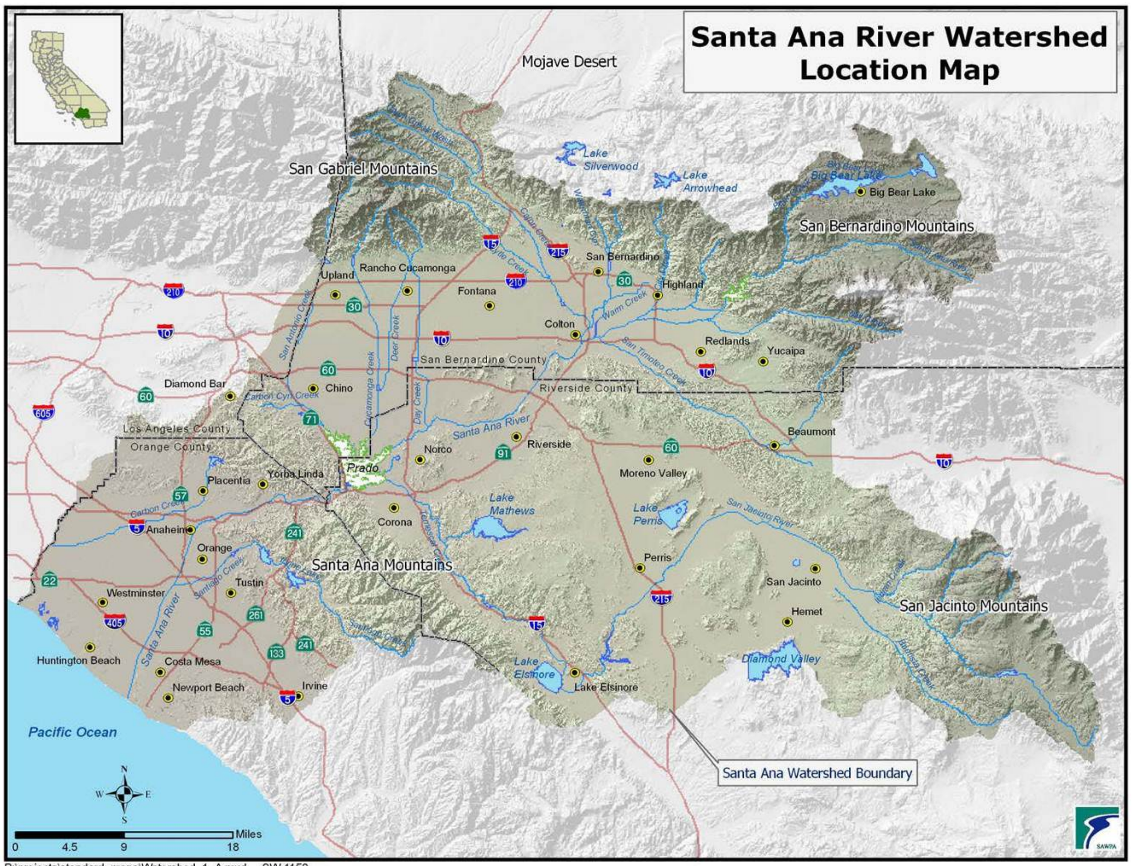
# RECLAMATION

*Managing Water in the West*

Summary Report

# Santa Ana Watershed Basin Study




P:\projects\standard_maps\Watershed_1_A.mxd SW-1150

U.S. Department of the Interior
Bureau of Reclamation

September 2013

# Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Summary Report

# Santa Ana Watershed Basin Study

**Prepared by:**

**Jack Simes, Project Manager**
**Bureau of Reclamation**
**Southern California Area Office**
**Temecula, California**

**Reviewed by:**

**Mark Norton, P.E., LEED AP**
**Santa Ana Watershed Project Authority**
**Riverside, California**

***"Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure how we live on the land."***

**~ Luna Leopold**
**Former USGS Chief Hydrologist,**
**and son of conservationist Aldo Leopold**

# Acknowledgements


Effective water resources management approaches like those used in California's Integrated Regional Water Management Planning process, also known as the One Water One Watershed (OWOW) 2.0 Plan in the Santa Ana Watershed, requires much involvement from many sources to craft a useful guide to help meet future water supply and demand requirements. To that end, the Bureau of Reclamation through the Basin Study program and many people throughout the Santa Ana River Watershed were engaged in that intensive planning process in support of accomplishing various objectives over the past two years. Much thanks goes to:

**Santa Ana Watershed Project Authority**

Commissioners Terry Catlin, Phil Anthony, Ron Sullivan, Mark Bulot, and Don Galleano

Alternate Commissioners Angel Santiago, Dave Slawson, Harry Sidhu, P.E., Ed Kilgore, and Tom Evans

General Manager Celeste Cantu and Water Resources Planning Manager/Co-Study Manager Mark Norton, P.E.

SAWPA staff: Jeff Beehler, Rick Whetsel, Rich Haller, P.E., Carlos Quintero, Peter Vitt, Dean Unger, Marie Jauregui, Sara Villa, and Zyanya Blancas

Master Craftsmen: Joe Grindstaff, Wyatt Troxel, Mark Wildermuth, Gerard Thibeault, Tim Moore, Jerry King, Larry McKenney, Don Schroeder, Steve PonTell, Pete Dangermond, and Jeff Mosher

**Bureau of Reclamation**

Deputy Commissioner David Murillo

Southern California Area Office Manager Bill Steele

Technical Services Center staff: Subhrendu Gangopadhyay, Kristine Blickenstaff, and Ian Ferguson

Lower Colorado Region Engineering Services Office staff: Tom Nichols, P.E. and Colleen Dwyer

Southern California Area Office: Co-Study Manager Jack Simes and Leslie Cleveland

**Kennedy Communications**

Maria Elena Kennedy

**The OWOW Pillar Chairs and Co-Chairs**

Water Resources Optimization: Robert Tincher, P.E. and Mark Tettemer
Beneficial Use Assurance: Greg Woodside and Mark Adelson
Water Use Efficiency: Pam Pavela and Gail Govey
Land Use and Water Planning: Susan Lien-Longville and Jerry Blum
Multi-Hazard Preparation: Maryanne Skorpanich and Stewart Mckibben
Natural Resources Stewardship: Lee Reeder and Nancy Gardner
Operational Efficiency and Water Transfers: Behrooz Mortazavi and Craig Miller
Disadvantaged and Tribal Community: Maria Elena Kennedy and Leslie Cleveland
Government Alliance: Eileen Takata and Jack Simes
Energy and Environment Impact Resources: Roy Herndon and Craig Perkins

And all the Santa Ana River Watershed water and wastewater stakeholders and interested parties also have our sincere thanks. Everyone's time and expertise in this study is truly appreciated.

# Contents



# Tables

# Figures



# Attachments

Appendix A: Santa Ana Watershed Frequently Asked Questions and Findings
- A1: Climate and Water Supply
- A2: Climate and Groundwater Supply
- A3: Climate and Recreation
- A4: Climate and Forest Ecosystems
- A5: Climate and Snowpack at Big Bear
- A6: Climate and Temperature
- A7: Climate and Flood Frequency
- A8: Climate and Sea Level Rise

Appendix B: SARW Vulnerability Assessment
Appendix C: SARW Groundwater Screening Tool

# Supporting Documents

Technical Memorandum No. 1: *Climate Change Analysis for the Santa Ana Watershed*
Technical Memorandum No. 2: *Greenhouse Gas Emissions Calculator: User's Manual*
Technical Memorandum No. 3: *Inland Empire Interceptor Appraisal Analysis*
Report: *Overview of Disadvantaged Communities and Native American Tribes in the Santa Ana River Watershed*
Santa Ana Watershed Project Authority 'One Water One Watershed' documents – on-line at: http://www.sawpa.org/owow/

# Acronyms and Abbreviations

| | |
|---|---|
| AB | Assembly Bill |
| AF | Acre-Feet |
| BMP | Best Management Practice |
| BOD | Biochemical Oxygen Demand |
| DAC | Disadvantaged Community |
| FAQ | Frequently Asked Question |
| GCM | Global Climate Model |
| GHG | Greenhouse Gas |
| GPD | Gallons per day |
| IRWMP | Integrated Regional Water Management Plan |
| MAFY | Million acre-feet per Year |
| mtCO2e | Metric Tons of Carbon Dioxide Gas Equivalent |
| OCWD | Orange County Water District |
| OWOW | One Water One Watershed |
| Prop | California State Proposition |
| Reclamation | Bureau of Reclamation |
| SAWPA | Santa Ana Watershed Project Authority |
| SARI | Santa Ana Regional Interceptor |
| SARW | Santa Ana River Watershed |
| SLR | Sea Level Rise |
| Study | Santa Ana Watershed Basin Study |
| SWE | Snow Water Equivalent |
| SWP | State Water Project |
| TDS | Total Dissolved Solids |
| TF | Treatment Facility |
| TM | Technical Memorandum |
| Tribe | Native American Tribe |
| TSS | Total Suspended Solids |
| U.S. | United States |
| WaterSMART | Sustain and Manage America's Resources for Tomorrow |
| WRMS | Water Resources Management System |

# 1.0 Summary

The U.S. Department of the Interior's WaterSMART (Sustain and Manage America's Resources for Tomorrow) program allows all bureaus of the Department to collaboratively work with States, Tribes, local governments, and non-governmental organizations to pursue a sustainable water supply for the Nation. This is done through a framework that provides federal leadership and assistance on the efficient use of water, and by integrating water and energy policies to support the sustainable use of all natural resources. Basin Studies, one of the tools of this program, are basin-wide efforts to evaluate and address the impacts of climate change, and define options for meeting future water demands in river basins in the western United States where imbalances in water supply and demand exist or are projected.

The Bureau of Reclamation (Reclamation) and the Santa Ana Watershed Project Authority (SAWPA) partnered in the WaterSMART Santa Ana Watershed Basin Study (Study). The work done under the Study was used to help SAWPA update its One Water One Watershed (OWOW) Plan. OWOW is an Integrated Regional Water Management Plan (IRWMP) for the Santa Ana River Watershed (SARW) that serves as the blueprint for SAWPA, its member agencies and key stakeholders to effectively manage water resources over the next 30 years.

**Figure 1: Santa Ana River headwaters**
**(Source: http://dorjeixchel.typepad.com/blog/2011/08/index.html)**

The Santa Ana Watershed Basin Study illustrates how effective collaboration can improve water management. This Study takes a crest-to-coast and corner-to-corner approach throughout a 2,400-square-mile watershed, which encompasses everything from beach to mountain communities, to address the area's unique water resource challenges. The SARW is home to more than 6 million people, and tens of millions more people visit the area each year. The region also has a large manufacturing, industrial, and agricultural base. More than 350 water, wastewater, and groundwater management, flood control, environmental and other non-governmental organizations, are working together as partners with SAWPA on the OWOW Plan. Through the Basin Study Program, Reclamation is partnering with SAWPA and its stakeholders to update key components of the Plan, now known as OWOW 2.0.

The OWOW 2.0 Plan takes a region-wide look at water supply and demand, population growth, water quality, flood control, and projected effects of climate change. Local water sources like the Santa Ana River are critical to the region, but water imports from the Colorado River and State Water Project (SWP) also play a key role. However, by the time water from the Colorado River reaches arid southern California, it contains high concentrations of salt; plus, many of the region's agricultural and manufacturing industries generate salt that requires disposal. This salt imbalance is just one example of the many challenges facing local water managers who work collaboratively through SAWPA to effectively and efficiently manage water resources in the region.

**Figure 2: Santa Ana River near Costa Mesa**
**(Source: http://geology.campus.ad.csulb.edu/people/bperry/AerialPhotosSoCal/HuntBeachToCostaMesa.htm)**

Reclamation and SAWPA share a vision for effectively managing the Santa Ana River basin's finite water resources to meet future needs. This Basin Study, which is a 50/50 cost-share partnership, assesses past, present, and future water needs, especially under climate change scenarios through 2099. The Santa Ana Watershed Basin Study helped SAWPA and its member agencies identify data gaps, conduct tradeoff analyses, address the effects of climate change, and develop effective adaptation strategies.

Reclamation conducted several tasks as part of this Study effort, and provided SAWPA technical analyses of critical water resources information pertinent to the

SARW, especially those related to climate change, flooding, and sea level rise. This Study is unique in that this was the first Urban setting in which Reclamation conducted its climate change analysis. Additionally, decision support tools developed as part of the analysis helped SAWPA answer a series of frequently asked questions (FAQs) for the basin. The results are documented in the *Climate Change Analysis Technical Memorandum No. 1* (TM 1); the FAQs are attached as Appendix A of this report.

The *GHG Emissions Calculator for the Water Sector: User's Manual* (TM 2) was developed by Reclamation as a tool to support the *Climate Change Analysis*. It evaluated mitigation strategies, while the Climate Change Analysis focused primarily on adaptation and vulnerability analysis. The GHG Emission Calculator is a decision-making tool that can be used to explore the links between water resources, energy, and GHG emissions. It can be used to determine water supply and energy demands for a study area ranging from a city block to an entire watershed, regardless of the level of detailed data available. It is a vital tool for decision-makers when developing water supply plans for the future, and is also equipped to evaluate long term GHG emission reduction potential for new projects that will alter the water supply portfolio.

An appraisal-level analysis was also conducted on the Santa Ana Regional Interceptor (SARI), also known as the Inland Empire Interceptor or Brine Line. SARI was one of three salt management alternatives that SAWPA wanted examined for the basin. In the OWOW 2.0 Plan, the present phase of the OWOW effort, SAWPA addresses the other two salt management alternatives. One alternative option considers the cost and impacts of adding an advanced water treatment system to the Brine Line, and the other option explores direct brine discharge to the Sea. The appraisal analysis of the Brine Line is found in *Reclamation's Inland Empire Interceptor Appraisal Analysis Technical Memorandum No. 3* (TM 3), a 5-volume report which addressed the SARI history; engineering, brine and flow data; various options and strategies; projected cost information; recommendations; and an executive summary.

As part of the Study, a Reclamation contractor conducted outreach activities with Disadvantaged Communities (DACs) within the SARW to develop proposed actions that would ensure these communities – and their related concerns – would be included in the water resources planning process. That scope of that work was coupled with Reclamation's own outreach effort with Native American Indian Tribes (Tribes) in and/or associated with the SARW. The merging of these two outreach engagement efforts expanded SAWPA's original OWOW 1.0 Plan approach, which only addressed DACs as part of Environmental Justice activities. This joint outreach effort paved the way for additional groups to have a voice in the watershed's water resources management process. The results of that engagement are captured in the report entitled *Overview of Disadvantaged Communities and Native American Tribes in the Santa Ana River Watershed.*

Reclamation’s technical expertise employed during this Study offered a systematic, science-based approach to address key issues within the SARW. With the results documented in a number of technical memorandums and report, an informational foundation has been established to help SAWPA answer certain questions as the agency enters into the next phase of integrated regional watershed management (IRWM) that is guided by the OWOW 2.0 Plan. This collective approach provides SAWPA water resources planners the tools to quantify the challenges and uncertainty related to climate change and its potential impacts, and to plan accordingly to ensure sustainable water resources.

Through this Study, SAWPA and Reclamation have provided leadership on the path to a secure and sustainable water future, because without action, the demand for more water will quickly outstrip the amount available to the watershed’s populations, agriculture, and industries. The Santa Ana Watershed Basin Study provides the scientific and financial tools and the collaborative environment needed to help balance water supply and demand through the efficient use of current supplies and the development of new sources. By working together, SAWPA and Reclamation can sustain the shared water resources of the Santa Ana Watershed now and for future generations to come.

**Figure 3: Quail Valley, a disadvantaged community within the SARW**
**(Source: http://www.menifee247.com/2009_01_01_archive.html)**

# 2.0 Purpose, Scope and Objectives

The Santa Ana River is nearly 100 miles long, the longest river in Southern California. Today, it retains little of its historical character, but despite being tamed by two massive dams and confined for much of its course to a flood-control channel, it remains one of the most important natural features in the highly urbanized Southern California landscape.

Over the years, the river has supported a series of increasingly intensive economic regimes, each one making more demands on the river's resources. The Spanish first introduced irrigation to their sprawling ranches in the local floodplains. These cattle ranches were replaced with towns that rapidly grew into modern-day Anaheim, San Bernardino, Santa Ana, Riverside, and other thriving neighborhoods. To protect these growing communities from the threat of floods and to help capture stormwater runoff that could support the region's water supply, Prado and Seven Oaks dams were constructed on the river's mainstem.

**Figure 4: Seven Oaks Dam in the San Jacinto Mountains (Source: http://en.wikipedia.org/wiki/File:Seven_Oaks_Dam.jpg)**

This history has shaped much of the regulatory policy and delivery infrastructure that support SAWPA plans to ensure sustainable, reliable water supplies for the region. However, new approaches are necessary to adjust to future cycles of regional growth, aging infrastructure, and economic developments.

