SANTA CRUZ IRWM

Conceptual Framework Update

Final Report/March 2013

2NDNATURE
ecosystem science + design

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LIST OF ACRONYMS

CoEHS	County of Santa Cruz Department of Environmental Health
CWD	Central Water District
CW	City of Watsonville Water District
IRWM	Integrated Regional Water Management
LWD	Lompico Water District
SCWD	City of Santa Cruz Water District
SLVWD	San Lorenzo Valley Water District
SqCWD	Soquel Water District
SVWD	Scotts Valley Water District

1 EXECUTIVE SUMMARY

The Santa Cruz Integrated Water Management (IRWM) Conceptual Framework was developed to supplement the update of the 2005 Northern Santa Cruz IRWM plan. The existing 2005 IRWM plan is derived from numerous water and water-resources related plans and studies, and at its core consists of a list of priority projects. The existing prioritization process evaluates projects against a set of funding objectives and their state of readiness, among other factors. While this is appropriate for developing funding proposals, it does not necessarily prioritize strategies for their potential to achieve the plan's objectives. As part of the plan update, the Steering Committee seeks to implement a planning process that will more directly link strategies with achievement of objectives. The process and final products of this conceptual framework is intended to guide priority action selection in an effort to ensure that those actions with the greatest benefit are identified. The conceptual framework will also assist in the selection and interpretation of meaningful indicators to track progress toward regional IRWM objectives over time. This approach allows managers to identify the most influential actions for achieving IRWM objectives and select appropriate performance measures to characterize how actions incrementally contribute to achieving these objectives.

Conceptual models were created for each of the four IRWM functional areas (Water Supply, Water Quality, Aquatic Ecosystems, and Stormwater/Flood Management) and include goals, objectives, diagrams and tables that will guide effective strategy implementation (Chapters 3-6). Each conceptual model represents a hypothesis of cause and effect between components of the system and management strategies. A climate change vulnerability assessment (Chapter 2.4) was completed with best available projections of future climatic conditions and used to identify strategies with climate change adaptation benefits. Explicitly stated within each conceptual model is the hypothesis that effective implementation of particular strategies will result in an improvement of natural resource conditions. Specific indicators and performance measures were identified that will be used to measure changes over time. The framework structure provides the documentation to guide regional managers in identifying the highest priority water resources strategies for achieving IRWM objectives.

IRWM goals arranged by functional area include:

Water Supply: Ensure a reliable and sustainable local water supply through strategies that diversify the supply portfolio, develop production from alternative sources, protect and enhance surface and groundwater, and maximize efficient delivery and use.

Water Quality: Maintain and improve regional surface and groundwater quality to protect beneficial uses. Reduce the sources of harmful pollutants (i.e., sediment, bacteria, nitrate, persistent organics and other toxic constituents) and their impacts on aquatic resources.

Aquatic Ecosystems: Improve the condition of riparian and aquatic ecosystems to support the native species, watershed functions, and regional water needs, by increasing the habitat quality and quantity of critical aquatic ecosystems (i.e., streams, tidal wetlands and freshwater wetlands).

Flood & Stormwater Management: Implement integrated flood management strategies that reduce hazards and impacts from floods and, where feasible, provide multi-benefits (e.g., improve stormwater quality, ecosystem benefits, LID development and groundwater recharge).

The following priority strategies were identified through the conceptual framework process as having the greatest ability to achieve these goals.

Increase water supply and reduce demand: Water supply is not sustainable within the Santa Cruz IRWM region in normal years, a situation that is exacerbated when below average water years occur. Surface water supply is highly dependent upon local precipitation, timing and available storage capacity. A greater volume of water is extracted annually from regional groundwater aquifers than is naturally recharged. Increased flexibility in regional water management and increased groundwater recharge are necessary to improve regional water supply reliability and improve resource conditions. The achievement of a reliable and sustainable local water supply requires both increased supply and reduced demand. The regional water supply management strategies include:

- increased conservation measures inspired by rebates, rate increases, and water neutral development policies,
- developing alternative sources of water to meet supply needs including the infrastructure necessary to facilitate inter-district transfers, and
- increasing production from existing sources including increased ability to capture and store greater winter storm volumes.

Annual tracking of aquifer water surface elevations and stream flow conditions relative to desired sustainable targets will serve as the measurable indicator of benefit from these strategies (see Figures 7.1 and 7.2).

Bacteria and sediment source control: Water quality impairments due to elevated bacteria and sediment levels are among the most pressing water quality concerns in the region (see Figure 4.5). Elevated bacteria levels in surface waters can limit recreational activities and create human health threats. An important and controllable regional source of bacteria (and nitrate) to streams and the near shore is the dense and aging septic system networks in rural areas. Upgrades and maintenance to rural residential septic systems (as well as urban sewer lines and laterals) to reduce leakage, spills and failures are priority IRWM strategies. A reducing trend of dry season bacteria levels in regional surface water may demonstrate future progress of reducing bacteria sources.

The supply of sand-sized sediment to streams significantly degrades the aquatic habitat quality, resulting in a myriad of negative ecosystem impacts that particularly affect the spawning and rearing habitat of sensitive salmonid species. Implementation of effective erosion control actions to reduce sediment generated from rural road networks, timber harvest activities and agricultural lands are priority IRWM strategies. Simple methods to measure the relative risk of rural road sediment generation are being developed and could be used to track effective IRWM supported efforts (improvements and maintenance) on public and private roads over time. Consistent, cost-effective methods to evaluate salmonid habitat quality that are sensitive to improved spawning quality, among other characteristics, would be extremely useful to track stream habitat quality and quantity over time.

Riparian protection and enhancement: Strategies aimed to acquire, enhance, and protect the riparian zones throughout the region are expected to contribute to all of the SC IRWM functional goals and reduce the region's vulnerability to climate change. Significant opportunities exist to widen riparian corridors; increase riparian vegetation distribution and complexity; restore morphologic function; and improve overall riparian condition in watersheds throughout the region, and effective riparian enhancement strategies will vary by stream type, location and adjacent land uses. Riparian zone acquisitions and easements or cash compensation for parcels within the floodplain could allow future land use changes, potential improvements in flood conveyance and an associated reduction of flood hazards. Many of the regional flood prone urban areas are located near the coast, where effective riparian enhancement actions would increase the habitat quality and quantity of tidal wetlands, which are critical habitat for rearing salmonids. Functional riparian zones have access to their floodplains, a well-established vegetation canopy, an energy balanced morphology, and a complex physical structure. All of these attributes support natural fluvial processes that improve water quality and remove pollutants through deposition, filtering and sorting. A riparian zone in good condition can flush fine sediment from the channel bed, thereby improving salmonid spawning habitat qualityas well benthic invertebrate abundance and diversity (i.e., fish food). Given the dependence on local water for potable supply, improved riparian conditions will reduce water treatment requirements, increase local recharge and retention of water volumes on the landscape, and contribute to the goal of providing a sustainable water supply. The future near term progress of the IRWM will be communicated, in part, by tracking effective improvements to riparian habitat quality and quantity throughout the region (see Figure 7.3).

Increase infiltration and recharge: Strategies to reduce the impact of impervious surfaces on the hydrologic function of regional watersheds were identified in each of the four functional areas. Regional opportunities to increase the fraction of rainfall that is infiltrated can be realized by disconnecting impervious surfaces; increasing localized parcel-based infiltration though low impact development (LID) on both private and public lands; the construction and maintenance of recharge basins; and the prevention and/or removal of impervious surfaces in known recharge zones. In order to have a measurable impact on the amount of water lost as runoff in developed areas, these strategies would have to be implemented on a vast spatial scale throughout the impervious areas within the region. Effective implementation of these strategies is collectively intended to restore the natural storm hydrograph in local tributaries and increase groundwater recharge. Increasing infiltration opportunities will retain greater annual volumes on the landscape and mitigate several projected climate change impacts, including a longer, warmer dry season and increased drought frequency. These infiltration strategies are consistent with the strategies recommended by UCSC (2012) to improve water supply security during droughts by implementing regional programs to develop a locally based groundwater drought reserve.

The increasing competition for available public funding has been coupled with requirements to quantify the incremental and quantitative contribution of natural resource improvement projects. The framework products and its identified process for articulating measureable objectives, identifying indicators or performance measures, and tracking and reporting progress are intended to assist the Santa Cruz region's competitive funding advantage into the future.

2 IRWMP CONCEPTUAL FRAMEWORK

2.1 DEVELOPMENT PROCESS

Conceptual models have been developed for each of the four Santa Cruz Regional IRWM Functional Areas: Water Supply, Water Quality, Aquatic Ecosystems, and Flood & Stormwater Management. The models were created in close collaboration with a diverse and representative group of regional stakeholders (Table 2.1). Most Working Group members served on at least one functional area team and reviewed and contributed to draft conceptual diagrams that included functional goal statements, diagrams, linkage tables and draft objectives.

The Working Group meetings included 1) a review of the 2006 IRWM Plan and objectives to be updated, 2) an introduction of the format and development process used for the conceptual models, 3) a review and discussions of the draft conceptual models and objectives developed by each development team, and 4) a review and discussion of the draft final version of this document and selection of specific objectives that will be used to track IRWM progress immediately. The final version of this document includes incorporation of Working Group comments and suggestions as appropriate and the quality of the content has greatly benefited from the participation and commitment of the Working Group members.

The final products document the current understanding of each functional area and serve as a tool to prioritize regional management strategies. Quantifiable objectives and condition targets have been identified and will be used to track progress of the IRWM implementation towards achieving regional objectives. Each model represents a working hypothesis of cause and effect linkages between the most important components of the system and management strategies. Included in these hypotheses is the concept that effective implementation of particular strategies will result in an improvement of natural resource conditions that can be measured by changes in specific indicators or performance measures over time.

Table 2.1. Santa Cruz IRWM update working group members, affiliation and respective functional area development team.

Working group member	Affiliation	Functional area team
Chris Coburn	County of Santa Cruz	All
John Ricker	County of Santa Cruz	
Tim Carson	Regional Water Management Foundation	
Ron Duncan/ Taj Dufour	Soquel Creek Water District	Water Supply
Charles McNiesh	Scotts Valley Water District	
Mike Ferry	City of Santa Cruz	Water Quality
Chris Berry	City of Santa Cruz	
Kristen Kittleson	County of Santa Cruz	Aquatic Ecosystems
Nik Strong-Cvetich	Resource Conservation District of Santa Cruz County	
Mike Cloud	County of Santa Cruz	Flood and Stormwater Management
Robert Ketley	City of Watsonville	
Mike Sepunor	City of Santa Cruz	
Siobhan O'Neil	City of Santa Cruz	
Bridget Hoover	Monterey Bay National Marine Sanctuary	-
Armand Ruby	Coastal Watershed Council	

2.2 APPLICATIONS OF CONCEPTUAL MODELS

Conceptual models provide an organizational construct for communication and identification of important components, relationships, and dynamics of a system. They can identify the relative importance, sensitivity, and degrees of connectivity of the various model components under different scenarios. Conceptual models can be applied to 1) focus management actions where they are most likely to have the greatest beneficial impacts on natural resources of concern (key system attributes), 2) identify indicators to measure the cumulative benefit of management actions over time, 3) specify performance measures to track incremental progress of effective management actions, and 4) document the current understanding of the causal linkages between management actions and expected outcomes. By aligning the model development process with the needs of the users and incorporating the best scientific understanding and available information, the conceptual model can serve as a planning, decision support and reporting tool.

Development of a conceptual model is an important step towards estimating responses of a natural system to management actions by organizing the best knowledge of how a system works in an explicit and transparent manner. A simple personal well-being conceptual model is provided to illustrate the components and functions of a conceptual model format used to create the Santa Cruz IRWM Update.

2.3 CONCEPTUAL MODEL COMPONENTS

Conceptual models consist of:

- Goal: A general summary of the desired state of the functional area that regional strategies are collectively working to achieve.
- Objective: Specific quantitative statement detailing the desired outcomes of regional strategies for each functional area.
- Diagram: A visual summary of the linkages between system components: IRWM *strategies* are hypothesized to change the state of system *drivers* and thereby change the status or condition of *key system attributes* in the desirable direction to achieve the stated goals and *objectives*.
- Linkage table: To maintain visual simplicity, the diagram does not include specific connections (i.e., lines and arrows) between components. Linkage tables are used to summarize the critical cause and effect linkages contained within the diagrams and document which drivers specific strategies are hypothesized to modify, thereby achieving desired outcomes.
- Strategy justification: A brief narrative that documents the rationale and working hypotheses of how specific IRWM strategies can influence critical drivers, contribute to the desired change of the status of the key system attributes, and ultimately achieve the stated IRWM goals and objectives.
- Strategy implementation objectives: Strategy implementation objectives are specific, quantifiable and time-limited statements of the desired condition of a key system attribute or driver that are directly measurable over time to track IRWM progress using either indicators or performance measures.

2.3.1 DIAGRAM FORMAT

Figure 2.1. Format and structural relationship of components represented in the diagram.

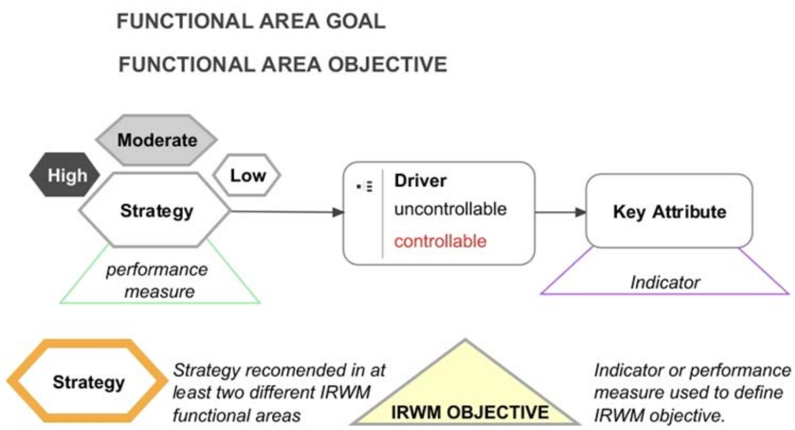
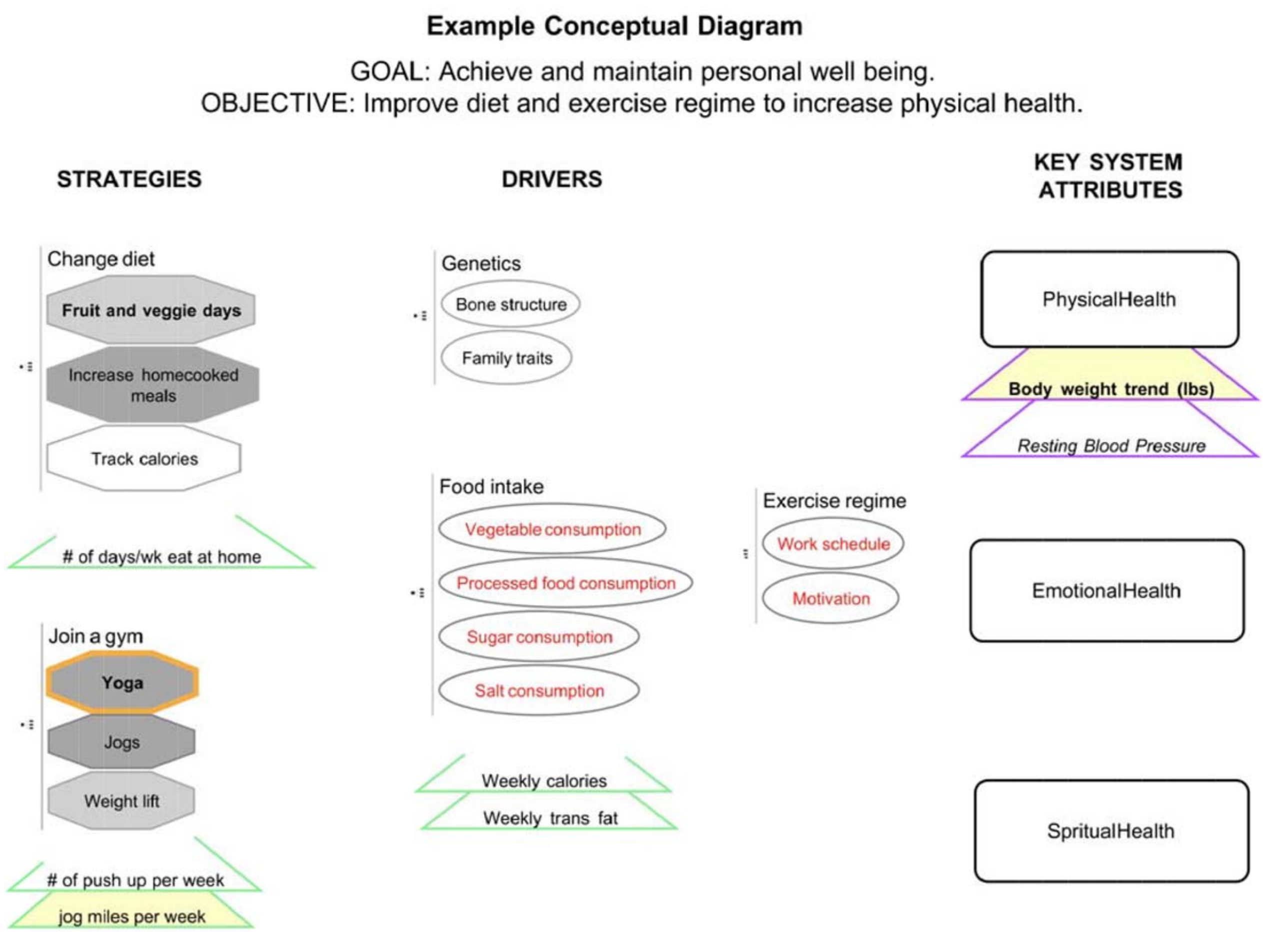


Figure 2.2. Example diagram illustrating potential components of a personal well being conceptual model, with key system attributes of personal well being including physical, emotional and spiritual health. Only the components relevant to physical health are provided.



2.3.2 COMPONENT DEFINITIONS

Goal

A goal is a broad and generalized statement of the overarching intention of the IRWM actions and the future desired state of regional aquatic resources.
Well-Being Model Example: Achieve and maintain personal well-being.

Objectives

Each IRWM functional area has a generalized objective statement that includes a desired change in key attributes from existing conditions and/or minimization of adverse impacts, but may not be directly quantifiable. These objective statements are supported by a set of 'Strategy Implementation Objectives' that are directly quantifiable by either a performance measure or indicator (described below).
Well-Being Model Example: Improve diet and exercise regime to increase physical health.

Strategy implementation objective

Strategy implementation objectives are specific statements that define future desired conditions of either critical controllable drivers or key attributes. Strategy implementation objectives are quantifiable statements of the desired condition of a key system attribute or driver and are directly measurable using either indicators or performance measures. Strategy implementation objectives contain specific targets to be achieved in a discrete time interval. They include working hypotheses and available knowledge that informs the selection of the specific targets, including current conditions and an understanding of what is feasible, yet achievable. The implementation objectives include statements of data or information needs to facilitate progress tracking and reporting to funders, stakeholders and the public. Once the strategy or strategies are implemented, tracking actual progress toward the target allows hypothesis testing of initial assumptions and provides direct information to revise targets, adjust strategies, and/or revisit working hypotheses. Ideal strategy implementation objectives are:

- Explicit future values of an indicator or performance measure that includes date of achievement.
- Quantitative and directional statements of future measurable conditions for which both incremental progress of actions and system response can be accounted and tracked.
- Collectively inform progress toward achieving IRWM goals.
- Leverage and focus existing data/information collection and management efforts.
- A basis for evaluation of strategy effectiveness, while minimizing the annual tracking and reporting requirements.

Strategy implementation objectives will be used to track progress toward achieving IRWM goals over time.
Well-Being Model Example:
WB1. Reduce weight to 150 lbs in 6 months and maintain as average weekly weight indefinitely.
Indicator or performance measure: Body weight (lbs) reported as average weekly body weight to nearest pound.

Hypotheses: Based on the general weight targets for the subject individual's gender (female), height (5 ft 8 in) and age (40) it is hypothesized that a weekly average of 150 lbs is a healthy weight target. Current weight is 170 lbs and it is assumed that loss of 20 lbs over 6 months is achievable and will result in a significant physical health improvement.
Critical Need: Systematic process to measure, manage and analyze daily body weight data.
Monitoring element: Measure and document body weight daily at 8am. Track progress relative to objective using average weekly weight over time (lbs) compared to target of 150 lbs.

Key system attributes

Key system attributes are the highest level organizational components of the system that are closely connected to the primary management issues within each functional area. IRWM objectives are directly or indirectly linked to the improvement of the condition of key attributes as a result of effective actions. The key system attributes are focal points for the drivers and are chosen based on the resources of interest, management objectives, and the application scale of the model. Key system attributes help distinguish important changes in the system from changes that have little importance on achieving the goal.
Well-Being Model Example: Physical Health

Indicators

Indicators are a measurable characteristic of a key system attribute that can be used to quantify its current status or track changes over time. The measurable change in an indicator is hypothesized to be a cumulative system response of effective management actions (i.e., strategies). The condition of key system attributes often cannot be measured directly or easily quantified at all locations of interest, thus indicators can be proxies to define condition of a key system attribute. The most effective indicators include techniques to constrain other inherent sources of variability in the system, thereby increasing confidence that measured changes in the indicator are due to management actions and not attributable to natural or sampling variability.
Well-Being Model Example: Body weight; Resting blood pressure

Drivers

Changes in natural systems are the result of forces on the system called *drivers*. Drivers are the natural and anthropogenic structures, processes, or regimes that define the system being modeled and control changes in environmental conditions (physical, chemical, or biological). Drivers included in the diagram are those that affect the key system attributes. We differentiate between drivers that can be influenced by management strategies or other actions (controllable or anthropogenic) and those that are beyond our control and therefore cannot be altered by our actions (non-controllable or natural).
Well-Being Model Example: Salt consumption (controllable); Bone structure (non-controllable)

Strategies

Strategies are actions implemented to address IRWM objectives. High priority strategies are those with the greatest assumed potential to achieve the desired conditions of the key attributes. Cross-cutting strategies that are assumed to contribute toward more than one IRWM functional area goal are outlined in orange.
Well-Being Model Example: Join a gym, jogs. Notice that yoga is highlighted in orange indicating that doing yoga is a recommended strategy to achieve both physical and emotional health goals.

Performance measures

Performance measures are used to track progress of high priority strategies. However, performance measures are one level removed from measuring the change in the system attributes, and rather specifically quantify the change of a driver or the implementation effectiveness of a strategy. Since we typically expect a time lag in the response of a system attribute as a result of cumulative actions, performance measures allow a demonstration and tracking of the incremental progress of our actions on much shorter and immediate time scales. The achievement of objectives tied to performance measures is hypothesized to directly result in incremental progress toward a functional area goal.
Well-Being Model Example: Miles jogged per week.

2.3.3 LINKAGE TABLE FORMAT

To maintain visual simplicity, the diagram does not include specific connections (i.e., lines and arrows) between components. Linkage tables summarize the critical cause and effect relationships contained in the diagram. For each key system attribute the critical drivers and associated strategies implemented to change the status and/or condition of each driver are provided. Considerations for strategy implementation provide spatial and temporal variation of the drivers that can influence potential strategy effectiveness. Considerations typically include how uncontrollable drivers may affect the opportunity to implement effective strategies.

Table 2.2. Example personal well being linkage table illustrating the critical drivers and associated strategies for the key system attribute of physical health.

Key Attributes	Controllable Drivers	Relevant Strategies	Considerations for strategy implementation
Physical Health	Food intake	Change diet Fruit and veggie days	Food allergies Available time (work/family schedule) to obtain healthier food
	Exercise regime	Join a gym Increase weekly yoga frequency Increase weekly jog miles Increase weekly pushups	Physical injuries or limitations Available time (work/family schedule) to exercise regularly

2.3.4 STRATEGY JUSTIFICATION

A brief narrative that documents the rationale and working hypotheses of how specific IRWM strategies can influence critical drivers, contribute to the desired change in the status of the key system attributes, and ultimately achieve the stated IRWM goals and objectives. The considerations or limitations are explained for each strategy. The economic cost is an inherent implementation consideration of every potential strategy and thus the economic cost should be incorporated into the decision making process when the cost/benefit of specific projects are being evaluated and prioritized for actual implementation. Economic cost is not discussed nor considered within the IRWM conceptual framework.

Strategies to improve and maintain physical health

Physical health is a critical component of personal well being, and the primary indicators are body weight and resting blood pressure, which are desired to be within a defined healthy range given the individual's gender, height and age. The priority strategies to improve and maintain physical health are:

- Dietary changes by reducing daily processed food and caloric intake and increasing consumption of fruits and vegetables. Based on best available data and human health understanding, it is hypothesized that effectively following a healthy diet will significantly contribute to attaining physical health objectives. The specific dietary intake must consider an individual's allergies as to avoid foods that negatively impact health. It is assumed that the availability and attainment of healthier food will require additional daily planning and time due to limited availability compared to fast food and other readily available food with higher calorie content.
- Increased physical exercise can be achieved by increased weekly yoga and jogging frequency, duration and intensity. Based on best available data and human health understanding, it is hypothesized that effectively following a regular exercise regime will significantly contribute to attaining physical health objectives. The increase in physical exercise is assumed to require increased planning and time management by the individual to allocate regular workouts that were previously not scheduled.

2.4 INCORPORATION OF CLIMATE CHANGE CONSIDERATIONS

There is now scientific consensus that the temperature of the earth's climate has been increasing more than natural climatic cycles can explain and that this warming is due to human activities (IPCC, 2007; Oreskes, 2004). Projected climate changes are expected to have a number of negative impacts on the natural and socioeconomic systems throughout the world. Recently developed regional downscaling approaches have increased the usability of climate change projection information for regional decision makers. Climate change model predictions specific to California and the Santa Cruz region have been reviewed and incorporated into the IRWM conceptual framework in a format that is intended to be accessible and useful for regional decision makers.

Modeled climate projections and hydrologic responses in the Santa Cruz region are summarized below. The potential impacts of these future climatic and hydrologic changes are then evaluated in the context of each of the IRWM functional areas to identify opportunities for adaptation to reduce the vulnerability of water supply, water quality, aquatic ecosystems and flood hazards in the region. In some instances projected changes may dramatically exacerbate the severity of local water issues, thus providing additional justification for the implementation of effective strategies now. Integration of climate change changes to the IRWM conceptual framework can reduce the vulnerability of local systems to droughts, extreme temperatures and rainfall pattern changes.

2.4.1 CLIMATE PROJECTIONS

All projections of future climate changes are based on models that vary in the structure of climatic dynamics and feedback. In addition, future emissions of greenhouse gases (GHG) are unknown, requiring a range of possible fossil fuels scenarios. Given the large uncertainty in predicting future climatic conditions, the agreement in the direction of change by different models improves confidence in future trends. The pathway leading from global greenhouse gas emissions to atmospheric composition changes, climate changes, and finally to system-level impacts in the Santa Cruz region is indeed complex and requires a multitude of important simplifying assumptions to model such a chain of cause and effect. The cumulative uncertainty resulting from assumptions employed at each step of the process should be considered when using results for decision making. The content of this synthesis represents the current understanding, which is rapidly evolving. A confidence ranking scale has been defined to simply communicate confidence in a number of different climate change projections throughout this document (Table 2.3).

Table 2.3. Ranking scale used to communicate general confidence in a number of future climate change projections.

Confidence Ranking	Description
High	General scientific agreement of conclusion that is supported by a number of monitoring data, modeling results, research, or best available scientific information.
Moderate	Scientifically supported but consensus or agreement is not present due to lack of information, moderate differences between studies, or limitations for drawing general conclusions from limited scientific information.
Low	Lack of information or conflicting results between studies, model outputs, expert opinions, and/or research findings.

