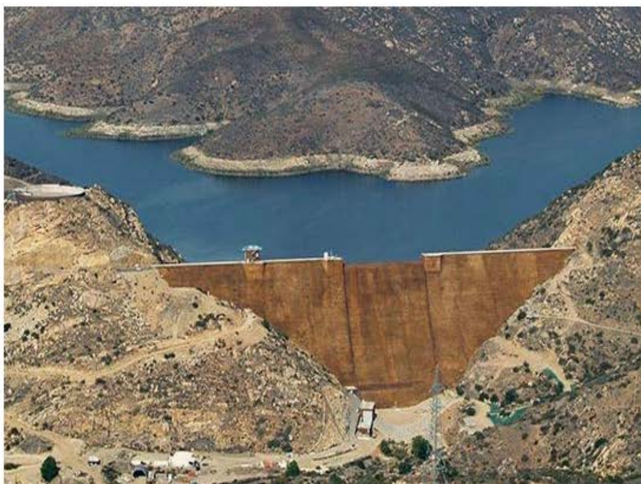
RECLAMATION

Managing Water in the West

San Diego Basin Study

Task 2.3 – Existing Structural and Operations Guidelines Response Analysis



U.S. Department of the Interior
Bureau of Reclamation

City of San Diego
Public Utilities Department

August 2017

Mission Statements

The mission of the City of San Diego Public Utilities Department is to ensure the quality, reliability, and sustainability of water, wastewater and recycled water services for the benefit of the ratepayers and citizens served.

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.

Cover Photos: Clockwise from top left: San Vicente Reservoir facing northwest; Twin Oaks Valley Water Treatment Plant facing northeast; Carlsbad Desalination Plant facing east; and City of San Diego facing north.

San Diego Basin Study

Task 2.3 – Existing Structural and Operations Guidelines Response Analysis

August 2017

Prepared by:

Bureau of Reclamation
Lower Colorado Region
Engineering Services Office

Prepared for:

City of San Diego
Public Utilities Department

Bureau of Reclamation
Lower Colorado Region
Southern California Area Office

Peer Reviewed by:

Ken Weinberg
Water Resources Consultant
Water Resources Consulting LLC

Contents

Page

Tables

Figures

Acronyms and Abbreviations

AF	acre-feet (1 AF = 43,560 cubic feet = 325,851 gallons)
AF/y or AF/d	acre-feet per year or acre-feet per day
Cal-Am	California American Water Company
cfs	cubic feet per second
CMIP Phase 3 & 5	Coupled Model Intercomparison Project climate projections
CVWD	Coachella Valley Water District
CRB	Colorado River Basin
CRBSDS	Colorado River Basin Supply and Demand Study
DWR	California Department of Water Resources
ECRTWIP	East County Regional Treated Water Improvement Program
GCM	Global Climate Model
IID	Imperial Irrigation District
IQR	Interquartile Range
IRP	Integrated Water Resources Plan
IRWM	Integrated Regional Water Management
KAF	Thousand acre-feet
M&I	Municipal and Industrial
MAF	Million acre-feet
mgd	Million gallons per day
MWD	The Metropolitan Water District of Southern California
PET	Potential Evapotranspiration
QSA	Quantification Settlement Agreement
RCP	Representative Concentration Pathways
Reclamation	United States Department of the Interior, Bureau of Reclamation
RWMG	Regional Water Management Group
SANDAG	San Diego Association of Governments
SDBS / Basin Study	San Diego Basin Study

SDCWA	San Diego County Water Authority
SDMMP	San Diego Management and Monitoring Program
SDPUD	City of San Diego Public Utilities Department
SSJBS	Sacramento-San Joaquin Basins Study
SWP	State Water Project
UWMP	Urban Water Management Plan
WTP	Water Treatment Plant

Glossary

Baseline System: For Task 2.3 of the San Diego Basin Study, the CWASim model was updated to run the 2015 SDCWA UWMP supply and demand scenarios, and water supply infrastructure including all verifiable projects. It was also updated to allow simulation of climate change scenarios developed specifically for the Basin Study and to improve modeling of imported water supplies. This version of the model is referred to as the 'Baseline SDBS CWASim Model,' or 'Baseline System.'

CWASim: A GoldSim model originally developed for SDCWA by CH2M in support of the 2013 Regional Facilities Optimization and Master Plan Update to simulate the regional water system. The model was adapted and updated for use in the San Diego Basin Study.

Fiscal Year (SDCWA): The 12-month period from July 1, for any given year, through June 30 of the following year. The fiscal year is designated by the calendar year in which it ends. Thus, the year ending June 30, 1999 is called the "1999" fiscal year.

GoldSim: A simulation software program for dynamically modeling complex systems in business, engineering, and science. GoldSim supports decision and risk analysis by simulating future performance while quantitatively representing the uncertainty and risks inherent in all complex systems.

IRWM Program: A California DWR program for supporting water resources planning under the Regional Water Management Planning Act (SB 1672). Integrated Regional Water Management (IRWM) is a collaborative effort to manage all aspects of water resources in a region. The fundamental principle of IRWM is that regional water managers, who are organized into regional water management groups (RWMGs), are best suited and best positioned to manage water resources to meet regional needs.

San Diego Basin Study Area: The area bounded on the north, west, and south by the San Diego County boundary and on the east by the boundaries of 11 Study Watersheds. The Study Area is the same as the San Diego IRWM Region.

Study Watersheds: The entirety of the San Luis Rey, Carlsbad, San Dieguito, Peñasquitos, San Diego River, Pueblo, Sweetwater, and Otay watersheds and the portions of the San Juan, Santa Margarita, and Tijuana watersheds within San Diego County.

Urban Water Management Plans: Plans prepared by California's urban water suppliers every five years to meet the requirements identified in the California Water Code, Sections 10608 – 10656 and submitted to the DWR. Every urban water supplier that either provides over 3,000 acre-feet of water annually, or serves more than 3,000 urban connections, is required to assess the reliability of its water sources over a 20-year planning horizon, and report its progress on 20% reduction in per-capita urban water consumption by the year 2020, as required in the Water Conservation Act of 2009.

Watershed: Surface drainage area upstream of a specified point on a watercourse. A geographical portion of the Earth's surface from which water drains or runs off to a single point.

Water Year: The 12-month period from October 1, for any given year, through September 30 of the following year. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1999 is called the "1999" water year.

Executive Summary

Study and Task 2.3 Overview

The purpose of the San Diego Basin Study (Basin Study) is to determine potential climate change impacts on water supplies and demands within the San Diego region and to identify how potential adaptation strategies could mitigate supply shortages. The intention of Task 2.3 is to create a computer simulation model to forecast supply and demand imbalances under current and future conditions, and current and future demands under a baseline water system infrastructure in the Study Area. This Interim Report describes the methodologies and findings of this Task.

Methodology

Task 2.3 of the Basin Study used an updated version of the CWASim model to simulate operations of the water supply system in the study area. CWASim is a GoldSim model originally developed for the San Diego County Water Authority (SDCWA) by CH2M in support of the 2013 Regional Facilities Optimization and Master Plan Update.

CWASim runs on a daily timestep and represents the San Diego water system with elements and connectors representing reservoirs, water treatment plants, pipelines, delivery points, and other water supply infrastructure components. It includes the representation of local and imported supply sources, member agency demands, SDCWA facilities, and member agency facilities that are connected to the SDCWA system. It does not include representation of member agency facilities that are not connected to the SDCWA system. Operational logic describes how water is distributed throughout the system at each simulation timestep. Input data provides the water supply and demand volumes that drive the operations of the system.

The Baseline model runs included 13 simulations under a range of demand and climate conditions. Observed 2015 demands, SDCWA Urban Water Management Plan (UWMP) 2025 demand projections, and UWMP demand projections extended to 2050 made up the three Baseline demand scenarios (2015, 2025, and 2050) that were used in the Baseline analysis. A current climate scenario and five climate change scenarios (central tendency, warm-wet, warm-dry, hot-wet, and hot-dry) made up the Baseline climate scenarios.

Findings

Metric outputs from the CWASim model evaluate the performance of the San Diego water system in four impact categories: 1) Water Delivery; 2) Hydroelectric Power; 3) Recreation; and 4) Flood Control. Environmental impacts were described through literature review rather than quantitative metrics.

Water Delivery

Demands projections increase in the future due to demographic and economic changes and vary between climate scenarios. Baseline water deliveries increased to meet demands. Reliance on imported water purchased from MWD was also found to increase. Water shortages occurred more frequently and were found to be larger in magnitude under future demand scenarios. Treatment plant utilization is expected to increase under future demand scenarios with minimal difference between climate scenarios. Conveyance system limitations could contribute to water shortages.

Hydroelectric Power

Energy generation was found to increase slightly with increased water demand. As demands increase in the future, energy use is also expected to increase. The result is an expected increase in net energy consumption as more energy is required to treat and distribute water.

Recreation

Reservoir natural inflows were found to vary between years and within years. Boat ramps were found to typically remain accessible, yet may become inaccessible at some reservoirs from time to time.

Flood Control

The number and volume of flood releases or spills (not for water supply) were found to decrease in the future. This decrease is likely the by-product of lower reservoir storage volumes, which result in more available reservoir capacity to store larger flows during storm events.

1. Introduction

1.1. Study Overview and Purpose

The purpose of the San Diego Basin Study (Basin Study or SDBS) is to determine potential climate change impacts on water supplies and demands within the San Diego region, and to analyze structural and non-structural concepts that can assist the region in adapting to the uncertainties associated with climate change. The Basin Study will investigate potential changes to existing operating policies for regional water supply facilities (i.e., dams, reservoirs, conveyance facilities, and water treatment and water recycling plants), modifications to existing facilities, development of new facilities that could optimize reservoir systems, and additional new water supply options including desalination and indirect potable reuse options.

The Study's two primary objectives are:

1. Determine how climate change will impact the current and future water supply portfolio of the San Diego region; and
2. Develop structural and non-structural concepts within the San Diego region that can serve as adaptation strategies to manage climate change impacts, focusing on improving operations of existing facilities and supplies, and further developing new core water supply sources.

The Basin Study is divided into two interrelated tasks. Task 1 comprises the project management aspects of the work, while Task 2 addresses the detailed scientific, engineering, and economic analyses that are being completed to meet the study objectives. Task 2 is further divided into sub tasks 2.1 through 2.6:

2.1 – Water Supply and Water Demand Projections
2.2 – Downscaled Climate Change and Hydrologic Modeling
2.3 – Existing Structural Response and Operations Guidelines Analysis
2.4 – Structural and Operations Concepts
2.5 – Trade-Off Analysis and Recommendations
2.6 – Final Report

1.2. Overview of Task 2.3

This Interim Report describes the methodologies and findings for Task 2.3 – Existing Structural and Operations Guidelines Response Analysis. The purpose of Task 2.3 is to identify water supply and demand imbalances for current and future climate conditions and current and future demands under the baseline water system infrastructure within the Study Area.

Chapter 2 of the report includes a summary of the San Diego water system supplies and demands, and water resources infrastructure. This builds upon the work completed for Task 2.1 –

Water Supply and Water Demand Projections, and for Task 2.2 – Climate Change Impacts and Hydrologic Modeling.

Chapter 3 of the report describes CWASim, the model used in Task 2.3 to simulate operations of the San Diego regional water supply system to meet water demands with local and imported supply sources. It was originally developed for SDCWA by CH2M in support of the 2013 Regional Facilities Optimization and Master Plan Update to simulate the regional water system. It was revised for use in the Basin Study with improved modeling of imported water supplies and additional metrics that allow analysis of the supply and demand scenarios being examined in the Basin Study.

Chapter 4 of the report describes the water supply and demand scenarios and baseline system infrastructure conditions that were analyzed in the baseline model runs. Supply and demand scenarios and water infrastructure were based on the 2015 SDCWA UWMP and adjusted to incorporate climate change projections. System infrastructure consisted of existing facilities and planned and verifiable projects described in the 2015 SDCWA UWMP.

Chapter 5 of the report describes the baseline run results and findings. A set of metrics and model outputs was used to quantify impacts as they relate to water deliveries, hydroelectric power, recreation, flood control, and environmental resources.

1.3. Study Background

For more than 60 years, the San Diego area has relied on imported water as the primary source of supply for the region. Unlike other large metropolitan areas within southern California, such as those located within the Los Angeles or Santa Ana watersheds, San Diego does not have large productive groundwater basins within its borders. This is due to a number of factors including limited productive sand and gravel (alluvial) aquifers, the relatively shallow nature of most existing alluvial aquifers, lack of rainfall and groundwater recharge, and degraded water quality resulting from human activities.

Prior to the introduction of imported water supplies to the region, surface water reservoirs served as the primary source of water supply for the region. Local surface water supplies remain an integral part of the region’s supply portfolio and are currently yielding supply volumes comparable to seawater desalination; these two sources currently provide the majority of local supplies (San Diego County Water Authority, 2016).

With a strong military presence before, during, and immediately after World War II, San Diego’s growing population was in desperate need of water supply solutions. In response, the Department of the Navy and the Bureau of Reclamation (Reclamation) constructed the San Diego Project, two large-diameter pipelines that connect the area to The Metropolitan Water District of Southern California’s (MWD) infrastructure system, to bring in supplemental supplies from the Colorado River. The first pipeline was completed in 1947 and the second in 1954 (together known as the ‘First Aqueduct’), which the San Diego County Water Authority (SDCWA) now owns and operates along with three additional large-diameter pipelines (collectively, the ‘Second Aqueduct’) that deliver imported supplies into the region. Imported supplies from the Colorado

River and State Water Project (SWP) remain the region's predominant source of supply, comprising approximately 70% to 90% of the supplies utilized within the region. These imported supplies consist of water purchased from MWD and other imported supplies resulting from agreements that provide access to senior water rights on the Colorado River via long-term transfers. Imported water purchases are dependent on availability of water from MWD, while the long-term transfer agreements guarantee 100,000 acre-feet per year (AF/y), increasing by 30,000 AF/y in 2018, and then to 200,000 AF/y by 2021 of conserved water from the Imperial Irrigation District (IID) and an additional 80,200 AF/y of conserved water as a result of canal lining projects. The imported water purchases and the IID transfer water and the canal lining water are wheeled through MWD's conveyance facilities and delivered to SDCWA's aqueducts.

While SDCWA and its member agencies have taken steps to diversify the region's supply portfolio through the development of local supplies, through the formation of agreements to access senior water rights on the Colorado River, and through conservation and water use efficiency improvements, the region remains highly reliant on imported water sources. The reliability of imported water deliveries to the San Diego region is uncertain due to periodic droughts in northern California and the Colorado River Basin, regulatory restrictions related to endangered species in the Bay-Delta that limit State Water Project deliveries, the potential for catastrophic events such as earthquakes, and climate change. Over the last 25 years, multi-year supply cutbacks have been experienced on three separate occasions (San Diego County Water Authority, 2017). To meet current and future water supply reliability goals, it is essential that the region evaluate its existing system, identify ways to improve the ability to store imported and local water supplies when available, and develop new water supplies, making the region more resistant to drought, climate change, and water delivery service interruptions.

2. Study Area

2.1. Study Area Overview

The Study Area (Figure 1) delineates the area for which water supplies and demands are examined in the Basin Study. It is equivalent to the planning regions of the San Diego IRWM Plan and the SDCWA 2015 Urban Water Management Plan. The Study Area is bounded on the north, west, and south by the San Diego County boundary and on the east by the boundaries of 11 regional watersheds (the Study Watersheds) (Table 2). Eight of the Study Watersheds are completely within the Study Area (San Luis Rey, Carlsbad, San Dieguito, Los Peñasquitos, San Diego, Pueblo, Sweetwater, and Otay) and two northern watersheds (San Juan and Santa Margarita) and one southern watershed (Tijuana) are partially within the Study Area.

The SDCWA and its member agencies (Table 1) are the primary suppliers of water within the Study Area. The SDCWA service area is entirely within the Study Area and encompasses most of the western portion of San Diego County. It is divided into 24 member agency service areas, the largest of which is the City of San Diego that makes up approximately one-third of the SDCWA service area (Figure 2). The Study Area overlaps numerous other municipal and water agency boundaries. Many other ongoing planning efforts, such as Urban Water Management Plans produced by the City of San Diego (City of San Diego, 2015) and other individual SDCWA member agencies, examine portions of the Study Area.

Table 1. SDCWA Member Agencies

Agency Listing	
Camp Pendleton Marine Corps Base	Padre Dam Municipal Water District
Carlsbad Municipal Water District	Rainbow Municipal Water District
City of Del Mar	Ramona Municipal Water District
City of Escondido	Rincon del Diablo Municipal Water District
City of Oceanside	San Dieguito Water District
City of Poway	Santa Fe Irrigation District
City of San Diego	Sweetwater Authority
Fallbrook Public Utility District	Vallecitos Water District
Helix Water District	Valley Center Municipal Water District
Lakeside Water District	Vista Irrigation District
Olivenhain Municipal Water District	Yuima Municipal Water District
Otay Water District	

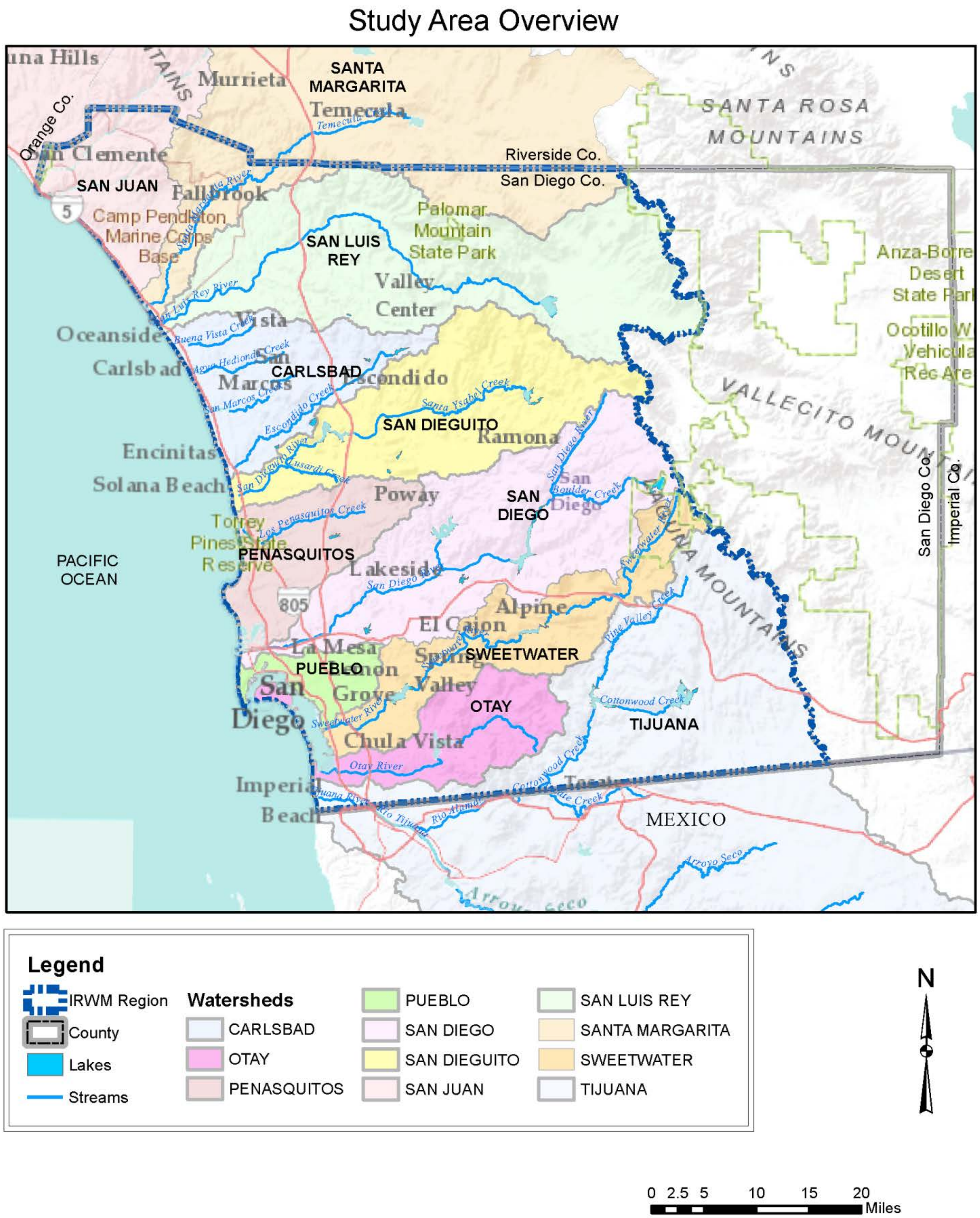


Figure 1. Overview of the San Diego Basin Study Area

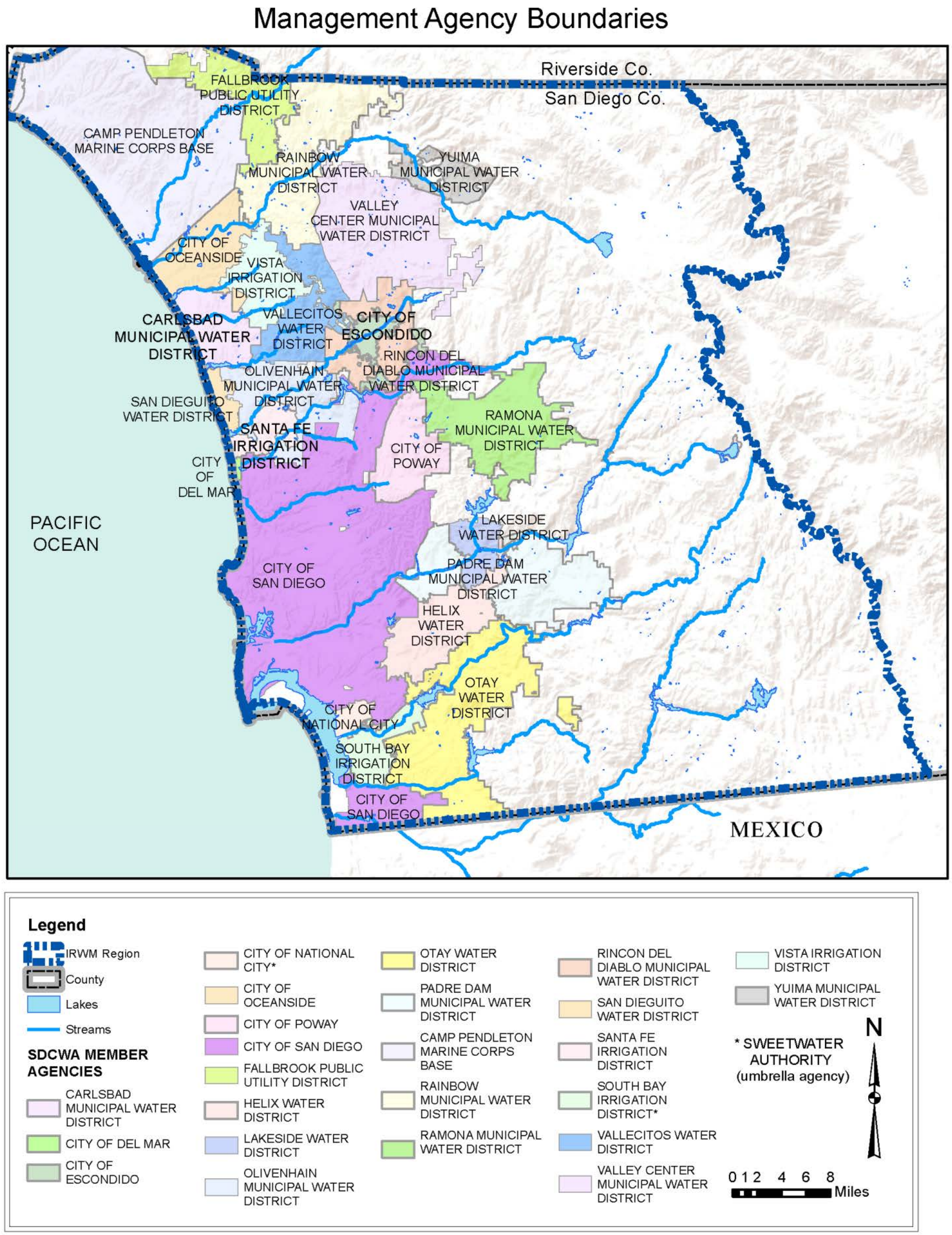


Figure 2. SDCWA member agency boundaries

Table 2. Study Watersheds

Watershed	Area (mi^2)	Major Drainages in Study Area	Groundwater Basins	Reservoirs
San Juan	496 (150 in Study Area)	San Mateo Creek	San Mateo Valley, San Onofre Valley	none
Santa Margarita	750 (200 in Study Area)	Santa Margarita River	Santa Margarita Valley	none
San Luis Rey	562	San Luis Rey River	San Luis Rey Valley, Warner Valley, Ranchita Town Area	Henshaw, Turner
Carlsbad	211	small stream systems draining to coast	Batiquitos Lagoon Valley, San Elijo Valley, San Marcos Area, Escondido Valley	Wohlford, Dixon, Olivenhain, San Dieguito
San Dieguito	346	San Dieguito River	San Pasqual Valley, Santa Maria Valley, San Dieguito Valley, Pamo Valley	Sutherland, Ramona, Poway, Hodges
Peñasquitos	162	small streams	Poway Valley	Miramar
San Diego River	440	San Diego River	Mission Valley, San Diego River Valley (including Santee-El Monte), El Cajon	El Capitan, San Vicente, Cuyamaca, Jennings, Murray
Pueblo	60	none	Sweetwater Valley	none
Sweetwater	230	Sweetwater River	Sweetwater Valley	Loveland, Sweetwater
Otay	160	Otay River	Otay Valley	Lower Otay (Savage Dam)
Tijuana	1,750 (467 in Study Area)	Tijuana River	Tijuana, Cottonwood Valley, Campo Valley, Portrero Valley	Morena, Barrett

