Indicators and Performance Measures for North Bay Watersheds

Prepared for the
North Bay Watershed Association

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FINAL DRAFT January 11, 2010

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Executive Summary

To accomplish its mission of working cooperatively to protect the water resources of North San Pablo Bay (part of the San Francisco Bay estuary), the North Bay Watershed Association (NBWA) seeks to establish and promote a clearly defined set of science-based watershed indicators and performance measures. "Indicators" are here defined as field measurements that provide a direct indication of watershed condition, while "performance measures" quantify program implementation and progress towards meeting programmatic objectives. The purpose of utilizing indicators and performance measures is to assess success in achieving established NBWA watershed stewardship goals. These goals include:

- Improve water supply
- Improve water quality
- Restore and enhance habitat
- Increase recreational opportunities and public involvement, and
- Increase flood protection (NBWA 2005).

This report recommends a suite of eight indicators and twelve performance measures (20 parameters total organized using NBWA's five stewardship goals as a framework) to be applied across North Bay watersheds to assess watershed health and stewardship. These recommended measures are described in Section 3 (and summarized in Tables 4-11). The parameters were selected based on the following criteria; *validity* (scientific soundness), *meaning* (simplicity of interpretation), and *availability* (a combination of technical feasibility and cost-effectiveness). We also discuss the critical role of evaluating the "climate context" of annual indicators using standardized, published data sources in order to differentiate between wet year and dry year watershed performance.

For organizations just starting to build capacity in watershed assessment, we recognize potential constraints on resources and the need to leverage volunteer efforts. To meet the needs of all of our partner organizations, we have identified a subset of *four* priority indicators and *one* performance measure, described below.

<u>Priority Indicators</u>

- Dissolved oxygen: a critical indicator of water quality that reflects both utility for ecosystems and value for water supply.

- Temperature: an indicator of aquatic and riparian ecological function and water quality.

- Summer stream flow: an indicator of aquatic and riparian ecological function, water quality, and (in some cases) of reduced dry season flow and/or reduced groundwater discharge to streams.

- Percent impervious watershed area: an indicator of watershed alteration in terms of the area that does not provide.

<u>Priority performance measure</u>

- Per capita water use: a direct performance measure of collective water efficiency and water conservation program effectiveness based on data generally available from water agencies but not typically summarized on a watershed basis.

This report also identifies data gaps, defines next steps for using the recommended indicators, and provides a complete annotated list of other considered ("Tier 2") parameters, and reference literature reviewed.

The objective of summarizing this body of work and selecting measures appropriate to the NBWA service area is to support region-wide implementation of recommended priority indicators to effectively assess investments in watershed management.

1. Introduction

1.1 *NBWA Background*

The North Bay Watershed Association (NBWA) is a group of 15 local agencies with a shared mission of working cooperatively to protect the water resources of North San Pablo Bay. To accomplish this mission, NBWA seeks to establish and promote a clearly defined set of watershed indicators and performance measures to assess the success of the region's planning efforts in achieving established goals for North Bay watersheds. In 2005, NBWA developed goals and resource objectives for evaluating Integrated Regional Water Management Plan (IRWMP) projects (NBWA 2005). Subsequently, the San Francisco Estuary Institute (SFEI) reviewed monitoring efforts and found that appropriate indicators of watershed condition were needed to measure the effectiveness of programs aimed at meeting the IRWMP goals and to help answer assessment questions related to the NBWA resource objectives (Ridolfi, et al. 2007). NBWA also recognizes the value of having appropriate performance measures to track implementation of the IRWMP and other management actions. Throughout this report, "indicators" describe direct field measurements of watershed condition (e.g., pollutant concentration in the water column, or riparian corridor width), while "performance measures" describe quantitative measures of program implementation and progress towards meeting a programmatic goal (e.g., estimated water savings from conservation measures, acres of non-native riparian invasive species removed).

1.2 *Purpose of Indicators Project*

The intended audience for this report is resource agencies, water utilities, and watershed stewardship and business groups working to improve various aspects of watershed health. Many watershed management manuals and publications encourage resource and program monitoring to inform effective adaptive management (an iterative process designed to improve watershed management over time through program evaluation; e.g., West, et al. 2009). However, in practice, very few North Bay watersheds have consistent and sustained monitoring efforts in place capable of comparing resource conditions over time to goals, targets, or benchmarks

This project identifies indicators of watershed condition and performance measures for watershed stewardship that can be used in the context of a wide range of North Bay plans, programs, and projects. For example, if a management plan objective is for salmonid recovery (a typical regulatory target for watersheds impacted by sediment); habitat (e.g., fish passage barriers removed and length of restored stream) and water quality (e.g., dissolved oxygen, temperature) metrics should be routinely measured to assess progress towards this goal. If the targets are not met within an agreed upon time period, the targets, the metrics used, or the management actions implemented to meet those targets might need to be revised in order to meet resource objectives. Thus, field-based monitoring of the condition of the resource along with objective measurement of watershed program success are both critical to successful adaptive management

Current approaches to data collection tend to be highly localized and project-focused without the ability to track long-term environmental outcomes at the watershed scale. The purpose of this analysis is to lay a framework of indicators to guide cost-effective watershed-scale monitoring across the region. This report recommends a suite of indicators and performance measures that can be used in various types of watershed management activities, including watershed plans, local land and water-use policies, and programmatic approaches to water supply and stormwater management. The recommendations will help to streamline the monitoring design process for individual watersheds and provide a basis for collaboration on a regional monitoring effort that would allow comparison across watersheds.

This project builds on previous work (Environment Canada and USEPA 2007; Gunther and Jacobsen 2002; Pawley and Nur 2007; The Bay Institute 2003, 2005; Thompson and Gunther 2004; USEPA 2000; USEPA 2008; Young and Sanzone 2002) to identify appropriate monitoring indicators and performance measures for North Bay watersheds. These studies laid the groundwork for how to measure watershed health at the project, program, and watershed scales. Measuring watershed health can be a very challenging task, but the level of difficulty ranges from relatively easy, when one is simply documenting project or program activities, to very difficult, when one must prove that the project or program has succeeded in protecting or restoring watershed function (Figure 1).