During recent years a number of valuable sources have been developed to facilitate incorporation of global climate change projections to regional planning processes (e.g., http://cal-adapt.org/), along with statewide (Cayan et al., 2009) and regional studies. A recent study by the USGS downscaled 250 km resolution projection data provided by the International Panel on Climate Change (IPCC) to 12 km resolution over a 100-yr time frame, analyzed the outputs for the Santa Cruz region, and used them to drive hydrologic models (Flint et al., 2012). The researchers chose to use projections from global climate models and emission scenarios that have proven capable of simulating recent historical climate for California: the Parallel Climate Model (PCM) developed by National Center for Atmospheric Research (NCAR) and the National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory (GFDL) model (see Flint et al., 2012 for details). The A2 greenhouse gas emissions scenario (medium-high future emissions) was used, which most accurately reflects the measured data in California (Flint et al., 2012).

Tables 2.4 and 2.5 below summarize relevant findings from the USGS study (Flint et al., 2012), which showed strong evidence for temperature changes in the future, but disagreement between models for future precipitation patterns. Temperature projections showed an increase of 3-4° C for average monthly maximums and an increase in the variability (20-30% larger standard deviation) above the historic reference period (1971-2000), with spring and fall months experiencing warmer temperatures (see Table 2.4). Sea levels are projected to rise 1.0-1.4 cm above 2010 levels, expanding the coastal areas inundated during a 100 year flood event. While there is disagreement amongst climate model projections as to the timing of precipitation patterns, there is agreement that the future will be generally drier, resulting in a higher frequency of droughts and less groundwater recharge (see Table 2.5).

2.4.2 VUNERABILITY ASSESSMENT

Borrowing from the ICLEI (2007) climate change guide for local governments, we provide a vulnerability assessment of potential impacts to provide regional managers with a clearer understanding of the relative sensitivity and adaptability of Santa Cruz water systems to future climatic conditions. Vulnerability analysis is a planning tool now applied at multiple spatial scales throughout out California (2NDNATURE, 2010) and in the Santa Cruz region (Griggs and Haddad, 2011). Below we define the terms and considerations for evaluating the relative sensitivity, adaptive capacity and vulnerability of the key attributes within each IRWM functional area. These definitions are used to provide a preliminary vulnerability assessment and identify potential climate change adaptation opportunities within the Santa Cruz regional IRWM context. Collation of climate change science into an accessible format should be an ongoing effort as new information becomes available and the adaptation process evolves over time to incorporate new perspectives, priorities and tools.

PROJECTED CLIMATE CHANGES FOR THE SANTA CRUZ REGION

Changes are summarized for selected climate variables that were quantified by a recent USGS study (Flint et al., 2012) unless otherwise indicated. Key seasonal changes are bolded.

Climate variable	Projected changes by 2100	Confidence ranking	Supporting evidence	Seasonal and spatial patterns
Average maximum air temperatures (30 yr intervals)	↑ Expected to increase 3-4ºC above the historic reference period of 1971-2000	high	Climate model agreement. Projections are consistent with statewide projections (Cayan et al., 2009).	High spatial variability with the largest changes expected in the Santa Cruz mountains. **Warmer temperatures are projected to extend further into fall months** compared to the historic reference period of 1971-2000.
Air temperature variability (30 yr intervals)	↑ Expected 20-30% larger standard deviation than the historic reference period of 1971-2000	high	Climate model agreement. Projections are consistent with statewide projections made in other studies (Cayan et al., 2009).	Increased variability but reduced range of extreme temperatures. Largest changes expected in the Santa Cruz mountains with a high degree of spatial variability across the region.
Sea levels	↑ Expected 1-1.4m rise above 2010 elevations	high	Standardized projections with general model agreement (Knowles, 2010), data available at www.caladapt.org.	Coastal low lying areas and areas adjacent to streams most vulnerable when coupled with high tides during a high runoff event.
Annual precipitation totals (30 yr intervals)	⇔ Direction of change undetermined	low	Climate models disagree on the direction of change, but both show the most pronounced changes during winter months. Climate models disagree on which months are responsible for annual precipitation changes.	Total annual precipitation changes cannot be determined, but **projections indicate less precipitation in the fall and spring with the timing of peak annual precipitation shifting from January to February.** Summers are projected to be longer and drier.
Precipitation variability (30 yr intervals)	⇔ Expected < 10% larger standard deviation than the historic reference period of 1971-2000	low	Very small changes (<10%) are detected which may be smaller than the uncertainty associated with the model outputs.	Largest increases in precipitation variability projected in the Santa Cruz mountains.

DESIGNED BY
2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

PROJECTED HYDROLOGIC CHANGES FOR THE SANTA CRUZ REGION

Changes are summarized for selected hydrologic variables that were quantified by a recent USGS study (Flint et al., 2012) unless otherwise indicated. Key seasonal changes are bolded.

Hydrologic variable	Projected change by 2100	Confidence ranking	Confidence evidence	Seasonal and spatial patterns
Drought frequency	↑ 50% increase in frequency of occurrence (above historic reference period of 1971-2000)	high	Agreement between models.	Historically in the Santa Cruz region about 4 to 5 droughts occurred in 90 years. **Future projections include more than one drought every decade, with a multi-decadal drought for the GFDL-A2 model projection at the end of the 21st century. Additionally, summers are projected to be longer and drier.**
Groundwater recharge	↓ 10-30% decrease (50-200 mm/yr) (above historic reference period of 1971-2000)	high	Agreement of change direction between models regardless of precipitation and runoff disagreements between models.	Reductions across most areas of the region, with slight increases in the San Lorenzo River basin recharge zone, as well as along the coastal plain. The largest recharge reductions are in the Santa Cruz mountains. **Peak recharge shifts from January to February and the largest recharge decreases occur in fall.** There is disagreement as to whether recharge increases or decreases in spring.
Potential evapotranspiration	↑ 0-5% increase (0-10 mm/yr) (above historic reference period of 1971-2000)	moderate	Agreement of change direction between models, but very small changes are detected	**Largest changes in summer months with very little or no change in winter months.**
Climatic water deficit*	↑ 4-25% increase (above historic reference period of 1971-2000)	moderate	Model agreement on change direction, wide range of change predictions.	Substantial variation of changes across the region. This will create generally drier soil moisture conditions in watersheds which will shift zones of habitat suitability for vegetation.
Annual runoff	↔ Direction of change undetermined	low	Model disagreement of change direction and magnitude during all seasons.	**Possible runoff increases during winter months, along with changes in seasonal runoff volumes for fall and spring.** Variation across the region with possible larger effects in Zayante Creek than San Lorenzo River. GFDL-A2 model shows all flows except the very highest are lower than historical flows, and the highest flows exceed historical flows by about 20–30 percent. In the PCM-A2 projection, low flows are somewhat lower than historical flows, whereas the top 40 percent of flows are higher than the historical period (1971-2000).

* Climatic water deficit integrates the effects of increasing temperatures and varying precipitation patterns by quantifying the difference between evapotranspiration and soil moisture storage. It is calculated as the amount by which potential evapotranspiration exceeds actual evapotranspiration. An increase in climatic water deficit indicates a more water stressed condition and in Mediterranean climates can be thought of as a surrogate for irrigation water supply availability.

Vulnerability is the susceptibility of a system component to harmful impacts due to climate change. The degree of vulnerability is used to identify management actions that may be able to reduce the negative consequences of climate change impacts. The vulnerability assessment provides a context to focus discussions on IRWM strategies that also can serve as potential adaptation actions and may directly improve our preparedness for projected climate changes.

Sensitivity

Sensitivity is the degree to which system components (e.g., water supply, stream habitat quality, or flood hazards) respond to climate conditions (e.g., temperature and precipitation) or system impacts (e.g., stream temperature increases or reduced recharge). If the system or system component is likely to be strongly affected by future climatic conditions then it is considered sensitive. Table 2.6 defines the relative sensitivity scale. Factors considered when determining the relative degree of sensitivity include:

- The degree of exposure of the impact to climate change.
- The existing stressors in the system and whether projected future climatic conditions would exacerbate these stressors.
- The existing balance of resource demand and supply such that climate may increase demand and/or reduce supply.

Table 2.6. Scoring definitions for sensitivity to climate change impacts.

Sensitivity	Definition
High	The system responds measurably to an impact based on historical observations or modeling studies.
Moderate	The system response to an impact has not been measured, but based on our understanding system function there are likely to be direct or indirect responses.
Low	The system does not respond measurably to impacts and based on understanding of system function there are not likely to be direct or indirect responses.

Adaptive capacity

Adaptive capacity reflects the inherent natural ability of a system or system components to accommodate climate change without any human intervention. Table 2.7 defines the categories of the relative adaptive capacity scale. In determining how adaptive a system is to climate change the following elements are considered:

- Current level of stressors and flexibility to respond to future stressors. Can or has the system component adapted to historic climatic changes or inclement conditions?
- Are there any barriers (legal, physical, biological) to the system's abilities to accommodate adjustments in response to future climate?
- Are there efforts currently underway that would increase adaptability (e.g., water conservation)?

Table 2.7. Scoring definitions for adaptive capacity to climate change impacts.

Adaptive Capacity	Definition
High	The system is expected to accommodate climate changes and expected impacts in ways that avoid negative consequences.
Moderate	The system has some capacity to adjust, and the degree of negative consequences will depend on the magnitude of individual and cumulative impacts.
Low	The system has little or no capacity to accommodate expected impacts so that negative impacts cannot be avoided.

Vulnerability

Vulnerability is the susceptibility of a system component to harmful impacts due to climate change. The vulnerability of systems to specific climate change impacts is determined by combining sensitivity and adaptive capacity scores in the manner outlined in Table 2.8. System components that have high sensitivity to climate changes and a low capacity to adapt are considered to be highly vulnerable to climate changes. As sensitivity decreases the higher weighting of adaptive capability is preserved, such that even a system component that is considered not sensitive to climate change but has a low ability to adapt is considered moderately vulnerable.

Table 2.8. Vulnerability ranking matrix, taken from 2NDNATURE (2010)

		Sensitivity		
		High	Moderate	Low
Adaptive Capacity	High	Moderate	Low	Low
	Moderate	High	Moderate	Low
	Low	High	High	Moderate

Our confidence in the vulnerability scores is limited by the available science and body of information used to score sensitivity and adaptability. It must be noted that these determinations for both sensitivity and adaptive capacity are somewhat subjective and depend upon the perspective and information considered.

3 WATER SUPPLY CONCEPTUAL MODEL

3.1 GOAL

Provide a safe, reliable and affordable water supply to meet current and expected regional demand without causing undesirable environmental impacts.

3.2 OBJECTIVE

Ensure a reliable and sustainable local water supply through strategies that diversify the supply portfolio, develop production from alternative sources, protect and enhance surface and groundwater, and maximize efficient delivery and use.

3.3 DIAGRAM

Water supply is a continued balance between available water sources and community demand, resulting in two distinct supply (Figure 3.1) and demand (Figure 3.2) diagrams.

3.4 LINKAGE TABLE

Table 3.1 is the Water Supply linkage table.

3.5 STRATEGY JUSTIFICATION

3.5.1 REGIONAL WATER SOURCES AND PRESSING ISSUES

Table 3.2 provides a regional summary of the range of current wet and dry year annual production volumes by source and service populations for each of the 6 water districts and other unregulated private users. Figure 3.3 presents the service area of each water district. As of 2012, 99% of the average annual 34,000 acre feet of water used for public and private supply is extracted from local surface and groundwater sources. Approximately 60% of the annual supply is extracted from groundwater aquifers and the remaining portion comes from surface water sources. One percent is currently supplied from recycled water processes.

The Mediterranean climate of the Central Coast is characterized by 80% of the annual rainfall occurring in a 5 month period (November to March). The region is dependent on surface and groundwater storage during the dry summer months when seasonal water demand reaches its peak. Groundwater extraction in the region continues to exceed the annual recharge and the continued reliance on groundwater from the major aquifers (see Figure 3.3) as a reliable future supply is in question. While demand varies substantially across user types and locations, within the regional population of 262,000 users there is an average estimated per capita demand of 0.14 ac ft per year.

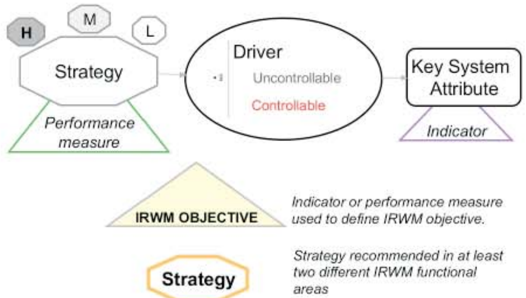
The primary issues facing each water district vary depending primarily upon which water source type the district relies. For instance, Santa Cruz Water District (SCWD) relies on surface water sources and faces the lack of adequate water supply during droughts due to the wide range in yield from year to year and the limited surface water storage capacity (Erler & Kalinowski, 2011). In comparison the Soquel Water District (SqCWD)

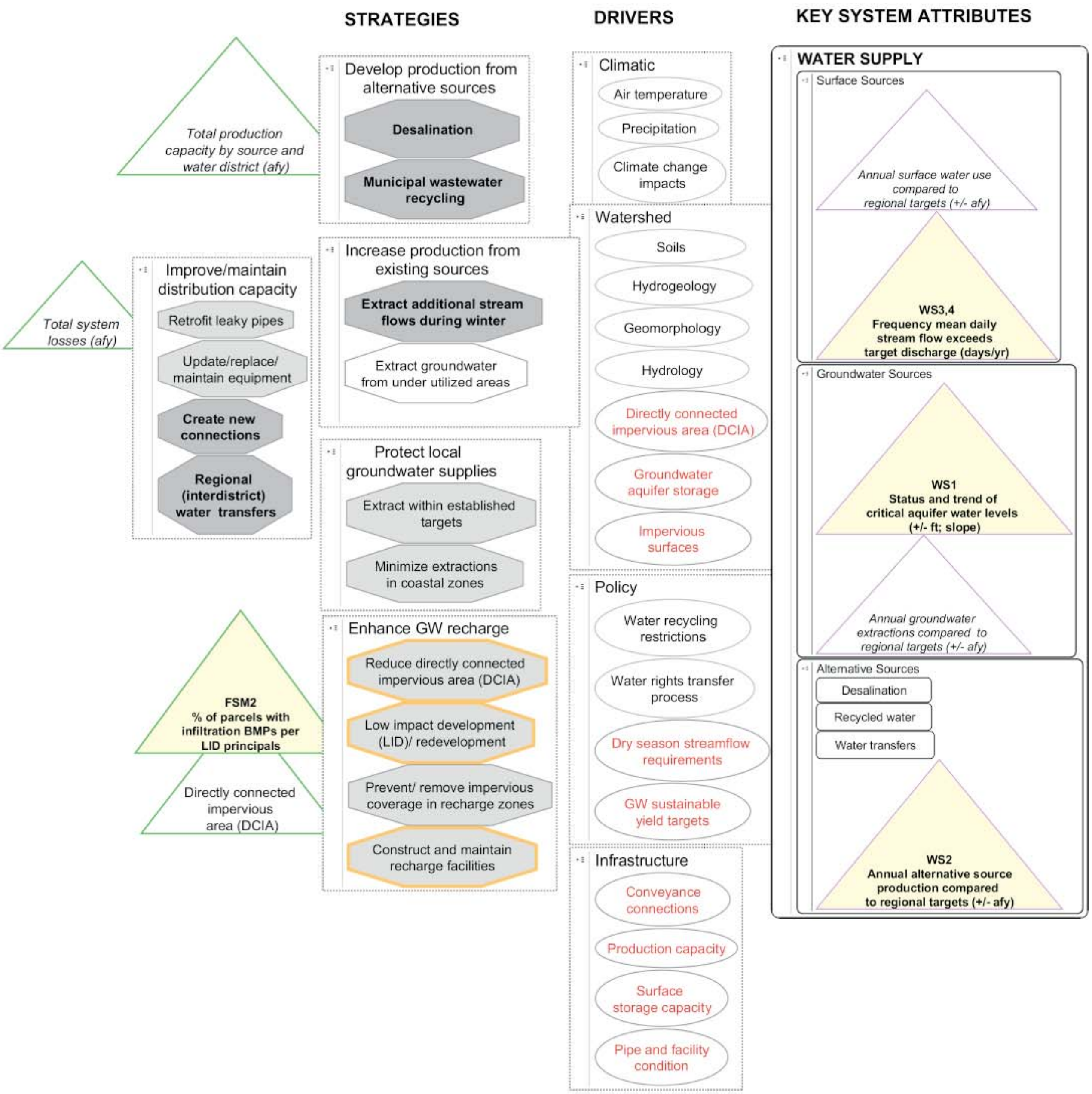
Santa Cruz IRWMP Update
Functional Area: Water Supply
Conceptual Diagram

SUPPLY

GOAL - Provide a safe, reliable and affordable water supply to meet current and expected regional demand without causing undesirable environmental impacts.

OBJECTIVE - Ensure a reliable and sustainable local water supply through strategies that diversify the supply portfolio, develop production from alternative sources, protect and enhance surface and ground water, and maximize efficient delivery and use.



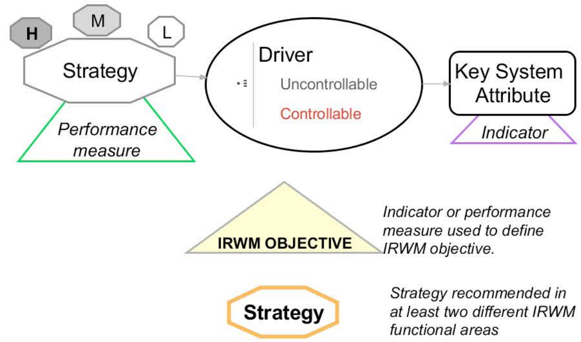


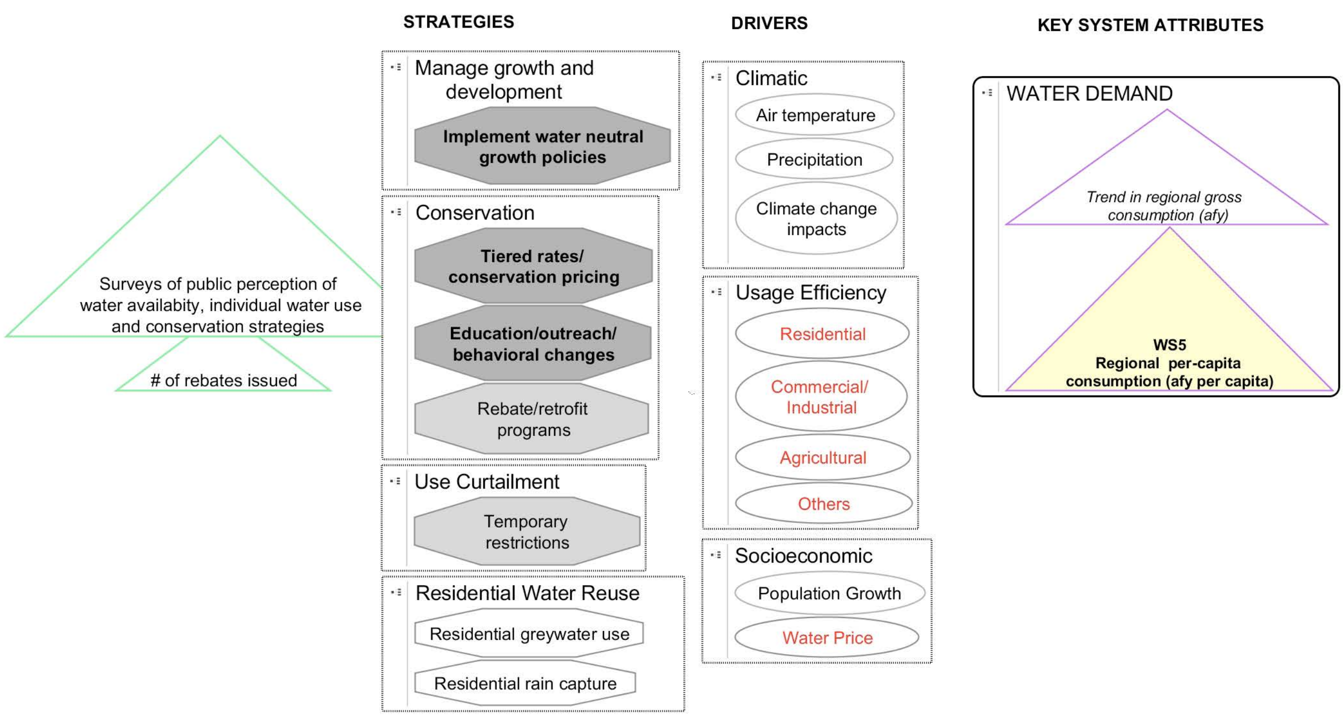
Santa Cruz IRWMP Update
Functional Area: Water Supply
Conceptual Diagram

DEMAND

GOAL - Provide, safe, reliable and affordable water supply to meet current and expected regional demand without causing undesirable impacts.

OBJECTIVE -Reduce per capita water demand to sustainable levels.





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TEL: 831.426.9119
FAX: 831.426.7092
www.2ndnaturellc.com

WATER DEMAND DIAGRAM

FIGURE 3.2

WATER SUPPLY LINKAGE TABLE

See Figures 3.1 and 3.2 for the associated water supply and water demand diagrams.

Expected relative impact of strategy on key attribute(s)

High | Moderate | Low

Key attribute	Controllable driver	Relevant strategies	Considerations to prioritize strategy implementation
WATER SUPPLY	Production capacity	*Develop production from alternative sources*	
		Desalinization	Distribution capacity GHG emissions Energy requirements Potential impacts on future urban development Other potential environmental impacts
		Municipal wastewater recycling	Restrictions on recycled water uses Distribution capacity Demand for recycled water Dry weather inflows
		Conjunctive water use and transfers	Water rights transfer process isssues Distribution capacity
		Increase production from existing sources	
		Extract additional stream flows throughout region during winter conditions	Seasonal stream flow requirements Distribution capacity Surface water storage capacity Potential aquatic ecosystem impacts
		Extract groundwater from under utilized areas	Groundwater sustainable yield targets Potential long-term supply availability
	Conveyance connections	*Increase distribution capacity*	
		Create new connections	
	Pipe and facility condition	Retrofit leaky pipes Update/replace equipment	Knowledge of priority repairs
	Groundwater aquifer storage	*Protect groundwater resources*	
		Construct and maintain groundwater recharge facilities	Infiltration capacity of soils Hydrologic connectivity to groundwater aquifer
		Extract within established targets Minimize groundwater extractions in coastal zones	Availablity of alternative water sources
		Prevent/remove impervious coverage in existing recharge zones	Impervious density/distribution Infiltration capacity of soils Hydrologic connectivity to groundwater aquifer
		Reduce directly connected impervious area (DCIA) Low impact development (LID)/redevelopment on public/private parcels	Infiltration capacity of soils Potential flooding implications of modifications
WATER DEMAND	Water price	Tiered rates /conservation pricing	Water pricing policies Customer affordability
	Usage efficiency	Education/Outreach on consevation strategies	Priority audience accessiblity Anticipated impacts on key offenders
		Implement water neutral growth policies	
		Temporary use restrictions	Impact on overall water usage Socio-economic impacts
		Rebate/retrofit programs	Priority audience accessiblity
	Residential water reuse	Residential greywater use Residential rain capture	

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TEL: 831.426.9119 FAX: 831.426.7092
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EXISTING WATER DEMAND AND PRODUCTION BY WATER DISTRICT WITHIN SANTA CRUZ IRWM REGION

METRIC	CITY OF SANTA CRUZ (SCWD)	SAN LORENZO VALLEY WATER DISTRICT (SLVWD)	SCOTTS VALLEY WATER DISTRICT (SVWD)	SOQUEL CREEK WATER DISTRICT (SqCWD)	CENTRAL WATER DISTRICT (CWD)	OTHER USERS	Santa Cruz IRWM REGION
AVERAGE ESTIMATED DEMAND - acre-fee per year (AFY)	**10,808**	**1,801**	**1,507**	**4,610**	**580**		
DRY YEAR PRODUCTION BY SOURCE TYPE (AFY)	**9,821**	**2,320**	**1,507**	**4,610**	**580**	**8,500**	**27,338**
SURFACE WATER	9,299	830	0	0	0	1,100	**11,229**
GROUNDWATER	522	1,490	1,358	4,610	580	7,400	**15,960**
SUPPLEMENTAL SUPPLY	0	0	149	0	0	0	**149**
SURPLUS / (DEFICIENCY)	(987)	519	0	0	0	8,500	**8,032**
NORMAL YEAR PRODUCTION BY SOURCE TYPE (AFY)	**12,675**	**2,250**	**1,507**	**4,610**	**500**	**6,500**	**28,042**
SURFACE WATER	12,153	1,770	0	0	0	1,500	**15,423**
GROUNDWATER	522	480	1,358	4,610	500	5,000	**12,470**
SUPPLEMENTAL SUPPLY	0	0	149	0	0	0	**149**
SURPLUS / (DEFICIENCY)	1,867	449	0	0	(80)	6,500	**8,736**
2010 POPULATION SERVICED	91,300	22,200	10,300	37,700	2,700	31,900	**196,100**
DRY YEAR PER CAPITA USE (AFY/PER CAPITA)	0.12	0.08	0.15	0.12	0.21	0.00	

DATA SOURCE INFORMATION

METRIC	SCWD	SLVWD	SVWD	SqCWD	CWD	OTHER USERS	Santa Cruz IRWM REGION
SURFACE WATER GROUNDWATER SUPPLEMENTAL SUPPLY	*SCWD (UWMP Tables 5-6, 5-8, 12/3/12 MEM to W.Comm)*	*SLVWD (draft UWMP* Tables 3-3, 4-1a, b)	*SVWD 2011 (UWMP - Tables 6-4, 6-6, 6-7)*	*SqCWD, 2011 (UWMP)*	*CWD pers com*	*Estimate by Co EHS; Others include private wells and illegal diversions.*	*Calc:sum of water district values*
NORMAL YEAR PRODUCTION BY SOURCE TYPE	*CALC: Sum of all sources*						
SURFACE WATER GROUNDWATER SUPPLEMENTAL SUPPLY	*SCWD (UWMP Tables 5-6, 5-8, 12/3/12 MEM to W.Comm)*	*SLVWD (draft UWMP* Tables 3-3, 4-1a, b)	*SVWD 2011 (UWMP - Tables 6-4, 6-6, 6-7)*	*SqCWD, 2011 (UWMP)*	*CWD pers com*	*Estimate by Co EHS; Others include private wells and illegal diversions.*	
2010 POPULATION SERVICED	*Population numbers rounded to nearest 100 people*						
	SCWD (UWMP Table 4-6)	*SLVWD 2009*	*SVWD 2011*	*SqCWD*	*CWD pers com*	*CALC: 2010 Census-WD service pops*	
DRY YEAR PER CAPITA USE (AFY/PER CAPITA)	*CALC: 2010 Production/ 2010 Population*						

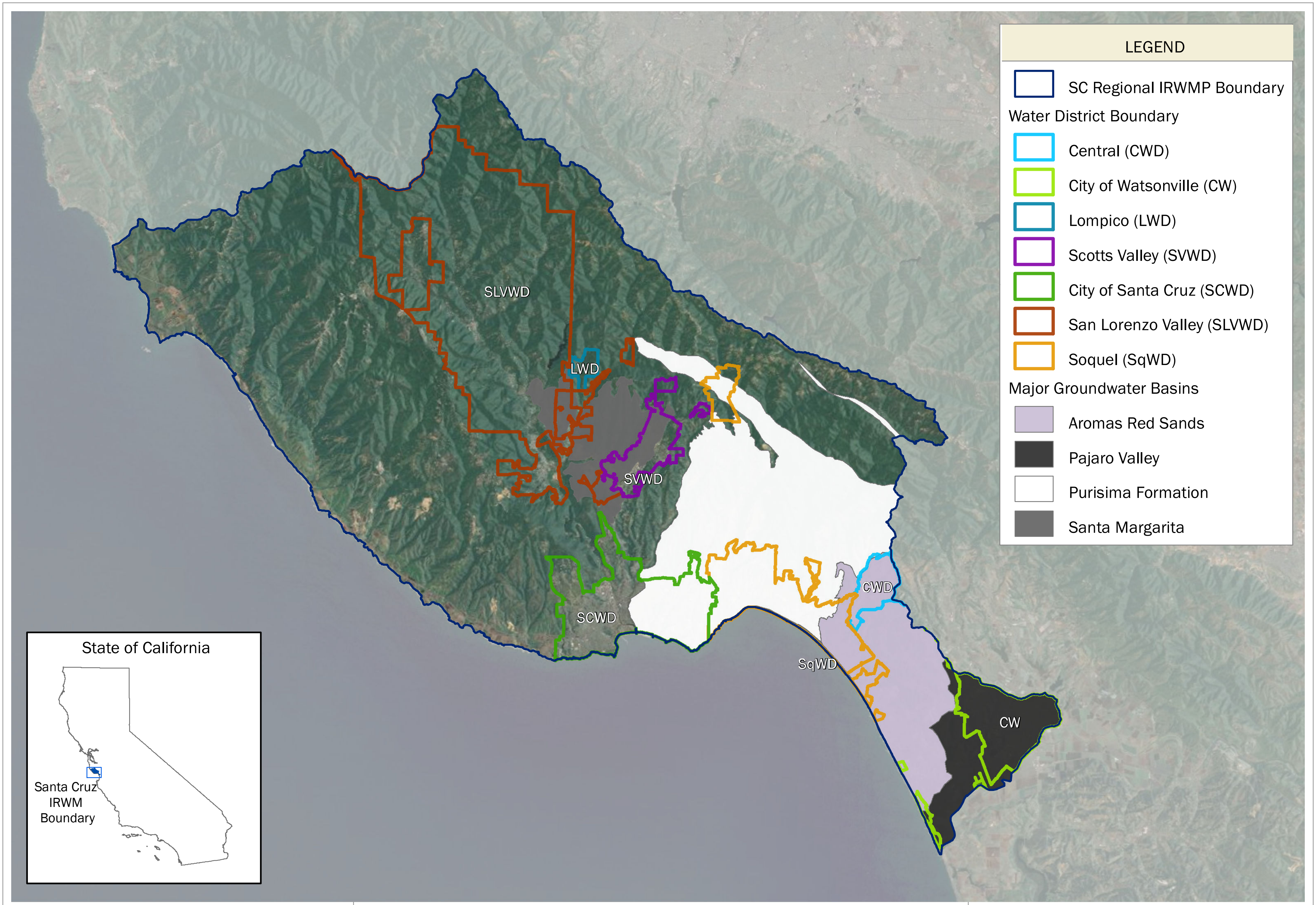

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Figure 3.3: Major groundwater basins and water district service area boundaries in the Santa Cruz Region. NOTE: all water users outside the water district service area boundaries are categorized as *OTHER* users on private wells.

and Central Water District (CWD) rely solely on groundwater extractions from the Purisma Formation and Aromas Red Sands aquifers (see Figure 3.3) to meet supply needs. Based on the current understanding of the Soquel-Aptos Area Basin, the total sustainable yield is assumed to be no more than 6,200 afy in the Purisima Formation and no more than 3,200 afy in the Aromas Red Sands (Johnson et al., 2004). As of 2007, SqCWD had been pumping in excess of the targets for a number of years, contributing to overdraft conditions and a commensurate rate of saltwater intrusion in the area. SqCWD set targets to reduce its pumping to no more than 4,800 afy: no more than 3,000 afy from the Purisima Formation and no more than 1,800 afy from the Aromas Red Sands (SqCWD and CWD, 2007). CWD's annual pumping of 143 afy in the Purisima Formation and 479 afy in the Aromas Red Sands meets 2007 target objectives for pumping within the localized sustainable yield (SqCWD and CWD, 2007). Table 3.2 indicates recent usage by SqCWD and CWD are within the 2007 extraction targets.

