connection with floodplain	
	Reduce artificially increased inputs of sediment to streams, particularly those due to increases in runoff from developed areas	1. Impervious area runoff: % area impervious		1. Pollutant reduction through TMDL: load reduction (NBWA)					
BD. Promote watershed awareness and stewardship through improved education, recreational access, and community involvement in decision-making						1. Public discussion of watershed issues in the press			
	2. Improve community recreational access to public watershed lands					Recreational access to public open space			
E. Conserve, protect and improve native plant, wildlife and fish habitats and their communities		Landscape fragmentation and connectivity as indicated by the effective emsh size metric (Girvetz et al., 2008)			1. Salmon population:number of returning adults and Redds; 2. Bird population and sensitive species abundance/diversity (Breeding Bird Survey, Christmas Bird Count: # spp., total annual count, wading and tidal marsh birds); 3. Benthic macro-invertebrates: EPT, spp richness; 4. Native fish counts, diversity, native vs. non-native				
CF. Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity								1. Recurrence intervals for fire in different plant communities (SAB); 2. % of un-developed watershed burned per year (SOE-WA)	

	Improve and protect flows to benefit aquatic communities and ecosystem processes		1. Instream base-flow: 7-day min average flow at gage (NBWA) (SEC)						
	Reduce reliance on imports by reducing demand, improving the efficiency of water use, and increasing the reliability of water quality and yields from groundwater basins		1. Ground water storage: spring and fall water table depth (NBWA) (SEC)				1. Water use and savings: per capita use, efficiency savings, re-use (NBWA) (SOE-WA) (SOE - CAA)		
	Protect and improve water quality for aquatic ecosystems			1. Water quality: T, DO					
G. Reduce greenhouse gas emissions and adaptively manage watershed resources to address climate change *could be subsumed under the previous goal*									1. Net carbon storage (standing stock and sequestration) in natural and landscapes
HI. Support community planning and management actions that protect and improve adequate public facilities and infrastructure, including affordable housing, in order to further the goal of a healthy, happy, and economically just community							1. School lunch program enrollment; 2. Housing affordability for modeerate income families		
							Use township prices in Table 18, compare: 1= moderate income can afford, divide maximum afford (Table 19) by median home price (Table 18) OR set St. Helena median to 0 score		
							Rich control of access to benefits from streams through property ownership		

8.6 Data Analysis Framework

Data Analysis Framework for the North Bay-Delta Transect Watershed Assessment Framework

INDICATOR DEVELOMENT AND REPORTING PLAN – County of Napa 4600007937

Prepared by:
Fraser Shilling (University of California, Davis)

2/27/2010

Contents

Executive Summary

This report describes a data analysis framework and plan for indicators in the North Bay and Delta region of California. Watershed goals and objectives were developed by local stakeholders in the North Bay. Indicators of watershed condition were selected corresponding to the stakeholder goals and objectives. The focus watershed for data analysis using the WAF approach will be the Napa River watershed. The focus watershed is intended to be representative example of the region, while recognizing that intra-regional differences in ecosystem properties would likely limit the direct application of the identical indicators elsewhere. The combination of the focus watershed and regional watershed assessment framework provides a foundation for a region-wide application of the WAF at the watershed scale, as well as serving as an example for the state.

The analysis plan is divided into two main sections: 1) geo-spatial analysis and statistics and 2) data analysis and statistics for data collected over time at single points. Because the point-data will eventually be attributed to a sub-watershed or watershed, the division between (1) and (2) is largely for convenience in describing methods and organizing data. The plan also includes an approach for including the results of studies recently completed by others for one or more of the WAF indicators.

1) Geospatial analysis will be conducted within a geographic information system (GIS). Digital maps (e.g., vegetative land cover) are stored, analyzed, and published using the GIS.
2) Point-data analyses will be conducted separately for each metric. The data will be numeric (e.g., surface water temperature) and analyses will be combination of condition assessment and trends analysis.

An important step in indicator reporting is comparison between the state or condition of the ecological, social, or economic attribute or process and some reference condition. This step involves determining a scale to which each metric value will be converted where 0 = “poorest condition” and 100 = “best condition”. In highly disturbed landscapes, 100 may be equivalent to the best restorable condition, not the historical condition. Once the scale is determined for each metric, then the raw condition values (e.g., oC) can be converted to an equivalent score. Because all metric scores are then on the same scale, then they compared to each other and potentially aggregated.

1. Geo-spatial Data Analysis

This section describes analysis of spatial data corresponding to individual metrics and indicators chosen for each objective and WAF category. The steps below are generally in the sequences shown, but may be recursive, depending on the desired end-point and confidence in the findings.

a. Geographic Information System

The spatial data strategy we will use will involve developing a single geodatabase (GDC, data storage and management environment) for each indicator. Downloaded data corresponding to the natural or social process or conditions will be stored in the GDB and will generally include a map of the sub-watershed and watershed boundaries. The single GDB per indicator approach reduces the complexity of the GDB structure in that all intermediate calculations, versions of files, and changes in attribute tables are made in a single environment.

Once indicator calculations are finalized, a map product from each indicator GDB will be imported into a single WAF-GDB, providing a single location for all summary data. The results of point data calculations will be attributed to corresponding sub-watersheds and watersheds and also added to the WAF-GDB. Storing all WAF indicator calculations in a single GDB allows for aggregations to be easily carried out.

The remainder of this section discusses data collection and summary viewing/analysis.

i. Collecting data from outside sources

Most of our watershed data will come from other organizations and agencies. This will affect how much work will have to be done in terms of re-projection into the same map-coordinate system, collecting metadata, and analysis of the data. The sections below provide some mileposts for this process.

Downloading data from others Our spatial data will take one of several forms when downloaded from others from CD or online sources. One is .e00 files, which are exported coverage files generated by ArcInfo, a GIS program from ESRI Inc. This file type is often used to transfer spatial data files among computers. Another possible file type is as a compressed file (e.g., Zip files). Finally, shapefiles can be easily downloaded from email, internet sources, or CD.

Quality control Not all data are created equal and we will make no assumptions about data quality based upon source type. We will go through several steps immediately after receiving data to make sure they are of high enough quality to meet our needs. The first step is to look through the metadata available with the data. If there are none, we may interview the individual or institution about the data in order to ascertain quality. The next step is to visually inspect the data to make sure 1) that it is what we expected, 2) that there are no obvious flaws or errors, and 3) to make sure that we understand the connection between the visual presentation of the data and the attribute tables. The third step is to zoom in to different parts of the watershed and make sure the data line up to our expectations about spatial resolution and information content.

Projecting spatial data We will choose a data projection for the WAFGIS that is most commonly used by our WAF partners. We may need to re-project data we receive/download using ArcGIS. Common data projections include Albers and Universal Transverse Mercator (UTM), or spherical coordinate systems like Geographic.

ii. Summary statistics

Many people are curious about the basic layout and geographic description of the watershed. Quantifying characteristics of the watershed can be straightforward and if nothing else may be educational for stakeholders. Part of our visualization of spatial data will include summarizing properties of spatial data corresponding to particular metrics. For example, impervious surface distribution by sub-watershed.

We may also summarize by attribute category, which involves calculating the area of the landscape or waterways that falls into a particular category. It could also involve calculating the % of landscape or waterways that fall into different categories (e.g., 15% of watershed waterways are in designated Wilderness areas). Finally, it could consist of summarizing across multiple attribute categories (e.g., 27% of riparian roads are adjacent to or cross the 10% of watershed creeks that have TMDLs). Part of the goal with this summarizing is to sort the spatial attributes into pots of information that tell something very generally about the watershed. A secondary goal is to take information about the watershed that has been sorted into pots (e.g., % or area of landscape in private ownership) and sort it again into further categories (% or area of landscape that is privately owned that contains waterways with endangered fish and wildlife). These secondary sorting exercises may start pointing at potential problems or start quantifying the extent of risks or values that are present in the watershed.

