Chapter 3.1
Water Quality and Quantity Protection and Enhancement

Forests and forestry practices can help protect, restore, and sustain water quality, water flows, and watershed health. Healthy urban and rural forested watersheds absorb rainfall and snow melt, slow storm runoff, recharge aquifers, sustain stream flows, and filter pollutants. Assessments should identify watersheds where continued forest conservation and management is important to the future supply of clean municipal drinking water, or where restoration or protection activities will improve or restore a critical water source. Resource strategies should include actions for managing and conserving these priority watersheds for water quality and supply, and other ecosystem services (excerpted from the U.S. Forest Service State and Private Forestry Farm Bill Requirement and Redesign Strategies).

KEY FINDINGS

- The major watersheds across California differ distinctly in climate, geology, ecosystems and land use. Flexible water management tools and policies are needed to account for this tremendous variation.
- Protecting and managing forests in source watersheds is essential to future strategies for providing sustainable supplies of clean water for a broad range of beneficial uses.
- The public is generally unaware of the role forests play in protecting critical water supply assets and of the existing threats to water supplies in headwater regions.

Water Supply

Spatial analysis identified a priority landscape (PL) where water supply would benefit from forest management designed to protect or enhance water resources.

- High priority landscape (HPL) is concentrated in watersheds across the Sierra bioregion. Some watersheds in the Cascade Range also have a high concentration of HPL.

- Projected decreases in snowpack due to climate change are expected to affect the timing and distribution of runoff in watersheds throughout the Sierra bioregion.
- Restoration of mountain meadows offers an opportunity to improve the storage, groundwater recharge and timing of runoff in Sierra upper elevation watersheds.
- The Klamath/North Coast bioregion also has substantial water supply assets, but little storage capacity. These watersheds are predominately rain fed; the water supply impacts from climate change will likely be less dramatic than in the Sierra bioregion. Impacts in the Klamath Mountains are expected to be between those in the Sierra and those in the Coast Ranges.
- Groundwater basins in the Central Valley are an abundant resource heavily threatened due to over pumping.
- Watersheds in South Coast mountain ranges contribute to local municipality water supplies which reduces dependence on imported water from central and northern portions of the state.

Water Quality

The analysis identified locations where high value water assets in watersheds supporting a broad range of beneficial uses coincide with high risks that threaten water quality. The threat to water quality in a watershed was assumed to increase with the number of water quality stressors that are present.

- Water quality impairments from forests and rangelands are most pronounced in watersheds in the Klamath/North Coast bioregion. These watersheds are critical for recovery of state and federally listed anadromous salmonids.
- Watersheds in the Sierra bioregion include a mix of high and medium priority landscape based on an assessment of threats to water quality. The Lake Tahoe basin has the highest priority for watersheds in this region.
- The Central Coast and South Coast bioregio watersheds are mostly ranked as medium priorities. Forest health (see Chapter 2.2) and fire management practices greatly influence water quality conditions in these watersheds.

CURRENT STATUS AND TRENDS

Forested watersheds across California provide clean water that supports a broad range of beneficial uses. Nearly 85 percent of California's average annual runoff is produced from forested watersheds. Forests filter and meter the movement of rainfall, and at higher elevations the forest snowpack acts as a natural reservoir. The rainfall in turn, replenishes aquifers and delivers water to streams. Forest and rangeland vegetation and soils are valuable for absorbing snowmelt and rain, storing moisture, cooling and cleansing water, and slowing storm runoff. Physical and biological processes combine to create the ecological condition of a watershed and define the environmental services that the watershed can support. The natural variability of these processes in space and time gives rise to a diverse array of environmental conditions across a watershed. Over time, environmental conditions vary with disturbance from both natural sources and land management activities. Across California, water resources are under continued stress from multiple sources (Mount, 1995).

California Climate

Precipitation is highly variable by year although the trend line over 120 years of data is flat, showing no distinct trend (Figure 3.1.1). Significant temporal variations in rainfall for California extend from synoptic to intraseasonal, interannual, decadal and longer time scales. Mount (1995) provides a detailed discussion of the factors for this high variability in precipitation for any given year, including sea surface temperatures, El Niño and La Niña events, etc. Given the large variability, the chance of having average precipitation in a given year is extremely low. Water management in California is largely influenced by the highly variable precipitation.

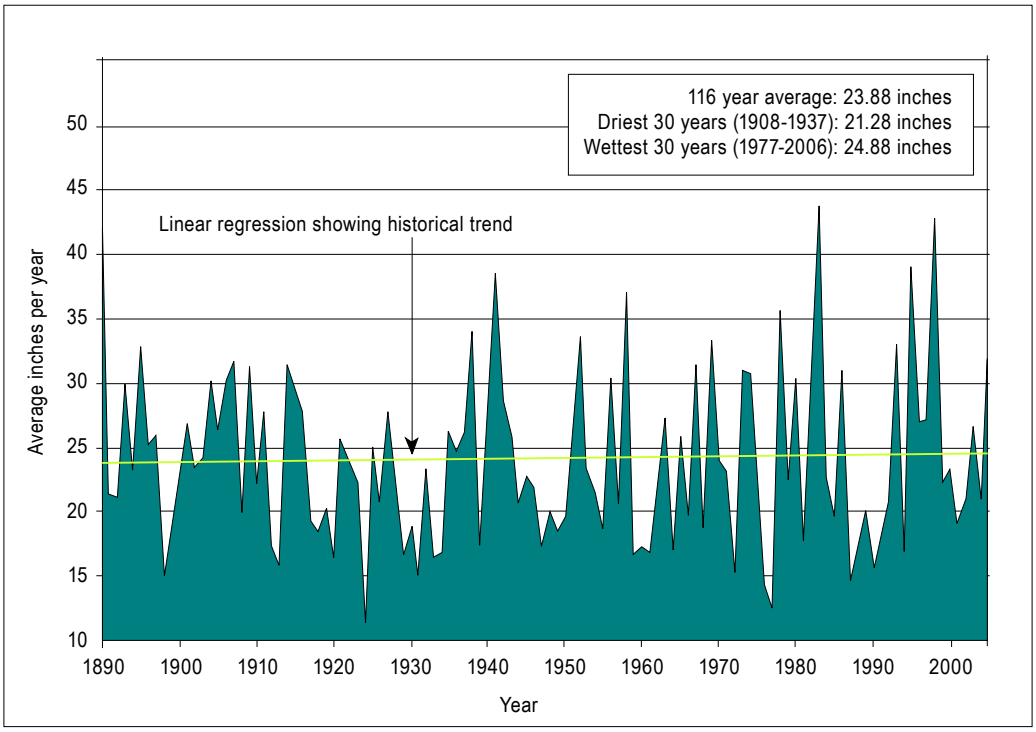


Figure 3.1.1.
Precipitation supporting California's water supply has high inter-annual variability, but the trend line has remained mostly flat over last 100 years.
Source: DWR, Division of Flood Management, 2009

Drought Conditions

As of 2009, California has experienced a third year of drought conditions. Statewide runoff has been approximately 60 percent of the historical average over the past three winters (2006–2007, 2007–2008, 2008–2009) (Department of Water Resources, 2009). In addition, groundwater withdrawals have been occurring at a deficit rate of one to two million acre feet per year. Impacts of drought include decreased availability of water for agriculture and environmental uses. In forested and other vegetated areas, prolonged drought decreases the moisture content of forest fuels and increases the risk of high severity wildfires. Prolonged drought also increases forest susceptibility to pests and can increase tree mortality. For additional information see http://www.water.ca.gov/drought/.

Climate Change

Climate change will likely adversely impact the ability of watersheds and ecosystems to deliver important ecosystem services. There is a broad range of climate change impacts that affect water resources in California (Table 3.1.1). These changes may limit the natural capacity of healthy forests to capture water and regulate stream flows. Peterson et al., (2008) report that Sierra Nevada mountain winters and springs are warming, and on average, precipitation as snowfall relative to rain is decreasing. A warming climate with reduced snowpack will result in earlier snowmelt and will subsequently reduce downstream water availability during summer and early fall.

Water Demand

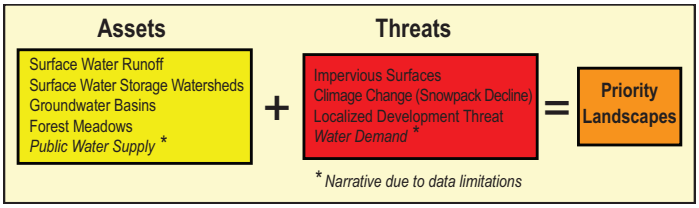
With California's increasing population, currently estimated at 38 million, the demand for water is growing while the supply remains static (Isenberg, 2009; Figure 3.1.2). This has placed a priority on water conservation. Following several consecutive dry years, California has begun to implement water conservation. Through the California Senate Bill No. 7 (2009) urban and agricultural lands have a targeted reduction in water use of 20 percent by 2020.

Table 3.1.1. Summary of climate change impacts on water resources

Resource	Type of Impact	Description
Sea Level	Direct	Sea level is rising and will likely impact coastal areas.
Soil Moisture	Direct	Prolonged dry seasons can lead to decreases in soil moisture; drier vegetation
Vegetation	Indirect	Longer and more intense fire season with increased extent or area burned.
Stream Conditions	Direct	Increases in water temperature; potential effects on fish
Snowpack	Indirect	Increases in temperature will lead to decreases in snowpack
Runoff	Direct	Warmer temperatures are likely to lead to a shift in peak runoff from spring to winter and a likely decrease in summer baseflow.
Hydropower	Indirect	Decreased summer flows resulting from earlier snowmelt and a shift in peak runoff could affect hydropower generation during summer months.
Precipitation	Direct	Warmer winter temperatures will result in a greater percentage of precipitation falling as rain rather than as snow.
Groundwater	Indirect	Reduction in snowpack and extended periods of drought are likely to increase dependency on groundwater.

Ecosystem – Conflicts and Constraints

The watersheds listed in Table 3.1.2 are important to California's water resources and represent current priorities for water management.



WATER SUPPLY

Analysis: Water Supply

A spatial analysis was conducted to identify a priority landscape (PL) where water supply would benefit from forest management designed to protect or enhance water resources. The analysis was based on a geographic information systems (GIS) model that combines threats and assets to produce a priority landscape (see diagram below). This model was used to evaluate threats to water supply assets. The evaluation of threats and assets contains data summaries at multiple watershed scales that are referred to as hydrologic unit codes (HUC). For additional information on watershed units and GIS procedures for ranking threats and assets see the Fire and Resource Assessment Program website (http://frap.fire.ca.gov/) and U.S. Geological Survey website (http://water.usgs.gov/GIS/huc.html).