Reliability of the regional water supply can be improved either by increasing supplies or reducing demands on surface and groundwater sources. Priority strategies to increase supply include development of alternative water sources, increased groundwater recharge, and the capture and exchange of additional winter runoff. A recent UCSC (2012) study in cooperation with the California Energy Commission provides a review of the water supply vulnerability of many Santa Cruz regional water agencies and documents viable opportunities, incentives, and tools to enhance the development of a strategic groundwater drought reserves as an important climate change adaptation strategy. Key opportunities to reduce demand are through water conservation strategies and management of future population growth. Regional coordination of future water supply management is critical to achieve the Santa Cruz regional IRWM water supply goal.

3.5.2 CLIMATE CHANGE IMPLICATIONS

The local climate change projections suggest longer and drier summers, an increased frequency of droughts, increased evapotranspiration rates and reduced groundwater recharge (see Tables 2.4 and 2.5). These projected changes will exacerbate current water supply issues and reduce the reliability of the local water sources to meet demand.

Using the best information available, we provide an assessment of the vulnerability of key attributes of the water supply system to specific climate changes in Table 3.3. The table lists stressors on key attributes within the water supply system (closely related to the drivers). For simplicity, Table 3.3 includes only those climate change projections for which confidence is relatively high. The table also indicates whether opportunities exist to reduce vulnerability to climate change impacts with the implementation of management strategies.

3.5.3 WATER SUPPLY INCREASE STRATEGIES

3.5.3.1 Alternative water sources

Opportunities exist for regional water districts to achieve the IRWM water supply goal and minimize negative environmental impacts through (1) better management of water extraction from surface and groundwater resources and (2) increased production and availability from alternative water sources. The most feasible alternative sources include desalination, municipal wastewater recycling and conjunctive water use and transfers between water districts; each of these sources has specific opportunities and constraints detailed below.

VULNERABILITY ASSESSMENT OF WATER SUPPLY KEY ATTRIBUTES

The sensitivity and adaptive capacity for each potential impact was determined based on the approach and criteria outlined in Section 2.4. The vulnerability is the combined result of sensitivity and adaptive capacity (see Table 2.8). Since alternative water sources have yet to be fully developed and are not be directly impacted by climate changes, they are excluded from the analysis.

Key attribute	Stressors	Relevant projected climatic/hydrologic changes	Expected impact of future climate conditions	Sensitivity	Adaptive capacity	Vulnerability	Can future impact of climate change be lessened by strategy implementation?
WATER SUPPLY							
Surface water sources	Population growth, Aquatic ecosystem streamflow requirements	Drought frequency increase	Surface water reliability reduction, Increased potential for water use conflicts	h	l	h	YES Strategies that reduce reliance on surface and groundwater sources.
		Seasonal precipitation/ runoff pattern changes	Surface water reliability reduction, Increased potential for water use conflicts	h	l	h	YES Strategies that reduce reliance on surface and groundwater sources.
		Increased evapotranspiration	Greater evaporative losses from surface reservoirs, Drier summer soil moisture conditions	h	l	h	NO
	Aquifer overdraft, Saltwater intrusion	Groundwater recharge reductions, Sea level increases	Reduced groundwater availability	h	m	h	YES Strategies that reduce reliance on surface and groundwater sources. Strategies that reduce groundwater pumping in coastal zones. Strategies that increase groundwater infiltration.
WATER DEMAND							
Water demand	Population growth	Average temperature increase, Temperature variability increase, Drought frequency increase	Extended period of peak demand	h	h	m	YES Strategies to reduce demand can reduce vulnerability of surface water and groundwater sources.

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The need for an alternative water supply has become clearer. Existing surface diversions are targeted for future reductions to improve stream habitat conditions, and sustainable yields for the groundwater basins relied upon by SqCWD have been revised downward from previous estimates. Climate change projections for the region include increased drought frequency, an extended dry season (Flint et al., 2012), and more severe droughts throughout the state (Cayan et al., 2009); all of which will exacerbate water shortages during droughts.

Desalination: Desalination offers a viable opportunity to meet the IRWM water supply goal to provide a reliable water supply, particularly during droughts, and meet current and future demands while producing a relatively minimal environmental impact. Desalination is appealing because unlike recycled water, the water produced is considered to be of drinking water quality or better and can therefore be distributed through a city's existing plumbing infrastructure. Alternative supplemental supplies from drilling additional wells or water exchanges have been determined to be less viable options compared to desalination (City of Santa Cruz, 2010). Desalination comes with substantial initial costs associated with facility and distribution infrastructure construction. The project concept adopted by the Santa Cruz City Council involves building a seawater intake and desalination plant with a production capacity of 2.5 mgd (2,800 acre feet/yr) and the distribution system. The initial implementation of the plant would be primarily for drought protection and would be used intermittently during dry seasons and during very dry years with some water transferred to Soquel Creek Water District (SqCWD) to lessen its reliance on groundwater and reduce the threat of seawater intrusion.

Disadvantages of desalination include potential harm to marine life, initial cost, and energy requirements. The future risk of additional urban development as a result of increased water availability from desalination is a predominant concern within the community. The estimated cost for design, permitting, property acquisition, and construction is approximately $116 million to be shared between the City of Santa Cruz and SqCWD. The cost of water production will increase from current levels and some fraction of those costs would be passed on to customers.

Municipal wastewater recycling: Municipal wastewater recycling has a significant regional potential to directly reduce the annual volume of potable water production needed. By removing solids and impurities waste water can be made suitable to irrigate landscaping, golf courses and agricultural lands, thereby reducing the volumes of potable water used for irrigation. Recycled waste water is also being used by other water agencies in California to recharge groundwater aquifers, to create strategic seawater intrusion barriers and to supplement water inputs to wetlands, streams or other natural systems. Given recent advances in wastewater treatment technology and health studies of indirect potable reuse, many predict that planned indirect potable reuse will soon become more common. Recycling waste and gray water requires far less energy than treating salt water via desalination. The opportunities for use of municipal waste waters to meet non-potable water demands in the region have not yet been incorporated to the extent feasible and regional water districts are encouraged to explore and implement feasible recycling projects to increase water re-use in the region by 2030. The increased use of reclaimed water will require significant infrastructure development and upgrades.

Scotts Valley Water District (SVWD) is the first district in the region to use municipal waste water to supplement their supply needs. In 2002, the City of Scotts Valley upgraded its treatment plant to include tertiary treatment and the system has been recycling 200 acre ft/yr of the 950 acre ft/yr dry season wastewater inflow (~ 20%) for residential and commercial landscape irrigation. The City of Santa Cruz (CSC) operates a wastewater collection, treatment, and disposal facility at Neary Lagoon with a current dry season inflow of approximately 9,750 acre ft/yr. The CSC wastewater plant is currently not permitted to produce recycled water for offsite use, and to date produces 175 to 225 acre ft/yr for internal facility use, but given the 20% recycled capacity of SVWD, CSC could potentially recycle 1,950 acre ft/yr for irrigation purposes. The quality of waste water produced by the CSC is suitable for limited landscape and agricultural irrigation or sewer system flushing. The CSC investigated potential opportunities to use recycled waste water for landscape irrigation, agricultural irrigation on the North Coast, and groundwater recharge (SCWD, 2011). Opposition to use of recycled waste water for North Coast agricultural irrigation by California Department of Parks and Recreation and organic farmers has reduced the feasibility of this potential use. Irrigation opportunities for golf courses using reclaimed water throughout the region should be considered. Use of recycled groundwater recharge in the City's jurisdiction may not be practical due to several geological and operational constraints, as well as current regulatory constraints, that limit feasibility (Kennedy/Jenks Consultants, 2010).

Implement conjunctive water use and transfers: Conjunctive water use is a way to use regional water sources more efficiently by transferring water among regional water districts to better align the seasonal supply and demand variations. For example, there is an opportunity to divert additional winter flows from the San Lorenzo River to SVWD and Soquel Creek Water District (SqCWD) for direct use during winter months. These transfers would increase the capture of additional winter flows and reduce the annual groundwater extractions by these water districts by augmenting their supply with available surface waters. Transferred volumes could also be used for groundwater recharge in critical areas. The greatest limitation to this strategy is the current lack of infrastructure to transfer water throughout the region. Major upgrades would be required and have been determined to be technically feasible (Kennedy/Jenks Consultants, 2010). The development of regional water transfer infrastructure would create a number of future opportunities to improve the management of available water resources.

3.5.3.2 Existing water sources

Opportunities exist to improve the management of local surface and groundwater to ensure long-term viability.

Groundwater: Over-extraction from the two primary aquifers in the region, the Purisma Formation and Aromas Sands Formation (see Figure 3.3), has reduced aquifer water levels well below historic conditions and resulted in extensive saltwater intrusion at the coast. Current rates of groundwater extraction from specific locations within the Purisma and Aromas are not sustainable and opportunities exist to implement strategies to reduce extractions and increase recharge. It is recommended that the regional water districts utilize available information, studies and data to define annual groundwater extraction targets and populate Table 3.4. As these extraction targets are developed, potential reductions in groundwater recharge in the future as a result of climate change should be considered. In addition, the expected influence of future groundwater extraction rates on the rate of saltwater intrusion should also be considered as a management strategy to reduce and/or eliminate the progression of saltwater intrusion. Opportunities may exist to extract groundwater from other underutilized groundwater aquifers or areas within the region.

Annual recharge to priority aquifers can be increased through implementation of specific projects, such as the construction and maintenance of recharge basins and the prevention and/or removal of impervious surfaces in known recharge zones. Regional opportunities to increase the fraction of rainfall that is infiltrated can be realized by disconnecting impervious surfaces, increasing localized parcel-based infiltration though low impact development (LID) on both private and public lands, as well as other strategies that reduce the volume of runoff generated. In order to have a measurable impact on the amount of water lost as runoff in developed areas, these strategies would have to be implemented on a vast spatial scale throughout the impervious areas within the region (see Figure 6.2 for regional urban land use distribution). Increasing infiltration opportunities have benefits across the IRWM functional areas and will mitigate several projected climate change impacts,

ESTIMATED YEAR 2030 WATER DEMAND AND PRODUCTION BY WATER DISTRICT WITHIN SANTA CRUZ IRWM REGION

METRIC	CITY OF SANTA CRUZ (SCWD)	SAN LORENZO VALLEY WATER DISTRICT (SLVWD)	SCOTTS VALLEY WATER DISTRICT (SVWD)	SOQUEL CREEK WATER DISTRICT (SqCWD)	CENTRAL WATER DISTRICT (CWD)	OTHER USERS	Santa Cruz IRWM REGION
ESTIMATED DRY YEAR DEMAND - acre-feet per year (AFY)	**11,419**	**2,409**	**1,766**	**4,116**	**600**	**8,500**	**28,810**
DRY YEAR PRODUCTION BY SOURCE TYPE (AFY)	**9,704**	**2,150**	**1,501**	**2,900**	**600**	**8,500**	**25,355**
SURFACE (DRY WY)	6,382	820	0	0	0	1,100	**8,302**
GROUNDWATER	522	1,330	1,051	2,900	600	7,400	**13,803**
SUPPLEMENTAL SUPPLY	2,800	0	450	0	0	0	**3,250**
SURPLUS / (DEFICIENCY)	-1,715	-259	-265	-1,216	0	0	**-3,455**
NORMAL YEAR PRODUCTION BY SOURCE TYPE (AFY)	**11,419**	**2,409**	**1,766**	**4,116**	**600**	**6,500**	**26,810**
SURFACE (WET WY)	10,557	1,246	0	0	0	1,500	**13,303**
GROUNDWATER	522	1,163	1,316	2,900	600	5,000	**11,501**
SUPPLEMENTAL SUPPLY	340	0	450	1,216	0	0	**2,006**
SURPLUS / (DEFICIENCY)	*0*	*0*	*0*	*0*	*0*	*-2,000*	**-2,000**
2030 PROJECTED POPULATION	98,600	22,520	11,100	39,600	2,900	34,500	**209,220**
DRY YEAR PER CAPITA USE (AFY/PER CAPITA)	0.12	0.11	0.16	0.10	0.21	0.25	

DATA SOURCE INFORMATION

Targets informed by recent production, targeted studies, and desire to provide a safe, reliable and affordable water supply to meet current and expected regional demand without causing undesirable environmental impacts.

METRIC	CITY OF SANTA CRUZ (SCWD)	SAN LORENZO VALLEY WATER DISTRICT (SLVWD)	SCOTTS VALLEY WATER DISTRICT (SVWD)	SOQUEL CREEK WATER DISTRICT (SqCWD)	CENTRAL WATER DISTRICT (CWD)	OTHER USERS	Santa Cruz IRWM REGION
DRY YEAR TARGET PRODUCTION BY SOURCE TYPE (AFY)	*CALC: Sum of all sources*						*CALC: sum by source type*
SURFACE (DRY WY)	*SCWD (UWMP Tables 5-6, 5-8, 12/3/12 MEM to W.Comm)*	*SLVWD (draft UWMP Tables 3-13)*				*Estimate by Co EHS; Others include private wells and illegal diversions.*	
GROUNDWATER			*SVWD 2011 (UWMP - Table 6-4 (DRY) 6-6 (Normal)*	*HydroMetrics, WRI 4/3/2012*	*CWD pers com*		
SUPPLEMENTAL SUPPLY	*SCWD^2 Fact Sheet 2012*			*SqCWD 2012 Update to Integrated Resources Plan 9-18-12*			
NORMAL YEAR TARGET PRODUCTION BY SOURCE TYPE (AFY)	*CALC: Sum of all sources*						
SURFACE (WET WY)	*SCWD (UWMP Tables 5-6, 5-8, 12/3/12 MEM to W.Comm)*	*SLVWD (draft UWMP Tables 3-13)*				*Estimate by Co EHS; Others include private wells and illegal diversions.*	
GROUNDWATER			*SVWD 2011 (UWMP - Table 6-4)*	*HydroMetrics, WRI 4/3/2012*	*CWD pers com*		
SUPPLEMENTAL SUPPLY	*SqCWD 2012 Update to Integrated Resources Plan 9-18-12 & EHS Water Transfer Estimate*			*SqCWD 2012 Update to Integrated Resources Plan 9-18-12 & EHS Water Transfer Estimate*			
2030 PROJECTED POPULATION	*SCWD - UWMP*	*SLVWD - UWMP*	*SVWD - UWMP*	*SqCWD - UMWP - Table 4-1*	*EHS ESTIMATE*		

Recommend regional coordination to define targets collectively.

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RECOMMENDED FORMAT FOR WATER USE TARGET DEFINITIONS BY WATER DISTRICT

TABLE 3.4

including groundwater recharge reductions, a longer warmer dry season, and increased drought frequency. These infiltration strategies are consistent with the strategies recommended by UCSC (2012) to improve water supply security during droughts by implementing regional programs to develop a locally based groundwater drought reserve. The UCSC (2012) priority approaches to replenish aquifers include the capture and harvesting of stormwater via a wide distribution of smaller-scale measures, such as the use of permeable pavements, constructed wetlands, and landscaping that spreads and slows the rate of stormwater runoff. Considerations to determine priority recharge locations include soil infiltration capacity, density and distribution of impervious surfaces, the surface area availability to place infiltration features or reroute surface drainage, and the potential increased risk of localized flooding by implementing the modifications.

Surface water: Excessive surface water extractions can reduce the quality and quantity of habitat of aquatic ecosystems. Identification and achievement of seasonal stream flow targets can guide the timing, amount, and distribution of surface water extractions for water supply and minimize these impacts. The seasonal variability of rainfall makes the collection and storage of adequate surface water runoff during the wet winter months for summer distribution challenging, but opportunities exist to increase extractions of excess runoff from local streams during winter storms for transfer throughout the region, but this strategy would require a substantial increase in infrastructure. In addition, climate change projections suggest an increased frequency of droughts and increased evapotranspiration rates, further reducing the potential reliability of local surface waters for water supply.

3.5.4 DELIVERY CAPACITY AND EFFICIENCY

Regardless of the water sources used to supply the regional community with potable water, the improvement and continued maintenance of the distribution system is critical. The viability of distributing alternative or new local sources of water requires adequate connections and associated infrastructure. Reducing total system losses by ensuring maintenance is a continued priority and will minimize the amount of water production necessary to meet demand. Especially if reliance on local water sources continues, maintaining system delivery efficiency will directly reduce the extraction volumes necessary to meet the the same demand. Challenges associated with obtaining funding to support adequate and regular municipal maintenance actions need to be addressed.

3.5.5 DEMAND REDUCTION STRATEGIES

Annual water demand in the region is dependent upon per-capita water use and the number of users. The expected increases in air temperature and drought frequency have the potential to increase demand without a commensurate increase in water use efficiency. As mentioned above, municipal recycling opportunities can supplement demand for the irrigation users throughout the region. Regional strategies that can reduce per-capita consumption include increasing unit water costs using either tiered rate structures or conservation pricing. Water neutral population growth strategies and water conservation programs can mitigate impacts to water sources. Conservation programs include residential appliance and fixture replacements (toilets, washers, shower heads, etc.), water waste prevention, residential and commercial water audits, large landscape water audits, and education and outreach programs.

3.5.6 ROLE OF EDUCATION AND OUTREACH PROGRAMS

Education and outreach programs that inform the community members about regional water resource issues are considered critical to reducing demand. While it is difficult to isolate their effect from other demand reduction measures, conservation programs contributed substantially to overall demand reduction in the region in recent year as documented by the City of Santa Cruz (SCWD, 2011). The public can be engaged through news media, newsletters, websites, public meetings and speaking events, tabling at local fairs, and distribution of conservation brochures. Distribution of free water conservation devices (e.g., showerheads, faucet aerators, etc.), rebates, and subsidized pricing on rain barrels and high efficiency appliances encourages their adoption throughout the region. School programs teach students about our water resources, residential assistance programs provide leak detection services, and landscape water surveys help residents create water efficient landscapes. Rebates and 'green' business certification programs are key components of commercial and industrial outreach.

Education and outreach programs are rarely able to quantify the benefits of their programs and track behavior changes over time. Often times, the number of volunteers, hours, or people reached is quantified, but there is not a corresponding link to the impact the programs have on the desired outcomes (e.g., reduction in water usage, etc.). The development and implementation of repeatable and standardized surveys to track community perception and behavior regarding personal water conservation actions over time would provide a meaningful standard to report effectiveness of outreach to stakeholders, funders and the public and to identify priority topics and community demographics for future outreach programs.

3.6 STRATEGY IMPLEMENTATION OBJECTIVES

Below are the specific Water Supply strategy implementation objective statements that include desired target conditions by 2030, the working hypothesis of how IRWM strategies will result in objective obtainment and a summary of the data needed to report and track incremental progress. All of the IRWM Water Supply strategy implementation objectives require a coordinated regional effort to define future targets that quantify (1) the sustainable, desired extractions from local surface and groundwater supplies, (2) water production capacity from alternative sources, and (3) desired demand reductions. Table 3.4 provides a simplified format to document the final water supply/demand targets by regional water districts and track progress towards any one of the below IRWM objectives.

WS1. By 2030, meet or exceed target groundwater elevations or maintain increasing trends in groundwater elevations for wells that do not have targets.

Indicator: Minimum groundwater elevations for selected monitoring wells by water district compared to elevation targets and demonstrated net increasing trend in groundwater elevations. Comparisons of targets to actual groundwater elevations reported as +/- ft. Trend reported as +/- slope and statistical significance (see Section 7).

Hypotheses: The coastal groundwater aquifers in the region are currently over drafted and the corresponding groundwater elevations have been decreasing over time, increasing the landward progression of saltwater intrusion. Groundwater elevation targets by 2030 are defined for a series of regional monitoring wells and demonstration of achievement and/or increasing water level trends will demonstrate protection of groundwater resources as a result of multiple effective strategies.

Critical need: Groundwater elevation targets defined by participating water district for specific wells at critical locations to reduce and/or stop the landward progression of saltwater intrusion and minimize additional overdraft.

WS2. **Increase the annual production to meet alternative water source supply targets established by participating water districts by 2030.**

Indicator: Annual alternative source production compared to regional targets. Comparisons of targets to actual annual production reported as +/- afy and +/- % relative to regional targets.

Hypotheses: Alternative sources include desalination, municipal recycling and water transfers. Increasing the maximum potential production from alternative sources will improve flexibility to meet regional demand while also lessening pressure on local surface and groundwater resources. Dry years will be the most critical times for water use from alternative sources to protect the condition of streams, reservoirs and aquifers.

Critical need: Alternative source production targets for participating water districts *(see Table 3.4)*.

WS3. **Reduce the number of days Tier 3 flow targets are not achieved in the San Lorenzo River and North Coast streams.**

Indicator: Frequency that the actual mean daily streamflow is less than the Tier 3 flow target specified in the City of Santa Cruz Habitat Conservation Plan (CSC 2011, pp. 17-19, 113). Objective tracked as number of days per year where mean daily flow is less than target and maximum % deviation of mean daily discharge (cfs) from target by site.

Hypotheses: Ability to achieve in-stream flow targets will indicate both flexibility in supply and improved aquatic habitat conditions.

Critical needs: Identify indicator streams gage(s) and associated critical discharge (cfs) to serve as regional targets at which extractions should cease until levels recover. The determination of specific flow targets should be informed by rigorous surveys and evaluations at critical locations in the respective tributaries. These evaluations should link the hydro-geomorphic conditions with the desired habitat characteristics for salmonids and their supporting ecosystem, therefore providing high confidence that achievement of objective WQ3 corresponds to the desired distribution of suitable habitat.

Objective supports both Water Supply and Aquatic Ecosystem goals.

WS4. **Reduce the number of days each year where streamflow in Soquel Creek is less than 4 cfs between June 1 and December 1.**

Indicator: Frequency that the actual mean daily streamflow is less than the 4 cfs reported as number of days per year when mean daily flow is less than target and maximum % deviation of mean daily discharge (cfs) from target by site.

Hypothesis: Maintenance of summer baseflow in Soquel Creek, 4 cfs as specified in the water rights adjudicated in 1977 demonstrates both flexibility in supply and improved aquatic habitat conditions.

Critical needs. Identify indicator stream gage within Soquel Creek to be monitored.

WS5. **Decrease and maintain per capita consumption for commercial, residential, and agricultural customers to meet 2030 targets specified by each water district.**

Indicator: Regional per capita consumption; Calculate per capita consumption by water district using average water production by district for previous 5 years divided by district average service population for same time period.

Hypotheses: Reducing customer water demand will directly reduce water supply needs. Increases in usage efficiency, conservation and water recycling techniques will directly lessen pressure on the municipal water supply sources. District specific per capita consumption targets will accommodate the difference in per-capita consumption across districts that are due to localized climate and land-use variations.

Critical need: Residential per capita consumption targets defined by water district (see Table 3.4).

4 WATER QUALITY CONCEPTUAL MODEL

4.1 GOAL

Maintain and improve regional surface and groundwater quality to protect beneficial uses.

4.2 OBJECTIVE

Reduce the sources of harmful pollutants (i.e., sediment, bacteria, nitrate, persistent organics and other toxic constituents) and their impacts on aquatic resources.

4.3 DIAGRAM

The conceptual diagram for Water Quality is presented in Figure 4.1, along with pollutant specific diagrams for sediment (Figure 4.2), bacteria (Figure 4.3), and nitrate (Figure 4.4).

4.4 LINKAGE TABLE

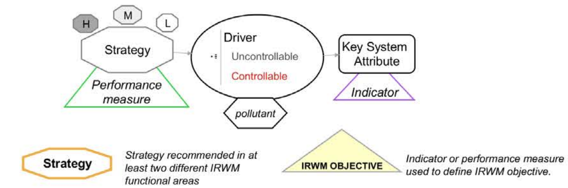
Table 4.1 is the Water Quality linkage table.

4.5 STRATEGY JUSTIFICATION

The water quality conceptual model is focused on the specific pollutants that threaten local surface and groundwater beneficial uses in order to protect water quality standards. The surface and groundwater resources within Santa Cruz County have a wide variety of defined beneficial uses as designated by the State Water Quality Control Board[1]. For simplicity, we have grouped the standard list of beneficial uses based on 4 key attributes: Aquatic Habitat, Domestic Supply, Recreation, and Agricultural Irrigation (Table 4.2). For each beneficial use, the key pollutants known to impair water bodies are shown in the water quality diagram in general order of concern (Figure 4.1). The diagram shows a relative ranking so that pollutants listed at the top of each key attribute list are of greater concern with respect to the listed beneficial use than those at the bottom of the list. Figure 4.5 provides a regional summary of the impaired water bodies for pathogens (i.e., bacteria), nutrients, sediment and pesticides. The sources, forms and environmental fate and transport of these pollutants greatly vary across the region. Since the implementation approach and potential effectiveness of water quality protection and improvement strategies will vary for each pollutant, the isolation and focus by pollutant provides clarity on the hypotheses associated with cause and effect linkages between strategy selection and expected water quality benefits. In development of the IRWM water quality conceptual model, we focused on 3 key pollutants: bacteria, sediment and nitrate for a number of reasons that are included in the description of each pollutant below.