2.2. Study Area Water Supplies

The Basin Study examines local supplies produced within the Study Area by SDCWA and its member agencies, as well as imported supplies from other regions. Local supplies originate as surface water in the Study Watersheds, local groundwater from some of the 24 groundwater basins in the region, locally recycled water, and local desalination. Imported supplies include Imperial Irrigation District transfer water, conserved water from canal lining projects, and purchased MWD supplies imported from the State Water Project (California Aqueduct) and Colorado River (Colorado River Aqueduct).

2.2.1. Surface Water

Water supply from surface water runoff in the Study Watersheds is limited. San Diego County's climate is relatively mild year-round and large precipitation events are rare due to the semiarid nature of the region. Annual rainfall varies between an average of 10 inches near the coast to 40 inches near the inland mountains. Over 80 percent of the average annual rainfall occurs between December and March and contributes runoff to the major streams in the region, including the Otay River, San Diego River, San Dieguito River, San Mateo Creek, San Luis Rey River, Santa Margarita River, Santa Maria Creek, Sweetwater River, and Tijuana River. Many streams in the region are regulated by storage reservoirs whose primary purpose is to capture runoff as supply.

Flood control is not a designated operating objective for these reservoirs, although operations for water supply can sometimes provide a secondary flood reduction benefit. For unregulated streams, more than 75% of the annual runoff volume generally occurs between December and April, and flows can drop to zero during the dry summer months. Surface water runoff generated from rainfall at times represents the largest single local water source in the SDCWA service area; however, surface water runoff only averaged 7% of the region's total annual water supply during the past 10 years. Local surface water supplies are currently yielding supply volumes that are comparable to volume of seawater desalinated by the newly constructed Carlsbad Desalination Plant. These two sources provide the majority of local supplies (San Diego County Water Authority, 2016).

2.2.2. Groundwater

There are 24 groundwater basins underlying the Study Watersheds. All municipal groundwater supplies for the region are operated by member agencies; SDCWA itself does not own groundwater rights or operate any groundwater facilities. SDCWA member agencies have produced an annual average of 18,944 AF/y of water supply from groundwater (San Diego County Water Authority, 2015). Groundwater is produced from either brackish groundwater desalination or municipal wells. Privately owned groundwater wells may be used by individual irrigators or households; those users are outside the scope of the Basin Study.

The potential for production of groundwater in the study area is limited. The most productive types of aquifers are alluvial deposits that formed in narrow river valleys, but the extent of these sand and gravel aquifers is small and most are at shallow depths. Groundwater may also be produced from fractured bedrock and sedimentary deposits, but yields are small. Further, the low rainfall in the region results in low groundwater recharge. There are also water quality concerns with available groundwater resources, such as contamination from septic tanks. High quality aquifers that produce water requiring minimal treatment have generally already been developed.

2.2.3. Recycled Water

Recycled water refers to wastewater that has been treated and disinfected so that it may be used in place of other supplies. Under current permitting regulations, recycled water may be used for non-potable uses including irrigation of parks and golf courses, dust control, cooling, and toilet flushing. Approximately 30,000 acre-feet of recycled water is reused annually by SDCWA member agencies and is distributed throughout the county through the "purple pipe" non-potable water system. Under potential future regulations water may be treated to higher standards and used for indirect potable or direct potable supply. Potable reuse is not allowed under current State of California regulatory guidelines, but legislation is currently being considered to create future regulations in order to allow direct potable reuse. The City of San Diego, Padre Dam Municipal Water District, and other agencies are currently planning for and/or developing an Indirect Potable Reuse program. The two projects at the most advanced stage of planning, City of San Diego's Pure Water and Padre Dam's Advanced Water Purification, are proposing to introduce advanced treated wastewater into an environmental buffer such as a surface water reservoir, then extract the water and treat it at a surface water treatment plant for distribution through the potable distribution system.

2.2.4. Seawater Desalination

In 2015, SDCWA added desalinated seawater to the water supply portfolio of San Diego County. The Claude 'Bud' Lewis Carlsbad Desalination Plant (Carlsbad Desalination Plant) is adjacent to the Encina Power Station in Carlsbad, California. The Plant was constructed and is operated through a Public-Private Partnership between SDCWA and Poseidon Resources. Poseidon Resources financed the construction of the Plant and entered into a 30-year water purchase agreement with SDCWA. The Carlsbad Desalination Plant was designed to produce 56,000 AF/y (50 million gallons per day [mgd]) of desalinated drinking water.

Two other seawater desalination projects in the San Diego area are under consideration, Camp Pendleton and Rosarito Beach. For the proposed Camp Pendleton Desalination Plant, two site locations have been investigated and both sites were found to be capable of supplying up to 168,000 AF of potable water to the region each year. The Rosarito Beach Desalination Project in Baja California is also being proposed. The initial phase of the project includes the production of about 28,000 AF/y (25 mgd), expandable to 56,000 AF/y (50 mgd). This is expected to offset a portion of the water Tijuana currently takes from Mexico's Colorado River water allotment. Excess water produced from this facility could be made available to Otay Water District in the U.S. (Otay Water District, 2017).

2.2.5. QSA Water

In 2003 the Colorado River Quantification Settlement Agreement (QSA) was completed to settle longstanding disputes between Imperial Irrigation District (IID), MWD, and Coachella Valley Water District (CVWD) related to priority, use, and transfer of Colorado River water. The agreement established terms for distribution of Colorado River water among the parties for up to 75 years and facilitated actions to enhance the reliability of Colorado River water supplies. Two actions identified in the QSA were the transfer of water made available by lining the All-American and Coachella Canals and the transfer of water conserved by IID initially through land fallowing transitioning entirely to Imperial Valley on-farm conservation. Both conservation efforts resulted in allocations of specific, firm annual volumes of water available to SDCWA.

2.2.6. MWD Purchases

In addition to local supplies and QSA imported water, SDCWA imports water purchased from MWD. MWD is a regional water wholesaler that supplies water to its 26 member agencies, including SDCWA. MWD obtains its water from the State Water Project (SWP) and the Colorado River Basin (CRB) and stores it in in-region surface water storage (Diamond Valley, Matthews, Skinner, and other local reservoirs, in-region groundwater storage, Colorado River storage (Lake Mead Intentionally Created Surplus), and Central Valley and State Water Project storage (SWP carryover, flexible storage programs at terminal reservoirs of the SWP, and Central Valley groundwater banks). Table 3 provides a summary of MWD's maximum available storage capacity and estimated usable storage. MWD uses the stored water to meet the demands of its member agencies.

During wet and normal years, MWD available supplies generally exceed demands, allowing MWD storage to increase. During dry years, supplies are often insufficient to meet demands and water is extracted from MWD storage to meet member agency demands. When MWD storage reaches low levels, the MWD Board of Directors may implement water allocations to member agencies at less than full deliveries to protect against future dry years.

Table 3. MWD Water Storage Capacity and Estimated Usable Storage

MWD Water Storage Capacity Summary (AF)		
	Maximum Capacity	Estimated Usable
In Region Surface Reservoirs		
Diamond Valley	810,000	810,000
Lake Matthews	182,000	182,000
Lake Skinner	44,000	44,000
Other Local	32,000	32,000
Member Agency Conjunctive Use	210,000	210,000
San Bernardino MWD Groundwater Storage	50,000	50,000
	1,328,000	1,328,000
Colorado River		
Lake Mead ICS Storage	2,390,000	300,000
	2,390,000	300,000
Central Valley and SWP		
SWP Article 56 Carryover Program	200,000	200,000
Lake Castaic and Lake Perris Flexible Storage	219,000	219,000
Semi-Tropic	350,000	150,000
Arvin-Edison	350,000	150,000
Kern Delta	250,000	150,000
Mojave	390,000	200,000
	1,759,000	1,069,000
TOTAL	5,477,000	2,697,000

2.3. Study Area Water Demands

The Basin Study examines water demands in the SDCWA service area. Together, SDCWA member agencies make up approximately 95% of the demands for San Diego County. Unincorporated areas of the County within the Study Watersheds are included in the Study Area for purposes of accounting for local water supplies, but their water demands are not included because they are met by individual wells. Demands for Marine Corps Base Camp Pendleton are also not included because they produce almost all of their own water, are not connected to the regional conveyance system, and serve only a small demand through Fallbrook Public Utilities District water system on the eastern edge of the Base.

Demand for water in the SDCWA service area falls into two classes of service: municipal and industrial (M&I), and agricultural. In fiscal year 2015, total demand was 539,361 acre-feet of which 92% was for M&I uses and 8% was for agricultural uses (San Diego County Water Authority, 2015). Agricultural demands have decreased significantly since 2007, when MWD implemented mandatory restrictions on water it sold under agricultural rates. Agricultural products produced in the San Diego region include avocados, citrus, cut flowers, and nursery products, along with crops and livestock for local markets. In fiscal year 2005, agricultural demands made up 13% of water use, while in 2015, only 8% of the total water demand was for agricultural use (San Diego County Water Authority, 2015). In the future, M&I demands are expected to increase while agricultural demands are expected to continue to decrease, leading to an even greater dominance of M&I demands in the region.

2.4. Study Area Water Resources Infrastructure and Operations

The Basin Study examines water resources infrastructure and facilities operations within the Study Area that contribute to the storage, treatment, and distribution of local supplies (surface water, groundwater, recycled water, and desalinated water) and imported MWD purchases and QSA transfer water (Figure 3 and Figure 4). These infrastructure components are described briefly below, and their implementation in the CWASim model for analysis is described in Chapter 3.

2.4.1. Reservoirs

The San Diego region features 25 major reservoirs as shown in Figure 3 below.

2.4.2. Pipelines

Water purchased from MWD or transferred via the QSA is imported into the San Diego region through MWD facilities. SDCWA takes delivery of treated and untreated imported water from MWD six miles south of the Riverside-San Diego County line at a point known as the “MWD Delivery Point.” Water then flows southward to the SDCWA service area through five large diameter pipelines owned and operated by SDCWA that make up the First Aqueduct and Second Aqueduct.

The First Aqueduct alignment includes Pipelines 1 and 2 and extends from the MWD Delivery Point to San Vicente Reservoir. The two pipelines are operated as a single unit. North of the Crossover Pipeline, Pipelines 1 and 2 deliver treated water from MWD. South of the Crossover Pipeline, Pipelines 1 and 2 are filled with untreated water.

Pipelines 3, 4, and 5 make up the Second Aqueduct alignment. The pipelines are divided into a number of reaches. Depending on the pipeline and reach, these pipelines convey treated or untreated water and are operated independently or as a unit. Pipeline 3 conveys treated or untreated water between the MWD Delivery Point and Lower Otay Reservoir. Pipeline 4 conveys treated or untreated water from the MWD Delivery Point to the southern portion of San Diego County. Pipeline 5 conveys untreated water from the MWD Delivery Point to water treatment plants in the southern portion of San Diego County.

Lateral pipelines that run generally eastward or westward distribute water throughout the San Diego region to treatment plants, reservoirs, or delivery points for member agencies. There are also a variety of smaller conveyance facilities in the water distribution system used for retail purposes which transport water to its point of use. For example, the City of San Diego oversees approximately 3,300 miles of distribution pipeline delivering water to approximately 276,000 service connections (City of San Diego, 2015).

2.4.3. Pump Stations

Most of the treated and untreated water delivered by SDCWA in San Diego County relies on gravity to flow through the water distribution system. However, all SDCWA member agencies operate pump stations to provide flexibility in the distribution system and help the agencies meet daily, seasonal, and emergency needs.

2.4.4. Seawater Desalination Plants

San Diego County currently has one operational seawater desalination plant and two others are being considered at this time. See section 2.2.4 for more information.

2.4.5. Water Treatment Plants

Raw imported supplies and locally sourced water must be treated prior to potable use. Water treatment facilities within the Study area (Figure 4) are operated by SDCWA and/or its member agencies to treat water for human consumption.

2.4.6. Recycled Water Facilities

Thirteen water reclamation plants in San Diego County treat water to an acceptable standard suitable for a range of reuse purposes as described in the following subsections. The City of San Diego has also initiated the design of an advanced water treatment facility called ‘Pure Water San Diego.’ This project has not yet been built and is not included in the baseline analysis of Task 2.3. Task 2.4 of the SDBS will explore this project in detail.

2.4.6.1. North City Water Reclamation Plant

The North City Water Reclamation Plant can treat up to 92 acre-feet of wastewater per day. The reclaimed water is distributed through 79 miles of pipelines for irrigation, landscaping, and industrial use. The Plant also delivers reclaimed water to the City of Poway and Olivenhain Municipal Water District.

2.4.6.2. South Bay Water Reclamation Plant

The South Bay Water Reclamation Plant can treat up to 46 acre-feet of wastewater per day for the Otay Water District. In 2013, this Plant received and treated 8,900 acre-feet of wastewater while reclaiming 74% or 6,445 acre-feet.

2.4.6.3. San Luis Rey Wastewater Treatment Plant

The San Luis Rey Wastewater Treatment Plant uses reclaimed water to irrigate the Oceanside Municipal Golf Course with water treated to potable reuse standards. The Plant produces up to 2.1 acre-feet per day of tertiary recycled water.

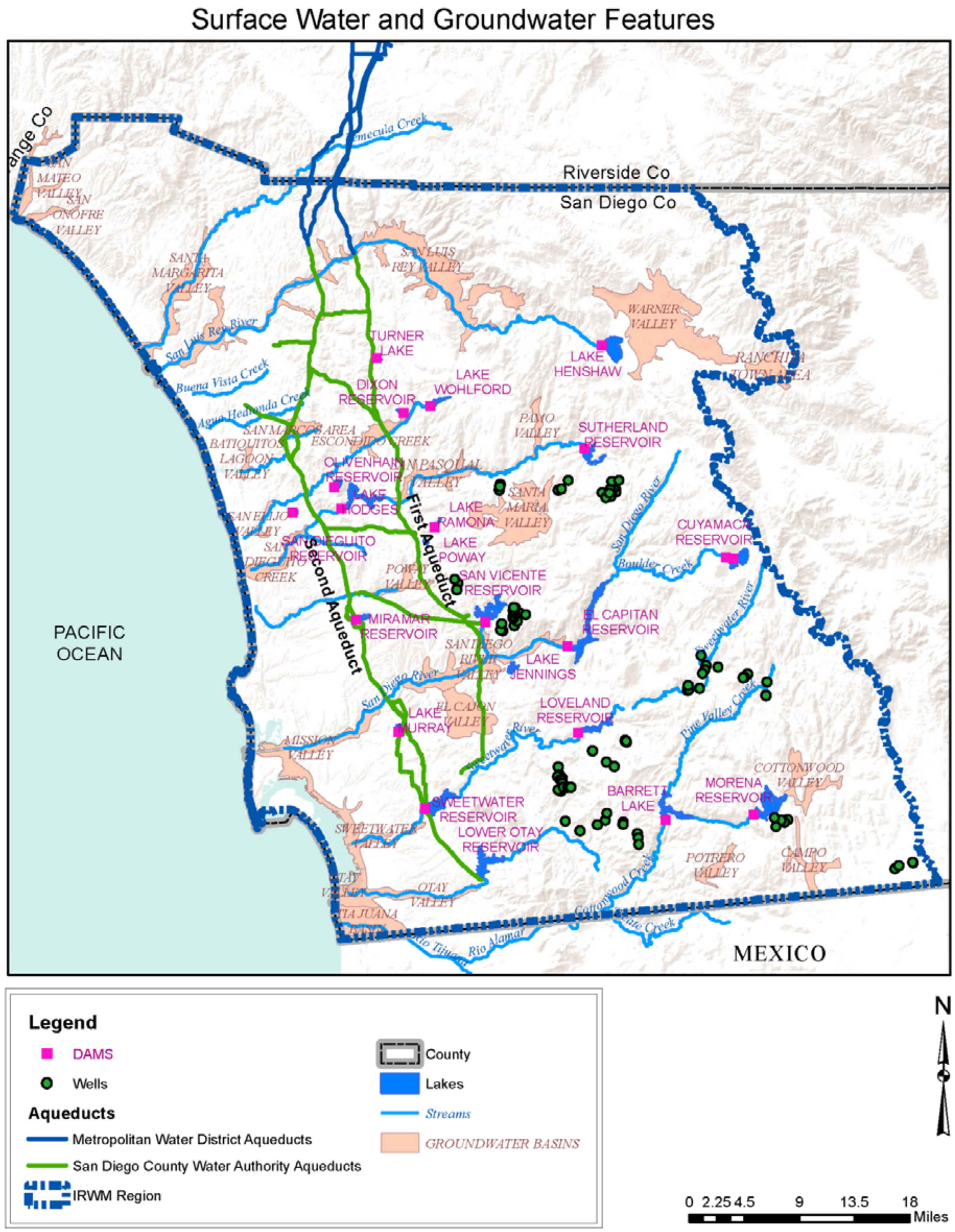


Figure 3. Surface and groundwater features in the San Diego Basin Study Area

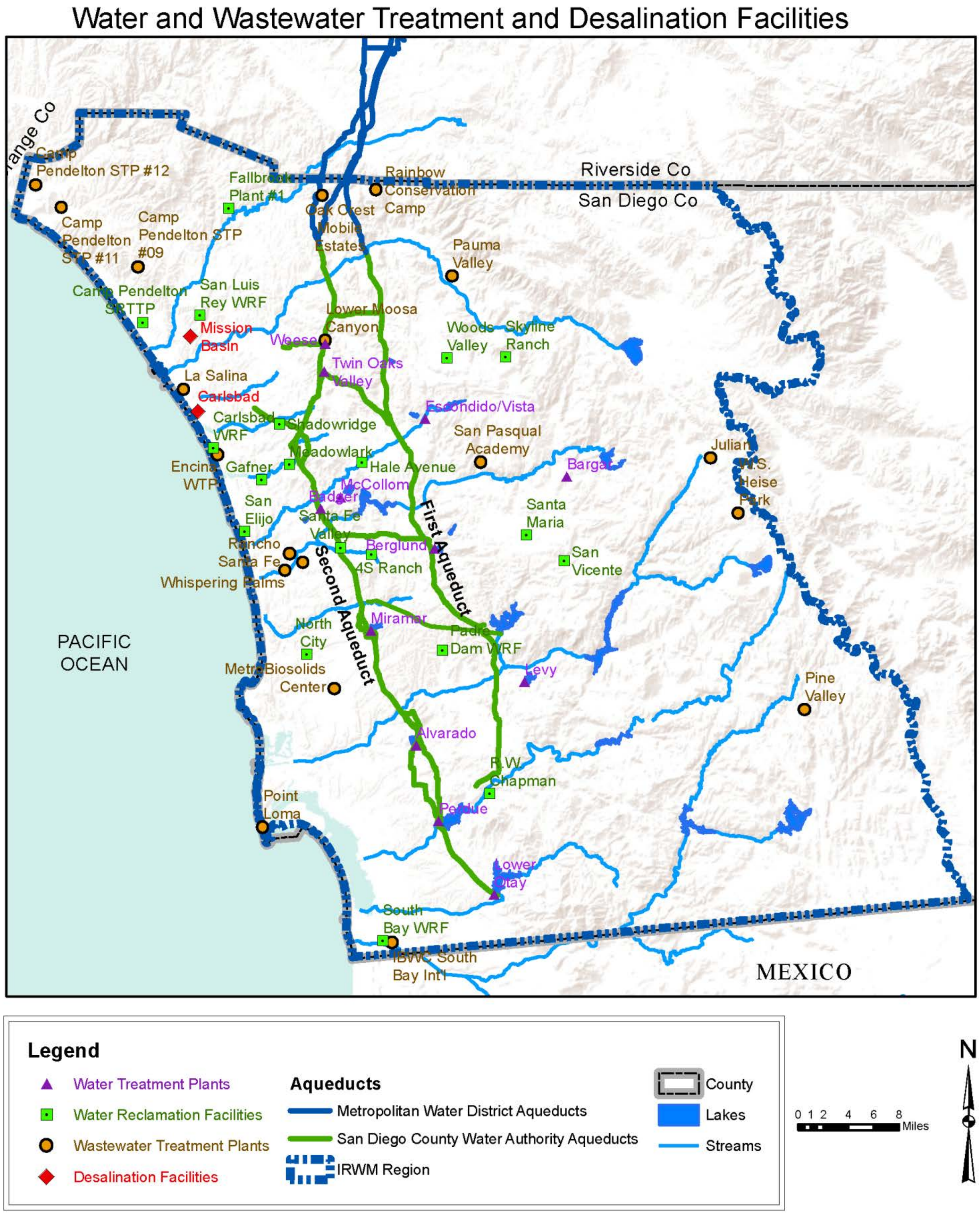


Figure 4. Water and wastewater treatment and desalination features in the Study Area

3. CWASim Model

Task 2.3 of the Basin Study used the CWASim model to simulate operations of the water supply system in the study area. CWASim is a GoldSim model originally developed for SDCWA by CH2M in support of the 2013 Regional Facilities Optimization and Master Plan Update (2013 Master Plan). GoldSim is a general purpose simulation software for dynamically modeling complex systems in business, engineering, and science. The original version of CWASim and a companion short-term operations model were extensively reviewed by SDCWA and were validated by comparison to historical measured monthly and annual flows at major delivery points and select internal system flows. For Task 2.3 of the Basin Study, the CWASim model was updated to run the 2015 SDCWA UWMP supply and demand scenarios, and water supply infrastructure. It was also updated to allow simulation of climate change scenarios developed specifically for the Basin Study and to improve modeling of imported water supplies. This version of the model is referred to as the 'Baseline SDBS CWASim Model.'

