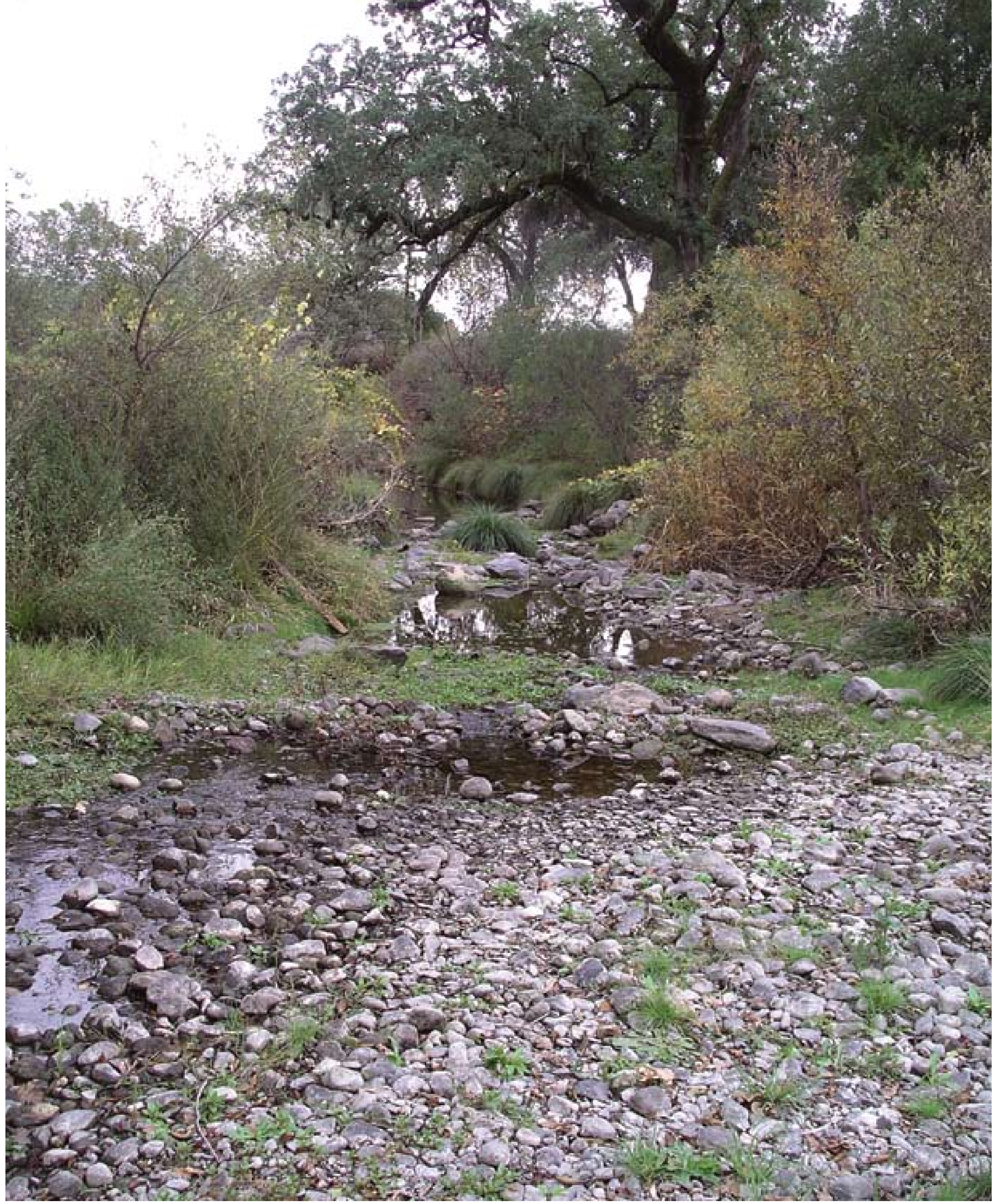
Habitats

The physical habitats of the Bay include tidal marshes and tidal flats—baylands, estuarine open water, managed ponds, subtidal habitat, and the local watersheds that drain to the Bay. The health of these habitats is assessed in the following sections. Subtidal habitat—the submerged area beneath the water surface of the Bay—is another very important type of habitat in the Estuary, but it is not evaluated in this report since a major analysis of this habitat was completed in December 2010. For more information see www.sfbaysubtidal.org.

Estuarine open water

The mixing of fresh water from rivers and saltwater from the ocean creates important open water habitat unique to estuaries. In the Bay, most of this brackish (or low salinity) habitat is formed by freshwater inflow from the Sacramento and San Joaquin rivers. The amount of inflow determines where in the Bay fresh and salt water first mix, a location known in scientific shorthand as "X2", the place where the salinity of the water near the bottom is two parts per thousand (about six percent of the saltiness



RAINER HOENICKE

of seawater), measured in kilometers from the Golden Gate.[13] When inflows are high, brackish water habitat is found farther downstream, closer to the Golden Gate, than when inflows are low. Because of the Bay's shape, the location of X2—whether in the wide open reaches of Suisun Bay or in the narrow channels where the Sacramento and San Joaquin Rivers enter the Bay—determines the amount (or area) of this important habitat. For a number of Bay fish and invertebrate species, each 10-kilometer upstream shift in X2 during the spring corresponds to a two- to five-fold decrease in abundance or survival.

Map 3.
The benchmark for healthy estuarine open water habitat was defined as X2 (the place where salinity is two parts per thousand) located downstream of 65 kilometers from the Golden Gate—see dashed line above—for more than 100 days between February and June.

HEALTH INDICATORS

Freshwater inflow to the Bay varies dramatically from year to year, a function of California's Mediterranean climate and the natural occurrences of droughts and floods. However, since the 1940s, large dams on the Bay's major tributary rivers have captured and stored the majority of their springtime flows in most years, with the result that less fresh water flows into the Bay (see also Freshwater Inflow Index). Reduced spring inflows produce more upstream locations of X2, reducing the quality and quantity of estuarine open water habitat and impacting the plants and animals that use it. The Estuarine Open Water Habitat indicator uses three measurements to assess the occurrence of high quality estuarine open water habitat in the Bay during the spring:

- frequency (how often?)
- magnitude (how much?) and
- duration (how long?)