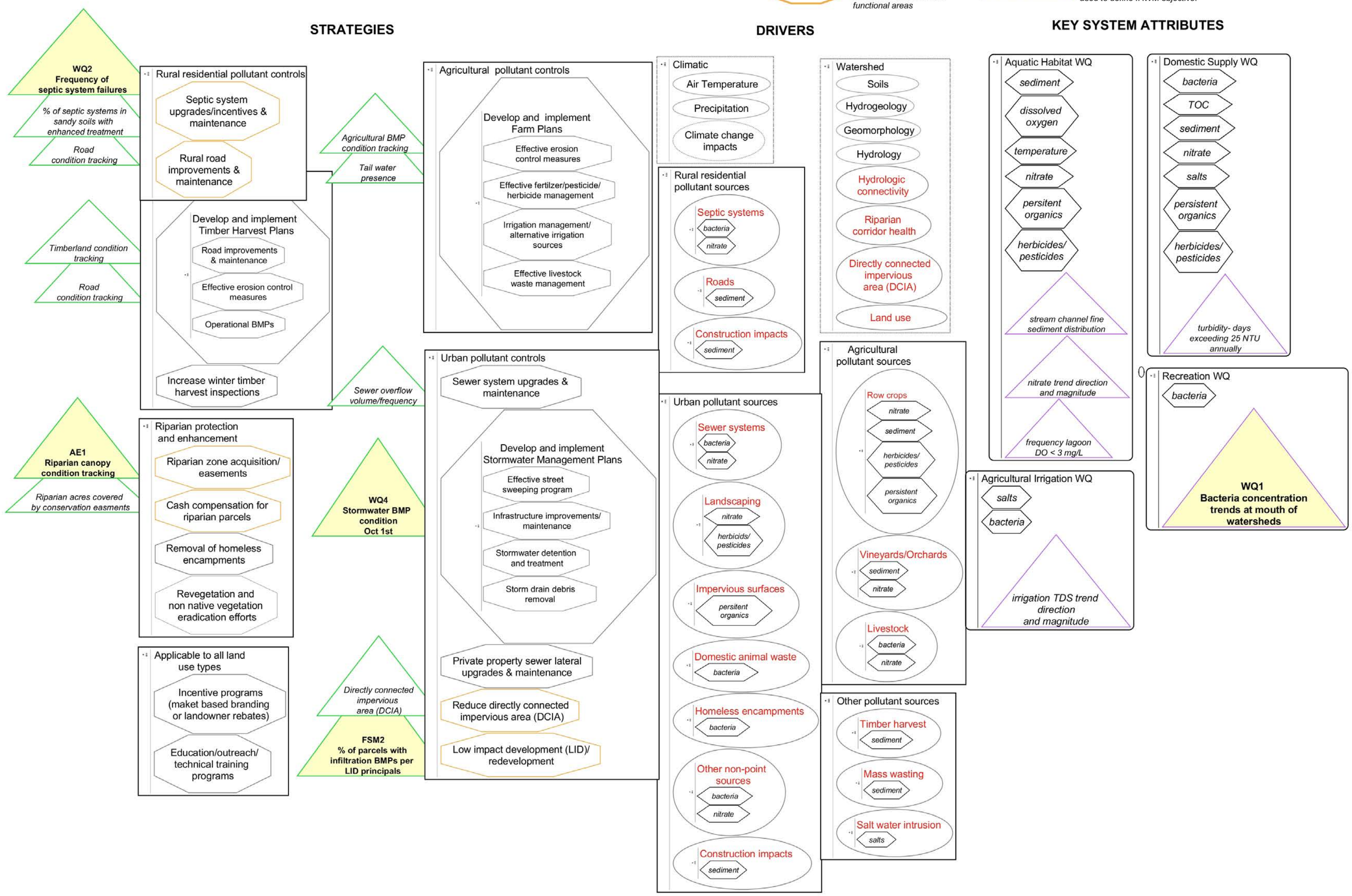
[1] Definitions of beneficial uses
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/planningtmdls/basinplan/web/bp_ch2.shtml

Santa Cruz IRWMP Update
Functional Area: Water Quality
Conceptual Diagram



GOAL - Maintain and improve regional surface and groundwaterwater quality to protect beneficial uses.

OBJECTIVE - Reduce the sources of harmful pollutants (i.e. sediment, bacteria nitrate, persistent organics and other toxic constituents) and their impacts on aquatic resources.



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WATER QUALITY DIAGRAM

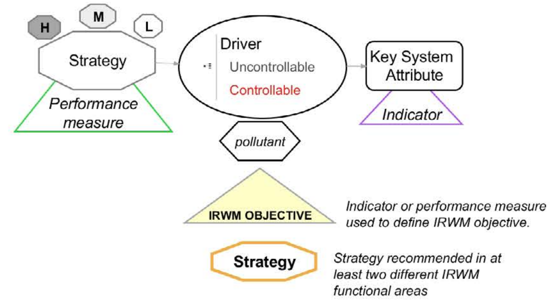
FIGURE 4.1

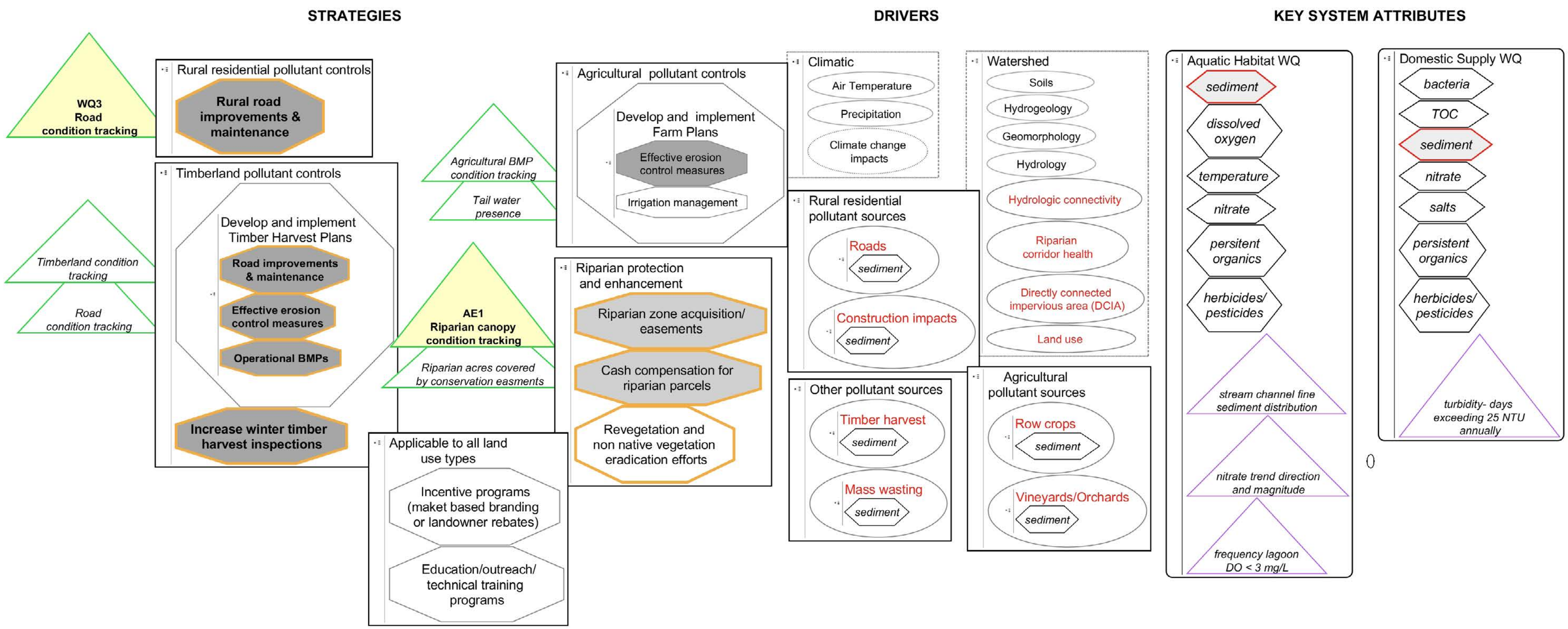
Santa Cruz IRWMP Update
Functional Area: Water Quality
Conceptual Diagram

SEDIMENT

GOAL - Maintain and improve regional surface and groundwaterwater quality to protect beneficial uses.

OBJECTIVE - Reduce the sources of harmful pollutants (i.e. sediment, bacteria nitrate, persistent organics and other toxic constituents) and their impacts on aquatic resources.





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SEDIMENT - WATER QUALITY DIAGRAM

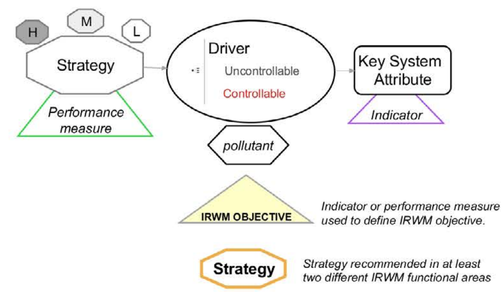
FIGURE 4.2

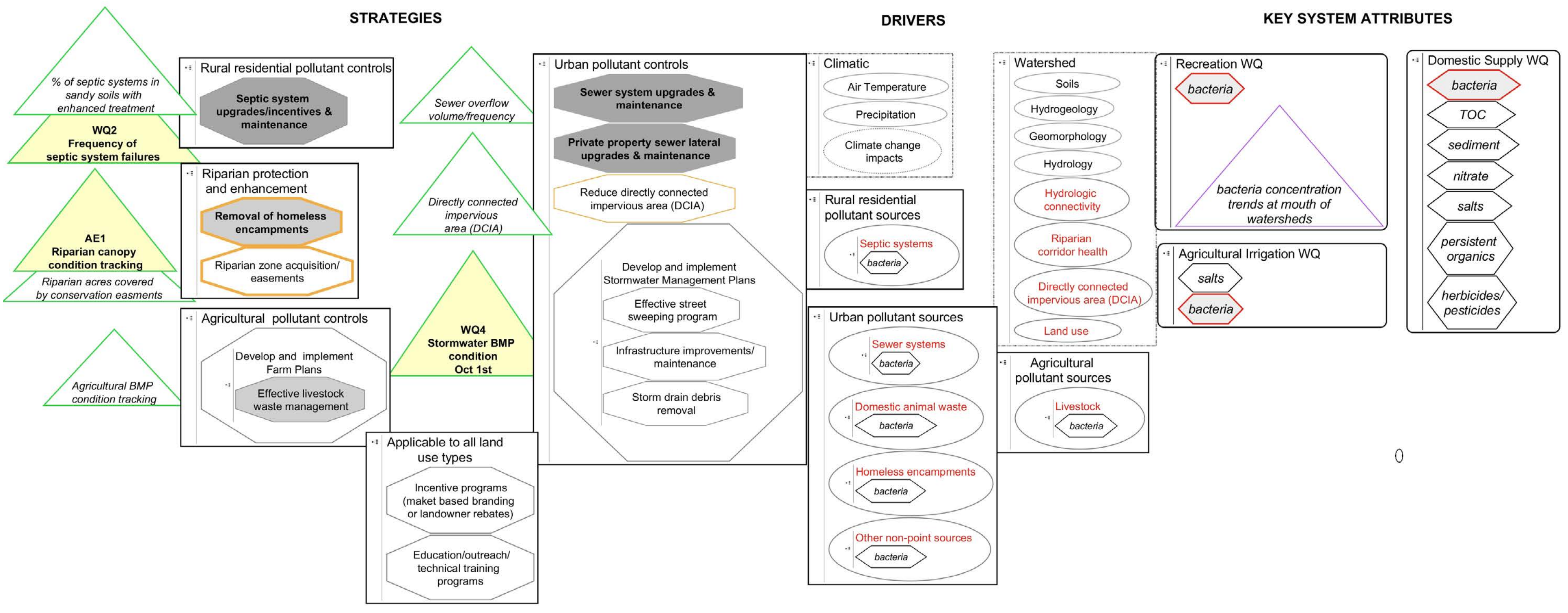
Santa Cruz IRWMP Update
Functional Area: Water Quality
Conceptual Diagram

BACTERIA

GOAL - Maintain and improve regional surface and groundwaterwater quality to protect beneficial uses.

OBJECTIVE - Reduce the sources of harmful pollutants (i.e. sediment, bacteria nitrate, persistent organics and other toxic constituents) and their impacts on aquatic resources.





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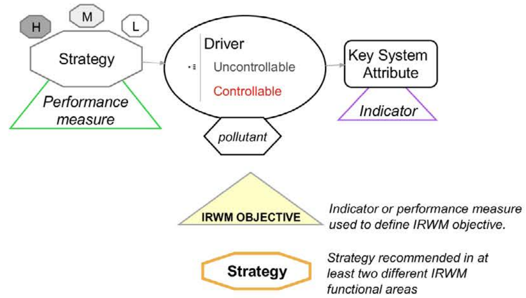
BACTERIA - WATER QUALITY DIAGRAM

FIGURE 4.3

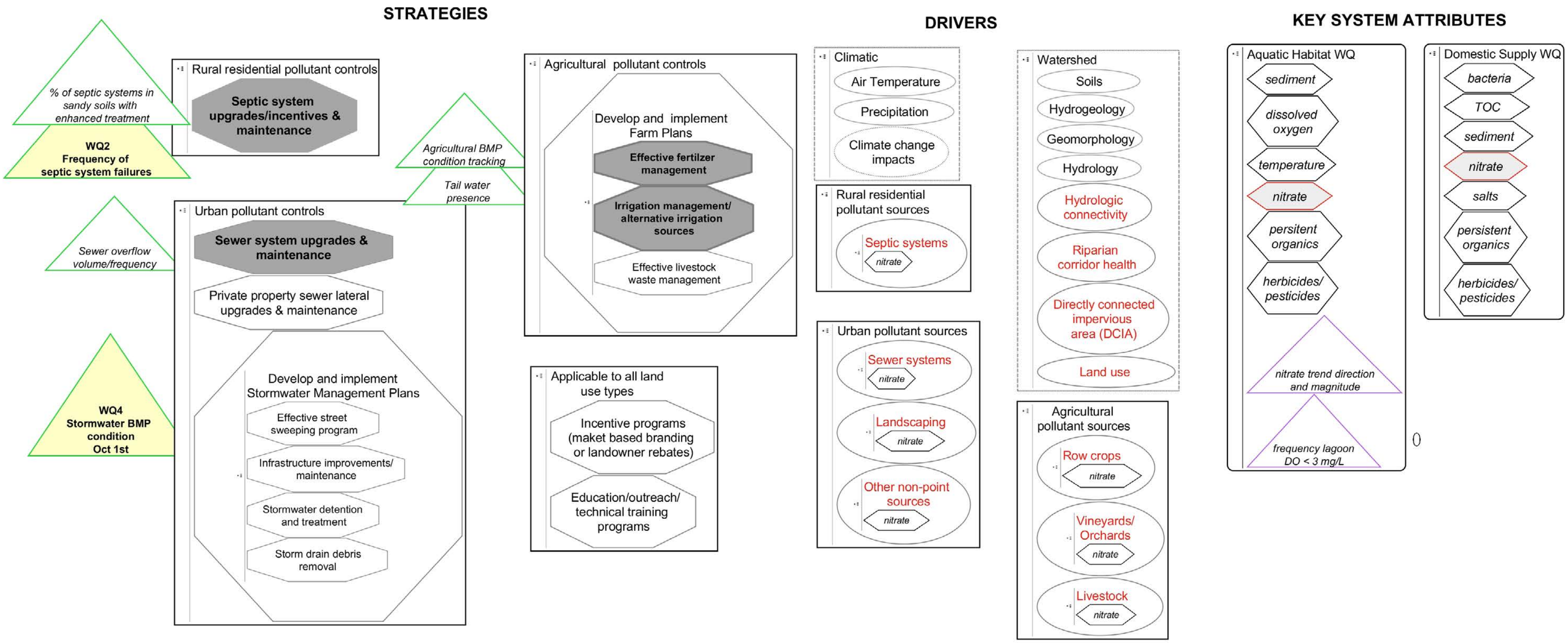
Santa Cruz IRWMP Update
Functional Area: Water Quality
Conceptual Diagram

NITRATE



GOAL - Maintain and improve regional surface and groundwaterwater quality to protect beneficial uses.

OBJECTIVE - Reduce the sources of harmful pollutants (i.e. sediment, bacteria nitrate, persistent organics and other toxic constituents) and their impacts on aquatic resources.



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NITRATE - WATER QUALITY DIAGRAM

FIGURE 4.4

WATER QUALITY LINKAGE TABLE (PAGE 1)

See Figure 4.1 for the associated water quality diagram.

Water Supply beneficial

Recreational beneficial uses

Expected relative impact of strategy on key attribute(s)

High | Moderate | Low

Aquatic habitat beneficial uses

Agricultural irrigation beneficial uses

Pollutant of concern	Controllable drivers (Pollutant sources in relative order of impact)	Relevant strategies (Pollutant reduction strategies)	Considerations for strategy implementation
SEDIMENT	Roads	Effective rural road improvements and maintenance	Road slope and/or cut slope Road distribution/density Hydrologic connectivity to surface water Proximity to salmonid priority stream Erosivity of soils
	Timberlands	Develop and implement Timber Harvest Plans (THPs) that include effective erosion control measures Increase winter timber harvest inspections	Land slope Road distribution/density Harvest activity distribution/density Hydrologic connectivity to surface water Proximity to salmonid priority stream Erosivity of soils
	Row crops Vineyards/Orchards	Develop and implement Farm Plans that include effective erosion control measures	Land slope Crop distribution/density Hydrologic connectivity to surface water Proximity to salmonid priority stream Erosivity of soils
	Riparian corridor health	Riparian acquisition and restoration Riparian vegetation restoration	Value and impacts of existing land uses Level of existing degradation Adjacent land ownership Flood hazard impacts to adjacent populations
	Mass wasting	Landslide repairs Effective rural road improvements maintenance	Hydrologic connectivity to surface water Proximity to salmonid priority stream
	Potential pollutant sources as applicable	*Education/Outreach technical training programs* *Market based incentives/branding*	*Degree and extent of impacts* *Priority audience accessibility* *Anticipated impacts on key offenders*
BACTERIA	Septic systems	Septic system upgrades, incentives and/or maintenance	Septic system density, distribution, age and integrity Hydrologic connectivity to both surface and ground water Organic content and permeability of soils Private party willingness/financial capacity to comply
	Sewer systems	Sewer system upgrades and maintenance	Sewer system density, distribution, age and integrity Hydrologic connectivity to both surface and ground water Organic content and permeability of soils
		Private property sewer lateral upgrades and maintenance	Lateral density, age and integrity Hydrologic connectivity to both surface and ground water Organic content and permeability of soils Private party willingness/financial capacity to comply
	Homeless encampments	Removal of homeless encampments	Social and political constraints
	Urban non point sources	Develop and implement Stormwater Management Plans that include effective street sweeping programs,regular infrastructure cleaning and maintenance	Timing of stormwater maintenance to reduce pollutants available for transport prior to wet season
	Livestock	Effective livestock waste management BMPs Riparian exclusion	Livestock distribution and density Hydrologic connectivity to both surface and ground water
	Domestic animal waste	*Education/Outreach technical training programs*	Domestic animal use distribution and density
	Potential pollutant sources as applicable	*Education/Outreach technical training programs*	*Focused and specific to increase frequency and distribution of implementation strategies listed above.*
NITRATE	Row crops Vineyards/Orchards	Develop and implement Farm Plans that include effective fertilizer and irrigation management measures	Crop distribution/density Hydrologic connectivity to both surface and ground water Nutrient retention capacity and permeability of soils
	Septic systems	Septic system upgrades, incentives and/or maintenance	Septic system density, distribution, age and integrity Hydrologic connectivity to both surface and ground water Nutrient retention capacity and permeability of soils
	Sewer systems	Sewer system improvements and maintenance	Sewer system density, distribution, age and integrity Hydrologic connectivity to both surface and ground water Nutrient retention capacity and permeability of soils
		Private property sewer lateral upgrades and maintenance	Lateral density, age and integrity Hydrologic connectivity to both surface and ground water Organic content and permeability of soils Private party willingness/financial capacity to comply
	Other urban non point sources	Develop and implement Stormwater Management Plans that include effective street sweeping programs,regular infrastructure cleaning and maintenance	Timing of stormwater maintenance to reduce pollutants available for transport prior to wet season
	Livestock	Effective livestock waste management BMPs Riparian exclusion	Livestock distribution and density Hydrologic connectivity to both surface and ground water
	Potential pollutant sources as applicable	*Education/Outreach technical training programs* *Market based incentives/branding*	*Degree and extent of impacts* *Priority audience accessibility* *Anticipated impacts on key offenders*

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WATER QUALITY LINKAGE TABLE (PAGE 2)

See Figure 4.1 for the associated water quality diagram.

Water Supply beneficial — Recreational beneficial uses — Expected relative impact of strategy on key attribute(s): High / Moderate / Low — Aquatic habitat beneficial uses — Agricultural irrigation beneficial uses

Pollutant of concern	Controllable drivers (Pollutant sources in relative order of impact)	Relevant strategies (Pollutant reduction strategies)	Considerations for strategy implementation
Salts	Saltwater intrusion	Alterative water sources to reduce groundwater overdraft Increased use of recycled water for irrigation Irrigation Management Water conservation	Proximity to coastline Annual extraction to recharge volume deficit
Herbicides/ Pesticides	Row crops Vineyards/Orchards	Develop and implement Farm Plans that include effective pesticide/herbicide management	Crop distribution/density Hydrologic connectivity to both surface and ground water
	Other urban non-point sources	Education/outreach programs targeting commercial and residential users	Ability to identify/convince use of alternative products
Persistent Organics	Row crops	Develop and implement Farm Plans that include effective pesticide/herbicide management	Crop distribution/density Hydrologic connectivity to both surface and ground water
	Other urban non-point sources	Develop and implement Stormwater Management Plans that include effective street sweeping programs,regular infrastructure cleaning and maintenance	Timing of stormwater maintenance to reduce pollutants available for transport prior to wet season
	Potential pollutant sources as applicable	*Education/Outreach technical training programs*	*Degree and extent of impacts* *Priority audience accessibility* *Anticipated impacts on key offenders*
Temp	Riparian corridor health	Riparian zone acquisition and easments Riparian vegetation restoration	Value and impacts of existing land uses Level of existing degradation Adjacent land ownership Flood hazard impacts to adjacent populations
Dissolved Oxygen	*See nitrate pollutant reduction strategies to reduce primary production rates and associated dissolved oxygen consumption by respiring bacteria.*		
	Riparian corridor health	Riparian zone acquisition and easments Riparian vegetation restoration	Value and impacts of existing land uses Level of existing degradation Adjacent land ownership Flood hazard impacts to adjacent populations
Total Organic Carbon (TOC)	*See nitrate pollutant reduction strategies as they directly apply to reduced sources of TOC.*		

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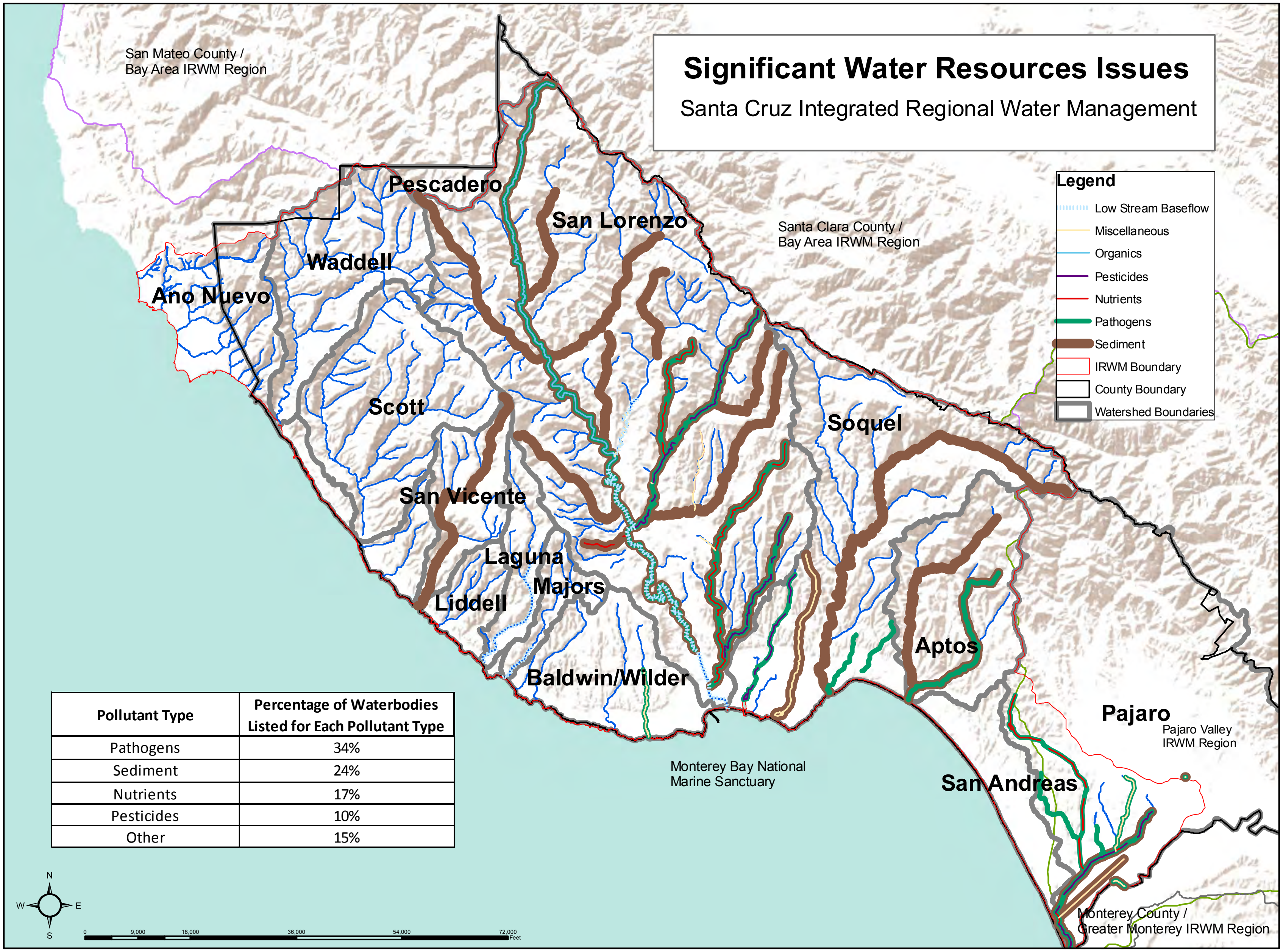

Pollutant Type	Percentage of Waterbodies Listed for Each Pollutant Type
Pathogens	34%
Sediment	24%
Nutrients	17%
Pesticides	10%
Other	15%

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IMPAIRED WATER BODIES IN SANTA CRUZ REGION

FIGURE 4.5

Table 4.2. Linkage of beneficial use categories to key attributes in IRWM water quality conceptual model.

IRWM water quality key attribute	Relevant beneficial uses[1]	Beneficial use definition
Aquatic Habitat	Cold Freshwater Habitat (COLD)	Uses of water that support coldwater ecosystems, including but not limited to preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
	Estuarine Habitat (EST)	Uses of water that support estuarine ecosystems, including but not limited to preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds), and the propagation, sustenance, and migration of estuarine organisms.
	Fish Migration (MIR)	Uses of water that support habitats necessary for migration, acclimatization between fresh water and salt water, and protection of aquatic organisms that are temporary inhabitants of waters within the region.
	Fish Spawning (SPWN)	Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.
	Preservation of Rare and Endangered Species (RARE)	The water quality criteria to be achieved that would encourage development and protection of rare and endangered species should be the same as those for protection of fish and wildlife habitats generally. However, where rare or endangered species exist, special control requirements may be necessary to assure attainment and maintenance of particular quality criteria, which may vary slightly with the environmental needs of each particular species. Criteria for species using areas of special biological significance should likewise be derived from the general criteria for the habitat types involved, with special management diligence given where required.
	Commercial and Sport Fishing (COMM)	Uses of water for commercial or recreational collection of fish, shellfish, or other organisms, including but not limited to uses involving organisms intended for human consumption or bait purposes.
	Wildlife Habitat (WILD)	Uses of waters that support wildlife habitats, including but not limited to the preservation and enhancement of vegetation and prey species used by wildlife, such as waterfowl.
	Marine Habitat (MAR)	Uses of water that support marine ecosystems, including but not limited to preservation or enhancement of marine habitats, vegetation (e.g., kelp), fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).
Domestic Supply	Municipal and Domestic Supply (MUN)	Uses of water for community, military, or individual water supply systems, including but not limited to drinking water supply.
	Groundwater Recharge (GWR)	Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting saltwater intrusion into freshwater aquifers.
Recreation	Non Contact Recreation (REC2)	Uses of water for recreational activities involving proximity to water, but not normally involving contact with water where water ingestion is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.
	Water Contact Recreation (REC1)	Uses of water for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, whitewater activities, fishing, and uses of natural hot springs.