Summarizing by sub-watershed involves calculating the attributes or characteristics for each sub-watershed. This process moves us toward understanding the "where" of watershed conditions and the processes and activities that are affecting condition. The goal of this process is usually to compare the summarized attributes (e.g., % imperviousness) to a standard or to compare sub-watersheds with each other. Comparing among sub-watersheds can provide important information and facilitate prioritization of places in the watershed needing particular actions – for example, monitoring, restoration, or controlling pollution.

b. Spatial Data Calculations

There are several proposed indicators where GIS calculations are likely to be conducted. The following are their short descriptors: Proportion flood-plain accessible by channel, Impervious area, Capital valuation of properties at risk from erosion, Protected floodplain area, Proportion of protected to developed lands, Riparian, channel and wetland restoration, Fire return intervals, Proportion of un-developed watershed burned per year, Percent of historic vegetation types remaining undeveloped, Weed invasion, landscape connectivity, Proportion of original tidal wetlands remaining, Bird count, Carbon storage in agricultural and natural landscapes, Community planning to improve infrastructure and affordable housing,

i. Analyzing vector data

Vector data are point, line, and polygon data representing attributes of the Earth's surface. They will vary in how well they represent the attributes, including limitations of resolution, content representation, and field validation of the data. There are many ways of analyzing vector data. Examples of primary methods we will use are described here:

Line and point density Calculating the density of lines is useful for understanding potential road impacts (road density), identifying areas of high stream density, identifying areas with fragmented ownership (parcel boundary lines), and understanding recreation impacts or opportunities (foot or OHV trail density). Calculating point density is useful for things like understanding distributions of wildlife or plants. The product of a line or point density calculation will be a raster (grid) file, with a density value for each grid cell. The density values will depend on the size of the grid cell, the distance from the center of the cell for which density is calculated (analysis area), and the total length of line or number of points occurring within the analysis area. The density can be calculated for just the approximate area of the grid cell, or for a larger analysis area in order to give a density calculation for a "neighborhood" of lines or points. If the analysis area is very large compared to the grid cell, there will be a smoothing of apparent densities, and a tendency to lose the extreme values. An analysis area the size of the grid cell will tend to have abrupt changes in values and tend to include extreme values. These densities can be calculated in ArcGIS 9.x or using Hawth's Tools (http://www.spatialecology.com/index.php).

Line-line intersection There are a few watershed features that are represented by lines, including streams, roads, trails, and other infrastructure. Where these features intersect, there may be impacts to social and environmental benefits and costs in the watershed. Just the intersections themselves may be worth finding, but there are other attributes to the intersection that are sometimes worth finding out and recording (e.g., type of stream crossing). Both ArcGIS9.x and Hawth's Tools have tools to find and identify line-line intersections. We may also classify the different types of intersection either before or after the analysis. For example, in terms of potential watershed effects, dirt roads intersection with small ephemeral streams is a different kind of event and has different potential impacts than highways crossing rivers.

Line and point buffering Linear and point features of the watershed will have sensitivities and impacts that extend beyond the point or line itself. For example, roads have an "effect zone" mediated by processes like runoff and traffic volumes, that extends many meters beyond the road surface. There are several ways to think of this analysis. One is that one would buffer the watershed attribute (e.g., stream) that might be impacted by an activity or feature of the watershed. This buffered area would then represent the zone within which certain activities or infrastructure could influence or impact the watershed attribute. The converse of this is to buffer the impacting feature or activity (e.g., road) a certain distance based on the anticipated extent of the impact. This buffered area represents the zone within which an influential or harmful feature could affect other watershed attributes or processes. A more neutral buffering could take place where you buffer various watershed attributes to see how they associate with each (e.g., riparian corridor based on distance from stream and the area around weed occurrences).

Line-polygon or –point intersection Certain features in the watershed will be linear and others polygonal in their extent, for example roads (linear) and plant communities (polygonal). Interactions between these features can be found and classified in terms of extent and/or type of interaction. This type of intersection is very similar to line-line intersection in terms of the types and mechanics of intersection. Where needed, we will find the interactions between linear and polygonal features of various kinds and measure the degree, the types, and the locations of interactions. We will summarize these interactions by linear segment or polygon, or summarize to a geographic extent, such as sub-watershed.

ii. Analyzing raster data

Raster or grid data can be analyzed as grid data or summarized as polygons or lines and then analyses performed, as above. Certain grid calculations are described below.

Creating grid maps from vector maps Grid maps are usually created from vector maps where a particular field in the attribute table of the vector map is converted into the equivalent grid (with a certain cell size) using a software command. The values for a particular grid cell are calculated from the equivalent area in the vector maps. The area in the vector map used to calculate the value of the grid cell can vary according to the user's needs. This process can be useful as a step in summarizing watershed information by some boundary extent (e.g., sub-watershed boundaries or county).

Calculating map layers With grid data for the same area, with the same grid cell size, multiple map layers can be sum, subtracted, multiplied, or divided. For example, grid cell values for one map can be added to values of other maps to obtain a summed value map. This is useful for very simple calculations where the operation (e.g., adding) is the same for the whole analysis area. We may also conduct operations with a single map where grid cell values are multiplied etc. For example, if we calculated road densities (see vector data section) in miles per square mile and wanted to convert the densities to kilometers per square kilometers we could perform the operation with the whole map.

The following table lists a few common GIS calculations and their role in the WAF application:

Calculation	Product	Example Metrics	Example Watershed Assessment Processes
Line density	Grid map of density values	Road density Trail density Ownership boundary density Stream density	Impacts to hydrology, geomorphology, wildlife, & aquatic biota
Point density	Grid map of density values	Bird or wildlife observation density Dam density	Bird or mammal diversity Impacts to hydrology & geomorphology; aquatic toxicology
Line intersection	Vector map of points	Road-stream intersections Parcel boundary-stream intersections	Impacts to hydrology & geomorphology; land-use effects; planning complexity
Line-polygon intersection	Vector map of points and/or segments	Road-wetland intersections Stream-parcel intersections	Impacts to hydrology, geomorphology, habitat; land-use effects; planning complexity
Buffered line intersections	Vector map of points and/or segments	Road-stream/riparian intersections	Impacts to hydrology, geomorphology, habitat
Co-occurrence	Vector map of points or polygons	Toxic sites and habitats	Impacts to habitat

2. Point Data

There are several proposed indicators where data are calculated at points or for areas like counties, where calculations are not conducted within a GIS and where trends analysis is more likely. The following are their short descriptors: Integrated storm-water/flood management, Detention of urban storm-water for infiltration, Annual sediment load, Pollutant load reduction through TMDL, Embeddedness/permeability, Channel morphology, dynamicism, Restoration projects to improve upland, riparian, and stream conditions, Community involvement in watershed management/restoration, Proportion of residents that have positive view towards environment, Watersheds with citizen monitoring programs and/or watershed groups, Stream physical habitat, Salmon population, BMIs (benthic macroinvertebrates), Instream base-flow, Ground-water storage, Proportion of population served by community water systems with no reported violations, Water use and savings, Water quality, Pollutant load reduction through TMDL, Nitrogen budget/constituents (e.g., ammonia), Precipitation, Transportation, Prevalence of child-hood asthma, Rate of public assistance, and Economic disparities.

a. Database management

Organizing a large amount of data from different organizations for different sub-watersheds and for different indicators requires good coding and robust structure. Ideally, this would be in a relational database. We will use a system that can be incorporated into an RDB, but will be a series of spreadsheets. There will be a single spreadsheet for each indicator, with the date, time, monitoring location, source institution, and parameter value recorded in columns. This will allow data to be sorted for particularly analyses, foir example for trends over time and for specific sub-watersheds.

i. Data collection

Data will be collected from two primary sources: local monitoring programs hosted by the RCD or similar organization and statewide datasets from state and federal programs. Metadata for each dataset will be collected, or if not available, created by the person downloading based upon available information. A log will be kept of the data downloaded, including why they were chosen, where they came from, and any modifications that may have been made during or after retrieval.

ii. Summary statistics

For most data, we will provide a graphical display of the data, especially if there are changes over time. For certain data, a tabular presentation will be provided (e.g., school lunch program enrollment for geographic locations).