Assets

Surface Water Storage Watersheds

Surface water storage watersheds are areas that contribute directly to one of the 150 major reservoirs monitored by the California Department of Water Resources (DWR) (http://cdec.water.ca.gov/cgi-progs/reservoirs/STORAGE). Catchment areas were delineated for all of these reservoirs using the Watershed Boundaries Database HUC12 watersheds. Each catchment area was then assigned the average volume of the reservoir it supplied. The catchments for water supply systems, such as the Feather River and the American River, were assigned the combined volume of all reservoirs within the system. These catchments were ranked high, medium and low according to the average reservoir storage volume (Figure 3.1.3).

The majority of the surface water storage watersheds lie in the upper elevations of the Cascade and Sierra Nevada mountain ranges. Many factors in headwater areas affect downstream water supply, water use and water quality. Fire management, land management,

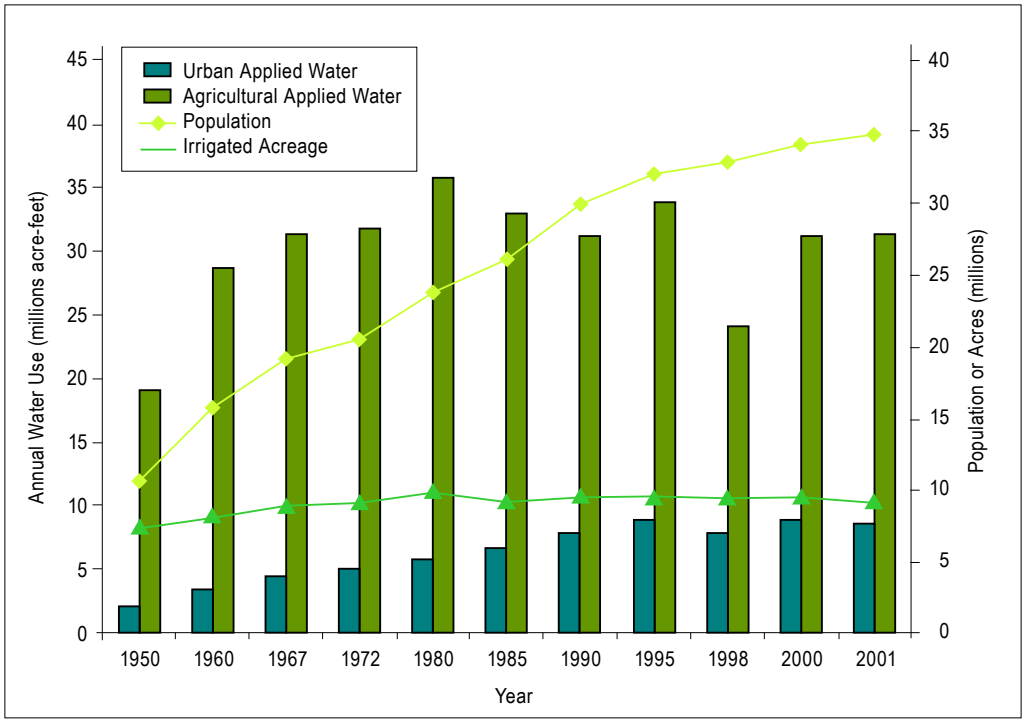


Figure 3.1.2.
Water demand: the relationship between water demand and population growth.
Data Source: Delta Vision Strategic Plan, Blue Ribbon Task Force, 2008

timber harvesting plans, watershed plans and conservancy plans all contribute to watershed health and downstream water supply. The many factors and many actors involved highlight the need for improving coordination between upstream and downstream interests.

Surface Water Runoff

Certain areas of the state rely on surface water runoff for water supply. These are areas with a significant amount of precipitation and thus a high amount of runoff. The data on mean annual runoff was obtained from the U.S. Geological Survey. Mean annual runoff was estimated for HUC 8 watersheds and represents average conditions over a 30 year time period (1970–2000).

Groundwater Basins

Groundwater basins are an important and often overlooked component of water supply in California. Much of the state, including the Central Coast, relies heavily on groundwater rather than surface water for its water supply. There are currently 431 groundwater basins delineated, underlying about 40 percent of the surface area of the state. Of those, 24 basins are subdivided into a total of 108 sub-basins, giving a total of 515 distinct groundwater systems in California (California Department of Water Resources, 2003).

The majority of groundwater used in California is stored in alluvial groundwater basins. In addition to withdrawals of groundwater for domestic, agricultural or industrial uses, groundwater basins also support the natural baseflow of streams during the dry summer months. In some locations the demand and withdrawal for groundwater exceeds the rate of recharge and leads to overdrafting. This has particularly been true for Central Valley basins over the past six years, due to both low precipitation for surface runoff and reduced allocations of river water for Central Valley farmers. The volume pumped for agriculture, cities and industry is not believed to be sustainable if current trends continue.

Table 3.1.2. Current high priority water management issues

Watershed	Bioregion	Water Resource Issue(s)	Resources
Delta	Bay/Delta	An immense estuary spanning 1300 square miles that drains the Sacramento and San Joaquin watersheds; water delivery for Southern California flows through the Delta; conflict between water supply and ecosystem health.	www.deltavision.ca.gov
Sacramento River	Sacramento Valley	Primary river that originates near Mount Shasta and flows through the Central Valley and eventually empties into the delta; historically supported significant salmon runs.	www.sacriver.org
San Joaquin River	San Joaquin Valley	Primary river originating in the high southern Sierra before flowing to the delta near Stockton; historically supported significant salmon runs; conflict over water diversions for agriculture and restoring flows to support salmon runs.	www.restoresjr.net
Klamath	Klamath / North Coast	Large watershed originating in Southern Oregon and crossing through Northern California before draining to the ocean; declining salmonid fish populations, tribal water rights, and water quality impairments have constrained water management options and left the watershed impaired. A recent settlement proposes to remove four large dams as part of a fisheries restoration plan.	
Lake Tahoe Basin	Sierra	This deep Sierra lake is renowned for its clear waters, development pressures, historic timber harvesting, and recreational opportunities. Vehicle emissions, wood smoke, road dust, and development related erosion and runoff contribute to water quality impairment. Fire management and current forest stand conditions in the basin also threaten water quality.	www.tahoescience.org; www.waterboards.ca.gov/lahontan
Colorado River	Colorado Desert	Threats to this ecosystem are numerous. Dams created for irrigation and residential use have altered the water flow blocking migratory paths for fish, and changed water temperatures. Very little of the Colorado River actually flows to the Gulf because much of it is diverted to Arizona and Southern California for residential and irrigation needs. Drought conditions and increased population have amplified the water shortage issue and water disputes have developed as water demands exceed the supply available from the Colorado River.	
Coastal Rivers	Klamath / North Coast; Central Coast	Recovery of 303(d) listed impaired waterbodies for sediment and temperature; recovery of state and federally listed salmonid species	www.swr.nfms.noaa.gov; www.swrcb.ca.gov
Coastal Rivers	Klamath / North Coast; Central Coast	Recovery of 303(d) listed impaired waterbodies for sediment and temperature; recovery of state and federally listed salmonid species	www.swr.nfms.noaa.gov; www.swrcb.ca.gov

Using groundwater basins from DWR and monitoring data from the State Water Resources Control Board (SWRCB), groundwater basins were classified based on use and vulnerability (Figure 3.1.4).

Forest Meadows

Forest meadows in California are mostly found in the higher elevations within the Sierra bioregion. Meadows comprise approximately 10 percent of the land area in the Sierra. Forest meadows play an important role in water supply and quantity, acting as a natural water storage device, holding water and regulating flows in high elevations. They are often located in the upper part of the watershed and can act as a type of sponge, in that they can hold water and slowly release it over time. As snowpack is reduced due

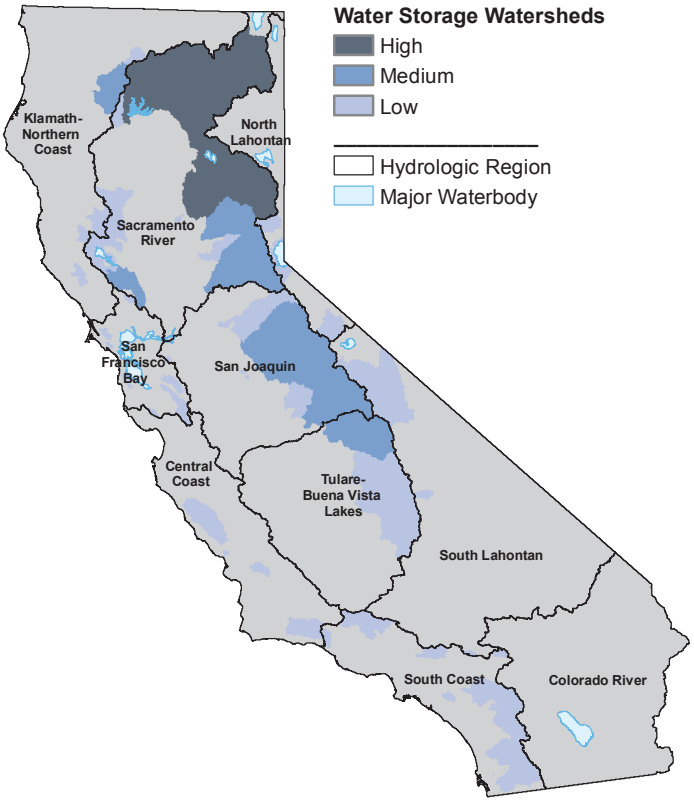


Figure 3.1.3.
Ranking of water supply watersheds. The ranking is based on reservoir storage capacity.
Data Sources: Watershed Boundaries Database for California, NRCS (2009); Monthly Storage in Major Reservoirs, DWR (2009); National Inventory of Dams (NID), U.S. Army Corps of Engineers (2009)

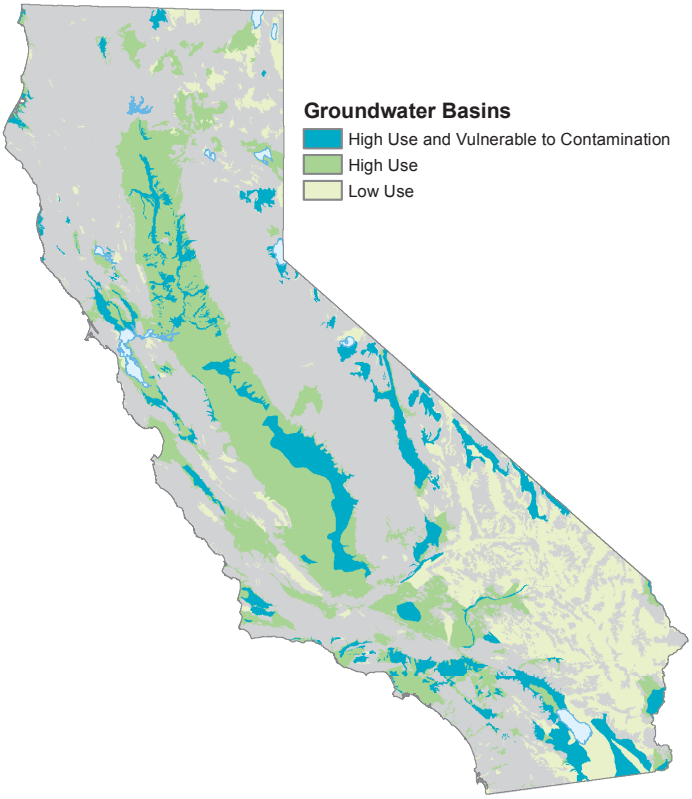


Figure 3.1.4.
Watershed ranking of groundwater basins.
Data Sources: State Water Resources Control Board (2000); DWR Bulletin 118 (2003); USGS (2003)

to climate change, forest meadows may play a more important role in California's water supply. Historically, mountain meadows have been an important resource to Native Americans and currently provide forage for grazing. Meadows provide the bulk of forage on Sierra grazing allotments.