IRWM water quality key attribute	Relevant beneficial uses[1]	Beneficial use definition
Agricultural Irrigation	Agricultural Supply (AGU)	Uses of water for farming, horticulture, or ranching, including but not limited to irrigation, stock watering, or support of vegetation for range grazing.

The IRWM goal to improve and protect local water quality has significant relevance for certain pollutants to two other functional areas: 1) local water resources relied upon for the community water supply and 2) the habitat quality to support aquatic ecosystems. The critical drivers and recommended regional strategies to reduce pollutants are provided in detail in the Water Quality conceptual model and referenced as such in Water Supply (Section 3) and Aquatic Ecosystems (Section 5).

4.5.1 CLIMATE CHANGE IMPLICATIONS

The two water quality variables most susceptible to future regional climate conditions are salts in groundwater and surface water temperatures. The current extent and magnitude of saltwater intrusion as a result of historic and continued groundwater overdraft would be exacerbated in coastal areas by increasing sea level elevations if effective management actions are not implemented (see Section 3 Water Supply). Projected higher air temperatures in the future (particularly during summer) will result in a corresponding increase in surface water temperatures that could have a detrimental impact on coldwater fish species and the overall health of local aquatic ecosystems (see Section 5 Aquatic Ecosystems). The potential climate impacts and associated adaptation measures are mentioned below for salt and temperature, but sea level rise is more extensively addressed in Section 3 and water temperature as it relates to the habitat quality of aquatic ecosystems is detailed in Section 5.

Statewide predictions of increased rainfall intensities (Cayan et al., 2009) have the potential to increase pollutant transport, sediment erosion rates and delivery during future episodic storm events (Kundzewicz et al., 2008). However, the effect may be small relative to other water pollution drivers and pollutant source control strategies (2NDNATURE et al., 2010).

4.5.2 SEDIMENT

Human land uses and associated activities have greatly increased the amount of sediment, particularly fine sediment defined as sand (< 2mm) or finer, that is introduced to local surface water streams (see Figure 4.2). Fine sediment impairs aquatic habitat quality by reducing substrate complexity and the diversity of ecologically niches and reducing salmonid spawning gravel permeability (see Section 5 Aquatic Ecosystems). The negative impacts on spawning habitat quality, benthic invertebrate biomass and substrate complexity have been well documented throughout regional streams. These impairments are assumed to have significantly impaired habitat quality of local streams and contributed to reduced populations of the sensitive resident salmonid species: the Steelhead Trout and Coho Salmon (see Figure 4.5 and Figure 5.2). Elevated fine sediment in source water extracted for water supply can reduce the suitability of the waters for treatment. Therefore extracting surface waters for water supply during storm runoff when turbidity and associated sediment concentrations are elevated becomes extremely expensive and reduces the amount of winter surplus water available for extracting.

Sediment is transported mechanically by surface water runoff, stormwater or overland flow during storm events. Sediment is a natural component of streams but timber harvest, agricultural activities, residential clearing and grading, and roads in the region have significantly increased the rate of loading to surface waters. In addition, urban stormwater runoff, riparian encroachment and other hydrologic and geomorphic modifications to the streams themselves have increased channel incision, bank failure and other factors that increase the rate of internal stream erosion. The priority regional strategies to reduce controllable sediment sources to local streams are the implementation of effective erosion controls on timber lands, roads, and agricultural lands. Strategies should aim to implement improvements to reduce sediment loading from acute sources, as well as increase regular maintenance actions and associated inspections to ensure improvements are effective and load reductions are sustained long-term.

The hydrologic connectivity of a sediment source to a surface water system is dependent upon physical characteristics such as proximity of the source to the stream, slope of the land where the sediment originates and the path to the local surface water. Determination of priority locations for improvements should consider the density and distribution of the potential high risk land use types that have a relatively high hydrologic connectivity.

4.5.3 BACTERIA

Elevated bacteria (i.e., pathogen) levels in local surface and groundwater resources present a significant human health concern with regards to recreational contact or consumption. High levels of coliform bacteria can cause gastrointestinal distress and other human health issues and is a primary pollutant of concern in protecting recreational beneficial uses and domestic water supply. Bacteria is a high priority pollutant in the Santa Cruz region because so many people recreate in the coastal waters. A number of coastal beaches and urban water bodies are impaired due to elevated bacteria levels. Some beaches and tidal wetlands are permanently posted communicating to the public the potential health impacts of water contact as a result of elevated bacteria levels (see Figure 4.3). Total coliform, fecal coliform, *Escherichia coli* (*E. coli*) and enterococcus are the typical bacterial strains measured to document the amount of bacteria present in a water body. E. coli is a specific type of fecal coliform that lives in the intestines of humans and other warm-blooded animals and in their waste. The Santa Cruz County Department of Environmental Health (CoEHS) uses an exceedance standard of the 30-day geometric mean or single sample bacteria maximum concentrations to determine if a human health risk is present at local beaches.

The primary sources of coliform bacteria in regional waters are human and domestic animal waste and include septic systems, sewer systems, livestock, dogs, homeless encampments, etc. (see Figure 4.3). Bird waste has also been identified as an important source of bacteria to tidal wetlands and coastal waters (CoEHS, 2006). Given the density, distribution and age of many septic systems, particularly in the San Lorenzo Valley, it is assumed that septic system failures, leaking sewer lines and private parcel sewer laterals in high permeability soils and close proximity to surface waters are the greatest controllable sources of bacteria in the region.

Strategies to reduce contributions of bacteria from wastewater management are expected to have a measurable long term improvement in the frequency of bacterial standard exceedances and the long term trend of bacteria concentrations. Considerations for the prioritization of where improvements should be in the region include the **hydrologic connectivity**[2] of a site for allowing bacteria to reach the local surface and

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[2] Hydrologic connectivity is the relative risk of a pollutant to migrate and reach the groundwater aquifer and/or surface water resource of concern. Factors that influence hydrologic connectivity of a pollutant will vary based on the pollutant behavior in the environment (i.e., does it migrate with water, does it adhere to soil, is the transport mechanism physical (sediment) or chemical (nitrate), etc.) and proximity to the water resource of concern. Depending upon the pollutant fate

groundwater resources. Connectivity is influenced by the permeability and organic content of the local soils to retain and decompose the pollutants, the proximity of the source to surface waters, and the depth to groundwater. Information regarding the age and condition of the systems in question should be used to target improvements to the most degraded systems with relatively high hydrologic connectivity to surface waters. A continuing challenge is the ability of private land owners to comply and/or the availability of resources to conduct desired improvements. Waste water also contains elevated nutrients (particularly nitrogen) and effective bacteria source control strategies are also expected to reduce nitrogen loading to local surface and groundwaters.

Urban stormwater management practices that reduce the amount of bacteria available for transport via the stormwater system, such as street sweeping, infrastructure clean outs and maintenance, are recommended. Equipment upgrades should be considered, such as the replacement of old sweepers with more advanced regenerative air models that pick up finer particulates and increase sweeping effectiveness. Reducing annual stormwater volumes by disconnecting impervious areas could also reduce the bacteria loads that reach surface water systems, and increasing the soil water interactions through infiltration can effectively reduce the concentration of bacteria as a result of biodegradation.

4.5.4 NITRATE

Nitrate is the inorganic dissolved form of nitrogen and is typically the nitrogen compound of greatest water quality concern due to its high mobility in soils and potential negative impacts on aquatic ecosystems. The ability of nitrate to migrate in the subsurface creates a significant risk that nitrates can reach groundwater aquifers and surface water bodies far from their initial sources. Water sources for potable supply must contain less than 10 mg/L of nitrate (as N), and nitrate can be toxic to humans at levels greater than 45 mg/L (as N) (USEPA website http://water.epa.gov/drink/contaminants/index.cfm), but much lower concentrations than these can impair aquatic ecosystems. Anthropogenic increases in surface water nitrogen concentrations can drastically alter the ecosystem at the base of the food chain (i.e., eutrophication), increasing the frequency, extent, and persistence of algal blooms. Such algal blooms can be associated with reduced dissolved oxygen levels and negatively impact resident aquatic species. Evidence of eutrophication in regional streams, tidal wetlands and freshwater wetlands has been widely documented by a variety of studies, particularly in surface water systems downstream from intensive agricultural activities (see Figure 4.5). Eutrophication can also adversely impact drinking water supply, contributing to taste and odor issues and increased TOC levels.

Nitrate pollution is a concern in both surface and groundwater sources (see Figure 4.4). Primary sources of nitrate pollution include agricultural activities (particularly row crops where intensive fertilizer use is required), urban landscaping, and poorly maintained wastewater systems. Regional strategies to reduce nitrate loading from agricultural lands include:

1. improved fertilizer management strategies to reduce application rates and associated excess nitrate available to migrate from the place of application,
2. irrigation management strategies to reduce tail water discharge and excess runoff or leaching from cultivated lands, and
3. other land best management practices to minimize the hydrologic connectivity (i.e., likelihood of pollutant reaching a surface water resource) of nitrogen sources on a parcel.

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and transport characteristics, other factors will likely influence the relative hydrologic connectivity and these factors are noted in the "Strategy Implementation Considerations" in the respective Linkage Tables.

Regional strategies to reduce nitrate loading from wastewater sources include replacing or maintaining failing septic systems, leaking sewer lines and private parcel laterals, particularly in sandy soils. Effective nitrate source control strategies are also expected to have a measurable benefit on reducing priority bacteria sources and are discussed in bacteria pollutant control strategies above. Native species planted in municipal landscaped areas whenever possible can minimize the need for watering and use of fertilizers that may contain nitrate.

4.5.5 SALTS

Extensive saltwater intrusion in coastal zones has been documented in coastal areas where groundwater extractions for both potable and irrigation use have reduced groundwater elevations to below sea level. Elevated salt in potable water sources increase treatment costs and can become cost prohibitive. Elevated salt in irrigation water can be extremely toxic to cultivated plants and can result in increased irrigation volumes in order to achieve growth rates typical using water with much lower salt content. Future climate change impacts include potential rises in sea level that would exacerbate the magnitude and distribution of regional saltwater intrusion, given current groundwater management practices.

The extraction of groundwater from local aquifers at a greater rate than annual recharge has resulted in continued inland migration of seawater, which is expected to continue until groundwater extraction rates are balanced with recharge. The primary strategy to halt or reverse the rate of saltwater intrusion landward includes the definition and adherence to annual groundwater extraction targets that balance recharge and extraction, which will require the development of alternative water sources for the region. Improved irrigation management to conserve water use and the increased use of recycled water for irrigation are critical strategies that would contribute to reduced pressure to extract local groundwater volumes. Priority locations for strategy implementation are aquifers where extraction rates have the greatest deviation from annual recharge estimates and/or coastal locations where reduced water levels are directly resulting in continued saltwater intrusion. *See Section 3 Water Supply for a more complete evaluation of strategies to improve and protect local groundwater resources.*

4.5.6 HERBICIDES/PESTICIDES

Herbicides and pesticides impair water bodies in locations where runoff is received from landscaped urban areas or agricultural fields, particularly where row crops are cultivated. Harmful pesticides applied to landscaping before heavy rains make their way directly into urban storm drains. When concentrations are high enough, toxic conditions can develop in streams and sediments that are harmful for fish, invertebrates, and algae and can pose human health concerns. Toxic conditions in streams throughout the Central Coast were common during the period 2000 -2010 and recent monitoring has detected low levels of toxicity in the San Lorenzo River, Zayante Creek, and Arana Gulch (Anderson et al., 2012). Chlorpyrifos, diazinon, and pyrethroid pesticides have often been identified as the source of toxicity in Central Coast rivers (Anderson et al., 2006) and toxic conditions show significant correlations with both urban and agricultural land uses (Anderson et al., 2012).

Source control strategies that reduce or eliminate the use of herbicides/pesticides and prevent runoff will be the most effective for reducing impacts on aquatic ecosystems. Herbicides/pesticide application and irrigation runoff management are commonly included as part of farm plans and urban stormwater management plans in the region. Integrated pest management policies should be implemented for all urbanized areas in the region (as it has been in the City of Santa Cruz) and require non-pesticide alternatives to be considered for maintenance of landscaped areas such as city buildings, parks, street medians, and golf courses. Since the majority of herbicide and pesticide compounds have a higher affinity to adsorb to soils than dissolve in water, the removal of directly connected impervious area in urban environments can create soil/water interactions and retain pesticides/herbicides in the soil column where they degrade over time to less harmful compounds.

4.5.7 PERSISTENT ORGANICS

Persistent Organic Pollutants (POPs) are toxic chemicals that persist for long periods of time in the environment, adversely affect human health and biological systems, are transported by wind and water, and can accumulate in animal tissues and magnify up the food chain. Many POPs were used in the past as pesticides or are currently used in industrial processes. They include polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), dichorodiphenyl trichloroethanes (DDTs), dioxins, chlordane, and dieldrin. Exposure can cause illness or death in humans and has been linked to sediment and water toxicity to fish and invertebrates.

The Central Coast Long-term Environmental Assessment Network (CCLEAN) program has measured POP loads from wastewater dischargers in the region (City of Watsonville, City of Santa Cruz) and major rivers around the Monterey Bay, including the San Lorenzo and Pajaro, from 2004-2010 and has documented that river discharges contain the greatest loads for most POPs (CCLEAN, 2011). However, loading of PBDEs, which are primarily used as flame retardants, from wastewater treatment plants were more than twice that from rivers (CCLEAN, 2011). River discharges cause the nearshore waters of the region to continually violate the California Ocean Plan objective for protection of human health for PCBs. Monitoring has also shown that sediment DDT concentrations are higher in the Monterey Bay than San Francisco Bay and are not declining (CCLEAN, 2010). High loading at river mouths indicates diffuse sources of POPs throughout the regional watersheds, including both urbanized and agricultural areas.

Since POPs can persist in sediments and tissues for long periods of time, the most effective strategies are source control. There is a continuing shift away from POP pesticides in agricultural and landscaping applications both on a volunteer basis and for regulatory compliance. Effective implementations of programs for illicit point source discharge detection and elimination can minimize industrial contributions of POPs and street sweeping programs can remove pollutants from city streets before they are entrained and transported to water bodies.

4.5.8 TEMPERATURE

Aquatic organisms from microbes to fish are dependent on certain temperature ranges for their optimal health, since rates of biological and chemical processes depend on temperature. Salmonids are generally expected to survive and grow well at temperatures up to about 19°C to 21°C, with temperature of 19°C or less considered optimal under most conditions (Bidgood and Berst, 1969; Hokanson et al., 1977; Smith and Li, 1983). Salmonids may actually grow faster at higher temperatures if food is abundant (Smith and Li, 1983), but at temperatures in excess of 21°C increased mortality may offset the benefits of increased growth rates at the population level (Hokanson et al., 1977). Temperatures of 25°C to 26°C are generally considered lethal (Bidgood and Berst, 1969; Hokanson et al., 1977). Causes of elevated water temperature include removal of riparian and wetland vegetation, water extractions that reduce dry season flows, urban stormwater runoff, and water stagnation.

Projected higher air temperatures in the future (particularly during summer) will result in a corresponding increase in surface water temperatures that could have a detrimental impact on coldwater fish species and the overall health of local aquatic ecosystems (see Section 5 Aquatic Ecosystems). Although optimal stream temperatures vary with geographical area and food abundance, temperatures below 21°C are best suited to support the local aquatic species. Strategies that increase the riparian and wetland vegetation in streams and wetlands will help retain suitable habitats for desired biota including coldwater fish species. These include actions to protect and enhance streams and wetlands through acquisition, protection and restoration programs.

4.5.9 DISSOLVED OXYGEN

Where the concentration of oxygen varies away from 100% saturation in natural waters, it results from either increases by photosynthesis or reductions by respiration. Dissolved oxygen concentrations can significantly vary on daily time scales in waters with high nutrient availability, which stimulates primary production. Dissolved oxygen can be supersaturated during the day when light is available and below atmospheric saturation at night. Elevated primary production leads to an increased supply of organic matter that, when decomposed, often results "in depletion of dissolved oxygen (hypoxia) in stratified bottom waters at levels too low to sustain fishes and invertebrates" (Boesch, 2002). Anoxia has been denoted as the cause of widespread water quality and ecological impacts throughout the world (Nixon, 1995; Diaz, 2001). Many invertebrate and fish species become stressed in low oxygen conditions (< 3 mg/L), making them more susceptible to diseases and death (Theede, 1973; Diaz, 2001). Fish, shellfish and benthic organisms cannot survive in anoxic conditions (DO=0 mg/L) for extended periods of time.

Specific locations within regional streams with high nitrate sources and elevated stream temperatures may experience periods of low DO during warm summer days. The persistence of low DO concentrations has been document in regional tidal wetlands during warm summer days when the sandbar is closed and attributed to the combination of increased nutrient sources in the contributing catchments and reduced shading as a result of riparian and wetland vegetation removal. Low dissolved oxygen conditions are exacerbated when density stratification of the water column exists; the stratification prevents the exchange of dissolved oxygen produced in the surface waters with the repressed oxygen levels (due to respiration activity) in the bottom waters. Strategies that reduce nutrient sources and restore the physical and vegetation function of regional streams and wetlands (see Section 5 Aquatic Ecosystems) will be the most effective at reducing the frequency of sustained low dissolved oxygen conditions in regional surface water systems.

4.5.10 TOTAL ORGANIC CARBON (TOC)

TOC is primarily derived from the decay of terrestrial vegetation, with lesser contributions from aquatic vegetation sources, synthetic sources, urban stormwater and domestic waste water. TOC is a concern for water bodies that serve as surface drinking water sources, as the treatment process of the source water can cause formation of carcinogenic disinfection byproducts (DBPs), such as trihalomethanes (THMs) due to bonding of chloride disinfectants with organic compounds. If TOC levels in the source water are too high, it must be removed prior to the disinfection process to reduce production of the THMs in the drinking water.

While strategies that control land-use based TOC sources may have localized benefits, they are likely not very important for controlling TOC problems in drinking water since TOC is primarily derived from dead leaves falling directly into water bodies. The US EPA has not established a national water quality criterion, because problems are usually highly localized. In some cases, TOC may actually be beneficial to water quality: its ability to bind with copper makes the copper non-toxic and algal TOC is an important food source for higher trophic level organisms.

4.5.11 ROLE OF EDUCATION AND OUTREACH PROGRAMS

The most important contributors of pollutants in the region are non-point sources distributed diffusely throughout watersheds. Since these sources are extremely difficult to identify and track, voluntary compliance and commitment by the regional community to minimize pollutant generation is critical to achieving significant long term reductions in the key pollutants loaded to water resources. This compliance is facilitated by education and outreach programs operated by agencies and non-profit organizations that can communicate the actions necessary and associated benefits of effective pollutant source control to the local community. Distribution of educational media via television, radio, internet, and postal services can educate community members about the water quality impacts of applying pesticides and fertilizers to their lawns, washing cars on city streets, or not properly disposing of toxic household materials. School programs and teacher workshops can train additional community stewards and propagate the source control messages to a wider audience. Volunteer clean up and monitoring events such as First Flush and Snapshot Day allow community members to participate in the identification of problem areas throughout the region and fulfill municipal stormwater monitoring requirements. Outreach to rural landowners and farmers by programs run by the Santa Cruz County Resource Conservation District (RCDSCC) and stakeholder partnerships, such as the Agricultural Water Quality Alliance (AQWA), provide training on BMP implementation to improve the water quality of their runoff. Outreach to local businesses, such as restaurants, landscaping firms, office buildings, etc., can help them identify practices to reduce urban stormwater pollutant contributions, minimize application of herbicides/pesticides, and increase stormwater infiltration on site.

Education and outreach programs are rarely able to quantify the benefits of their programs and track behavior changes over time. Often, the number of volunteers, hours, or people reached is quantified, but there is not a corresponding link to the impact those programs have on the desired outcomes (e.g., reduction in pesticide usage, maintenance of septic systems, etc.). The development and implementation of repeatable and standardized surveys to track community perception and behavior regarding personal pollutant source control actions over time would provide a meaningful standard to report effectiveness of outreach to stakeholders, funders and the public and to identify priority topics and community demographics for future programs.

4.6 STRATEGY IMPLEMENTATION OBJECTIVES

Below are the specific Water Quality strategy implementation objective statements that include desired target conditions by 2030, the working hypothesis of how IRWM strategies will result in objective obtainment and a summary of the data needed to report and track incremental progress.

WQ1. Achieve statistically significant decreasing trends of bacteria at key locations of the San Lorenzo, Soquel and Aptos watersheds by 2030.

Indicator: Bacteria log mean trends (MPN/yr) at key locations on 3 to 5 yr time steps.

Hypotheses: Cumulative source control actions within watersheds are expected to reduce monthly and annual bacteria concentrations within water bodies over the long term. Utilize existing and continued County bacteria sampling dataset to conduct annual trend analyses that account for seasonal climatic and flow variability.

Critical need: Standard approach for statistical analysis and reporting.

WQ2. Reduce frequency of septic system overflows and failures by 30% by 2030.

Performance measure: Frequency of septic system failures; Number of parcels with septic systems that experience overflows and other issues annually.

Hypotheses: Septic system failures are an important source of bacteria to surface water systems and may contribute to human health impacts in rural wells and coastal waters with high recreational use.

Critical need: Refine the procedure and information system to identify and document septic system problems and failure locations.

WQ3. Improve the rural road condition in the San Lorenzo, Soquel and Aptos watersheds by 40% as measured by increases in rural roads rapid assessment scores by 2030.

Performance measure: Rural road condition tracking using Rural Road Rapid Assessment Method (RAM). Quantitative objective would be defined as 40% reduction in the miles of rural roads with RAM scores < 2.0 by 2030.

Hypotheses: Rural roads are significant source of sediment to surface waters that can be mitigated with effective road improvements and continued maintenance. The development and application of Rural Road RAM will facilitate quantification of road condition distribution and tracking of improvements over time.

Critical need: Need to develop the Rural Road RAM in 2013 (funding available) and obtain/map existing conditions of known and accessible road networks. Once existing conditions are mapped, miles of road within each RAM category < 2.0, 2-4 and >4 can be quantified and the 40% reduction placeholder can be evaluate and revised if necessary.

Objective supports both Water Quality and Aquatic Ecosystem goals.

WQ4. Clean out 100% of urban roads and storm drain drop inlets to best achievable conditions by October 1 of each year.

Performance measure: Stormwater BMP condition Oct 1; Probabilistic sampling of 20-30% of urban roads and drop inlets throughout urban areas and frequency of samples with BMP RAM scores < 4. In order to achieve objective, 100% of samples must obtain BMP RAM scores > 4.

Hypotheses: Pollutant delivery is particularly high during initial winter storms, and this 'first flush' of pollutants is responsible for substantial delivery of bacteria, sediments, nutrients, persistent organic pollutants (POPs), etc. to rivers and nearshore ocean waters. Focused stormwater maintenance actions such as effective street sweeping and drop inlet cleanouts during the late summer and early fall can reduce the mobilization and transport of urban derived pollutants to local surface waters.

Critical need: Adaption of Best Management Practices Rapid Assessment Method (BMP RAM; 2NDNATURE et al., 2009; www.tahoebmpram.com) or equivalent to inventory and track road and storm drain drop inlet condition using simple and rapid visual methods to verify street sweeping and DI cleanouts were effective.

5 AQUATIC ECOSYSTEM CONCEPTUAL MODEL

5.1 GOAL

Improve the condition of riparian and aquatic ecosystems to support the native species, watershed functions, and regional water needs.

5.2 OBJECTIVE

Increase the habitat quality and quantity of critical aquatic ecosystems (i.e., streams, tidal wetlands and freshwater wetlands).

5.3 DIAGRAM

The Aquatic Ecosystem diagram is presented in Figure 5.1.

5.4 LINKAGE TABLE

Table 5.1 is the Aquatic Ecosystem linkage table.

5.5 STRATEGY JUSTIFICATION

5.5.1 AQUATIC ECOSYSTEM FOCUS

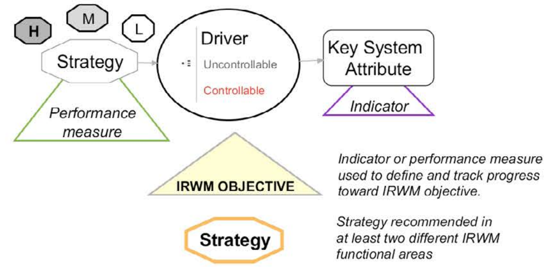
The Aquatic Ecosystem functional area is focused on the improvement and protection of habitat quantity and quality for resident aquatic species that are supported by a functional and resilient ecosystem. The aquatic system is categorized into streams, tidal wetlands (i.e., lagoons and estuaries) and freshwater wetlands due to the fundamental differences in the physical, chemical and biological functions of the systems and the associated impacts that human activities have on each of these components.

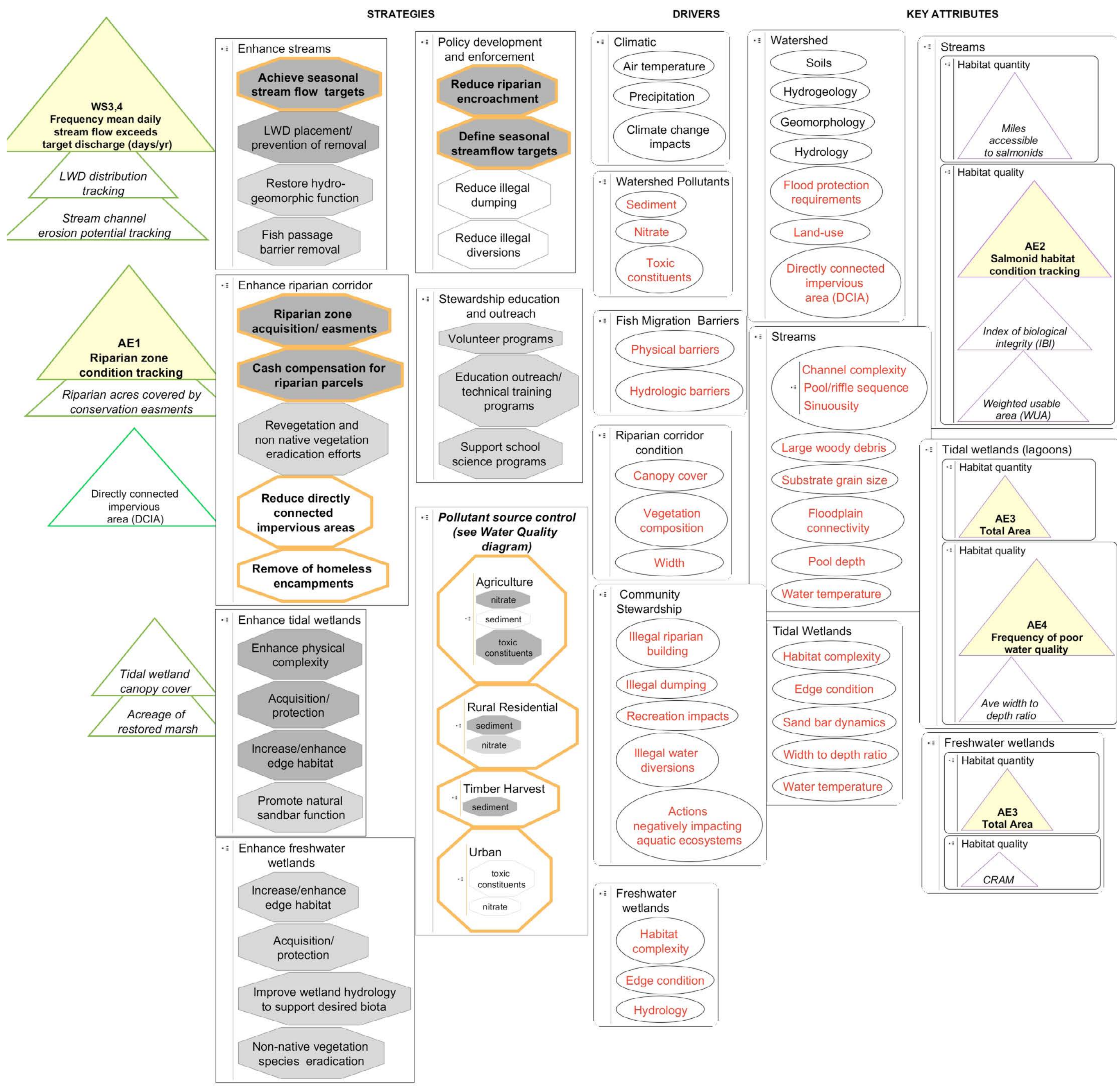
Streams include all freshwater tributaries and associated riparian zones in the region and have unidirectional water flow. Tidal wetlands are the confluence of coastal watersheds and experience extremely variable water levels and salinity ranges as a result of nearshore hydrologic interactions. Regional stream and tidal wetlands support a large array of species from primary producers to fish. Each species has specific habitat requirements and ecological interactions that influence its presence, survival and role in the aquatic community. The documentation and targeting of strategies to improve the habitat characteristics for all native species could be extremely valuable, but overly complex for the IRWM purposes. Therefore, the Aquatic Ecosystem conceptual model focuses on the rearing, migration and spawning habitat needs for sensitive anadromous fish species: the threatened Steelhead Trout (*Oncorhynchus mykiss*) and the endangered coho salmon (*Oncorhynchus kisutch*). The assumption is that stream ecosystems that meet the optimal habitat needs for the critical life stages of native salmonids, located at the top of the aquatic food chain, require functional components that will simultaneously support native communities of desired primary producers, secondary producers, invertebrates and other fish species. Anadromous fish life cycles generally depend upon adequate habitat quality and quantity of tidal wetlands for rearing and streams for migration and spawning, and the majority of the major watersheds within the region have been identified to support or potentially support salmonids (Figure 5.2).