Summary statistics could include: means and variation, ranges of values, “n” sampled vs. “N” population. The point of the summary statistics are to get an initial look at the state and potential change in state of a system condition. It is not the same as the final finding for that state or trend in state.

b. Point data calculations

Most water quality data are reported for monitoring station-locations with various identifying characteristics, such as date, time, site coordinates. All of these data have a geographic location, even if it is for an area (e.g., city), but the indicator is generally associated with a point rather than for an area like a watershed. We will conduct most statistical analyses and trends analyses on data at point locations, then attribute the findings to a sub-watershed or watershed.

i. Trends analysis

Changes in ecosystem characteristics over time are an important type of analysis and one of the most valuable types of information conveyed with indicators. There are particular statistical tests that can detect change over time, while controlling for natural variation or cycles (e.g., seasonal, pacific-decadal oscillation). Almost all environmental data will have daily, seasonal, inter-annual, and/or inter-decadal cycles. This means that one can’t detect change in these data without taking into account and controlling for these cyclic effects. The Seasonal Kendall test and other related tests can be used to determine whether or not significant changes have occurred over time, while taking into account variation due to seasonal effects (Hirsch *et al*., 1982; Hirsch and Slack 1984; Esterby 1996). The power of this test is that it can be used for non-normal and cyclical data and is invariant with data that have been transformed (e.g., logarithmic). We will use this approach to measure trend in certain indicators, while controlling for seasonality. The output of this analysis is an assessment of the trend slope and its statistical significance. For certain indicators, there may be infrequent data collection (e.g., annual), or only a few years of data collection (i.e., <5 years), in which case we will not conduct a trends analysis.

Decomposition of a time series into its component parts (trend, oscillations, seasonal factors, and disturbances) is not always possible or practical (Jassby & Powell 1990). Distribution-free trend analysis is ideal due to the unknown nature of the data, so non-parametric tests, such as Seasonal-Kendall and Mann-Kendall, are preferred (Berryman et al. 1988). Another important distinction is whether the trend test is stepwise (difference between two or more means) or monotonic (steady change over time). Some tests can handle periodicity and persistence (serial dependence), where the latter terms refer to the dependence of a current condition value on a past condition value. However, in this case, the minimum sample size required increases by an order of magnitude. Berryman et al. (1988) compared different trend tests and their appropriateness, with various forms of the Kendall and Spearman tests generally the strongest. A flowchart is included for formal decision making about which test to use.

Hess et al. (2001) ran simulations for six linear trend analysis techniques, and determined that the strongest are the seasonal-Kendall test and a *t*-test adjusted for seasonality. For non-seasonal data with autocorrelation, the modified Mann-Kendall is probably superior (Hamed & Rao 1998).

Mann-Kendall (Hamed & Rao 1998)

-standard Mann-Kendall or Seasonal-Kendall don't adjust for autocorrelation
-modified Mann-Kendall is superior for such cases
-handles non-normal data, but not seasonal data

Seasonal-Kendall (Hirsch et al. 1982)

-non-parametric (normal distribution unnecessary)
-handles missing or "less than" values
-"B" slope estimator determines trend magnitude as well
-better than regression if data are skewed, worse if data are normal
-assumes monthly data, and tests for seasonal periodicity
-some adjustment is needed for multiple data points per season
-gives trend statistic for entire time period; subdivide if interested in sub-trends
-strongest for seasonal data, and best if seasonality is unknown (France et al. 1992)
-modified form handles serial dependence with lower power (Hirsch & Slack 1984)
-modified form requires very long time series
-Regional-Kendall adjusted for subsets of data (Helsel & Frans 2006)

An example of trends analysis using Seasonal Kendall with actual environmental data is shown in Appendix A.

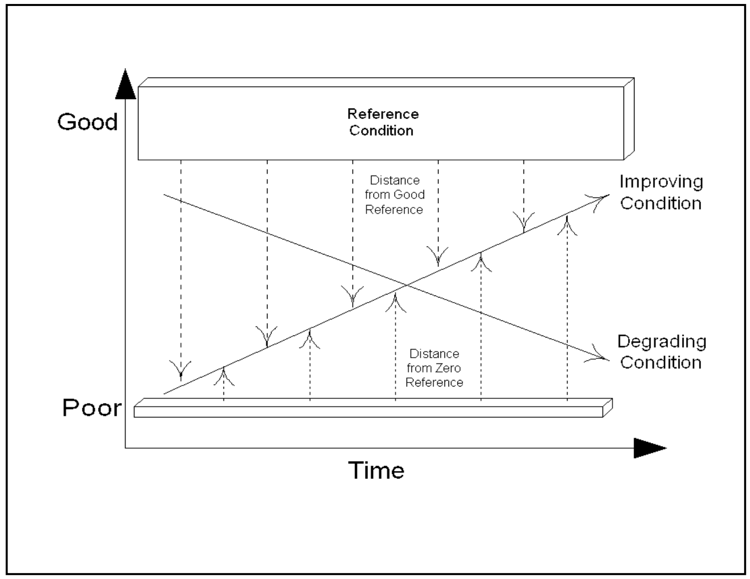
3. Comparison to Reference/Target

An important step in turning parameters into indicators is describing why particular values or ranges of values have some meaning from an education or decision-making perspective. For example, surface water temperature is a parameter for which daily or annual reporting can be conducted. When water temperatures are "valued" relative to salmonid life cycle needs, then water temperature can be reported as an indicator of condition relative to the needs of fish, rather than some abstract parameter reporting. A creek with a temperature of 20^{o}C may be fine for recreating, support certain fish and wildlife, and otherwise seem healthy, however, salmon eggs and fry will be stressed at this temperature, thus the equivalent indicator score may be low for this temperature.

Each indicator state value will be compared to a reference value. This could be a legal threshold, a stated desired condition, or an historical condition. Although it is important to pick a reference condition that is meaningful for decision-making, it is just as important to make the choice transparent so that it can be readily changed in the future or by someone questioning the approach.

a. Choosing reference/target

For each indicator, we will choose a quantitative reference condition against which to compare metric values. For a given indicator, there may be several possible targets that differ from each other. For example, in the case of water temperature, selecting reference temperature regimes for fish species adapted to cold water (e.g., salmonids) could result in a reference temperature of 18oC (maximum). In contrast, selecting a reference condition for warm-water fish species could result in a higher maximum reference temperature (>20oC).



Two types of reference conditions are commonly used for comparative purposes. One involves comparing conditions in the watershed to standards established by regulatory agencies or scientific literature. Water quality standards are one example. The second involves comparison to “ideal” historic conditions, “best attainable” conditions given the current constraints of the landscape, or “threshold” or poor conditions, such as statutory water quality standards or minimum viable populations (Figure). For many indicators, the reference condition cannot be accurately described, which results in low statistical robustness. Within a single indicator system, reference conditions may come from a variety of sources and perspectives, depending on the indicator and the social goals for the process or attribute the indicator represents.

The mixing of “good” and “poor” reference conditions within a single index or indicator suite may have unforeseen effects on the output of the system. The relative accuracy of indicators that are compared to a modeled historical condition will be different from indicators that are compared to a legal minimum standard or zero population. In addition, there may be different confidence associated with comparing a data set with a known degraded condition (“poor”), a “best attainable”, or an unknown (“ideal”) condition. The decision whether to use (a) historic, pre-European conditions and/or (b) the best attainable condition for extremely degraded or constrained systems (e.g., in urban settings) may also have impacts for different individual indicators within the same index or region of concern. The consequences of choosing an historic standard against which to compare condition data is that there will be less confidence in the determination of a difference. In contrast, comparing values to a contemporary standard (e.g., for water quality) will probably allow for greater confidence in conclusions about differences. The reason this is important is that when these values are combined into an index of condition, confidence in the overall conclusion about conditions and changes in conditions will be affected by the use of historic conditions as standards.

We will choose reference conditions specific to the indicator using best available science, goals expressed by stakeholder organizations, and professional opinion. These are all mutable choices and can be regarded as proposals for how indicators can be evaluated.

4. Aggregation of Disparate Indicator Values in Goals and WAF Attributes

For WAF attributes or goals that have more than one indicator, we will combine the indicator scores into an overall score for that attribute or goal. The steps for doing this include: 1) analyzing individual indicators, 2) transforming indicator values to a single scoring scale, and 3) creating a multi-metric index based on the transformed indicator scores (Figure).

Several different nested geographic scales at which aggregated indices can be developed include: (a) whole ecosystem/watershed, (b) primary sub-system habitat types (e.g., uplands, wetlands, in-stream), (c) categories of parameters within habitat types (e.g., wetland water quality), and (d) parameters within habitat types (e.g., in-stream nitrogen concentration). The scale or scales at which the index is going to be developed will be explicitly described. For the Napa River we will report indicator values and aggregated values (to goals or WAF attributes) at the sub-watershed extent. This could be for upper, mid, and lower watershed, or for groups of tributary creeks. The division will be along the lines of dramatic changes in topography and/or land-management. For example, the oak-studded hills are quite different from the mixed urban and agricultural landscape of the Napa Valley floor.