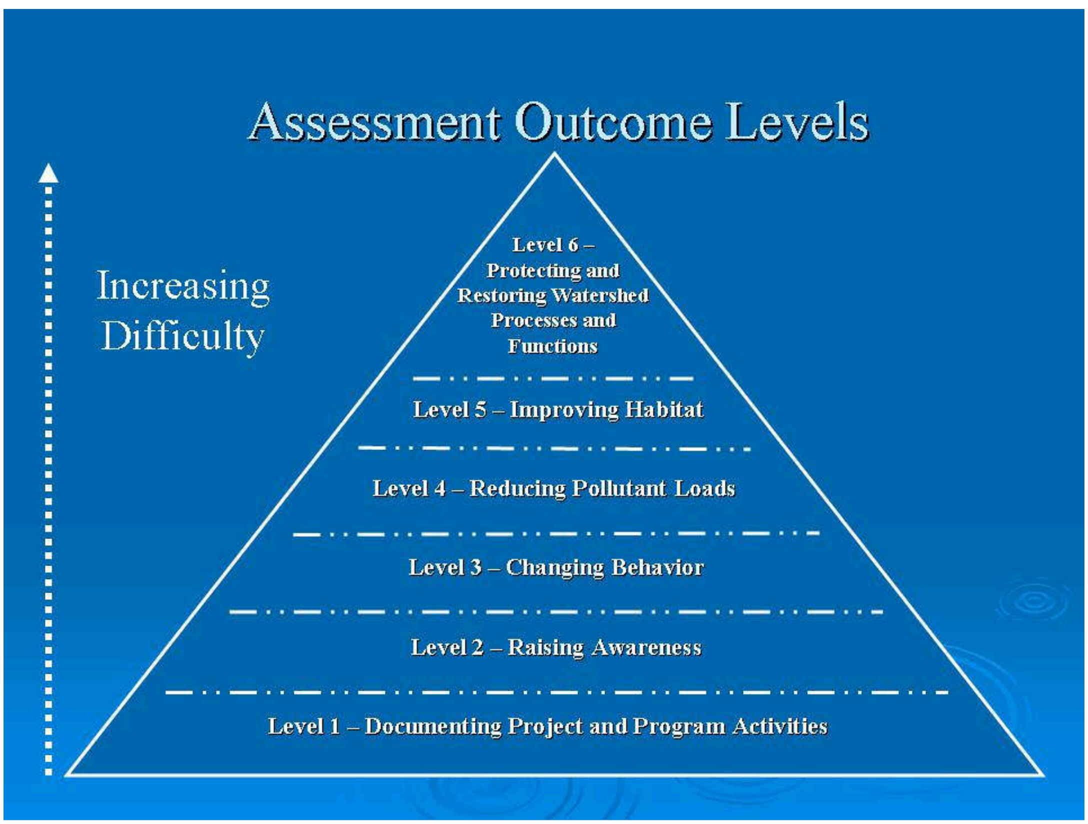

Figure 1. Hierarchy of the difficulty of measuring "performance" at various scales. Source: modified from Brosseau 2007

The goal of applying a consistent set of indicators and performance measures across North Bay watersheds is to answer questions related to watershed conditions, stressors, and management responses such as:

- What conditions exist in this watershed: are they getting better or worse?
- Do watershed conditions align with broad goals or specific targets (e.g., are we being good stewards of our water resources?)
- Are pollutants impacting drinking water supplies?
- How can we track progress towards regulatory targets?
- Are required buffer zones improving bank stability?

Good indicators of watershed health can augment existing monitoring efforts by organizing data into a meaningful assessment of how well watershed or regional objectives and goals are being met. For example, the Surface Water Ambient Monitoring Program (SWAMP) collected a range of discrete and continuous water quality data for the Petaluma River watershed in 2003-2004 (SFBRWQCB 2007a). However, without a set of targets and goals to compare these results against, the data are not as informative as they could potentially be. In addition, performance measures will help determine how well a plan is being implemented. Questions that can be answered by performance measures include:

- Are management actions directly addressing the priorities of the plan?
- Are regional priorities being met?
- Are we meeting program implementation targets?

The use of indicators and performance measures will enable watershed managers to evaluate existing conditions, set targets for improvement, and measure progress towards those targets across a variety of scales (e.g. specific reach, watershed-wide, regional).

1.3 *Scope*

This project took place over the course of one year. The core team consisted of three technical experts who involved numerous stakeholders, including NBWA subcommittees in several work tasks and products (Table 1).

Table 1. Project schedule.

Item	Purpose	Date
Dataset Review	Collate existing regional datasets	October-November 2008
Technical Working Group Meeting #1	Review dataset, agree on term definitions, and review previous indicator work	November 2008
Draft glossary submitted to NBWA	Establish clear definitions of indicator terms	December 2008
Technical Working Group Meeting #2	Decide on a draft set of indicators and performance measures	February 2009
Presentation and Summary submitted to NBWA Board	Present progress and solicit feedback on draft indicators and performance measures	March 2009
Outreach to indicator end-users		March-June 2009
Presentation to North Bay Watershed Council		June 2009
Draft Report to NBWA for comments	Summarize project, provide rationale for selecting final set of indicators, and solicit comments	September 2009
Final Report submitted to NBWA	Provide NBWA with final set of indicators and performance measures	November 2009

1.4 *Partners*

This project was led by a technical team of staff from the San Francisco Estuary Institute (SFEI), The Bay Institute (TBI), and Sonoma Ecology Center (SEC). NBWA Executive Director Harry Seraydarian provided oversight. Other important contributors included staff from Napa County Planning, and Marin County Public Works. The members of the NBWA Board and participants in the North Bay Watershed Council, Napa County Resource Conservation District (RCD), and the Southern Sonoma County RCD have also provided important comments and direction.

2. Methods

2.1 *Previous Indicators Work*

Several related efforts to develop indicators for the region laid the groundwork for this effort. The Bay Institute developed a scorecard of Bay Health in 2003, and updated it in 2005 (TBI 2003, 2005). The Bay Health Scorecard represents the first effort at scoring regional watershed health; however, it has a strong focus on in-estuary, as opposed to watershed-wide health indicators. Building on this work, several projects in the San Francisco Bay-Delta region (some were suspended until recently due to the state budget crisis) are developing indicators at a range of scales using the Watershed Assessment Framework developed by the U.S. Environmental Protection Agency (Young and Sanzone 2002). In addition, a scorecard for water supply indicators is nearly complete for the Napa River and Sonoma Creek watersheds (Table 2).

Table 2. Other, related watershed health indicators work in California used as background for this project.

Name of Project (year complete)	Contributors	Watersheds Covered
Bay Scorecard (2003, 2005)	The Bay Institute	San Francisco Bay and Delta inflow-- most of the indices exclude local watersheds
Watershed Assessment Framework (ongoing)	TBI, SFEI, SFEP, CEMAR, PRBO	12 Bay-Delta counties
Watershed Assessment Framework (ongoing)	Sacramento River Watershed Program	Sacramento River watershed
Watershed Assessment Framework (ongoing)	SEC, Napa County Planning	Napa River, Cosumnes River watersheds
Napa-Sonoma Scorecard (ongoing)	TBI, SFEI, SEC, Napa County RCD, USGS	Napa River, Sonoma Creek-- water supply indices only

2.2 *Glossary for Indicator Terminology*

The first task in this project was to establish definitions for commonly used terms in order to reduce confusion, and compile them into a glossary (Table 3).

Table 3. Glossary of terms used to describe indicators and performance measures.

Term	Definition	Example
Goals	Describe desired outcomes for a watershed through a particular project or program in a stated timeframe	Improve water supply
Objectives	Tactics to achieve the goals. They recommend a course of action 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.	Provide reliable water supply to meet the long-term needs of the watershed's residents, local industry, and agriculture, while protecting natural resources
Targets	Translate objectives into quantifiable guidelines or standards of success	50,000 acre-feet
Performance measures	A means to track progress towards achieving an environmental condition or management response target	Number of reservoirs at capacity on April 1
Metrics	Discrete measurements that constitute the building blocks of indicators. One or more metrics are combined to comprise an indicator.	Percent of target surface storage (acre-feet)
Indicators	Measureable characteristics designed to represent and communicate the condition of a larger environmental system that includes human communities. They inform the public and guide management actions.	Surface storage
Index	Composite of several, related indicators to express an environmental condition	Storage

2.3 ***Selection Framework***

Indicator selection and organization required three initial steps: framework selection, evaluation of available metrics, and organization of indicators. The first step was to pick a framework to guide selection of watershed indicators and indices. Five major resource goals were identified in the 2005 North Bay IRWMP:

- Improve water supply
- Improve water quality
- Restore and enhance habitat
- Increase recreational opportunities and public involvement
- Increase flood protection (NBWA 2005)

By using these five goals as our framework, this project fulfills the goal of the IRWMP to link objectives to measurable indicators and performance measures.