Santa Cruz IRWMP Update
Functional Area: Aquatic Ecosystems
Conceptual Diagram

GOAL - Improve the condition of riparian and aquatic ecosystems to support the native species, watershed functions, and regional water needs.

OBJECTIVE - Increase the habitat quality and quantity of critical aquatic ecosystems (i.e. streams, tidal wetlands and fresh water wetlands).





AQUATIC ECOSYSTEMS LINKAGE TABLE

See Figure 5.1 for the associated aquatic ecosystems diagram.

Q_L Driver influences Habitat QUALITY

Driver influences Habitat QUANTITY of Key Attribute Q_N

Expected relative impact of strategy on key attribute(s)

High | Moderate | Low

Key Attributes	Controllable Drivers	Relevant Strategies	Considerations for Strategy Implementation
STREAMS	Hydrologic barriers Q_N	Achieve seasonal stream flow targets Reduce illegal diversions Restore hydro-geomorphic function	Extractions required for water supply Flow required to eliminate hydrologic barriers Potential salmonid habitat suitability
	Q_L Riparian corridor width Floodplain connectivity Q_N	Riparian zone acquisition/easments Reduce riparian encroachment Cash compensation for riparian parcels Restore hydro-geomorphic function	Value and impacts of alternative land-uses Flood hazard impacts to adjacent properties
	Q_L Substrate grain size	Reduce watershed sediment sources *(see Water Quality conceptual model)* Restore hydro-geomorphic function	Severity of existing degradation relative to habitat potential Potential aquatic habitat suitability
	Q_L Pool depth Channel complexity	Achieve seasonal streamflow targets Prevent illegal diversions Restore hydro-geomorphic function	Extractions required for water supply Severity of existing degradation Potential aquatic habitat suitability
	Q_L Large woody debris (LWD) Q_N	LWD placement/removal prevention Reduce riparian encroachment	Flood hazard impacts to adjacent properties
	Q_L Riparian corridor canopy cover Riparian vegetation composition	Non-native species eradication Revegetation efforts Reduce riparian encroachment	Likelihood of revegetation success Non-native presence/establishment
	Constructed fish passage barriers Q_N	Fish passage barrier removal	Miles of access above barrier Downstream passage barriers Potential salmonid habitat suitability
TIDAL WETLANDS	Q_L Habitat complexity Edge condition Width to depth ratio Q_N	Increase/enhance physical structure and biotic habitat complexity Increase/ enhance edge habitat	Flood hazard impacts to adjacent properties Adjacent land ownership Recreation pressure Geomorphology Severity of existing degradation relative to habitat potential
	Q_L Bar dynamics Q_N	Promote natural sand bar function	Ability to achieve seasonal streamflow targets Flood hazard impacts to adjacent properties Water quality impacts Recreational pressure Liability of bar management
FRESHWATER WETLANDS	Q_L Edge condition Q_L Habitat complexity	Increase/enhance physical structure and biotic habitat complexity Increase/enhance edge habitat Increase inundation surface area Non-native species eradication	Opportunities given existing morphology Opportunties for land acquisition and wetland surface area expansion Potential impacts to upstream flood hazards
	Q_L Hydrology Q_N	Improve wetland hydrology to support desired biota	Water availability Routing capability, capacity Hydrogeology to sustain desired hydroperiods
Streams Tidal Wetlands Freshwater Wetlands	Land use Flood protection requirements Q_N	Acquisition/protection of adjacent lands Reduce riparian encroachment	Value and impacts of existing land-uses Potential aquatic habitat suitability and value Adjacent land ownership Flood hazard impacts to adjacent properties
	Q_L Community Stewardship	Education/outreach/technical training programs Volunteer programs Support school programs Reduce illegal dumping Reduce illegal diversions	Accessibility to and influence on bad actors Priority audience accessibility Anticipated impacts on key offenders
	Q_L Water temperature	Riparian corridor acquisition/protection Riparian revegetation efforts Restore hydro-geomorphic function Achieve seasonal stream flow targets	Value and impacts of alternative land-uses Flood hazard impacts to adjacent properties Severity of existing degradation relative to habitat potential Extractions required for water supply
	Q_L *Watershed pollutants* Sediment Nitrate Toxic constituents	*See Water Quality conceptual model for drivers and strategies to reduce pollutant sources and the associated pollutant impacts on aquatic habitat quality.*	

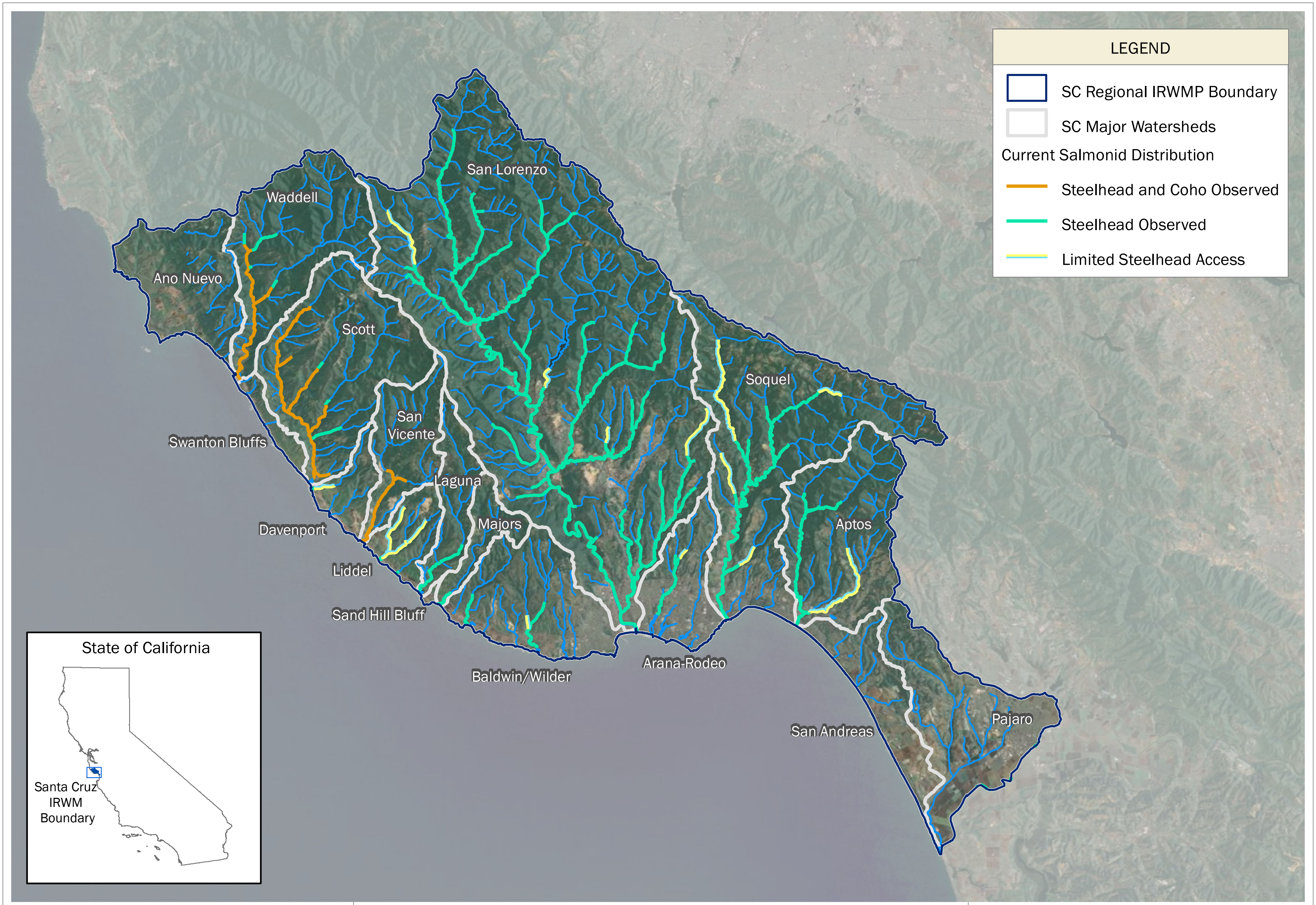


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Figure 5.2: Salmonid supporting streams in the Santa Cruz Region. Data provided by the County of Santa Cruz.

While it is expected this approach over generalizes the complexity of species needs and biological interactions, it focuses on the drivers and associated strategies that are expected to reduce human impacts and protect and enhance riparian and tidal wetland systems that are critical to the native salmonid populations and their supporting ecosystem.

Freshwater wetlands are distributed throughout the region and include all perennially inundated freshwater systems. They typically support a wide array of aquatic and amphibian species, including some listed as threatened or endangered. The habitat quality and quantity characteristics of freshwater wetlands are approached from a more general regional perspective, focusing quantity and quality on water availability, hydrology and desired geomorphic characteristics.

The region faces continued challenges to balance the water and land use conflicts between humans and aquatic ecosystems, and the protection and maintenance of ecosystem services are a priority. A number of potentially effective strategies have been identified to improve the condition of regional aquatic ecosystems, thereby sustaining ecosystem services that support regional beneficial uses including water supply, recreation, fishing, etc. The function and opportunities for habitat enhancement actions in specific locations must consider the existing conditions, ecological dynamics and expected benefits and impacts of future modifications in detail, using the conceptual guidance provided by the IRWM Aquatic Ecosystem conceptual model.

5.5.2 CLIMATE CHANGE IMPLICATIONS

Using the best information available, we provide an assessment of the vulnerability of key attributes of the aquatic ecosystem system to specific climate changes in Table 5.2. The table lists stressors on key attributes within aquatic ecosystems that are closely related to the drivers specified in Figure 5.1. For simplicity, Table 5.2 includes only those climate change projections for which confidence is relatively high. The table also indicates whether opportunities exist to reduce vulnerability to climate change impacts with the implementation of management strategies.

The local climate change projections suggest an increase in average maximum air temperatures, temperature variability, evapotranspiration, climatic water deficit, frequency of droughts, and sea level (see Tables 2.4 and 2.5). These projected changes would increase the challenges to improve the habitat quality and quantity for aquatic species given current land use and water requirements. Ensuring adequate water availability in streams, tidal wetlands and freshwater wetlands to support native aquatic species is highly susceptible given the current regional water supply reliance on local sources. In addition, increased air temperatures are expected to impact the habitat quality of streams and tidal wetlands for coldwater fish species, namely steelhead trout and coho salmon. Rising sea levels will likely lead to the landward migration of tidal wetlands from saltwater inundation and erosion, and loss of tidal wetland area is likely in urban areas where inland channels are severely encroached by development (Natural Capital Project, 2013). The impacts of climate change to aquatic ecosystems are expected to be most pronounced during the dry, warm summer and early fall months (July-October).

5.5.3 STREAM IMPROVEMENTS

Land use modifications have had direct and indirect impacts on the riparian and stream ecosystem hydrologic, geomorphic and chemical function. Salmonid migration upstream during fall/early winter requires adequate surface water depth and access to upper tributaries devoid of passage barriers. Elements of channel complexity are critical during migration to provide refuge and protection against predation, including physical

VULNERABILITY ASSESSMENT OF AQUATIC ECOSYSTEM MANAGEMENT KEY ATTRIBUTES

The sensitivity and adaptive capacity for each potential impact was determined based on the approach and criteria outlined in Section 2.4. The vulnerability is the combined result of sensitivity and adaptive capacity (see Table 2.8). IRWM strategies that are also potential climate adaptation actions are provided.

Key attribute	Stressors	Relevant projected climatic/hydrologic changes	Expected impact of future climate conditions	Sensitivity	Adaptive capacity	Vulnerability	Can future impact of climate change be lessened by strategy implementation?
AQUATIC ECOSYSTEMS (STREAMS, TIDAL WETLANDS, FRESHWATER WETLANDS)							
Habitat quantity	Surface water extractions, Morphologic and vegetative alterations, Pollution inputs Sea level rise	Increased frequency of droughts, Extended dry season	Greater risk of reduced water availability for aquatic ecosystems	h	m	h	YES Diversify water supply for drought resilience. Optimize surface water extraction timing during excess flow conditions (water exchanges). Increase annual infiltration volumes.
Habitat quality		Average maximum air temperature increases, Air temperature variability increases	Increased temperature stress on coldwater species*	h	l	h	YES Improve and protect riparian canopy (shading). Increase annual infiltration volumes. Improve habitat conditions.
			Increased nitrogen availability will increase risk of low dissolved oxygen conditions (water quality impact)	m	m	m	YES Nutrient source control strategies. Improve and protect riparian corridor condition. Promote natural function of sandbars for tidal lagoons.
		Sea level rise	Inland migration of tidal wetland locations	m	m	m	YES Minimize riparian encroachment of tidal wetlands

*Impact not relevant for freshwater wetlands

TABLE 5.2

features such as large woody debris, overhanging banks, deep pools, etc. In addition, complexity provides a greater array of physical niche habitat for benthic invertebrates and insects that are a critical salmonid food source.

Available habitat for aquatic species (including migrating and rearing salmonids) is particularly limited during the dry months in this Mediterranean climate due to reduced stream flows as a result of water extractions by both water districts and illegal diversions. Stream flow targets are being identified for critical tributaries to guide the timing and magnitude of stream diversions by regional water districts. Efforts to identify and eliminate illegal stream diversions in locations where extractions are significant, particularly during the dry season, could increase in-stream flows. The removal of remaining physical passage barriers will increase the miles of accessible stream to aquatic species, though efforts over the last decade have remedied the majority of the critical priority barriers in the region.

The close proximity of residential development to the riparian corridor throughout the region limits the feasible and effective stream improvement opportunities to increase habitat quality and quantity. While the degree of stream impact due to encroachment varies spatially and temporally, riparian zones throughout the region could greatly benefit from a program that systematically acquires, protects and enhances the riparian zones of targeted steam reaches. Depending upon the local conditions, setbacks of development from riparian zones can reduce flood hazards, improve water quality and greatly benefit aquatic ecosystems. Riparian protection could be followed by strategic geomorphic modifications that increase channel and riparian corridor width, improve channel geometry (i.e., sinuosity, channel capacity, pool depth, pool/riffle sequence, etc.), and provide the geomorphic form necessary to support successful riparian revegetation efforts. Non-encroached stream segments can help restore more natural hydrologic regimes and morphological functions that reduce sediment loads, better sort fine sediment delivered, accumulate large woody debris without significant flood hazard concerns, and generally increase the habitat complexity over time.

Spawning salmonids require well-flushed coarse gravel beds in upper tributaries to store the eggs and increase the likelihood of survival. The increase of fine sediment (sand and finer) delivery to regional streams from roads, timber harvest, development and other sources has severely reduced the amount of adequate spawning habitat due to increased embeddedness and reduced oxygen available to the egg nests (i.e., redds). It is hypothesized effective actions to significantly reduce the chronic sources of fine sediment to regional tributaries and concurrent improvements to geomorphic function will increase the distribution of quality spawning habitat in critical streams (see Figure 5.2). Reductions in fine sediment loading to surface streams will improve the habitat quality for benthic invertebrates, a critical food source supporting rearing salmonids.

Improved management of surface and groundwater extractions can reduce daily maximum surface water temperatures as a result of increased dry season baseflow and increased groundwater inputs. Functionally, the desired hydrologic modification is an extension of the seasonal timing when streams are gaining water from adjacent groundwater as opposed to losing streams, when net water flux is reversed from the bed of the stream to groundwater. Since groundwater temperatures are much cooler than surface waters during warm seasons, this functional hydrologic shift could reduce the frequency of elevated water temperatures and reduce daily maximums. These efforts coupled with successful riparian revegetation efforts could provide a viable adaptation strategy to protect coldwater fisheries from the expected increases in daily maximum air temperatures as a result of climate change (see Section 2.4).

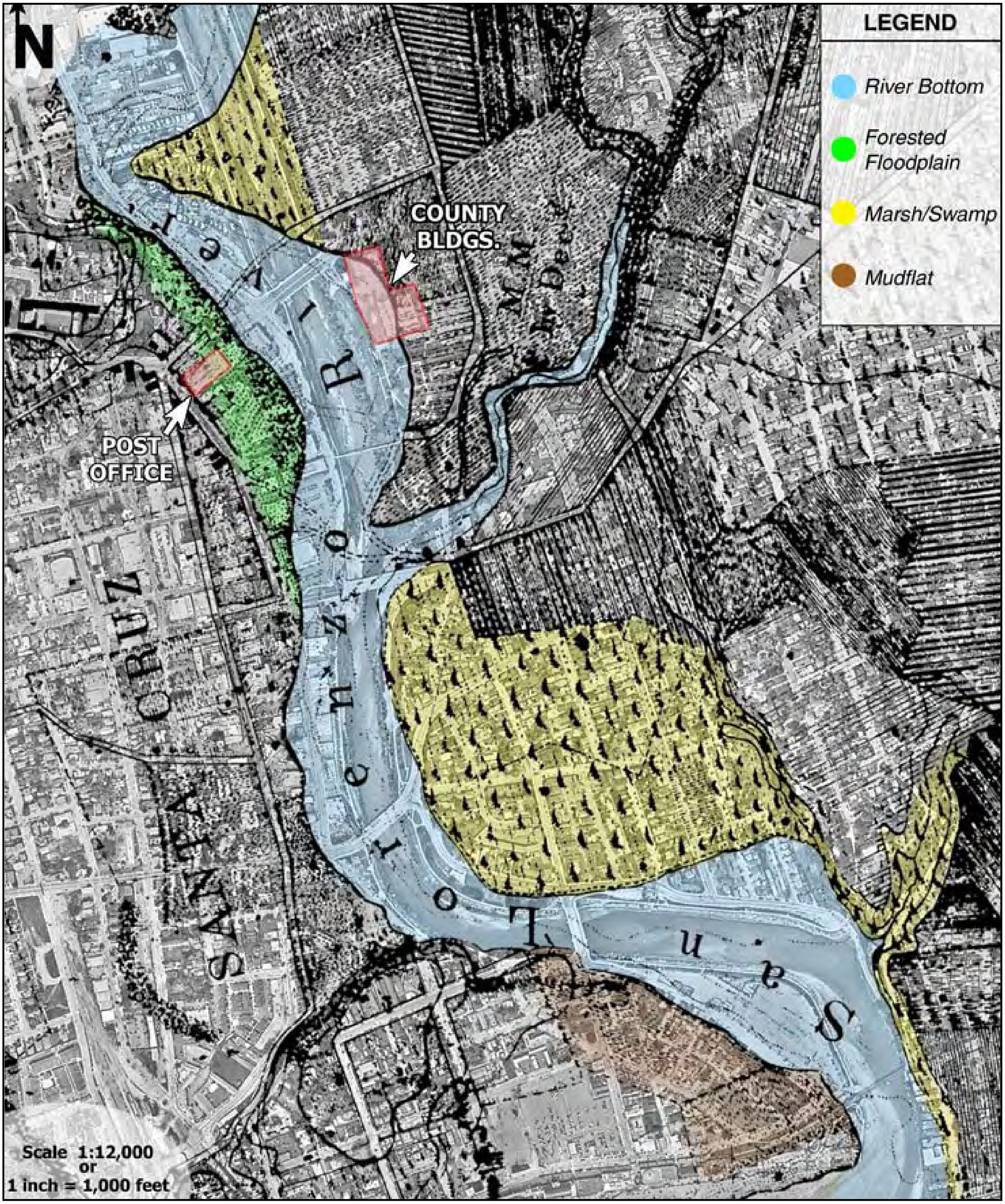
Improved land management and targeted pollutant source control practices throughout the region can reduce the risk of pollutant use, generation and transport to streams and are recommended strategies that would protect all beneficial uses, including aquatic ecosystems, with the primary pollutants of concern being sediment, nutrient, herbicides/pesticides, and persistent organics (see Section 4 Water Quality).

5.5.4 TIDAL WETLAND IMPROVEMENTS

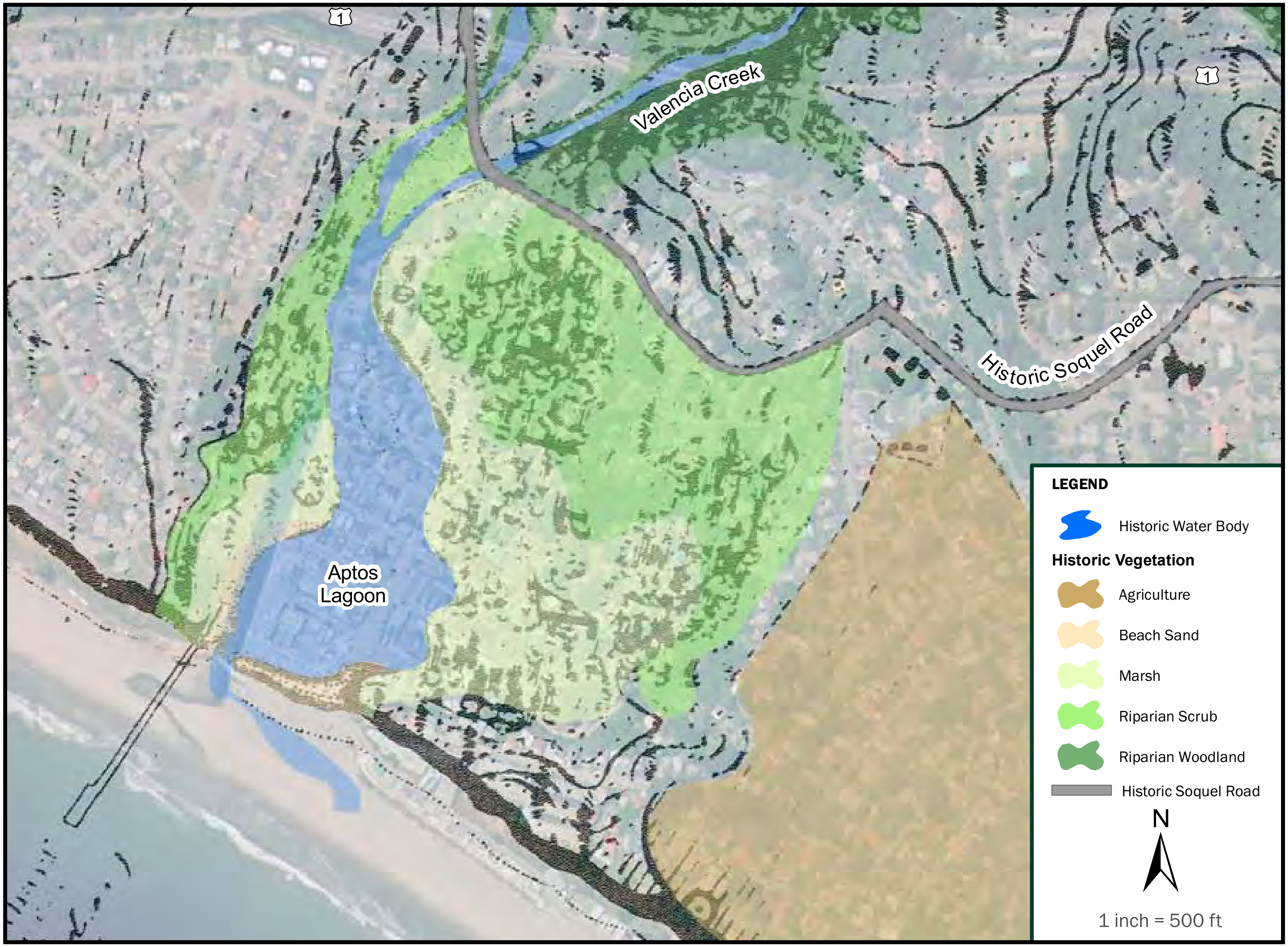
Similar to the stream impacts, many tidal wetlands in the region have been encroached by urban or agricultural development that has increased the need to reduce flood hazards using levees, vegetation management, and in some historic cases, dredging. Recent analyses suggest that over 60% of the natural tidal marsh area between the City of Santa Cruz and the southern IRWM boundary in the region has been lost (2NDNATURE, 2006; CCWG 2012 pers comm.). These losses along with alterations have resulted in minimal marsh shallow water habitat and have irrevocably altered historic vegetation communities. The alteration of tidal wetland morphology has precipitated a complete transformation of all natural tidal wetland processes, with habitat repercussions throughout the biological communities. The tidal wetlands within the region experience sandbar formation at the mouth during the summer when stream flows recede and sand delivery to the beach increases. A recent evaluation of a range of regional tidal wetlands found a shorter annual duration of sandbar closure in flood controlled urban tidal wetlands compared to those less morphologically constrained on the North Coast (2NDNATURE 2006). Future management strategies to restore the natural sandbar function in the summer can either be achieved by modifying the wetland morphology such that sandbar function trends toward a natural regime, or the sandbar can be manually formed using heavy equipment and a well designed strategy for management such as conducted at the mouth of Soquel Creek (Alley et al 2004). Without concurrent morphologic improvements, the manual sandbar closure approach faces many inherent challenges, including but not limited to potential adjacent property flooding risks, liability associated with manual management of the sandbar, and potential deleterious water quality implications of sustained closures.

While development of the historic marsh of tidal wetland is less common on North Coast streams, the construction and presence of the Pacific Railway and Highway 1 have resulted in morphologic modifications at the upstream boundary of all of these systems. Many of the larger north coast tidal wetlands (Laguna, Scott and Waddell; see Figure 5.2) were modified in the past to allow seasonal agricultural activities on the productive marsh soils and portions of these remnant levees remain today.