Reporting on the methods for developing an index and analyzing the data is a very important component of the indicator system. During this reporting, there are several properties of the aggregated index scores to keep track of and potentially measure: (a) Sensitivity of the final aggregated scores to different possible approaches to combining values (e.g., additive vs. weighted averaging). Different mathematical operations for combining data may make the output more or less sensitive to changes in the data values. (b) Propagated error associated with aggregated condition score at each hierarchical level analyzed. This means aggregating error for individual parameters into a propagated error for each analysis where numeric values with errors are aggregated. (c) Measure trends over time of aggregated scores toward or away from a qualitatively expressed "goal" (e.g., number and types of riparian and wetland habitats restored/protected). Figure X gives a simplistic example of the process of aggregating indicators into an index where error is propagated and a combined index score can be identified.

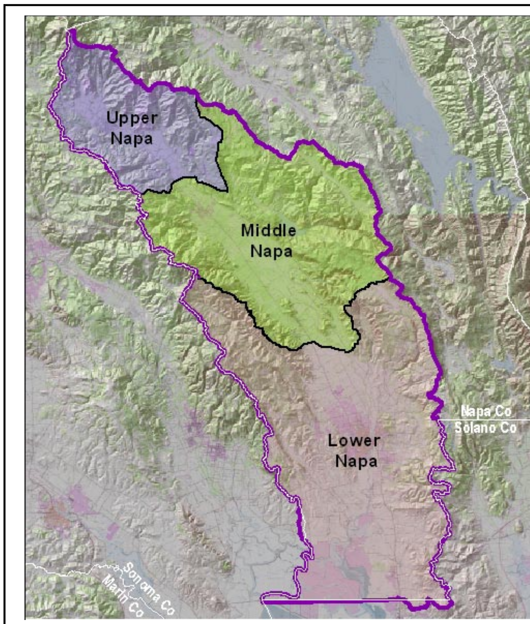


Figure Possible delineation of watershed into upper, middle, and lower sub-watersheds.

5. Phased approach for aggregating indicators

Aggregation of indicator scores from different categories of system attributes can give a measure or index of condition. The aggregation process will involve re-scaling of raw data in a way that takes into account the types of data, the presence of variation in the data, and the type of question being answered. A phased process for developing this aggregated index is described below.

Phase 1 Re-scaling metrics

Most indicator systems rely on a combination of both topical (e.g., landscape disturbance) and geographic (e.g., region of watersheds) organizational schemes. Once the appropriate and available indicators are identified for each geographic area or topic, the next step is to convert the metrics to a common scale. For example, the Oregon Water Quality Index (Cude, 2001) ranges from 1 (poor) to 100 (excellent). Beyond the formulas, each index process must make a choice about what type of standardized scale will be used. If possible, it is better to choose an index that can be computed as a continuous range of values, such as 1 to 100. These types of variables require fewer assumptions for statistical analysis, especially for analyzing trends. The point of doing this is to allow you to combine information about very different aspects of a natural system into one evaluation of condition. For example, let's say you measured fish populations, water temperature, and extent of landscape disturbance. The native fish populations are at 20% of their former range (your goal is 100%) and these populations seem healthy. The water temperatures in 50% of the waterways previously home to salmonids are above those considered healthy for salmonid species for at least 2 weeks during the summer (your goal is 0%). 80% of the landscape has been converted from its natural state to agricultural or urban

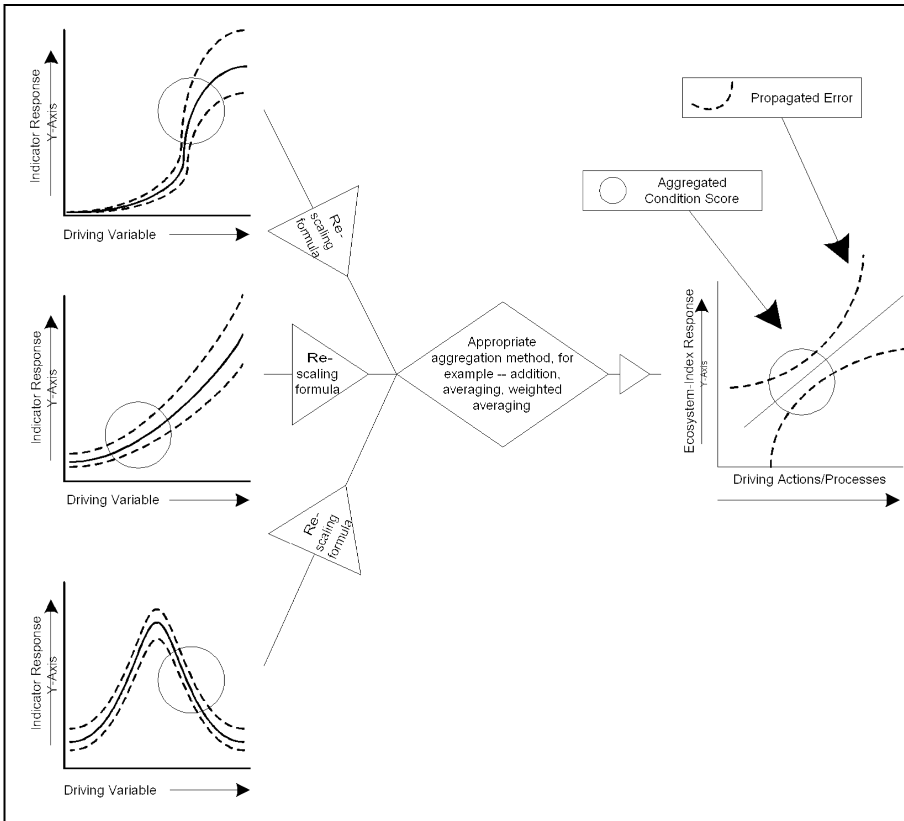


Figure Aggregation of indicators into condition index uses (your reference is 0%). Comparison between the goal or reference and your measured values could give you the following re-scaled values (out of 100) fish = 20, temp = 50, land = 20. You could later combine these into one score by summing (90 out of a possible total of 300), averaging (30 out of a possible 100), or weighted averaging based on either your concerns (maybe emphasize fish) or regulatory requirement (maybe emphasize water temperature).

We will measure and re-scale condition values compared to a desired measurable condition, as implied by objectives for the system. Indicator metrics will be quantified in their native units (e.g., tons C sequestered), and evaluated on the basis of their separation from the "ideal point" (Malczewski, 1999). The ideal point method was first introduced in the late 1950s and expanded by Milan Zeleny in the 1970s (Pomerol and Barba-Romero 2000). Zeleny (1982) operationalized the measurement of closeness with

$$d_i = f_i^* - f_i(x_{ji})$$

Where d_i is the distance of attribute state x_{ji} to the ideal value f_i^*, i indicates the attribute and j indicates the objective. The distances will be calculated in their native units and converted to a common scale (0-100) to be compared among disparate indicators, or to be aggregated into composite indices. The common scale conversion will be relative to a threshold or objective for the indicator and will be based on the appropriate rate of change relationship. For example, there is a linear rate of increase in carbon sequestration with area of vegetative cover, but non-linear rates of increase with time or succession of vegetation types.

Phase 2 Integration of economic and social indicators with ecological indicators

The integration of measures of social and economic condition with the ecological indicators present challenges in creating quantitative multi-metric indices. To create scores with rough parity, the social and economic indicators can be referenced to benchmarks in the existing literature on sustainability indicators, and the distances can be measured using standardized scaling. The social and economic indicators can then be combined in the same scoring system with the ecological indicators because they are functioning on the same scale.

Phase 3 Aggregating indicators

The next step is to aggregate the re-scaled indicator values into a combined index of condition or performance of management actions. This combined index could be as comprehensive as the one shown in the EPA-SAB framework, or it could be something like a water quality index (WQI) or index of biological integrity (IBI). Many ecosystem evaluation processes rely on a logic-based "best professional judgment". To reinforce this approach, the Oregon Water Quality Index (OWQI) also uses a survey-based method (the Delphi method; http://www.iit.edu/~it/delphi.html) to try and gain expert consensus on the appropriate parameters. Continuous values can be later categorized into grades of similar "poor" to "good" ranges. This is essential for communicating ecosystem condition to the public and others not experienced in the natural sciences, or who only need condition scores for decision-making.