California's montane meadows have been significantly stressed and altered by external pressures for over 100 years. Livestock grazing became widespread in the Sierra during the gold rush era in the mid-1800s and continues through present time. Grazing can have a number of adverse effects on meadows such as defoliation, trampling and soil compaction, mineral redistribution and the introduction of invasive vegetation (Ratliff, 1985). Grazing management practices can be compatible with meadow health if it is restricted to light use, conditions are monitored regularly and include a restoration component (Ratliff, 1985). Other meadow stresses can come from rodent activity, lodgepole pine invasion, erosion and water channeling. Many of these issues are related, and all are accelerated by livestock overgrazing. Meadows have also been stressed by development, road or culvert construction, dams and diversions, homesteading, recreational hiking, camping and fishing. During the peak logging era, they were even a common and convenient site for building railroad beds. Once a meadow has been altered by these pressures its relationship to fire is also changed. Hotter, more devastating fires are more likely in compromised meadows. These types of fires tend to burn mulch and peat, and create sediment deposits that alter the natural state of the meadow even further (Ratcliff, 1985).

As people begin to recognize the benefits of mountain meadows, more effort has been directed towards restoring and reclaiming affected meadows and properly managing meadows in order to enhance

their ecological benefits. The results have been positive. The U.S. Forest Service has estimated that there could be an increase of 50,000 to 500,000 acre-feet of groundwater storage per year with proper meadow restoration just within national forest lands in the Sierra bioregion alone (DWR, 2009). Currently California relies heavily on snowpack as its main water source, but as climate change alters the precipitation and snow patterns, meadows may be relied upon more heavily to act as natural water storage.

Forest meadows were evaluated using data from CALVEG and U.S. Forest Service (USFS) vegetation mapping programs. Forest meadows were identified by using all of the meadows mapped by the USFS and located in the Region 5 GIS database. The USFS montane meadow data only includes meadows within USFS lands in the Sierra. To identify montane meadows outside of the USFS dataset, all meadow-related WHR types above 4,000 feet elevation and not mapped as having a land use type of urban or developed, were extracted from the CAL FIRE vegetation database. The CAL FIRE vegetation database is largely based on USFS CALVEG maps. The two datasets were combined, and overlayed with HUC 12 watersheds. The percentage of meadows within each watershed was calculated, and then each watershed was ranked based on the percentage of meadow within the watershed (Figure 3.1.5).

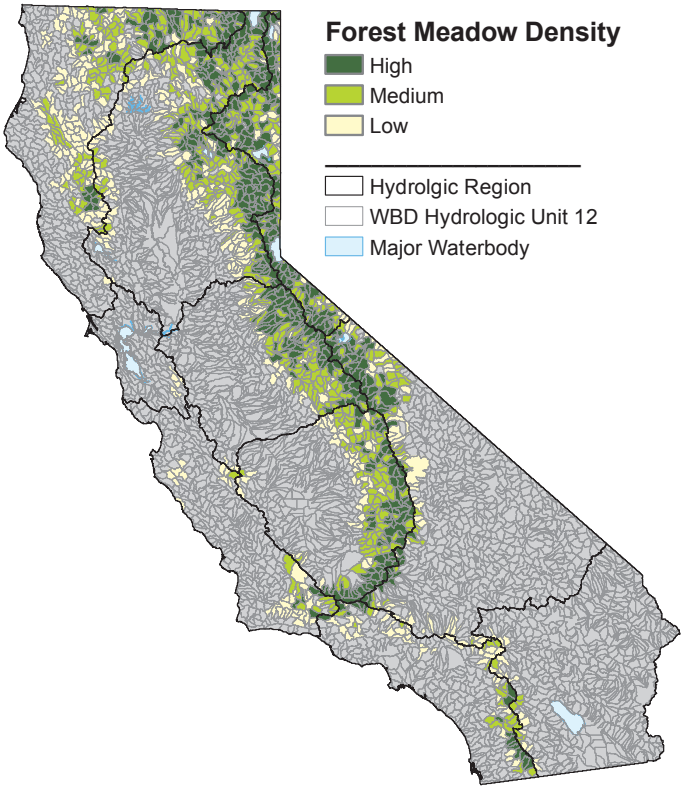


Figure 3.1.5.
Watershed ranking of the density of forest meadows.
Data Sources: Sierra Nevada Montane Meadows, USFS R5 (2000); Statewide Land Use / Land Cover Mosaic, FRAP (2006); Watershed Boundaries Database for California, NRCS (2009)

Composite Assets

Surface water runoff, surface water storage watersheds, groundwater basins and forest meadows were combined to produce the composite landscape for both surface water supply and groundwater assets. The highest ranked assets for surface water supply tend to originate in the North Coast and Sierra watersheds, while the greatest utilization of groundwater resources occurs in Central Valley and other agricultural valleys (Table 3.1.3).

Threats

Disturbance in a watershed comes from both natural events (e.g., intense precipitation, large floods, severe wildfires, earthquake and storm induced mass wasting, etc.) and from land management activities (e.g., mining, grazing, road building, timber harvest, vegetation management activities, developed recreation sites, off-highway vehicle use, etc.). Understanding the timing and frequency of disturbance events places the magnitude from any single event into a watershed perspective (Naiman et al., 1998; Benda, 1998). Stream channels typically exhibit a wide variety of morphologies that result in a broad array of stream types throughout a watershed. Channel classification is performed to take the continuum of conditions that are found in a stream system and group channel segments by function and form. Stream order is one of the commonly used channel classification systems. Stream order correlates with drainage area and can serve as a proxy for stream size. In the Strahler stream order classification system, two first order channels will combine to form a second order channel, second order streams combine to make third order streams, and so on (Strahler,

Table 3.1.3. Watersheds with the highest composite assets to water supply

Sub-basin Name (HUC 8)	Sub-basin Total Square Miles	Percent High	Percent Med	Percent Low	Percent High-Med[1]	Composite[2]
Upper Pit	2,681	100.0	0.0	0.0	100.0	100.0
Lower Pit	2,638	100.0	0.0	0.0	100.0	100.0
McCloud	681	100.0	0.0	0.0	100.0	100.0
Sacramento Headwaters	592	100.0	0.0	0.0	100.0	100.0
North Fork Feather	1,212	100.0	0.0	0.0	100.0	100.0
East Branch North Fork Feather	1,028	100.0	0.0	0.0	100.0	100.0
Middle Fork Feather	1,365	100.0	0.0	0.0	100.0	100.0
North Fork American	1,013	100.0	0.0	0.0	100.0	100.0
South Fork American	850	100.0	0.0	0.0	100.0	100.0
Upper San Joaquin	1,639	100.0	0.0	0.0	100.0	100.0
Upper King	1,544	100.0	0.0	0.0	100.0	100.0
South Fork Kern	981	99.6	0.4	0.0	100.0	99.8
Upper Kern	1,092	97.3	2.7	0.0	100.0	98.6
Battle Creek–Sacramento River	563	94.1	5.9	0.0	100.0	97.1
Butte	596	94.0	5.6	0.4	99.6	96.9
Lost	1,719	90.2	9.8	0.0	100.0	95.1
Upper Yuba	1,345	85.2	14.7	0.1	99.9	92.6
Crowley Lake	1,854	83.3	16.5	0.2	99.8	91.6
Upper Tuolumne	1,873	82.6	17.0	0.3	99.7	91.2
Upper Stanislaus	1,197	82.0	17.9	0.1	99.9	91.0
Upper Merced	1,269	81.8	17.3	0.9	99.1	90.7
Lower American	293	79.4	20.6	0.0	100.0	89.7
Upper Bear	474	77.6	22.1	0.3	99.7	88.7
Applegate	91	77.2	22.8	0.0	100.0	88.6
Putah Creek	654	81.4	7.3	11.4	88.6	87.8
East Walker	504	71.0	27.9	1.1	98.9	85.2
Upper Klamath	852	64.5	35.5	0.0	100.0	82.3
Lake Tahoe	371	64.3	35.7	0.0	100.0	82.2
Truckee	432	62.4	37.6	0.0	100.0	81.2
Upper Calaveras California	529	63.2	32.3	4.5	95.5	80.4
Middle Fork Eel	753	57.6	42.4	0.0	100.0	78.8
Upper Eel	709	53.9	46.1	0.0	100.0	76.9
San Pablo Bay	1,226	53.7	45.6	0.7	99.3	76.7

[1] Percent High-Med = Percent High + Percent Medium
[2] Composite = (Percent High) + (Percent Medium) x 0.5 + (Percent Low) x 0.25

1957). In general, low order streams experience less frequent disturbance, but at a higher magnitude. Higher order streams drain larger catchment areas and thus integrate environmental conditions. This factor results in more frequent occurrence of disturbance, but of a lesser magnitude. The degree of disturbance in a watershed can be influenced by both the continuing impacts from historic management practices and impacts from current management activities.

The analysis used three indicators to model threat to water supply: impervious surfaces, future development, and climate change (snowpack change). Of the factors affecting water supply declining snowpack was considered the most significant threat and has a greater influence in the resulting priority landscape.

Impervious Surfaces

A high degree of imperviousness can negatively impact water quality and limit groundwater recharge. Land use decisions affecting recharge areas can reduce the amount of groundwater in storage. In many basins, little is known about the location of recharge areas and their effectiveness. Protection and

preservation of recharge areas are seldom considered in land use decisions. If recharge areas are altered by paving, channel lining or other land use changes, available groundwater will be reduced (DWR, 2003). A GIS layer representing impervious surfaces was used to represent impacts from the current footprint of development. It should be noted that this analysis looks at impervious surfaces over the entire landscape, not just recharge areas. A more refined analysis would separate out recharge areas for special consideration.