Several tidal wetlands in the region are currently below their achievable level of health due in large part to adjacent land use and human induced stressors within the contributing watersheds. Opportunities to increase the habitat quality of regional tidal wetlands exist though the specific improvements that depend on impairments and opportunities for each system. Tidal wetlands located in urban areas have been channelized, significantly reducing the width to depth ratio of a wide shallow marsh system. In addition, the condition of the edge of water has been transformed from a shallow sandy substrate with marsh vegetation to a steep earthen or concrete levee where riparian vegetation is typically minimal or absent (Figures 5.3 and 5.4). General improvement strategies involve opportunities to increase the total inundation area (through land acquisition and wetland expansion), which concurrently will increase the average width to depth ratio. Other physical improvement strategies include reducing the slope and increasing the area of edge of water habitat, which also would require wetland area expansion and modifications that would increase the morphologic complexity. Strategies could include morphologic modifications to increase the sinuosity of the main channel during low flow conditions while still maintaining adequate capacity to contain back water volumes during sandbar closures. Increased morphologic complexity would increase hydrologic variability during winter storm flows and promote more physical complexity (variable depths, improved sediment sorting, etc.) during summer backwater conditions. Physical modifications, coupled with successful riparian revegetation efforts would



1853 US Coast Survey overlain on 1999 aerial (Source: Swanson Hydrology + Geomorphology, 2002)



1853 US Coast Survey overlain on 2000 color aerial provided by WAC Aerial.
Source: 2NDNATURE, 2006

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APTOS CREEK LAGOON COMPARISON: HISTORIC (1853) VS PRESENT DAY (2000)

FIGURE 5.4

greatly increase the ecological complexity, diversity and habitat quality of regional tidal wetlands for rearing salmonids.

Several tidal wetlands, particularly those at the terminus of urban watersheds, have been documented as impaired particularly by elevated nutrients and bacterial pathogens, low dissolved oxygen and elevated surface water temperatures during times of sandbar closure (2NDNATURE, 2006; CoEHS, 2006; see Figure 4.5). The primary sources of controllable anthropogenic nutrients (nitrogen and phosphorous) are assumed to be septic and sewer leakages, particularly in the San Lorenzo Valley. Reduced dissolved oxygen concentrations are a direct result of increased availability of nitrate, thus effective strategies to reduce septic and sewage failures would improve both nitrate loading and dissolved oxygen issues in the associated tidal wetlands. Pesticides/herbicides, POPs, bacteria and other pollutants that impact tidal wetlands can be addressed with several management strategies (discussed in Section 4, Water Quality).

Daily maximum surface water temperatures typically exceed 25°C on warm summer days in the urban tidal wetlands, which have been extensively modified compared to the North Coast wetlands (2NDNATURE, 2006). Temperatures above 21°C are known to stress coldwater fish species such as resident rearing salmonids (Bidgood and Berst, 1969; Hokanson et al., 1977; Smith and Li, 1983). Tidal wetlands in the region with flood protection features are typically devoid of in-stream emergent, submerged or riparian vegetation that provide shade and can mitigate thermal heat transfer. Morphologic modifications that increase the width to depth ratios and improve edge condition will create substrate to promote establishment of marsh vegetation. Such habitat improvement strategies have the additional benefit of protecting rearing coldwater fishes against projected increases in summer maximum air temperatures.

5.5.5 FRESHWATER WETLAND IMPROVEMENTS

The total area of freshwater wetlands in the region has also been reduced as a result of urban and agricultural development, especially in the Watsonville area. The largest freshwater wetland system in the county is the Watsonville Sloughs complex with a system of six interlinked sloughs fed by the Pajaro River. These sloughs provide some of the best shorebird habitat in the region and support native fish, reptile, amphibian, and invertebrate species. Similar to tidal wetlands, freshwater wetlands have undergone extensive modification due to encroachment of urban and agricultural land uses, which has severely impaired the natural functioning of this system. The sloughs were dredged by County of Santa Cruz and adjacent land owners to prevent flooding until 1983. Excessive sediments may adversely impact aquatic organisms, smother benthic habitat, and reduce aquatic habitat due to aggradation.

The sloughs are also adversely affected by delivery of nutrients, bacterial pathogens, and pesticides from upstream and adjacent lands use activities (see Section 4, Water Quality). High fecal coliform bacteria levels measured in the sloughs may be indicative of microbial growth in waterways. Hagar et al. (2004) notes that the adjacent agricultural and urban land uses in particular may create optimal conditions for microbial growth: high nutrients, warm temperatures, high turbidity (low light), microbial predator control by pesticides, and sluggish, relatively deep water (ditches). Agricultural runoff has also been cited as the primary source of pesticide caused toxicity (toxaphene, DDT, diazinon) to invertebrates living in the sloughs and adjacent waterways (Hunt et al., 1999).

Strategies that manage the sources of pollutants (see Section 4, Water Quality) can vastly improve the habitat quality of freshwater wetlands. Acquisition and protection of adjacent lands to wetlands are can both improve the water quality as well as increase the inundation areas to restore a more natural hydrologic regime.

Effective hydrologic improvements could support a diverse wetland vegetation community and surrounding riparian cover, thereby providing the habitat to support the desired freshwater wetland biota and increase the resilience of the habitat to pollutant delivery.

5.5.6 ROLE OF EDUCATION AND OUTREACH PROGRAMS

Education and outreach programs can create a fundamental shift in community behavior towards voluntary stewardship of aquatic systems by educating people about the value of healthy ecosystems, empowering people to identify problems locally and work towards solutions, and advocating for policy changes concerning natural resources. Various non-profit and agency groups operate throughout the region and focus on different components of aquatic ecosystems including the nearshore ocean, wetlands, and/or stream systems. These groups are also often involved with management, restoration, or policy development efforts. Activities they employ to increase awareness include media development, school programs, educational workshops, field tours, experience camps, and volunteer monitoring networks.

Since enforcement of environmental regulations at the individual level is infeasible, voluntary changes in behavior an important component of reducing impacts and ensuring long-term health of aquatic systems. Most people in the region live in close proximity to some aquatic system and have the potential to degrade those systems, perhaps unknowingly. By alerting people to the harm that certain activities could cause and providing alternatives, those impacts may be avoided. Examples in rural residential areas include communicating the impacts of illegal dumping, riparian encroachment, and degraded private roads. Outreach to agricultural, ranching, and other industries provides access to information about best management practices that can minimize impacts to aquatic ecosystems either via pollution prevention (see Section 4, Water Quality) or by minimizing physical encroachment on aquatic systems.

Similar to water supply and water quality education and outreach, an ongoing challenge of watershed stewardship programs has been their inability to quantify the benefits of the programs and track behavior changes over time. Often times, the number of volunteers, hours, or people reached is quantified, but there is not a corresponding link to the impact those programs have on the desired outcomes (e.g., improvement of riparian corridor conditions, reduction of sediment loads, etc.). The development of a system to track the cumulative impacts of education and outreach programs in a way that aligns with stream and wetland condition assessment would provide a mechanism to test such linkages, determine effectiveness of programs, and prioritize efforts in the region.

5.6 STRATEGY IMPLEMENTATION OBJECTIVES

Below are the specific Aquatic Ecosystem strategy implementation objective statements that include desired target conditions by 2030, the working hypothesis of how IRWM strategies will result in objective obtainment and a summary of the data needed to report and track incremental progress.

AE1. Improve riparian zone condition by 40% as measured by increases in rapid riparian zone condition assessment scores by 2030.

Performance measure: Riparian zone condition tracking. Quantified as miles of riparian zone at or above a desired threshold condition.

Hypotheses: The amount and composition of vegetation cover, channel stability, channel floodplain relationship, degree of encroachment, etc., are critical components of stream aquatic habitat quality. Significant opportunities exist to improve the condition of riparian areas throughout the region.
Critical need: Identify assessment methods to document and quantify riparian condition; opportunities exist to create simple techniques using aerial imagery, tributary characteristics, parcel datasets, and field verifications that can be feasibly implemented throughout the region. Alternative options include utilizing existing methods such as California Rapid Assessment Method (CRAM; www.cramwetlands.org). There is a need to quantify existing riparian conditions and define achievable improvements in order to set a quantitative objective target.
Objective supports both Aquatic Ecosystem and Flood/Stormwater Management goals.

AE2. Improve habitat conditions in streams that currently support salmonids for spawning, migration and rearing by 40% as measured by increases in salmonid habitat condition tracking scores by 2030.
Indicator: Salmonid habitat condition tracking. Quantified as miles of stream at or above a desired threshold condition.
Hypotheses: The condition of regional streams can be greatly improved to support salmonid spawning, migration and rearing life cycles. The critical components of the priority streams where improvements are necessary include:

- reductions in the amount and spatial extent of fine sediment (sand or finer) in the channel,
- increased amount and spatial distribution of large woody debris (LWD),
- increased riparian cover and condition,
- increased hydro-geomorphic function,
- reduce water depth limitations for salmonid migration during base flow conditions,
- removal of critical physical barriers that prevent fish passage

Critical need: Identify assessment methods to document and quantify habitat conditions that integrate the critical stream components listed above and can be feasibly implemented throughout the region. Opportunities exist to adopt/adjust existing rapid assessment methods implemented by other monitoring programs. There is a need to quantify existing salmonid habitat conditions and define achievable improvements in order to set a quantitative objective target.

AE3. Increase the wetland habitat area by 30% by 2030 to support native plants and animals.
Indicator: Sum of tidal and freshwater wetland habitat acreage.
Hypotheses: Opportunities exist to increase the area of tidal and freshwater wetlands within the region through acquisition, protection and restoration. Effective areal increases would include morphologic improvements that reduce the width to depth ratio of the wetted area and restoration of native vegetation.
Critical need: Defined standardized approach and subsequent inventory of existing wetland area and future achievable target that may adjust the initial 30% increase target defined above.

AE4. Reduce frequency of dissolved oxygen conditions < 3 mg/L in San Lorenzo and Aptos tidal wetlands by 30% by 2030.
Indicator: Frequency of dissolved oxygen conditions < 3 mg/L.
Hypotheses: Measurable improvements in the dissolved oxygen conditions of tidal wetlands will contribute to the improved success of fish species of concern that depend on healthy tidal wetlands.

Since tidewater goby spend their entire lives within local tidal wetlands, they are dependent on tidal wetland habitat quality during both summer and winter. Summer rearing of steelhead trout in local tidal wetlands is a critical component of supporting the watershed's adult population.

Critical need: Extensive and continued water quality monitoring has been completed in a number of local tidal wetlands (2NDNATURE, 2006; 2012) to identify factors that contribute to healthy habitat conditions. A preliminary standardized data analysis approach has been developed using long-term dissolved oxygen data from San Lorenzo and Laguna tidal wetlands, but continued and comparable water quality data collection would need to be expanded to Aptos and any other tidal wetlands of interest.

6 FLOOD & STORMWATER MANAGEMENT CONCEPTUAL MODEL

6.1 GOAL

Reduce flood hazard and manage stormwater runoff through policies and projects that enhance natural hydrologic function while balancing cost, ecological and community benefit.

6.2 OBJECTIVE

Implement integrated flood management strategies that reduce hazards and impacts from floods and, where feasible, provide multi-benefits (e.g., improve stormwater quality, ecosystem benefits, LID development and groundwater recharge).

6.3 DIAGRAM

The Flood and Stormwater Management conceptual diagram is presented in Figure 6.1.

6.4 LINKAGE TABLE

Table 6.1 is the Flood and Stormwater Management linkage table.

6.5 STRATEGY JUSTIFICATION

6.5.1 FLOOD HAZARDS

Flooding risk depends primarily on watershed morphology, soil type, land cover, duration and intensity of a rainfall event, and antecedent moisture conditions in the watershed. Areas at greatest risk of flooding are low lying zones adjacent to the mainstem rivers and tributaries. Given the seasonal precipitation patterns, regional flood hazards are greatest during the wet months of October – March.

Flood hazard is mitigated in urbanized areas such as downtown City of Santa Cruz with levees to contain flows within the main river channel for larger storm runoff events and with the stormwater conveyance infrastructure (culverts and stormwater drains). Flood hazards are reduced in rural areas by limiting or reducing vulnerable development within the floodplain. Flooding can occur in primary rivers when a runoff event exceeds the design specification of the levees or if water conveyance is blocked within a channel or culvert. Riparian areas and historic floodplains in the lower portion of many regional watersheds currently contain high value property that, if flooded, would result in significant economic losses (Figure 6.2).

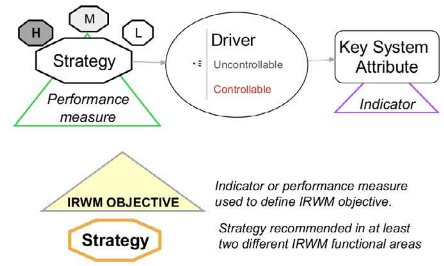
6.5.2 CLIMATE CHANGE IMPLICATIONS

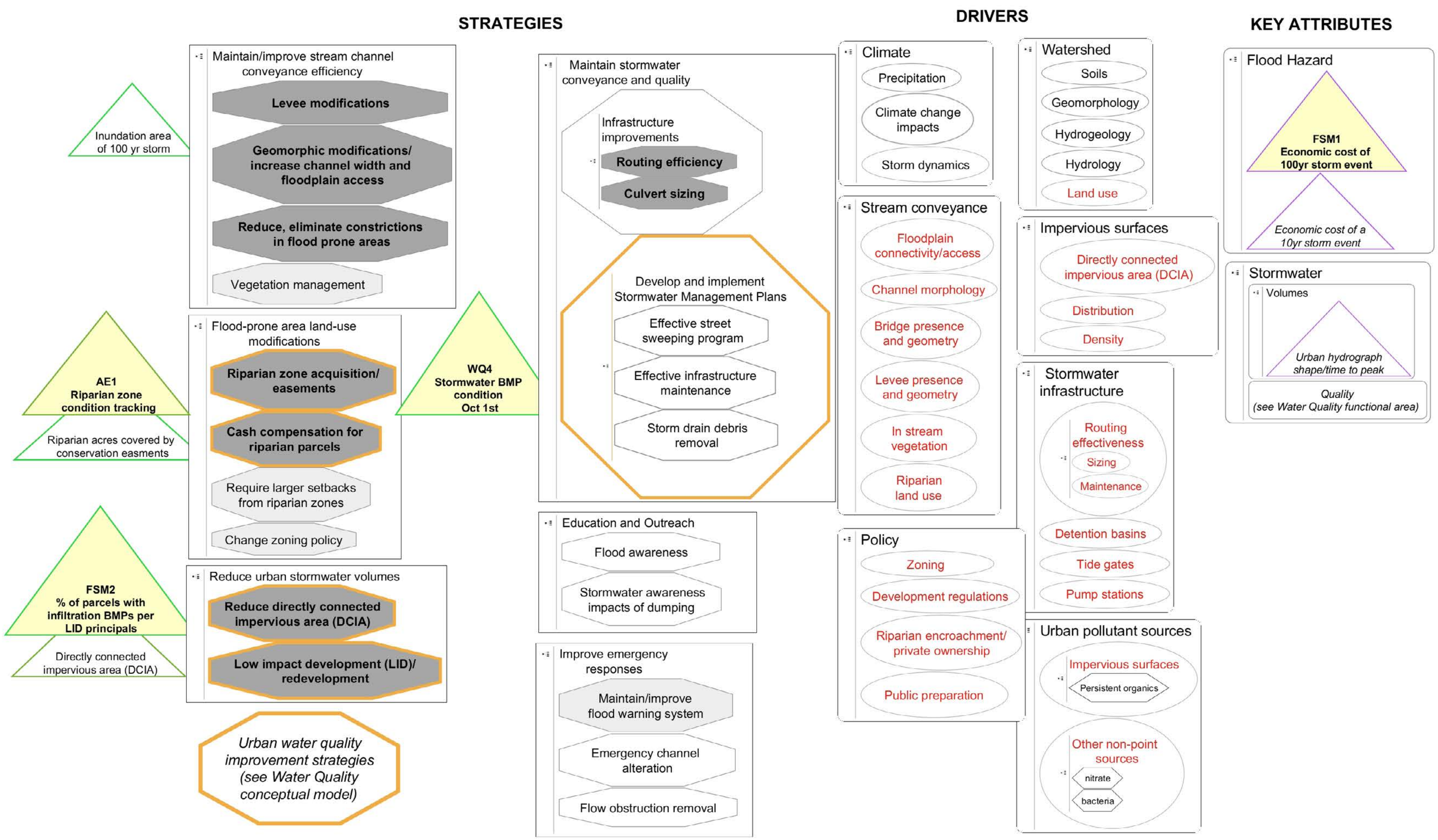
Global climate change projections include expected increases in sea level in the Santa Cruz region (see Table 2.4). Increased sea level elevation will increase the boundary elevation at the terminus of coastal streams, resulting in an increase of the flooding risk for coastal low lying areas (Table 6.2). Statewide models predict an increased frequency of intense winter precipitation events, which will also increase the risk of Santa Cruz flooding.

Santa Cruz IRWMP Update
Functional Area: Flood and Stormwater Management
Conceptual Diagram

GOAL - Reduce flood hazard and manage stormwater runoff through policies and projects that enhance natural hydrologic function while balancing cost, ecological and community benefit

OBJECTIVE - Implement integrated flood management strategies that reduce hazards and impacts from floods and, where feasible, provide multi-benefits (e.g., improve stormwater quality, ecosystem benefits, LID development and groundwater recharge).





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FLOOD AND STORMWATER MANAGEMENT DIAGRAM

FIGURE 6.1

FLOOD AND STORMWATER MANAGEMENT LINKAGE TABLE

See Figure 6.1 for the associated flood and stormwater management diagram.

Expected relative impact of strategy on key attribute(s)

High	Moderate	Low

Key Attributes	Controllable Drivers	Relevant Strategies	Considerations for strategy implementation
Flood Hazard	Riparian land use	Riparian zone acquisitions and easements Cash compensation for riparian parcels	Value of existing land in floodprone area Potential to reduce flood risk to adjacent properties
		Change zoning policy in flood prone areas Require larger setbacks from riparian zones	
	Stream conveyance	Levee modifications Geomorphic modifications/ increase channel width and floodplain function Reduce, eliminate constrictions	Value of existing land in floodprone area Potential to reduce flood risk to adjacent properties Potential impacts on riparian and stream habitat quality
		Vegetation management	
	Stormwater infrastructure	Maintain storm drain conveyance efficiency Infrastructure improvements & maintenance	Locations where undersized infrastructure may create flooding Urban drainage patterns Infrastructure age and condition Timing of maintenance to reduce potential for obstructions during wet season
	Public preparation	Improve flood warning and emergency responses Community awareness of flood risks	Antecedent conditions and expected storm intensity Focus on public in high flood risk locations
Stormwater Volumes	Directly connected impervious area (density and distribution)	Reduce directly connected impervious area Low impact development/redevelopment	Infiltration capacity of native soils Surface area availability for infiltration feature placement Risk of localized flooding by modifications
	Stormwater infrastructure		
Stormwater Quality	Urban pollutant sources Impervious sources Other non-point sources	*Urban water quality protection strategies (see Water Quality functional area)*	
		Storm drain debris removal Effective street sweeping program Infrastructure maintenance	Timing of stormwater maintenance to reduce pollutants available for transport prior to wet season Hydrologic connectivity of urban locations
		Community awareness of stormdrain dumping and other human impacts	Priority audience accessibility Anticipated impacts on key offenders

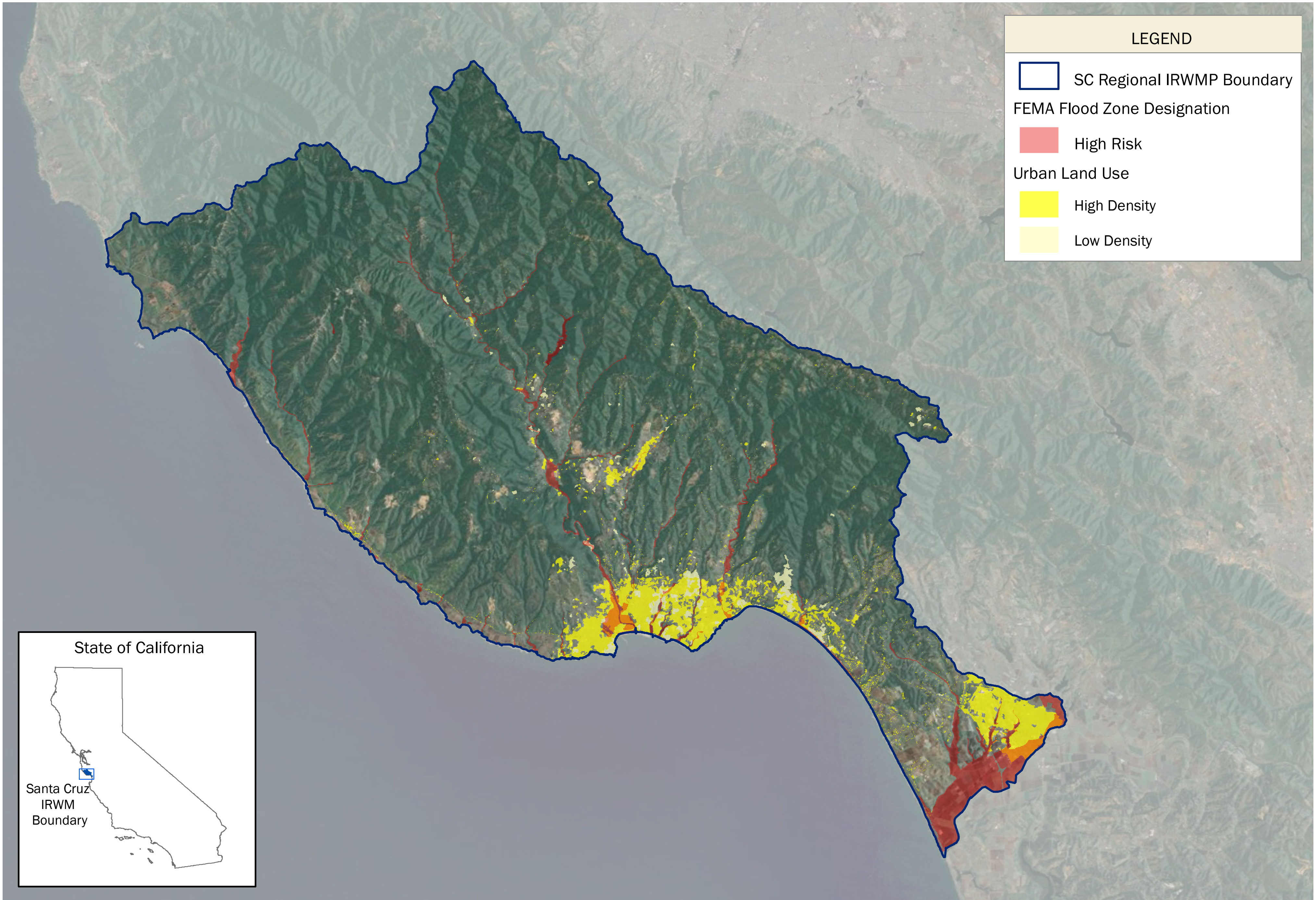

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Figure 6.2: FEMA flood zone designations and land use distribution in the Santa Cruz Region.

VULNERABILITY ASSESSMENT OF FLOOD AND STORMWATER MANAGEMENT KEY ATTRIBUTES

The sensitivity and adaptive capacity for each potential impact was determined based on the approach and criteria outlined in Section 2.4. The vulnerability is the combined result of sensitivity and adaptive capacity (see Table 2.8). IRWM strategies that are also potential climate adaptation actions are provided.

Key attribute	Stressors	Relevant projected climatic/hydrologic changes	Expected impact of future climate conditions	Sensitivity	Adaptive capacity	Vulnerability	Can future impact of climate change be lessened by strategy implementation?
FLOOD AND STORMWATER MANAGEMENT							
Flood hazard	Areas with high degree of DCIA, Developed areas	Increased sea level elevations, Possible (low confidence) seasonal runoff changes	Flood hazard increase for flood prone areas	h	l	h	YES Reduce cost of flooding in susceptible areas and improve channel conveyance efficiency during large storms.
Stormwater volumes	Areas with high degree of DCIA	Possible increased frequency of high intensity precipitation events, Possible seasonal runoff changes	Localized risk of episodic flooding	m	h	m	YES Strategies that reduce DCIA and maintain the stormwater conveyance system.
Stormwater quality	Areas with high degree of DCIA		Potential to increase pollutant entrainment during winter storms	l	h	l	YES Pollutant source control strategies.

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6.5.3 FLOOD HAZARD REDUCTION STRATEGIES

The IRWM regional strategies to reduce flood hazards include increasing stream channel conveyance efficiency by increasing channel width, improving floodplain function and removing constrictions. Strategies also include reducing the potential economic cost should a parcel be inundated by flood waters, and increasing emergency response systems to minimize human and property damage should a flood occur, to the extent possible.

6.5.3.1 Stream channel conveyance efficiency

Opportunities exist to improve and maintain stream channel conveyance during storm events to reduce flood hazard potential. These opportunities include increasing stream channel capacity by:

- increasing channel depth via increasing levee heights,
- increasing channel width via physical channel widening,
- improving floodplain function and flood attenuation,
- reducing potential hydrologic constrictions associated with existing bridges or other infrastructure,
- managing in-stream vegetation to increase conveyance during flood conditions, and
- reducing sediment loading from the watershed to reduce the maintenance needs of conveyance features.

Considerations for implementation include prioritizing areas with the highest current flood hazard and potential economic cost of such an event, the anticipated benefit of specific modifications as determined by hydrologic models, and the potential negative impacts associated with the specific modifications to other resources. The impacts of flood control on aquatic ecosystem habitats create continual regional management challenges that will require both compromises from past land management decisions and innovative solutions to maintain conveyance and minimize ecological impacts (see Section 5 Aquatic Ecosystems).

6.5.3.2 Riparian land use

Opportunities exist to modify flood prone areas through land use changes and/or acquisition of riparian corridors to reduce the economic cost should the parcels be inundated during flooding. Strategies include:

- zoning changes to prevent development and/or modify existing land uses,
- land acquisition (e.g., easements or cash compensation),
- land use conversion (e.g., structure removal and riparian restoration),
- redevelopment modifications (e.g., basement garage requirements).

Changes in riparian land use would facilitate opportunities to increase the riparian width and enhance other morphologic characteristics that would improve conveyance efficiency and reduce flooding hazard, as well as greatly benefit the aquatic ecosystem habitat quality (see Section 5 Aquatic Ecosystems). Considerations for implementation include prioritizing areas with the highest current flood hazard and estimated economic cost should inundation to a parcel occur, redevelopment opportunities, and the anticipated flood hazard reduction benefit of specific modifications.

6.5.4 EMERGENCY RESPONSE SYSTEM IMPROVEMENTS

Flooding costs can be reduced if people in a flood zone can be efficiently warned and they know how to respond appropriately. Strategies to modify river morphology or floodplain land use to reduce flooding risk and costs will require many years to implement, will be expensive, and will never completely eliminate the risk. Since floods are episodic events that cannot be predicted with much confidence very far in advance, effective preparation, emergency response systems and community awareness can greatly reduce the loss of property and life should such an event occur. The capacity and capability of the emergency response systems to forecast flood timing and location, communicate potential flood occurrence, and prepare the community for safe evacuation procedures will reduce flood impacts.

6.5.5 STORMWATER IMPACT REDUCTION STRATEGIES

The high distribution and density of impervious surfaces in urban areas have elevated runoff volumes due to reduced infiltration (see Fig 6.2). Urban stormwater runoff during large storms can result in localized flooding and/or contribute to stream flood hazards. Urban runoff is also known to contain and transport pollutants and impair the water quality of surface and groundwater resources.

Long-term stormwater network improvements should focus on reducing the fraction of rainfall that is translated into runoff by disconnecting impervious surfaces and increasing localized parcel-based infiltration. The intensive implementation of low impact development (LID) or redevelopment practices on public and private parcels that retain the majority of rainfall on the parcel is hypothesized to have a significant cumulative benefit on reducing stormwater volumes and improving stormwater quality. The implementation of this strategy on the public right away to incrementally retain and infiltrate road and sidewalk runoff is also recommended (see photos below). While each individual infiltration feature (such as infiltration trenches, rain gardens, vegetated swales, etc) will contain and infiltrate very small volumes, an aggressive, wide-spread program to implement infiltration features and other strategies to reduce urban runoff volumes could achieve multiple benefits including:

- reducing stormwater volumes contributed during flood conditions,
- increasing recharge volumes to local groundwater,
- increasing subsurface return flows to local streams,
- reducing climate change vulnerability by reducing the amount of water lost as runoff,
- reducing urban pollutant transport and contributing to regional water quality goals.