BENCHMARKS

Current regulatory standards for freshwater flows into the Bay were designed to prevent extreme low inflows during the spring, but these minimum requirements still do not produce healthy estuarine conditions. Therefore, we developed a benchmark for evaluating estuarine open water habitat conditions based on the population and survival responses of many Bay fish and invertebrate species and defined high quality estuarine open water habitat as X2 located downstream of 65 kilometers (or X2 less than 65) for more than 100 days during the February through June period. Frequency was measured as the number of years in the past decade that this high quality habitat occurred. Magnitude was measured as the average springtime value for X2, and duration as the number of days in which X2 was downstream of 65 kilometers from February through June. Measured conditions that exceeded the benchmark were considered to indicate good conditions while those that were lower were considered to indicate fair or poor conditions.

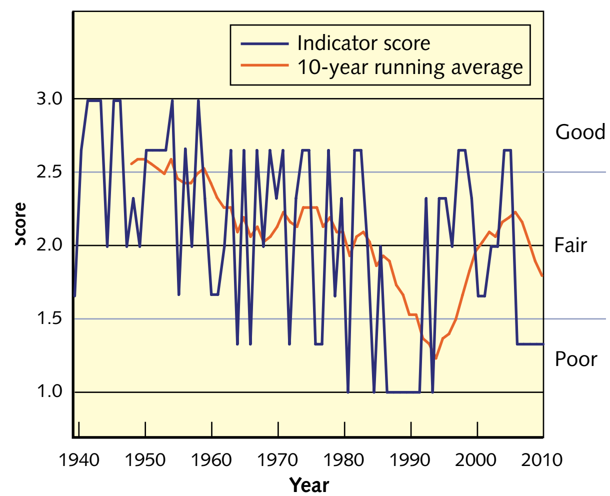
For each year, the Estuarine Open Water Habitat indicator was calculated by combining the results of the three measurements into a single score (1–3).

KEY RESULTS AND TRENDS

Results of this analysis reveal a steady decline in springtime estuarine open water habitat, from consistently good or fair conditions prior to the 1960s to mostly poor conditions by the 1990s (Figure 4).

Conditions improved during the late 1990s, during a sequence of unusually wet years but declined again in the 2000s. Declining habitat conditions were driven by reductions in all three component measurements of the indicator. In the 1940s and 1950s, high quality open

Figure 4. The quality and quantity of low salinity, open water habitat in the San Francisco Estuary in the spring has declined during the past 50 years.

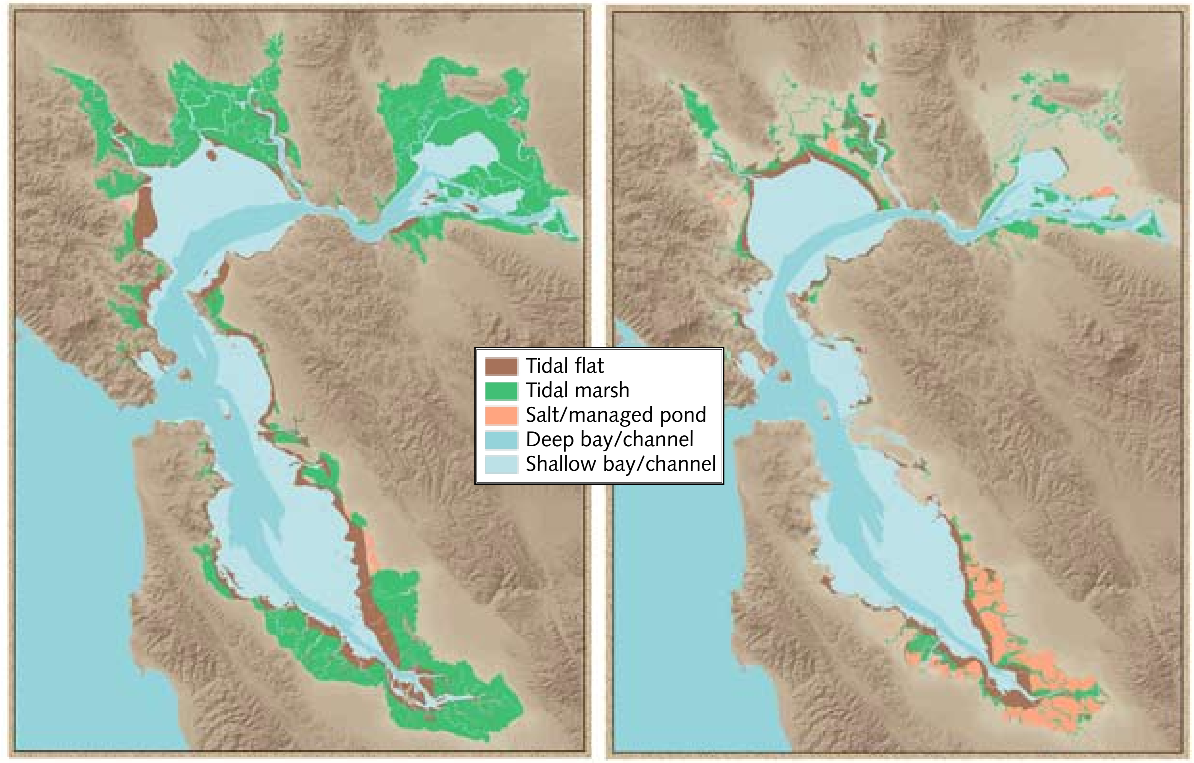


water habitat occurred on average in 70 percent of years. By the last decade, it occurred in just 37 percent of years, with the average location of springtime X2 shifting upstream nearly 7 kilometers. The number of days with good habitat conditions during the spring has declined by two thirds, from an average of 100 days per year in the 1940s and 1950s to just 43 days per year in the most recent decade.