Phase 4 Develop sample reporting system to communicating performance

The statistically robust system described here can be mirrored by a reporting system suitable for use with a wider stakeholder and public audience. The draft system can be presented to regional stakeholder groups for their guidance on the utility, strengths, and weaknesses of the system, and suggestions for modification. It is important to make a direct and transparent correlation between the index values calculated and the reporting system rating. For example, if we calculate an index value of 65 $\pm$ 12, then it should be made obvious what this value means in terms of both ecosystem well-being and peoples' expectations for a healthy ecosystem.

A reporting system's structure would ideally not change over many years of use. An example of an indicator-based reporting system is the one for the Chesapeake Bay (http://www.chesapeakebay.net). It reflects the measured change in various indicators of water and habitat quality. These numeric scores (e.g., 73) are based on scientific studies of changes in these indicators and how they interact with other parts of the system.

The scores could be converted into a letter grade, but ideally this will only be done if the numeric scores reflect a social valuation of the system. For example, if most people think that protecting healthy native fish populations is a good idea ("A" or "B"), then places where native fish were extirpated or threatened and in decline would get a low letter grade (e.g., "D" or "F"). Because conversion to letter scores is usually only done as a way to communicate with the public and because people already have an opinion about what "A", "C", and "F" mean, the letters should be chosen first and the corresponding scores second. In the native fish example, if one area had low and declining native fish populations and was given a corresponding "D", then the numeric score for fish in that area should be defined as "D". If another area has healthy stable or increasing populations and was given an "A", then the numeric score for fish in that area should be defined as "A".

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Appendix A Example Trend Analysis

This R example uses methods and example code from the Kendall package (http://cran.r-project.org/web/packages/Kendall/index.html). Code for linear regression is based on examples in “Practical Regression and ANOVA in R” by J.J. Faraway (http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.123.1025&rep=rep1&type=pdf). The data below are for phosphorous (P) concentrations in a waterway. The steps are indicated below, showing the computer code within R that executes the various steps.

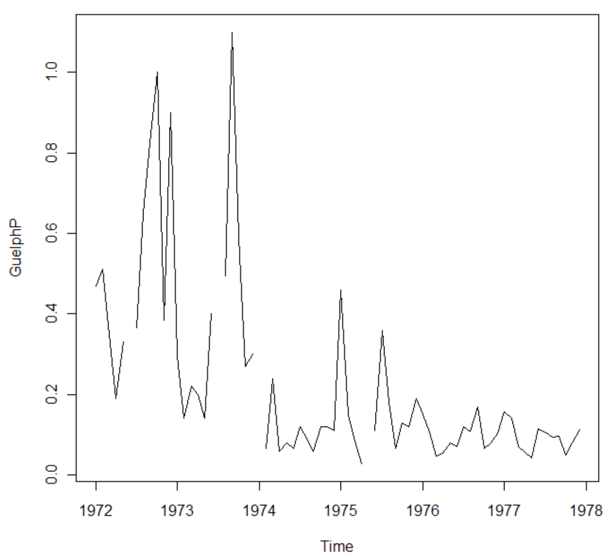
Step 1. Load the package and example data

```
library(Kendall)
data(GuelphP)
GuelphP
```

```
       Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
1972 0.470 0.510 0.350 0.190 0.330    NA 0.365 0.650 0.825 1.000 0.385 0.900
1973 0.295 0.140 0.220 0.200 0.140 0.400    NA 0.495 1.100 0.590 0.270 0.300
1974    NA 0.065 0.240 0.058 0.079 0.065 0.120 0.091 0.058 0.120 0.120 0.110
1975 0.460 0.150 0.086 0.028    NA 0.110 0.360 0.180 0.065 0.130 0.120 0.190
1976 0.150 0.107 0.047 0.055 0.080 0.071 0.121 0.108 0.169 0.066 0.079 0.104
1977 0.157 0.140 0.070 0.056 0.042 0.116 0.106 0.094 0.097 0.050 0.079 0.114
```

-this is phosphorus concentration data included in the Kendall package

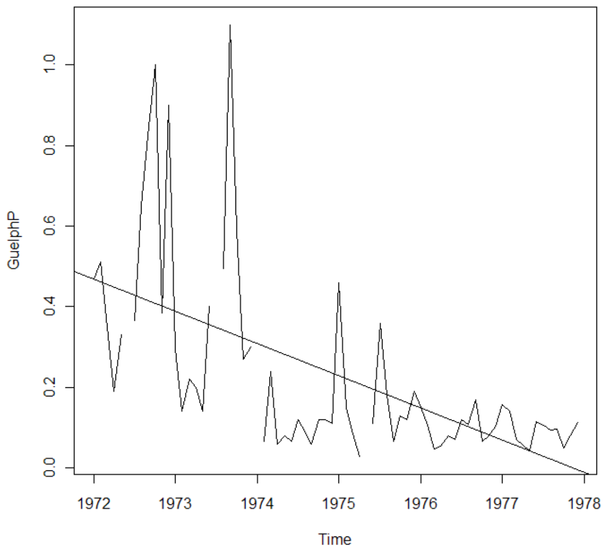
```
plot(GuelphP)
```



-notice the missing values, overall negative trend, and division into two regions

Step 2. Attempt a linear regression

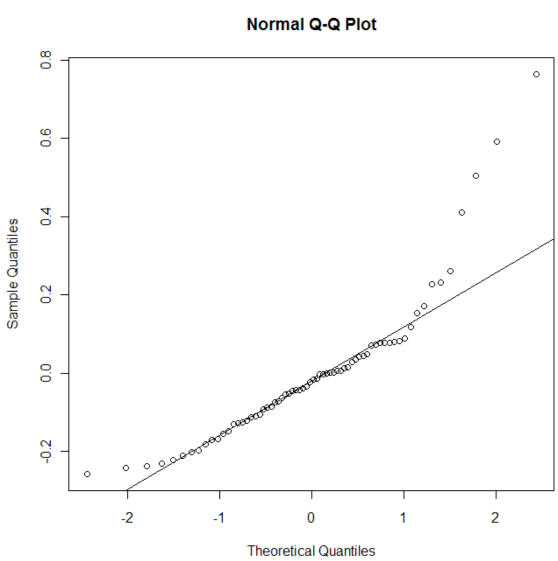
```
timeV = time(GuelphP)
pLine <- lm(GuelphP~timeV, GuelphP)
abline(pLine$coef[1], pLine$coef[2])
```




```
summary(pLine)
…
Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    158.008    25.98731    6.080 6.73e-08 ***
time(GuelphP)  -0.07989 0.01316    -6.071 6.97e-08 ***
…
```

-looks like a significant decreasing trend. But is the data normal?

```
qqnorm(pLine$res)
qqline(pLine$res)
```



-the residuals are skewing a bit, and the data appears to be non-normal

Step 3. Non-parametric trend detection

-the Kendall functions are non-parametric, and handle both non-normal data and missing values (which were excluded from the regression)

```
MannKendall(GuelphP)
```

```
tau = -0.452, 2-sided pvalue =5.8856e-08
```

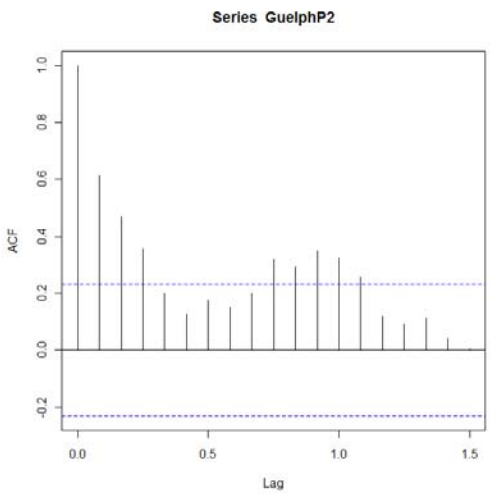
-a significant decreasing trend is detected

-currently, no slope estimator is available

-since the data is monthly, there may be a seasonal effect

-the autocorrelation function doesn't tolerate missing values, so fill in the NA values with estimates (taken from the Kendall example in the manual; averages could be used)

```
missingEst<-c(0.1524, 0.2144, 0.3064, 0.1342)
GuelphP2<-GuelphP
GuelphP2[is.na(GuelphP)]<-missingEst
acf(GuelphP2)
```