Next, we evaluated as broad a pool as possible of potential watershed metrics. The candidates came from previous analysts' exhaustive compilations (see Table 2; Gunther and Jacobsen 2002; Thompson and Gunther 2004; Pawley and Nur 2007; USEPA 2000) of potential indicators combined with the professional judgment of the technical advisory team. In many cases we identified a lack of comprehensive watershed-wide habitat, biological, and water quality monitoring data capable of providing a baseline condition and context for targets. From this list of potential parameters, the technical review team performed a culling process to select the most appropriate indicators for North Bay watersheds given current management priorities. Key criteria included:

> **Validity:** technical relevance to the IRWMP and North Bay watersheds, ability to demonstrate a trend, presence of acceptable uncertainty levels;
> **Meaning:** the significance of proposed measures should be easily interpreted by local resource managers, residents, and political representatives; and
> **Availability:** data either exist or are reasonably easy (cost effective and technically within reach of most watershed groups) to measure on long-term basis.

Finally, we organized the potential indicators into a nested hierarchy of index, indicators/performance measures, and metrics. (See Table 3 for definitions of these terms.) For example, if one is interested in the supply of water available from municipal reservoirs in a given year, the information would be organized as follows:

Index: Storage
Indicator: Surface storage
Metrics: Percent of target surface storage

Indicators and performance measures that we deemed informative but that did not meet all of our criteria (our "Tier 2" list) are listed in the Appendix, divided into tables by NBWA goals. The reasons that they were not recommended are explained as well.

Those that did make our recommended list, including rationale for choosing them, are explained in detail in the following section.

3. **Recommended Indicators and Performance Measures**

3.1 *A Starting Point: Priority Watershed Health Indicators and Performance Measure*

Given limited time, resources, and data throughout the North Bay, we chose four indicators and one performance measure that could be used as a starting point for an organization interested in using the results of this work in a limited way. Ideally, the full suite of indicators and performance measures would be used, especially for a regional North Bay or Bay Area-wide effort. However, if funding is limited, we recommend the following four priority watershed health indicators and one priority performance measure:

Indicators:

1. Temperature
2. Dissolved oxygen
3. Summer base flows
4. Percent watershed impervious area

Performance Measure:

5. Per capita water use

These five parameters were chosen because of their ability to address multiple objectives of watershed health important to the North Bay in a technically meaningful and cost-effective manner.

Temperature and dissolved oxygen

Temperature and dissolved oxygen are important water quality indicators not only because targets for these parameters exist for the protection of local aquatic life (SFBRWQCB 2007b), but also because they are simple to measure, and can be indicators of larger water quality or aquatic population issues. It is important to keep seasonal and daily fluctuations (see cimate context indicators) in mind when sampling so as not to skew or misinterpret data.

Summer base flows

The quantity of summer (July-October) stream flow indicates availability of habitat for aquatic organisms and water supply for people at a time when access to essential resources can be limited. In places where groundwater is a primary component of water supply, dry season flow indicates how much water is available in excess of what is needed to recharge groundwater. This indicator should be evaluated with the climate context indicators in mind, to incorporate fluctuations in water availability.

Percent watershed impervious area
Numerous studies have established that extensive impervious surface (i.e., pavement and other hardscaping that do not allow for natural infiltration of water into the ground) in a watershed is correlated with declining integrity of aquatic biological communities, as well as other physical (e.g., intact riparian forest, size of buffer from other uses) and hydrologic characteristics of otherwise healthy, natural aquatic systems (e.g. Center for Watershed Protection 2003; Arnold and Gibbons 1996; Paul and Meyer 2001). National data exist for impervious surface, and were calculated for North Bay watersheds for comparison with steelhead populations for the forthcoming NOAA Steelhead Recovery Plan.

Per capita water use (performance measure)
Per capita water use is simple to understand, is based upon a relatively long record of readily available data, and is a good measure for tracking progress towards conservation goals and indicating how efficiently water supplies are being managed. Since much of the North Bay's residential water is imported from other watersheds, water use does not exactly measure local watershed health. However, it is still an important priority indicator because it is one of only a few stewardship metrics that consider the human aspect of watershed health.

Though we recommend using the full suite of indicators and performance measures for a given watershed, this list of five is a robust starting point if funding is limited.

3.2 ***Recommended Indicators and Performance Measures***

For agencies or other organizations capable of implementing a full suite of watershed indicators and performances measures, we recommend eight indicators and twelve performance measures for determining watershed health. All of the indicators and performance measures can be adapted to indicate the level of health at a variety of spatial scales. The rationale behind choosing each will be discussed in the following section, along with more details including the index they fit into and the reference for collecting data.

Table 4. Recommended indicators of watershed health

NBWA Objective	Recommended Indicator
Water supply	Surface water storage
	Groundwater storage
Habitat Enhancement	Salmonid population
	Christmas bird counts
	Summer stream flow (base flow)
Flood Protection	Impervious area
Water Quality	Physical water quality
	Stream benthic macro-invertebrates (BMIs)

Table 5. Recommended performance measures of watershed health

NBWA Objective	Performance Measure
Water supply	Per capita potable water use
	Conservation program effectiveness
	Water reuse
Habitat Enhancement	Upland restoration
	Bayland restoration
	Freshwater wetland restoration
	Stream/riparian restoration
	Fish passage
Flood Protection	Innovative and integrated stormwater and flood management implementation
	Floodplain protection
Recreation and Public Involvement	Community involvement in watershed management and restoration
Water Quality	TMDL implementation

In many cases it can be argued that the definitions of specific indicators and performance measures overlap. However, distinguishing between them is useful in that the methods to measure indicators (generally drawn from the field sciences) are often distinct from the administrative monitoring required to measure program success (via performance measures). We anticipate that in many cases, the baseline conditions will be unknown, and there may be a lag time between the implementation of management measures and watershed resource response.

4. Rationale for Selection

4.1 *Improve Water Supply*

The indicators and performance measures recommended for the water supply objective primarily assess the quantity (how much do we have?) and management (how well do we use it?) of water resources for human use (Table 6). Assessment of water supply for aquatic life is measured by a summer stream flow indicator, which is described under habitat enhancement. Better stewardship of the North Bay water supply generally means better conditions for aquatic and riparian resources since conserving water results in more water left in streams (i.e., higher instream flows)

Table 6. Water supply indicators and performance measures

Index	Performance Measure (PM) or Indicator (I)	Metrics	Reference
Water use	Per capita potable water use (PM)	Per capita residential or total water use	NBWA water supply agencies; CUWCC http://bmp.cuwcc.org/bmp/read_only/list.lasso ; CADWR Public Water System Survey
Water savings	Conservation program effectiveness (PM)	Estimated water savings from water efficiency measures	NBWA water supply agencies; CUWCC http://bmp.cuwcc.org/bmp/read_only/list.lasso; conservation scorecard http://www.cawaterpolicy.us/scorecard.php
	Water reuse (PM)	Potable water supply offset by reclaimed water	NBWA water supply agencies; CUWCC http://bmp.cuwcc.org/bmp/read_only/list.lasso; CADWR Public Water System Survey
Storage	Surface water storage (I)	% of target surface storage (acre-feet)	NBWA water supply agencies; SWP and Russian River reservoirs: http://cdec.water.ca.gov/cgi-progs/reservoirs/RES
	Groundwater storage (I)	Spring and fall water table elevation (depth to surface measurements)	NBWA water supply agencies

Water use

In this report, assessing how much water we use and how well it is managed are represented as performance measures although they can also be represented as stewardship or management indicators. Due to a lack of data, we limit the water use assessment to municipal use served by water districts or incorporated municipalities.[1]

Gallons of potable water an individual uses per day (measured in gallons per capita per

[1] Domestic water use outside of the cities and districts is relatively small. Agriculture water use is significant in the NBWA watersheds in Sonoma and Napa Counties but measurement of its use is not done on a consistent enough basis (see data gaps).