SUMMARY

Reduced quantity and quality of springtime estuarine open water habitat impairs the health of the Bay. The availability of this habitat is closely linked to the abundance and survival of many of the Bay's native fish and shrimp species (see also the Fish Index, Living Resources section). This seasonal estuarine habitat is also often associated with (and created by) high flow "flood events," an ecological process that transports nutrients to the Bay, promotes productivity, and improves food availability for Bay fish and wildlife (see the Flood Events Index, Ecological Processes section). The connection of this habitat attribute with both ecological processes and living resources underscores the importance of acting to improve freshwater inflow conditions during the spring if we are to achieve the CCMP goals of increasing freshwater availability to the Estuary and restoring healthy estuarine habitat.

Figure 5. Historical (ca 1800 on left) and present-day (2009) baylands.



Tidal marshes and flats

Baylands are the tidal flats and marshes subject to regular inundation by the Bay's tides, plus the lowlands around the Bay that would be tidal if not for levees, dikes, tide gates, and other water control structures. Whereas tidal marshes support abundant vegetation, tidal flats are intertidal areas that lack rooted vegetation. Tidal flats and tidal marshes form in relatively calm areas along the margins of the Bay where fine sediments carried by the Bay currents and waves tend to accumulate.

Baylands have many important ecological and hydrological functions that contribute to the health of the Bay. The healthiest flats support dense colonies of shellfish and other invertebrates that serve as food for fish, birds, and other wildlife. Tidal marshes support many species of Bay fishes and water birds, while serving as water quality filters, trapping fine sediment and breaking down some of the contaminants that enter the Bay from local watersheds. Storage of fine sediment in tidal marshes helps reduce the need for expensive dredging in ports, marinas, and shipping channels.

Since the Gold Rush era there has been a dramatic decline in the amount of tidal baylands (Figure 5) as dikes and levees were constructed to separate tidal baylands from the waters of the Bay.

PETER BAYE

A diked marsh used for hay farming

These diked baylands were drained and converted to agricultural, industrial, or urban uses. Although undeveloped diked baylands do provide a variety of important wildlife habitats, the significant historical loss of tidal marsh and tidal flats has caused the health of the Bay to deteriorate.

HEALTH INDICATORS

Since baylands provide important ecological and hydrological functions, indicators of their condition can help assess the overall health of the Bay. Specifically, baylands are evaluated here by assessing:

- regional extent
- parcel size
- physical/biological condition

The extent of tidal flats and marshes matters because the ecological and hydrological benefits they provide increase as extent increases. The size of existing bayland parcels matters because when larger areas are fragmented into smaller ones, their value as wildlife habitat tends to decrease —few very large parcels close together are better for Bay wildlife than many small parcels farther apart. Lastly, measuring the condition of baylands helps assess how well they are providing their intrinsic ecological and hydrological functions.

BENCHMARKS

REGIONAL EXTENT

In the late 1990s a science-based public process identified a long-range goal of establishing 100,000 acres of tidal marshes in the Bay, or about 50 percent of the acreage of tidal marsh that existed historically. This process culminated in the 1999 *Baylands Ecosystem Habitat Goals* report. Here we assess progress toward that goal by evaluating the current extent of tidal marshes in the Bay.

No quantitative goal exists for tidal flats, so we derived a benchmark from the 1993 California Wetlands Conservation Policy. That policy calls for "no net loss" and a net overall gain in the state's wetlands, which implies that the number of acres of tidal flat that existed in 1993 is the minimum acceptable amount.[14] The 1993 figure represents a little more than 50% of the tidal flat that existed historically, making this benchmark consistent with the tidal marsh goal of 100,000 acres.

PARCEL SIZE

To evaluate bayland size, we compared historical and present-day distributions among six different size categories.[15] We developed a benchmark for both tidal marsh and tidal flat size by assuming that the historical distribution of bayland parcel size is an appropriate measure today for a healthy Bay (*i.e.*, the relative abundance of different sizes of bayland parcels should be the same as historical, even if the total area they cover is less).[16] Given this assumption, we set the benchmark for parcel size of baylands as the percent similarity between their historical and present-day distribution among size categories (±25% due to the range of sizes in each category).[17]

PHYSICAL/BIOLOGICAL CONDITION

There are no regional data for setting a benchmark for tidal flat condition. The few existing data only represent a handful of points scattered around the Bay.[18] Tidal flats are an under-studied component of the Bay ecosystem. Their ecological importance for migratory shorebirds and other wildlife warrants a comprehensive approach to assessing their condition. The condition of tidal marshes has recently been comprehensively surveyed using the California Rapid Assessment Method (CRAM). This standardized method has been widely used to assess California wetlands and wadeable steams. Because goals for tidal marsh condition have yet to be established, we set the benchmark for marsh condition in the Bay by comparing their CRAM score for *physical structure* (one of the four CRAM attributes—see description, page 29) to that for the less impacted marshes along the North Coast of California.

KEY RESULTS AND TRENDS

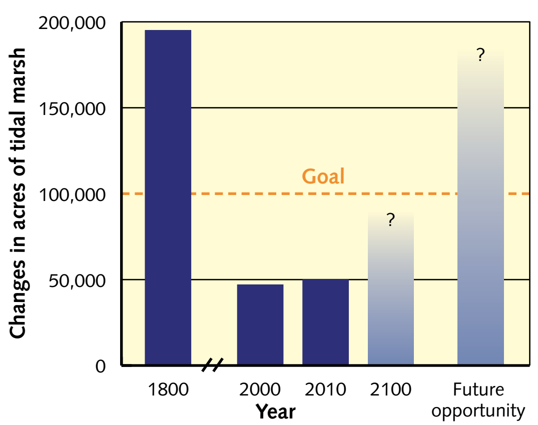
REGIONAL EXTENT

Our evaluation indicates that the region is half-way to the established goal of 100,000 acres of tidal marsh (Figure 6).

For tidal flats, the existing acreage is 10 percent less than the 30,000-acre benchmark adopted for this report (Figure 7).

Over the last decade, tidal marsh habitat in the Bay has gradually increased. Based on the marsh restoration projects now funded or likely to be funded in the foreseeable future, the total acreage of marshland will increase but is not likely to meet the acreage goal for 2100.

Figure 6. Change in acres of tidal marsh from 1800 to present, plus forecasts of future acreage due to anticipated restoration (year 2100) and combinations of restoration and sea level rise (Future Opportunity). The South Bay Salt Pond Restoration Project represents about 20 percent of the expected gains in tidal marsh acres by 2100. Sea level rise creates uncertainties about the survivability of existing and restored marshes.