CWASim runs on a daily timestep and represents the system with elements and connectors representing reservoirs, water treatment plants, pipelines, delivery points, and other water supply infrastructure components. It includes representation of local and imported supply sources, member agency demands, SDCWA facilities, and member agency facilities that are connected to the SDCWA system. It does not include representation of member agency facilities that are not connected to the SDCWA system. Operational logic describes how water is distributed throughout the system at each simulation timestep. Input data provides the water supply and demand volumes that drive the operations of the system.

3.1. CWASim Model Layout and Schematic

CWASim elements, connectors, and functions are grouped into containers. The water supply system is described by four containers (North, Central, Crossover, and South) that group system elements based on their physical location and a Network container with elements that further describe model water distribution operations. CWASim also has a container for dashboards used to interact with the model, a mass balance check container, a model input container, a requests container that contains water demands and performs allocations, and a results container.

Because of the complexity of the model, CWASim also contains a simplified model schematic (Figure 5, Table 4 and Table 5) that allows users to interact with and navigate the model based on the physical layout of the system rather than through the more abstract representation of the containers. The schematic does not contain any model logic or elements that perform model simulations. Instead, it is an image with manually created links to model elements. The schematic shows demand nodes, reservoirs, treated and untreated water pipelines, pipeline connections, desalination plants, water treatment plants, and pump stations. The schematic is updated and maintained separately from the model simulation elements.

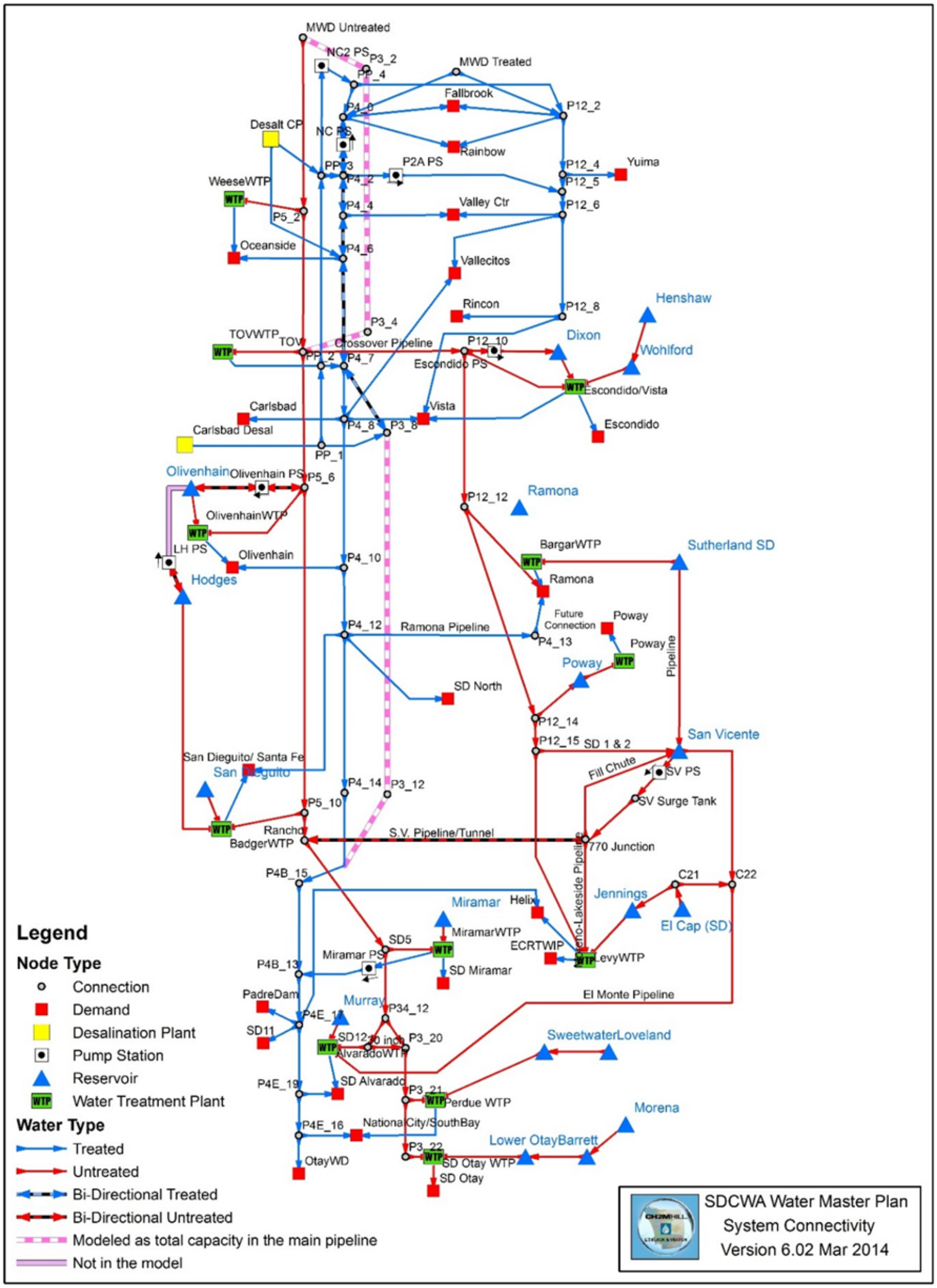


Figure 5. CWASim system schematic

Table 4. Schematic Legend

Schematic Element	Schematic Image	Schematic Element	Schematic Image
Connection		Reservoir	
Demand		Treated Water	
Desalination Plant		Untreated Water	
Water Treatment Plant	WTP	Bi-Directional Treated Water	
Pump Station		Bi-Directional Untreated Water	

Table 5. Abbreviations Used in the CWASim Schematic

Model Abbreviation	Description	Model Abbreviation	Description
WTP	Water Treatment Plant	El Cap	El Capitan Reservoir
SD	San Diego	CP	Camp Pendleton
SV	San Vicente	WD	Water District
PS	Pump Station	LH	Lake Hodges
NC	North County	TOV	Twin Oaks Valley
WA	Water Authority	AP	Annual Production
MWD	Metropolitan Water District		

3.2. Model Representation of System Infrastructure and Operations

The Baseline San Diego Basin Study CWASim model represents the system as it existed in 2015, with the addition of all "verifiable" projects from the 2015 SDCWA UWMP.

3.2.1. Reservoirs

Of the 25 reservoirs in the San Diego region, CWASim models the 18 reservoirs that are connected to the SDCWA system (Table 6). The remaining seven reservoirs shown in Table 6 are excluded from CWASim because of their small volume or because they are not connected to the SDCWA system and only serve local demands. The reservoirs included in the model store local surface water runoff, imported MWD water, water transferred from another reservoir, or a combination of water from multiple sources.

Table 6. San Diego Region Reservoirs

Reservoir	Owner	Water Source(s)	In CWASim Model?	Receives inflow in CWASim?	Modeled Capacity (Total) AF
Lake Wohlford	City of Escondido	surface water transfers local runoff	Yes	Yes	6,940
El Capitan Reservoir	City of San Diego	local runoff	Yes	Yes	112,807
Hodges Reservoir	City of San Diego	imported untreated water local runoff	Yes	Yes	33,600
Lower Otay Reservoir	City of San Diego	imported water surface water transfers local runoff	Yes	Yes	49,849
Morena Reservoir	City of San Diego	local runoff	Yes	Yes	50,200
Sutherland Reservoir	City of San Diego	local runoff	Yes	Yes	31,960
San Vicente Reservoir	City of San Diego	imported untreated water local runoff	Yes	Yes	272,528
Olivenhain Reservoir	SDCWA	local runoff imported water	Yes	No	25,382
San Dieguito Reservoir	San Dieguito Water District/ Santa Fe Irrigation District	imported water surface water transfers local runoff	Yes	No	883
Loveland Reservoir	Sweetwater Authority	local runoff	Yes	Yes	25,400
Sweetwater Reservoir	Sweetwater Authority	local runoff imported untreated water	Yes	Yes	27,700
Dixon Reservoir	City of Escondido	imported untreated water local runoff	Yes	No	2,610
Lake Jennings	Helix Water District	imported untreated water	Yes	No	9,790
Lake Poway	City of Poway	imported untreated water	Yes	No	3,320
Lake Ramona	Ramona Municipal Water District	imported untreated water	No	No	N/A

Reservoir	Owner	Water Source(s)	In CWASim Model?	Receives inflow in CWASim?	Modeled Capacity (Total) AF
Barrett Reservoir	City of San Diego	surface water transfers local runoff	Yes	Yes	37,900
Miramar Reservoir	City of San Diego	imported untreated water	Yes	No	6,050
Murray Reservoir	City of San Diego	imported water local runoff	Yes	No	5,200
Lake Henshaw	Vista Irrigation District	local runoff groundwater	Yes	No	53,400
Maerkle Reservoir	Carlsbad Municipal Water District	treated	No	N/A	N/A
Red Mountain Reservoir	Fallbrook Public Utility District	treated	No	N/A	N/A
Beck Reservoir	Rainbow Municipal Water District	treated	No	N/A	N/A
Morro Hill Reservoir	Rainbow Municipal Water District	treated	No	N/A	N/A
Lake Cuyamaca	Helix Water District	natural runoff	No	N/A	N/A
Turner	Valley Center Municipal Water District	imported water	No	N/A	N/A

Each reservoir in CWASim is modeled as an element containing a number of functions that simulate water inflow, storage, and outflow. Maximum and minimum storage values and maximum releases are assigned to each reservoir, as well as evaporation losses and flood releases/spills.

Reservoirs in CWASim are controlled by rule curves. The rule curves divide the reservoir storage into nine reservoir zones or "pools". The zones range from the *Dead Pool Zone* corresponding to the lowest possible water storage, to *Zone 1* corresponding to the reservoir flood zone. Water stored in flood and seasonal pools is available to meet demands at any time during a simulation. Water stored in carryover pools, however, is only available under certain conditions. The operational details for each reservoir can be found in the CWA Model Documentation. An example of a reservoir rule curve is shown in Figure 6.

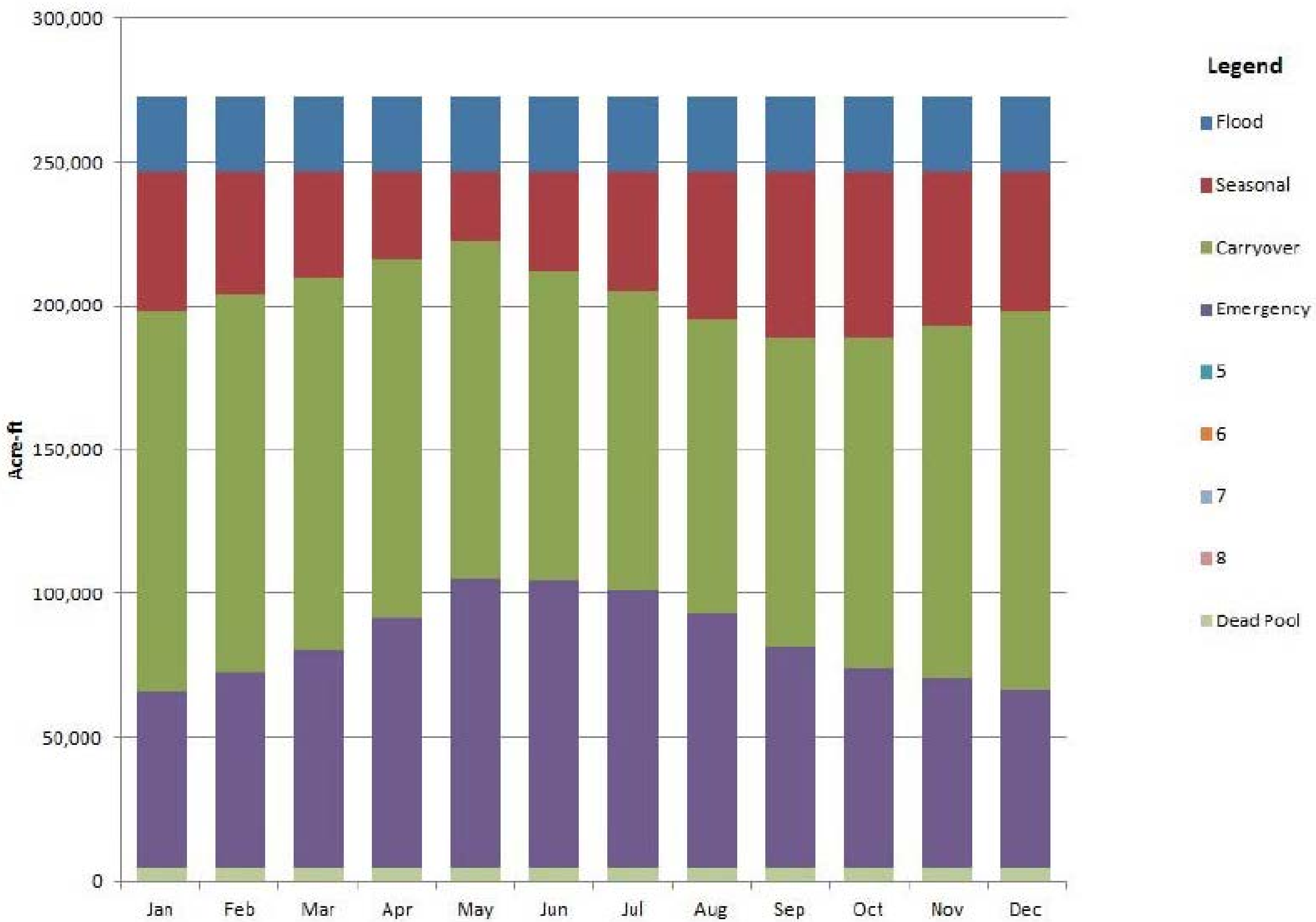


Figure 6. SDCWA reservoir operating zones example

3.2.2. Pipelines

Pipelines (Table 7) are represented in CWASim by both elements and links connecting elements. Elements describe pipeline characteristics and operational logic, and links allow water to be transferred between elements by the model logic. Multiple elements and links may represent different reaches of the same pipeline.

Pipelines 3, 4, and 5 make up the Second Aqueduct alignment. The pipelines are divided into a number of reaches. Depending on the pipeline and reach, these pipelines convey treated or untreated water and are operated independently or as a unit. Pipeline 3 conveys treated or untreated water between the MWD Delivery Point and Lower Otay Reservoir. Pipeline 4 conveys treated or untreated water from the MWD Delivery Point to the southern portion of San Diego County. Pipeline 5 conveys untreated water from the MWD Delivery Point to water treatment plants in the southern portion of San Diego County stopping at Miramar.

Table 7. San Diego Region Pipelines

Pipeline Name	Owner	Water Type	Conveys water from	Conveys water to	In CWASim Model?
Pipeline 1 and 2 (First Aqueduct)	SDCWA	Treated (North of Crossover Pipeline) and Untreated (South of Crossover Pipeline)	MWD Delivery Point	San Vicente Reservoir	Yes
Pipeline 3 (Second Aqueduct)	SDCWA	Treated or Untreated	MWD Delivery Point	Lower Otay Reservoir	Yes
Pipeline 4 (Second Aqueduct)	SDCWA	Treated or Untreated	MWD Delivery Point	Southern San Diego County	Yes
Pipeline 5 (Second Aqueduct)	SDCWA	Untreated	MWD Delivery Point	Southern San Diego County stopping at Miramar	Yes
Crossover Pipeline	SDCWA	Untreated	Second Aqueduct near Twin Oaks Valley Water Treatment Plant	First Aqueduct near Escondido-Vista Pipeline Pump Station	Yes
North County Distribution Pipeline	SDCWA	Treated	Second Aqueduct (Pipeline 4) near the Weese Filtration Plant	Oceanside, Vista Vallecitos, and Rainbow member agencies	Yes, in aggregate fashion by delivery of water from Second Aqueduct

Pipeline Name	Owner	Water Type	Conveys water from	Conveys water to	In CWASim Model?
Tri-Agency Pipeline	SDCWA	Treated	Second Aqueduct	Vista, Carlsbad, and Oceanside member agencies	Yes, in aggregate fashion by delivery of water from Second Aqueduct
Ramona Pipeline	SDCWA	Treated	Second Aqueduct	Ramona, Olivenhain, and the City of San Diego member agencies	Yes
San Vicente Pipeline/Tunnel*	SDCWA	Untreated	Second Aqueduct (Pipeline 5)	San Vicente, El Capitan, and Jennings Reservoirs and the Levy WTP	Yes
			San Vicente Reservoir	Second Aqueduct (Pipeline 5)	Yes
Valley Center Pipeline	SDCWA	Treated	Second Aqueduct (Pipeline 4)	First Aqueduct (Pipelines 1 & 2)	Yes
Olivenhain-Hodges Pipeline*	SDCWA	Untreated	Lake Hodges	Olivenhain Reservoir	Yes
			Olivenhain Reservoir	Lake Hodges	Yes
El Monte Pipeline	City of San Diego	Untreated	San Vicente and El Capitan Reservoirs	Murray Reservoir or Alvarado WTP	Yes
La Mesa-Sweetwater Extension	SDCWA	Untreated	First Aqueduct	Sweetwater Reservoir	No
		Treated	Levy WTP	Otay Water District and Sweetwater Authority Member Agencies	Yes, through ECRTWIP[1]

Pipeline Name	Owner	Water Type	Conveys water from	Conveys water to	In CWASim Model?
Moreno-Lakeside Pipeline	SDCWA	Untreated		Levy WTP	Yes
Sutherland-San Vicente Conduit	SDCWA	Untreated	Sutherland Reservoir	San Vicente Reservoir	Yes

*=Pipeline can flow both directions
[1] East County Regional Treated Water Improvement Program

3.2.3. Pump Stations

CWASim includes seven elements representing the pump stations in the 2013 Master Plan plus one additional pump station (N2C PS) should it be implemented in the future (Table 8). The model pump station elements include maximum flow capacities and distribute flows among the member agencies.

Table 8. Major Pump Stations in the San Diego Region

Pump Station	Owner	Water Type	Use	Capacity (cfs)	In CWASim Baseline Model Runs?
Escondido	SDCWA	Untreated	MWD untreated water enters the station from the Crossover Pipeline and P12_10 and is pumped to Dixon Reservoir.	20	Yes
Miramar	SDCWA	Treated	MWD treated water enters the station from the Miramar WTP and is pumped to San Diego 11.	85	Yes
Valley Center (P2A)	SDCWA	Treated	Used to deliver Twin Oaks Valley WTP treated water to north county agencies.	60	Yes
North County Pump Station	City of San Diego	Treated	Used for reverse P4 pipe option and limited by the Fallbrook demand.	N/A	No. Only used for reverse P4 operation, which is not included in Baseline conditions.
North County Pump Station 2	N/A	Treated	Does not currently exist.	N/A	No

Pump Station	Owner	Water Type	Use	Capacity (cfs)	In CWASim Baseline Model Runs?
San Vicente	SDCWA	Untreated	MWD untreated water is pumped from San Vicente Reservoir through a surge tank toward Junction 770.	150	Yes
Olivenhain	SDCWA	Untreated	Can receive and/or deliver MWD untreated water between Olivenhain Reservoir and Pipe 5. When water is transferred downhill from Olivenhain Reservoir into Hodges Reservoir, the process generates up to 40-megawatts of hydroelectricity, helping to offset some of the project operating costs.	N/A	No
Lake Hodges Pump Station	SDCWA	Untreated	Pumps MWD untreated water between Lake Hodges Reservoir and Olivenhain Reservoir.	N/A	No
Twin Oaks Valley	SDCWA	Untreated	Used only as part of the Emergency Storage Project	N/A	No

3.2.4. Seawater Desalination Plants

For the Baseline analysis, the CWASim model simulates supply from seawater desalination at the Carlsbad Desalination Plant. The user may specify the capacity of the plant if desired. Once the capacity of the plant is selected, it is held constant through the model run. The model default for the desalination capacity of the Carlsbad Desalination Plant is 153 AF/d (50 mgd).

Table 9. Carlsbad Desalination Plant Information

Desalination Plant	Capacity (AF/d)	Recipients of Water	In CWASim Baseline Model Runs?
Carlsbad Desalination Plant	153	Oceanside, Carlsbad, Vallecitos West, Valley Center West, Ramona, San Diego Otay, San Diego North, San Dieguito/Santa Fe, Del Mar, Fallbrook Public Utilities District, Rainbow, Rincon and Yuima	Yes

3.2.5. Water Treatment Plants

Ten water treatment plants are modeled as elements within the CWASim model (Table 10). Treatment plant capacity determines how much water can be supplied through the treatment plant. The capacity value for each plant is held constant throughout a run. Water treatment plant usage is determined by the demands of the agencies that have access to the treatment plant and the priority of sources that may supply water to that member agency. Most water treatment plants have only one or two member agency recipients and the capacity of the treatment plants is large enough to meet the demands for both agencies. However, Twin Oaks Valley Water Treatment Plant is owned by SDCWA and can supply water to many member agencies. Therefore, member agencies are assigned priorities to Twin Oaks Valley treated water that determine the order for deliveries.