day or gpcd) is an increasingly prescribed performance measure for assessing municipal water use and is recommended here. This metric can be compared to a target water use, represented as a percentage reduction or a reference use.[2] There is not one standard metric for calculating gpcd although gpcd generally uses the annual (12 month) water use, either the total for all sectors or for just one sector such as residential use (indoor and outdoor). The metric for total use is the simplest to calculate and is generally accepted as appropriate for assessing regional water use, or for assessing individual district performance. Calculating residential per capita use has the advantage of making individual use more meaningful and understandable to residents. Residential per capita use also facilitates comparison between suppliers. In some cases suppliers roughly represent a watershed; thus if the residential land use and density are comparable (which is generally true in the NBWA watersheds), then per capita use is comparable between watersheds. Residential use captures a significant portion of the total municipal water use, so it is a good indicator of general water supply stewardship.[3]

Water savings

The water savings index assesses two broad types of conservation measures: improving water-use efficiency and substituting reclaimed water for some end uses. By quantifying the potable water savings and supply increases from all the different measures that are being implemented in the NBWA watersheds/counties/region,[4] the water use savings of the North Bay could be assessed by comparing the total annual water savings and water supply increases from reuse to the increase in demand due to population and economic growth. Inadequate data, however, make assessment of savings from measures outside the purview of NBWA water suppliers[5] very difficult;[6] therefore, this index focuses on assessing water suppliers' conservation programs and reclaimed water use from wastewater treatment plants. If trends toward establishing guidelines and incentives for grey water re-use and rainfall harvesting continue, these conservation measures could be included in the index.

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[2] A reference or target gpcd indoor use can be derived from existing studies. A reference or target outdoor use is more difficult to determine but model landscape ordinances provide guidance for quantifying outdoor water budgets.

[3] Residential per capita use is calculated either with the single-family residential (SFR) water use only or the combined single and multi-family residential (MFR) use. Calculating just the SFR per capita use requires knowing the average number of persons per account and the number of accounts in order to determine the water-using population. The combined SFR and MFR per capita use assumes that those two sectors equal the total population reported by the supplier. If accurate SFR population data is available in all the NBWA districts then it is the better metric to use to make comparisons among the districts. Absent that data, however, NBWA water suppliers would need to determine if their SFR and MFR accounting is similar.

[4] Including district implemented water efficiency measures, agricultural consumptive use reductions, reclaimed water supplies from treatment plants, greywater reuse, desalination, rainwater harvesting and infiltration)

[5] Out-of-district residents and agricultural users are the most common users whose data will not be available when calculating water savings, although in-district users who implement water saving measures not tracked by a district-managed program may also not be directly quantified.

[6] Another challenge to assessing water use sustainability is separating demand increases or decreases that are climate driven from those due to population and economic expansion and contraction.

The water supplier programs for indoor savings through technological improvements (e.g. toilet and washing machine rebates, showerhead replacements) are the most easily tracked and quantified. It is more difficult to quantify water supplier measures to reduce potable water use for landscape irrigation purposes (e.g. incentives for irrigation controllers and landscape replacement) although it is possible using industry-accepted estimates. To make this a meaningful performance measure, the water savings achieved through district programs need to be compared with savings targets that either the supplier or some other entity has established.

Water recycling, also known as reclamation or reuse, is a reliable way to replace water supplies extracted from streams and groundwater basins, limit the need for new water diversions and water imports from other watersheds (which often require substantial energy expenditures), and reduce wastewater discharge to sensitive water bodies. In the NBWA watersheds, treated wastewater is used to irrigate landscapes, golf courses, and crops and to augment freshwater flow to wetlands. Reclaimed water use can be assessed by quantifying the potable water supplies that it replaces and comparing it to the wastewater stream, established recycled water use targets, or the potential demand for recycled water. Some of the reclaimed water use does not replace an existing potable water use or is used outside the municipal water supplier boundary; it is a new water supply for a demand that may not have been met without the reclaimed water supply or that was previously met through groundwater or non-municipal sources. This new supply could be captured under the water efficiency metric, but it would depend on the supplier.

Storage

The water supply for most of the residents in North Bay watersheds is derived from surface water reservoirs[7] that are largely supplied by stream runoff during the rainy season. A commonly used indicator is the volume of water in storage at a given time, represented as a percentage of the total storage and percent of average for that date.[8] Although many water districts report storage on a daily basis, we recommend that annual variations in storage be tracked by choosing a date close to the end of the rainy season (e.g. April 1) when supplies for the subsequent high-demand dry season should be near their maximum. All municipal storage reservoirs that supply the North Bay should be tracked, including the North Bay, Russian River, and State Water Project reservoirs.

Groundwater is the primary water supply source for agriculture[9] and for residents outside of the water districts in the NBWA watersheds in Sonoma and Napa County.[10] Where data are available, such as in the Sonoma Creek watershed and parts of the Napa River

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[7] Many of the residents who live outside of the NBWA municipalities and the water districts serving them are self-supplied with groundwater.

[8] The volume in storage may not be entirely available if the supply outlet is above the bottom of the reservoir and thus a percentage may be more meaningful than an acre-foot volume in storage. In some cases, some of the volume may be dedicated for instream release, or a minimum level must be maintained for recreational purposes and is therefore not available for human use. If possible consideration should be given to representing the volume available for the different uses (e.g. municipal supply and instream uses).

[9] Reclaimed water is a growing water supply source for agriculture.

[10] Groundwater aquifers and alluvial basins in the Marin County NBWA watersheds, including the San Rafael and Novato Basins, are relatively small, and groundwater is a much smaller source of supply.

watershed, a method commonly used to determine the relative storage in groundwater is to measure the depth to the water surface in representative (index) wells. These measurements should be done in the spring and fall to assess intra-annual and inter-annual changes in water levels and the change in storage if the specific yield and acreage of the basin is known.

Climate context

Although the water supply indicators and performance measures are by definition responsive to human management, they also will be greatly influenced by the climate—particularly rainfall and evapotranspiration—which drives the water supply and the agricultural and urban landscape demand for water. Therefore, we recommend that the use of water supply indicators and performance measures be accompanied by the use of climatic context indicators. We designate these as informational "indicators"—they are not indicators in the strict sense because people cannot directly manage the climate (Table 7).

Table 7. Climate context indicators

Index	Indicator	Metrics	Reference
Precipitation	Cumulative annual departure from long-term average	Cumulative annual departure from long-term average	California Data Exchange Center http://cdec.water.ca.gov/
Evapotranspiration	Actual evapotranspiration	Watering schedules developed by districts	California Irrigation Management Information System http://wwwcimis.water.ca.gov/cimis/welcome.jsp

Water suppliers often present cumulative totals and percent of average rainfall for a particular year for the local watersheds. We recommend that additional rainfall information be presented to show the cumulative precipitation and departure from the long-term average to indicate whether we are in a wetter or drier period.[11] This should be developed for all the watersheds, local and imported, from which the water supply is derived.

Vegetation demand for water can be tracked by measurements and calculation of evapotranspiration (ET). We recommend that an actual ET indicator be tracked throughout the year and over the long term in an easy to understand manner. Some water suppliers provide information on outdoor water demand as a watering schedule.

[11] This could also be done for runoff although it would require having a measurement or calculation of the runoff unimpaired by diversions or storage to show what nature is providing.

4.2 *Restore and Enhance Habitat*

A common frustration encountered in watershed management is the regulatory focus on habitat enhancement absent coordinated biological monitoring and appropriate indicators for populations of concern. For example, many North Bay watersheds have impaired cold water fisheries and impaired threatened or endangered species beneficial uses (defined as elements of water quality pursuant to the Clean Water Act), as indicated by declines of salmonid species. We recommend five performance measures and three indicators to address the objective of restoring and enhancing habitat (Table 8).