SAWPA, formed in 1968 as a Joint Powers Authority, is a water resources planning agency that plans and builds facilities to protect the water quality of the Santa Ana River Watershed. It is classified as a government agency that supports the missions of its member agencies: Inland Empire Utilities Agency, Orange County Municipal Water District, Eastern Municipal Water District, Western Municipal Water District, and San Bernardino Valley Municipal Water District. It also works with more than 350 water, wastewater and groundwater management, flood control, environmental, and other non-governmental organizations within and outside the basin.

SAWPA is facilitating efforts to develop a watershed planning framework to guide water resource management throughout SARW through the year 2030. To date, that has resulted in the development of the initial OWOW Plan. The genesis of this name and process is the recognition of a need for stakeholders across the watershed to participate in the development of an integrated plan for its water resources, or an IRWMP. Such a plan ensures all types of water (local surface and groundwater, imported water, stormwater, and treated wastewater effluent) are viewed in a comprehensive manner and as a single water resource. Completed in 2010, the OWOW 1.0 Plan provided a foundation for integrated water resource management throughout the Santa Ana River Watershed.

SAWPA, through the OWOW 2.0 Plan update process, is now exploring future steps to effectively plan projects that can provide multiple benefits for a variety of users. As funding resources become scarcer and the challenges of the 21$^{st}$ century more pronounced, it becomes even more important that each dollar provide the maximum benefit possible. The OWOW 2.0 Plan examines the connections between stormwater management and local water supply, land use and water quality, and accommodation of a growing population with finite water resources, with the understanding that it is only through a view of the watershed as an integrated system that successful operational efficiencies can be developed.

This WaterSMART Basin Study offers essential information to help SAWPA update their OWOW Plan (scheduled to be published in December 2013) to effectively prepare for the water resources management challenges of the near future (over the next 30 years).

## 2.1 Authority

In 2009 Congress passed the SECURE Water Act, directing the U.S. Department of the Interior to develop a sustainable water management policy. In 2010, the Secretary of the Interior established WaterSMART, combining existing programs with new initiatives to create a broad framework for wisely managing the Nation’s water supplies. Through these programs, Interior is actively working with Tribal, State, regional, and local water managers to address a range of urgent issues associated with water scarcity.

## 2.2 Partner and Stakeholder Involvement

Reclamation and SAWPA collaborated on this Basin Study and throughout the OWOW 2.0 Plan update process in a variety of ways. Reclamation led a series of workshops for SAWPA stakeholders to address the basin’s climate change projections and impacts to water supply, and met and engaged with various governmental, environmental, regulatory, and business community representatives.

The Study's core work was completed through coordination with SAWPA's staff and their experts representing various technical disciplines (known as Pillars) that addressed specific issues ranging from water supply and quality to climate change and environmental justice. SAWPA's planning success requires a comprehensive, and at times, a rigorous systems approach to adequately address barriers that can serve as impediments to progress. Reclamation engagement with SAWPA, its member agencies and key stakeholders was paramount for both the Basin Study and the OWOW 2.0 Plan update to succeed.

**OWOW Pillars**

- Beneficial Use Assurance
- Disadvantaged & Tribal Community
- Energy & Environmental Response
- Government Alliance
- Low Impact Development Planning
- Multi-Hazard Preparation
- Natural Resource Stewardship
- Operational Efficiency & Water Transfers
- Water Resource Optimization
- Water Use Efficiency

## 2.3 Challenges and Opportunities

OWOW provides a blueprint for SAWPA's IRWMP approach for the next 30 years. The use of the term 'integrated' ascribes multiple meanings in the concept of water resource management. Not only does it carry the obvious meaning of managing watershed resources in a cost-effective, efficient manner; it also means considering multiple needs when managing finite water resources. 'Integrated' also means that water agencies, working collaboratively to pool resources with their watershed neighbors, enables those jurisdictions to accomplish more with fewer local resources simply because the collaborative effort addresses multiple, rather than singular, goals. This economy of operation is especially important in light of today's environment of scarce resources.

OWOW 1.0 identified numerous projects that support the OWOW vision, but there continues to be a need to develop high-level watershed management concepts that, if implemented, can create opportunities to make the watershed fully sustainable from a water resource perspective within a 30-year planning horizon. Accordingly, OWOW 2.0 envisions water resources management from a high-level perspective to help identify concepts that, if adopted and implemented, would further OWOW's vision. To that end, SAWPA engaged with Reclamation through its Basin Study Program to conduct a basin-wide effort to evaluate and address impacts of climate change, assess an alternative for the basin's salt management program, and conduct effective outreach activities with DACs and Tribes to assess their water resource needs and challenges. The results and information gathered and reported during the Study will help SAWPA update their OWOW Plan.

# 3.0 Characterization of Future Conditions

The following ‘OWOW realities’ were identified by SAWPA’s Steering Committee and Pillars as assumptions to be included in the Basin Study planning process and research:

- The watershed’s economy has diminished and is changing. It is not likely to recover to a healthy level within the next 10 years. Utilities are significantly impacted by local, statewide and national conditions. The definition of ‘affordability’ has changed. Yet the need for providing and/or improving services, while at the same time meeting environmental and regulatory demands, remains the same.

- Traditional ways of planning, financing, and implementing projects for public benefit are not effective in the new economic environment. New approaches to planning and managing water resources using improved technologies are needed now. Future projects require a new economic construct and require extensive leveraging of resources to ensure their sustainability.

- Local projects will continue to be implemented with local and regional financing, but regional projects that provide broader, integrated benefits are more economical and sustainable. The gap between state projects and locally focused projects must be evaluated and infused with regional projects to reach sustainability goals.

- Uncertainty and variability of future water supplies drives the need for developing regional and sub-regional integrated solutions for water resource management. All water, regardless of source or origin, must be treated as a single resource; accordingly, the efforts to pursue within-watershed management of resources must be intensified and expanded.

- Solutions to Bay-Delta issues, which are expensive and still clouded in uncertainty, will not be implemented in time to meet the broader geographic needs of the watershed. SAWPA, using current project development and economic models, must move ahead with the development of affordable local and regional watershed solutions.

- SAWPA must move expeditiously from short-term to long-term thinking with regards to water resource management. Sustainability and reliability will be measured by decades. What is collectively done in this decade will establish the foundation for the future. Specifically, to achieve success three to four decades out requires aggressively implementing near-term solutions.

- Affordability of needed improvements will require intense pursuit and development of improved economic technologies and a skilled workforce. Thus, technology, workforce, and the economy must be developed simultaneously, not sequentially. Water resource planning and management must bear responsibility for all three.

- SAWPA increasingly experiences regulatory ‘tunnel vision’ because of the ongoing requirement to comply with program-specific, water-related regulations. There is a need to look at the watershed as a whole, identify what needs to be accomplished, and then work with regulators to ensure that regulatory requirements do not hinder common sense solutions that enhance water resource sustainability or limit the ability to address system-wide issues.

**Figure 5: Santa Ana River bridge and channel**
**(Source: http://alamar.sdsu.edu/projectphotosrrr.html)**

# 4.0 Climate Change Analysis

The climate change TM associated with the Santa Ana Watershed Basin Study explains the methods used to develop an analysis of potential implications of the changing climate, and describes how those implications might affect issues of importance to the SARW. More specifics on Reclamation's climate change analysis for the SARW are available in TM 1: *Climate Change Analysis*.

In 2009, the OWOW 1.0 Plan addressed the impacts of climate change on the watershed on a very broad scale based on the available science at the time. Climate change science has and continues to evolve; however, incontrovertible evidence suggests that changing weather patterns can have a profound impact on California and within the SARW.

SAWPA, its five member agencies, and key water sector stakeholders know that warmer temperatures, altered patterns of precipitation and runoff, and rising sea levels are, in all likelihood, going to continue to increase and may potentially compromise local and imported water supplies and SARW's environmental resources, and challenge the sustainability of SARW communities. SARW's water sector managers are aware of these unfolding events and are working toward developing adaptation strategies as they assess impacts on local water supply, infrastructure, and imported water sources, including the SWP.

Responding to climate change within the SARW presents significant challenges. Climate change impacts and vulnerabilities vary in each SARW sub-region, and the resources available to each water agency to effectively respond to climate change also differ.

In light of climate change, prolonged drought conditions, potential economic growth, and population projections, a strong concern exists to ensure an adequate water supply will be available to meet SARW's future water demands. The OWOW 2.0 Plan – through this Basin Study – is incorporating existing regional and local planning studies within the watershed; sustaining the innovative "bottom up" approach to regional water resources management planning; ensuring an integrated, collaborative approach; using science and technology to assess climate change and greenhouse emissions effects; facilitating watershed adaptation planning; and expanding outreach to all major water uses and stakeholders.

Regional solutions and integrated projects, such as those proposed through the OWOW 1.0 and 2.0 Call for Projects, are vital to SARW's future and key to addressing and developing necessary adaptation strategies to help combat effects of climate change. Reclamation's TM 1 developed during this Study explains the methods used to analyze potential implications of changing climate, and how those implications might affect issues of importance to SAWPA and the SARW.

This analysis is vital to planning for climate change to meet future water demands.

Global climate models (GCMs) used in this study were downscaled to 12-kilometer grids to make them relevant for regional analysis. The downscaled GCM projections are produced by internationally recognized climate modeling centers around the world and make use of greenhouse gas (GHG) emissions scenarios, which include assumptions of projected population growth and economic activity.

Future water supply was analyzed for the SARW using the downscaled GCMs and a hydrologic model to project streamflow using 112 different projections of future climate. Projected climate variables, including daily precipitation, minimum temperature, maximum temperature, and wind speed were included, as well as historical model simulations over the period 1950-1999. Final products include data sets at key locations for precipitation, temperature, evapotranspiration, April 1st Snow Water Equivalent (SWE), and streamflow.

**Figure 6: Mill Creek, one of the major tributaries of the Santa Ana River in the San Bernardino Mountains (Source: http://www.iewaterkeeper.org/photogallery.html)**

These data sets were used to develop key findings for the following frequently asked questions regarding impacts of climate change on the watershed. (These are attached to this Summary Report as *Appendix A*):

*Will surface water supply decrease?*

- Annual surface water is likely to decrease over future periods.
- Precipitation shows somewhat long-term decreasing trends.
- Temperature will increase, which is likely to cause increased water demand and reservoir evaporation.
- April 1st SWE will decrease.

*Will groundwater availability be reduced?*

- Groundwater currently provides approximately 54% of total water supply in an average year, and groundwater use is projected to increase over the next 20 years.

- Projected decreases in precipitation and increases in temperature will decrease natural recharge throughout the basin.
- Management actions such as reducing municipal and industrial water demands or increasing trans-basin water imports and recharge will be required to maintain current groundwater levels.
- A basin-scale groundwater screening tool was developed to facilitate analysis of basin-scale effects of conservation, increasing imported supply, changing agricultural land use, and other factors that impact basin-scale groundwater conditions.

*Is Lake Elsinore in danger of drying up?*

- Lake Elsinore has less than a 10% chance of drying up by 2099.
- In the 2000-2049 period, Lake Elsinore has a greater than 75% chance of meeting the minimum elevation goal of 1,240 ft.
- In the future period 2050-2099, Lake Elsinore has less than a 50% chance of meeting the minimum elevation goal of 1,240 ft.
- There is less than a 25% chance that Lake Elsinore will drop below low lake levels (1,234 ft) in either period.
- The Elsinore Valley Municipal Water District project does aid in stabilizing lake levels; however, for the period 2050-2099, additional measures will likely be required to help meet the minimum elevation goal of 1,240 ft.

*Will the region continue to support an alpine climate and how will the Jeffrey Pine ecosystem be impacted?*

- Warmer temperatures will likely cause Jeffrey pines to move to higher elevations and may decrease their total habitat.
- Forest health may also be influenced by changes in the magnitude and frequency of wildfires or infestations.
- Alpine ecosystems are vulnerable to climate change because they have little ability to expand to higher elevations.
- Across the State it is projected that alpine forests will decrease in area by 50-70% by 2100.

*Will skiing at Big Bear Mountain Resorts be sustained?*

- Simulations indicate significant decreases in April 1$^{st}$ snowpack that amplify throughout the 21$^{st}$ century.
- Warmer temperatures will also result in a delayed onset and shortened ski season.
- Lower elevations are most vulnerable to increasing temperatures.
- Both Big Bear Mountain Resorts lie below 3,000 meters and are projected to experience declining snowpack that could exceed 70% by 2070.

*How many additional days over 95°F are expected in Anaheim, Riverside and Big Bear City?*

- All the climate projections demonstrate clear increasing temperature trends.
- Increasing temperatures will result in a greater number of days above 95°F in the future.
- The number of days above 95°F gets progressively larger for all cities advancing into the future.
- By 2070 it is projected that the number of days above 95°F will quadruple in Anaheim (4 to 16 days) and nearly double in Riverside (43 to 82 days). The number of days above 95°F at Big Bear City is projected to increase from 0 days historically to 4 days in 2070.

**Figure 7: Santa Ana River in Los Angeles State Historic Park**
**(Source: http://lashp.wordpress.com/2009/07/07/empty-nest-concrete-river-and-lashp/santaana/)**

*Will floods become more severe and threaten flood infrastructure?*

- Simulations indicate a significant increase in flow for 200-year storm events in the future.
- The likelihood of experiencing what was historically a 200-year event will nearly double (i.e. the 200-year historical event is likely to be closer to a 100-year event in the future).
- Findings indicate an increased risk of severe floods in the future, though there is large variability between climate simulations.

*How will climate change and sea level rise affect coastal communities and beaches?*

- Climate change will contribute to global Sea Level Rise (SLR) through melting of glaciers and ice caps and thermal expansion of ocean waters, both of which increase the volume of ocean water.
- Regional SLR may be higher or lower than global SLR due to effects of regional ocean and atmospheric circulation.
- Average sea levels along the Southern California coast are projected to rise by 5 to 24 inches by 2050 and 16 to 66 inches by 2100.
- SLR is likely to inundate beaches and coastal wetlands and may increase coastal erosion. Effects on local beaches depend on changes in coastal ocean currents and storm intensity, which are highly uncertain at this time.
- SLR will increase the area at risk of inundation due to a 100-year flood event.
- Existing barriers are sufficient to deter seawater intrusion at Talbert and Alamitos gaps under a 3-foot rise in sea levels. However, operation of barriers under SLR may be constrained by shallow groundwater concerns.

As climate science continues to evolve, periodic reanalysis and evaluation will be needed to inform the decision-making process.

## 4.1 Water Supply and Demand Summary

Table 1 shown below is a summary of the projected effects of climate change on a variety of hydroclimate metrics for three future periods (above the most downstream location, Santa Ana River at Adams St. Bridge). Table 2 shows a summary of projected water demands out to 2050.

**Table 1: Summary of Effects of Climate Change on Supply**

| Hydroclimate Metric (change from 1990s) | 2020s | 2050s | 2070s |
|---|---|---|---|
| **Precipitation (%)** | 0.67 | -5.41 | -8.09 |
| **Mean Temperature ($^{o}$F)** | 1.22 | 3.11 | 4.1 |
| **April 1$^{st}$ SWE (%)** | -38.93 | -80.4 | -93.07 |
| **Annual Runoff (%)** | 2.6 | -10.08 | -14.61 |
| **Dec-Mar Runoff (%)** | 9.82 | -3.01 | -6.38 |
| **Apr-Jul Runoff (%)** | -6.35 | -25.24 | -31.39 |

**Table 2: Summary of Water Demand for the Santa Ana River Watershed**

| | 1990 | 2000 | 2010 | Present | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| **Demand (MAFY)** | 0.924 | 1.121 | 1.298 | 1.339 | 1.503 | 1.723 | 1.958 | 2.178 |

Imported water for the SARW will also likely be affected by the changing climate. The 2011 SWP Reliability report projects a temperature increase of 1.3° to 4.0 °F by mid-century and 2.7° to 8.1° F by the end of the 21$^{st}$ century. It predicts that increased temperatures will lead to less snowfall at lower elevations and decreased snowpack. By mid-century it predicts that Sierra Nevada snowpack will reduce by 25% to 40% of its historical average. Decreased snowpack is projected to be greater in the northern Sierra Nevada, closer to the origin of SWP water, than in the southern Sierra Nevada. Furthermore, an increase in “rain on snow” events may lead to earlier runoff.

Given these changes, a water shortage worse than the 1977 drought could occur one out of every six to eight years by the middle of the 21$^{st}$ century and one out of every two to four years by the end of 21$^{st}$ century. Also, warmer temperatures might lead to increased demand. This factor, combined with declining flows, will likely lead to decreased carryover storage from year to year. Alternative water supply options such as recycled water, rainwater harvesting, and desalination may need to be relied upon in order to meet the continually growing demand.

## 4.2 Sea Level Rise Impacts

Climate change will contribute to global SLR through melting of glaciers and ice caps and thermal expansion of ocean waters, both of which increase the volume of water in the oceans. Regional SLR may be higher or lower than global SLR due to effects of regional ocean and atmospheric circulation.