Localized Development Threat
Developed areas that were previously forested or rangeland have a limited capacity to capture and promote infiltration and allow groundwater recharge. Disturbance from development modifies the natural pathways of water across the watershed. The decrease in tree cover reduces the rate at which rainfall is intercepted. As infiltration is decreased, surface runoff and the delivery of rainfall to watercourses are accelerated, in turn accelerating channel erosion and gullying.

To prioritize threatened landscapes, watersheds with threats from development were identified in Chapter 1.1 (Figure 1.1.3). The GIS data layer for this analysis uses the projected areas of development, defined in Chapter 1.1, as well as existing areas of development. The GIS analysis displays the percent of each HUC 8 watershed in development or expected development.

Climate Change (Snowpack Decline)
Higher temperatures are expected to bring dramatic changes to California's snowpack and forest hydrology in Sierra watersheds (Peterson et al., 2008). The decline in snowpack is expected to reduce current snowpack by up to 90 percent by 2100 (Anderson, 2008; Mote, 2005). Higher temperatures are likely to have several effects that include:

- Increasing the amount of precipitation falling as rain rather than snow,
- Accelerating the rate of spring snowmelt, and
- Shortening the duration of snow accumulation in mountain watersheds, leading to earlier seasonal runoff and a decrease in summer baseflow.

The objective of this threat layer was to highlight areas that presently support a snowpack, but are expected to experience a declining snowpack under future climate change scenarios (Figure 3.1.6). The analysis highlights watersheds that are likely to shift from snow-dominated hydrology to more rain-based systems. The extent of snowpack was represented using snow water equivalent data developed for the A2 emissions scenario using the Global Fluid Dynamics Laboratory global climate model (Cayan et al., 2006; Cayan et al., 2008). The climate emissions scenario (A2) represents a medium-high emissions scenario with continuous population growth, slower adaptation of technological change, and an increase in carbon dioxide (CO_2) that reaches four times the present rate by the end of the century (Cayan et al., 2006). The decline in snowpack was represented by the percentage change over the following future time intervals: 2020, 2050 and 2100. The greatest decline in snowpack is expected in the northern and central Sierra, as well as portions of the Cascades.

Composite Threats
Individual threat layers were combined to represent a composite landscape for threats to water supply. Results were summarized by watershed units (WBD, HUC 8).

Table 3.1.4 lists watershed with the highest composite threat to water supply. Many watersheds had a composite threat rank of over fifty percent. These watersheds tend to be mid to upper watersheds located in the North Coast, Cascade and Sierra regions. These areas have seen an expansion of the wildland urban interface (WUI) which has increased development in fire prone areas. They are also expected to see decreases in snowpack.

Many watersheds had over fifty percent medium ranked threat. These watersheds were predominantly in the North Coast, Cascade and Sierra regions. These areas have seen an expansion of the WUI

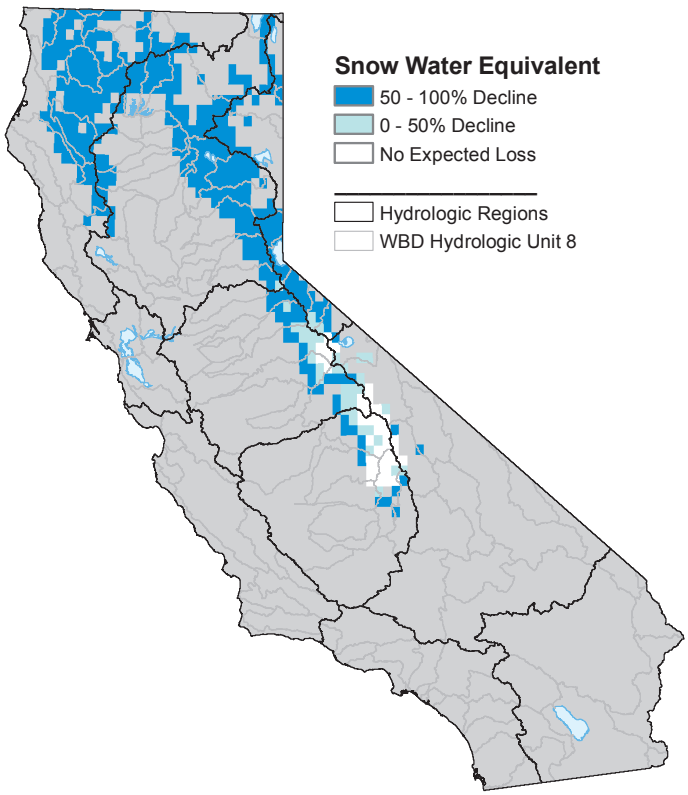


Figure 3.1.6.
Expected changes in April 1 snowpack from 2010 through 2100. The results show significant decreases occurring lower mountain elevations throughout the northern and central Sierra Nevada and Klamath Mountains. The higher elevations of the southern Sierra showed the greatest retention in snowpack.
Data Sources: Climate Change Scenarios and Sea Level Rise Estimates for California, California Energy Commission (2009); Watershed Boundaries Database for California, NRCS (2009)

which has increased development in fire prone areas. They are also expected to see decreases in snowpack.

Results

Combining the composite asset layer with the composite threat layer created a priority landscape layer for water supply. The high priority landscape (HPL) identifies locations where high value water supply coincides with high threats and thus represents areas where stewardship projects are most needed. The results are shown in Figure 3.1.7 and summarized in Table 3.1.5.

Discussion

The results of this analysis suggest that basins in the Northern Sierra and Cascades are facing increasing threats and represent a high priority for water supply. The majority of the forested basins across the Sierra were identified as high priority. Threats from wildfire and development are both substantial in these basins. In addition the threat of diminishing snowpack expected under future climate change scenarios is expected to have significant effect on the hydrology of these watersheds.

Bioregional Findings

- The Sierra bioregion has the greatest concentration of high priority landscape. The watersheds in this region contribute greatly to the state's water supply. They are under threat from climate change, wildfire and development.
- The Klamath/North Coast bioregion has substantial water supply assets. These watersheds are predominately rain-dominated systems; the water supply impacts from climate change are projected to be less dramatic, with the exception of higher elevation areas in the Klamath Mountains.
- Groundwater basins in the San Joaquin Valley and Sacramento Valley bioregions are an abundant resource that is heavily threatened by over pumping.

WATER QUALITY

This section evaluates threats and assets to water quality in California's predominately forested and rangeland watersheds. The analysis identifies locations where watersheds supporting a broad range of beneficial uses and high value water assets coincide with high risks that threaten water quality. (The Forest Management Strategy in the State Water Plan (http://www.water.ca.gov) presents a comprehensive treatment of water resources in California.)

Water quality impacts from forest management can affect a broad range of environmental processes that include: hillslope erosion, stream sedimentation, lack of instream large woody debris (an important fish habitat element in many streams), increased water temperature and hydrologic impacts (higher peak flows and reduced low flows). Some of these water

Table 3.1.4. Watersheds with highest composite threats to water supply

Sub-basin Name (HUC 8)	Sub-basin Total Sq. Miles	Percent High	Percent Medium	Percent Low	Percent High-Med[1]	Composite[2]
Truckee	432	100.0	0	0	100.0	100.0
Salmon	751	100.0	0	0	100.0	100.0
Upper Carson	453	93.3	0.1	0.1	93.5	93.4
East Branch North Fork Feather	1,028	89.8	0.0	0.3	89.8	89.9
South Fork Trinity	932	88.9	0.1	0.6	89.0	89.1
McCloud	681	86.1	0.0	0.4	86.1	86.2
Lake Tahoe	371	83.1	1.7	0.2	84.9	84.1
Trinity	2,038	80.7	0.3	1.0	81.0	81.1
North Fork Feather	1,212	80.3	0.2	2.2	80.5	81.0
Scott	814	76.3	0.1	1.0	76.4	76.6
West Walker	409	54.6	27.0	0.5	81.6	68.2
Lower Klamath	1,527	67.2	0.1	1.2	67.3	67.6
Sacramento Headwaters	592	66.2	0.1	1.5	66.2	66.6
Middle Fork Feather	1,365	55.3	0.2	3.2	55.4	56.2
Lower Pit	2,638	55.5	0.2	1.9	55.7	56.0
Upper Klamath	852	53.7	0.1	2.4	53.8	54.3
Upper Yuba	1,345	49.2	1.7	7.2	50.9	51.9
North Fork American	1,013	48.2	3.0	5.7	51.2	51.1
Middle Fork Eel	753	48.5	0.1	1.8	48.7	49.0

[1] Percent High-Med = Percent High + Percent Medium
[2] Composite = (Percent High) + (Percent Medium) x 0.5 + (Percent Low) x 0.25

quality impacts may also occur on rangelands, along with the possible addition of nutrients from animal waste. The following section provides a brief discussion of the major stressors that management actions can place on water quality.

Background

Stressors on Water Quality

Table 3.1.6 summarizes common water quality stressors in forested watersheds. See State Water Plan (Resource Management Strategies) for additional information of forest management and water quality.

Water Quality Status in California (303d and 305b report)

Operating under authorities from the California Water Code and the state Porter-Cologne Act, the State Water Resources Control Board has primary responsibilities for addressing water pollution and water quality issues in California. Reporting on the conditions of water quality is mandated under section 305b of the federal Clean Water Act. The most recent 305b report for California (2006) indicates that a majority of the California's waters are in fair or good condition based on biotic indicators of water quality (Table 3.1.7). Two biotic indicators were used. The O/E index is a ratio of the taxa observed at a site (O) to those that are expected (E) to occur in the absence of human disturbance. The Benthic Index of Biotic Integrity, which uses counts of macro-invertebrates as a proxy for water quality, was used as a second index (Ode et al., 2005).

Under section 303(d) of the Clean Water Act, the State Water Resources Control Board (SWRCB) and its nine Regional Water Quality Control Boards (RWQCBs) are required to maintain a list of impaired waterbodies. Updated every two years, the 2002 list of impaired waterbodies estimated that California has over 26,000 miles of impaired streams, about 14 percent of the total miles of streams and rivers in California. The current list (2006) shows very little change in the amount of impaired waterbodies associated with silviculture and agriculture.