Table 8. Recommended indicators and performance measures to restore and enhance habitat

Index	Performance Measure (PM) or Indicator (I)	Metrics	Reference
Habitat restoration	Upland restoration (PM)	Area treated; ratio of contemporary to historic or target area	San Francisco Bay Wetland Ecosystem Goals: www.sfei.org/sfbaygoals/
	Bayland Restoration (PM)		
	Freshwater Wetland Restoration (PM)		
	Stream/Riparian Restoration (PM)	Linear feet treated; ratio of contemporary to historic or target stream length	CDFG Habitat Restoration Manual http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp
	Fish Passage (PM)	Impaired linear feet opened up for fish passage; ratio of contemporary to historic or target area	CDFG Habitat Restoration Manual http://www.dfg.ca.gov/fish/REsources/HabitatManual.asp
Fish index	Salmonid Population (I)	Total # smolts produced per watershed per year[12]	CEMAR 2009
Bird index	Christmas Bird Counts (I)	# of species, total count per annual sample	www.sonomabirding.org
Instream flow	Summer base flow (I)	Total discharge (cfs) July-Oct at gage; 7-day minimum averaged flow at gage (cfs)	http://waterdata.usgs.gov/ca/nwis/rt

Habitat restoration

Artificial barriers to fish passage are considered a limiting factor on regional salmonid fisheries populations. With the support of the California Department of Fish and Game (CDFG), watershed-wide barrier assessments have been completed for the Petaluma River and Sonoma watersheds and are in process for the Napa River (CDFG 2008, Leigh Sharp *pers. comm.*). These assessments provide an opportunity to inventory stream lengths and sub-watershed areas that are no longer accessible to fish because of barriers. The assessments, based on straightforward spatial analysis, will help establish goals for

[12] This metric is recommended with reservations. At the time this report was completed, funding was not available at the scale required for comprehensive monitoring.

barrier remediation. We recommend that all North Bay watersheds estimate stream length lost to barriers and establish targets for remediating these barriers. Measuring increments of habitat re-opened to fish passage provides both a meaningful indicator of physical habitat and a performance measure of program success.

The best way to approach setting habitat restoration targets for freshwater wetlands, uplands, and baylands is to start with a comprehensive historical ecology analysis of the watershed. These are in process for some North Bay watersheds (Napa Valley, Sonoma Valley, and Miller Creek; see http://www.nbwatershed.org/millercreek/). Historical landscape assessments can be examined along with current opportunities and constraints on watershed structure and function to develop targets that reflect reasonable goals. These targets can be used to track performance measures of habitat restoration in the North Bay, which are best accomplished at the watershed scale in the process of developing watershed-specific plans.

Fish index
Regional fisheries biologists[13] agree that salmonid population is a reasonable indicator of overall native fisheries health. NBWA recently funded the development of a proposal for a comprehensive regional salmonid monitoring program that relies on watershed-scale smolt production as a primary indicator of aquatic habitat health. This proposal estimates that the cost of one year of monitoring salmonid smolts is $363,000 (CEMAR 2009), which is prohibitive without significant, longer-term resources. Thus, we recommend the metric of total smolt production to measure salmonid (and overall fisheries) health in a watershed with reservations (due to high cost).

Bird index
Birds can also be indicators of riparian function and habitat health. We recommend adopting portions of the results of the annual Christmas Bird Counts facilitated by the National Audubon Society as the core of the Bird Index. PRBO Conservation Science has identified important riparian species that will serve as appropriate indicators of riparian health in the North Bay (Pawley and Nur 2006). Other bird species (those that do not depend on riparian areas for habitat) will not be included. Presently there are three Christmas Bird Count "circles" established within the North Bay watersheds (Tom Rusert, Birding Sonoma Valley, *pers. comm.)*. In some cases circles do not align strictly with watersheds, but it is possible to separate surveyed areas by watershed boundary. The advantage of this methodology is that Christmas Bird Count protocols are standardized across the nation and undertaken by numerous trained volunteers. A locally-based organization comprised of world leaders in bird ecology, PRBO Conservation Science, provides count interpretation and assistance with sampling methods.

Instream flow
Monitoring of summer base flows is an integral part of measuring aquatic and riparian system health. This indicator was also considered for tracking the Water Supply objective, since it measures instream flows and groundwater available to both aquatic life

[13] Rob Leidy (USEPA), Jonathan Koehler (Napa RCD), Gordon Becker (CEMAR)

and people during the dry season. However, stakeholders recommended including it primarily as a habitat consideration, since base flows do not provide a primary water supply for most users. We recommend using installed USGS watershed gages (or comparable stations) to quantify the total dry season flow (July to October) and to calculate the average discharge during the week of lowest observed flow. Both of these should be evaluated with the climate context indicators, and can be weighted as a fraction of total annual discharge (as a volume or average flow). An evaluation of base flow in relationship to both habitat (aquatic and riparian) and groundwater levels may improve understandings of relationships among these parameters.

4.3 *Increase Flood Protection*

We considered a broad array of indicators that measured critical flood-related parameters including: stream buffer widths, structure density in floodplains, and effective impervious area (which entails mapping both impervious area and drainage routes). Establishing many of these indicators would have entailed intensive aerial photography analysis and a tool such as a Geographic Information System at the watershed scale. These are technologically sophisticated and resource intensive analyses that should be done on a regular basis, and so may be impractical at a broad scale, but encouraged if resources allow. We also considered a performance measure that would assess progress in identifying and treating flood hazards. However, standardization of this metric across jurisdictions would likely be difficult and may be redundant with existing management efforts. We reduced our analysis to one indicator (total watershed impervious area) and two performance measures (total area within the FEMA 100-yr floodplains and number of integrative stormwater implementation projects, Table 9).

Table 9. Flood protection performance measures and indicators

Index	Performance Measure (PM) or Indicator (I)	Metrics	Reference
Watershed runoff	Impervious area (I)	% impervious (total) area	http://www.mrlc.gov
Innovative and integrated stormwater and flood management	Innovative and integrated stormwater and flood management implementation (PM)	Volume of stormwater retained or recharged	Stormwater guidelines: http://www.waterboards.ca.gov/water_issues/programs/low_impact_development/
Floodplain protection	Floodplain protection (PM)	Total acres of floodplain	FEMA floodplain insurance rate maps www.fema.gov

Watershed runoff

Watershed impervious area directly drives runoff contributing to stormwater flows. A group of several federal agencies calculated percent imperviousness using Landsat imagery and orthophotographs to calibrate an algorithm that produces percent imperviousness per pixel (www.mrlc.gov). This particular dataset is ideal because it applies a consistent methodology to all 50 United States and Puerto Rico, so that data for imperviousness can be compared across many watersheds and regions. We recognize that total impervious area is a very coarse measurement, and is most useful in comparing relative impervious areas between watersheds, and over time. Other, finer measurements of impervious area are too complex and resource-intensive to be used at this time. We recommend assessment of impervious area at the watershed scale every five years, at a minimum.

Innovative and integrated stormwater and flood management
Since total impervious area cannot properly measure Low Impact Development (LID) [14] implementation (some improvements may be at too small a scale to be captured via typical assessment techniques), we recommend performance measures that track simply the number of integrative projects implemented (Dawson and Cornwall 2007) and the volume of water converted from runoff to recharge due to innovative flood management techniques. Projects of this nature implemented using state or federal funds will be required to measure the volume of water captured, so this metric should be readily available in the future.