-there appears to be some autocorrelation, which may be seasonal

```
SeasonalMannKendall(GuelphP2)
tau = -0.555, 2-sided pvalue =6.934e-08
```

-even controlling for a seasonal effect, the trend is still quite significant

Step 4. Broken-stick regression

-the data does appear to have two distinct sections, so it may be more logical to look at the trends separately

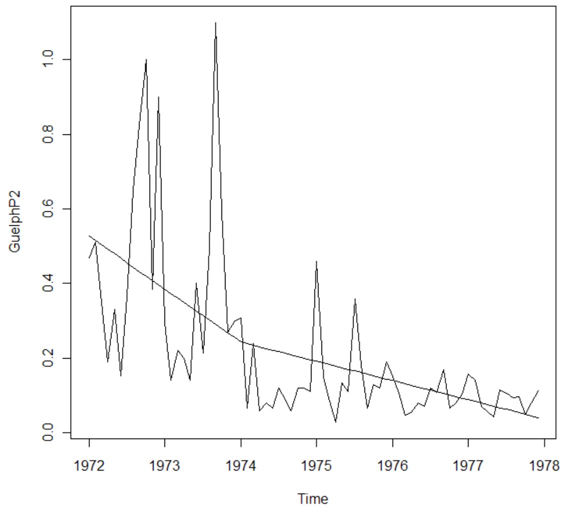
-the dividing point appears to be around 1974 (position 25 in the time vector)

```
library(stats)
wilcox.test(GuelphP2[1:25], GuelphP2[26:72])
data:  GuelphP2[1:25] and GuelphP2[26:72]
W = 1121.5, p-value = 2.763e-10
```

-the two sections are significantly different

-try two linear regressions

```
midp <- timeV[25]
lhs <- function(x) ifelse(x<midp, midp-x, 0)
rhs <- function(x) ifelse(x<midp, 0, x-midp)
line2 <- lm(GuelphP2~lhs(timeV) + rhs(timeV),
      GuelphP2)
py <- line2$coef[1] + line2$coef[2]*lhs(timeV) +
      line2$coef[3]*rhs(timeV)
plot(GuelphP2)
lines(timeV[1:72], py)
```



Step 5. Subset analysis

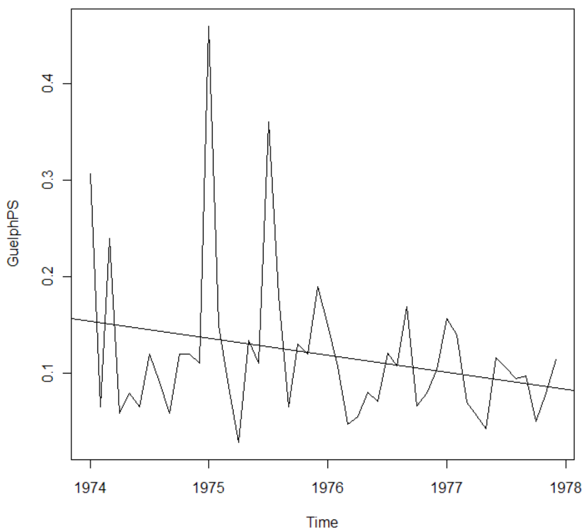
-perhaps we are only interested in the most recent trend (1974 onwards). The earlier analyses can be carried out only on that subset of the data.

```
GuelphPS = ts(GuelphP2[26:72], start=1974,
     frequency=12)
timeV2 = time(GuelphPS)
pLine <- lm(GuelphPS~timeV2, GuelphPS)
plot(GuelphPS)
abline(pLine$coef[1], pLine$coef[2])
summary(pLine)
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 34.856126  19.475093   1.790    0.080 .
timeV2      -0.017580   0.009856  -1.784    0.081 .
```

-notice that the linear regression is no longer significant

```
MannKendall(GuelphPS)
tau = -0.122, 2-sided pvalue =0.2264
SeasonalMannKendall(GuelphPS)
tau = -0.113, 2-sided pvalue =0.42829
```

-nor are the Kendall statistics



Step 6. Final summary

The proper choice of trend analysis is dependent on the nature of the data. While it is possible to automate a Mann-Kendall or Seasonal Mann-Kendall analysis for any suitable data set, it might not be appropriate if only the recent trend is of interest. This decision must be left to the user. In general, standard linear regression is probably unnecessary for simple trend reporting, since it makes more assumptions about the normality of the data which would need to be tested. Once the Kendall B slope-estimator function is available, it will provide a non-parametric estimate of trend magnitude.

8.7 Reporting Plan

Reporting Plan for the North Bay-Delta Transect Watershed Assessment Framework

REPORTING PLAN – County of Napa 4600007937

Prepared by:
Project team

4/26/2010

Contents

Executive Summary

This report describes a reporting plan for indicators in the North Bay and Delta region of California. Watershed goals and objectives were developed by local stakeholders in the North Bay. Indicators of watershed condition were selected corresponding to the stakeholder goals and objectives. The focus watershed for data analysis using the WAF approach will be the Napa River watershed. The focus watershed is intended to be representative example of the region, while recognizing that intra-regional differences in ecosystem properties would likely limit the direct application of the identical indicators elsewhere. The combination of the focus watershed and regional watershed assessment framework provides a foundation for a region-wide application of the WAF at the watershed scale, as well as serving as an example for the state.

Results of the indicator analysis in the Napa River watershed will be reported in three products: 1) a final report detailing the purpose of the project, the methods used to select and analyze indicators, and analyses results and discussion, 2) a brochure report, a one-page report describing the results of the analysis and its implications for future watershed management, and 3) a web-based report that contains elements of the brochure and final reports, as well as links to data sources. Each product will report results of the indicator analyses in the context of the identified Napa River watershed goals; however, each product will be targeted to a specific subset of watershed stakeholders.

Final Report

a. Goals

The final report will 1) record the accomplishments of the project, 2) provide useful material for the continued development of watershed health indicator practice across California and in Napa River watershed particularly, and 3) transmit required work products to the project's funder. The audience for the technical report will be those with a modest understanding of scientific analysis.

b. Approach

The final report will describe the background and purpose of the project, the methods used to set goals and objectives, the methods used to select indicators, the mechanisms used to analyze data and interpret the results, expected uses of the project's products, and recommended next steps. The report will consist primarily of text, with some graphs and tables. Appendices will contain deliverables for the project's funder, many of which will be the basis for sections of the main body of the report. We expect that DWR, the funder, may be the only reader of the appendices. Consistent subheadings will be used across indicators. Methods will be provided in detail such that the projects results may be reproduced by other groups. The content of portions of the report will become the content of the web-based report.

c. Outcome

The final report will be between 30 and 100 pages long, excluding appendices. It will be made available online.

2. Brochure Report

a. Goal

The Brochure Report will be designed to quickly convey the results of the indicator analyses for the Napa River watershed as a whole with graphics and text, as well as present our best interpretation of the results in the context of living in and managing the Napa River watershed. The Brochure Report will be designed to be understandable by a broad audience of watershed stakeholders, including residents, landowners, elected officials, and resource managers. This report will also provide readers with the website address for the project, so that readers may access the more detailed Technical Report.

Several important concepts will be communicated in the Brochure Report for each indicator: the goal that the indicator was chosen to assess, target that was chosen to represent excellent condition of indicator, current condition of indicator with respect to target, trend, variability in condition across the watershed, and statistical uncertainty of the condition. Additionally, we aim to develop a graphical way to convey the team's judgment of the quality of information with which each indicator was analyzed.

b. Approach

The Brochure Report will contain the following items: photos of the Napa River watershed, table summarizing indicator analysis for Napa River watershed as a whole, text describing goal and history of the WAF project, and website address for location of full technical report of project. The Brochure Report may also contain a map-based graphic or table that shows the condition of indicators for watershed subunits.

i. Reporting results for whole watershed

To encourage widespread readership and easy distribution of the Brochure Report, we will aim to keep the document as brief as possible. The Bay Institute's San Francisco Bay Index Ecological Scorecard (http://www.bay.org/publications/%C2%ADecological-scorecards) is one model that we will use to craft the brochure report. The Ecological Scorecard is a single 8.5" x 11" sized sheet of paper that is folded in half to look like a grade school report card. On the interior of the card, the indicators are listed with their scores in a table.