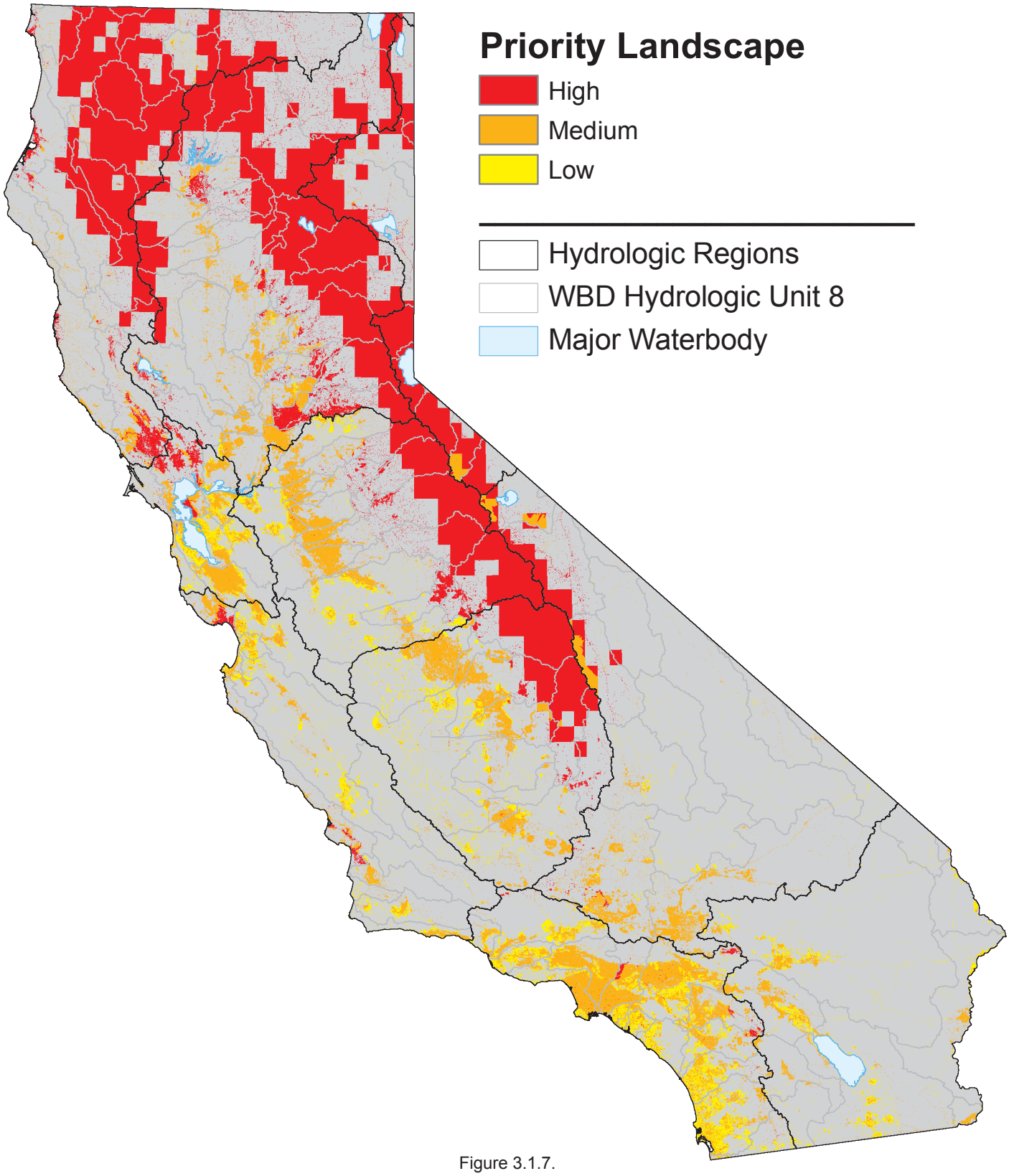


Figure 3.1.7.
Priority landscape for water supply.
Data Sources: Groundwater Basins, DWR (2009); Watershed Boundaries Database for California, NRCS (2009); National Hydrography Dataset, USGS (2009); USGS National Land Cover Dataset (2001); Sierra Nevada Montane Meadows, USFS R5 (2000); Statewide Land Use / Land Cover Mosaic, FRAP (2006); Climate Change Scenarios and Sea Level Rise Estimates for California, California Energy Commission (2009); ICLUS, U.S. Environmental Protection Agency (2009); National Inventory of Dams (NID), U.S. Army Corps of Engineers (2009); Monthly Storage in Major Reservoirs, DWR (2009); Thornthwaite Water Balance Model, USGS (2007); PRISM Climate Data, Oregon State University (2000); Commission on Local Governance for the 21st Century (2000)

Table 3.1.5. Summary of the priority landscape for water supply

Basin Name (HUC 6)	Sub Basin (HUC 8)	Basin Total Sq. Miles	Percent High Priority	Percent Medium Priority	Percent Low Priority
Black Rock Desert	Smoke Creek Desert, Massacre Lake	203	29.2	0.1	0.3
Carson	Upper Carson	453	93.3	0.2	0.0
Central California Coastal	San Lorenzo, Soquel, Pajaro, Carrizo Plain, Estrella, Salinas, Central Coastal, Cuyama, Santa Maria, San Antonio, Santa Ynez, Alisal, Elkhorn Slough, Carmel, Santa Barbara Coastal	11,300	1.1	6.6	6.1
Central Nevada Desert Basins	Fish Lake, Soda Spring Valley, Ivanpah Valley, Pahrump Valley	1,155	0.0	0.5	1.1
Klamath	Lost, Butte, Klamath, Shasta, Scott, Salmon, Trinity	10,023	61.7	0.8	0.1
Laguna–San Diego Coastal	Aliso, San Onofre, Santa Margarita, San Luis Rey, Escondido, San Diego, Cottowood, Tijuana	3,861	0.7	16.4	22.1
Lower Colorado	Havasu–Mohave Lakes, Piute Wash, Imperial Reservoir, Colorado	3,826	0.0	2.3	2.4
Lower Sacramento	Sacramento, Stone Corral, American, Stony, Cache, Feather, Yuba, Bear, Clear, Cow, Cottonwood, Battle, Paynes, Thomes, Big Chico, Butte, Honcutt, Auburn Ravine, Coon, Putah, Cache Slough	20,125	32.6	7.6	0.3
Mono–Owens Lakes	Mono Lake, Crowley Lake, Ownes Lake	4,188	18.6	8.2	0.0
North Lahontan	Suprise Valley, Madeline Plains, Honey Lake, Eagle Lake	3,704	33.5	1.1	0.0
Northern California Coastal	Smith, Mad, Redwood, Eel, Mattole, Big, Navarro, Garcia, Gualala, Salmon, Russian	9,242	20.1	4.4	0.0
Northern Mojave	Eureka–Saline Valleys, Amargosa, Death Valley, Panamint Valley, Indian Wells, Searles Valley, Antelope Valley, Fremont Valley, Coyote–Cuddeback Lakes, Mojave	21,330	0.3	4.8	1.0
Oregon Closed Basins	Warner Lakes	43	19.4	0.5	0.0
Salton Sea	Whitewater River, Carrizo Creek, San Felipe Creek, Salton Sea	7,164	0.0	5.2	4.3
San Francisco Bay	Suisun Bay, San Pablo Bay, Coyote, San Francisco Bay, Tomales Bay, Drakes Bay, South San Francisco Coastal	4,516	6.1	20.6	9.6
San Joaquin	San Joaquin, Chowchilla, Merced, San Joaquin Delta, Fresno, Tuolumne, Stanislaus, Calaveras, Mokelumne, Cosumnes, Panoche, San Luis Resevoir, Rock, French Camp Slough	15,825	22.0	10.0	3.8
Santa Ana	Seal Beach, San Jacinto, Santa Ana, Newport Bay	2,706	1.4	34.8	17.3
Southern Mojave	Southern Mojave	8,867	0.0	1.6	2.5
Southern Oregon Coastal	Applegate, Illinois, Chetco,	168	87.8	0.5	0.0
Truckee	Lake Tahoe, Truckee River	803	93.1	0.0	0.0
Tulare–Buena Vista Lakes	Kern, Tehachapi, Grape, Poso, Deer, White, Tule, Kaweah, Dry, King, Tulare Lakes, Buena Vista Lakes	16,414	15.2	10.2	4.9
Upper Sacramento	Goose Lake, Pit, McCloud, Sacramento Headwaters	6,955	48.9	0.0	0.0
Ventura–San Gabriel Coastal	Ventura, Santa Clara, Calleguas, Santa Monica Bay, Los Angeles, San Gabriel	4,383	0.8	32.2	12.3
Walker	Walker River	913	54.2	11.9	0.0

Table 3.1.6. Summary of water quality stressors in forested watersheds

Stressor	Cause(s)	Primary Response	Secondary Response	Type
Sediment	Hillslope erosion; land disturbance (silviculture, agriculture, etc.); road erosion	Delivery of fine sediment to streams; delivery of sediment from mass wasting associated with the road prism.	Effect spawning gravels; channel morphology; effect stream turbidity	Chronic and Episodic
Stream Temperature	Forest management; agriculture and other land uses	Stream shading; large woody debris	Changes in temperature affecting coldwater fish; change in aquatic habitat	Chronic and Episodic
Nutrients	Land management; wildfires	Increase concentration of nitrogen and phosphorus	Raise nutrient loadings in lakes and streams	Chronic and Episodic
Contami-nants	Land management	Water contamination from application of herbicides, pesticides, or fuel spills	Effects on riparian habitat and aquatic organisms	Episodic

Table 3.1.7. Summary of water quality conditions based on biotic indicators for perennial streams in California

Indicator	Percent Non-Impaired	Percent Impaired
Statewide		
Macroinvertebrate IBI	78	22
Macroinvertebrate O/E	67	33
North Coast		
Macroinvertebrate IBI	94	6
Macroinvertebrate O/E	60	40
South Coast		
Macroinvertebrate IBI	66	34
Macroinvertebrate O/E	67	33

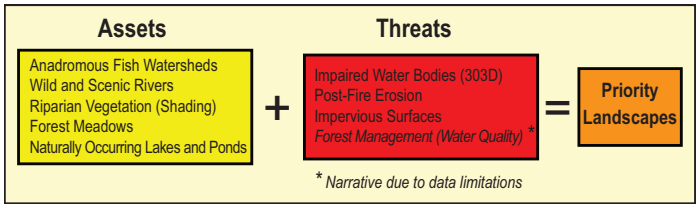
Data Source: State Water Resources Control Board 305b Report (http://www.waterboards.ca.gov/water_issues/programs/tmdl/305b.shtml)

Impairment information for RWQCB basins provides a description of the cause of pollution that results in impairment. Most watercourses have many different potential causes (Table 3.1.8).

Due to differences in how each RWQCB defines impairment, listing whole watersheds versus individual stream segments, it is difficult to assess regional differences in water quality. Impaired waterbodies with silviculture and rangeland activities occur in the North Coast, Central Coast, Central Valley and Lahontan RWQCB regions (Table 3.1.9). For example, over 60 percent of the impaired water bodies in the North Coast list silviculture as one of the causes of pollution. Rangeland grazing activities are one listed cause of impairment on approximately 40 percent of the impaired waterbodies in the Lahontan Regional Water Quality Control Board region, a significant portion of which is in the Sierra region.

Analysis: Water Quality

A GIS based model was developed to evaluate water quality threats and assets (see below). The goal of the analysis was to identify priority watersheds where high value assets (i.e., watersheds supporting a broad range of beneficial uses) are at risk due to water quality threats.