Table 10. San Diego Region Water Treatment Plants

Water Treatment Plant	Owner	Baseline Capacity (AF/d)	Location(s) of Source Water	Member Agency Recipients
Alvarado	City of San Diego	614	Second Aqueduct, Lake Murray, San Vicente and El Capitan Reservoirs via the El Monte Pipeline	San Diego (Alvarado area)
Badger	Santa Fe Irrigation District and San Dieguito Water District	123	MWD, Lake Hodges, San Dieguito/Santa Fe reservoir	San Dieguito/Santa Fe
Escondido-Vista	City of Escondido	199	MWD via Crossover Pipeline, Lake Henshaw, Lake Wohlford, and Dixon Reservoir	Escondido, Vista
Levy	Helix Water District	325	Lake Jennings, El Capitan, and San Vicente Reservoir via the Moreno-Lakeside Pipeline	Helix, ECRTWIP[1]
Miramar	City of San Diego	660	Second Aqueduct, Miramar Reservoir, or from San Vicente	San Diego (Miramar area)
Otay	City of San Diego	123	Lower Otay Reservoir, Second Aqueduct	San Diego (Otay area), Cal-Am
Olivenhain	Olivenhain	104	Olivenhain Reservoir, Pipeline 5	Olivenhain and City of SD, Santa Fe, Ramona, Del Mar, and San

Water Treatment Plant	Owner	Baseline Capacity (AF/d)	Location(s) of Source Water	Member Agency Recipients
				Dieguito through exchange with Olivenhain
Perdue	Sweetwater Authority	92	Sweetwater Reservoir, Loveland Reservoir, Second Aqueduct	National City/South Bay
Twin Oaks Valley	SDCWA	307	Untreated MWD water from P5 or P4	Vallecitos, Vista, Carlsbad, Oceanside, Valley Center, San Dieguito, Santa Fe, San Diego North, Del Mar, Ramona, Otay, Rincon, Rainbow, Fallbrook, Yuima, Helix, Padre Dam, San Diego, Sweetwater, and Olivenhain. During reverse operation (not implemented in Baseline), supplies Fallbrook, Oceanside, Rainbow, and Rincon member agencies
Weese	City of Oceanside	77	Second Aqueduct	Oceanside

[1]East County Regional Treated Water Improvement Program

3.2.6. Recycled Water Facilities and Potable Reuse Facilities

The Baseline version of CWASim addresses recycled and potable reuse water by aggregating the two water types and modeling them as demand reductions. Once combined, they are referenced as ‘Recycled Water Supplies’ in the ‘Input_Demand’ spreadsheet. Task 2.4 of the SDBS will consider recycled water and potable reuse water as separate sources. The separation of the two water sources will provide an improved picture of how they impact lake level fluctuations and could be used in the development of future reservoir management plans.

3.3. Other Model Features

3.3.1. Model Water Losses

Water losses from a water supply system may include seepage, evaporation, spills, distribution losses, and other general losses. While these losses are unavailable for water supply, they may provide groundwater recharge or support environmental systems. Water loss is included in CWASim as reservoir evaporation, reservoir spill, and general losses.

3.3.1.1. Evaporation Losses

Evaporation loss functions are included in CWASim at Hodges Reservoir where they are shared among water users as follows:

Table 11. Allocation of Water Loss

Evaporation Losses in Hodges Reservoir	
City of San Diego	16.7% of total evaporation
SDCWA	66.6% of total evaporation
Santa Fe/San Dieguito	16.7% of total evaporation

3.3.1.2. Reservoir Spill Losses

Reservoir spill losses occur when the reservoir is filled beyond its storage capacity. Spilled water from reservoirs may be recaptured and used as supply, with the model logic varying between reservoirs.

3.3.1.3. General Losses

General water losses are included in CWASim in the following locations:

- Downstream of Lake Henshaw including an estimated 670 AF/y of losses in the Escondido Canal. These losses are modeled as 6% of the Escondido Canal releases.
- The San Luis Rey River (modeled as approximately 23% of the releases) includes 2,600 AF/y of water losses.
- Water that supplies the downstream tribes (San Luis Rey River Tribes) is modeled as a 6 cfs loss except for the summer months (July, August, and September) when that amount drops to 3 cfs.
- A 7% loss is included between Sutherland Reservoir and San Vicente Reservoir and is applied whenever there is flow between the two reservoirs.

3.3.2. Power Generation/Use

CWASim calculates power generation by SDCWA hydropower facilities, power consumption for SDCWA pumping facilities, and power consumption by SDCWA's Twin Oaks Valley WTP. Power generation and consumption are represented in two ways in the model depending on the location:

1. Calculated on a daily basis from power (P) vs flow (Q) relationships developed by a consultant for SDCWA and incorporated into CWASim. The model calculates the energy generation or consumption based on the flow rate at a given time.
2. Input in the model as an annual energy consumption or generation value and converted to a daily value for each element.

3.4. Model Representation of Water Supply

The CWASim model simulates the delivery of water to meet member agency demands. As described in section 2.2 (Study Area Water Supplies) water supplies in the San Diego region consist of local surface water runoff, local groundwater, local recycled water, desalinated water, imported QSA water, and imported water purchased from MWD. However, only local surface water, desalinated water, imported QSA water, and imported water purchased from MWD are dynamically simulated in the model on a daily basis. Local groundwater and local recycled water are modeled as static annual demand reductions.

3.4.1. Supply Sources Represented as Annual Demand Reductions

Local groundwater (brackish recovery and municipal pumping) and recycled water are represented as static annual demand reductions as described in Section 3.6.2.2 (Net Demands). Groundwater and recycled water supply projections are input as demand reductions for use in the model rather than supplies. See Section 3.6.3 (Demand Inputs and Settings) for more information.

3.4.2. Dynamically Modeled Supply Sources

Local surface water runoff, desalinated water, imported QSA water, and imported water purchased from MWD are dynamically simulated within the model on a daily basis.

3.4.2.1. Local Surface Water

3.4.2.1.1. Unadjusted Surface Water Supplies (No Climate Change)

Surface water supplies from precipitation runoff and stream baseflow are input as historical monthly reservoir inflow timeseries for 10 reservoirs from a spreadsheet called “Input.xlsx”.

3.4.2.1.2. Climate Change Adjusted Surface Water Supplies

The monthly inflow timeseries values are adjusted in the model by monthly climate change factors for each of the 10 reservoirs. The climate change factors are input from a spreadsheet called “Streamflow Adjustment Factors.xlsx”, which lists multiplicative factors for each month for each of the 10 reservoirs with surface water inflows. A multiplicative factor value of 1 indicates no change from historical, while a value between 0 and 1 indicates a decrease in future inflow and a value greater than one indicates an increase in future inflow compared to historical. The change factors are manually input into a table in the CWASim model that is referenced during the model run. Each column of the table represents one of the 11 climate change scenarios (no climate change, five 2020s scenarios, and five 2050s scenarios). The climate change scenario is selected on the main dashboard of the model as part of model run scenario setup. Adjusted reservoir inflows are calculated during the model run by applying the change factors to the historical inflow timeseries values.

3.4.2.2. Seawater Desalination

The CWASim model includes the Carlsbad Desalination Plant (described in Section 2.2.4). The capacity of the Carlsbad Desalination Plant is set by the user and limits the maximum amount of water that can be supplied from the plant. Requests from demand nodes determine the daily deliveries.

3.4.2.3. MWD Purchases

MWD purchases are determined based on supply priorities and requests for treated and untreated water. The volume of imported water available for purchase from MWD is determined in the CWASim model by the logic for MWD supply allocation.

The CWASim model has three allocation options: No allocation, deterministic allocation, and dynamic allocation. The dynamic allocation methodology was implemented in the SDBS Baseline model runs. This methodology was added to the CWASim model as part of the San Diego Basin Study in order to better reflect actual operations, including the ability of MWD to store and release water that it receives from the SWP and CRB. This approach improves the estimation of MWD allocation timing by incorporating the quantitative estimates of supplies from the SWP and CRB and simulating MWD storage dynamics to characterize the delayed onset of allocation during drought periods.

The dynamic allocation methodology consists of a group of GoldSim elements that simulate inflows and outflows from MWD's storage. Rather than modeling all the individual components of the MWD system, the CWASim model simplifies the system as a single storage reservoir element that represents cumulative MWD system storage. The storage reservoir element can store a total of 2.7 MAF, equivalent to the sum of MWD's total usable in-region, Colorado River, and Central Valley and State Water Project storage.

Inflows into the storage element are the sum of supplies from the State Water Project and Colorado River, provided as monthly time series. The reservoir element calculates monthly and annual MWD storage. Outflows from the element are the releases made to meet MWD member agency annual demands (adjusted for allocation when applicable) and evaporation from surface storage reservoirs. For the SDBS, MWD cumulative member agency demands were obtained from MWD's 2015 Integrated Water Resources Plan (IRP) (Metropolitan Water District of Southern California, 2016). The demands include water for consumptive use, seawater barriers, and groundwater replenishment. The MWD IRP demands were available to 2040, so for the SDBS, the demands were linearly extrapolated to 2050 based on the demands for 2035 and 2040. Evaporation is calculated by multiplying a monthly evaporation in inches by the surface area of storage. For the SDBS modeling, the monthly evaporation in inches for MWD's storage was assumed to be the same as the evaporation from San Vicente Reservoir. Surface area of storage was estimated by adapting the area-capacity curve for San Luis Reservoir to match Diamond Valley Reservoir's capacity, and then the curve was extended upwards to 3 MAF.

Through the dynamic allocation logic, the CWASim model uses an adjustable minimum target storage level to trigger the need for allocation. For the Baseline SDBS model, it was assumed that the minimum target was 1.0 MAF, as stated in MWD's IRP (2015). Therefore, in any year in which projected end of year storage levels fall below 1.0 MAF, the model implements MWD allocation such that a storage will not fall below this level. This methodology is consistent with the assumptions described in MWD's 2015 IRP.

When MWD shortage allocation is in place, the maximum amount of water that can be purchased from MWD by SDCWA to meet demands is set to a percentage of the annual total MWD storage. For the SDBS, the percentage was assumed to be 18.7% based on projected annual preferential rights as described in Section 135 of MWD's enabling legislation (California

State Legislature, 2008) and used in the 2015 SDCWA UWMP. The total volume available to SDCWA from MWD is calculated as the allocation percentage (18.7%) multiplied by the annual MWD storage above the storage target threshold of 1.0 MAF.

The inputs required for MWD purchases depend on the choice of MWD allocation method. For the Baseline San Diego Basin Study model, the dynamic allocation method was selected. For the dynamic allocation method, the CWASim model requires monthly and annual timeseries of inflows to MWD from the State Water Project and the Colorado River Basin under each climate scenario.

3.4.2.4. QSA Water

QSA water is represented in the model by an annual timeseries of water supply volumes for each year in the model run. The annual QSA volume is added to the annual MWD purchase for SDCWA and then both are disaggregated to daily volumes and then delivered to meet demands according to the model priorities and logic.

Supplies from IID transfers and canal lining are input as annual timeseries of deliveries via the model dashboard. These values are added to the water available to purchase from MWD and the total is disaggregated to daily values to determine the volume available to meet demands from those two sources.

3.5. Model Representation of Conservation

Water conservation volumes are treated as demand reductions in CWASim. See Section 3.6.2.2.

3.6. Model Representation of Water Demand

3.6.1. Demand Nodes

The model simulates water deliveries to all 24 SDCWA member agencies except Camp Pendleton, plus the Cal-American Water Company (Cal-Am), which is not a SDCWA member agency but receives local surface water from the City of San Diego through a water rights settlement (Table 12). Demands for the member agencies are represented as single or multiple demand node containers depending on how the agency receives water (e.g., water source, treated vs untreated).

The North container of the model contains demand nodes for City of Carlsbad, City of Oceanside, Fallbrook, Rainbow, Rincon, Vallecitos Water District, Valley Center Municipal Water District, Vista Irrigation District, and Yuima Irrigation District.

The Central container of the model contains demand nodes for Olivenhain Municipal Water District, City of Del Mar, San Dieguito Water District, and Santa Fe Irrigation District.

The Crossover container of the model contains demand nodes for the City of Escondido, Poway, and Ramona.

The South section of the model contains demand nodes for Helix, Padre Dam, Otay Water District, Lakeside, and Sweetwater Authority. Helix is represented with a single demand node. Demands for Padre Dam and Otay Water District are represented as two demand nodes each: one that receives water from the main system and one that receives water through the East County Regional Treated Water Improvement Program (ECRTWIP). Lakeside is represented by a single demand node that receives water through the ECRTWIP. Sweetwater Authority, consisting of the City of National City and South Bay Irrigation District, is represented as a single demand node.

The City of San Diego's demands are divided into five nodes due to the differences in how various parts of the city receive water. San Diego North is located in the Crossover section of the model and San Diego Miramar, San Diego 11, San Diego Alvarado, and San Diego Otay are located in the South section of the model.

Camp Pendleton Marine Corps Base is not represented as a demand in the model because its demands are met almost exclusively by locally produced supplies (San Diego County Water Authority, 2016).

Table 12. CWASim Representation of SDCWA Member Agencies

Agency	CWASim Model Representation
City of Carlsbad	Carlsbad
City of Del Mar	Del Mar
City of Escondido	Escondido
City of National City[1]	National City/South Bay
City of Oceanside	Oceanside
City of Poway	Poway
City of San Diego	SD 11
	SD Alvarado
	SD Miramar
	SD North
	SD Otay
Fallbrook Public Utility District	Fallbrook
Helix Water District	Helix
Lakeside Water District	Part of ECRTWIP[2]
Olivenhain Municipal Water District	Olivenhain
Otay Water District	Split between OtayWD and ECRTWIP[2] (portion of Otay that can receive water from Levy Water Treatment Plant)

Agency	CWASim Model Representation
Padre Dam Municipal Water District	Split between Padre Dam and ECRTWIP[2] (portion of Padre Dam that can receive water from Levy Water Treatment Plant)
Camp Pendleton Marine Corps Base	Not in CWASim
Rainbow Municipal Water District	Rainbow
Ramona Municipal Water District	Ramona
Rincon del Diablo Municipal Water District	Rincon
San Dieguito Water District	As San Dieguito/Santa Fe
Santa Fe Irrigation District	As San Dieguito/Santa Fe
South Bay Irrigation District[1]	As National City/South Bay
Sweetwater Authority[1]	As National City/South Bay
Vallecitos Water District	Vallecitos
Valley Center Municipal Water District	Valley_Ctr
Vista Irrigation District	Vista
Yuima Municipal Water District	Yuima

[1]City of National City and South Bay Irrigation District make up the Sweetwater Authority
[2]East County Regional Treated Water Improvement Program (ECRTWIP) includes Lakeside and the portions of Otay WD and Padre Dam capable of receiving service from Levy Water Treatment Plant

3.6.2. Annual Member Agency Demand Volumes

3.6.2.1. Gross Demands

Gross demands are the total water demands for each member agency. Demands are calculated outside the model and provided as a model input. Demands may be calculated using a variety of methods (e.g., demand models, regression projections), but should represent the total amount of water needed by each member agency to serve its customers. Demand calculations generally include M&I and agricultural demands and any adjustments for climate change.

3.6.2.2. Net Demands

Net demands calculated within the CWASim model from model inputs are the demands remaining after local groundwater supplies, recycled supplies, and conservation volumes are subtracted from gross demands, which are assumed to be used to meet demands prior to use of any other supply options and therefore reduce demands on all other sources. The supply volumes of water available from local groundwater and recycled water, and the annual volumes of water conservation are assumed to be constant annual values that are subtracted from the gross demand volume inputs.

3.6.3. Demand Inputs and Settings

CWASim is able to use demand values that represent projected demands for a time period or scenario of interest to the user. The demands may be stable or variable over the course of a run. Demands can also be adjusted within the CWASim model to account for climate change effects.

3.6.3.1. Unadjusted Demand Inputs (No Climate Change)

The model receives demand inputs for each member agency via a Microsoft Excel spreadsheet called "Input_Demands.xlsx". The spreadsheet must contain a tab labeled DEMANDS, which is read by the CWASim model. The DEMANDS tab contains a single table with sections for demands in each hydrologic year type, along with the local supplies (or demand reductions) from groundwater, recycled water, and conservation. Rows within each of the sections list the values of demands, groundwater and recycled water supply, and conservation for different hydrologic year types for each SDCWA member agency. Table columns tabulate the demands for different years. The Baseline SDBS version of the CWASim model contained columns for demands in 2015, 2020, 2025, 2030, 2035, 2040, 2045, and 2050. The development of the demand values for the SDBS is described in Section 4.4.

The CWASim model has options for selecting demands based on hydrologic year type. It allows the user to select a particular hydrologic year type for the entire run or it allows the model to select the appropriate hydrologic year type based on the water year of input hydrology data. For the SDBS, the selection of year type was linked to the water year. The CWASim model contains a table of water years and their corresponding hydrologic year type for each possible year of input hydrologic data. For every simulation timestep, the model checks the water year, determines the corresponding hydrologic year type, and sets the demands to the corresponding values.

3.6.3.2. Climate Change Demand Adjustment Factors

The CWASim model requires a table of demand adjustment factors corresponding to the climate change scenarios being analyzed in the model. This table is created in an Excel spreadsheet based on the demand adjustment model (see Section 4.4.2.2) and then manually copied to the corresponding GoldSim table element in the CWASim model.

3.7. Model Operational Logic for Water Deliveries and Shortages

At each model timestep, the model evaluates the available supplies and the net water demands and determines water deliveries and shortages. The determination of deliveries is completed in loops based on the priority of supply sources. For the Baseline CWASim model, the model had eight loops: Loop zero for calculating daily demands from the annual demands and Loops 1-7 for calculating water deliveries for each of the supply sources. The supply source loops are completed in the priority order of the supply sources.

As described above, the water supply for the San Diego region is made up of local and imported water from a variety of source types. Of these source types, some are accounted for through the calculation of net demand (local groundwater and recycled water) and some are dynamically modeled. The dynamically modeled supply sources produce either untreated water that must be treated before it can be used to meet demands (surface water, purchases of MWD untreated water, and untreated QSA water), or treated water that can be used directly (desalinated water and purchases of MWD treated water).

3.7.1. Water Source Availability and Priorities

Seven source groupings are implemented in the Baseline SDBS CWASim model (Table 13) and are distributed during model loops 1 through 7 based on their priority order. Some of these source groups originate as untreated water, and others originate as treated water. Source priorities in the model describe the order in which sources are used to meet demands. Depending on the time of year and storage in San Vicente reservoir, the priority order used by the SDBS baseline model changes from Order 1 (March 1 to September 30 and San Vicente more than 70% full) to Order 2 (October 1 to February 28). The priority settings for the SDBS Baseline model reflect the preference for locally treated supplies first, then imported raw water (in order to maximize local WTP use including TOV WTP), then imported treated water. Maintenance of storage in San Vicente in case of dry conditions is another high priority in the model logic.

Table 13. Water Source Groups and Source Priorities

Source	Description	Originates As	Priority Order 1	Priority Order 2
Local	Local surface water treated at local treatment plants. MWD water stored in local reservoirs (excluding San Vicente) is included in this source.	Untreated	1	1
MWD Untreated (Treated at local WTPs)	MWD untreated water treated at local WTPs and then delivered as treated water.	Untreated	3	2
SDCWA Treated (TOVWTP)	MWD Untreated water treated at Twin Oaks Valley WTP then delivered to selected agencies as treated water.	Untreated	5	4
MWD Treated	MWD treated water delivered to SDCWA.	Treated	7	6
Pendleton	Not used in Baseline model runs. Treated ocean water delivered to select agencies from the Camp Pendleton Desalination Plant. Only included in priority order if option to use Camp Pendleton is selected in the model.	Treated	6	5
Carlsbad Desalination Plant	Treated ocean water delivered to select agencies from the Carlsbad Desalination Plant.	Treated	4	3
San Vicente Regional Carryover/ Seasonal	San Vicente seasonal storage pool treated at local WTPs then delivered. Carryover storage pool is used to supplement reduced supply due to drought, or shortages from MWD or State Water Project.	Untreated	2	7

Member agencies have access to some or all the source groups as shown in Table 14. Within a given source group, member agencies can receive water from that source group via one or more infrastructure elements (reservoirs, pipelines, pump stations, and treatment plants). The connections between infrastructure elements and member agency demand nodes are described in the model Network container.

Table 14. Member Agency Access to Source Groups

CWASim Model Representation	Local Surface Water (Treated at local WTPs)	MWD Untreated (Treated at local WTPs)	MWD Treated	SDCWA Treated (Twin Oaks Valley WTP)	Carlsbad Desalin-ation Plant	San Vicente Regional Carryover/ Seasonal
Carlsbad	--	--	Pipeline 4	x	x	--
Del Mar	--	Miramar WTP	Pipeline 4	x	x	--
Escondido	Wohlford & Henshaw Reservoirs treated at Escondido-Vista WTP	First Aqueduct via Crossover Pipeline treated at Escondido-Vista WTP	--	--	--	--
Oceanside	--	Pipeline 5, treated at Weese WTP	Pipeline 4	x	x	
Poway	--	First Aqueduct via Crossover Pipeline, treated at Poway WTP	--	--	--	--
SD11	--	Treated at Miramar WTP	Pipeline 4	x	x	Treated at Miramar WTP
SD_Alvarado	San Vicente and El Capitan Reservoirs through El Monte System treated at Alvarado WTP	Second Aqueduct treated at Alvarado WTP	Pipeline 4	x	x	San Vicente Tunnel and Second Aqueduct treated at Alvarado WTP
SD_Miramar	San Vicente treated at Miramar WTP	Second Aqueduct treated at Miramar WTP	--	--	--	San Vicente Tunnel and Second Aqueduct treated at Miramar

CWASim Model Representation	Local Surface Water (Treated at local WTPs)	MWD Untreated (Treated at local WTPs)	MWD Treated	SDCWA Treated (Twin Oaks Valley WTP)	Carlsbad Desalin-ation Plant	San Vicente Regional Carryover/ Seasonal
						WTP
SD_North	--	--	Pipeline 4	x	x	--
SD_Otay	Barrett, Lower Otay via P4 and Morena Reservoirs treated at Otay WTP	Second Aqueduct treated at Otay WTP	--	--	--	San Vicente Tunnel and Second Aqueduct treated at Otay WTP
Fallbrook	--	--	First Aqueduct and Pipeline 4	x	x	--
Helix	El Capitan treated at Levy WTP	First Aqueduct via Crossover Pipeline treated at Levy WTP or Second Aqueduct via San Vicente Pipeline and Morena Lakeside Pipeline, treated at Levy WTP	Pipeline 4	x	--	Moreno-Lakeside Pipeline treated at Levy WTP
ECRTWIP[2]	El Capitan treated at Levy WTP	First Aqueduct via Crossover Pipeline treated at Levy WTP or Second Aqueduct via San Vicente Pipeline and Morena Lakeside Pipeline, treated at Levy WTP	--	--	--	Moreno-Lakeside Pipeline, treated at Levy WTP

CWASim Model Representation	Local Surface Water (Treated at local WTPs)	MWD Untreated (Treated at local WTPs)	MWD Treated	SDCWA Treated (Twin Oaks Valley WTP)	Carlsbad Desalin-ation Plant	San Vicente Regional Carryover/ Seasonal
Olivenhain	--	Pipeline 5 treated at Olivenhain	Pipeline 4	x	x	--
OtayWD	--	--	Pipeline 4	x	x	--
Padre_Dam	--	--	Pipeline 4	x	x	--
Rainbow	--	--	First Aqueduct, Pipeline 4	x	x	--
Ramona	Sutherland Reservoir treated at Bargar WTP	First Aqueduct and Crossover Pipeline treated at Bargar WTP	Ramona Pipeline	x	x	--
Rincon	--	--	First Aqueduct	x	x	--
San Dieguito/Santa Fe	Lake Hodges and San Dieguito Reservoir treated at Badger WTP	Pipeline 5 treated at Badger	--	--	--	--
National City/South Bay	Sweetwater Reservoir and Loveland Reservoir treated at Perdue WTP	Pipeline 5 treated at Perdue WTP	--	--	--	San Vicente Tunnel and Second Aqueduct treated at Sweetwater WTP
Vallecitos	--	--	Pipeline 4	x	x	--
Valley_Ctr	--	--	First Aqueduct and Pipeline 4	x	x	--

CWASim Model Representation	Local Surface Water (Treated at local WTPs)	MWD Untreated (Treated at local WTPs)	MWD Treated	SDCWA Treated (Twin Oaks Valley WTP)	Carlsbad Desalin-ation Plant	San Vicente Regional Carryover/ Seasonal
Vista	Henshaw & Wohlford Reservoirs treated at Escondido-Vista WTP	First Aqueduct via Crossover Pipeline treated at Escondido-Vista WTP	Pipeline 4	x	x	--
Yuima	--	--	First Aqueduct	x	x	--

3.7.2. Distribution Logic

Water is distributed to member agency demand nodes on a daily timestep through model elements and logic representing the conveyance system. For untreated water distribution, water must first be treated at a WTP, so member agency requests are assigned to the corresponding treatment plant for the water source group and member agency. For treated water distribution, requests are made directly to the corresponding water source infrastructure rather than first requesting it through a WTP. The water treatment plant then transfers the request to the pipeline and/or reservoir elements that supply the water.