NATURAL SYSTEM BENEFITS

- ✔ Provide Habitat
- ✔ Slowly Release Storm Flow
- ✔ Filter Pollutants
- ✔ Recharge Groundwater
- ✔ Reduce Erosion

Strategies that increase the spatial distribution of stormwater infiltration are hypothesized to have a concurrent water quality benefit due to reduced volumes, reduced pollutant transport capacity, and the attenuation of many urban derived pollutants (e.g., persistent organics, trace metals, fertilizers, pesticides, etc.) in the unsaturated zone during infiltration. Considerations to determine priority locations to disconnect impervious surfaces and implement LID principles include the infiltration capability of native soils, the current density and distribution of impervious surfaces, the surface area availability to place infiltration features or reroute surface drainage, and the potential increased risk of localized flooding by implementing the specific modifications. A disadvantage of this approach in certain areas may be the space required to provide adequate storage for stormwater infiltration given the infiltration capacity of soils (see photos above).

Short term improvements to reduce stormwater impacts, including regular and effective urban maintenance actions, can improve stormwater conveyance during large storms and reduce the transport of urban generated pollutants. Stormwater best management practices (BMPs) include effective street sweeping programs, extensive fall stormwater network cleanouts and maintenance in preparation for winter storms, and upgrades of degraded, undersized or failing components of the stormwater infrastructure.

6.5.6 ROLE OF EDUCATION AND OUTREACH

The cost of flooding in terms of life and property can be reduced when community members are educated on flood preparedness and know what to do when a flood watch or warning is issued by the county office of emergency services. Flood hazard maps distributed by the County delineate and educate people about the degree of risk they may incur by living, conducting business, or buying property in different areas. In addition to educating the community on emergency responses, education of hydrologic function and flooding should extend to policy makers so that development practices and zoning work towards minimizing the economic costs of flooding in the future. For example, a regional planning requirement that new or re-development projects within the FEMA 100 yr flood zone include raised structures with base level parking is one option to greatly reduce the economic cost of property damage during a subsequent flood.

Urban runoff is one of the leading sources of water pollution in the region and water from roofs, roads, and parking lots flows directly into urban waterways and storm drains. Education programs implemented by local agencies and non-profit groups should continue to focus on communicating the connectivity of urban landscapes with natural watershed systems and the fate and impacts of urban pollutants in streams and the near shore waters of the Monterey Bay National Marine Sanctuary. Programs include volunteer clean up and monitoring events, media distribution, storm drain stenciling, and green business programs. These programs that encourage voluntary action are essential components of urban stormwater pollution reduction since enforcement of stormwater dumping regulations is not feasible.

Similar to the other functional areas, repeatable and standardized surveys to track behavior changes over time as a result of education and outreach programs are needed. These surveys would provide a link to the impact those programs have on the desired outcomes (e.g., increased infiltration on private parcels), create a meaningful standard to report effectiveness of outreach to stakeholders, funders and the public, and identify priority topics and community demographics for future outreach programs.

6.5.7 STRATEGY IMPLEMENTATION OBJECTIVES

Below are the specific Flood & Stormwater Management strategy implementation objective statements that include desired target conditions by 2030, the working hypothesis of how IRWM strategies will result in objective obtainment and a summary of the data needed to report and track incremental progress.

FSM1. Reduce the estimated regional economic cost of a 100 year discharge event by 30% by 2030.

Indicator: Regional economic cost of a 100 yr storm event.

Hypotheses: Economic loss in flood-prone areas can be significantly reduced by either greater flood protection (i.e., reduction of flood-prone area) or reducing the economic cost of flooding in high risk areas through land-use modifications such the creation of riparian easements, transformation to parks or parking lots, raised structures and basement parking, etc.

Critical Need: Identify and adopt a method to quantify the economic cost associated with a 100yr flood occurrence in the region and define approach to control for inflation or deflation of property value. Develop an existing FEMA HAZUS analysis and update every 5 years. Existing conditions need to be quantified to set/adjust appropriate target and then objective would be revised to include a target that quantifies desired flood risk cost savings.

FSM2. Increase the number of private and public parcels that retain the 1 inch 20 year rainstorm on site using LID principles either by retrofit or new construction by 2030.

Performance measure: Percent of public/private parcels with infiltration BMPs per regional low impact development (LID) principles.

Hypotheses: A large spatial application of LID principles in the region will significantly reduce the directly connected impervious area (DCIA) in urban areas. Infiltration features on public and private parcels will reduce stormwater volumes by allowing rainfall to infiltrate and reduce the fraction of rainfall that this routed to the stormwater system and lost to the ocean. Infiltration to the soil will directly reduce the public infrastructure capacity needs, restore urban areas to a more natural hydrology and reduce climate change vulnerability. In addition, soil water interactions filter pollutants and can improve regional groundwater and surface water quality.

Critical Need: Expand and implement programs to assist, guide, educate and track the implementation of public and private parcel LID modification and infiltration BMP implementation. Track parcel certifications issued for proper installation and renewon 5 yr inspection basis to demonstrate adequate maintenance and continued performance.

Objective supports both Flood and Stormwater Management, Water Supply, and Water Quality goals.

7 MONITORING ELEMENTS

A subset of implementation objectives was identified by the Working Group as near term priorities to initiate the tracking and reporting of IRWM progress. The intent of the monitoring elements is to provide guidance to SC IRWM Partner Agencies on how to manage, track and report regional progress towards achieving these objectives to a broader audience of implementation affiliates and stakeholders. The recommendations below are oriented towards improving management decisions by simply and effectively communicating progress of IRWM implementation strategies over time. The tracking vision is to create a set of standardized IRWM status updates that consist of a collection of meaningful objectives. Progress will be analyzed and reported annually.

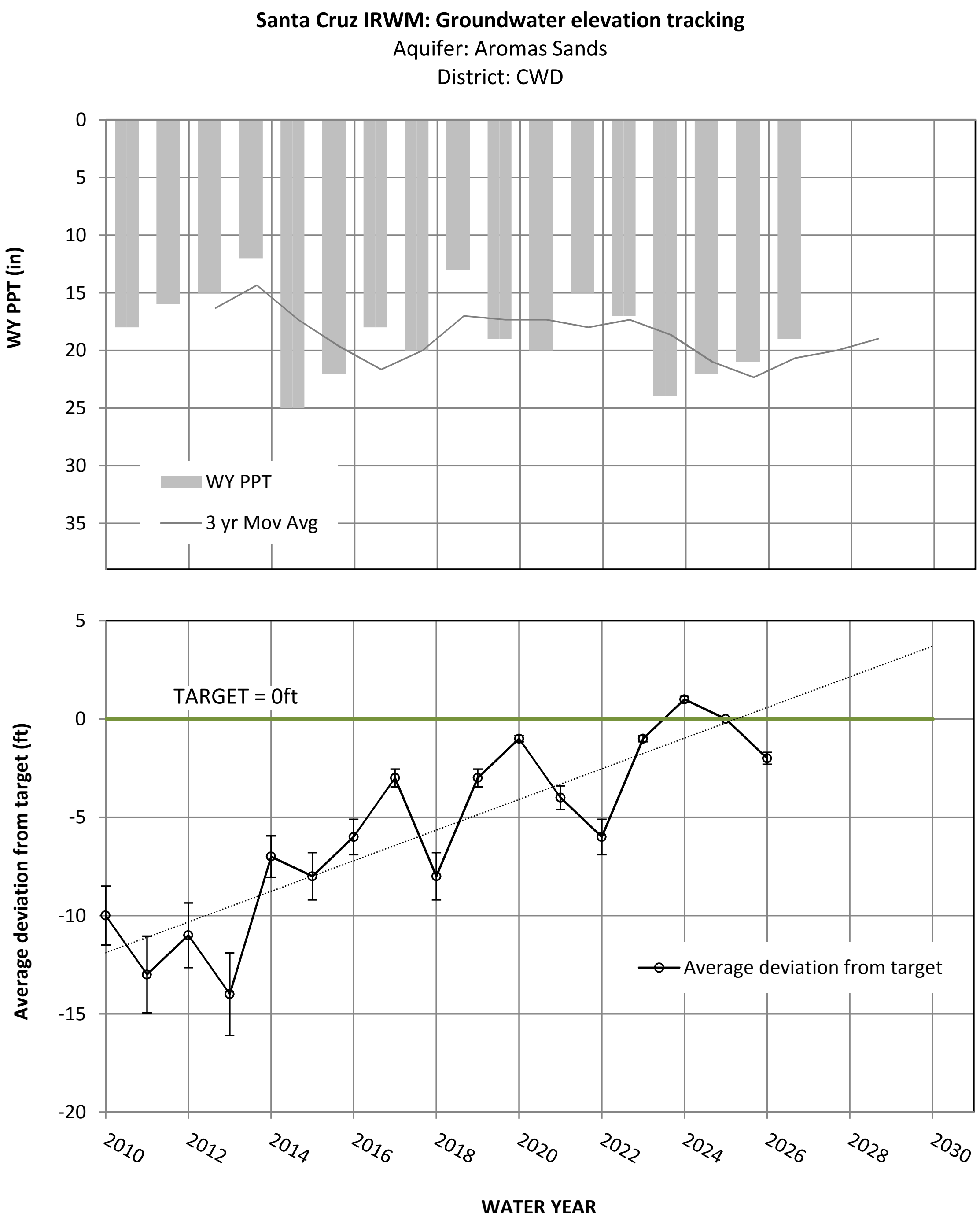
WS1. By 2030, meet or exceed target groundwater elevations or maintain increasing trends in groundwater elevations for wells that do not have targets.

Existing studies, hydrogeologic knowledge and monitoring efforts were used to identify key monitoring wells and associated water elevation targets. The Soquel Creek Water District and the City of Santa Cruz have both identified protective water surface elevations for a number of monitoring wells within the Purisima and Aromas Red Sands aquifers (see Figure 3.3). A subset of these monitoring wells, ideally those with groundwater elevation targets, will be selected to represent desired groundwater elevations for each aquifer of interest. To avoid redundancy, monitoring wells whose elevations are strongly correlated could be removed. Target groundwater elevations will be specific to each well and will be evaluated using the minimum elevation measured during the sampling year. To track the selected monitoring wells, the following information should be documented:

- Metadata including: Monitoring well ID, location, responsible water agency, aquifer, year installed, screen interval, top of casing elevation, datum, and other necessary details.
- Water level sampling protocols including: Frequency, responsible party, and data collection, management and reporting protocols.
- Elevation target (ft): Protective elevation target established by the respective water district, expressed as an average annual threshold elevation (ft).

For each selected monitoring well, if resources allow, historic datasets can be compiled to identify the minimum water year surface elevation for all available water years of data. The minimum water elevation observed each water year should be subtracted from the target elevation for each monitoring well and expressed as a deviation from the target in feet. Minimum elevations lower than the target should be expressed as negative values. Groundwater elevations from individual wells will be integrated (with accounting for spatial interactions) as a single metric (e.g., average or median) to summarize the condition of respective aquifers relative to the protective elevations. Should tracking and trend analyses be desired for monitoring wells without established elevation targets, it is recommended that a network of non-correlated wells be identified and the water elevation sampling data be summarized and integrated using the same methods described above. Instead of using a target elevation for each monitoring well, a baseline elevation year in the past should be identified and used to quantify the annual elevation change relative to baseline for each monitoring well within the aquifer network. All other data management and reporting approaches would be consistent with the monitoring networks that possess target elevations.

While this data reporting approach will be less sensitive to localized changes, the approach will document effective regional progress toward this IRWM objective on longer (decadal) time periods using a simple and consistent format. This integration of selected aquifer monitoring wells will provide a single status and trend for each aquifer of interest as illustrated in Figure 7.1, including:



Hypothetical Santa Cruz Region water year types

WY Type	Precipitation Range (in)
Very Dry	<10
Dry	≥10 - <15
Average	≥15 - <20
Wet	≥20 - <25
Very Wet	≥25

SUMMARY

Water Year	2026
WY Precip (in)	19.2
WY Type	Average
Average deviation from target (ft)	-2.5

After removing annual precipitation variabililty, the Aromas Sands aquifer groundwater elevations have been increasing at an average rate of 0.39 ft/yr, and this trend is statistically significant ($p<0.005$).

DESIGNED BY
2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

WS1: HYPOTHETICAL EXAMPLE OF TRACKING AND REPORTING FORMAT

FIGURE 7.1

- Water year precipitation totals and 3 year trends given the strong dependence of groundwater recharge on water year type. A frequency analysis of relevant long-term precipitation datasets can be used to define and communicate water year types (see top graph in Figure 7.1 as an example).
- Time series of aquifer water elevation status, reported each water year as the average deviation of the aquifer monitoring wells to their respective targets and the standard deviation of population.
- Summary of the results of time series trend analysis conducted on the regional aquifer water elevation data sets.

Methods to determine aquifer water elevation trends may involve qualitative comparisons over time, inspection of graphical plots, and different types of statistical tests. The trend analysis will identify the following:

- Statistically significant trend (yes or no) and the significance level
- Metric trend direction (increase or decrease)
- Trend magnitude or rate of annual change

The non-parametric, distribution-free, seasonal Mann-Kendall test (Helsel and Hirsch, 1992) should be used to identify monotonic (one-directional) trends in the well elevation data. The analysis can be done using monthly data so that only values from the same month of each year are compared to determine each monthly trend and then combined to assess overall annual trends for the period of record. Trend tests for individual wells can be combined to assess the trend for an entire aquifer for regional reporting purposes, as shown in Figure 7.1. The slope of the trend line quantifies the magnitude of the change in well elevations over time. Since much of the variation in well elevations over time is driven by precipitation variability, a locally-weighted regression (LOWESS) model (Cleveland and Devlin, 1988) should be used to account for precipitation before the trend test is performed.

WS3. Reduce the number of days Tier 3 flow targets are not achieved in the San Lorenzo River and North Coast streams.

AND

WS4. Reduce the number of days each year where streamflow in Soquel Creek is less than 4 cfs between June 1 and December 1.

Knowledge of past hydrologic conditions and salmonid habitat requirements has resulted in regional minimum stream flow targets for a number of critical tributaries, including Soquel Creek, San Lorenzo River and a selection of North Coast Streams. Tracking progress towards specific targets in regional streams will indicate IRWM implementation progress. For each watershed selected, the following information should be documented in a format accessible to regional stakeholders:

- Metadata including: Watershed, stream gage ID, gage location, responsible agency for data collection, year installed, data extent, etc.
- Discharge monitoring protocols including: Frequency, field personnel or responsible agency, and instrumentation, field QA/QC and other data collection, management and reporting protocols.
- Mean daily discharge target (cfs): The specific minimum discharge defined for the respective locale. For San Lorenzo River, these mean daily discharge targets have been defined as Tier 3 flow targets in the City of Santa Cruz Habitat Conservation Plan (2011).

Data will be analyzed and reported by watershed, and data obtained from stream gage networks chosen to represent the same watershed should be integrated to provide a single watershed status and trend. Opportunities exist to compile, analyze and express historic water year conditions relative to targets if resources are available. For each day the flow target is not met, the % deviation from the target should be calculated (i.e., [mean daily flow – target]/target). The water year flow conditions at each site are expressed as the number of days discharge was below the target and the average % deviation for all days when the respective target was not met for each stream gage. Integration across sites within the same watershed should be calculated as the average deviation from the respective targets and the standard deviation of the population.

Annual status and continued trend data can be presented in graphical format, as illustrated in Figure 7.2, and could include the water year precipitation record and a simple summary of the most recent water year results. Trend analysis on the annual stream flow deviation should be conducted using a Mann-Kendall statistical approach to remove precipitation variability and reported annually on the graphic.

This integration of one or more stream gages will provide a single status and trend for each watershed of interest as illustrated in Figure 7.2, including:

- Water year precipitation totals and trends, given the strong dependence of minimum baseflows on water year type. A frequency analysis of relevant long-term precipitation datasets can be used to define and communicate water year types (see top graph in Figure 7.2 as an example).
- Time series of watershed baseflow condition status, reported each water year as the average number of days flows were below target and standard deviation of population. (If only one gage is used, standard deviation would not be applicable).
- For all days when the minimum flow was below target, annual time series of average % deviation below target and standard deviation: [Target (cfs) - Measured (cfs)]/Target (cfs).
- Summary of the results of time series trend analysis.

Methods to determine baseflow condition trends may involve qualitative comparisons over time, inspection of graphical plots, and different types of statistical tests. The trend analysis will identify the following:

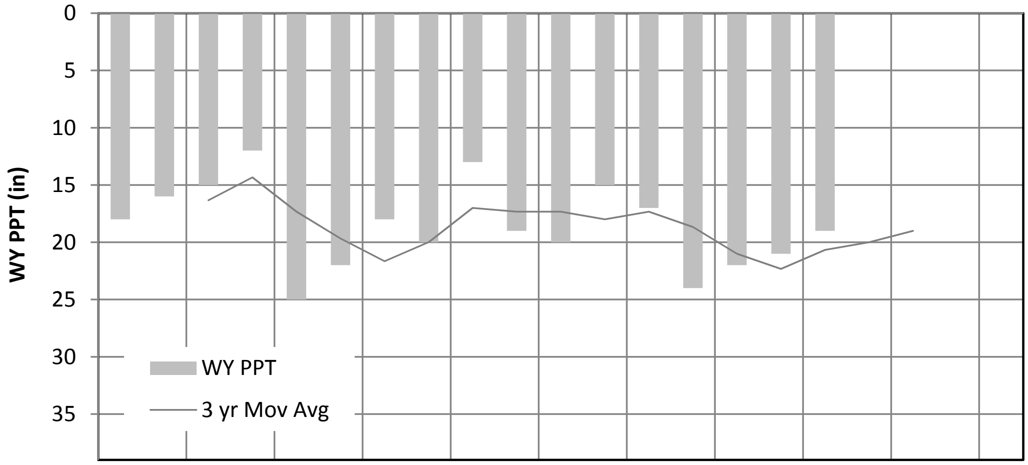
- Statistically significant trend (yes or no) and the significance level
- Metric trend direction (increase or decrease)
- Trend magnitude or rate of annual change

The non-parametric, distribution-free, seasonal Mann-Kendall test (Helsel and Hirsch, 1992) should be used to identify monotonic (one-directional) trends in the time series data. The analysis can be done using monthly data so that only values from the same month of each year are compared to determine each monthly trend and then combined to assess overall annual trends for the period of record. Trend tests for individual gages can be combined to assess the trend for an entire watershed for regional reporting purposes as shown in Figure 7.2. The slope of the trend line quantifies the magnitude of the change in minimum stream flow conditions over time. Since much of the variation in baseflow over time is driven by precipitation variability, a locally-weighted regression (LOWESS) model (Cleveland and Devlin, 1988) should be used to account for precipitation before the trend test is performed.

AE1. Improve riparian zone condition by 40% as measured by increases in rapid riparian zone condition assessment scores by 2030.

Extensive research, studies, assessments and surveys have been conducted on the quality of regional riparian zones, suggesting a great opportunity for regional improvements. A number of IRWM priority strategies include direct or indirect improvements to riparian zones to support aquatic ecosystems, improve regional water quality and reduce flooding risks. The priority IRWM critical need is a standardized rapid assessment technique to document the relative riparian condition throughout watersheds in the region, either by

Santa Cruz IRWM: Stream minimum flow tracking
Watershed: San Lorenzo River
District: City of Santa Cruz



Hypothetical Santa Cruz Region water year types

WY Type	Precipitation Range (in)
Very Dry	<10
Dry	≥10 - <15
Average	≥15 - <20
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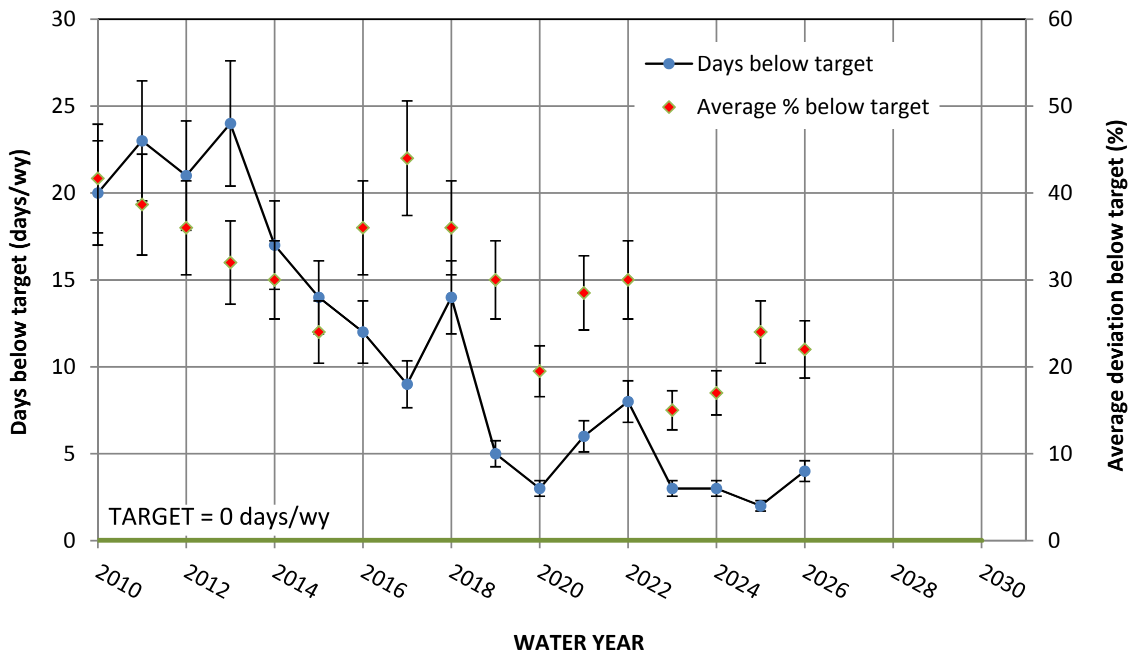
Very Wet	≥25



SUMMARY

Water Year	2026
WY Precip (in)	19.2
WY Type	Average
San Lorenzo frequency of min flow below baseline (days)	4
Average deviation below target when not met (%)	22%

After removing annual precipitation variability, the number of days the San Lorenzo River flows have been below the minimum flow targets has been decreasing at an average rate of 1.4 days/yr, and this trend is statistically significant (p<0.001).

developing a new technique or adopting an existing methodology. While the actual reporting units of condition will vary by technique, guidance below is provided to apply such a technique, establish future targets and track annual IRWM progress into the future.

- Document field data collection, data management and data reporting protocols. Verify the assessment technique and scoring metric is sensitive to the expected range of riparian conditions from degraded to best achievable in Santa Cruz County. Commit to utilizing assessment to evaluate riparian condition both pre- and post-improvements and to verify improvements were effective over time.
- Apply fundamental concepts of riparian condition assessment to remotely map locations and extents of reaches in poor/degraded conditions where improvements may be a future priority. Apply available datasets, imagery, survey results, etc. to approximate scores for degraded sites. Field verify a subset of sites to improve precision of estimated scores. This process is intended to calibrate the Rapid Assessment Method (RAM) to streams in the region to ensure that the scoring accurately reflects habitat conditions relative to key attributes of habitat quality. An example scoring rubric is shown in Table 7.1.

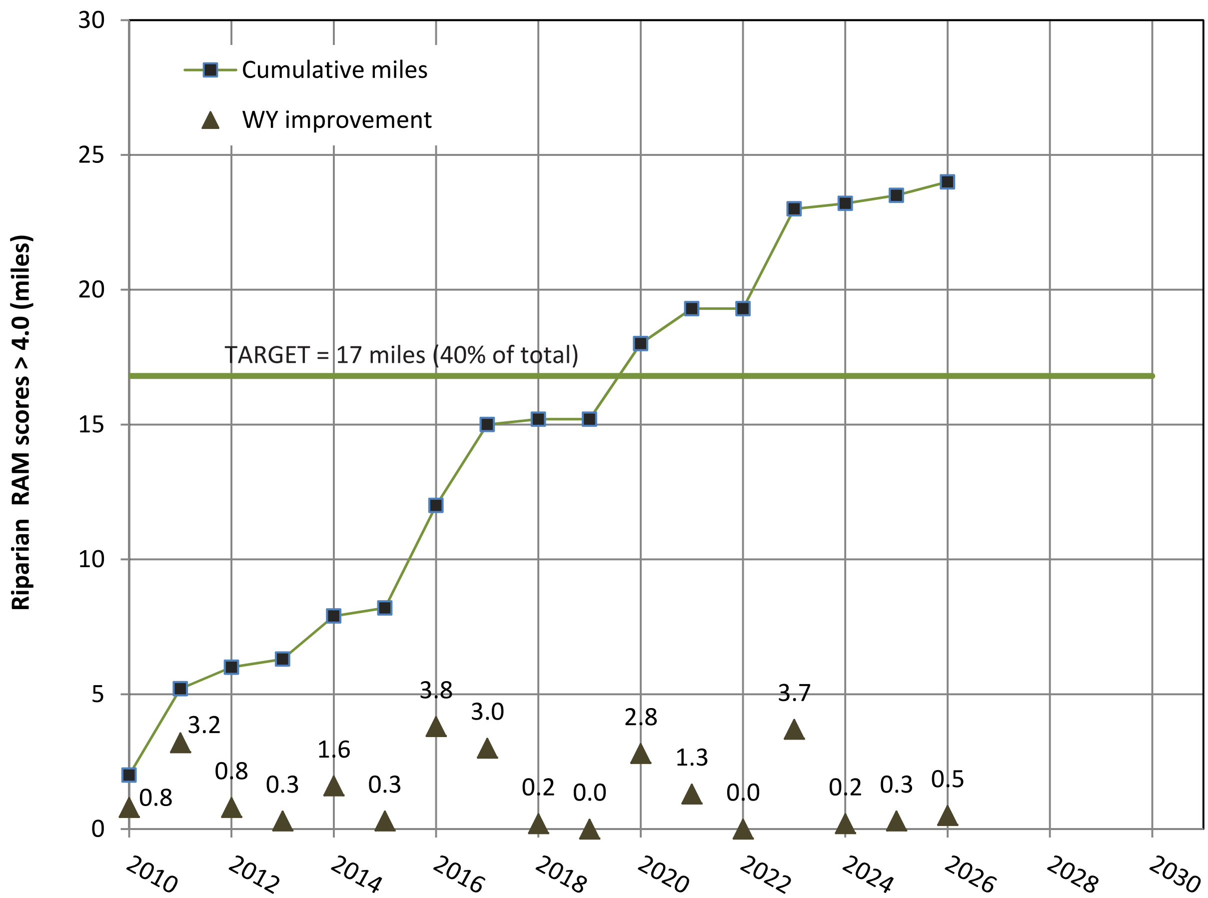
Table 7.1. Example scoring rubric for riparian condition assessment.

Score	Condition
0-1	Degraded
1-2	Poor
2-3	Fair
3-4	Acceptable
4-5	Best Achievable

- Perform a validation analysis on riparian segments not included in the remote assessments or field verifications to assess the accuracy of the RAM relative to other indicators of habitat quality.
- Map the priority riparian improvement zones to establish the baseline conditions for assessing progress towards the objective of 40% improvement.
- Create a process to integrate the spatial extent of assessed streams segments and the condition scores to assess progress towards the 40% improvement goal.
- Conduct assessments annually, prioritizing locations where improvement actions have been conducted. Revisit improved locations on reasonable intervals to verify condition is sustained.
- Track incremental condition improvements to individual stream segments over time and present in graphical format as illustrated in Figure 7.3. Include a simple summary of the most recent results and progress relative to target. Supplementing Figure 7.3 with a map locating the improved areas is recommended. A dynamic mapping application with simple color-coded categories that reflect riparian zone condition (see Table 7.1) would be a key component of such a system and would facilitate dissemination of conditions and IRWM progress to a wide array of audiences.

Santa Cruz IRWM: Riparian condition tracking

Priority degraded riparian area: 42 miles



SUMMARY

Water Year	2026
Riparian improvements in 2026 (miles)	0.5
Cumulative miles of degraded riparian habitat improved to RAM Score > 4.0	24

Since 2010, 57% of the region's degraded riparian zones (24 of the 42 total miles) have been improved. This well exceeds the 2030 target of 40%.

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