Assets

Anadromous Fish Watersheds

All watersheds support a variety of beneficial uses. These uses are protected by law (see Water Code 13050(f)) against water quality degradation. This analysis used anadromous salmonid watersheds as a proxy for beneficial uses because, in addition to supporting salmonids through cold freshwater habitat, they tend to support a broad range of other beneficial uses. The ranking of watersheds considered both the current and historic extent of salmonids (Figure 3.1.8). For current extent, a GIS layer was developed based on the intersection of watershed boundaries and evolutionary significant units (ESUs) that have

Table 3.1.8. Summary of water quality impairments from 2006 303d list

General Pollution Source	Lakes and Reservoirs	Freshwater Wetlands	Bays and Harbors	Estuaries	Saline Lakes	Rivers and Streams
	Surface Area (Acres)					Miles
Rangeland	108,708		1,922	199		8,002
Agriculture (non-range)	24,688	73,597	159,901	94,758	291,761	9,844
Atmospheric Deposition	109,492		269,224	47,393		87
Construction/Land Development	88,255	62,590	1,922	716	58,421	6,540
Habitat Modification	88,142		2,001	2,934		19,520
Hydromodification	88,362		10,546	199	97,499	14,716
Industrial and Municipal Wastewater	20,868		510,674	97,818	263,551	5,148
Land Disposal	23,436		12,906	1		1,587
Marinas and Recreational Boating	108,682		2,637			
Natural Sources	143,596	62,590	271,146	49,838	98,164	8,135
Resource Extraction	102,982		279,767	91,007		6,672
Silviculture	106,068					13,344
Source Unknown	83,548	11,007	288,726	89,566	72,581	6,889
Urban Runoff	110,538		4,757	47,401		2,294

Data Source: State Water Resources Control Board, Total Maximum Daily Load Program

Table 3.1.9. Impaired miles of streams

RWQCB Region Number	Region Name	Total Miles Impaired Stream	Percent Impaired due to Rangeland Grazing	Percent Impaired due to Silviculture
1	North Coast	19,917	38	66
3	Central Coast	1,050	6	8
5	Central Valley	1,612	10	1
6	Lahontan	318	42	32

Data Source: State Water Resources Control Board, Total Maximum Daily Load Program

been defined by the National Ocean and Atmospheric Administration National Marine Fisheries Service (NMFS). The historic extent of salmonids was identified based on intrinsic potential data (IP) developed by NMFS. The IP data used geomorphic data and other environmental constraints to determine conditions that historically were likely to support salmonids. Using data on current extent and historic distribution, watersheds were ranked as shown in Figure 3.1.8. Under this ranking scheme watersheds that currently support salmonids were given the highest rank.

Wild and Scenic Rivers

Wild and Scenic Rivers are federal and state designations that protect free flowing rivers that possess remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values. These rivers contain a range of beneficial uses including recreation and fish habitat. The GIS layer for Wild and Scenic Rivers was developed based on the intersection of watershed boundaries (WBD HUC8) and rivers recognized as Wild and Scenic by state and federal agencies.

Riparian Vegetation (Shading)

This asset layer was used to identify intact riparian areas with tree cover that has the potential to moderate stream temperatures (Figure 3.1.9). Riparian forests were estimated by creating a riparian buffer around perennial and intermittent streams defined from a statewide stream layer (i.e., National Hydrography Dataset, 1:24,000). The riparian buffer was then intersected with a statewide vegetation layer (i.e., National Land Cover Database).

Forest Meadows

Methodology for developing this asset is discussed in the previous section (Figure 3.1.5).

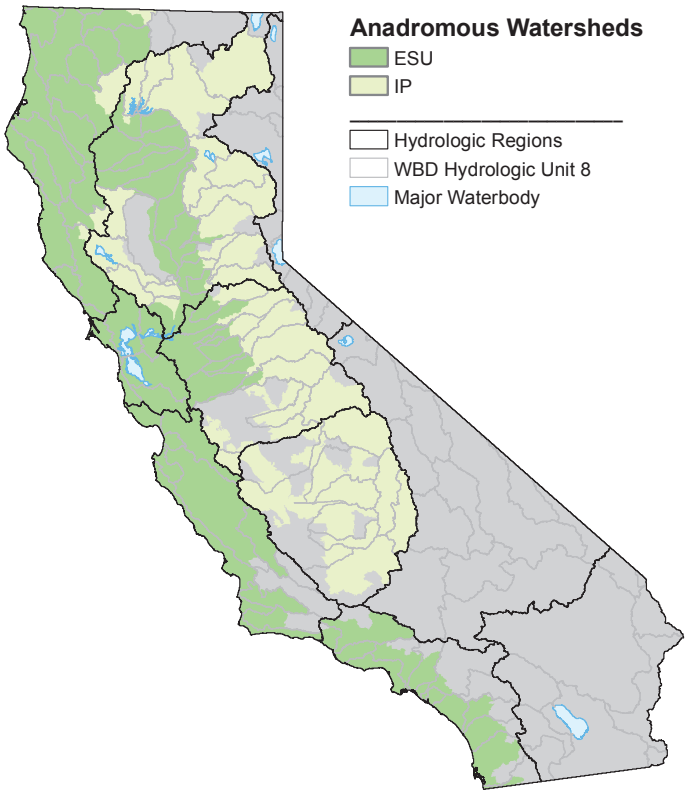


Figure 3.1.8.
Watersheds supporting salmonids where current range is the Evolutionary Significant Unit (ESU) and potential range from an Intrinsic Potential (IP) model. Salmon watersheds were used as a proxy for beneficial uses.
Data Sources: Watershed Boundaries Database for California, NRCS (2009); Evolutionary Significant Units (ESU) for Coho, Chinook, and Steelhead in California, NMFS (2006); Historic Range for Salmonids in California, NMFS (2003)

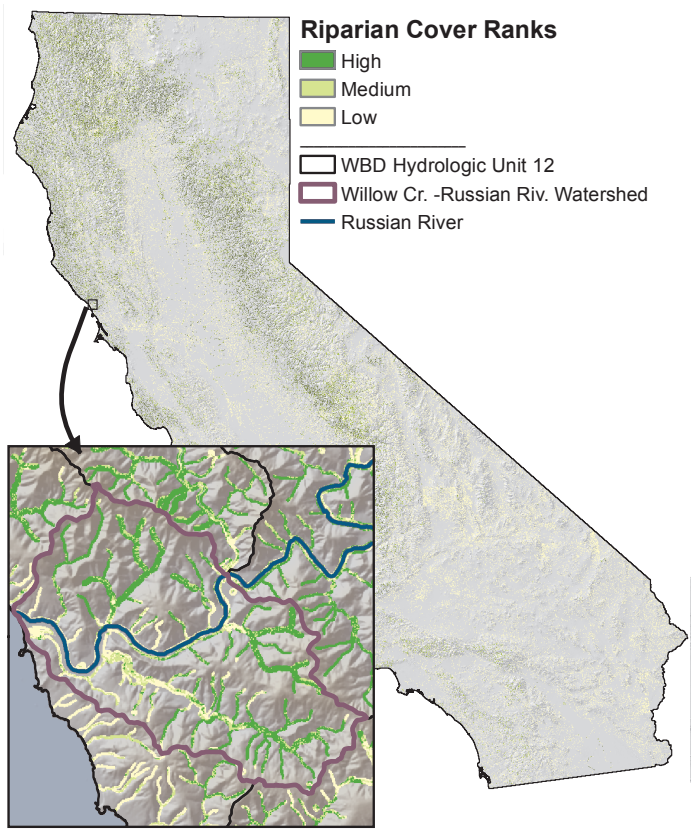


Figure 3.1.9.
Percentage of riparian cover by HUC8 watersheds.
Data Sources: National Hydrography Dataset (NHD), USGS (2009); National Land Cover Dataset, USGS (2001)

Naturally Occurring Lakes and Ponds
Freshwater lakes support a broad range of beneficial uses that can contribute to both water quality and water supply. This asset layer was used to represent natural lakes in California. The data is a subset of the National Hydrography Waterbodies dataset. It was created by limiting the waterbodies dataset to only include lakes and ponds. The lakes and ponds in this data layer correspond to features that would be identified on a U.S. Geological Survey 1:24,000 topographic map.

Composite Assets
An overlay of the water quality assets layers was performed to create the composite asset layer. Assets related to water quality were combined with equal weights for:

- Anadromous Fish Watersheds
- Wild and Scenic Rivers
- Riparian Vegetation (Shading)
- Forest Meadows
- Naturally Occurring Lakes and Ponds

The composite asset layer shows water quality assets were ranked highest in watersheds along the North Coast, along with watersheds in the Sierra. The data used for these ranking places an emphasis on assets for forest and rangeland watersheds and should not be used to infer conditions across all state lands. In addition, monitoring data is generally lacking to identify watersheds that maintain good water quality conditions. Instead, the emphasis is typically placed on monitoring impaired waterbodies.

Threats

There are a number of stressors that can impair water quality. The following threat layers are being used in the GIS-based model to represent threats to water quality.

Impaired Waterbodies (303d)
Information on water quality impairments was derived from the EPA's 303(d) list for California which is developed by the Total Maximum Daily Load Program of the State Water Quality Control Board. For this analysis a data layer was created that summarized causes of impairment by HUC 10 watershed units (Figure 3.1.10). The ranking applied to the HUC 10 watershed units assumes that more causes, or stressors, per watershed implies a higher level of impairment. For additional information on water quality conditions in California see the State Water Resources Control Board's website (http://www.swrcb.ca.gov).

Forest Management (Impacts Related to Timber Operations)
Timber harvesting, road building, and other types of land management activities can have both positive and negative effects on forest hydrology. Watershed studies have typically shown temporary increases in water yield when more than 20 percent of the stand has been harvested. Table 3.1.10 provides a summary of forest management effects on water resources. Timber operations and other types of disturbance from intensive land management can also lead to water quality impairments. Threats to water quality were identified as TMDL watersheds that are listed as impaired from a pollutant where silviculture or grazing was identified as a contributing source. Typical pollutants include sediment, temperature and nutrients.

For additional information on water resources related to forest management throughout California, review the State Water Plan draft section on Forest Management (http://www.waterplan.water.ca.gov/docs/cwpu2009/1009prf/v2ch23-forest_mgt_pf_09.pdf).