3.7.2.1. Constraints on Water Distribution

3.7.2.1.1. Pipeline capacity

When an agency requests water in the form of a demand, a pipe capacity limitation check is performed to ensure that pipe capacities are not exceeded. Model pipe capacities are shared equally by all member agencies. A percentage of the total pipe capacity is allocated to each member agency every time they make a request. As more requests are made, the available pipe capacities are reduced thus limiting the amount of water an agency can receive through a particular pipeline.

3.7.2.1.2. Minimum flows of treated water

The First Aqueduct treated water pipelines and Pipeline 4 both have minimum flows that are implemented in the model to ensure that the MWD treated flow minimum requirements are met. Since the model is a demand-driven model, these flows must be used by a member agency to meet demands. The model has logic that is used at each timestep to identify agencies that could take the minimum flows, distribute the flows to those agencies and reduce the agencies' demands, and allocate MWD treated water.

3.7.2.2. Distribution to Reservoirs

Water can only be stored in the reservoirs after the untreated water demands are met with the exception of the San Vicente Emergency Storage Project pool. Specific rules provide priority preference to the pool if it is below the rule curve causing it to be refilled first.

3.8. Model Run Setup and Inputs

Model inputs and settings control how the model implements the available logic described by the network of model elements, links, and functions, and sets the supply and demand values that drive each simulation. Prior to starting a model run, the settings must be adjusted to describe the supply, demand, and infrastructure conditions for the model run. CWASim offers a dashboard user interface that can be used for setting up and performing model runs. The Main Dashboard is where the user can create model scenarios, run a model scenario, and identify the Forecast Start Year. Dashboards for demand settings, supply settings, system settings, simulation settings and results can also be accessed from the Main Dashboard.

3.8.1. Model Run Setup Spreadsheet

An Excel spreadsheet called ‘CWASim Run Setup’ was developed for the San Diego Basin Study to provide an organizational tool for verifying that each model run includes the desired settings before the run begins. The spreadsheet walks the user through each of the user adjusted settings in each of the CWASim dashboards and includes a checklist for each category.

3.8.2. Scenario Manager

The Scenario Manager serves as a tool for managing the scenarios, or model runs with different input parameters, in a GoldSim model. Scenarios differ from one another by having different values for one or more data elements.

As part of setting up a scenario, CWASim provides a dropdown menu to select the climate change scenario for the run. The dropdown menu contains eleven options: one option for no climate change, five options for 2020s climate, and five options for 2050s climate. The climate scenarios are described further in Chapter 4. The dropdown menu is connected to a model element that controls the selection of climate change adjustment factors for supplies and demands (described in Sections 4.3.1.1 and 4.4.2.2). If a climate change scenario is selected using the dropdown, the corresponding adjustment factors will be applied to both the supply and demand inputs.

3.9. Model Outputs

CWASim runs produce time series results that can be stored using result elements. CWASim displays model results in either the Results Dashboard, or by exporting the results to a spreadsheet. Results used for the San Diego Basin Study include sets of descriptive and impact metrics. Descriptive metrics are used to characterize water supply system operations and to contextualize impacts that are described with impact metrics. See Chapter 5 for further details.

4. San Diego Basin Study Baseline Scenarios

4.1. Scenario Overview

Task 2.3 of the San Diego Basin Study investigated impacts to water delivery, hydropower, recreation, flood control, and the environment for 13 climate and demand scenarios under the baseline infrastructure and operations portfolio. The baseline infrastructure and operations portfolio represented the system as it existed in 2015, with some minor modifications to include water supplies that have been or will be implemented (e.g., Carlsbad Desalination Plant and the full QSA annual transfer volume). The thirteen climate and demand scenarios consisted of combinations of one of three demand years (actual demands for 2015 and projected demands for 2025 and 2050), one of three climate time periods (current climate, 2020s, and 2050s) and one of five climate change projection groups (Central Tendency (ct), Warm-Wet (ww), Warm-Dry (wd), Hot-Wet (hw), and Hot-Dry (hd)). Table 15 summarizes the baseline scenarios and corresponding scenario names.

Table 15. Summary of Baseline Scenarios

Scenario Name	System Infrastructure and Operations Portfolio	Supply Projections	Demand Projections
B2015-cc	Baseline	current climate	2015 demands, current climate
B2025-cc	Baseline	current climate	2025 demands, current climate
B2050-cc	Baseline	current climate	2050 demands, current climate
B2025-ct-2020s	Baseline	2020s central tendency climate	2025 demands, 2020s central tendency climate
B2025-ww-2020s	Baseline	2020s warm-wet climate	2025 demands, 2020s warm-wet climate
B2025-wd-2020s	Baseline	2020s warm-dry climate	2025 demands, 2020s warm-dry climate
B2025-hw-2020s	Baseline	2020s hot-wet climate	2025 demands, 2020s hot-wet climate
B2025-hd-2020s	Baseline	2020s hot-dry climate	2025 demands, 2020s hot-dry climate
B2050-ct-2050s	Baseline	2050s central tendency climate	2050 demands, 2050s central tendency climate

Scenario Name	System Infrastructure and Operations Portfolio	Supply Projections	Demand Projections
B2050-ww-2050s	Baseline	2050s warm-wet climate	2050 demands, 2050s warm-wet climate
B2050-wd-2050s	Baseline	2050s warm-dry climate	2050 demands, 2050s warm-dry climate
B2050-hw-2050s	Baseline	2050s hot-wet climate	2050 demands, 2050s hot-wet climate
B2050-hd-2050s	Baseline	2050s hot-dry climate	2050s hot-dry climate

4.2. System Infrastructure and Operations Portfolio

The baseline runs were all done using the Baseline system infrastructure and operations portfolio. This portfolio represents the facilities and operations as they existed in 2015, with the addition of all "verifiable" projects from the 2015 SDCWA UWMP. See Section 3.2 for further details.

4.3. Water Supply Projections

Water supply projections for the San Diego Basin Study Baseline model runs (Table 16) include 85-year-long timeseries of surface water inflows to reservoirs under current and future climate conditions, 85-year-long timeseries of imported MWD supplies available to be purchased for use in the San Diego region, constant QSA water supply volumes for each time period, and constant water supply volumes for groundwater, recycled water, and desalination. Potable reuse supply was not included in the baseline runs.

Table 16. Summary of Water Supply Projections

Scenario Name	Ground-water	Recycled Water	Potable Reuse	Desalina-tion	Surface Water	QSA	MWD SWP Supply	MWD CRB Supply
B2015-cc	2015 UWMP Verifiable Supplies 2015	2015 UWMP Verifiable Supplies 2015	None	Carlsbad	current climate	Full agree-ment volume	No climate change	No climate change
B2025-cc	2015 UWMP Verifiable Supplies 2025	2015 UWMP Verifiable Supplies 2025	None	Carlsbad	current climate	Full agree-ment volume	No climate change	No climate change

Scenario Name	Ground-water	Recycled Water	Potable Reuse	Desalina-tion	Surface Water	QSA	MWD SWP Supply	MWD CRB Supply
B2050-cc	2015 UWMP Verifiable Supplies 2050 (same as 2040)	2015 UWMP Verifiable Supplies 2050 (same as 2040)	None	Carlsbad	current climate	Full agree-ment volume	No climate change	No climate change
B2025-ct-2020s	2015 UWMP Verifiable Supplies 2025	2015 UWMP Verifiable Supplies 2025	None	Carlsbad	2020s central tendency climate	Full agree-ment volume	median (Q5)	median
B2025-ww-2020s	2015 UWMP Verifiable Supplies 2025	2015 UWMP Verifiable Supplies 2025	None	Carlsbad	2020s warm-wet climate	Full agree-ment volume	warm-wet (Q4)	warm-wet
B2025-wd-2020s	2015 UWMP Verifiable Supplies 2025	2015 UWMP Verifiable Supplies 2025	None	Carlsbad	2020s warm-dry climate	Full agree-ment volume	warm-dry (Q1)	warm-dry
B2025-hw-2020s	2015 UWMP Verifiable Supplies 2025	2015 UWMP Verifiable Supplies 2025	None	Carlsbad	2020s hot-wet climate	Full agree-ment volume	hot-wet (Q3)	hot-wet
B2025-hd-2020s	2015 UWMP Verifiable Supplies 2025	2015 UWMP Verifiable Supplies 2025	None	Carlsbad	2020s hot-dry climate	Full agree-ment volume	hot-dry (Q2)	hot-dry
B2050-ct-2050s	2015 UWMP Verifiable Supplies 2050 (same as 2040)	2015 UWMP Verifiable Supplies 2050 (same as 2040)	None	Carlsbad	2050s central tendency climate	Full agree-ment volume	median (Q5)	median
B2050-ww-2050s	2015 UWMP Verifiable Supplies 2050 (same as 2040)	2015 UWMP Verifiable Supplies 2050 (same as 2040)	None	Carlsbad	2050s warm-wet climate	Full agree-ment volume	warm-wet (Q4)	warm-wet

Scenario Name	Ground-water	Recycled Water	Potable Reuse	Desalina-tion	Surface Water	QSA	MWD SWP Supply	MWD CRB Supply
B2050-wd-2050s	2015 UWMP Verifiable Supplies 2050 (same as 2040)	2015 UWMP Verifiable Supplies 2050 (same as 2040)	None	Carlsbad	2050s warm-dry climate	Full agree-ment volume	warm-dry (Q1)	warm-dry
B2050-hw-2050s	2015 UWMP Verifiable Supplies 2050 (same as 2040)	2015 UWMP Verifiable Supplies 2050 (same as 2040)	None	Carlsbad	2050s hot-wet climate	Full agree-ment volume	hot-wet (Q3)	hot-wet
B2050-hd-2050s	2015 UWMP Verifiable Supplies 2050 (same as 2040)	2015 UWMP Verifiable Supplies 2050 (same as 2040)	None	Carlsbad	2050s hot-dry climate	Full agree-ment volume	hot-dry (Q2)	hot-dry

4.3.1. Surface Water Projections

Surface water projections consist of inflows to the ten reservoirs in the San Diego region that receive the majority of surface water flow. The projections were developed by multiplying historical reservoir inflows by change factors representing percentage changes in reservoir inflows for future climate scenarios. The change factors were developed by comparing modeled historical reservoir inflows to modeled future reservoir inflows from archived simulations of streamflow under climate change scenarios.

4.3.1.1. Calculation of Change Factors

To obtain the change factors, climate change projection groups were identified from Coupled Model Intercomparison Project, Phase 5 (CMIP5) temperature and precipitation projections and then monthly change factors were calculated for these groups from the streamflow projections. Projection groups consisted of 10 projections that were identified by calculating mean annual changes in precipitation (in percent) and temperature (in degrees Fahrenheit), between the 1990-1999 current climate period and the 2025 (2020-2029) and 2050 (2050-2059) future periods for all models and Representative Concentration Pathways (RCPs) in the CMIP5 archive (Table 17). The 10th, 50th, and 90th percentile values were calculated for temperature change and precipitation change and used to group the CMIP5 projections into five climate change projection groups (Table 18 and Figure 7). The 10 CMIP5 projections closest to the percentile intersections were used to inform to each climate change projection group for each time period.

Table 17. Climate Time Periods

Time Period	Years Included from Streamflow Projections
Current Climate	1990-1999
2025	2020-2029
2050	2050-2059

Table 18. Climate Change Projection Groups

Scenario	Scenario abbreviation	Temperature Change (°F)	Precipitation Change (%)
hot-dry	hd	90th percentile	10th percentile
hot-wet	hw	90th percentile	90th percentile
central tendency	ct	50th percentile	50th percentile
warm-dry	wd	10th percentile	10th percentile
warm-wet	ww	10th percentile	90th percentile

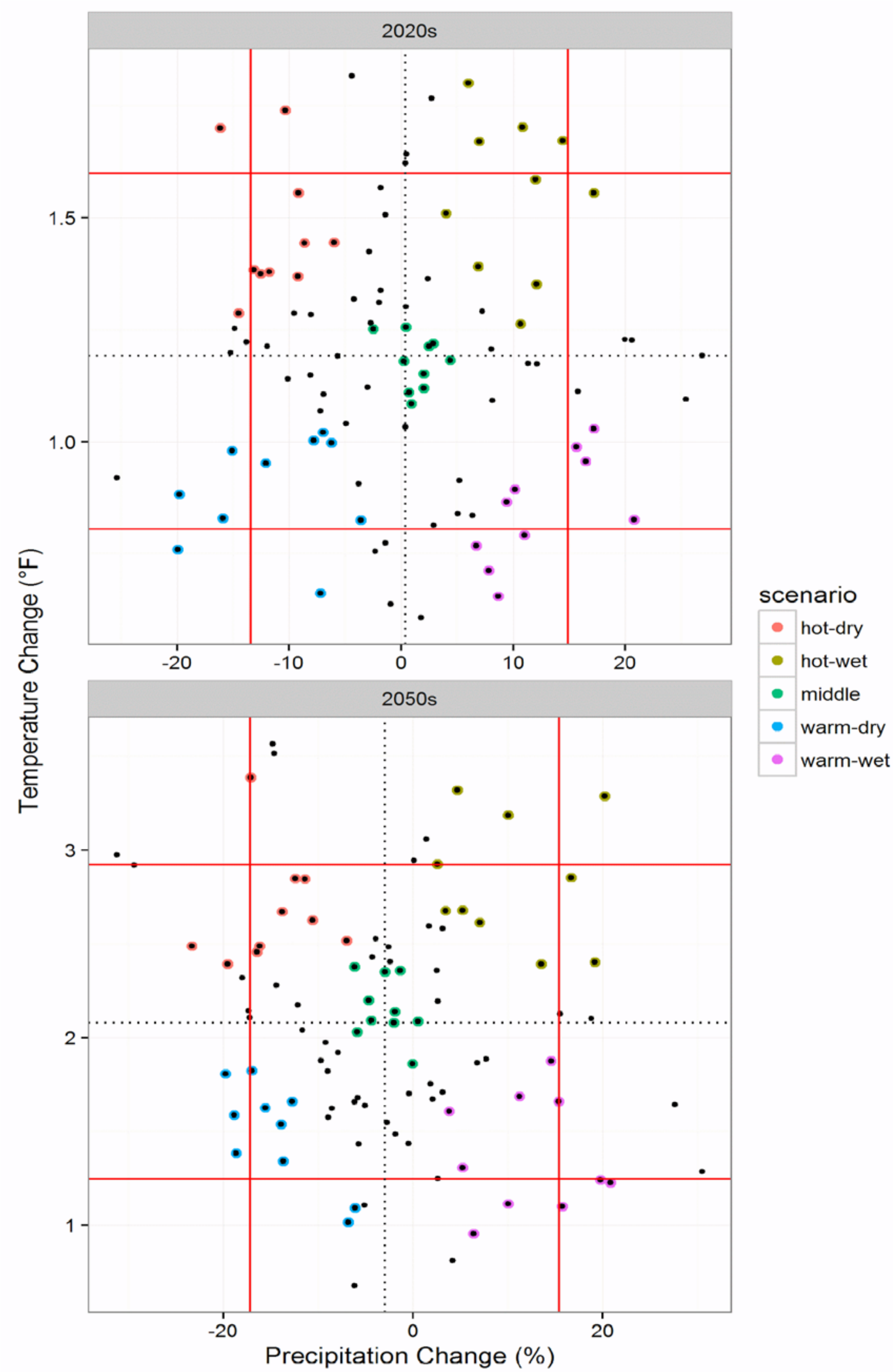


Figure 7. Projection groupings for developing climate change scenarios

Monthly change factors were calculated from calculated natural streamflow for each of the selected groupings of projections. For each of the future time periods (2020s and 2050s), the mean change in streamflow across the 10 projections was computed, resulting in one change factor per month (e.g., January), per scenario (e.g., hot-dry), and per time period (e.g., 2020s).

4.3.1.2. Source of Temperature, Precipitation, and Hydrology Projections

Projections of temperature, precipitation, and hydrological parameters were obtained from the Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections (DCHP) archive (CMIP5, 2013) which contains downscaled climate information (temperature and precipitation) and corresponding hydrology projections (e.g., surface runoff, baseflow, and evapotranspiration) for the contiguous United States. The archive is meant to provide access to climate and hydrologic projections at spatial and temporal scales relevant to watershed and basin-scale decisions facing water and natural resource managers and planners dealing with climate change. The archive includes both Coupled Model Intercomparison Project (CMIP) Phase 3 climate projections of temperature and precipitation (CMIP3, 2007) and CMIP 5 climate projections (Taylor et al., 2012), and corresponding hydrological simulations produced using the Variable Infiltration Capacity model (VIC) (Liang, Wood, and Lettenmaier 1996; Liang et al. 1994; Nijssen et al. 1997). VIC is a large-scale, semi-distributed hydrologic model that calculates surface runoff and baseflow estimates for each grid cell and routes the flow to stream channels.

The CMIP5 hydrological projections were used for the San Diego Basin Study. The CMIP 5 archive includes VIC model results for 97 climate projections representing 31 Global Climate Models (GCMs) and four emissions pathways. For the historical period, GCM models were constrained by observations of atmospheric conditions. Several alternative futures are reflected in the Representative Concentration Pathways (RCPs) which vary future atmospheric conditions. In addition, many GCM modeling groups provided projections from the same model initialized from multiple climate states in order represent uncertainties stemming from natural low frequency climate variability (Reclamation, 2013). For the San Diego Basin Study, all GCMs and all RCPs were used to develop the change factors.

4.3.1.3. Calculation of Streamflow Projections for Change Factors

The VIC hydrological projections from the DCHP CMIP5 archive were used to calculate modeled historical and future natural streamflow values that were then used to calculate the change factors. Historical and future natural streamflow was calculated for reservoir inflow locations at each of the 10 reservoirs that receive surface water inflows in the CWASim model. For each inflow location, the upstream grid cells reflecting the watershed of that point were identified using a digital elevation model. Summing the streamflow values for each grid cell within the watershed gave an estimate of the naturalized streamflow at that location. This streamflow does not reflect any management or operation within the watershed.

4.3.1.4. Surface Water Projections for CWASim

To obtain surface water projections for use in the CWASim model, the change factors were applied to an 85-year-long (1900-1984) set of historical reservoir inflows to calculate future reservoir inflows for the 2020s and 2050s. The historical reservoir inflow set (Figure 8) came from a reconstructed dataset of reservoir inflows developed for a previous basin simulation model (called Confluence).

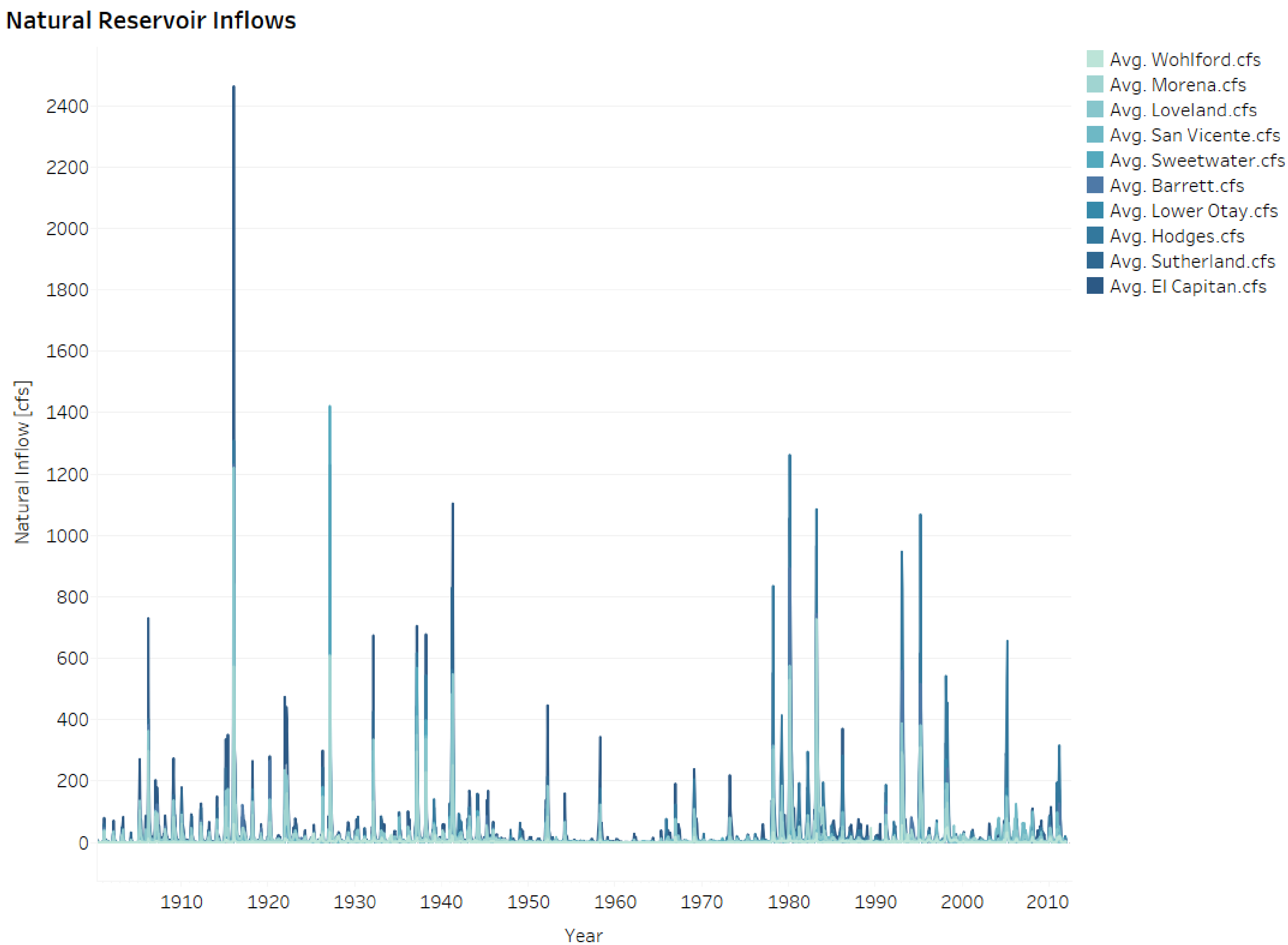


Figure 8. Natural reservoir inflow dataset, 1900-2011

4.3.2. Groundwater Projections

Groundwater supply projections for the SDBS are based on the projected capacity of groundwater facilities accessible to each SDCWA member agency (Table 19). The Study used groundwater facility development information from the SDCWA 2015 UWMP to project groundwater supplies. In the 2015 SDCWA UWMP, seven member agencies provided volumes of normal year groundwater yield from existing and verifiable proposed expansions that they plan to use to meet demands for 2015-2035. For 2040, 2045, and 2050, the groundwater yield was assumed to be constant at the 2035 volume, under the assumption that the remaining undeveloped groundwater sources are limited and member agencies will have fewer opportunities to expand groundwater production in the future.