California’s 2,000 miles of coastline has experienced just under eight inches of sea level rise over the past decade, a number that is likely to increase drastically as the climate continues to change. Critical infrastructure, such as roads, hospitals, schools, emergency facilities, wastewater treatment plants, powerplants, and more will also be at increased risk of inundation, as are vast areas of wetlands and other natural ecosystems.

Flooding and erosion already pose a threat to communities along the California coast and there is compelling evidence that these risks will increase in the future. In areas where the coast erodes easily, sea level rise will likely accelerate shoreline recession due to erosion. Erosion of some barrier dunes may expose previously protected areas to flooding.

Within the SARW, Orange County Water District (OCWD) conducted a study to evaluate the potential effects of projected sea level rise on coastal Orange County groundwater conditions. Two locations were selected near the Talbert and Alamitos seawater intrusion injection barriers for analysis. The model for the analysis used data from well logs, aquifer pump tests, groundwater elevation measurements, hand-drawn contour maps, geologic cross sections, water budget spreadsheets, and other data stored in OCWD's Water Resources Management System (WRMS) database.

The results showed that regional mean sea level along the southern California coast is projected to rise by 1.5 to 12 inches by 2030, 5 to 24 inches by 2050, and 16 to 66 inches by 2100. Inundation due to SLR is likely to reduce the area of beaches and wetlands along the southern California coast. In addition, SLR is likely to increase erosion of sea cliffs, bluffs, sand bars, dunes, and beaches along the California coast. However, the overall effects of climate change on local beaches will depend on changes in coastal ocean currents and storm intensities, which are less certain at this time.

SLR is likely to increase the coastal area vulnerable to flooding during storm events. Also, detailed analysis carried out by OCWD found that the Talbert Barrier would be effective at preventing seawater intrusions through the Talbert Gap under a 3-foot sea level rise. In the case of the Alamitos Barrier, seawater intrusion through the Alamitos Gap would likely be prevented once current plans to construct additional injection wells are implemented. At both barriers, however, shallow groundwater concerns could limit injection rates and thus reduce the effectiveness of the barriers.

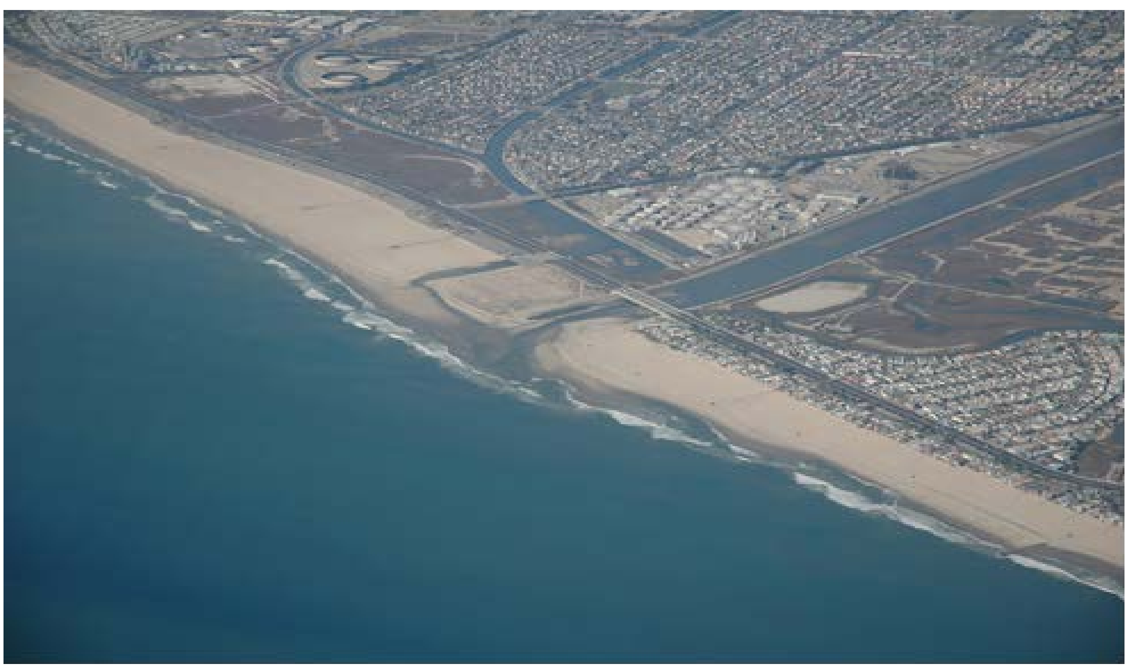


**Figure 8: Santa Ana River outlet at the Pacific Ocean**
**(Source: http://geology.campus.ad.csulb.edu/people/bperry/AerialPhotosSoCal/HuntBeachToCostaMesa.htm)**

## 4.3 Addressing Climate Change

Reclamation's climate change analysis provided SAWPA, its member agencies, key stakeholders, and OWOW Plan participants specific information necessary to plan, assess, and rank proposed Proposition (Prop) 84 grant-funded projects within the Watershed. (Prop 84, the Safe Drinking Water Bond Act, provides funds to water quality improvement projects that protect drinking water supplies.) These projects must also address reductions to GHG emissions within their water management activities. Projects were also given a performance measure to help determine how effectively the criteria were addressed, which helped with SAWPA's ranking process. The table below outlines the climate change analysis provided by Reclamation that was also included in update of the OWOW 2.0 Plan.

**Table 3: OWOW 2.0 Plan Climate Change Information**

| OWOW Plan Section | Climate Change Information Included |
|---|---|
| SARW Description | Describes likely climate change impacts in SARW, determined by a vulnerability assessment (attached to this Summary Report as Appendix B) |
| OWOW Objectives | Adaptation to climate change:<br>• Addresses adapting to changes in amounts, intensity, timing, quality and variability of precipitation, runoff, and recharge.<br>• Considers SLR effects on water supply and other water resource conditions (e.g., recreation, habitat) and identify suitable adaptation measures. Consider Ocean Protection Council's SLR Policy.<br>Reducing emissions (mitigation of GHG):<br>• Reduces carbon consumption, embedded energy in water, and GHG emissions.<br>• Strategies adopted by California Air Resources Board in its AB32 Scoping Plan, including innovative applications.<br>• Options for carbon sequestration where options are integrally (direct or indirect) tied to OWOW objectives. |

| | |
|---|---|
| Resource Management Strategies | Identifies and implements adaptation strategies that address SARW specific or local climate change contributions or impacts. |
| Project Review Process | Includes these factors:<br>• Project contribution to adapt to climate change; and<br>• Project contribution in reducing GHGs, compared to the alternative. |
| Local Water Planning to OWOW | Considers and incorporates water management issues and climate change adaptation and mitigation strategies from local plans into OWOW. |
| Relation to Local Land Use Planning | Demonstrates information sharing and collaboration with regional land use planning in order to manage multiple water demands through the state (as described in California Water Plan Update 2009), adapt water management systems to climate change, and potentially offset climate change impacts to water supply. |
| Plan Performance and Monitoring | Contains policies and procedures that promote adaptive management. |
| Coordination | Considers the following:<br>•Stay involved in California Natural Resources Agency Adaptation Strategy process, and<br>• Join The California Registry (www.theclimateregistry.org) |

(Source: DWR's 2012 Prop 84 and Prop 1E IRWM Guidelines, Appendix C, Table 7)

## 4.4 Greenhouse Gas Reduction

Climate change threatens California's natural environment, economic prosperity, public health, and quality of life. Recognizing the need for action, California has put in place ambitious emission reduction goals in the form of Assembly Bill (AB) 32, the Global Warming Solutions Act. By requiring in law a reduction in GHG emissions, California has set the stage to transition to a sustainable, clean energy future. AB 32 directly links GHG emissions and climate change, provides a timeline for statewide GHG emissions reduction, requires quantitative accounting of GHG emissions, and enforces disclosure of GHG emissions from every major sector in the state.

AB 32 requires that every major sector in California reduce its GHG emissions to 1990 levels by 2020, and to 80% below the 1990 levels by 2050, shown below in Figure 9. These targets were developed from the levels of reduction climate scientists agree is required to stabilize our climate. The red line represents the projected GHG emissions out to 2050, if no action is taken. In order to reach the GHG emissions target set by AB 32 for 2020, a reduction of approximately 30% is required from the 'no action' scenario.

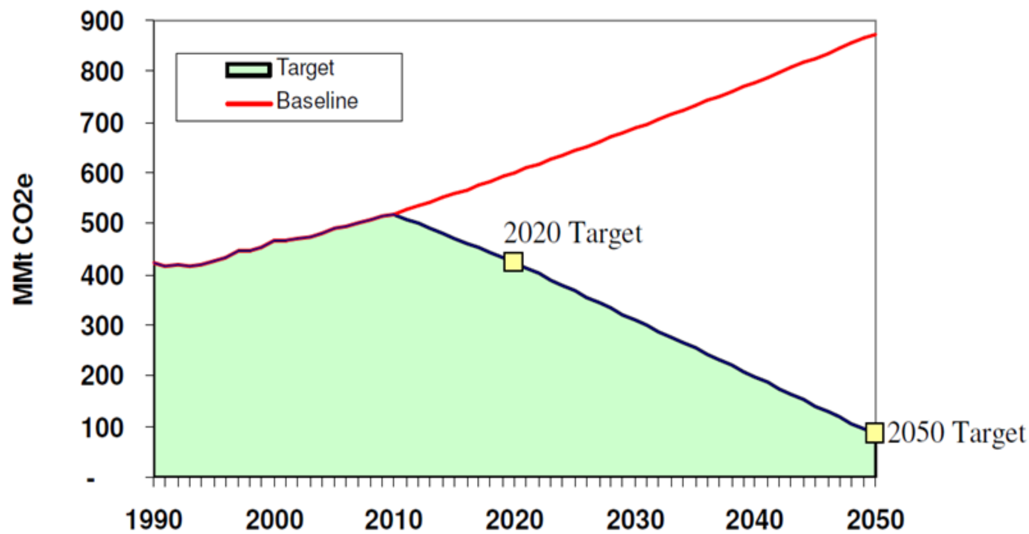



**Figure 9: AB 32 GHG Emission Reduction Targets**

Each water agency must address its carbon footprint to help the region meet the compliance requirements spelled out in AB 32. GHG emissions related to water consumption in the region must be continually measured and reported. A GHG Emissions Calculator developed by Reclamation as part of this Basin Study will help the water sector meet these mandated requirements that drive compliance with projected GHG targets out to 2050. The Calculator allows users within the SARW to easily and quickly evaluate how their water management decisions affect their water demand, energy use, and GHG emissions. More specifics on this tool are in *Reclamation's GHG Emissions Calculator for the Water Sector: User's Manual* (TM 2).

TM 2 explains the methods used to develop the calculator and provides instructions on how to use it by introducing examples. The examples focus on the SARW and demonstrate how to develop a GHG emissions baseline, evaluate what actions are required to meet specific GHG emission reduction goals, and illustrate how the GHG Emissions Calculator can be used to analyze projects.

The GHG analysis was designed to take advantage of best available datasets and modeling tools and to follow methodologies documented in peer-reviewed literature. However, there are a number of analytical uncertainties that are not reflected in Reclamation's GHG Emission analysis, including uncertainties associated with the following analytical areas that can be grouped under two categories—climate projection information and assessing hydrologic impacts that inform many of the Study FAQs.

The OWOW 2.0 Plan examines current climate change projections to determine potential impacts, assesses water resource vulnerabilities, and develops a series of strategies that can be used in projects to adapt to climate change and mitigate GHGs.

The table below lists suggested implementation actions for SARW stakeholders that can help reduce energy consumption and ensure AB 32 compliance.

**Table 4: AB 32 Global Warming Solutions Act Compliance**

| Action | Ways and Means |
|---|---|
| Inventory the Water Sector | Calculate the watershed's carbon footprint |
| Promote Electricity Conservation | Use appliances and vehicles that are efficient; weatherization; implement temperature controls (on A/C and heating units); turn off lights; install CFP bulbs; install LCD computer screens; and use natural light. |
| Promote Water Conservation | Reduce urban and ag water demands; build resilient communities; integrate water resources management practices; and promote project collaboration and partnerships. |
| Promote Alternative Energy Use | Install solar, wind, geothermal, tidal, and biomass fuel capacity; and implement any hydropower capabilities. |
| Implement Offsets | Purchase carbon offsets; plant trees; promote innovative approaches and solutions that foster community vitality, environmental quality, and economic prosperity. |
| Review or Implement Effective Policies | Conduct a gap analysis on the watershed's policies on dealing with Greenhouse Gas Emissions; create an energy solutions campaign - save energy, reduce your carbon footprint; review applicable laws and ordinances; and promote and implement energy efficiencies and sound conservation practices. |

(Source: Climate Adaptation Knowledge Exchange, see: www.cakex.org )

## 4.5 Vulnerabilities

To help SAWPA determine potential watershed vulnerabilities, SAWPA's Energy and Environmental Impact Response Pillar assessed Reclamation's *Climate Change Analysis*, and all applicable climate change technical data compiled about the SARW and its projected outlook through the year 2099. Reclamation used existing or new climate change models and other resources to help look beyond what SAWPA described in the OWOW 1.0 Plan and evaluated the amount, intensity, quality, variability of runoff, recharge, and imported water deliveries to the watershed that will potentially result from climate change.

Climate change is projected to affect many aspects of water resources management in the SARW. A critical first step to help prevent and/or mitigate those impacts is identifying key water sector vulnerabilities. Below is a summary of four key vulnerabilities in the Santa Ana Watershed (also see Appendix B):

**Water Supply**
- Insufficient local water supply
- Increased dependence on imported supply
- Inability to meet water demand during droughts
- Shortage in long-term operational water storage capacity

**Water Quality**
- Poor water quality
- Increased water treatment needs

**Flooding**
- Increased flash flooding and inland flooding damage
- Increased coastal flooding and inundation of coastal community storm drains
- Damage to coastal community sewer systems from sea level rise

**Ecosystem and Habitat**
- Damage to coastal ecosystems and habitats
- Adverse impacts to threatened and sensitive species from reduced terrestrial flows and sea level rise

Reclamation also coordinated directly with OCWD on SLR modeling in Orange County that was conducted to help assess potential impacts to the OCWD seawater intrusion barrier infrastructure and groundwater basins. Another part of critical criteria in addressing SARW's vulnerabilities is addressing GHG emissions from water operations.

## 4.6 Climate Change Adaptation Strategies

Climate adaptation strategies were developed through a consultative process involving Reclamation and SAWPA staff, and three members of the Energy and Environmental Impact Response Pillar.

By identifying SARW's vulnerabilities (listed as a 'checklist' in Appendix B), SAWPA staff, its member agencies, and key water sector stakeholders can work toward implementing the necessary actions needed to address, adapt to and mitigate the projected effects of climate change. Detailed in the table below are adaptation strategies that will be addressed in OWOW 2.0 Plan activities.

**Table 5: SARW Adaptation Strategies**

| SARW Adaptation Activities | Description |
|---|---|
| Reduce Demand | Promote the State's 20x2020 Water Conservation Plan in the watershed. |
| Improve Operational Efficiency | Promote systems reoperations, water transfers, and improved local and regional water conveyance. Optimize operational efficiency, promote water transfers, and develop regional water projects. |
| Increase Water Supply | Promote conjunctive management and groundwater storage; consider brackish and ocean desalination opportunities and more recycled water use, and local and regional surface storage opportunities. Identify watershed supply sources and increase storage capacity, and improve surface water operating efficiencies. |
| Land Fallowing | Implement land-use policies that address and reduce ag and urban water use; improve flood and fire risk management; identify ecosystems vulnerabilities, and ways/means to improve water quality. Reduce ag and landscape water demand, promote xeriscape, and improve water supply reliability. |
| Reduce Coastal Infrastructure Threats | Plan for SLR; optimize coastal infrastructure system operations; maintain and improve infrastructure; and reduce impacts of flooding on habitat and water quality. |
| Resource Stewardship | Improve management of watershed lands, wildlife, and water resources through conservation, preservation, and ecosystem restoration. |

| | |
|---|---|
| Improve Water Quality | Improve drinking water treatment, distribution, and groundwater use. Improve stormwater capture practices; address urban landscape improvements and urban runoff management; improve salinity management practices; implement groundwater remediation and pollution prevention practices. |
| AB 32 Compliance | Develop methodology for quantifying energy intensity of SARW water supplies and uses. Perform carbon footprint assessment and use the GHG Calculator Tool to identify additional opportunities for reducing carbon emissions. |
| Public education | Increase public outreach and education through the OWOW process |

### 4.6.1 Tradeoff Analysis

Based on the OWOW 2.0 Plan Energy and Environmental Impact Response Pillar's review and analysis of Reclamation's *Climate Change Analysis* TM, the SARW is potentially highly sensitive to climate change, with a particular vulnerability to changes in its precipitation, temperature, evapotranspiration, snow water equivalent, and streamflow. A Tradeoff Analysis was employed to assess the various climate change adaptation strategies noted in the OWOW 2.0 Plan update.