WHAT IS CRAM?*

CRAM is a rapid health check-up tool for wetlands and wadeable streams (www.cramwetland.org). Two or more trained practitioners can use CRAM in the field over a period of 1-3 hours to score a wetland or stream based on a standard set of visual health indicators.

Habitats with good scores are likely to provide high levels of ecological and hydrological functions, based on the habitat type, location within its watershed, and its surrounding landscape. CRAM is part of a comprehensive monitoring plan in three levels:

- Level 1 (landscape assessment) uses aerial photography and other remote sensing data to inventory wetlands and streams.
- Level 2 (rapid assessment) uses visible field indicators of condition in the field to assess the overall health of wetlands and streams. CRAM is an example of a Level 2 assessment method.
- Level 3 (intensive assessment) uses quantitative methods in the field to measure particular aspects of wetland or stream health, and to understand the causes of health conditions. Counts of fish, birds, and plants are examples of Level 3 data.

There are different versions of CRAM for different kinds of wetlands and streams. All the versions are based on the same basic method. CRAM produces a site score that ranges up to 100 (100% of good health based on statewide surveys). The site score is the average of 4 attribute scores; each attribute score is the sum of 3-4 metric scores. The metric scores and attribute scores can be used to identify ways to improve the site scores. All the scores are maintained in a statewide database (www.cramwetland.org).

ATTRIBUTES		METRICS
Buffer and Landscape Context		Landscape Connectivity Percent of Assessment Area with Buffer Average Buffer Width Buffer Condition
Hydrology		Water Source Channel Stability Hydrologic Connectivity
Structure	Physical	Structural Patch Richness Topographic Complexity
Structure	Biological	Number of Plant Layers Present Number of Co-dominant Species Percent Invasion Horizontal Interspersion and Zonation Vertical Biotic Structure

How is CRAM Being Used?

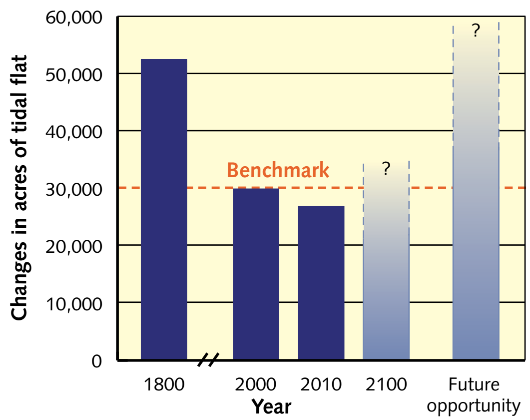
CRAM is being used to help assess wetland and stream projects, and to assess the average condition of streams and wetlands for watersheds, regions, and statewide. Over time, CRAM will help land managers and scientists understand how projects can be planned to maximize their benefits to people and ecosystems.

Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2008. California Rapid Assessment Method (CRAM) for Wetlands and Riparian Areas (website). www.cramwetlands.org

For tidal flats, the existing acreage is a little less than the 30,000-acre benchmark developed for this report (Figure 7). Since 1993, some tidal flats have been diked, dredged, or eroded by Bay currents and waves, or colonized by marsh vegetation. Some new flats have formed in the early stages of marsh restoration projects. Both seasonal and annual variations in the amount of tidal flat have been observed in some locations, but there has been a slight net decrease in the overall acreage of tidal flat since 1993.

Scientists are uncertain about the future extent of tidal flats and marshes in the Bay. We expect that sea level rise associated with climate change will cause the Bay to rise faster than it has since the oldest flats and marshes were formed. This deeper Bay might generate stronger currents and waves that prevent fine sediment from being deposited at the Bay's edges—a prerequisite for plant colonization. We also expect that there is less sediment coming into the Bay for the tides to deposit onto the marshes—less of the fine silts and clays that marshes need to build upwards as the Bay rises. Plants help build marshes by adding debris and roots. Whether or not sedimentation and plant growth will keep up with the rising Bay is not known. Studies are being conducted to help forecast the effects of climate change, including that of the rising Bay on tidal marshes. However, even with a rapidly rising Bay, some new marshes can result from allowing the tides to return to suitable diked baylands and uplands. Such efforts, in addition to the marsh restoration projects that are already being planned, could help us meet the goal of 100,000 acres of tidal marsh.

Figure 7. Change in acres of tidal flat from 1800 to present, plus forecasts of future acreage due to anticipated restoration (year 2100) and combinations of restoration and sea level rise (Future Opportunity). Sea level rise creates uncertainties about the survivability of existing and restored flats.