Floodplain protection
Evaluation of floodplain area (through FEMA maps or local land use plans) should be conducted at a similar temporal scale, yet this may be driven by the schedule for land use plan updates. The overall objective is to increase floodplain area, and maintain or reduce effective impervious area[15] through a concerted focus on LID and re-development principles. In addition, the stream and riparian restoration performance measure will lend information.

4.4 *Increase Opportunities for Recreation and Public Involvement*

This was the most difficult category in which to choose appropriate indicators and performance measures. First, there is a wide variety of ways to measure recreation and public involvement, but many we considered were not very meaningful. For example, "number of access points for aquatic recreation" measures availability of recreational opportunities but not whether people use or appreciate those areas or whether they are well maintained. Therefore, it is hard to gauge from that metric whether the objective of improving and enhancing recreational opportunities is met by just the existence of access. Second, some more meaningful metrics are difficult to calculate or gather the necessary information for either because the answers are subjective or it would be overly time-consuming to do so. For example, we originally wanted to include a metric to capture users' experiences directly. However, this would require a survey methodology that is

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[14] "LID is an innovative stormwater management approach with a basic principle that is modeled after nature: manage rainfall at the source using uniformly distributed decentralized micro-scale controls. LID's goal is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source." (http://www.lowimpactdevelopment.org/lidphase2/#lid)
[15] "Effective impervious area" differs from "total impervious area" in that "effective" only measures the impervious area that is directly connected to a storm drain system. Total impervious area also includes impervious surfaces that may drain to natural areas. However, we recommend total impervious area as an indicator because effective impervious area is much more difficult to measure.

time-consuming to conduct and design in order to obtain good quality data. Data generated from such an effort are expected to be highly valuable and may warrant consideration in the future, as discussed later in this report. Third, we found that some metrics, though relatively easy to measure and address the objective properly, might not necessarily tell us much about the overall goal of watershed health. For example, we wanted a metric to address the objective of providing educational opportunities associated with cultural and historic resources, so we initially suggested "number of cultural/historic events each year." However, in the end we decided that this metric was not relevant enough to watershed health.

Thus we narrowed our list of candidate performance measures and indicators down to one performance measure that will measure participation in watershed-related events, such as creek clean-ups and restoration work parties (Table 10). This performance measure met all of our criteria, directly related to and informed the NBWA goals and objectives, and was a data set that was already being collected by various environmental and business groups throughout the North Bay such as STRAW, local chambers of commerce, and the Sonoma Ecology Center. Over time it will be valuable to expand the number of groups that collect this type of data, perhaps through incentives or more centralized data collection methods.

Table 10. Recreation and public education performance measure

Index	Performance Measure	Metrics	Reference
Education promotion	Community involvement in watershed management and restoration	Number of community members participating in restoration or education programs	Local conservation and business organizations, e.g. STRAW (http://www.bay.org/watershed_education.htm)

4.5 *Improve Water Quality*

Water quality is a category for which a seemingly endless list of candidate indicators, performance measures, and metrics exist, due to the myriad of parameters that can inform the public about water quality. We considered several alternative performance measures and indicators, all of which failed to meet our criteria. After analyzing the cost of various performance measures and indicators, we narrowed our initial candidate list. In addition, some watersheds in the North Bay are fairly pristine and thus analysis of certain toxic pollutants is not necessary unless other, more ancillary parameters (e.g. dissolved oxygen, specific conductivity) indicate a more complicated water quality issue. A second criterion that resulted in the removal of a performance measure from the pool of candidates was availability of information. The technical team wanted to track progress in reducing the amount of pesticides used in each watershed; however, in looking into the available data on this subject, we found that the data was not consistent across the North Bay, and was only available by county and not by watershed. Without consistent data available for a range of scales and across the North Bay watersheds, some metrics were removed from our priority list. Our final list contains two indicators (physical water quality and stream benthic macroinvertebrates), and one performance measure (tracking of TMDL implementation and pollutant load reduction), in Table 11.

Table 11. Water quality performance measures and indicators

Index	Performance Measure (PM) or Indicator (I)	Metrics	Reference
Pollutant reduction	TMDL implementation (PM)	Pollutant load reduced through TMDL project implementation (cubic yards, tons); stage of TMDL implementation (# acres, stream miles)	http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/
Water quality standards	Physical water quality (I)	Continuous temperature, DO, turbidity, conductivity	APHA 1992
Invertebrate index	Stream benthic macro-invertebrates (BMIs) (I)	BMI Protocol metrics	Harrington 1999

Pollutant reduction
The North Bay is currently regulated by the San Francisco Bay Regional Water Quality Control Board under several Total Maximum Daily Loads (TMDLs), in various stages of implementation[16]. These plans require landowners and agencies to reduce specific pollutants and measure the amount of pollutant load reduced. Due to their regulatory importance, TMDLs also tend to attract implementation funding. Thus, the status of implementation (which tends to roughly correlate with amount of work completed and funded) and the pollutant load reduced, compared to the target set in the TMDL, are excellent performance measures of water quality in impaired waters of the North Bay.

Water quality standards
Physical water quality metrics (temperature, dissolved oxygen, conductivity, turbidity) are some of the most basic parameters to collect and interpret. In addition, they are useful for predicting larger water quality issues that may occur. Measurement requires a regularly calibrated water quality meter that could cost several hundred dollars, but is an investment that many monitoring groups have already made.

Temperature is an important indicator for the type of organisms that can survive in water, in particular fish. The temperature needed for optimum survival varies by species and by life history stage (APHA 1992).

Dissolved oxygen (DO) measures the amount of oxygen in water, which also helps to determine the kind of life that can survive in it, since aquatic organisms obtain oxygen from the water they live in. Dissolved oxygen is related to velocity and temperature, since faster-flowing cold water tends to have higher DO than warmer, stagnant water (APHA 1992). For coldwater streams, the Basin Plan objective is 7.0 mg/L (SFBRWQCB 2007b).

[16] TMDLS are the plans developed to reduce pollutants in a water body. For information on implementation stage, see http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/

Conductivity measures the ability of water to pass an electrical current. It also is an indicator of the presence of dissolved solids such as magnesium, aluminum, nitrate, sulfate, and phosphate. A greater presence of such substances (i.e., higher conductivity) can indicate polluted runoff from agricultural and urban areas. Conductivity is also related to temperature, as warmer water is more conductive (APHA 1992).

Turbidity is a measurement of the side scatter of light from particles (including, but not limited to, sediment) in the water, and is helpful for determining the cloudiness of water, and approximate transport of suspended sediment, which can have negative impacts on instream habitat for fish, invertebrates, and wildlife. It is measured using a nephelometer and is expressed in nephelometric turbidity units (NTU). Turbidity is also related to the other physical water quality parameters. At a certain high turbidity, temperatures will increase due to the absorption of heat of particles, which in turn can decrease DO, and affect organism survival (APHA 1992).

There are many important considerations to incorporate into a monitoring design that assesses these indicators. The EPA has some basic guidance, especially useful for volunteer groups, available at http://www.epa.gov/owow/monitoring/volunteer/stream. This group of parameters can be measured together, and with relatively little training volunteers can produce meaningful information regarding aquatic life.

Invertebrate index

Benthic macroinvertebrates (BMIs) are important for assessing watershed health because they provide food for larger organisms, and can be sensitive to changes in water quality. The presence of certain sensitive taxa of BMIs can indicate superior water quality, whereas other taxa can survive under poor conditions, so the number and diversity of taxa provide excellent information on the quality of a stream's waters. A standard methodology for collecting BMIs was developed by Harrington (1999) and is relatively easy to perform with little training or equipment. For these reasons, assessment of stream BMIs is recommended as an indicator of water quality and overall watershed health. The Surface Water Ambient Monitoring Program has adopted protocols for measuring benthic macroinvertebrates (http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/reports/assess_nocal2005.pdf), and we recommend them for use.