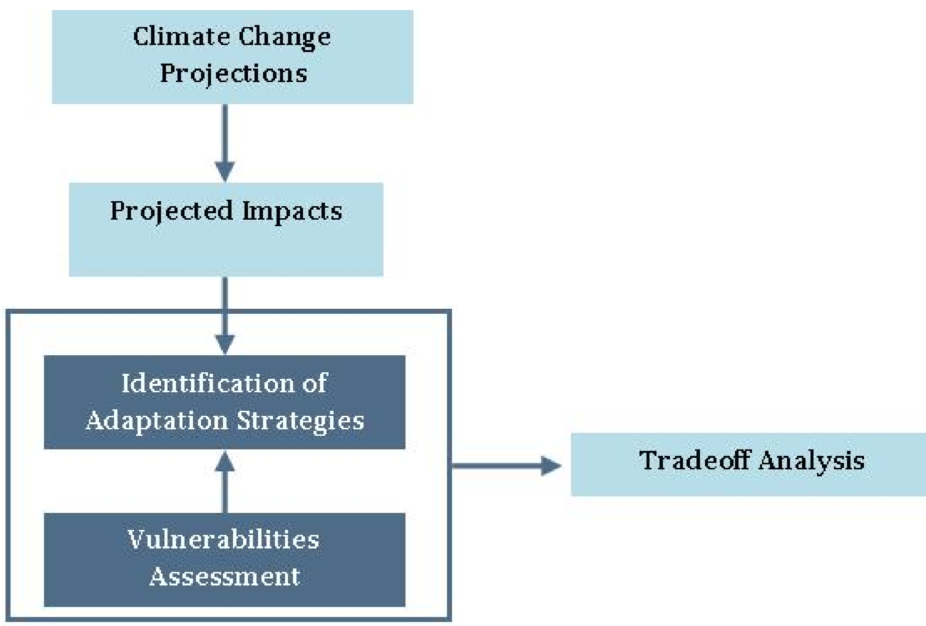



**Figure 10: Tradeoff Analysis Methodology**

Adaptation strategies (listed in Table 5) were cross-referenced with the vulnerability issues (see Section 4.5) discussed above to determine the number and type of climate change vulnerabilities that can be addressed. This interaction is shown in Table 6.

**Table 6: Cross-reference of vulnerability and adaptation strategies**

| | | Vulnerability | | | |
|---|---|---|---|---|---|
| | | Water Supply | Water Quality | Flood | Ecosystem |
| Adaptation Strategies | Reduce Demand | ✓ | ✓ | - | ✓ |
| | Improve Operational Efficiency | ✓ | ✓ | ✓ | ✓ |
| | Increase Water Supply | ✓ | ✓ | - | ✓ |
| | Land Fallowing | ✓ | ✓ | - | ✓ |
| | Reduce Coastal Infrastructure Threat | - | ✓ | ✓ | ✓ |
| | Resource Stewardship | ✓ | ✓ | ✓ | ✓ |
| | Improve Water Quality | ✓ | ✓ | - | ✓ |
| | AB32 Compliance | ✓ | ✓ | ✓ | ✓ |
| | Public Education | ✓ | ✓ | ✓ | ✓ |

In this table, the adaptation strategy that will address a vulnerability is marked with a checkmark (✓). Analysis of this table shows that four adaptation strategies – improve operational efficiency, resource stewardship, AB32 compliance, and public education – would address the four key vulnerabilities in the watershed.

These four adaptation strategies collectively form what is referred to as the ‘no regrets strategy,’ a strategy which argues that energy-saving measures should be undertaken immediately to help reduce climate change impacts. Such a strategy is one that would provide benefits in the present while also reducing vulnerability to future climate change impacts. If immediately implemented, such a strategy may provide some benefit even under the uncertainty of climate change projections. Specific actions under the ‘no regrets strategy’ are listed in Table 7.

**Table 7: Proposed actions in the ‘no regrets strategy’**

| | Proposed Action | | | |
|---|---|---|---|---|
| | Improve Operational Efficiency | Resource Stewardship | AB32 Compliance | Public Education |
| Urban Water Use Efficiency | ✓ | ✓ | ✓ | ✓ |
| Improved Conveyance System | ✓ | ✓ | ✓ | ✓ |
| GW Management | ✓ | ✓ | ✓ | ✓ |
| Pollution Prevention | ✓ | ✓ | ✓ | ✓ |
| Stormwater BMP | ✓ | ✓ | ✓ | ✓ |
| Forestry Management | ✓ | ✓ | ✓ | ✓ |

(Source of ‘no regrets’: http://economics.socialsciencedictionary.com/Environmental-Economics-Dictionary/No_Regrets_Strategy)

Description of individual proposed actions under the ‘no regrets strategy’ is given below.

#### *4.6.1.0 Urban Water Use Efficiency*

Conservation of existing water supplies is of utmost importance to a growing population in the SARW. A representative analysis from Orange County (see TM 1, Chapter 5, Section 5.3) shows that per capita water use will need to be reduced from the current value of about 175 gpd (gallons per day) to about 98 gpd by 2030.

#### 4.6.1.1 Improved Conveyance Systems

By increasing the efficiency of local and regional conveyance systems, water can be moved at a decreased cost. This is particularly important in the context of being compliant with the AB32 legislation, and is related to urban water use efficiency. With reduced per capita water use (see Orange County example in TM 1, Chapter 5, Section 5.3), greenhouse gas emissions (mtCO2e) can be reduced from the current level of about 120,000 mtCO2 to about 75,000 mtCO2e by 2030.

#### 4.6.1.2 Groundwater Management

By taking into account the balance between groundwater and surface water, managers can improve long-term viability of each resource. Reclamation developed a Groundwater Screening Tool (included in TM 2) to evaluate impacts to groundwater from a changing climate, and to evaluate effective conjunctive surface water groundwater management. The groundwater screening tool was applied to four groundwater basins (Orange County, Upper Santa Ana Valley, San Jacinto, and Elsinore) within the watershed. As an example, potential actions to avoid projected water level declines in Orange County are listed below. Each alternative listed will protect against groundwater declines through 2060.

- Reduce M&I demand with a gradual reduction of approx. 15% by 2020 (i.e., reduce per capita use from ~175 gpd in 2010 to ~150 gallons per day by 2020 to ~98 gpd by 2030).
- Increase local water supplies by ~75,000 af per year through recycled water treatment capacity, development of seawater desalination capacity, and increase stormwater capture efficiency.
- Increase imports from the Colorado River Aqueduct and State Water Project gradually from ~30,000 acre-feet (af) per year to ~105,000 af per year (this may not be feasible due to cost, greenhouse gas emissions, or availability).
- Reduce summertime groundwater pumping.

#### 4.6.1.3 Pollution Prevention

Preventing and remediating polluted water resources improves quality for users and improves long term viability of local resources. This includes improved salt management in brackish desalinization and water reuse systems in the Santa Ana River Watershed. Specific alternatives analyzed (see *Inland Empire Interceptor [IEI] Appraisal Analysis* TM 3) include:

- Modification to the existing Brine Line system.
- Salton Sea considerations including, restoration plans, salt load and increased water supply to Salton Sea.
- Brine pre-treatment strategies.
- Alternative pipeline alignments including easement, right of way, and designs.
- Remediate polluted groundwater to reduce treatment of larger quantities of migrating water (future avoided costs).

Further details on water quality and salinity impacts regarding concentrations and costs are presented in the IEI TM 3.

#### *4.6.1.4 Stormwater Best Management Practices (BMP)*

Implementing stormwater BMPs reduces storm runoff and pollution, improves groundwater recharge, improves air quality, reduces heat island effect, and decreases sun exposure to asphalt. Best Management Practices will continue to be required in the Watershed. SAWPA member agencies and flood control districts, and the Regional Water Quality Control Board will continue to enforce BMPs.

#### *4.6.1.5 Forestry Management*

Create plans to restore, sustain and enhance forest health and watershed functions within forests. As part of forest management, SAWPA has initiated a Forest First initiative in collaboration with the U.S. Forest Service. As home to the headwaters of the Santa Ana River, the San Bernardino and Cleveland national forests encompass approximately 33% of the Santa Ana watershed's land mass. These forest areas also receive 90% of annual precipitation. Forest management practices have direct effects on both water quality and quantity, particularly relative to forest fires and the consequential effects of soil erosion and water storage.

The collaborative efforts in the Forest First plan include four main watershed restoration strategies that would provide significant benefits to downstream water supply and quality. The first of these strategies includes forest fuels management, which would focus on reducing understory growth that can contribute to the intensity of fires, making them more devastating and difficult to fight. The second strategy involves restoration of chaparral plant communities in areas that have not recovered due to repeated fires, and where native vegetation has been replaced by grasses that increase runoff, instead of the chaparral capturing and dispersing rainfall, and allowing moisture to percolate and recharge groundwater basins. The third strategy is meadow restoration that would involve returning water that had been converted to conveyance back to a meadow sheet flow so that the meadow can function in a natural groundwater recharge capacity. The last strategy involves retrofitting roads in order to reduce water conveyance, reduce fire risk, and increase the number of fire breaks.

Further details on this initiative are available at: http://www.sawpa.org/owow/projects/forest-first/.

This analysis of the 'no regrets strategy' allows SAWPA, its member agencies, and key stakeholders an opportunity to assess proposed Prop 84 projects and specific adaptation strategies and the cost and benefits in terms of productivity, mitigation potential, resilience, and sustainability. The most promising projects and strategies can then become part of SAWPA's toolbox of climate change adaptation strategies. SAWPA's 'no regret strategies' will, however, tend to encourage incremental adaptation responses as opposed to more expansive adaptation responses.

### 4.6.2 Additional Strategies

Beyond 'no regrets strategies' a group of actions under what could be referred to as 'low regrets strategies' can be formulated. 'Low regrets strategies' are designed to facilitate adaptation with respect to climate change predictions. These strategies are marginally more costly than 'no regrets strategies' and have a stronger reliance upon climate change predictions, especially more severe scenario predictions. As such, they provide a scientifically conservative approach to public health and safety in terms of water supply.

'Low regret strategies' are important to consider in terms of a planning horizon. For example, such strategies for SAWPA might include changing the design of infrastructure that is intended to last many years to a design that, despite an incremental cost increase, will serve its intended purpose even under an increased risk climate change model.

**Table 8: Low regrets strategies**

| Low Regrets Strategy | Description |
|---|---|
| Emissions Targets | Conduct a survey of emissions generated from all water related operations and plan for a specific reduction in carbon emissions. |
| Expanded Flood Control Infrastructure | Climate change projections call for an increase in the intensity of storms and existing infrastructure may not be effective. |
| Solar Projects for Water Conveyance Systems | Using solar power as part of a renewable energy portfolio helps water districts control variable costs as well as decrease carbon emissions. |
| Consider high SLR<br><br>Model Predictions and Build New Infrastructure Accordingly | When in the planning process for building new water related infrastructure, deliberately plan for SLR and design the project accordingly. |
| Expansion of Wetlands | By expanding natural wetlands project areas, sea level rise will not inundate existing wetlands. In addition, wetlands provide carbon reduction benefits, water filtration benefits, heat island reduction and habitat benefits. |

## 4.7 SARW System Reliability and Risk Assessment

Under the SECURE Water Act Section 9503(b)(2), the Climate Change analysis developed by Reclamation in TM 1, Section 3 – *Water Supply and Demand Projections* assesses specific risks to SAWR's water supplies, including those related to:

- changes in snowpack;
- changes in the timing and quantity of runoff;
- changes in groundwater recharge and discharge; and
- any increase in the demand for water as a result of increasing temperatures and the rate of reservoir evaporation.

The impetus for effective integrated water and related resources management in the SARW is the recognition that the following factors threaten the future of the region’s water resources:

- Drought conditions in the Colorado River Watershed, a primary source of imported water to the Santa Ana River Watershed
- Unpredictability of future water imports from the San Joaquin-Bay Delta and Colorado River Watershed due to uncertainties in water availability and changing water management requirements
- Continued population growth and development that puts further stress on the natural hydrology of the watershed and increases the need for additional assured water supplies
- Uncertainties of climate change and its associated hydrologic variability

This Basin Study and Reclamation’s collaborative work effort with SAWPA, its member agencies and stakeholders on updating the OWOW Plan are the watershed’s preliminary answer to these threats. The Plan envisions stakeholders taking an active role in creating a watershed that:

- Is sustainable, drought-proofed and salt-balanced by 2030
- Protects its water resources and uses water efficiently
- Supports economic and environmental viability
- Mitigates and adapts to a changing climate
- Corrects environmental justice deficiencies
- Minimizes interruptions to natural hydrology
- Creates a new water ethic at both institutional and personal levels

## 4.8 Next Steps

Several tools have been developed by Reclamation for SAWPA, its member agencies and key water sector stakeholders to address the effects of climate change and plan ways to adapt or mitigate those potential impacts. Adaptation is the key component in the toolbox to help water resources planners and water sector decision-makers thoroughly understand and evaluate potential vulnerabilities from climate change impacts.

Research on climate change impacts is still evolving and as new findings are developed, they are shared throughout the SARW and California. Reclamation will continue to explore innovative quantitative tools to help assess vulnerabilities and conduct decision support analysis to help SAWPA progress toward addressing climate change impacts in SARW. Actions that have been productive, and will continue to be in working toward this goal include:

- Aggregation of climate change knowledge from state and federal research;
- Further assess No and Low Regret strategies;
- Develop a centralized a clearinghouse of information and lessons learned for member agencies;
- Offer web-based and workshop-delivered information on climate change impacts for the SARW;
- Create adaptation strategies and share that information with the water sector;
- Conduct webinars to further collaboration among water agencies;
- Develop regional case studies to discuss implementation actions;
- Bring additional agencies and officials into the discussion;
- Encourage innovative projects and search for flexibility;
- Seek to use evaluation studies/economic analysis as part of the message;
- Examine co-benefits to gain more support;
- Ensure disadvantaged and tribal communities have roles in the planning;
- Continue to involve key watershed stakeholders;
- Explore supportive resources/connections: Water Research Foundation, Water Environment Federation, Climate Ready Estuaries; and
- Collaborate whenever possible.

# 5.0 SARW Brine Management Alternative


Figure 11: SAWPA logo for brine line to the Salton Sea alternative

The Santa Ana Watershed Basin Study addressed SAWPA's Regional Interceptor (SARI) system, also known as the Inland Empire Interceptor (IEI) Brine Line. The Brine Line was constructed to help SAWPA manage the basin's water quality by exporting highly saline waters from the Inland Empire to a wastewater treatment plant in Orange County where the effluent is processed for ocean discharge. Like nearly all watersheds in arid climates, salt management is essential for water resource managers to ensure populations and ecosystems continue to thrive. Reclamation's *Inland Empire Interceptor Appraisal Analysis* is listed part of this Basin Study as TM 3.

SAWPA's Brine Line, an important tool in managing inland groundwater basins, has allowed businesses with industrial processes that produce brine to move into and expand in the Inland Empire. Orange County also benefits from the Brine Line through the removal of salinity from the Santa Ana River, providing a reliable level of protection for its water quality and reducing the area's dependence upon imported water.

The salt management alternative analyzed by Reclamation assumes all the flows in the Brine Line would be collected just below Prado Dam, the lowest elevation in the upper watershed, and that a separate pipeline would be constructed to transport that flow directly to the Salton Sea. The Salton Sea, California's largest inland lake, is a shallow, highly saline basin with no outfall to external water bodies. It is 14,000 parts per million saltier than ocean water.

Such a pipeline could accommodate additional saline flows which would be treated to some extent prior to discharge into the Salton Sea. Reclamation's engineering analysis and recommendations are attached as TM 3, and are an appendix in the OWOW 2.0 Plan. Based on that analysis, SAWPA remains hopeful that as new partnerships are developed with potential brine customers throughout the Basin and other parts of the state, the viability of this salt management alternative will become a truly system-wide solution. Reclamation's TM 3 recommended that SAWPA conduct an economic analysis to help examine the viability of this proposed undertaking.

Developed as part of the Basin Study, the Conclusions (Opportunities) and Recommendations (Optimization Strategies) associated with this IEI Brine Line alternative are summarized in Table 9. Priority rankings are assigned to Recommendations, which are loosely based on the potential influence on the estimated project costs and/or the value of anticipated benefits. Details for each of these elements follow the table.