Groundwater supplies are assumed to be unaffected by climate change and year-to-year hydrologic variability and it is assumed that member agencies will use their full capacity of groundwater each year. Therefore, a single annual value of groundwater supply for each time period is used for all climate projection groups for that time period.

Table 19. Groundwater Supply Projections

Demand Time Period and Climate Projection Group	Groundwater Supply Volume (AF)
2015 Demands, cc	11,466
2025 Demands, (cc, ct, wd, ww, hd, hw)	22,930
2050 Demands, (cc, ct, wd, ww, hd, hw)	22,930

4.3.3. Recycled Water Projections

Similar to groundwater, recycled water supply projections are based on projected capacity of recycled water facilities from the 2015 SDCWA UWMP (Table 20). For recycled water, 16 member agencies provided expected yields for existing and verifiable proposed expansions. A regression between projected recycled water supply and year for 2035-2040 was used to project water supply for 2040, 2045, and 2050. Because the recycled water supply relies on the wastewater stream that already exists in the San Diego system, rather than sources with naturally limited availability like surface water and groundwater, it may continue to be expanded in the future. The amount of expansion and type of recycling (non-potable, indirect potable, or direct potable) will likely depend on factors such as economics and the success of current projects.

Recycled water supplies are assumed to be unaffected by climate change and year-to-year hydrologic variability and it is assumed that member agencies will use their full capacity of recycled water each year. Therefore, a single annual value of recycled water supply for each time period is used for all climate projection groups for that time period.

Table 20. Recycled Water Supply Projections

Time Period and Climate Projection Group	Recycled Water Supply Volume (AF)
2015 Demands, cc	31,547
2025 Demands, (cc, ct, wd, ww, hd, hw)	45,984
2050 Demands, (cc, ct, wd, ww, hd, hw)	49,168

4.3.4. Desalination Projections

As the only ocean desalination project currently in operation, the Carlsbad Desalination Project was the only desalination facility included in the supply projections for the 2015 SDCWA UWMP. The volume of water available from desalination (Table 21) was set by the water purchase agreement between SDCWA and Poseidon Resources, the operator of the Carlsbad Desalination Project. The 30-year agreement commits SDCWA to purchasing at least 48,000 AF and up to 56,000 AF per year (Carlsbad Desalination Project, 2015). In the 2015 SDCWA UWMP, a value of 56,000 AF per year was assumed for 2015-2035, and this value was also used to extend the projection to 2050.

Table 21. Desalination Supply Projections

Time Period and Climate Projection Group	Carlsbad Desalination Plant Maximum Supply (AF/y)
2015 Demands, cc	56,000
2025 Demands, (cc, ct, wd, ww, hd, hw)	56,000
2050 Demands, (cc, ct, wd, ww, hd, hw)	56,000

4.3.5. QSA Water Projections

For the Baseline SDBS model runs, QSA water volumes (Table 22) were taken from the schedules in the applicable agreements for those transfers (QSA, 2003). These supplies are considered to be available at the scheduled volume regardless of climate change effects or other factors that could affect future water availability.

Table 22. QSA Water Projections

Time Period and Climate Projection Group	QSA Volume (AF/y)
2015 Demands, cc	280,200
2025 Demands, (cc, ct, wd, ww, hd, hw)	280,200
2050 Demands, (cc, ct, wd, ww, hd, hw)	280,200

4.3.6. Section Projections of Imported Purchases from MWD

To model imported water supplies purchased from MWD, the CWASim model requires monthly and annual time series of inflows to MWD from the State Water Project (SWP) and the Colorado River Basin (CRB) for each climate scenario. For the Baseline SDBS model runs, State Water

Project supplies were extracted from the Sacramento-San Joaquin Basin Study results (Reclamation, 2016) and Colorado River Basin supplies were extracted from the Colorado River Basin Supply and Demand Study results (Reclamation, 2012).

4.3.6.1. 4.3.6.1 State Water Project

State Water Project inflows to the consolidated MWD storage element were obtained from the Sacramento-San Joaquin Basins Study (SSJBS). The SSJBS examined the impacts of climate change on water supply in the Sacramento and San Joaquin Basins, which supply water to MWD via the SWP. The SSJBS examined the current system water supply infrastructure and operations under multiple future socioeconomic scenarios (Current Trends, Slow Growth, and Expanded Growth) and future climate scenarios (Warmer Drier, Warmer Wetter, Hotter Drier, Hotter Wetter, Central Tendency, and No Climate Change).

The San Diego Basin Study model runs used the SSJBS results of the Current Trends runs for each of the future climate scenarios.

4.3.6.2. Colorado River Basin

Inflows to the consolidated MWD storage element from the Colorado River Basin were obtained from the Colorado River Basin Supply and Demand Study (CRBSDS). The CRBSDS examined the impacts of climate change on water supply in the Colorado River Basin under multiple water supply, water demand, and operating condition scenarios (Reclamation, 2012). The water supply scenarios were Observed Resampled, Paleo Resampled, Paleo Conditioned, and Downscaled GCM Projected. The water demand scenarios consisted of a Current Projected scenario (A), a Slow Growth scenario (B), two Rapid Growth scenarios (C1 and C2), and two Enhanced Environment scenarios (D1 and D2). Because the Interim Guidelines (Department of Interior, 2007), which describe interim operations of Lake Powell and Lake Mead, expire in 2026 and it is uncertain whether they will remain in place after 2026, the CRBSDS considered two scenarios for post-2026 operating conditions (Extend Interim Guidelines and Revert to No Action).

The SDBS model runs used the CRBSDS results from runs using the Downscaled GCM Projected supply scenario, the Current Projected demand scenario, and the Extend Interim Guidelines operational scenario. The Downscaled GCM Projected supply scenario included 112 future climate projections from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (Intergovernmental Panel on Climate Change , 2007) that were subsequently downscaled, bias-corrected, and used as inputs to the VIC hydrology model to simulate hydrologic fluxes that were then routed to the natural flow locations required to run the Colorado River Simulation System (CRSS) model, which simulated operations of the Colorado River system. The Current Projected demand scenario assumed that growth, development patterns, and institutions in the Colorado River Basin continues following long-term trends, and that water demands for Agriculture, M&I, Energy, Minerals, FWR, and Tribes would evolve accordingly. The Extend Interim Guidelines scenario assumed that the Interim Guidelines would be kept in place through 2060.

The results of the selected runs were extracted as timeseries of monthly requested diversions and diversion shortages for MWD for each of the 112 climate projections. The diversion shortage was subtracted from the requested diversion to obtain the delivery to MWD for each climate scenario. For the selected scenarios, there were shortages in only 3 monthly timesteps across all of the 112 runs for 2012-2060. Because the SDBS is examining climate change scenarios based on change factors developed from groups of climate model runs (see Section 4.3.1), the 112 climate projections from the CRBSDS were divided into similar groups based on the average Temperature and Precipitation changes for each of the scenarios. The resulting projections consisted of projected monthly and annual MWD inflows from the Colorado River Basin for 2020 and 2050 for Warmer Drier, Warmer Wetter, Hotter Drier, Hotter Wetter, Central Tendency, and No Climate Change scenario groups.

4.3.7. Conservation Projections

2015 conservation (Table 23) was assumed to be 50,000 AF regionally based on differences between Gross and Adjusted Demands in the SDCWA 2015 Annual Report. Projected future conservation savings for 2025 were taken from the SDCWA 2015 UWMP, which used the Alliance for Water Efficiency Water Conservation Tracking Tool to develop conservation projections. Conservation was assumed to increase for 2045 and 2050 at the same rate of increase from 2035 to 2040 reported by the 2015 UWMP. The conservation values were proportioned out to each member agency based on 2020 UWMP projections.

Table 23. Conservation Projections

Time Period and Climate Projection Group	Conservation Volume (AF)
2015 Demands, cc	50,000
2025 Demands, (cc, ct, wd, ww, hd, hw)	89,110
2050 Demands, (cc, ct, wd, ww, hd, hw)	155,468

4.4. Water Demand Projections

Gross water demand projections for the SDBS consist of annual projections of agricultural and M&I demands for five hydrologic year types for each of the 13 time period and climate change projection group combinations. The projections were developed to quantify how demands in the Study Area may be expected to change between 2015 and 2050. From year to year, demands may increase or decrease based on annual weather conditions (e.g., dry or wet years). Over longer time periods such as the planning horizon of the SDBS, demands may increase or decrease based on long-term trends in factors such as population, demographics, and economic climate, changes in laws and regulations, shifts in demand type (e.g., shifts from agricultural demands to M&I demands), and changes in climate, (e.g., long-term shifts in temperature or precipitation). The SDBS demand projections account for these factors by using annual gross demand projections from the SDCWA 2015 UWMP, extending them to 2050, and adjusting them for projected climate change impacts.

4.4.1. 2015 Gross Demands

2015 gross demands were equivalent to actual demands in 2015 as documented in the SDCWA 2015 UWMP Annual Report.

4.4.2. Gross Demand Projections for 2025 and 2050

Gross demand projections for 2025 and 2050 were based on the demand projections in the 2015 SDCWA UWMP, as modified for the Basin Study including extension of the demands to 2050 and adjustment for climate change.

4.4.2.1. Current Climate Gross Demand Projections

Non-climate change-adjusted gross demands for 2020-2040 (Table 24 and Figure 9) were extracted from the 2015 SDCWA Urban Water Management Plan (San Diego County Water Authority, 2016). These demands were developed by SDCWA using demand models to calculate annual demands in five-year increments for each SDCWA member agency. These demands account for demographic and economic factors and year-to-year variability in weather conditions.

The UWMP contained demands for three categories of demand: M&I demand, agricultural demand, and near-term annexations (known future potential annexations). The UWMP also included projections of demands from accelerated growth and demand reductions due to conservation savings, but these were not included in the SDBS demand projections. Accelerated growth was not included as one of the scenarios to be analyzed for the SDBS, and conservation savings were incorporated directly into the CWASim model rather than being implicitly included via the demand projections. M&I demands were calculated for the SDCWA UWMP using an econometric model ("CWA-MAIN") that relates historical water demand patterns to climate, demographic, and economic variables. The UWMP projections were based upon demographic and economic projections from the San Diego Association of Governments (SANDAG) Series 13 Regional Growth Forecast (SANDAG, 2013). Climate variables for the UWMP CWA-MAIN M&I demand projections were based on historical observations as described below. Agricultural demands for the UWMP were based on historical water use factors and variables including irrigated acreage, crop type distribution, and projections of agricultural conversion to other uses from SDCWA member agencies, SANDAG, County of San Diego Agricultural Weights and Measures, and the California Avocado Commission.

The UWMP demands were given for three hydrologic year types: normal years, single dry years, and multiple (two and three consecutive) dry years. Normal year projections were based on hydrology for 1960 – 2013. Single dry years were based on 2015 weather. Multiple dry years assumed a 1 percent annual decrease in water use from the single dry year projections. For the Basin Study, the multiple dry year hydrologic year type was also extended to include a potential fourth consecutive dry year, and an additional hydrologic year type was added to account for demand differences in wet years. Wet year demands were assumed to be 5% less than normal year demands based on review of historic interannual demand variability.

To extend the non-climate change-adjusted demands to 2050, regression equations were developed for each member agency and hydrologic year type. The 2020-2040 long range demand projections for each hydrologic year type were linearly regressed against population projections for 2020 to 2040 from the SANDAG Series 13 (SANDAG, 2013) dataset. The regression coefficients were then used to project demands for 2045 and 2050.

Table 24. Total Gross Demand Projections for All Member Agencies

Demand Year	Wet Year Gross Demand (AF/y)	Normal Year Gross Demand (AF/y)	First Dry Year Gross Demand (AF/y)	Second Dry Year Gross Demand (AF/y)	Third Dry Year Gross Demand (AF/y)	Fourth Dry Year Gross Demands (AF/y)
2015	619,736	619,736	619,736	619,736	619,736	619,736
2025	675,642	722,507	772,648	766,687	761,726	756,597
2050	779,456	845,488	919,919	916,305	919,506	922,673

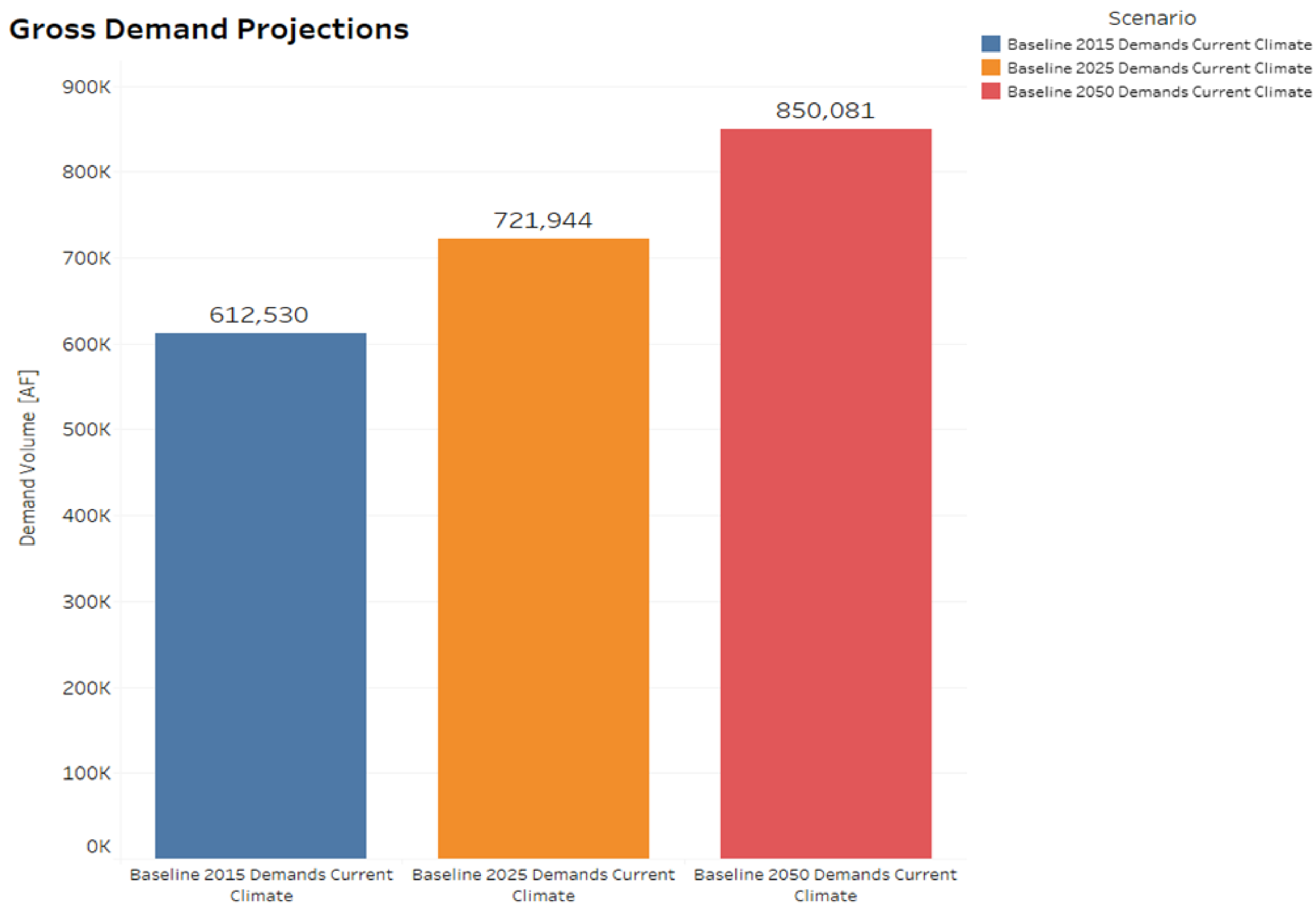


Figure 9. Current climate gross demand values averaged over all realizations

4.4.2.2. Climate Change Adjusted Demand Projections

Climate change adjusted demands (Table 25 and Figure 10) were calculated by applying a set of climate change adjustment factors for each time period and climate change projection group to the unadjusted projections. The adjustment was done individually for each member agency demand node using the same adjustment factor for all hydrologic year types.

Table 25. Average Climate Change Adjustment Factors and Resulting Average Gross Demand Projections

Scenario Name	Average Member Agency Demand Climate Change Adjustment Factor	Total Average Gross Demand (AF/y)
B2015-cc	1	619,736
B2025-cc	1	730,437
B2050-cc	1	860,082
B2025-ct-2020s	1.0320	753,815
B2025-ww-2020s	1.0309	752,765
B2025-wd-2020s	1.0327	754,018
B2025-hw-2020s	1.0305	752,416
B2025-hd-2020s	1.0331	754,681
B2050-ct-2050s	1.0315	886,942
B2050-ww-2050s	1.0310	886,413
B2050-wd-2050s	1.0330	887,540
B2050-hw-2050s	1.0315	886,862
B2050-hd-2050s	1.0325	887,453

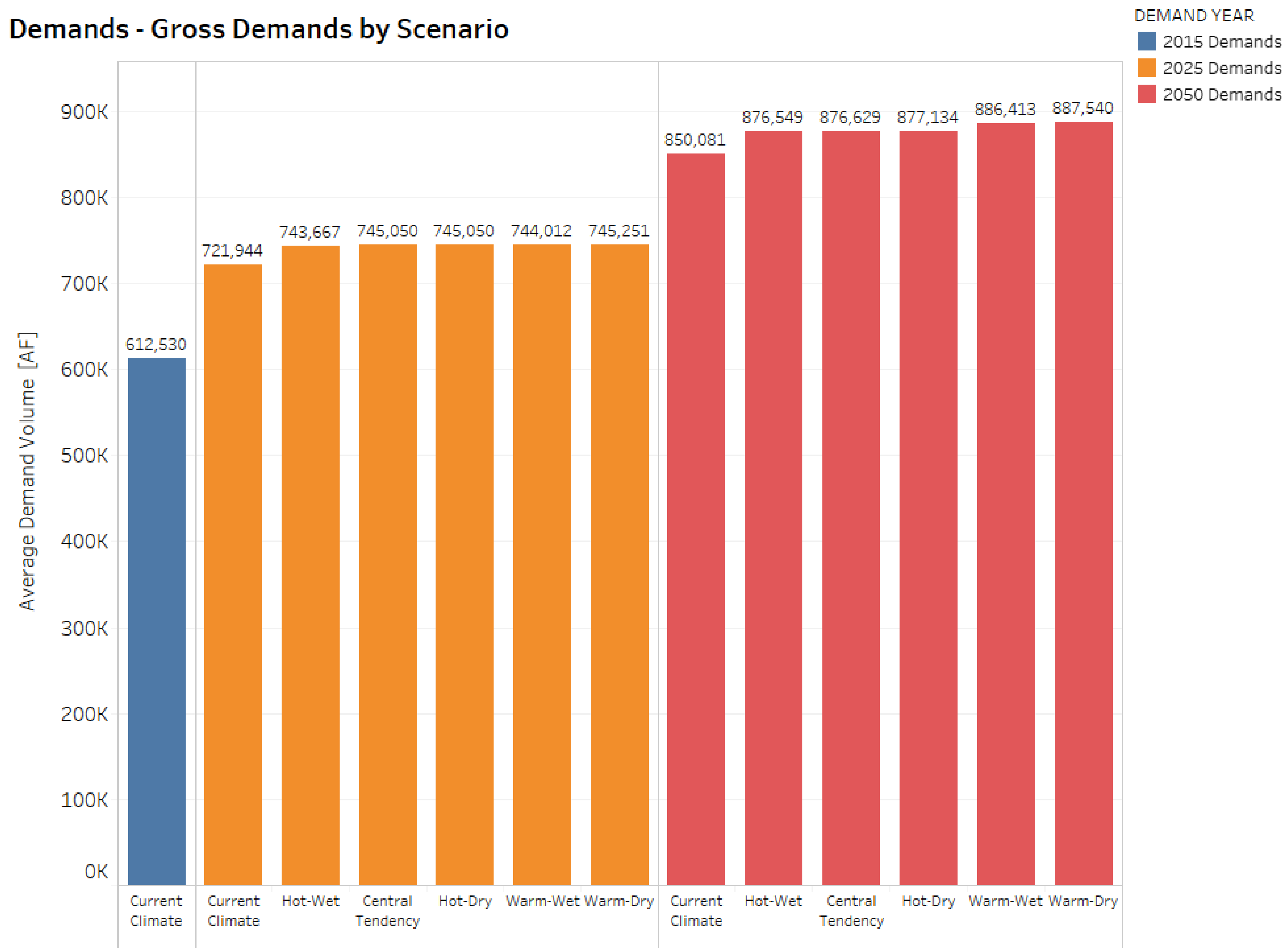


Figure 10. Current and future climate gross demands averaged across all realizations in each scenario

4.4.2.3. Development of Climate Change Adjustment Factors for Demand Projections

Demand adjustment factors were calculated with a spreadsheet model that relates projected changes in precipitation and potential evapotranspiration (PET) to changes in demand. The model was developed and calibrated as part of the analysis for the 2013 SDCWA Master Plan (San Diego County Water Authority, 2013) and applied for the San Diego Basin Study. The spreadsheet model requires input values of modeled historical and future precipitation and PET for grid cell locations representing each SDCWA member agency for each climate change scenario. For the San Diego Basin Study, the input precipitation and PET data was obtained from the same set of hydrology projections as the surface water supply projections (see Section 4.3.1).