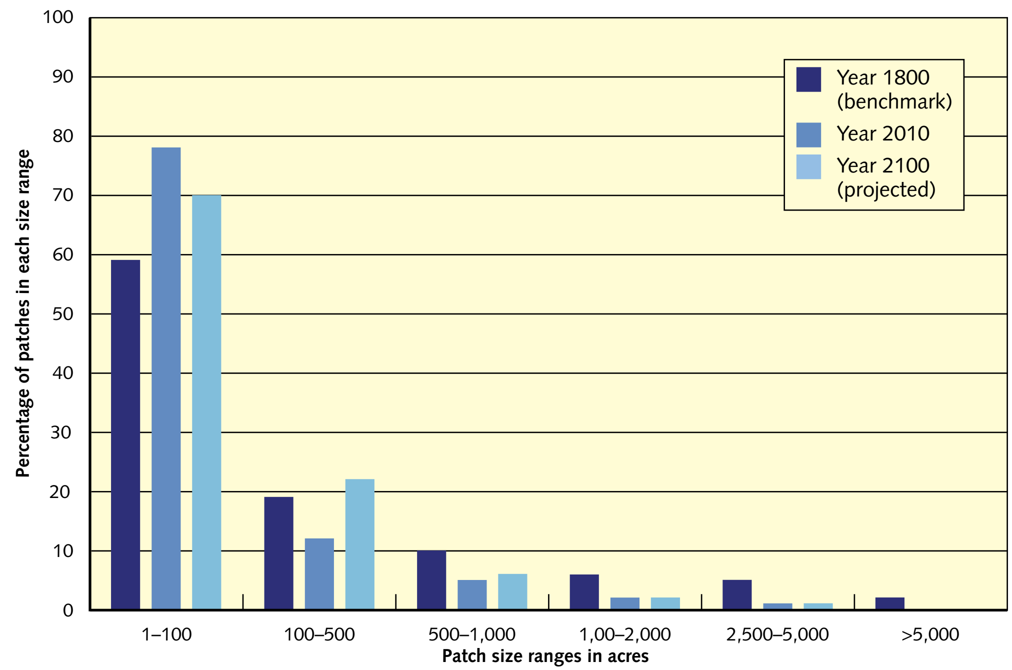


PARCEL SIZE

Our benchmark for tidal marsh size (± 25 percent) is only being met for two of the six size categories. We are meeting our benchmark for the two smallest sizes, and farthest from our benchmark for the largest size category (Figure 8). While critically important restoration efforts are now underway at several large sites around the bay, they will not restore continuous marshes in the two larger categories (see Technical Appendix for more information).

In general, the proportion of small marshes has increased, and the proportion of large marshes has decreased. None of the existing marshes are nearly as large as the largest historical marshes.

Figure 8. Historical (ca 1800), present-day (ca 2010), and plausible future (ca 2100) distribution of tidal marsh patches among size classes ranging from less than 100 acres to more than 5,000 acres.



BLACK RAIL NEEDS SHALLOW WATER, STEPPING STONE WETLANDS TO CONNECT TO MARSHES

The secretive, seldom-seen, marsh-dwelling black rail—often described as a "chunky robin"—may find itself in trouble as sea level rises and also because the Bay's marshes have become so fragmented. The threatened rail, with its stubby legs, needs very shallow water—less than 1.2 inches—and wetlands that are connected to one another, possibly by smaller, "stepping stone" wetlands, says UC Berkeley's Steve Beissinger, who has been studying rail populations around the Bay and in the Sierra foothills in the hope that science can help inform conservation strategies for this threatened species as the climate changes and Bay waters rise.

In a poster at the 2010 Bay–Delta science conference, Beissinger described his recent research finding a genetic link between black rails in wetlands in the Sierra foothills and San Francisco Bay—a surprise since rails are thought to be poor fliers, making it difficult for them to disperse long distances. "The study is preliminary, and we're just opening the book here, but the genetic connectivity we found going on between the foothills and the Bay was surprising—we didn't expect that. It looks to be recent, within the lifetime of the birds we captured," says Beissinger. In other words, at least one individual must have interbred with one from the population around the Bay, probably a foothills rail visiting the Bay. "They must be finding some sites where they can stop over—maybe the Yolo Bypass? That's the paradox of rails—they don't appear to be very good flyers; they're walking around under the vegetation all the time. They fly like butterflies; they wobble around and try to go right down into the vegetation." Yet rails have somehow reached islands in the middle of oceans, so "they got there somehow," says Beissinger.

STEVE BEISSINGER

The foothills population was discovered 15 years ago by Beissinger's colleague, Jerry Tecklin, when he found rails at the Berkeley research station and then started poking around on state-owned land and private ranches (with owner permission). Tecklin found rails in natural, spring-fed wetlands throughout the foothills in the oak woodland belt through which Bay-feeding streams flow. But he also found them in small wetlands that had been created accidentally. "There's a fair amount of water held back for irrigation purposes," says Beissinger. "And the rails have benefited from that." The wetlands are typically found a little above the valley floor up to about 2,000 feet above sea level, says Beissinger, in Placer, Yolo, Butte, and Nevada counties.

Beissinger and colleagues' genetics analyses revealed another surprise. "It suggests that the interchange of individuals within the Bay is less frequent than in the foothills—that the sites around the Bay, even though they are larger wetlands, are more isolated from each other. What we've learned from our foothill rails studies is that the more isolated the wetlands, the less likely they are to be colonized." Beissinger says the genetics also show that the foothill population may have existed historically.

For now, he hopes to get more genetic material from Bay rails and to expand his study to the South Bay. He and his doctoral student Laurie Hall are also planning to analyze the DNA of museum specimens in to better understand rail gene flow around the Bay prior to the large-scale landscape changes that occurred with development. "That will give us clues as to the original population size as well as whether genetic diversity has been lost with all of the changes to the Bay's wetlands over the past century."

Possibly most urgently, the studies will help resource managers plan for sea level rise. "As sea level rises, distances between wetland sites in the Bay will likely increase and they will become more isolated and reduced in sized. We want to get a better handle on the dispersal ability of these rails so we can look at the role of different configurations of sites. As certain places are restored in the Bay, it will be very useful to think about creating shallow water areas that don't get inundated." This could mean possibly creating "stepping stone" wetlands both within the Bay and east of the Delta, for example. The Department of Fish and Game has already created artificial marshes for the rails in some state game management lands in the Sierra foothills that have been very successful, says Beissinger. Whatever happens, rails will feel the squeeze at both ends—around the Bay with its rising waters, and in the foothills, one of the fasting growing regions in the state. "It's possible that they will survive sea level rise in the Bay by distributing themselves further inland," says Beissinger. "It may be that they can get around better than we had been thinking. But there is also a need to better plan for the location and connectivity of the sites we are restoring."

A slightly different version of this article first appeared in ESTUARY NEWS, December 2010.

The average size of marshes within each size category has become smaller over time. This decrease, along with the absence of marshes in the largest size class, indicates continuing marsh fragmentation.

Unlike tidal marshes, tidal flats meet the benchmark (±25 percent) for each size category, as they haven't changed significantly from their historic distribution. We expect that the proportion of flats in the smaller size classes will fluctuate as areas restored to tidal action evolve from tidal flats to tidal marshes.

PHYSICAL/BIOLOGICAL CONDITION

Based on the regional survey of tidal marsh condition using CRAM, the median overall score for marshes in the Bay is 78 on a scale of 100. This is lower than the overall score for North Coast marshes, mainly because Bay marshes tend to have lower scores for physical structure (Table 5). Using the CRAM *physical structure* median score for North Coast marshes as a benchmark for evaluating Bay marshes, the condition of Bay marshes is about 65 percent of the benchmark.[19]

Table 5. Median (50th percentile) scores for tidal marsh condition in different regions of the coast, based on the California Rapid Assessment Method (CRAM).