**Table 9: Conclusions and recommendations related to the IEI Brine Line**

| CONCLUSIONS (OPPORTUNITIES) | | RECOMMENDATIONS (OPTIMIZATION STRATEGIES) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | R1 - Economic Impact Analysis | R2 - Salton Sea Water Budget | R3 - Salton Sea Salinity & Water Quality Model | R4 - IEI Influence on Salton Sea Salinity | R5 - IEI Influence on Salton Sea Water Quality | R6 - Influence of Salton Sea on IEI Design | R7 - Basin Plan Amendment Process | R8 - Identify, Investigate, & Initiate Partnerships | R9 - Hybrid Strategies for Brine Treatment | R10 - Alternative Designs for Surplus Energy | R11 - Alternative Liner Materials | R12 - Tunneling in Lieu of Direct Bury | R13 - Phasing of Improvements |
| | PRIORITY | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 | 7 |
| C1 - Economic Development | 1 | X | | | | | | | | | | | | |
| C2 - Net Impact | 2 | | X | X | X | X | X | | | | | | | |
| C3 - Salton Sea Restoration | 2 | | X | X | X | X | X | | | | | | | |
| C4 - Basin Plan | 3 | | | | | | | X | | | | | | |
| C5 - Stakeholder Partnering | 4 | | | | | | | | X | | | | | |
| C6 - Salton Sea Salinity | 2 | | X | X | X | | X | | | | | | | |
| C7 - Salton Sea Water Quality | 2 | | X | X | | X | X | | | | | | | |
| C8 - Brine Pre-treatment and Treatment | 5 | | | | | | | | | X | | | | |
| C9 - Management of Surplus Energy | 6 | | | | | | | | | | X | | | |
| C10 - Other Opportunities | 7 | | | | | | | | | | | X | X | X |

## 5.1 Conclusions

The Conclusions from the Appraisal Analysis are summarized as follows:

C1. Economic Development: The economic development potential associated with the proposed IEI is significant and unique to this option. If implemented, the proposed IEI would make brine management infrastructure available to prospective employers located in the San Gorgonio Pass and Coachella Valley areas.

C2. Net Impact: The proposed IEI would impact the Salton Sea in various ways, some of which may be considered beneficial and others negative. Further investigation and analysis of these aspects would help determine design criteria for associated components of the proposed IEI.

C3. Salton Sea Restoration: Delays to implementation of a restoration plan for the Salton Sea have contributed to uncertainties regarding salinity and water quality aspects of the proposed IEI. Improved understanding of progress toward restoration of the Sea would help determine appropriate project design criteria for the affected components of the proposed IEI.

C4. Basin Plan: Uncertainties regarding Salton Sea salinity and water quality regulatory requirements contribute to uncertainties regarding planning and design of associated components of the proposed IEI and the associated costs.

C5. Stakeholder Partnering: The standards established in the Basin Plan for salinity and water quality in the Salton Sea are a deterrent to potential new sources of water supply to the Sea. Community and stakeholder support would enhance the likelihood of adoption of changes to those standards.

C6. Salton Sea Salinity: The salts in the IEI flows would add to the existing rate of accumulation of salts in the Sea. Whether those salts would cause total dissolved solids (TDS) concentrations in the Sea to increase will depend on such factors as the magnitude of the Salton Sea water budget imbalance over time and progress toward implementation of a Salton Sea restoration plan.

C7. Salton Sea Water Quality: Similar to salinity, whether the total suspended solids (TSS) and biochemical oxygen demand (BOD) in the IEI flows would cause an adverse impact on the water quality in the Salton Sea will depend on such factors as the magnitude of the Salton Sea water budget imbalance over time and progress toward implementation of a Salton Sea restoration plan. The estimated cost of the proposed Water Quality Treatment Facility (TF) represents a substantial portion of the total estimated costs for the project, which calls for careful scrutiny of the design criteria for this facility.

C8. Brine Pre-treatment and Treatment Strategies: The proposed TF could function in place of the Brine Pre-treatment and Treatment Strategies presented in the Salinity Management Program, or it could function as part of a hybrid design in combination with a Strategy from the Salinity Management Program.

C9. Management of Surplus Energy: The large estimated costs of the proposed IEI Turbine Generator Stations and associated electric transmission facilities indicate that the time period necessary to recover that investment in would be long. The estimated cost of the proposed IEI could likely be significantly reduced by using an alternative approach to remove surplus energy from flows in the system.

C10. Other Opportunities: Examples of other opportunities to refine, reduce and/or eliminate estimated costs identified in this Appraisal Analysis include but are not limited to the following:

- Synthetic Membrane Liner - The synthetic membrane liner under the TF is the largest single component of the estimated cost of that facility; use of an alternative approach to soil permeability could likely significantly reduce that cost.

- Tunneling – Tunneling in lieu of direct bury of the proposed pipeline through the Badlands west of the City of Beaumont along the Gas Main Alignment may reduce impacts associated with construction of the project.

- Phasing - Phasing of certain project components could allow some project costs to be deferred.

## 5.2 Recommendations

The recommended next steps for further investigation and analysis of the proposed IEI to refine the scope, conceptual designs, estimated costs and anticipated benefits of the proposed IEI include:

R1. Economic Impact Analysis: In response to Conclusion C1 (Economic Development), perform an economic impact analysis for the proposed IEI to quantify the economic development and other benefits of the proposed IEI.

R2. Salton Sea Water Budget: In response to Conclusions C2, C3, C6 and C7, develop water budgets for the Salton Sea and for the planned Salton Sea restoration, or update available existing water budgets.

R3. Salton Sea Salinity and Water Quality Models: In response to Conclusions C2, C3, C6 and C7, develop models for salinity and water quality in the Salton Sea and for the planned Salton Sea restoration, or update available existing models.

R4. IEI Influence on Salton Sea Salinity: In response to Conclusions C2, C3 and C6, use the water budgets and the salinity models for the Salton Sea to evaluate the impact of proposed IEI flows on TDS concentrations in the Salton Sea, to evaluate the influence of those impacts on the IEI design, and to refine estimated costs for the proposed IEI.

R5. IEI Influence on Salton Sea Water Quality: In response to Conclusions C2, C3 and C7, use the water budgets and the water quality models for the Salton Sea to evaluate the impact of the proposed IEI flows on TSS and BOD concentrations in the Salton Sea, to evaluate the influence of those impacts on the IEI design, and to refine estimated costs for associated components of the proposed IEI.

R6. Salton Sea Restoration Influence on IEI Design: In response to Conclusion C2, C3, C6 and C7, use the water budgets and the salinity and water quality models for the Salton Sea restoration to evaluate the impact of the proposed IEI flows on the planned restoration, to evaluate the influence of the planned restoration on the IEI design, and to refine estimated costs for the proposed IEI.

R7. Basin Plan Amendment Process: In response to Conclusion C4 (Basin Plan), evaluate the process and technical requirements for a Basin Plan Amendment to modify Salton Sea salinity and water quality regulatory requirements for the proposed IEI.

R8. Identify, Investigate & Initiate Partnerships: In response to Conclusion C5 (Stakeholder Partnering), seek opportunities to partner with other Salton Sea stakeholders in support of regulatory changes to encourage new sources of water supply to the Salton Sea in support of restoration efforts. This effort may include:

- Establish a dialogue with other organizations serving the San Gorgonio Pass, Coachella Valley areas, and/or other areas adjacent to the Salton Sea,

- Investigate community support for changes to the regulatory approach to Salton Sea salinity and water quality standards to encourage new sources of water supply for the Salton Sea, and

- Develop specific proposals for suggested regulatory changes and identify benefits. Communicate the suggested regulatory changes and associated benefits to the community.

R9. Hybrid Strategies for Brine Treatment: In response to Conclusion C8 (Brine Pre-treatment and Treatment Strategies), identify and evaluate alternative strategies for treatment of the IEI flows, which may include hybrid designs incorporating Salinity Management Program brine pre-treatment strategies in combination with alternative configurations of the wastewater treatment ponds and/or constructed wetlands that comprise the TF considered in this Appraisal Analysis.

R10. Alternative Designs for Surplus Energy: In response to Conclusion C9 (Management of Surplus Energy), develop and evaluate alternative strategies for management of surplus energy in IEI flows such as low-head in-line turbine generators and pressure reducing valves.

R11. Alternative Liner Materials: In response to Conclusion C10 (Other Opportunities), investigate alternatives to the proposed synthetic membrane liner under the TF, including site-specific soil investigations to determine actual soil permeability to facilitate investigation of alternatives such as soil treatment using clay and suitability of a “leaky wetland”.

R12. Tunneling: In response to Conclusion C10 (Other Opportunities), investigate the constructability of and the impacts associated with direct-bury of the proposed pipeline through the Badlands west of the City of Beaumont along the Gas Main Alignment and the feasibility of tunneling in lieu of direct bury in that area.

R13. Phasing of Improvements: In response to Conclusion C10 (Other Opportunities), investigate opportunities for phasing of selected project components (e.g. use of dual pipelines in Coachella Valley) to defer costs until warranted by system flows, including a Present Worth analysis of the phased project costs.

# 6.0 Disadvantaged Communities and Native American Indian Tribes

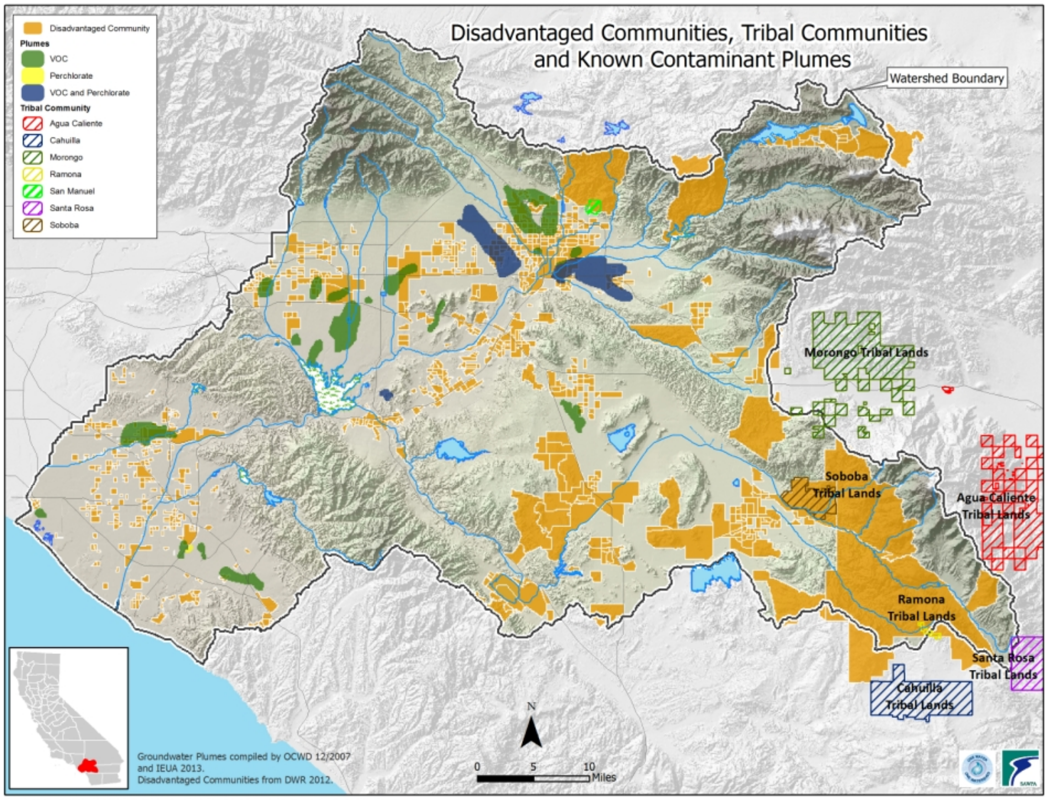
Disadvantaged Communities (DACs) and Native American Indian Tribes (Tribes) have water issues and concerns like other SARW communities. During the Basin Study, Reclamation and a contractor outreached to DACs and Tribes within the watershed to gather pertinent information on these communities and cultures, and to develop potential strategies that SAWPA could implement to address their water needs and challenges. Details of the joint outreach activity for these communities are captured in the report named *Overview of Disadvantaged Communities and Native American Tribes in the Santa Ana River Watershed.*

DACs are economically unique, as defined by the state, and reside in both urban and rural community settings. To assist in identifying DACs in each of the SARW sub-region, meetings were held with the California Department of Public Health and the Santa Ana Regional Water Quality Control Board. Once the DACs were identified, meetings were held with local public agencies that provided more detailed knowledge on the challenges DACs may face. Additionally, meetings were also held with the DAC residents. These outreach activities engaged 14 DACs in four counties that encompass the watershed.

Tribal communities are sovereign nations and must be respected for that difference. They reside on reservations, whose lands are set aside by the federal government in perpetuity. Engaging tribes is critical to giving them a voice in the process, and provides a means to be an equal and active participant with other watershed stakeholders. As part of the outreach process the four Tribes in the SARW were contacted, although not all provided input back to Reclamation for its report. Outreach was also extended to four other Tribes with lands extending into the watershed boundary.

DACs and Tribes face critical and serious challenges such as failing septic systems, isolation, language barriers, flooding, lack of funding, contaminant plumes, and lack of resources to name a few. It is imperative that water sector managers recognize DAC and Tribal water project needs and engage these communities early in the planning process. SAWPA's OWOW 2.0 update process recognizes the various funding needs for DACs and Tribes and the limitations of Federal and state funds available to them.

One solution to the issues identified in the report is to ensure that all communities have the information, financial and technical resources, and administrative and regulatory policies they need to make informed decisions that can result in benefits to all members of communities within the watershed. Engaging DACs and Tribes in water and related resources planning through effective outreach is good for both the community and the water sector itself. Water sector outreach and engagement should include speaking with DAC residents, listening to issues, attending Tribal meetings, participating on DAC- and Tribal-related committees, and continually networking. By recognizing the critical watershed issues within these communities, SAWPA can continue to foster open communication to find more immediate solutions to emerging issues.




P:\projects\dataRequest2013\DisadvantagedCommunitiesTribesPlumes.mxd SW-2176

**Figure 12: Known contaminant plumes underlying Disadvantaged Communities and Tribal Lands within the Santa Ana Watershed**

# 7.0 Future Considerations

The Santa Ana Watershed Basin Study explored several components that will help SAWPA meet future challenges in the SARW, including: a thorough review of historical integrated watershed studies, development of Reclamation's climate change analysis, associated FAQs, and decision support tools like the GHG Emissions Calculator; appraisal analysis of the SARI brine line as a critical salt management alternative; and implementing effective outreach to DACs and Tribes. But failure to address the present and projected water supply and demand and potential imbalances could result in significant impacts to the SARW and the State of California. A lack of water supply in this region will clearly dampen on-going economic recovery efforts and stall future SARW development.

SARW water managers, facing increased urbanization in the watershed, know that it is imperative to protect the quality of groundwater, which meets 69% of the region's water demands, and to prevent surface waters from becoming impaired. Regional treatment approaches are also being proposed to address surface runoff in order to protect recreational use benefits. SAWPA's watershed planning group has stressed that a multi-beneficial, multi-jurisdictional integrated approach to addressing these challenges makes the most economic sense.

Water and related resource management in the SARW occurs through an intricate, multi-level array of jurisdictional authorities, each with its own responsibilities at the local, county, or regional level. That can create significant challenges to SAWPA, its member agencies and key stakeholders in achieving the OWOW vision i.e., sustainable water and related resources management. This complexity is not unique to SARW, as all urban watersheds function within a complex framework of jurisdictional authorities.

What may be unique to the SARW is the recognition that this complexity exists and that there is a need to overcome such challenges so that the stakeholders within this watershed can take ownership of, and move forward with, implementing solutions that help SAWPA fulfill the OWOW vision. SAWPA's partnership with Reclamation in this Basin Study provides a significant first step toward collaboration , information sharing, and developing a path for future action.

# 8.0 Conclusion

Sustainable water management means striving for balance – balance between the water we have, the water we need, and the water we use; between water for the present and water for the future; and between the water we take from rivers, lakes, and aquifers, and the water we leave to preserve the healthy ecosystems on which we depend. Several factors contribute to the urgent need for balancing water supplies in SARW, including population growth and movement, changes in the economy, advances in technology, the movement toward energy independence, and variation in climatic conditions with associated impacts on water. Finite water resources coupled with growing demands results in shortage. Continued increases in the demand for all uses of water will place even greater stress on SARW's water supplies, especially in this arid Southern California region.

The Santa Ana Watershed Basin Study has enabled Reclamation and SAWPA to better understand water supply and demand imbalances and potential vulnerabilities in the SARW, and to comprehend the risk of any continued imbalances. SAWPA, its member agencies, and key stakeholders can integrate Reclamation's information into the OWOW 2.0 update planning process to help improve and optimize operations of existing water supply infrastructure, implement adaptation strategies to combat effects from climate change, calculate GHG emissions to meet AB 32 compliance, investigate the need for new infrastructure, recommend institutional reforms to improve project collaboration throughout the region, and discover improved ways to help reduce demands through conservation and efficiency.

Each of these elements was examined in the context of a changing climate to prepare the basin for the potential impacts of warmer temperatures and other variations in climatic conditions on water supply and demand. As a result, the information gained from this Study contributes to a more informed evaluation of possible adaptation strategies/options for meeting future water demands and to careful consideration of the consequences of various actions on water resources planning.