5. Recommendations and Next Steps

5.1 *Data Gaps*

There are many gaps in data that limit the pool of indicators and performance measures from which to choose. During our culling process, we found that lack of long-term, consistently collected, and well-funded data limited our choices of indicators and performance measures to recommend, and, in particular, will limit the ability for users to select targets or benchmarks. The Appendix includes an explanation of many of the indicators and performance measures that were considered but were categorized as "Tier

2." This group are worth considering once the full suite of recommended (or "Tier 1") measures are in place, should be applied only in special cases, or when resources available allow pursuing more time and labor intensive methods. Here we will highlight a few of these and comment on the data sets that would greatly improve future indicator development and use.

First, we wanted to recommend an indicator of total water use that includes agricultural water consumption to truly account for the total water use by watershed or region. One challenge is that agricultural water sources tend to be wells that are not metered consistently, making their use difficult to track. Currently, agricultural water use is estimated using land use information, which is only intermittently updated. More consistently collected well data and land use information would greatly improve the data needed for a total water use indicator.

Surface water is monitored in a limited number of locations through USGS-maintained stream gages. However, with more gages installed, a greater area of North Bay watersheds would have the necessary data for scoring indicators of water supply and habitat enhancement.

Enhancing recreation and public involvement opportunities is a difficult objective to track, but results of a survey aimed at trying to gauge the "eco-literacy" of people using public trails could improve our knowledge. The survey would have to be carefully designed and worded, and administered to hundreds of people. Its results could provide an indication of public knowledge of watershed health and how people connect their enjoyment of natural areas to choices they make when buying products or using natural resources. Survey results could also be used to identify areas where communities are receptive to stewardship campaigns.

The California Rapid Assessment Method (CRAM) is a standardized tool developed to asses the health of wetlands and riparian areas across the state, and if more widely implemented, it could provide meaningful information on wetland and riparian health. CRAM is useful because it is a carefully designed index, measured in terms of four attributes of condition: Buffer and Landscape Context, Hydrology, Biological Structure, and Physical Structure, and is designed to enable standardized ambient assessments at multiple scales: projects, watersheds, regions, and statewide. Most recently CRAM has been used to perform a statewide survey of wetlands including at the watershed scale. However, adoption of this indicator entails a commitment to developing a trained staff and securing resources on an ongoing basis to support a meaningful long-term effort. Further, the scoring system and metrics are not yet widely understood, and more education and communication could help make this indicator more meaningful to a wide audience. A guidance document for using CRAM to assess wetland projects is provided at http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/cram_access.pdf.

Consideration should be given to a somewhat more complex but potentially more informative climate or drought indicator that incorporates temperature, precipitation, and soil moisture because it may be a better indicator of the water supply condition that human and natural landscapes are experiencing. The challenge with this indicator is in developing it and explaining it to the public.[17]

The last example of a data set that is missing or not defined well enough to be used as an effective watershed health indicator in the North Bay is pesticide use. We found that some pesticide data, mostly for agricultural and municipal use, are tracked by county, but not by watershed or smaller scales. Residential pesticide use is currently not tracked anywhere that we could find. Thus the scale and type of pesticide consumption data available limited its ability to be recommended as an indicator of water quality.

5.2 *Applying Recommended Indicators and Performance Measures*

A primary recommendation of this report is that NBWA partners move forward with implementing, at a minimum, the recommended five priority monitoring parameters (discussed in section 3.1) in all North Bay watersheds. There are many steps involved in being able to properly use indicators to measure watershed health, and these are addressed in detail in reference materials (e.g. Gunther and Jacobsen, 2002; Thompson and Gunther, 2004; Young and Sanzone, 2002; West et al 2009; see Reference list). The following is a summary of basic steps to using the recommended indicators and performance measures.

- Assess existing data quality and availability for the chosen watershed. It is recommended that any catalogued data follow SWAMP formatting (see http://swamp.mpsl.mlml.calstate.edu/swamp-comparability) and protocols (see http://www.waterboards.ca.gov/water_issues/programs/swamp/tools.shtml#methods).
- Develop a list of assessment or management questions, and then choose the indicators and performance measures that are appropriate to answer these questions (see USEPA 2000, USEPA 2008).
- Organize monitoring efforts to address as many recommended measures as possible, provide new robust datasets, and fill in data gaps in partnership with technical experts and stakeholders.
- Develop a strategy for long-term funding to support data acquisition, collection, collation, and interpretation.
- Assess how to best leverage the efforts of volunteers.
- Organize collected baseline data in a centralized data repository.
- Communicate and coordinate with other organizations to provide or help collect and interpret data to be used in indicator scoring.
- Define assumed reference conditions, e.g. what is the assumed condition of the system prior to disturbance, or what condition is aimed for as a result of management.
- Develop a sampling network, including spatial distribution and frequency, and map locations to share with partners.

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17 See http://www.in.gov/dnr/files/ws-drought_indices_2008.pdf for a review of drought indices.

- Develop and implement a work plan defining partner roles and responsibilities, a sampling schedule, data collection, storage, and analysis protocols.
- Score the indicators and performance measures relative to the reference conditions.
- Combine these scores into an overall scorecard of watershed health for the particular scale and communicate the findings to the public (e.g., The Bay Institute 2005, Environment Canada and USEPA 2007, Sustainable Seattle 1998).
- Disseminate results, seek feedback from technical experts and stakeholders, and consider whether management actions should be revised based on results.

Remember that using indicators and performance measures to assess watershed health is not just reporting monitoring results, but rather assessing data based on reference conditions, looking for relationships between parameters, and aiming to answer important assessment and management questions. Using this framework, it is possible to track progress over time in meeting management goals and in improving watershed health. Trends observed can be used for making decisions using adaptive management methods.

These suggested indicators and performance measures of watershed health, plus the information on how they were chosen, were all carefully designed in order to be used in a variety of applications. Some examples of applications include:

- Watershed plans
- Pre- and post-project monitoring for implementation projects (e.g. bank stabilization, flood control, vegetation)
- Watershed monitoring programs
- Regional monitoring plans (in this case, North Bay-wide)
- Stormwater programs
- Local government ordinances and land and water use plans

5.3 *Program Evaluation and Adaptive Management*

It is necessary to assess the utility of chosen indicators and performance measures to conditions, stressors, and management actions on the ground. However, an important tradeoff in revising indicators is the interruption of long-term datasets, so changes should be made to indicators only after careful consideration. The results of indicator and performance measure scores can (and should) be used to evaluate goals and objectives. If programs are fully implemented yet scores are continuously falling short of goals, perhaps the targets are too high, the wrong metrics are being measured, the efficacy of applied programs was over-estimated, or the system has larger problems and management actions need to be adjusted. A reassessment plan should be developed to evaluate the utility of indicators every five years. This plan should consist of reassessing the important issues, management questions, and monitoring plan (USEPA 2008). Additional indicators and performance measures (from the Appendix for example) could be employed to complement or replace the current recommended list, based on data availability and the other criteria. Finally, the new indicators should be implemented, but hopefully not at the expense of maintaining the original indicator set, should that original set prove to measure the watershed effectively.

Indicators and performance measured recommended here should be used to monitor and assess watershed health at a variety of scales in the North Bay. A North Bay regional monitoring program specifically designed around the full recommended suite of indicators will be an important building block towards a Bay Area-wide program. Evaluating consistent indicators and performance measures on a regular basis will provide indispensable information to local scientists and managers and also will facilitate comparisons of watershed conditions across the region to better define and manage relationships between watershed stewardship and resource response.