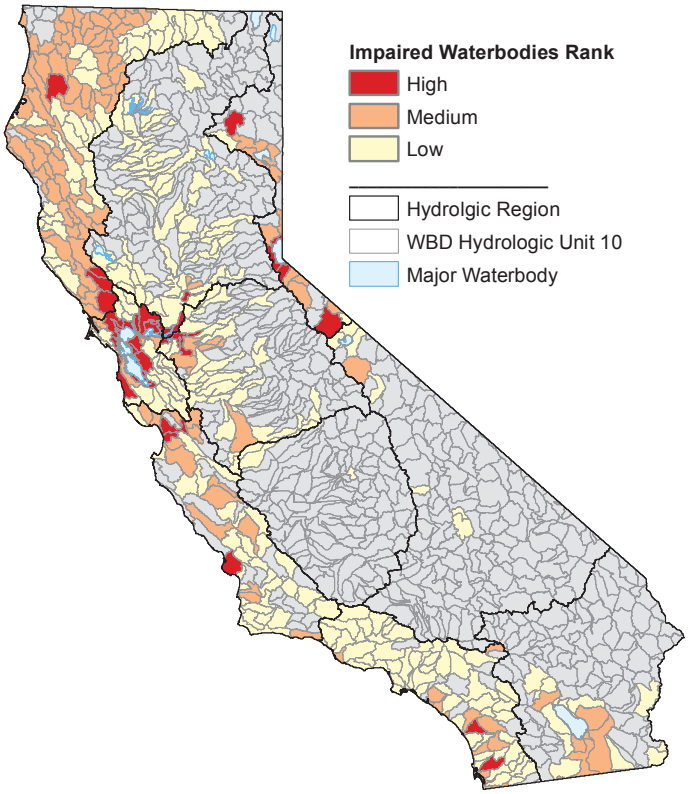


Figure 3.1.10.
Impaired waterbodies by HUC8 watershed units. Watersheds are shown ranked by the number of stressors that occur in a watershed.
Data Sources: Watershed Boundaries Database for California, NRCS (2009); 303(d) List, Total Maximum Daily Load Program, State Water Resources Control Board (2006)

Post-Fire Erosion
Potential increases in erosion rates following wildfires can accelerate the delivery of sediment downstream and lead to degraded environmental conditions. Wildfires have been shown to increase both runoff and surface erosion (Larsen et al., 2009). Increases in post-fire erosion rates can adversely affect water quality and aquatic habitat, but can also degrade water supply. Soil erosion from wildfires has the potential to contribute to downstream siltation that may reduce the capacity of water storage facilities. Minear and Kondolf (2004, 2009) found that approximately 200 reservoirs in California have likely lost more than half their initial capacity to sedimentation. Reservoirs with most risk of sedimentation were found to be primarily small reservoirs (<2,500 acre-feet), such as municipal water-supply reservoirs, especially those operated by coastal towns and cities. Reservoirs in the Coast and Transverse Ranges are the most at risk, due to

Table 3.1.10. Potential hydrologic response from changes in forest structure, changes in water flow paths and application of chemicals

Land Management	Potential Response
Forest Canopy Removal	decreased interception or rainfall; net increase in precipitation arriving at the soil surface
	reduced transpiration
	temporary increases in water availability and water yield
	increased soil moisture; potential impacts to root strength
	transpiration rates vary with stand age
Impervious Surfaces	modified flow pathways for runoff and delivery to stream channels
	potential increases for surface erosion and mass wasting
Application of Forest Chemicals	potential adverse affect on aquatic ecosystems particularly when applied near or directly to water bodies
	potential adverse affect on water quality dependent on type of chemical, toxicity, rate of application, etc.
	potential cumulative effects from repeated or chronic treatments
Data Source: Natural Resource Council, 2008	

high sedimentation rates, small reservoirs on large watersheds, and older reservoirs. The amount of erosion from wildfire has been shown to be highly variable, depending on the frequency and intensity of storms following wildfires, but have been shown to be greater following high severity burns (Benavides-Solorio and MacDonald, 2001, 2005).

The analysis used the Post-Fire Erosion layer (CAL FIRE, 2003) to represent threat of erosion following wildfires. This data layer estimates an expected erosion rate if an area experiences a high severity fire. This data layer was combined with information on fire rotation (see Chapter 2.1) to better identify those locations that are more likely to experience frequent high severity fires. Based on the existing post-fire erosion layer the percentage of the watersheds with a high post-fire erosion value was estimated and rankings were assigned to produce the threat from wildfire layer (Figure 3.1.11). See Chapter 2.1 for additional information of wildfire threat.

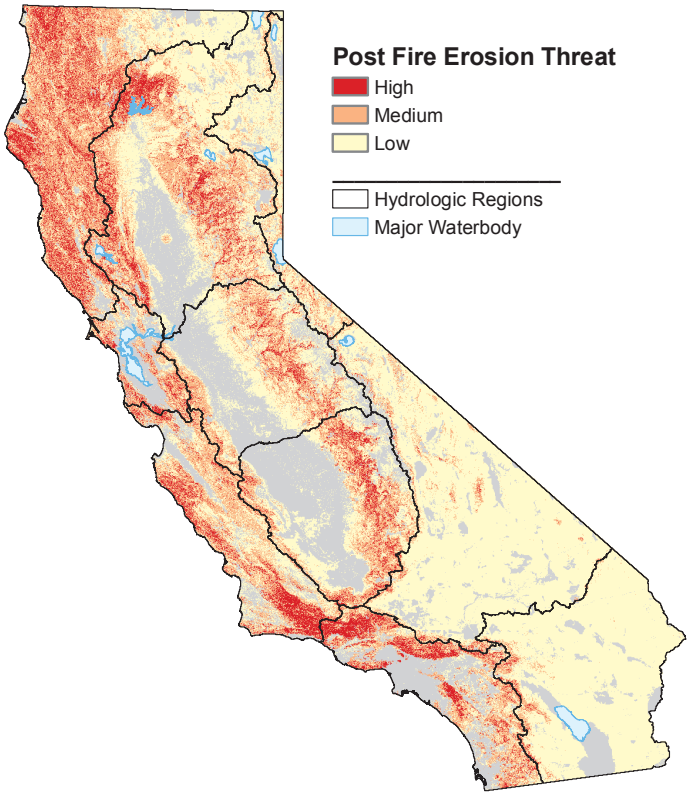


Figure 3.1.11.
Post-fire erosion threat. Soil erosion following wildfires can accelerate sediment delivery to stream courses and through siltation can impact to water storage facilities.
Data Sources: Post-Fire Erosion Potential, FRAP (2004); Fire Threat, FRAP (2005); Statewide Land Use / Land Cover Mosaic, FRAP (2006) Watershed Boundaries Database for California, NRCS (2009)

Impervious Surfaces
Stormwater runoff in developed areas contributes to water quality impairments. The degree of impacts tends to increase with larger areas of paved and impervious surfaces. Using a GIS data layer developed nationally by the EPA, areas were ranked based on the percent impervious surface area.

Composite Threats

The composite threat layer for water quality is based on the overlay of watersheds with water quality impairments. These impairments include forest management-related activities, development, hillslope surface erosion, mass wasting processes and post-fire erosion potential (Table 3.1.11).

Results

The high priority landscape (HPL) identifies watersheds that support a broad range of beneficial uses and coincide with high threats to water quality. The analysis highlights areas where stewardship projects have the highest potential to protect and enhance water quality. Table 3.1.12 displays the results from the GIS-based model and has been summarized by the major hydrologic regions in California. The analysis reported for large watershed units (100,000

Table 3.1.11 Threats to water quality – top watersheds per hydrologic regions

Sub-basin Name	Sub-basin Total Sq. Miles	Percent High	Percent Med	Percent Low	Percent High-Med[1]	Composite[2]
San Francisco Coastal South	257	48.7	44.7	6.7	93.3	85.5
Mattole	500	45	46.7	8.2	91.7	84.1
South Fork Eel	689	35.4	63	1.5	98.5	83.5
Trinity	2,038	35.2	59.8	5.1	94.9	82.5
Lower Klamath	1,527	29.6	69.2	1.2	98.8	82.1
Russian	1,485	34.6	58.5	6.9	93.1	81.9
Lake Tahoe	371	26.2	73.8	0	100	81.5
Upper Eel	709	25	72.6	2.4	97.6	80.7
Mad–Redwood	1,126	18.3	77.2	4.6	95.4	78.4
East Walker	504	22.4	68.5	9.1	90.9	78.3
Upper Klamath	852	9.3	89.2	1.5	98.5	77
Suisun Bay	652	18.4	70.6	11	89	76.8
Newport Bay	158	18.4	70.2	11.4	88.6	76.7
Scott	814	12.9	80.6	6.6	93.4	76.6
Lower Eel	1,529	15.4	70.1	14.5	85.5	75.2
San Pablo Bay	1,226	21.4	57.5	21.1	78.9	75.1
San Francisco Bay	1,333	15.5	68.8	15.7	84.3	74.9
San Lorenzo–Soquel	375	14.2	69.1	16.7	83.3	74.4
Alisal–Elkhorn Sloughs	184	14.3	67.7	17.9	82.1	74.1
Upper Carson	453	3.4	88.5	8.1	91.9	73.8
Gualala–Salmon	494	8	78	14	86	73.5
Big–Navarro–Garcia	1,251	10.5	72.6	16.8	83.1	73.4
Salmon	751	4.5	83	12.5	87.5	73
Middle Fork Eel	753	6.2	76.5	17.3	82.7	72.2
San Diego	1,383	11.7	62.3	26	74	71.4
Seal Beach	88	0	85.6	14.3	85.7	71.4
Tomales–Drake Bays	327	5.4	74.5	20.1	79.9	71.3
Santa Barbara Coastal	378	11.3	61.3	27.4	72.6	71
South Fork Trinity	932	0.4	81.7	17.9	82.1	70.6
San Gabriel	710	0.7	80.5	18.9	81.1	70.5
Santa Monica Bay	575	1.3	78.9	19.8	80.2	70.4
Ventura	266	0.9	75.2	23.9	76.1	69.3
Santa Clara	1,626	0.4	73.6	25.9	74.1	68.6
Coyote	720	0.6	71.8	27.7	72.3	68.2
Los Angeles	831	0.6	71.4	27.7	72	68
Pajaro	1,301	8.5	56.4	34	65	67.9

[1] Percent High-Med = Percent High + Percent Medium

[2] Composite = (Percent High) + (Percent Medium) x 0.5 + (Percent Low) x 0.25

acres or greater in size) and is not likely to adequately represent water quality conditions for smaller sub-basins.

The North Coast hydrologic region has the highest amount of HPL. The majority of forested watersheds in this region are important for recovery of state and federally listed anadromous salmonids and have also been listed for water quality impairments. The watersheds in the Sierra are composed of a mixture of high and medium priority landscape. The Lake Tahoe basin is likely the highest priority for watersheds in this region. The Central Coast and South Coast watersheds are also mostly ranked as medium priorities. Forest health (see Chapter 2.2) and fire management greatly influence water quality conditions in these watersheds. This assessment is not meant to represent conditions in agricultural and urban watersheds. In addition, results from large watersheds are necessarily generalized, and what holds true on average for the large watershed as whole may not be true for some of the smaller watersheds which comprise the larger watershed. Site-specific field checking is needed to determine if generalized conclusions for a large watershed also apply to a specific sub-watershed within the large watershed. For additional information on water quality conditions and priorities, see the Regional Water Quality Control Board's Basin Plans and the State 305(b) Water Quality Report for California.