# 9.0 Disclaimer

The Santa Ana Watershed Basin Study partners recognize this effort was constrained by funding limits, time, and other restrictions which could potentially raise future policy questions, in particular as related to the climate change analysis modeling and the Inland Empire Interceptor appraisal analysis. In such cases, assumptions were made and incorporated to help complete tasks in support of this Study effort and do not represent any legal position or interpretation by SAWPA and its member agencies, any federally recognized Tribe, any specific community, or the Federal government. Nothing in this Study is intended to interpret, diminish or modify the rights of SAWPA or its member agencies, or that of any Tribe, municipality or the Federal government under federal or state laws or administrative rules, regulations or guidelines.

# Appendix A:

# SARW Climate Change Frequently Asked Questions and Findings

## A1: Climate and Water Supply

SAWPA

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

# *Climate and Water Supply in the Santa Ana River Watershed*

### Key Findings

- Annual surface water is likely to decrease over the future periods.
- Precipitation shows somewhat long-term decreasing trends.
- Temperature will increase, which may cause increased water demand and reservoir evaporation.
- April 1st SWE will decrease.

## Results

**Will surface water supply decrease?**

Change analysis between the base reference period (1990s) and three future periods (2020s, 2050s, 2070s) was conducted for precipitation, temperature, April 1st Snow Water Equivalent (SWE), and flow at 36 sites throughout the basin. Figure 1, a summary at the Prado Dam Gage, shows the ensemble median change for precipitation is likely to increase by <1% over the basin during the 2020s, followed by a 5% decline in the 2050s, with increased decline through the 2070s (8%). Temperature ensemble median changes for the 2020s, 2050s, and 2070s show increasing temperatures throughout of 1.22°F, 3.11°F, and 4.10°F respectively. Spatial distribution of April 1st SWE shows a persistent decline through the future decades at 39% for 2020s, 80% for 2050s, and 93% for the 2070s.

Figure 2 shows annual seasonal streamflow impacts at Prado Dam Gage. The 2020s show an increase in annual runoff and winter runoff, while spring runoff will likely decrease. The 2050s and 2070s show a decrease in annual, winter, and spring runoff.

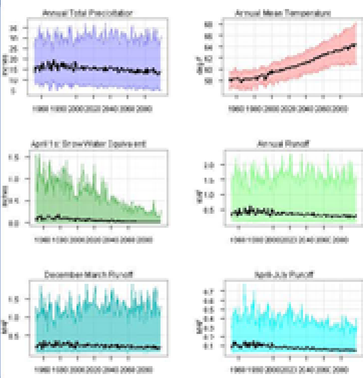



Figure 1 - Hydrology projections at Prado Dam Gage for P, T, SWE, and Flow, solid line is median, 5th and 95th percentile bounds

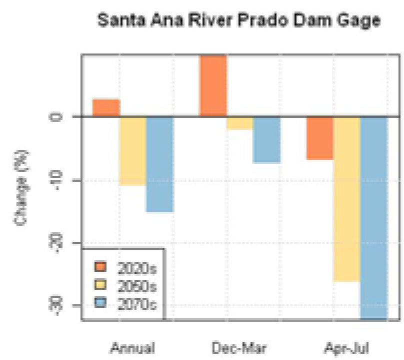



Figure 2 - Annual and seasonal streamflow impacts at Prado Dam Gage

### Additional Considerations

- VIC was an existing model and no refinements were made for this analysis.
- The model is calibrated to reproduce monthly to annual runoff in large sub-basins.
- These models have biases, and are best used for relative change.

## Methods

The Variable Infiltration Capacity (VIC) model was used to project streamflow for 112 different climate change projections. Daily precipitation, minimum temperature, maximum temperature, and wind speed came from the BCSD-CMIP3 archive. Modeled historical data from 1950-1999 came from Maurer et al. 2002, and subsequent extensions. For each grid cell daily forcings start on January 1, 1950 and run to December 31, 2099. Flow direction files and fractions were developed on a 1/8° x 1/8° (~12 km x 12km) grid. Through coordination with SAWPA, key locations in the basin were determined, so that sub-basins could be delineated. Change factors were developed by calculating decade mean total precipitation and temperature, then calculating percent change, and finally calculating the median change for all the 112 projections.

Link to full technical report: www.usbr.gov/lc/socal/basinstudies/OWOW.html

## A2: Climate and Groundwater Supply

SAWPA

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

# *Climate and Groundwater Supply in the Santa Ana River Watershed*

### Key Findings

- Groundwater currently provides approximately 54% of total water supply in an average year, and groundwater use is projected to increase over the next 20 years.
- Projected decreases in precipitation and increases in temperature will decrease natural recharge throughout the basin.
- Management actions such as reducing municipal and industrial water demands or increasing trans-basin water imports will be required in order to maintain current groundwater levels.
- A basin-scale groundwater screening tool was developed to facilitate analysis of basin-scale effects of conservation, increasing imported supply, changing agricultural land use, and other factors impacting basin-scale groundwater conditions.

### Additional Considerations

- Basin-scale groundwater conditions are an important consideration in basin management; however, local-scale groundwater conditions must be considered in evaluating individual projects.
- The groundwater screening tool does not reflect physical constraints on groundwater use, including the usable amount of groundwater available and decreases in pumping as groundwater levels decline.

## Results

**Will climate change reduce groundwater availability in the Santa Ana watershed?**

Future groundwater availability in the Santa Ana watershed will depend on future recharge from precipitation, stream seepage, and managed infiltration facilities, as well as future groundwater withdrawals to for municipal, industrial, and agricultural uses. A groundwater screening tool was developed to evaluate changes in basin-scale groundwater conditions under climate change. Projected increases in temperature and decreases in precipitation will result in increased water demands and decreased groundwater recharge, respectively. Management actions will be required to protect groundwater resources under projected future climate conditions.

Figure 1 illustrates the observed range of basin-averaged groundwater levels in the Orange County groundwater basin for 1990-2009, along with simulated groundwater levels under projected climate conditions. In the absence of groundwater management actions, groundwater levels are projected to decline significantly over the 21st century. It should be noted that projected declines are not constrained by the physical limits of the aquifer—i.e., projected declines may exceed the actual amount of usable groundwater in the basin.

The groundwater screening tool can be used to evaluate potential deficiencies in future supplies and to develop sustainable management alternatives. As an example, potential actions to avoid projected water level declines in Orange County are listed below. Each alternative listed will protect against groundwater declines through 2060. The groundwater screening tool can be used to develop and compare additional management alternatives.

***Projected Impacts of Climate Change on Orange County***

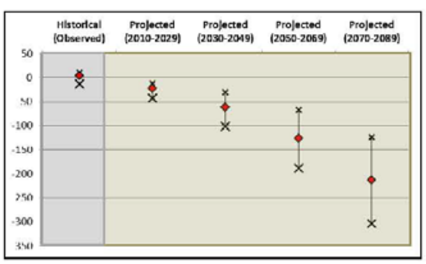



Figure 1 - Range of observed and simulated basin-averaged groundwater elevations for 1990-2009 and projected groundwater elevations for future periods assuming no management action to avoid groundwater deficits

***Groundwater Management Alternatives to Offset Projected Impacts of Orange County Groundwater***

- **Reduce M&I demand**
  Gradual reduction of approx. 15% by 2020 (i.e., reduce per capita use from ~175 gpd in 2010 to ~150 gpd by 2020)
- **Increase imports from Colorado River and SWP**
  Gradual increase in water imports from Colorado River and SWP from ~30,000 AF/yr to ~105,000 AF/yr by 2020 (this may not be feasible due to cost, greenhouse gas emissions, or availability)
- **Increase local water supplies**
  Increase local water supplies by ~75,000 AF/yr through increasing recycled water treatment capacity, development of seawater desalination capacity, and increasing stormwater capture efficiency

## Methods

A basin-scale groundwater screening tool was developed to facilitate evaluation of basin-averaged groundwater elevations under projected future climate conditions. The tool uses a multiple regression approach to estimate fluctuations in basin-averaged groundwater elevations in response to natural and anthropogenic drivers, including climate and hydrologic conditions, agricultural land use, municipal water demand, and trans-basin water imports. The tool allows users to quickly calibrate a regression model for a basin of interest, estimate basin-scale groundwater conditions under future scenarios, and compare management alternatives to protect groundwater resources under climate change.

Link to full technical report: www.usbr.gov/lc/socal/basinstudies/OWOW.html

## A3: Climate and Recreation

# Climate and Recreation in the Santa Ana River Watershed

SAWPA

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

### Key Findings

- Lake Elsinore has less than a 10% chance of drying up (2000-2099).
- In the future period 2000-2049 Lake Elsinore has a greater than 75% chance of meeting the minimum elevation goal.
- In the future period 2050-2099 Lake Elsinore has less than a 50% chance of meeting the minimum goal elevation.
- There is less than a 25% chance that Lake Elsinore will drop below low lake levels in either period.
- The EVMWD project does aid in stabilizing lake levels. However, for the period 2050-2099 additional measures will likely be required to meet the minimum goal elevation.

### Additional Considerations

- Operations of Canyon Lake, a reservoir upstream from Lake Elsinore, were not taken into account in this analysis.
- In addition to lake level stress, Lake Elsinore has many water quality issues.
- Lake Elsinore is not used as a drinking water source.

## Results

**Is Lake Elsinore in danger of drying up?**

Lake Elsinore, shown in Figure 1, is southern California's largest natural lake and is situated at the bottom of the San Jacinto Watershed. Because Lake Elsinore is a terminal lake, fed only by rain and natural runoff, it has been impacted by low lake levels. In 2005, the Elsinore Valley Municipal Water District (EVMWD) began a two-year project to introduce recycled water into Lake Elsinore to stabilize lake levels. The project now delivers approximately 5 million gallons per day (MGD) of recycled water to Lake Elsinore, and includes repair and retrofit of three local, shallow groundwater wells that deliver approximately 1 MGD. An analysis was done to determine if these measures are enough to meet the minimum goal volume of 41,704 acre-ft (elevation of 1,240 ft), avoid low lake levels (below 24,659 acre-ft, elevation of 1,234 ft), or prevent the lake from drying up altogether (as occurred in the 1930s).

Figure 2 shows the distribution of projected average annual volume for two future periods, 2000-2049 and 2050-2099, based on 112 different climate change projections. The two future periods were also analyzed with the addition of the EVMWD project. For the 2000-2049 period there is a >50% chance that the average annual lake level will meet the minimum goal; adding in the EVMWD project brings that likelihood up to >75%. For the 2050-2099 period there is a <5% chance that the minimum goal will be met; adding the EVMWD project brings that up to a >25% chance. Both periods are likely to stay above low lake level, with the 2050-2099 period having <10% chance of drying up completely.


Figure 1 - VIC model grid cell used to determine data for Lake Elsinore analysis

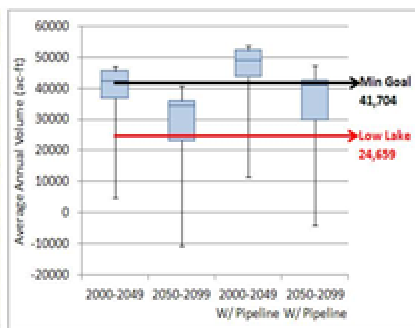



Figure 2 - Boxplot of projected average annual volumes for two future periods, with and without EVMWD project

## Methods

Monthly streamflow and open water evaporation values from 1950-2099 were determined by using BCSD-CMIP3 climate projections and the Variable Infiltration Capacity (VIC) macro-scale hydrology model. Historical observed data from 1950-1999 were modeled using the gridded daily data set from Maurer et al. 2002. The upstream contributing basin was determined at the inlet to Lake Elsinore, excluding the effect of any upstream regulation.

A mass balance analysis of Lake Elsinore was conducted, resulting in a natural (unregulated by upstream reservoirs) volume. Change values were determined for each future period using modeled observed average annual volume applied to historic annual average volume.

Link to full technical report: www.usbr.gov/lc/socal/basinstudies/OWOW.html

## A4: Climate and Forest Ecosystems

SAWPA

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

# Climate and Forest Ecosystems

### Key Findings

- Warmer temperatures will likely cause Jeffrey pines to move to higher elevations and may decrease their total habitat.
- Forest health my also be influenced by changes in the magnitude and frequency of wildfires or infestations.
- Alpine ecosystems are vulnerable to climate change because they do not have the ability to expand to higher elevations.
- Across the state it is projected that alpine forests will decrease in area by 50-70% by 2100.

### Additional Considerations

- The rate of climate change determines how quickly ecosystems must adapt, and influences the total impact.
- There is significant uncertainty about the role of increased $CO_2$ levels on forest productivity.
- In general predictions about forest productivity are uncertain and will rely mainly on future precipitation.
- Most available research has focused on the state of California as a whole and no studies explicitly consider the future of Jeffery pines or alpine ecosystems within the SAWPA area.

## Results

**Projected climate change impacts on forest ecosystems:**

While there is significant variability between climate change scenarios, all projections include increased temperature and increased levels of atmospheric carbon dioxide. As a result, the following general trends are predicted:

- Warmer temperatures will cause trees to move northward and to higher elevations
- Changes in total forest cover for California are projected by one study to range from a 25% decrease to a 23% increase by 2100 (Lenihan et al., 2008)
- Species with the smallest geographical and climate ranges are expected to be the most vulnerable to change
- Extended droughts and earlier snowmelt could cause fire seasons to start earlier and last longer (California, 2010)
- Temperature increases may change the frequency and magnitude of pest infestations such as the pine beetle

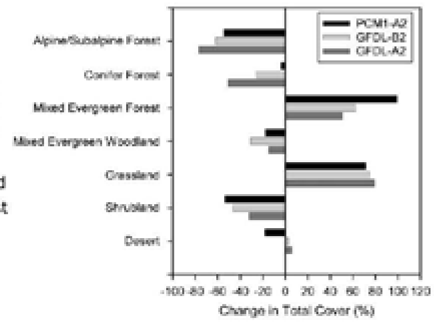



Figure 1 - Fig. 4 from Lenihan et al. 2008. Percent change in total land cover for vegetation classes by 2100 for three climate change scenarios predicted using the MC1 Dynamic Vegetation Model.

**How will the Jeffrey pine ecosystem be impacted?**

The Jeffrey pine is a high altitude coniferous evergreen tree that can occupy a range of sites and climate conditions (Moore, 2006). Based on the general trends noted above it is likely that the Jeffery Pines will migrate to higher elevations and some lower elevation forest area will be lost. Several studies predict that warming temperatures will result in the displacement of evergreen conifer forests by mixed evergreen forests across California (Hayhoe et al., 2004; California, 2010). However, no study has explicitly considered the migration of the Jeffery pine. Given its versatility it is possible that impacts to the Jeffery pine may be less than some other species.

**Will the Region continue to support an alpine climate in the local mountains?**

Alpine ecosystems are particularly vulnerable to increased temperatures because their habitat range is already limited and they cannot shift to higher elevations. One study projects that Alpine and subalpine forests will decrease in area by 50-70% by 2100 (Hayhoe et al., 2004).

## References

California Department of Forestry and Fire Protection, Fire and Resource Assessment Program. 2010. *California's Forests and Rangelands: 2010 Assessment.* Chapter 3.7. http://frap.fire.ca.gov/assessment2010.html.

Hayhoe, K. et al. 2004. *Emissions pathways, climate change, and impacts on California.* PNAS, 101:34, pp 12422-12427.

Lenihan, J. M., D. Bahelet, D. P. Nielson, R. Drapek. 2008. *Response of vegetation distribution, ecosystem productivity, and fire to climate change scenarios for California.* Climate Change, 87 (supply 1), pp. S215-S230. Doi 10.1007/s10584-007-9362-0.

Moore, L. M. 2006. *Jeffrey Pine Plant Guide.* United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS)

Link to full technical report: www.usbr.gov/lc/socal/basinstudies/OWOW.html

## A5: Climate and Snowpack at Big Bear

SAWPA

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

# Climate and Snowpack at Big Bear

### Key Findings

- Simulations indicate significant decreases in April 1st snowpack that amplify throughout the 21st century.
- Warmer temperatures will also result in a delayed onset and shortened ski season.
- Lower elevations are most vulnerable to increasing temperatures.
- Both Big Bear and Snow Summit lie below 3,000 m and are projected to experience declining snowpack that could exceed 70% by 2070.

## Results

**Will skiing at Big Bear be sustained?**

It is likely that future snowpack at Big Bear will be significantly less than what is currently normal and accumulated snowpack will remain on the ground for a shorter season. Projected declines in April 1st snowpack are between 30% and 40% by the 2020s and are generally projected to be greater than 70% by the 2070s. These changes are largely a result of increased winter temperatures and potential declines in winter precipitation. Warmer temperatures will result in a delayed onset of the ski season as well as earlier spring melting. Future precipitation is much more uncertain but many projections show decreased winter precipitation. Lower altitudes will likely be the most sensitive to increased temperature because small temperature changes can result in precipitation falling as rain rather than snow. Hayhoe et al. (2004) note that reductions in SWE are most pronounced below 3,000 m where roughly 80% of California's snowpack storage currently occurs. The Big Bear and Snow Summit ski areas both fall between roughly 2,100 and 2,600 m, making them vulnerable to increased temperatures.