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Appendix– Additional “Tier 2” indicators and performance measures to consider

In the course of culling potential indicators and performance measures for this project, the most difficult part for the core team and stakeholders was perhaps letting go of parameters of potentially great value in order to get to a feasible list. This appendix includes indicators and performance measures considered for all five NBWA resource goals, but classified as “Tier 2” (compared to the “Tier 1” full recommended suite) - based on a range of issues, such as limited data availability, prohibitive expense or technical resources needed, or applicability to only a subset of North Bay watersheds. The reason they were classified as “Tier 2” is explained in the far right column of each table below. This column also indicates where use of trained volunteers may be an effective approach. In many cases, an indicator category was retained as first tier, but a specific metric, shown here, was classified as second tier. Indicators and performance measures for each NBWA resource goal are displayed in separate tables.

Water Supply Indicators

Index	Indicators	Metrics	Why second tier?
Water use	Total water use per capita per area watershed	Total use in 4 categories (combined): agricultural, residential, industrial, commercial	Agricultural water use not tracked consistently throughout North Bay; hard to measure all uses in unincorporated areas that use well water
Streamflow	Summer stream flow (Base flow)	Length or area dry stream bed for a consistent representative reach	Extent of dry stream beds is currently only tracked in Sonoma, it requires coordinated field effort, and it can be difficult to establish targets due to lack of historical data. A strength is that volunteers may be capable of implementing this protocol.

Water Supply Performance Measures

Index	Performance Measure	Metrics	Why second tier?
Water use	Water Independence	Per-capita imported supply- gallons per annum or per day or percentage of local versus imported supply	Can only be applied to populations served by water districts and not those that use wells.

Appendix– Additional "Tier 2" indicators and performance measures to consider

Habitat Enhancement Indicators

Index	Indicator	Metrics	Why second tier?
Fish index	Fish Distribution	Locations: extent of watershed known to support fish populations (can be reported as % stream length below known barriers)	Patchy, often anecdotal historical data--few ongoing programs right now, requires extensive field effort. Potential for trained volunteer support.
Fish index	Fish Diversity	Total # of species, % natives vs. non-natives	Field intensive, can be cost prohibitive, salmonids provide surrogate indicator species. Requires trained biologist, and likely requires sampling permit.
Bird index	Winter shorebirds	Number of individuals, densities	Requires trained biologist and intensive field effort.
Bird index	Riparian Birds	number of riparian birds observed on 4 routes	In most areas, requires mobilizing an intensive field effort with a trained biologist.
Bird index	Migratory Waterfowl	midwinter waterfowl surveys for Canada Goose	Question about whether migratory species were best indicator of watershed-specific condition, applies to subset of watersheds, but might be an important goal.
Bird index	T&E Species	Clapper rail populations	Applies to subset of watersheds, but might be an important goal. Requires trained biologist, and likely requires sampling permit.
Riparian Habitat	Riparian Forest Health	% riparian cover / density, % native vs. non-native, complexity	A high priority, but measurements need to be coordinated to provide meaningful results; CRAM provides a standardized alternative.
Riparian Habitat	CRAM	Several metrics within the following categories: 1) Buffer and Landscape Context 2) Hydrology 3) Physical Structure and 4) Biotic Structure	Scoring is not widely understood; focus is on wetlands and less on riparian habitat, presently is financially out of reach for many organizations.

Appendix– Additional "Tier 2" indicators and performance measures to consider

Flood Protection Performance Measures

Index	Indicator	Metrics	Why second tier?
Flood hazards	Flood hazard removal	# flood hazards removed, as compared to target if available	Difficult to standardize, redundant with ongoing management efforts
Floodplain protection	Residential (and commercial) development in floodplain	Square feet of structures in FEMA floodplain (sq feet/area of floodplain)	Requires comprehensive, time intensive detailed mapping from air photos, multiple times to get time series.
Floodplain protection	Setback protection	% of projects that meet setback requirements during planning process	Requires comprehensive, time intensive detailed mapping from air photos. Difficult to locate "representative: sampling areas

Flood Protection Indicators

Index	Indicator	Metrics	Why second tier?
Watershed runoff	Storm hydrograph "flashiness"	Runoff coefficients (ratio of rainfall to runoff) for storms; flood peak attenuation	Lack of reference condition data. Difficult to compare peaks to "historic" hydrographs but can be estimated with model. Models can be complex, costly, and unrepresentative. (see Napa/Sonoma Water Supply scorecard)
Floodplain protection	Setback protection	Average width of required setback from streams compared to actual setback	Requires comprehensive, time intensive detailed mapping from air photos and detailed knowledge of variations in setback requirements.

Appendix– Additional "Tier 2" indicators and performance measures to consider

Water Quality Performance Measures

Index	Indicator	Metrics	Why second tier?
Pollutant reduction	TMDL implementation	% of TMDL implementation complete	TMDLs implemented in drawn out regulatory "steps"; not as meaningful as indicator that tracks actual pollutant load reduction
Monitoring and assessment	Monitoring efforts	% of NBWA watersheds with ambient or continuous monitoring	Challenging to set standard for a "complete" monitoring effort. Would be possible to set "5 indicator" standard for this in future.

Water Quality Indicators

Index	Indicator	Metrics	Why second tier?
Stream alteration	Stream geomorphic integrity	Repeat topographic channel cross-sections	Only serves a subset of NBWA watersheds where channel incision is a primary source of fine sediment (highly recommended for those watersheds), requires identifying "representative reaches" and funding a skilled survey team
Stream alteration	Stream Channel Sediment Erosion/Aggradation	Feet of erosion/aggradation per 100 foot reach of stream channel	Protocol not defined, requires identifying "representative reaches" and funding a skilled survey team
Pesticide and herbicides use	Pesticide and herbicides use	Commercial pesticide consumption by weight	Pesticide Action Network database is organized by county and not watershed

Appendix– Additional "Tier 2" indicators and performance measures to consider

Recreation and Public Involvement Performance Measures

Index	Indicator	Metrics	Why second tier?
Recreational Support	Trail length, and connectivity	Number of miles of trails designated for public recreation, Number of trail intersections along a given trail, % trail system open to public; as compared to target if available	Not as meaningful as desired as a watershed health metric
Recreational Support	Waterway access for recreation	Number of formally designated aquatic recreational access areas/points, Miles of publically accessible bay, stream, lakeside, and estuarine shoreline available for aquatic recreation, as compared to target if available	Issue of potentially more access causing more damage to natural areas? Access does not mean there is use, and use does not mean the watershed is healthy.
Education Promotion	Interpretive sign education	Number of interpretive sites, Number of interpretive sites improved, Distribution (# / sq. mi of accessible land) of interpretive signage, compared to target if available; program evaluation (added knowledge due to interpretive signage)	Site by site evaluation would be the most meaningful metric but hard to do on a wide scale basis; other metrics are not as meaningful as needed
Education Promotion	Level of online outreach	Number of posting/hosting of watershed related events on NBWA website; Number of monthly visitor "hits" on the NBWA site	This is a relatively easy metric, but the significance was not clear.
Recreational Support	Recreational Experience	"user group experience", e.g. number days/hours of active trail or waterways (user groups and or individuals)	A series of survey questions should be developed for each user group to ascertain if the "need" is being met. However developing and administering these questions is time and resource intensive, and requires expert design and implementation to be meaningful. Question about whether parks/recreation agencies are already doing this, and ability to tap into that data.
Education Promotion	Recognition of cultural & historical resources	Number of cultural/historical workshops/tours held each year	Hard to link this data to watershed health; very indirect. Participation would be more meaningful.