COASTAL REGION	MEDIAN CRAM SCORE physical structure
SOUTH COAST	59
CENTRAL COAST	57
SF BAY	56
NORTH COAST	86

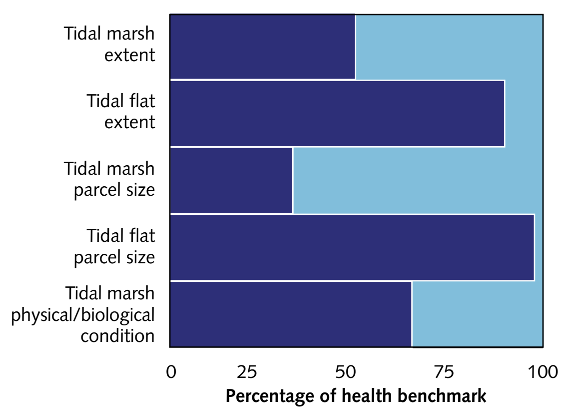
The lack of physical complexity in Bay marshes probably relates to their relatively young age. Few of the ancient marshes that are physically and ecologically complex have survived the land use changes since the Gold Rush. Completed restoration projects around the Bay are generally not old enough to have developed the natural complexity that characterizes ancient marshes.

SUMMARY

If we regard the tidal marsh and tidal flat indicators to be equally important and plot them together for the region as a whole, the overall health status of baylands is about 65 percent of excellent health (the dark blue area of Figure 9). If we exclude tidal flats from this analysis we find that that the overall health status of tidal marshes is about 49 percent. Based on these few indicators, tidal marshes are not as healthy as tidal flats.

To reach the health goals for tidal baylands we will need to restore physically complex parcels of tidal marsh that are larger than the projects currently planned. This means that tidal marsh restoration projects should be adjacent to or located very near one other, and they should be designed to develop the natural drainage networks, levees, pannes, and other features that contribute to physical complexity. Ancient, high-elevation marshes such as those at China Camp and the Petaluma River provide models for future restoration projects.

Figure 9. Assessment of the health status of tidal baylands. Based on all five indicators, the overall health of the tidal baylands has a score of 65 on a scale of 100 (65 percent of the graph is dark blue).



The increasing rate of sea level rise due to climate change will be a challenge and an opportunity for tidal baylands. The main challenge will be to maintain sufficient flats and marshes so they can serve their critically important roles for water quality, navigation, habitat, recreation, and aesthetics. Meeting this challenge may involve accepting the conversion of high marshland to low marshland, which means lowering our expectations for the physical complexity of Bay marshes. We may also need to nurture the continued evolution of marshes and flats by increasing the availability of sediment from local watersheds that is essential for sustaining tidal baylands—e.g., by re-using sediment from flood control projects or by restoring appropriate creek hydrologic functions—and by adding structures to tidal flats that reduce the ability of Bay waves to erode marsh shorelines.

Remaining undeveloped lands around the Bay could in time become healthy tidal baylands through careful planning and designs that accommodate sea level rise. Both the challenges and opportunities involved in such a process highlight the need to consider tidal baylands—marshes and mudflats—as integral parts of local watersheds.

Watersheds

A watershed is defined as all the lands and waters that drain to a common place.[20] Everyone lives in a watershed, and healthy watersheds are essential for the well-being of people. They are the primary source of fresh water, which can be captured by dams or extracted from groundwater. Watersheds are also managed to assure adequate flood control, pollution control, wildlife protection, and recreation. Yet some of these management actions can degrade watersheds and streams. For example, riprapping of stream and river banks for flood or erosion control purposes can destroy habitat and cause erosion upstream and downstream. If not managed properly, recreational activities—off-road vehicles, dog walking, mountain biking, to name a few—can also degrade stream habitat. But the biggest problem related to watershed health is urbanization. As our cities have grown and we have paved over the landscape, many watersheds have lost their permeability and resilience. During the rain, pollutants now race across a landscape of concrete and asphalt and straight into our rivers and streams. As a result of all of these activities, over 40 streams in the Bay watershed are now listed as "impaired" under the Clean Water Act.

HEALTH INDICATORS

While many possible watershed health indicators exist, the data required to analyze them are not available for most of the Bay's watershed areas. The State Water Resources Control Board is proposing that the three-level assessment framework described earlier (see Mudflats and marshes) should be used to characterize the

STORMWATER SOLUTIONS: PERMEABLE PLAZA

In downtown San Francisco, a former derelict alley has been transformed into a popular pedestrian plaza that removes as much as a half million gallons of stormwater runoff per year from the city's sometimes overwhelmed combined sewer/stormwater system. The project designers divided the plaza—just off of Fifth Street between Market and Mission—into three "mini" watersheds, explains CMG Landscape Architecture's Scott Cataffa. Two of the "watersheds" flow into and through stormwater planters at either end of the plaza; one flows into an almost invisible slot drain. From there the stormwater goes into an underground infiltration basin, where it slowly percolates into the native soil, which is sand and rubble from the 1906 quake, according to Sherwood Design's Bry Sarte. The new plaza, funded by a special tax assessment district facilitated by the Association of Bay Area Governments in which local businesses agree to increase their property taxes over the next 30 years, has spurred redevelopment all around it. Historic warehouses have been converted to condos, high-end coffee shops, and restaurants, while the plaza, in addition to treating stormwater, hosts concerts, farmers' markets, and dance performances.


LISA OWENS VIANI

"It's a win-win-win," says the city's Michael Yarne, who spearheaded the project while working for Martin Development Company. "The city got a beautiful public space for pretty much nothing, and the designers used an urban landscape to recreate some of the functionality of the original natural landscape." According to Yarne, the San Francisco PUC chipped in $150,000 from its depaving fund; that contribution plus $200,000 from a local hotel seeking an open space mitigation site downtown, helped offset the $3.2 million total cost. The project won the EPA's 2010 National Award for Smart Growth Achievement, Civic Places category. In an interesting twist of fate, the Old Mint, a Greek Revival building built in 1874, survived the big quake because rainwater had been captured in underground cisterns. Today the plaza "harvests" rainwater in a different way, says Sarte, by putting it back into the ground, helping avoid sewage overflows into San Francisco Bay.