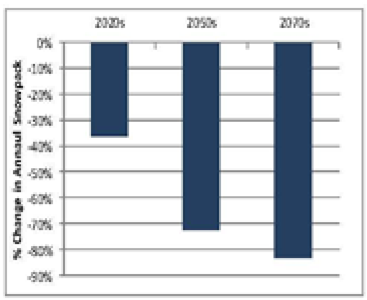



Figure 1 - Median percent change (from 112 climate scenarios) in April 1st SWE for the grid cells containing the Big Bear and Snow Summit ski areas

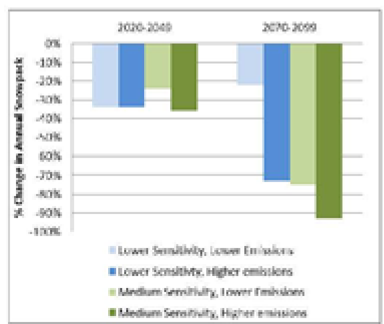



Figure 2 - Percent change in April 1st snowpack (SWE) from Hayhoe et al. (2004) for areas of 2,000 to 3,000 m elevation

### Additional Considerations

- Downscaled climate variables can be biased and there is significant variability between projections. For example, note that the low sensitivity low emissions scenario in Figure 2 projects only a 20% decrease in snowpack by 2070 while the other scenarios project greater than 70% decreases.
- The grid resolution for both methodologies is 1/8th degree which is much larger than either ski area. Therefore, results have been averaged over the ski area in addition to surrounding areas at lower elevation.

## Methods

April 1st Snow Water Equivalent (SWE) values from 1950 to 2099 are generated for 112 CMIP-3 climate projections using the VIC model forced with downscaled climate variables. Each climate projection has 1/8th degree x 1/8th degree (~12 km x 12km) grid cell daily forcings. For this analysis the locations of the Big Bear and Snow Summit ski areas were mapped within the single grid cell that contained them. Results summarize the median change (taken from the 112 projections) in April 1st SWE compared to the 1990s.

Results are also provided from a study of climate change impacts in California. Hayhoe et al. (2004) analyzed climate change scenarios. They used climate forcing data generated with two climate models of low (Parallel Climate Model, PCM) and medium (Hadley Center Climate Model version 3, HadCM3) sensitivity, forced using two emissions scenarios, one lower (B1) and one higher (A1fi). SWE results were generating using the VIC model forced with the bias-corrected and spatially downscaled temperature and precipitation. Results are provided on a statewide basis grouped by elevation

Hayhoe, K. et al. 2004. *Emissions pathways, climate change, and impacts on California*. PNAS. 101:34, pp 12422-12427.

Link to full technical report: www.usbr.gov/lc/socal/basinstudies/OWOW.html

## A6: Climate and Temperature

# Climate and Temperature in the Santa Ana River Watershed

### Key Findings

- All the climate projections clearly demonstrate increasing temperature trends.
- Increasing temperatures will result in a greater number of days above 95°F in the future.
- The number of days above 95°F progressively increases for all stations as you move further into the future.
- By 2070 it's projected that the number of days above 95°F will quadruple in Anaheim and nearly double in Riverside. Big Bear City is projected to increase from 0 days historically to 4 days in 2070.
- Although there are clear trends in the median values, the spread of results (shown by the red shading in Figure 1) is also quite large.

### Additional Considerations

- Results are shown for the single grid cell where the city is located. Additional analysis could consider regionally averaged temperature trends.
- Downscaled climate variables can be biased. Reported temperature values were not bias corrected to match projected historical values to local temperature gages.

## Results

**How many more days over 95°F are expected in Anaheim, Riverside and Big Bear City?**

Figure 1 shows the distribution of the annual number of days above 95°F from 1950-2099 for each city for all 112 climate projections. As shown here, there is a clearly increasing trend in the number of days above 95°F for all three locations. Riverside has the most days followed by Anaheim. Big Bear City has the least number of days with a median of zero for all years prior to about 2030. The red shading in Figure 1 shows the range of the 112 climate projections and demonstrates a large spread in projected results. Table 1 summarizes the median number of days above 95°F for each location for the historical time period (1951-1999) and three 30-year future time periods centered around 2020, 2050 and 2070. As shown in Table 1 the number of days increases for all stations as you move further into the future. Changes are quite significant; for example, the median value for Anaheim quadrupled from 4 to 16 days between the historical time period and 2070. Similarly the median value for Riverside nearly doubled between the historical time period and 2070, going from 43 to 82 days.

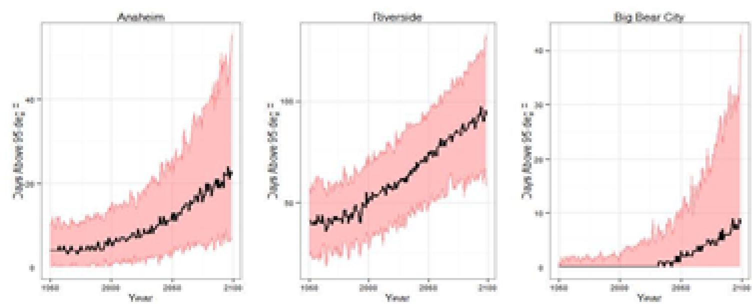



Figure 1 - Projected annual number of days above 95°F. Solid black line is the median and the red shading denotes the 5th and 95th percentile bounds

| | Historical | 2020 | 2050 | 2070 |
|---|---|---|---|---|
| Anaheim | 4 | 7 | 12 | 16 |
| Riverside | 43 | 58 | 72 | 82 |
| Big Bear City | 0 | 0 | 2 | 4 |

Table 1 - Median annual number of days above 95°F for one historical (1951-1999), and three future (2005-2034, 2035-2064, 2055-2084) time periods

## Methods

Daily maximum temperature values came from the BCSD-CMIP3 archive for 112 climate projections. Each projection has 1/8° x 1/8° (~12 km x 12km) grid cell daily forcings that start on January 1, 1950 and run to December 31, 2099. For this analysis the location of each city was matched to the single grid cell that contains it. Results summarize temperature trends for all 112 projections from 1950 to 2099 for the selected grid cell.

Link to full technical report at: www.usbr.gov/lc/socal/basinstudies/OWOW.html

## A7: Climate and Flood Frequency

# Climate and Flood Frequency in the Santa Ana River Watershed

SAWPA

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

### Key Findings

- Simulations indicate a significant increase in flow for 200-year storm events in the future.
- Similarly the likelihood of experiencing what was historically a 200-year event will nearly double (i.e. the 200-year historical event is likely to be closer to a 100-year event in the future).
- Findings indicate an increased risk of severe floods in the future.
- There is large variability between climate simulations.
- Although there are clear trends in the median values, the range of flows is also large.

### Additional Considerations

- Results are demonstrated for the Prado Dam gage but they can be easily replicated for other locations.
- Future work should expand this analysis to consider floods of different return periods as well as longer flood durations.
- Pearson Log III distributions were fit for this analysis. However, other extreme value functions may also be relevant (e.g. distributions with time varying parameters) .

## Results

**Will floods become more severe and threaten flood infrastructure?**

It is projected that floods will be more severe in the future. Figure 1 shows the distribution of 200-year flood estimates for the Prado Dam gage based on results from 112 CMIP-3 climate change projections. As shown here, the median 200-year flood value is projected to increase significantly in all future periods (from ~134,000 cfs in the historical period to ~239,000 cfs in the last future period (2055-2084)). However, there is significant variability between projections so there are cases where the 200-year flood intensity is projected to decrease.

**Are dams sufficiently sized for the 200-year storm, or does the risk level increase?**

The risk level is expected in increase significantly. Figure 2 shows the distribution of return periods for the median 200-year historical flood estimate (~134,000 cfs). In all future periods the median return period for the historical 200-year flood is decreased significantly (~80 years by 2020 and 2050, and ~70 years by 2070). This indicates an increase in the risk of a 200-year and larger storm events and potential for negative impacts to infrastructure. This same point can also be seen in Figure 1 with the increased flow values for a 200-year event. However, once again it should be noted that there is significant variability in results. While the median indicates a decrease return period for the historical 200-year flow value, there are outlying simulations where the return period increases.

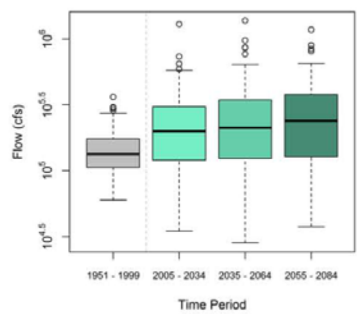



Figure 1 - Boxplot of 200-year flood estimates from 112 climate projections at the Prado Dam Gage

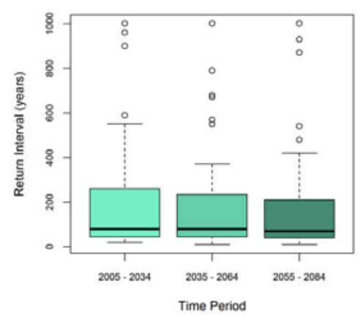



Figure 2 - Boxplot of return intervals for the median 200-year historical flood (134,000cfs) at the Prado Dam Gage

## Methods

Daily stream flow values from 1950 to 2099 are generated for 112 CMIP-3 climate projections using the VIC model forced with downscaled climate variables. Flood frequencies are estimated following the method outlined in Bulletin 17-B published by the Interagency Advisory Committee on Water Data (1982). For this methodology, annual one-day flow maximums are generated and fit to a log-Pearson III distribution for each time period and climate scenario using the L-moments approach. Using the parameters for the log-Pearson III distributions, the 200-year return period flow values are estimated for every climate simulation and analysis period. The distribution is also used to calculate the return period for the median historical 200-year flood for each climate simulation and future time period.

Link to full technical report: www.usbr.gov/lc/socal/basinstudies/OWOW.html

## A8: Climate and Sea Level Rise

SAWPA

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

# *Climate and Sea Level Rise in the Santa Ana River Watershed*

**Key Findings**

- Climate change will contribute to global sea level rise (SLR) through melting of glaciers and ice caps and thermal expansion of ocean waters, both of which increase the volume of water in the oceans.
- Regional SLR may be higher or lower than global SLR due to effects of regional ocean and atmospheric circulation.
- Average sea levels along the Southern California coast is projected to rise by 5-24 inches by 2050 and 16-66 inches by 2100.
- SLR is likely to inundate beaches and coastal wetlands and may increase coastal erosion. Effects on local beaches depend on changes in coastal ocean currents and storm intensity, which are highly uncertain at this time.
- SLR will increase the area at risk of inundation due to a 100-year flood event.
- Existing barriers are sufficient to deter seawater intrusion at Talbert and Alamitos gaps under a 3 -foot rise in sea levels. However, operation of barriers under SLR may be constrained by shallow groundwater concerns.

**Additional Considerations**

- Results were obtained from previous analysis; no additional modeling was done.

## Results

**Will climate change contribute to sea level rise (SLR)?**

Increasing temperatures will melt ice sheets and glaciers and cause thermal expansion of ocean water, both of which will increase the volume of water in the oceans and thus contribute to global mean sea level rise (SLR). Regional SLR may be higher or lower than global mean SLR due to regional changes in atmospheric and ocean circulation patterns. Figure 1 shows the range of projected global mean SLR by 2100. Regional mean sea level along the Southern California coast is projected to rise by 40-300 mm (1.5-12 in) by 2030, 125--610mm (5-24 in) by 2050, and 405-1675 mm (16-66 in) by 2100.

**How will climate change and SLR affect coastal communities and beaches in Southern California?**

Inundation due to SLR is likely to reduce the area of beaches and wetlands along the Southern California coast. In addition, SLR is likely to increase erosion of sea cliffs, bluffs, sand bars, dunes, and beaches along the California coast. However, the overall effects of climate change on local beaches will depend on changes in coastal ocean currents and storm intensities, which are less certain at this time.

SLR is likely to increase the coastal area vulnerable to flooding during storm events. Figure 2 shows the areas of Orange County that are currently vulnerable to inundation due to a 100-year flood event (blue) and areas that will be vulnerable to inundation with a 1400 mm (55 in) rise in mean sea level (source: http://cal-adapt.org/sealevel/).

**Will SLR increase seawater intrusion into coastal aquifers?**

Detailed analysis carried out by Orange County Water District found that the Talbert Barrier would be effective at preventing seawater intrusions through the Tablert Gap under a 3-foot sea level rise. In the case of the Alamitos Barrier, seawater intrusion through the Alamitos Gap would likely be prevented once current plans to construct additional injection wells are implemented. At both barriers, however, shallow groundwater concerns could limit injection rates and thus reduce the effectiveness of barriers at preventing seawater intrusion under rising sea levels.

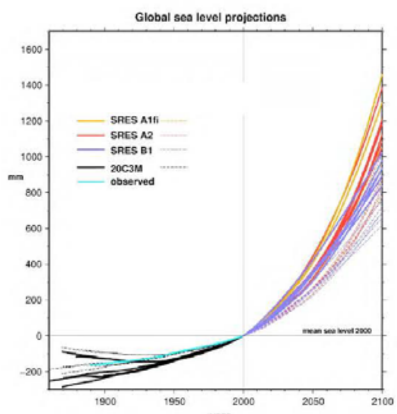



Figure 1 - Projections of global mean sea level rise based on selected climate projections.

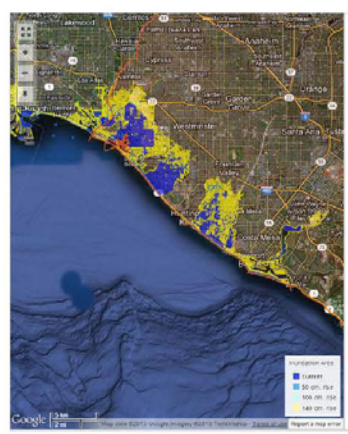


Figure 2 - Area at risk of inundation from 100-year flood event under current conditions (blue) and under 1400 mm sea level rise (yellow)

Link to full technical report: www.usbr.gov/lc/socal/basinstudies/OWOW.html

# Appendix B:

# SARW Vulnerability Assessment Checklist

# SARW Vulnerability Assessment Checklist

***SOURCE:*** *Adapted from the U.S. EPA Region 9 and the California Department of Water Resources* ***Climate Change Handbook for Regional Water Planning****, dated November 2011, Vulnerability Assessment Check*

***"If Yes, Check the Box"***

## Water Demand:

☑ *Are there major industries that require cooling/process water in the SARW?*

- As average temperatures increase, industrial cooling water needs may increase.
- Identify major industrial water users in your region and assess their current and projected needs for cooling and process water.

☑ *Does water uses vary by more than 50% seasonally in parts of the Watershed?*

- Seasonal water use, which is primarily outdoor water use, is expected to increase as average temperatures increase and droughts become more frequent.
- Where water use records are available, look at total monthly water uses averaged over the last five years (if available). If maximum and minimum monthly water uses vary by more than 25%, then the answer to this question is "yes".
- Where no water use records exist, is crop irrigation responsible for a significant (say >50%) percentage of water demand in parts of your region?

☑ *Are crops grown in the Watershed climate-sensitive? Would shifts in daily heat patterns, such as how long heat lingers before night-time cooling, be prohibitive for some crops?*

- Fruit and nut crops are climate sensitive and may require additional water as the climate warms. Landscape nurseries also exist and would require additional water under even a moderate climate change scenario.

☑ *Do groundwater supplies in the Watershed lack resiliency after drought events?*

- Droughts are expected to become more frequent and more severe in the future. Areas with an inelastic demand may be particularly vulnerable to droughts and may become more dependent on groundwater pumping.

☑ *Are water use curtailment measures effective in the Watershed?*

- Water conservation measures have been very effective in the SARW. Continued education and increased employment of efficient use technologies are still needed.

☑ *Are some instream flow requirements in the Watershed either currently insufficient to support aquatic life, or occasionally unmet?*

- Changes in snowmelt patterns in the future *may* make it difficult to balance water demands. Vulnerabilities for ecosystems and municipal/agricultural water needs may be exacerbated by instream flow requirements that are:
1. not quantified,
2. not accurate for ecosystem needs under multiple environmental conditions including droughts, and
3. not accepted by regional water managers.

## Water Supply

☑ *Does a portion of the water supply in the Watershed come from snowmelt?*

- The snowmelt window is expected to shrink as the climate warms. Water systems supplied by snowmelt are therefore potentially vulnerable to climate change.
- Where watershed planning documents are available, refer to these in identifying parts of your region that rely on surface water for supplies.
-Where planning documents are not available, identify major rivers in the Santa Ana River Watershed with large users. Identify whether the river's headwaters are fed by snowpack.

☑ *Does part of the Watershed rely on water diverted from the Delta, imported from the Colorado River, or imported from other climate-sensitive systems outside your region?*

- The Watershed does depend on imported water from sensitive regions; however, it is also very dependent upon its own groundwater supply.