The model calculates change factors based on the modeled precipitation and PET and then applies the change factors to a set of historical precipitation and evapotranspiration values for each member agency, resulting in climate change adjusted precipitation and PET values. The adjusted precipitation and PET values are then combined with calibration coefficients for irrigated area size, irrigation efficiency, and indoor use to produce multiplicative demand adjustment factors.

5. Baseline Impacts Assessment

The Baseline impacts assessment completed in Task 2.3 of the San Diego Basin Study serves as the basis of comparison for the portfolios of adaptation concepts to be developed and modeled in Task 2.4. The Baseline demand and climate scenarios described in Chapter 4 were developed to capture a broad range of current and future demands and climate conditions. The Baseline infrastructure and operations portfolio represents the system in approximately its current state (2015 facilities and system operations) with some modification to account for known system changes (e.g. the full ramp-up of the QSA).

5.1. Impacts Assessment Methodology

Basin Studies are required to consider eight impact areas: Water Delivery, Hydroelectric Power, Recreation, Flood Control, Habitat, Endangered/Threatened Species, Water Quality, and Ecological Resiliency (Reclamation, 2016). The San Diego Basin Study has grouped Habitat, Endangered Species, Water Quality, and Ecological Resiliency into a single Environmental impact area for assessment due to limitations of the CWASim model to simulate parameters related to these impact areas and/or a lack of available data to related CWASim model results to impacts. To analyze impacts to these areas, a set of descriptive metrics was developed to summarize the system conditions under the demand and climate scenarios and a set of impacts metrics was developed to quantify responses of the system to demand and climate changes in each of the impact areas.

5.1.1. Descriptive Metrics

Descriptive metrics (Table 26) quantify water supply, demand, delivery, conveyance, and operations parameters on annual and/or monthly timesteps. Each descriptive metric group contains one or more metrics pertaining to a particular location, facility, or type of water supply.

Table 26. Descriptive Metrics

Descriptive Metric Category	Descriptive Metric Group	Description
Water Delivery	Water Delivery	Contains annual metrics quantifying water deliveries
Reservoir Operations	Reservoir Releases	Contains monthly metrics quantifying reservoir release flow rate and volume
Reservoir Operations	Reservoir Storage	Contains annual and monthly metrics quantifying reservoir storage volume
Reservoir Operations	Reservoir Elevation	Contains annual and monthly metrics quantifying reservoir elevation
Reservoir Operations	Reservoir Surface Area	Contains annual and monthly metrics quantifying reservoir surface area

Descriptive Metric Category	Descriptive Metric Group	Description
Conveyance	WTP	Contains annual metrics quantifying water treatment plant treatment volume
Conveyance	Pipelines	Contains monthly metrics quantifying pipeline flow
Conveyance	Pump Stations	Contains annual metrics quantifying pump station utilization

5.1.2. Impact Metrics

Impact metrics (Table 27) are used to evaluate performance of the San Diego water supply system in four of the five impact categories: Water Delivery, Hydroelectric Power, Recreation, and Flood Control. Environmental impacts are described through literature review rather than quantitative metrics as described below. Each impact metric group contains one or more metrics pertaining to a particular location, facility, water supply type, water demand type, or other specific feature.

Table 27. Impact Metrics

Impact Metric Category	Impact Metric Group	Description
Water Delivery	Supply Shortage >20,000 AF for 2 years	Measures the number of times in a run when the shortage is greater than 20 KAF for two years in a row
Water Delivery	Supply Shortage Volume	Measures the magnitude of demand Water Authority-wide that is unable to be met by the available supplies and/or limited by conveyance system capacity
Water Delivery	Diversification	Measures the relative amounts of supply from local supplies, imported water, and desalination
Water Delivery	High Pipeline Utilization Summer Count	Measures the number of days that pipeline flow exceeds 95% of capacity during the summer for four pipeline locations: • Pipeline 4 just south of Twin Oaks Valley WTP, which serves treated water to Carlsbad, Vista, and Vallecitos member agencies • Pipeline 3 30-inch interconnect, which conveys untreated water near Murray Reservoir • Crossover Pipeline, which conveys untreated water • MWD Delivery Point treated water conveyed through Pipelines 1, 2, and 4 • Untreated
Water Delivery	High Pump Station Utilization	Measures the number of times per year that pump station exceeds 95% of capacity for 70% of pumping days for the following pump station locations: • San Vicente; 70% of pumping days = 107 days

Impact Metric Category	Impact Metric Group	Description
		• P2A; 70% of pumping days = 171 days
Water Delivery	Annual Treatment Plant Utilization	Measures WTP usage on an annual basis. Values are reported as the percentage of average annual treatment plant flow compared to treatment plant capacity.
Water Delivery	Seasonal Treatment Plant Utilization	Measures WTP usage during the summer (June through September). Values are reported as the percentage of average seasonal treatment plant flow compared to treatment plant capacity.
Water Delivery	Treatment Plant Utilization - Import	Measures WTP usage for treating imported water. Values are reported as the percentage of treatment plant flow that is made up of imported water.
Water Delivery	Treatment Plant Utilization - Local	Measures WTP usage for treating local surface water. Values are reported as the percentage of treatment plant flow that is made up of local surface water.
Water Delivery	Storage: End of September	Measures the volume remaining in local reservoirs at the end of September for Hodges, El Capitan, San Vicente, Lower Otay, Olivenhain, and Other reservoirs. Volume includes storage in all modeled reservoir pools.
Hydropower	Power generation	Measures the power generated by Water Authority facilities
Hydropower	Power consumption	Measures the power consumed by Water Authority facilities
Hydropower	Net Power	Measures the difference between power consumed and generated by Water Authority facilities. Power generation is subtracted from power consumption, so values represent the amount of additional power that must be generated or purchased to supply water.
Recreation	Elevation End of September	Measures the reservoir elevation, which can be compared to other elevations, such as boat ramp elevations
Flood Control	Annual Volume Spilled	Measures the number of days when water was spilled from a reservoir spillway
Flood Control	Number of Days with Spills	Measures the volume spilled from the reservoir during the year

5.2. Impacts Assessment

CWASim model runs were performed using the Baseline infrastructure and operations portfolio run for each demand and climate scenario, resulting in a set of 13 Baseline simulation runs. Each run was made up of 85 realizations of daily water system simulations. The 85 realizations were run consecutively through the model, and the order of the realizations was the same for all runs, allowing direct comparison between scenarios and realizations. The descriptive and impact metric outputs for each run were extracted on monthly and annual timesteps, compiled into spreadsheets, and post-processed to format the data for analysis. Data analysis consisted of calculation of summary statistics, comparison of metric values, and visualization of the results in graphical formats to identify trends and patterns. A summary of the impacts analysis is included below, and full results can be found in Appendix A.

5.2.1. Water Delivery

Water delivery impacts were measured by water delivery volumes, supply diversification, shortage volume and frequency, conveyance system operations, and reservoir storage.

As demands increase between the 2015, 2025, and 2050 demand projections, water deliveries are projected to increase as a result (Figure 11). Under all Baseline scenarios, local supplies and QSA supplies are utilized to their fullest possible extent. Volumes of groundwater, recycled water, and QSA water are fixed in all Baseline scenarios. Surface water delivery volumes and desalination delivery volumes are close to their maximum available amounts, but the actual volume varies slightly between the scenarios due to minor changes in the timing and location of water demands. Imported water supplies purchased from MWD are assumed to be available to meet all additional demands except when MWD allocations limited imported water deliveries. Therefore, the demand increases between the demand projections are met through increases in imported water purchases from MWD. Within a single demand year, deliveries differ somewhat between climate change scenarios. Differences between scenarios are greater for 2050s climate scenarios than for 2020s climate scenarios.

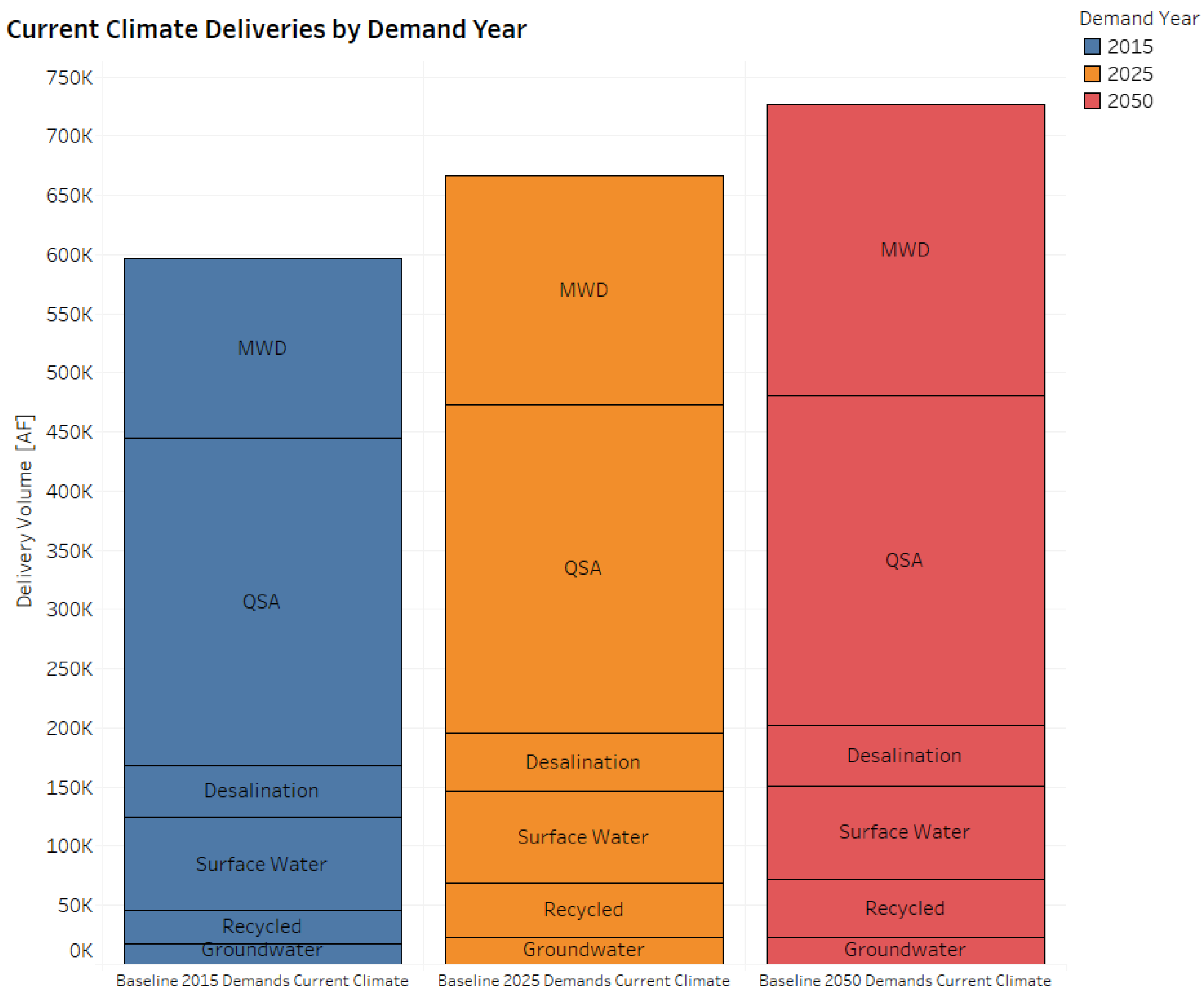


Figure 11. Water deliveries by supply type for 2015, 2025, and 2050 demand scenarios with current climate

As demands increase between 2015, 2025, and 2050 demand projections, the frequency and magnitude of shortages increases in the model simulations. With 2015 and 2025 demands and current climate, no shortages greater than the shortage threshold of 20,000 AF occurred for the 2015 and 2025 scenarios, but shortages larger than the threshold occurred in the 2050 demand scenario (Figure 12). Dry climate change scenarios had larger shortages than wet climate scenarios and greater numbers of shortages above the 20,000 AF threshold, including shortages in both the 2025 demand scenario and 2050 demand scenario (Figure 13).

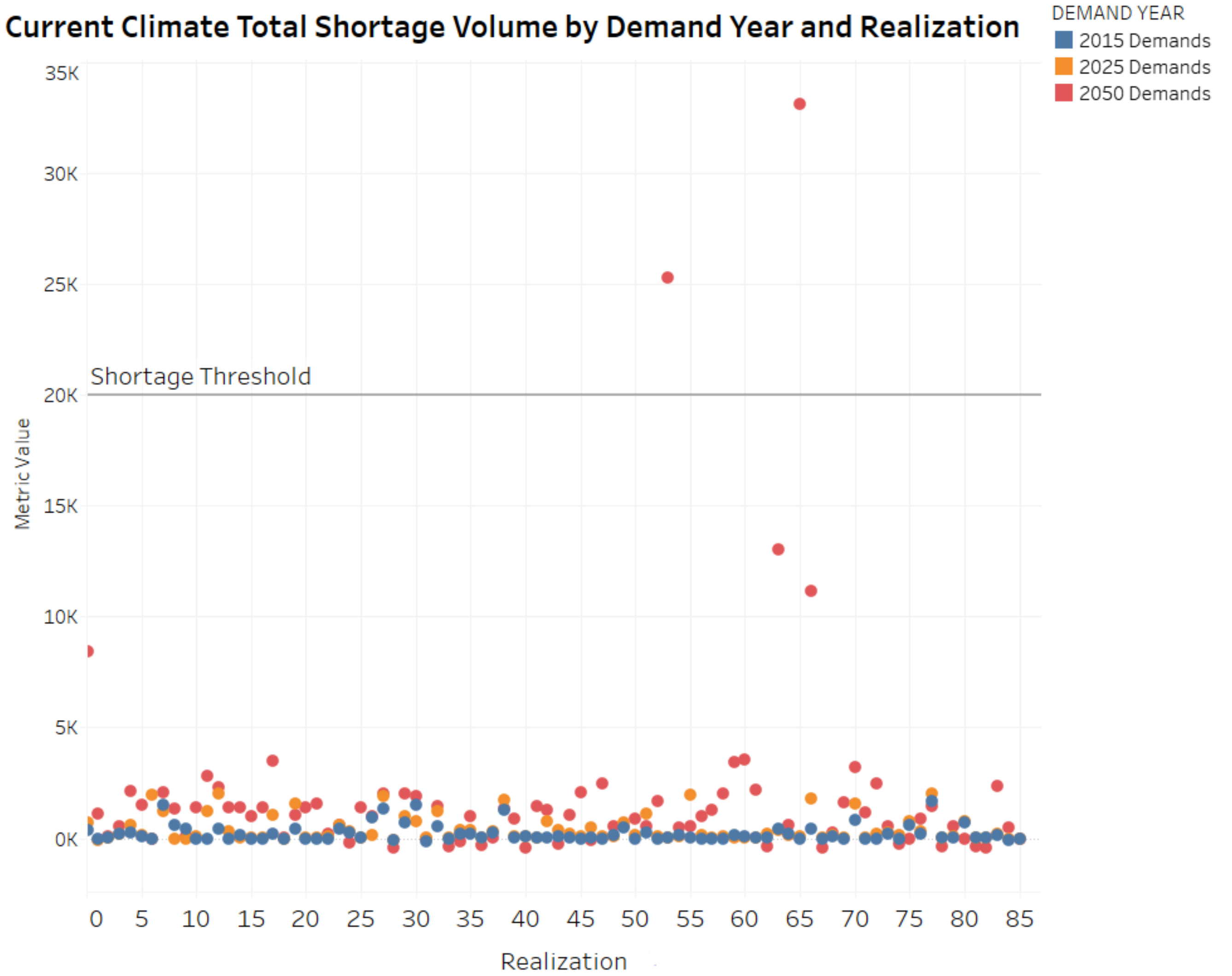


Figure 12. Total shortage volume by realization for 2015, 2025, and 2050 demand scenarios with current climate

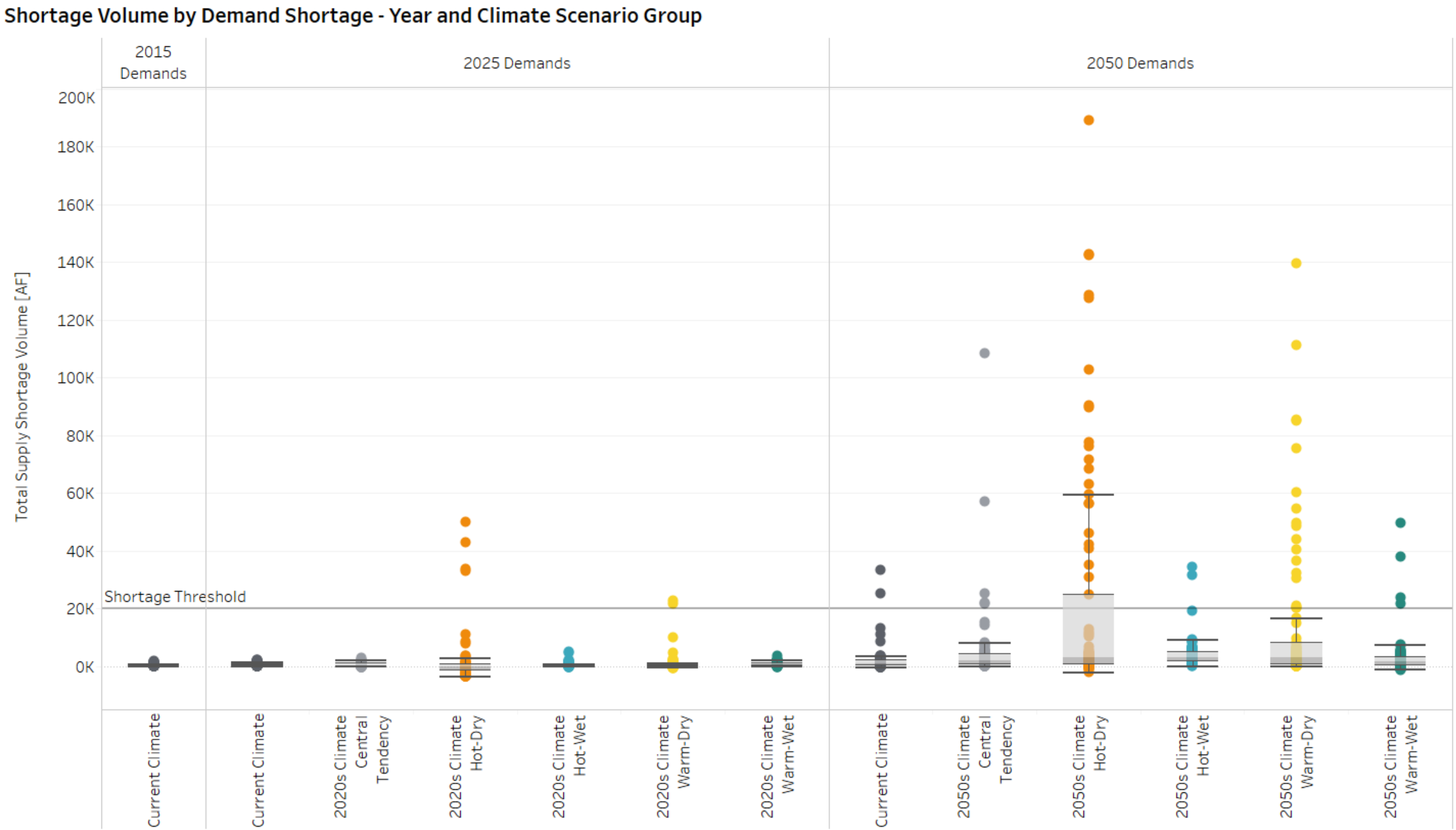


Figure 13. Total shortage volumes for 2015, 2025, and 2050 scenario with current climate, 2020s climate, and 2050s climate

Conveyance system limitations of pipelines and water treatment plants may contribute to shortages (Figure 14). As measured by the High Pipeline Utilization Summer Count metric, in the 2015 demand with current climate scenarios, one of the five pipelines analyzed (the Untreated pipeline) has periods when pipeline flow is at least 95% of capacity. Comparing 2015 to 2025 and 2050 demand projections under current climate, the number of days of high pipeline utilization increases and extends to a second pipeline (the Crossover pipeline). Comparing current climate to the climate change scenarios, pipeline utilization tends to be higher under the climate change scenarios (Figure 15 & Figure 16). Treatment plant utilization increases slightly between 2015, 2025, and 2050 demand current climate scenarios (Figure 17), but there are minimal differences in utilization between climate scenarios for most treatment plants.