A slightly different version of this article first appeared in ESTUARY NEWS, June 2011.

ANDY GUNTHER

health of watersheds. The assessments would be based on the extent of aquatic habitats, their overall condition (CRAM or another Level 2 method), and the condition of particular aspects of health, such as contamination, flood control, and biological community integrity. This is the approach used here. Currently there are regional data on habitat extent, but the data for overall condition and biological integrity are restricted to a few watersheds. We evaluated the health of two large Bay Area watersheds, Coyote Creek in Santa Clara County and the Napa River in Napa County, as an example of Bay Area watershed health. Three indicators of watershed health were assessed:

- width of riparian areas
- stream habitat condition
- stream biological integrity

WIDTH OF RIPARIAN AREAS

Riparian areas connect aquatic areas with their adjacent uplands. Healthy riparian areas transport surface and subsurface flows of water and other materials, maintain stream water quality, shade aquatic habitat, stabilize shorelines, store flood waters, and provide other ecological and physical functions depending on topography and vegetative structure. These beneficial functions are affected by the width of riparian areas.

BENCHMARK

The current riparian width assessment adopts a benchmark similar to that used for tidal marsh patch size by using historical condition as a reference.[21] According to this benchmark, riparian areas should be distributed among categories of width according to their historical distributions. This benchmark assumes that this historical distribution protects beneficial uses of watersheds. Each width category has its own benchmark (based on the historical distribution of widths), and riparian width is assessed as the percentage of these benchmarks that are being met. Given the range of widths in each width class, a 25 percent departure from the benchmarks was still considered to meet the benchmark.

STREAM HABITAT CONDITION

Streams are an important feature of our Bay Area watersheds, and the ability of stream habitat to support the invertebrates, fish, and wildlife that live in and use stream channels and riparian areas is considered by regulatory agencies to be a "beneficial use."

CRAM provides a cost-effective measure of stream health consistent with the state's proposed framework. CRAM was used in 2008 and 2010 to assess the health of wadeable streams in the Bay Area, and the survey results are used here to evaluate the health of Coyote Creek and the Napa River.

BENCHMARK

No goal for stream health has been set, and there are no historical data suitable for inferring a goal based on existing policies. Examination of the regional CRAM data revealed that many of the low scores were due to a lack of physical structure. This finding is similar to that for tidal marshes. The low physical structure scores are mainly due to a lack of natural floodplains. Based on this finding, a benchmark for stream health was set as 75 percent of the physical structure score for the highest scoring streams in the region.

STREAM BIOLOGICAL INTEGRITY

Benthic macroinvertebrates are aquatic insects and other non-vertebrate organisms that live in streams. The biological integrity of a stream can be assessed using the Benthic Marcoinvertebrate Index (BMI) as excellent, good, fair, or poor, based on the degree of difference between its benthic community and that of reference streams.

BENCHMARK

No regional goal for stream biological integrity has been set. However, a reasonable assumption is that the goal should reflect an increase in the relative abundance of streams in excellent or good health, based on the BMI. In this report we established a benchmark for biological integrity by assuming that at least 75 percent of the stream assessments for all watersheds should be ranked as having either excellent or good health.

KEY RESULTS AND TRENDS

Our evaluation of stream riparian width in the two example watersheds indicates that their riparian areas have narrowed substantially relative to historical conditions, despite a net increase in their overall length (Figures 10 and 11).

The narrowing is due to two main causes: riparian areas have been encroached upon by agriculture and other land uses, and in places, converted into ditches with only narrow fringes of riparian vegetation. The narrowed riparian widths mean that these streams cannot provide their intrinsic ecological and hydrological functions and cannot be considered healthy. Two of the five categories of riparian width represent the same proportion of the stream ecosystem as

Figure 10. Distribution of riparian area widths for Coyote Creek, Santa Clara County.

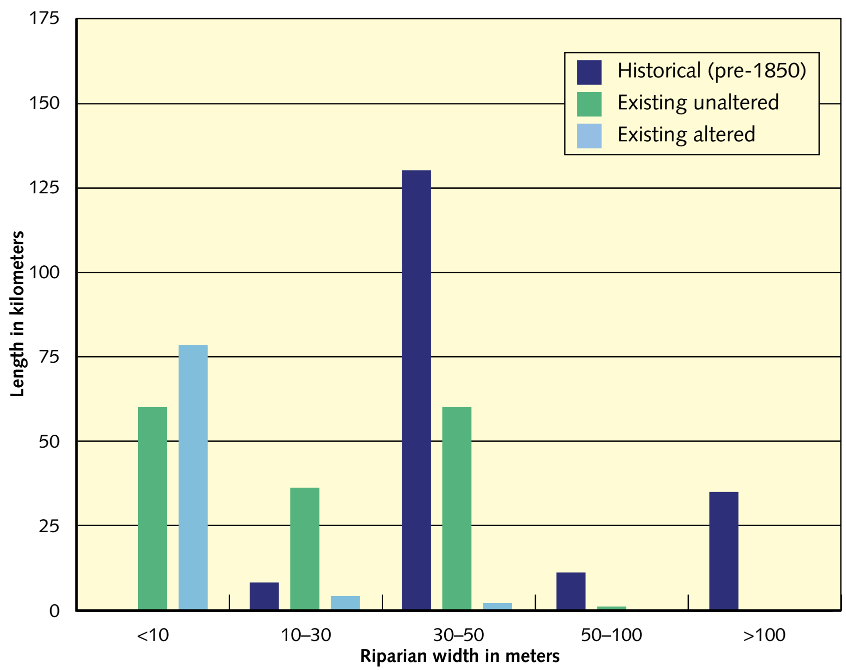
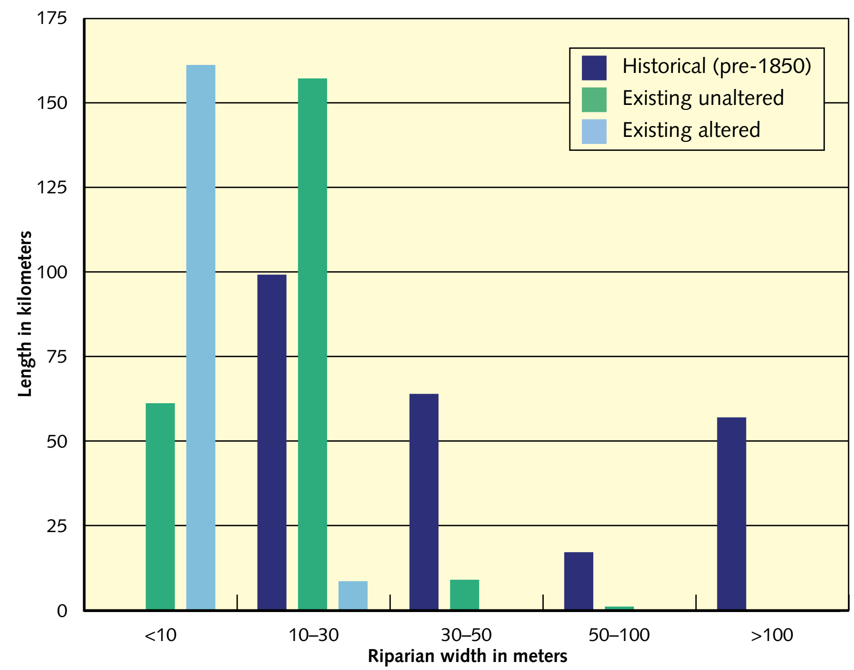