A large portion of the Brochure Report will be devoted to a table that summarizes most of the following information for each assessed indicator: the goal that the indicator was chosen to assess; the target that was chosen to represent the condition of the indicator considered optimal; and current condition of the indicator with respect to target, trend, variability in condition across the watershed, and statistical uncertainty of the condition. We may also convey a measure of the quality of information with which each indicator. Watershed goals will be listed in the left-hand column (see Table 1) to reinforce that the purpose of the watershed assessment framework approach is to provide a tool with which communities may assess progress towards common goals. The condition of each indicator will be represented by a rectangle positioned along a horizontal axis running from 0 to 100. The width of the rectangle will show statistical variation in condition, and measured condition will be represented by a vertical line in the center of the rectangle. The indicator's trend will be represented by arrows. We may choose to graphically show the time period over which the trend was evaluated. We may also choose to show the slope of the trend so that the public understands how rapidly indicators are changing. One option for showing the slope of the trend is to color-code the arrows, whereby steeper slopes in trend would be expressed by bolder or darker colors. Finally, the reliability of the condition and trend will be assessed by the project team, and may displayed in the Brochure Report. The intent of this parameter is to capture the degree to which the team thinks the results represent and reflect the true condition and trend of the indicator in the watershed. Several factors contributing to indicator analysis will be considered to determine the indicator's reliability, including: data point density across the region of analysis, completeness of time series data, and adequacy of measurement technique in representing indicator condition. This assessment of reliability will be subjective, as there is no established scale for this parameter. The team is considering using a scoring system similar to movie or restaurant ratings (stars, thumbs up or down, etc.), whereby the following rule-set could be used to rate reliability.

Rule set to assess data reliability

One Star-
The only available data is either poor in quality, very sparse / incomplete, poorly represents the region being evaluated, only indirectly describes the indicator being evaluated, or more than one of these.

Two Stars-
Available data is either questionable in quality, not complete, does a poor-fair job of representing the region being evaluated, does not directly describe the indicator being evaluated, or a combination of these.

Three Stars-
Available data is of a high quality and degree of completeness, does a good job of representing the region being evaluated, and directly describes the indicator being evaluated.

Table 1. Example of summary table that will be used to report indicator analysis in the Brochure Report.

Goal	**Indicator**	**Condition and variation in condition** **0……………………………………………………………………………….100**	**Trend**	**Reliability of findings**
Goal 1	Ind 1		▲	★☆☆
Goal 2	Ind 2		▼	★★★
Goal 3	Ind 3		◀▶	★★☆

ii. Reporting results for watershed sub-areas

Indicators will be analyzed for the Napa River watershed as a whole, and also for five sub-areas of the watershed to inform the community about watershed condition at a finer scale. In the Brochure Report, we will show a map of the sub-areas of analysis, and communicate that the more detailed analysis was conducted, and that results are located at the project's website. We may report on the condition of each indicator in each of the watershed sub-areas using a table or map-based graphic. The Sacramento

River Basin Report Card includes a table that shows the condition score for each indicator in each sub-area, as well as the overall trend for the indicator across the whole region. We may choose to add another column to this table that summarizes the condition of each indicator for the whole region (Table 2). Another model for how to report conditions for watershed sub-area is the Chesapeake Eco-Check's report card on health in the Chesapeake Bay watershed (http://www.eco-check.org/reportcard/chesapeake/2008/). They map condition of indicators in sub-units using a color scale.

Table 2. Example of table summarizing indicator analyses in Napa River watershed and in each of the Napa river watershed sub-area that may be used in the Brochure Report.

Goal	**Indicator**	**Sub-Area Condition Score (0 -100)**					**Watershed Condition Score (0 – 100)**	**Trend**	**Reliability of findings**
		WM	EM	NVF	SVF	LW			
Promote watershed awareness & stewardship	Access to open space	45	55	70	70	60	60	▲	★☆☆
	Mention of watershed issues in local press	55					55	▲	★☆☆
Goal 2	Ind 3								
	Ind 4								
Goal 3	Ind 5								
Overall Watershed Health									

This table has a format similar to the main reporting table in the Sacramento River Basin Report Card. Some indicators may not be evaluated for each sub-area, in that case, the cells in the indicator row will me merged across the subunits. WM = Western Mountains, EM = Eastern Mountains, NVF = North Valley Floor, SVF = South Valley Floor, LW = Lower Watershed.

c. Outcome

The outcome of this phase of funding and work on the Watershed Assessment Framework will include an interim draft of the above-described Brochure Report. The draft will show the intended layout of the Brochure Report, and include most of the photos and maps that will be included in the final Brochure Report. The table element that reports on the results of the indicator analyses will be included in the draft, and results from analyses of at least two indicators will be conveyed.

3. Web-based Report

a. Goal

The materials described above, including goals, indicators, and analysis results, would ideally be provided in a web-based format to encourage wide public access, paperless distribution, and an updatable structure. A web-based format would allow for flexibility of presentation and scalability as new analyses are conducted and additional watershed scorecards are completed in the future. Elements that are common across watersheds could be referenced from a shared source. For example, an individual watershed scorecard could link to WAF goals and indicator descriptions and present them together with the results of indicator analysis for that particular watershed, while a regional composite could be assembled from all the indicator analyses done for individual watersheds. A "clickable" map can be presented to the user and the sub-regions (watersheds or sub-watershed) linked to the results of analysis at the sub-unit level. The goal is a nested system that enables watersheds control over presentation of scorecard results at the watershed level as well as easy participation in a regional grouping.

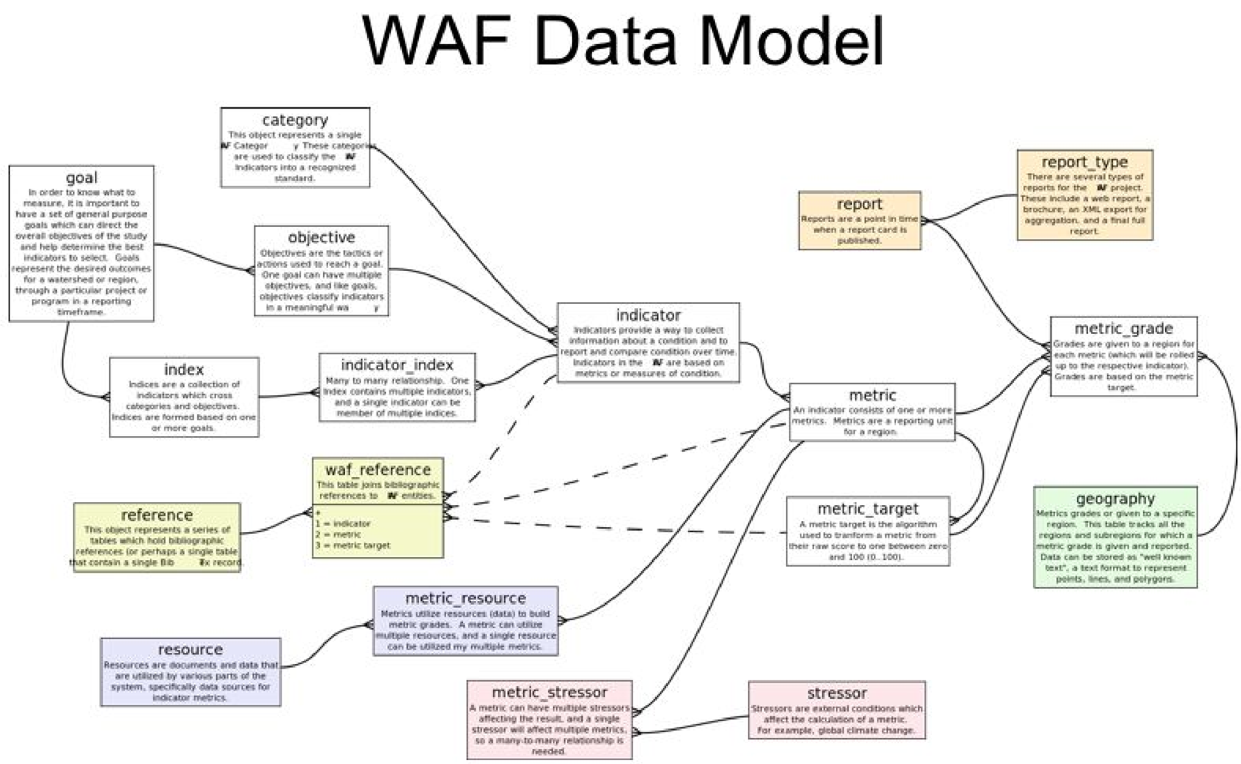
b. Approach

General Architecture:

A content management system is a useful tool for constructing containers for all of the elements of the Watershed Assessment Framework: goals, indicators, and indicator analysis results with supporting data and metadata. Such a system should provide for entry of the information into forms, with the resulting structured content held in a database. This method provides for flexibility of presentation of the materials as well as for linking and sharing the elements. As the effort grows and more watershed organizations evaluate indicators using the Watershed Assessment Framework, they would benefit from the system by finding examples, protocols, and a framework within which to easily report their results.