Discussion

The water quality model resulted in a priority landscape that highlights areas where important water quality assets coincide with high threats to water quality. High priority areas are concentrated in North Coast watersheds and in some basins in the Sierra and parts of the South Coast. The results suggest that water quality impairments in forested watersheds of the North Coast will continue to be a priority issue, as these watersheds support a range of beneficial uses and are of critical importance for restoring habitat for state and federally listed salmonids.

Bioregional Findings

- Water quality impairments associated with forest and rangeland are most pronounced in watersheds in the Klamath/North Coast bioregion and along watersheds in the Central and South Coast bioregions.
- Most water quality impairments in forested watersheds are associated with sediment, water

California Department of Water Resources employees conduct a snow survey

Table 3.1.12. Summary of water quality priorities – the priority landscape from the water quality analysis was summarized for each of the hydrologic regions across California

Hydrologic Region	Basin	Sub-basin	Acres	Priority Rank
Klamath/North Coast (1)	Klamath	Shasta, Scott, Upper Klamath, Lower Klamath, Salmon, Trinity, South Fork Trinity	5,301,783	High
	Coastal	Smith	510,241	High
		Big–Navarro–Garcia	800,505	High
		Gualala–Salmon	316,814	High
		Mattole	320,065	Medium
		Russian	950,344	Medium
		Mad–Redwood	737,035	Medium
		Lower Eel, Middle Fork Eel, Upper Eel, South Fork Eel	2,356,296	High
San Francisco Bay (2)	San Francisco Bay	San Pablo Bay	784,967	Medium
		Suisun Bay	417,503	Medium
		San Francisco Bay	853,238	Medium
Central Coast (3)	Coastal	Santa Maria	437,820	High
		Central Coastal	687,167	High
		San Lorenzo–Soquel	240,261	Medium
		Alisal–Elkhorn Sloughs	117,984	Medium
		Santa Barbara Coastal	242,117	Medium
		Pajaro	832,388	Medium
		Carmel	206,917	Medium
		Salinas	2,130,582	Medium
South Coast (4)	Coastal	Santa Clara	1,040,497	High
		Newport Bay	100,993	Medium
		San Diego	898,735	Medium
		San Luis Rey–Escondido	494,482	Medium
		Ventura	170,651	Medium
		Santa Monica Bay	368,140	Medium
Sacramento River (5)	Upper Sacramento	McCloud	435,718	High
	Lower Sacramento	Lower American, North Fork American	835,282	High
		Lower and Middle Fork Feather	873,423	High
		Upper Yuba	860,738	High
		Battle Creek	360,533	High
		Upper Cache	745,622	Medium
		Auburn Ravine–Coon Creek	277,766	Medium
San Joaquin (6)	San Joaquin	Merced	812,426	High
		Tuolumne	1,198,581	High
		San Joaquin Delta	788,778	Medium
		Middle San Joaquin,Lower Merced, Lower Stanislaus	587,233	Medium
Tulare Lake (7)	Tulare–Buena Vista Lakes	Upper Kern, South Fork Kern	1,327,132	High
Lahontan (8)	Lake Tahoe	Lake Tahoe	324,368	High
	Walker	East Walker, West Walker	1,435,288	Medium
	Carson	Upper Carson	613,469	Medium
	Truckee	Truckee	779,051	Medium

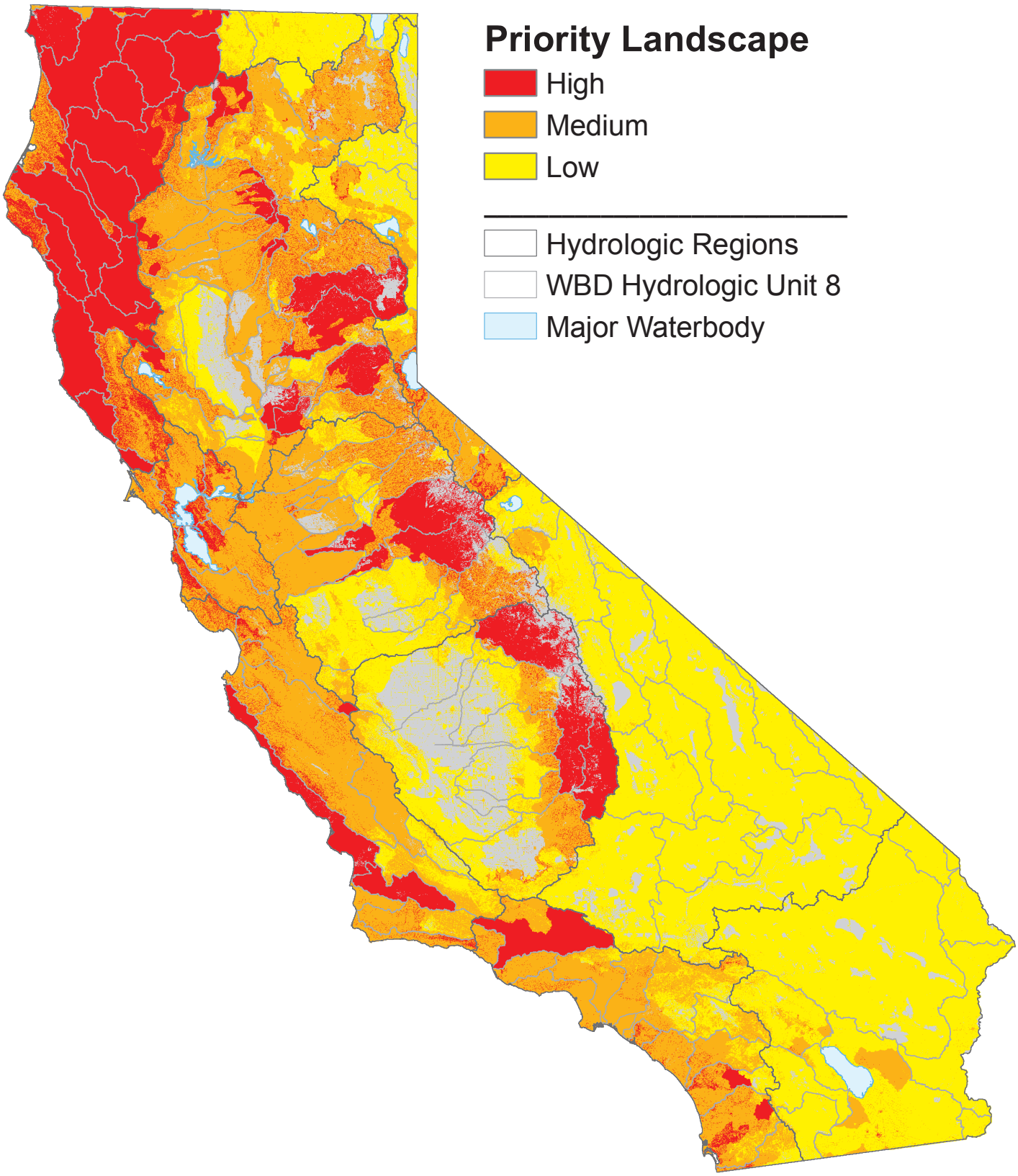


Figure 3.1.12.
Priority landscape for water quality.
Data Sources: Wild and Scenic River Designations, DFG (2008); Evolutionary Significant Units (ESU) for Coho, Chinook, and Steelhead in California, National Marine Fisheries Service (NMFS) (2006); Watershed Boundaries Database for California, NRCS (2009); National Hydrography Dataset, USGS (2009); National Land Cover Dataset, USGS (2001); Historic Range for Salmonids in California, NMFS (2003); 303(d) List, Total Maximum Daily Load Program, State Water Resources Control Board (2006); Post-Fire Erosion Potential, FRAP (2004); Sierra Nevada Montane Meadows, USFS R5 (2000)

temperature or nutrients.

Institutional Setting for Protecting and Enhancing Water Quality

The following programs and approaches are components of an existing strategy to protect and enhance water quality.

1. *TMDL Implementation* – Through the Porter-Cologne Water Quality Control Act the State Water Resources Control Board (SWRCB) and nine Regional Water Quality Control Boards (RWQCBs) have primary responsibility for developing water quality standards and ensuring that waterbodies are in attainment. As a part of that process, watersheds from the 303d list that have a TMDL developed, represent opportunities to begin to implement pollution load reductions and improve water quality. Watersheds that have an approved TMDL plan have already identified the sources of water quality impairment and have developed strategies to meet water quality objectives. Many of these watersheds represent priorities for implementing restoration projects and improving water quality.
2. *Regulatory* – The California Forest Practice Rules provide water quality protection measures that are designed to ensure that timber harvesting plans do not violate existing water quality standards. In addition, the California State Board of Forestry and Fire Protection (BOF) has implemented additional protection measures for waterbodies that are impaired or contained listed salmonid species.
3. *Watershed Management Plans* – Throughout California many local communities have developed watershed management plans that are designed to identify water quality stressors and to develop restoration plans.
4. *Integrated Regional Water Management (IRWM)* – The Department of Water Resources has developed IRWM planning as a method to prioritize water management needs on a regional level. The goal of IRWM planning is to promote integrated regional water management that improves water supply sustainability, water quality and addresses a range of environmental stewardship issues that affect both water supply and water quality.
5. *USFS Region 5 Water Quality Management Program* – This program provides water quality protection on U.S. Forest Service lands that includes the implementation and monitoring of Best Management Practices (BMPs). The USFS is currently working in collaboration with the State Water Resources Control Board to revise the existing Water Quality Management Plan (http://www.swrcb.ca.gov/water_issues/programs/nps/wqmp_forests.shtml).

TOOLS

Management activities on forests and rangelands can have an affect on both water supply and water quality. The following is a list of tools that can be used to protect and reduce risk to priority landscapes. For additional information on management tools and strategies the reader is referred to the Forest Resource Management Strategy in the State Water Plan (http://www.water.ca.gov/waterplan).

- Low-impact development (enhancing green infrastructure)
- Smart growth to avoid urban sprawl
- Meadow restoration
- Restoring riparian forests
- Fuels management, including prescribed burning and mechanical treatments
- Conservation of water use; see the 20x2020 Water Conservation Plan website (http://www.waterboards.ca.gov/water_issues/hot_topics/20x2020/index.shtml)
- Use of USFS Best Management Practices and BOF Anadromous Salmonid Protection rules for riparian protection and restoration
- Upgrading and decommissioning of forest roads; proper road maintenance
- Rapid and aggressive reforestation of wildfire areas
- Use of zoning (Timberland Production Zones), easements and other incentives to reduce land use conversion, reduce loss of forestlands and strengthen watershed protection.