Figure 11. Distribution of riparian area widths for Napa River, Napa County.



MIKE VUKMAN

Soil bioengineering—using plants and plant parts to stabilize creek banks—is an effective alternative to riprap and provides good riparian habitat.

they did historically. So we have reached 40 percent of the benchmark. However, these are the narrowest categories. These very narrow riparian areas provide fewer ecological and physical functions than the broader areas.

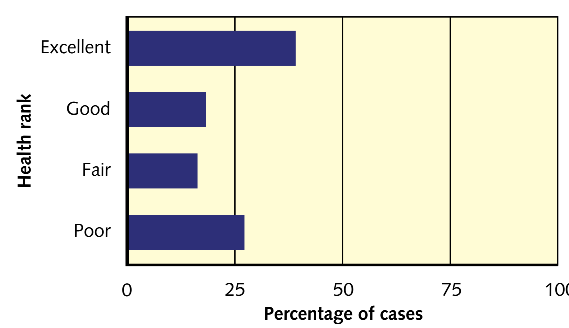
The average physical attribute CRAM score for the Coyote Creek and Napa River watersheds is 57, which is about 76 percent of the benchmark for this score (Table 6). A close examination of the CRAM survey results for these two stream networks indicates that low physical structure scores relate to stream entrenchment. Historical land use changes that have increased runoff have caused the streams to cut down until their beds are far lower than their natural heights, relative to their valleys. This means that the channels lack floodplains and complex riparian plant communities. It also means that the streams contain higher, flashier flows that wash away woody debris and other structures that contribute to the physical complexity of the stream ecosystem. The streams are physically much less complex than they were under more natural conditions, which reduces their ability to provide many of their natural functions.

Table 6. Average scores for the four attributes of the California Rapid Assessment Method (CRAM) for the wadeable streams of the Coyote Creek and Napa River watersheds combined.

CRAM ATTRIBUTE	MEAN SCORE
LANDSCAPE AND BUFFER	81
HYDROLOGY	79
PHYSICAL STRUCTURE	57
BIOLOGICAL STRUCTURE	72

Only about 57 percent of the stream assessments in the Bay Area indicate either excellent or good condition (Figure 12), which is about 76 percent of the benchmark. The condition of Bay Area streams is a result of many interacting processes and events affecting water chemistry, temperature, light, aquatic vegetation, flow regimes, and sediment characteristics. Despite these compli-

Figure 12. Relative abundance of stream assessments indicating excellent, good, fair, or poor health based on the benthic macroinvertebrate index. Assessments ranked as either excellent or good represent 57 percent of the total number of assessments.



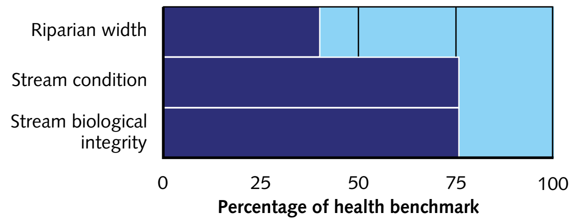
cations, a review of the regional distribution of assessments reveals a strong tendency for streams in the most urbanized settings to be in the poorest condition.

SUMMARY

We combined the watershed health indicators into a simple bar graph as a sample watershed health evalution. Based on this approach, the status of these watersheds is about 64 percent of good health (Figure 13, dark blue area).

Achieving the health goals for our watersheds will require providing the steams with enough room to develop functional floodplains with wide and naturally complex riparian areas. This is especially challenging in urban and densely industrialized settings. Where adequate space is available, we recommend that stream restoration efforts focus on increasing the overall complexity of the stream ecosystem. This can involve creating channels with multiple floodplains at different heights that provide different functions. The highest floodplains that are designed to accommodate the larger and less frequent floods may be suitable for some land uses, especially agriculture and recreation. Riparian width can be increased in some areas by adding suitable vegetation along the banks and floodplains of streams that run through urban and industrial landscapes.

Figure 13. Assessment of the health status of Bay Area streams based on example watersheds. Based on all three indicators, the overall health of the streams is 64 on a scale of 100 (64% of the graph is dark blue).



The future health of our watersheds will depend on how we manage them as the climate changes. At this time, precise local effects of climate change on watersheds and streams are very difficult to forecast. Generally, we can expect to see more intense rainstorms and a shorter wet season. This will likely cause our watersheds to discharge larger amounts of water faster, which will increase the need for flood control (which itself can impact stream health as discussed above) and erosion control. The general solution will probably be to redesign our watersheds so that they retain more rainfall. This will require creative uses of groundwater recharge, flood water bypasses, local detention basins, floodplain and wetland restoration, and universal water conservation practices.