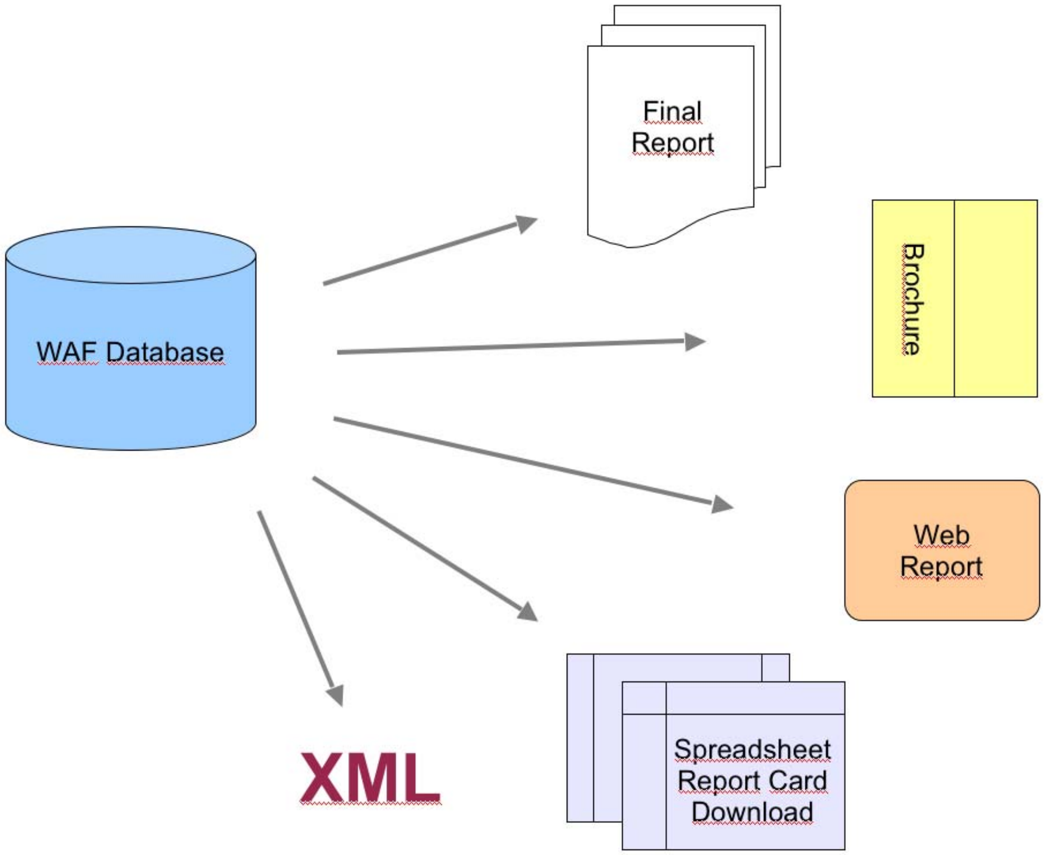
Database Schema:

As with any database, a carefully-designed schema is necessary to ensure that the information is stored and shared properly– for example it would provide for time series updates without the loss of previous year's data, and elements would reference one another appropriately. Below is the schema, or data model, designed by the WAF technical team, depicting the elements and their relationships. This will be useful in any future effort to construct the system.

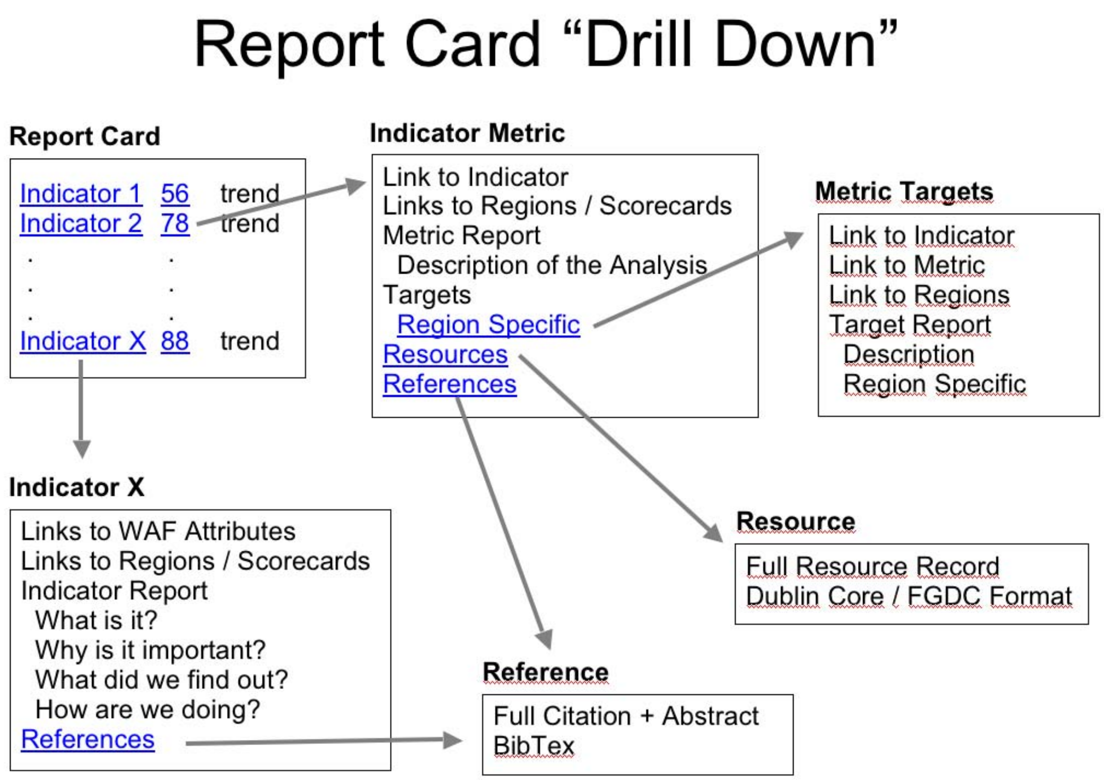


Presentation of the materials:

In addition to the printable materials a web-based report can be constructed that provides the same information as the printable materials in a linked format that allows the user to browse the pieces individually or in one or more groupings. At the top level of such a Web Report a user may be presented with the goals listed with their associated indicators, and score results similar to the graphical presentation described in the Technical Report section above. Clicking on goals and indicator names can give the user the descriptive information about those elements, along with recommended metrics and any available protocols for analysis. Clicking on the scores would produce an indicator data page, which would contain the analysis results and discussions from the Technical Report and a link to a metadata record which can provide for access to the source data. As analyses are repeated in subsequent years, producing new scores and trends, either the latest results can be presented on the online scorecard or a complete listing offered to the user, or both. The diagram below portrays the database and the variety of outputs that are possible to produce from the elements stored in such a database.



The following is a diagram showing the arrangement of the components and linkages in such a Web Report "Drill Down".



c. Outcome

The outcome of this phase of funding and work on the Watershed Assessment Framework included progress on the above-described Web Reporting System. Although it is beyond the original scope of the project we felt that prototyping and testing this design at least in part on the test watershed (Napa) and its indicators and results is an important step toward a working framework for producing, sharing, distributing, and evaluating watershed health assessment efforts across watersheds in California. We therefore produced a prototype that demonstrates partial functionality, focusing on distributing the Napa Watershed Assessment to the Napa community and next on interoperability with other WAF partners. We have published the core components of the Technical Report in a web-based system based on the designs described above for a subset of the indicators. This may be found at http://sfcommons.org/scorecards/waf/napa. The venue is the San Francisco Bay Area Conservation Commons, a new system still under development for encouraging sharing and communication about environmental information for the Bay Area region. The future envisioned system would be a distributed one, with common elements and services housed separately from local presentations and data.