☑ *Does part of the Watershed rely on coastal aquifers? Has salt intrusion been a problem in the past?*

- Coastal aquifers are susceptible to salt intrusion as sea levels rise, and many have already observed salt intrusion due to over-extraction, such as the West Coast Basin in southern California. Afflicted districts constantly work to manage the salt intrusion problem.

☑ *Would the Watershed have difficulty in storing carryover supply surpluses from year to year?*

- Droughts are expected to become more severe in the future. Systems that can store more water may be more resilient to droughts.

☑ *Does the Watershed have invasive species management issues at your facilities, along conveyance structures, or in habitat areas?*

- Invasive species are an issue with California’s water infrastructure, specifically the quagga mussel.

## Water Quality:

☑ *Are increased wildfires a threat in the Watershed? If so, does the Watershed include reservoirs with fire-susceptible vegetation nearby which could pose a water quality concern from increased erosion?*

- Increased wildfires are a major risk due to the location of the SARW basin. Cal-Adapt lists the upstream areas of the Santa Ana River as a high risk for fire danger.

☑ *Does part of the Watershed rely on surface water bodies with current or recurrent water quality issues related to eutrophication, such as low dissolved oxygen or algal blooms? Are there other water quality constituents potentially exacerbated by climate change?*

- Warming temperatures will result in lower dissolved oxygen levels in water bodies, which are exacerbated by algal blooms and in turn enhance eutrophication. Changes in stream flows may alter pollutant concentrations in water bodies.

☑ *Are seasonal low flows decreasing for some water bodies in the Watershed? If so, are the reduced low flows limiting the water bodies' assimilative capacity?*
- In the future, low flow conditions are expected to be more extreme and last longer. This may result in higher pollutant concentrations where loadings increase or remain constant.

☑ *Are there beneficial uses designated for some water bodies in the Watershed that cannot always be met due to water quality issues?*
- Ocean pollution from storm water runoff creates a significant impediment to ocean recreation.

☑ *Does part of the Watershed currently observe water quality shifts during rain events that impact treatment facility operation?*
- While it is unclear how average precipitation will change with temperature, it is generally agreed that storm severity will probably increase. More intense, severe storms may lead to increased erosion, which will increase turbidity in surface waters. Areas that already observe water quality responses to rainstorm intensity may be especially vulnerable.

## Sea Level Rise:

☑ *Has coastal erosion already been observed in communities in the Santa Ana River Watershed?*
- Coastal erosion is expected to occur over the next century as sea levels rise.

☑ *Are there coastal structures, such as levees or breakwaters, in Santa Ana River Watershed coastal communities?*
- Coastal structures designed for a specific mean sea level may be impacted by sea level rise.

☑ *Is there significant coastal infrastructure, such as residences, recreation, water and wastewater treatment, tourism, and transportation) at less than six feet above mean sea level in the Watersheds coastal areas?*
- Parts of Orange County are less than six feet above mean sea level. These areas contain significant water supply infrastructure as well as economic infrastructure.

☑ *Are there climate-sensitive low-lying coastal habitats in Watershed communities?*
- Low-lying coastal habitats that are particularly vulnerable to climate change include estuaries and coastal wetlands that rely on a delicate balance of freshwater and salt water.

☑ *Are there areas in the Watersheds coastal communities that currently flood during extreme high tides or storm surges?*
- Areas that are already experiencing flooding during storm surges and very high tides are more likely to experience increased flooding as sea levels rise.

☑ *Is there land subsidence in the coastal areas of the Watersheds coastal communities?*
- Land subsidence may compound the impacts of sea level rise.

☑ *Do tidal gauges along the coastal parts of the Watersheds communities show an increase over the past several decades?*

- Local sea level rise may be higher or lower than state, national, or continental projections.
- NOAA suggests that the mean sea level trend at Newport Beach is 2.22 millimeters per year.

## Flooding:

☑ *Does critical infrastructure in the Watershed lie within the 200-year floodplain? DWR's best available floodplain maps are available at: http://www.water.ca.gov/floodmgmt/lrafmo/fmb/fes/best_available_maps/.*

- While it is unclear how average precipitation will change with temperature, it is generally agreed that storm severity will probably increase. More intense, severe storms may lead to higher peak flows and more severe floods.
- Refer to FEMA floodplain maps and any recent FEMA, U.S. Army Corps of Engineers, or Department of Water Resources studies that might help identify specific local vulnerabilities for your region. Other follow-up questions that might help answer this question:

1. What public safety issues could be affected by increased flooding events or intensity? For example, evacuation routes, emergency personnel access, hospitals, water treatment and wastewater treatment plants, power generation plants and fire stations should be considered.
2. Could key regional or economic functions be impacted from more frequent and/or intense flooding?

☑ *Does aging critical flood protection infrastructure exist in the Watershed?*

- Levees and other flood protection facilities across the state of California are aging and in need of repair. Due to their overall lowered resiliency, these facilities may be particularly vulnerable to climate change impacts.
- DWR is evaluating more than 300 miles of levees in the San Joaquin and Sacramento Rivers Valleys and the Delta (http://www.water.ca.gov/levees/).

☑ *Have flood control facilities (such as impoundment structures) been insufficient in the past?*

- Reservoirs and other facilities with impoundment capacity may be insufficient for severe storms in the future. Facilities that have been insufficient in the past may be particularly vulnerable.
- Flood control has been an issue in the past. The Santa Ana River poses a significant flooding threat to areas in the basin.

☑ *Are wildfires a concern in parts of the Watershed?*

- Wildfires alter the landscape and soil conditions, increasing the risk of flooding within the burn and downstream areas. Some areas are expected to become more vulnerable to wildfires over time. To identify whether this is the case for parts of your region, the California Public Interest Energy Research Program has posted wildfire susceptibility projections as a Google Earth application at: http://cal-adapt.org/fire/. These projections are the results of only a single study and are not intended for analysis, but can aid in qualitatively answering this question. Read the application's disclaimers carefully to be aware of its limitations.

## Ecosystem and Habitat Vulnerability:

☑ *Does the Watershed include inland or coastal aquatic habitats vulnerable to erosion and sedimentation issues?*

- Erosion is expected to increase with climate change, and sedimentation is expected to shift. Habitats sensitive to these events may be particularly vulnerable to climate change.

☑ *Does the Watershed include estuarine habitats which rely on seasonal freshwater flow patterns?*
- Seasonal high and low flows, especially those originating from snowmelt, are already shifting in many locations.

☑ *Do climate-sensitive fauna or flora populations live in the Watershed?*
- Some specific species are more sensitive to climate variations than others.

☑ *Do endangered or threatened species exist in the Watershed? Are changes in species distribution already being observed in parts of the Watershed?*
- Species that are already threatened or endangered may have a lowered capacity to adapt to climate change.

☑ *Does the Watershed rely on aquatic or water-dependent habitats for recreation or other economic activities?*
- Economic values associated with natural habitat can influence prioritization.

☑ *Are there rivers in the Watershed with quantified environmental flow requirements or known water quality/quantity stressors to aquatic life?*
- Constrained water quality and quantity requirements may be difficult to meet in the future.

☑ *Do estuaries, coastal dunes, wetlands, marshes, or exposed beaches exist in the Watershed? If so, are coastal storms possible or frequent in these areas of the Watershed?*
- Storm surges are expected to result in greater damage in the future due to sea level rise. This makes fragile coastal ecosystems vulnerable.

☑ *Are there areas of fragmented estuarine, aquatic, or wetland wildlife habitat within the Watershed? Are there movement corridors for species to naturally migrate? Are there infrastructure projects planned that might preclude species movement?*
- These ecosystems are particularly vulnerable to climate change.

## Hydropower:

☑ *Is hydropower a source of electricity in the Watershed?*
- While hydropower is not a significant part of the energy production portfolio in the Watershed, drought implications for the Colorado River and its hydropower generators is worthy of attention in light of water conveyance energy needs.

☑ *Are energy needs in the Watershed expected to increase in the future? If so, are there future plans for hydropower generation facilities or conditions for hydropower generation in the Santa Ana River Watershed?*
- Energy needs are expected to increase in many locations as the climate warms. This increase in electricity demand may compound decreases in hydropower production, increasing its priority for a region.

# Appendix C:

# SARW Groundwater Screening Tool

# Appendix C1: Groundwater Screening Tool Setup

## Step-By-Step Quick Setup Guide

*Introduction*

- The Groundwater Screening Tool is based on a simplified mass balance of basin-scale groundwater supply.
- The Groundwater Screening Tool estimates future fluctuations in basin-scale groundwater conditions based on the historical relationship between groundwater elevations and six primary drivers of groundwater availability: precipitation, surface water availability (natural runoff), trans-basin imported water, municipal and industrial (M&I) demand, agricultural demand, and evaporative demand by landscaped and native vegetation.
- The Groundwater Screening Tool uses a regression-based approach, which provides significant flexibility in input data—specifically, representative (proxy) data may be used in place of comprehensive mass balance inputs where the latter are not available
  - Example: temperature may be used as a proxy for evaporative demand due to strong correlation between temperature and potential evapotranspiration
  - Example: irrigated acreage may be used as a proxy for agricultural demand, provided that cropping patterns and irrigation practices are reasonably consistent over time

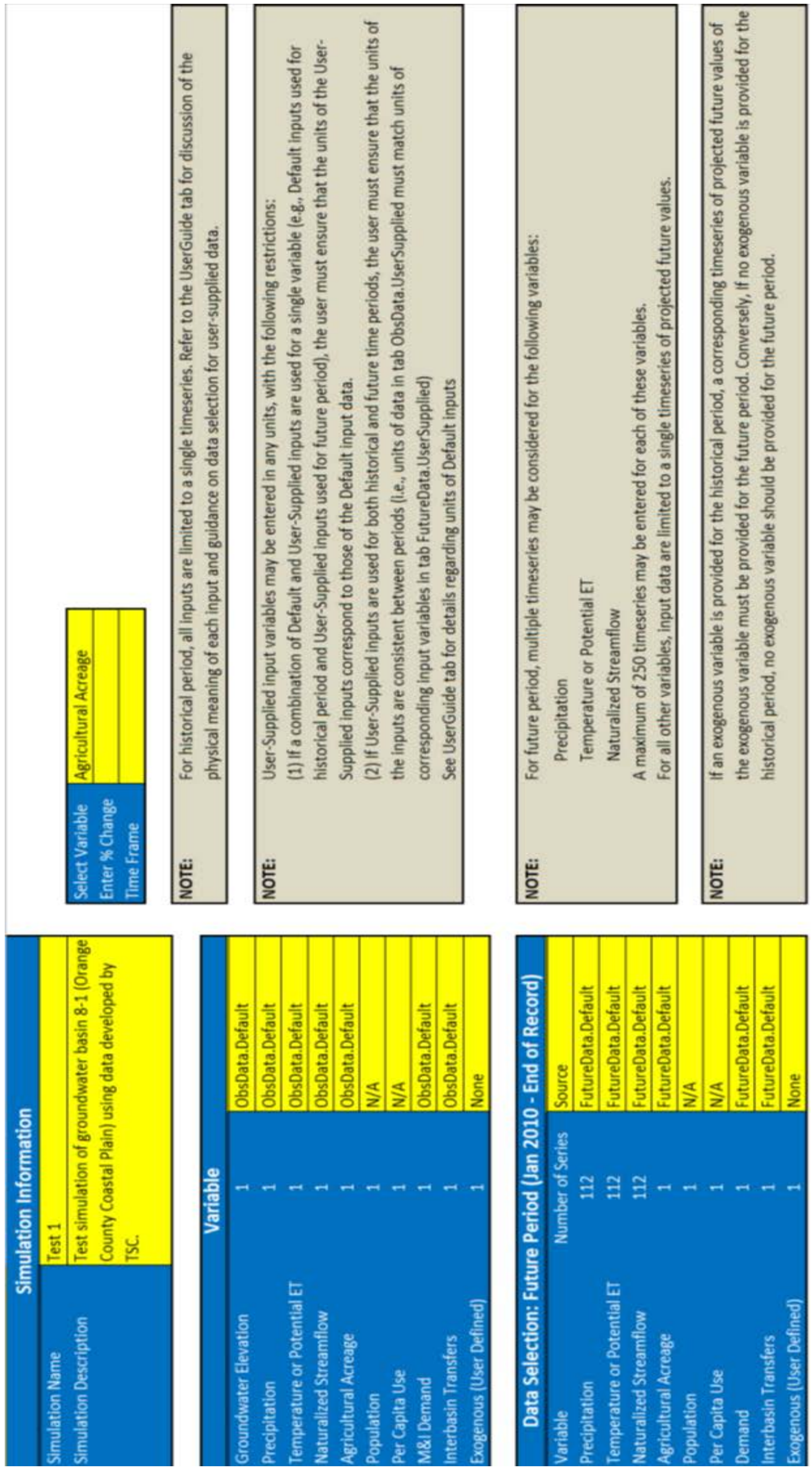
*Step 1: Select input options* *(Worksheet: "UserSetup")*

Required for all scenarios.

- Click on worksheet titled "UserSetup"
- Enter simulation name
  Entered as text input (cell B2)
- Enter simulation description
  Entered as text input (cell B3)
- Select source option for each variable for historical period (Jan 1990 – Dec 2009)
  Options selected from drop-down menus (cells C12:C22)
  - Option "ObsData.Default" indicates that default data in tab "ObsData.Default" will be used.
  - Option "ObsData.UserSupplied" indicates that data provided in tab "ObsData.UserSupplied" will be used.
  - Option "Calculate" indicates M&I Demand will be calculated by Population and Per Capita Use data
  - Option "NA" indicates that Population and Per Capita use data are not used to calculate M&I Demand, in which case data are not required.
  - Option "None" indicates that no exogenous variable is considered.
- Select source option for each variable for future period (Jan 2010 – Dec 2099)
  Options selected from drop-down menus (cells C26:C34)
  - Option "FutureData.Default" indicates that default data in tab "FutureData.Default" will be used.
  - Option "FutureData.UserSupplied" indicates that data provided in tab "FutureData.UserSupplied" will be used.
  - Option "Calculate" indicates M&I Demand will be calculated by Population and Per Capita Use data
  - Option "NA" indicates that Population and Per Capita use data are not used to calculate M&I Demand, in which case data are not required.
  - Option "None" indicates that no exogenous variable is considered.

*Step 2: Provide input data* *(Worksheet: "ObsData.UserSupplied",*

## Appendix C2: Groundwater Screening Tool Screenshot



| Simulation Information | |
|---|---|
| Simulation Name | Test 1 |
| Simulation Description | Test simulation of groundwater basin 8-1 (Orange County Coastal Plain) using data developed by TSC. |

| Select Variable | Agricultural Acreage |
|---|---|
| Enter % Change | |
| Time Frame | |

NOTE: For historical period, all inputs are limited to a single timeseries. Refer to the UserGuide tab for discussion of the physical meaning of each input and guidance on data selection for user-supplied data.

| Variable | | |
|---|---|---|
| Groundwater Elevation | 1 | ObsData.Default |
| Precipitation | 1 | ObsData.Default |
| Temperature or Potential ET | 1 | ObsData.Default |
| Naturalized Streamflow | 1 | ObsData.Default |
| Agricultural Acreage | 1 | ObsData.Default |
| Population | 1 | N/A |
| Per Capita Use | 1 | N/A |
| M&I Demand | 1 | ObsData.Default |
| Interbasin Transfers | 1 | ObsData.Default |
| Exogenous (User Defined) | 1 | None |

NOTE: User-Supplied input variables may be entered in any units, with the following restrictions:
(1) If a combination of Default and User-Supplied inputs are used for a single variable (e.g., Default inputs used for historical period and User-Supplied inputs used for future period), the user must ensure that the units of the User-Supplied inputs correspond to those of the Default input data.
(2) If User-Supplied inputs are used for both historical and future time periods, the user must ensure that the units of the inputs are consistent between periods (i.e., units of data in tab ObsData.UserSupplied must match units of corresponding input variables in tab FutureData.UserSupplied)
See UserGuide tab for details regarding units of Default inputs

| Data Selection: Future Period (Jan 2010 - End of Record) | | |
|---|---|---|
| Variable | Number of Series | Source |
| Precipitation | 112 | FutureData.Default |
| Temperature or Potential ET | 112 | FutureData.Default |
| Naturalized Streamflow | 112 | FutureData.Default |
| Agricultural Acreage | 1 | FutureData.Default |
| Population | 1 | N/A |
| Per Capita Use | 1 | N/A |
| Demand | 1 | FutureData.Default |
| Interbasin Transfers | 1 | FutureData.Default |
| Exogenous (User Defined) | 1 | None |

NOTE: For future period, multiple timeseries may be considered for the following variables:
Precipitation
Temperature or Potential ET
Naturalized Streamflow
A maximum of 250 timeseries may be entered for each of these variables.
For all other variables, input data are limited to a single timeseries of projected future values.

NOTE: If an exogenous variable is provided for the historical period, a corresponding timeseries of projected future values of the exogenous variable must be provided for the future period. Conversely, If no exogenous variable is provided for the historical period, no exogenous variable should be provided for the future period.