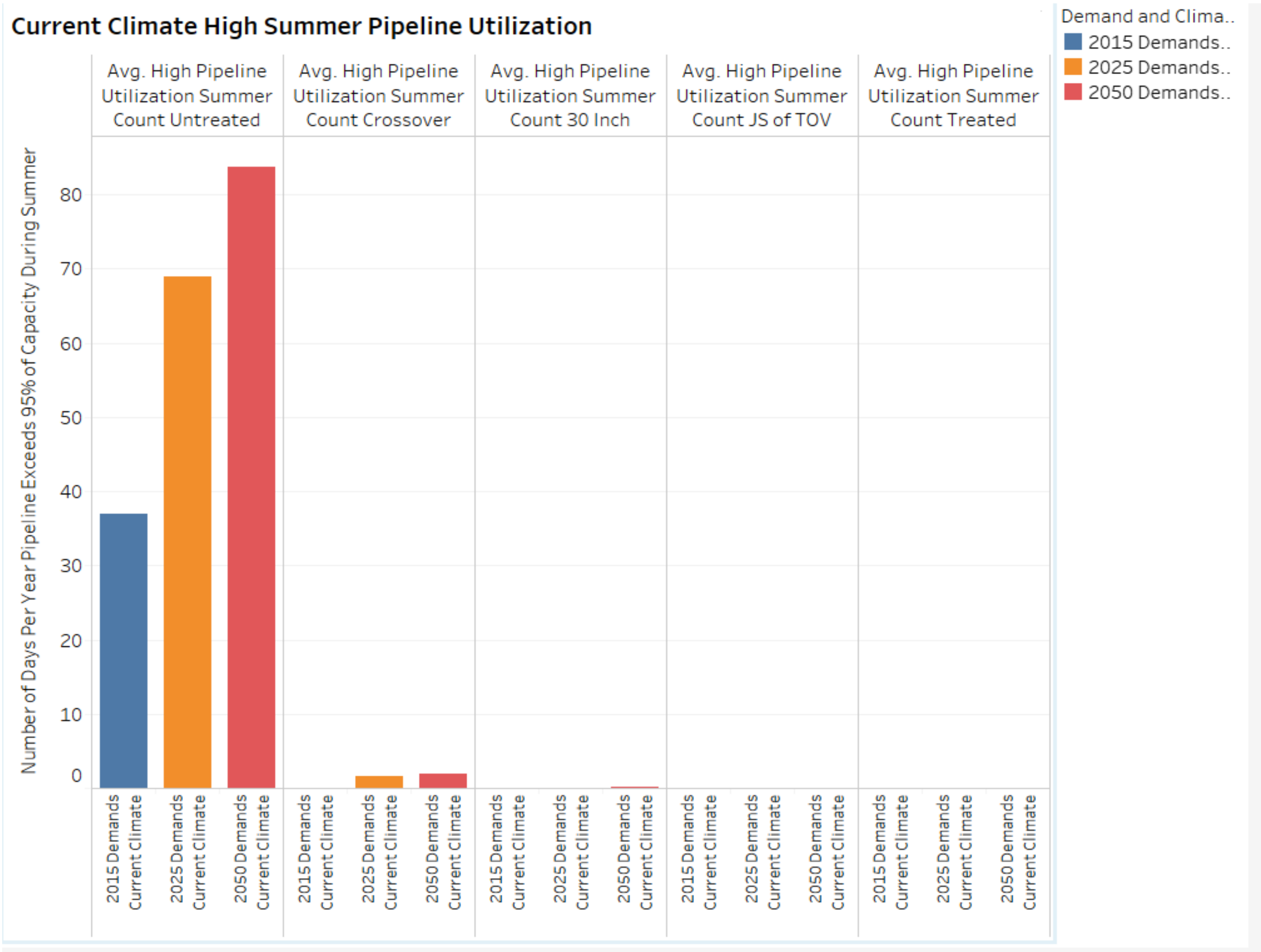


Figure 14. Summer pipeline utilization for 2015, 2025, and 2050 demand scenarios with current climate

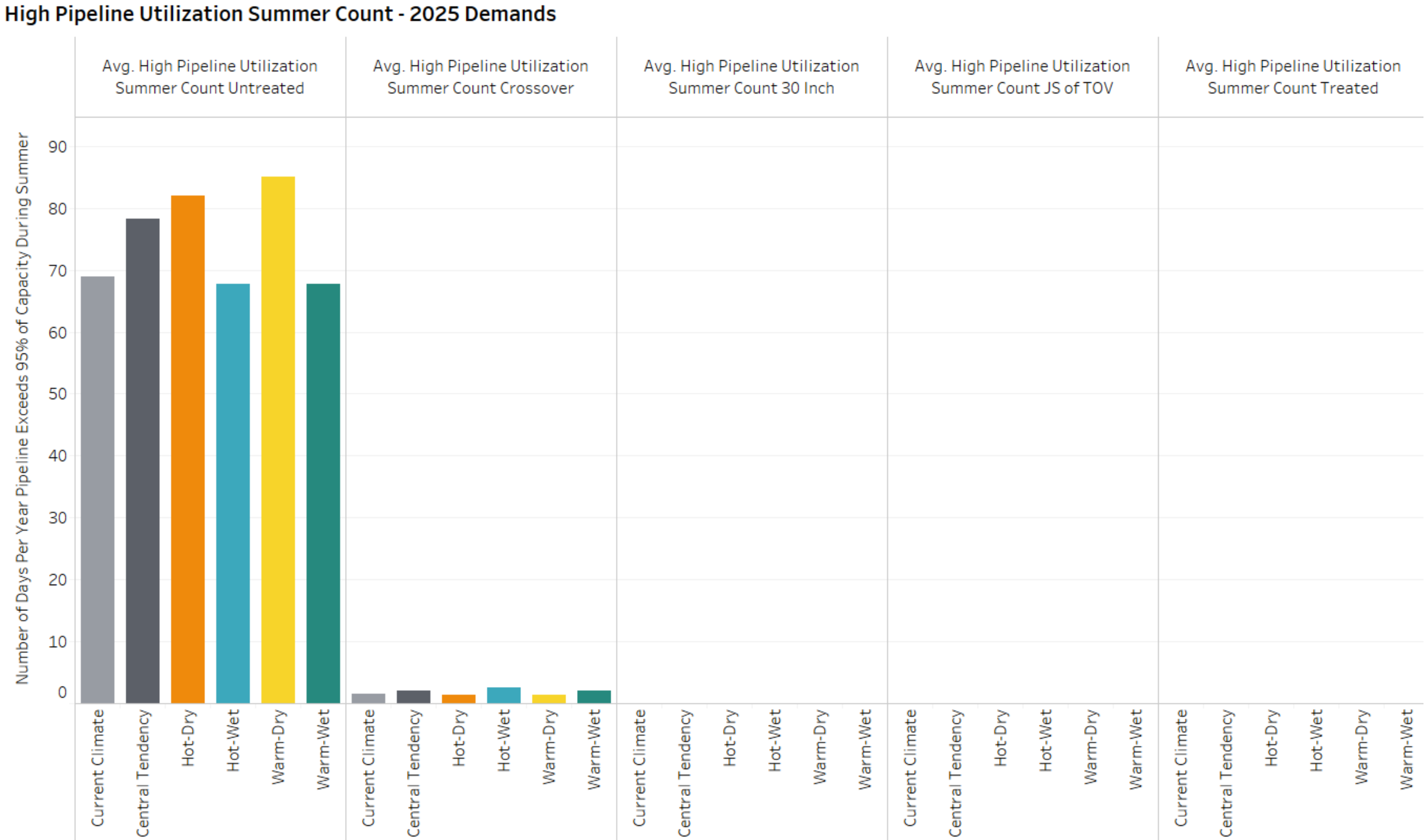


Figure 15. Pipeline utilization for 2025 demand scenarios with current climate and 2020s climate

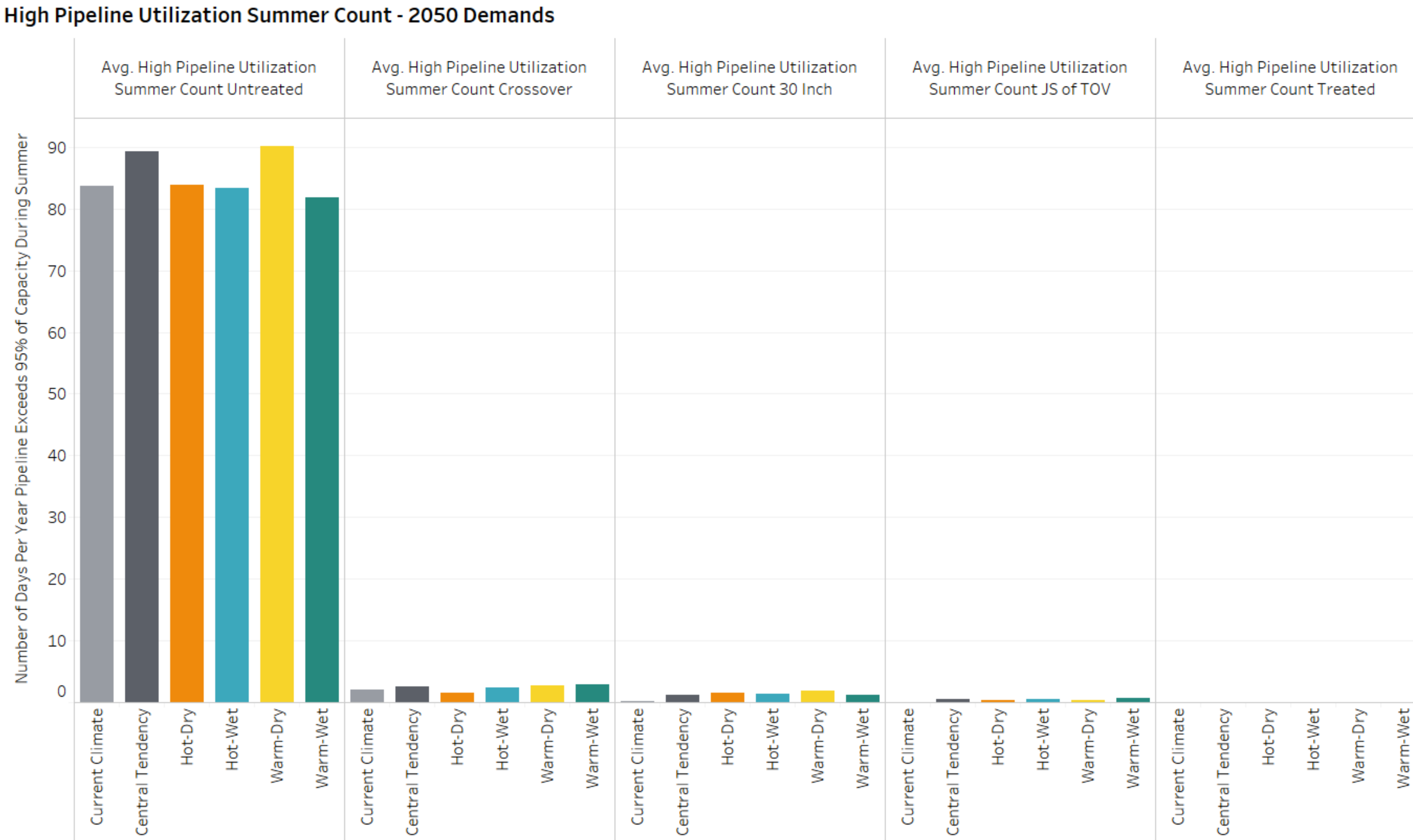


Figure 16. Pipeline utilization for 2050 demand scenarios with current climate and 2050s climate

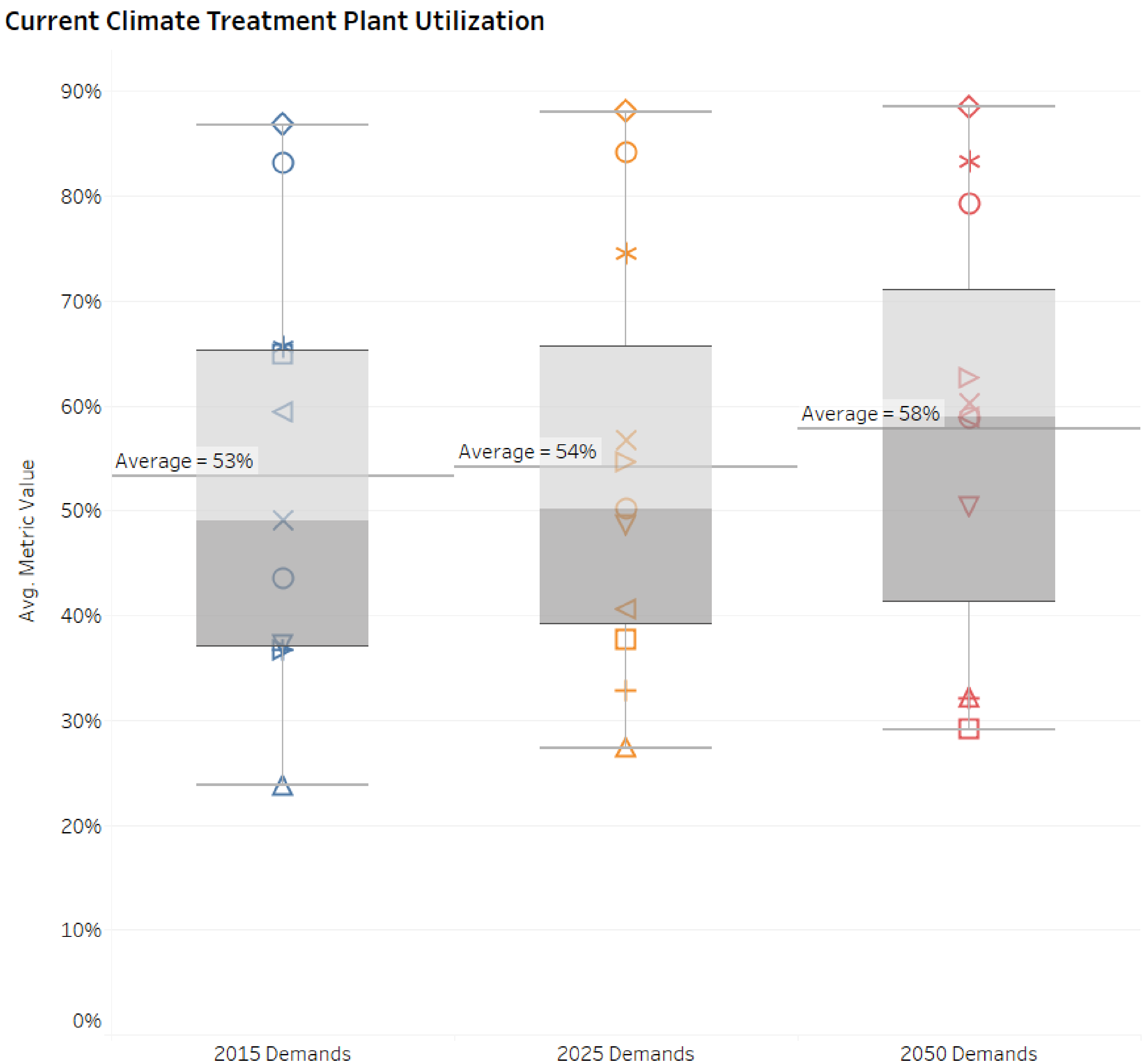


Figure 17. Treatment plant utilization for 2015, 2025, and 2050 demand scenarios with current climate

5.2.2. Hydroelectric Power

Hydroelectric power is generated in the San Diego region at Rancho Penasquitos hydroelectric facility and the Lake Hodges-Olivenhain pumped storage project to generate up to 44.5 megawatts of electricity. Water delivery consumes power for pumping groundwater, pumping water through the distribution system, desalination, and water treatment. Power generation can be used to offset the energy required to deliver water. Basin Study metrics describe regional power generation, consumption, and net power for SDCWA facilities. In current climate scenarios, hydropower generation increases slightly with the increases in demand between the 2015, 2025, and 2050 demand projections due to increased flows through the system. Power consumption also increases with increasing demand, as more energy is required to treat and deliver water (Figure 18). Overall, net energy consumption increases as demand increases, meaning that the increases in generation due to increased flows are insufficient to offset the increases in consumption. Because of the small differences in demands between current and future climate scenarios, energy generation, consumption, and net energy are very similar between current climate and climate change scenarios.

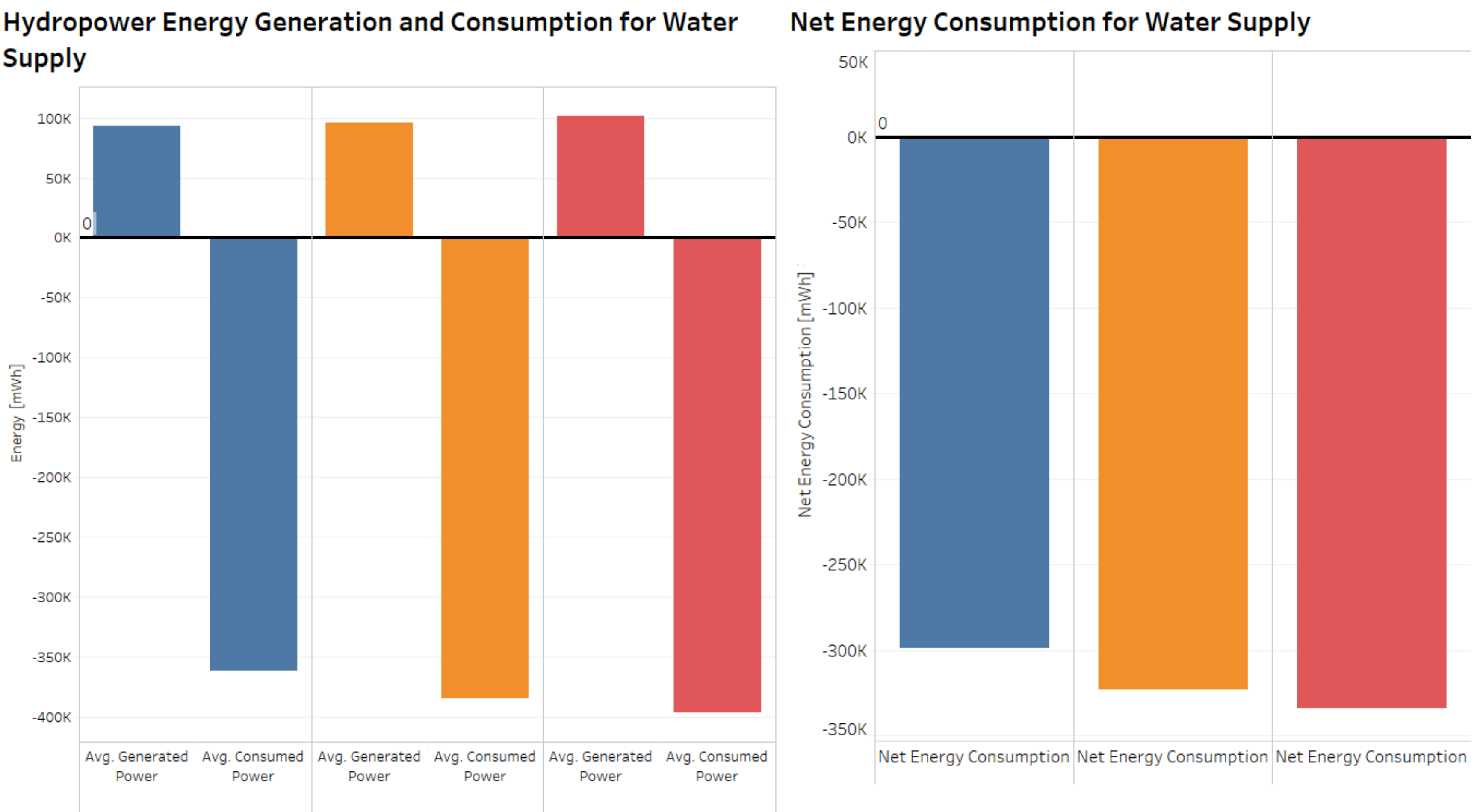


Figure 18. Average energy generation, consumption, and net consumption for 2015, 2025, and 2050 demand scenarios with current climate

5.2.3. Recreation

Although reservoirs in the San Diego region are not operated for recreation, recreation opportunities are an incidental benefit of reservoirs that may be impacted by climate change. Analysis of recreation impacts due to climate change in the San Diego region for the Basin Study focused on reservoir boat ramp accessibility. Impacts to other recreation-related metrics such as reservoir surface area or reservoir inflow for fishing, swimming, boating, and other recreational activities may also be affected by climate change, but parameters to relate those metrics to recreational impacts were not readily available for examination. Access to boat ramps was measured by the end of September reservoir elevation compared to the elevation of the lowest boat ramp at that reservoir (Figure 19). Boat ramps at San Vicente reservoir are accessible in all current climate scenarios. Hodges and El Capitan reservoirs generally are accessible for all demand projections under current climate scenarios. Lower Otay's elevation fluctuates around the level of the lowest accessible boat ramp, with years in all demand projection current climate scenarios dropping below the accessible level. Comparing across climate change scenarios, there are no obvious trends in boat ramp accessibility and climate change scenario.

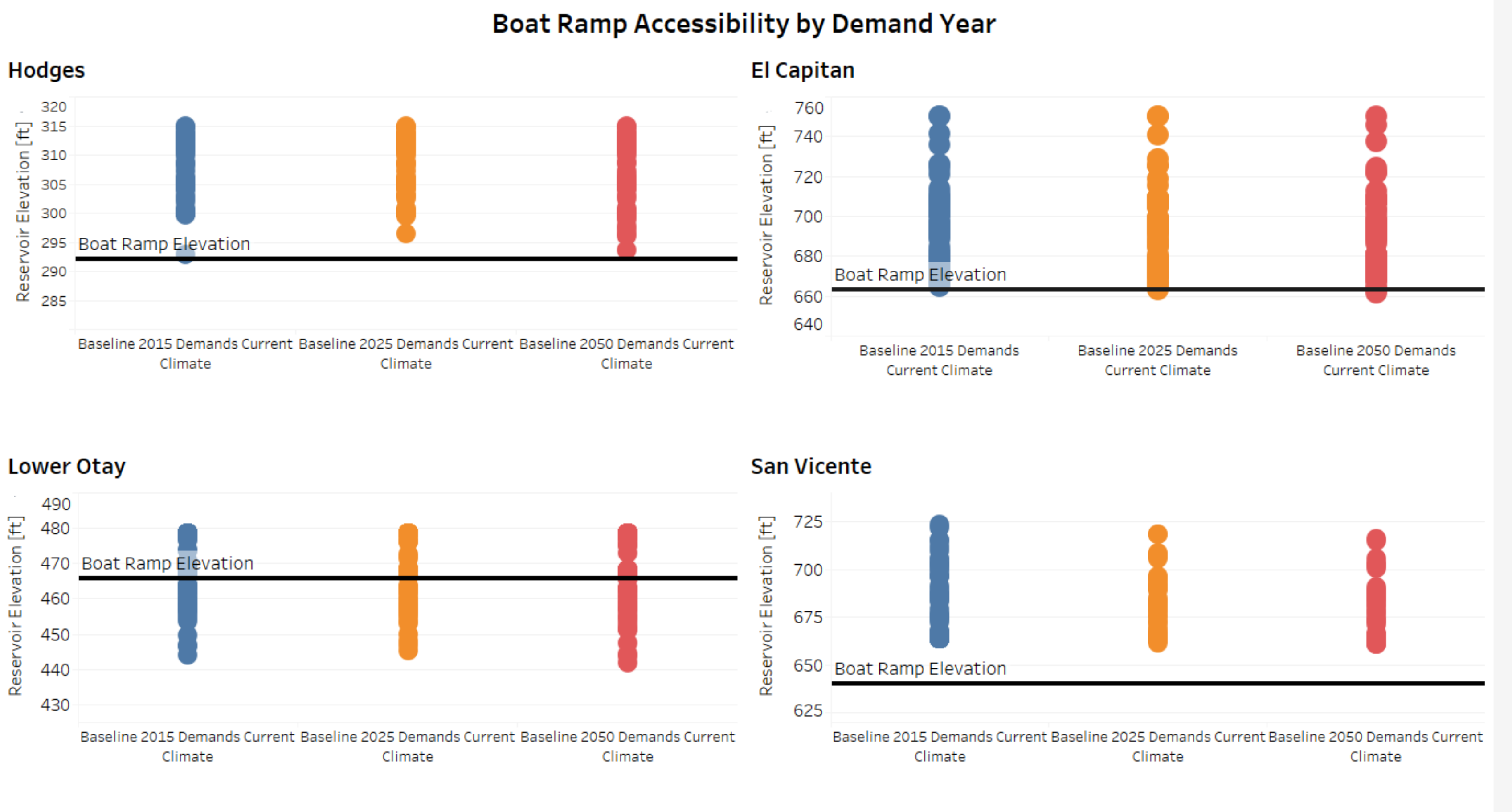


Figure 19. Boat ramp accessibility for current climate with 2015, 2025, and 2050 demand scenarios

5.2.4. Flood Control

Flood control impacts are measured by the number of spills from reservoirs that are not related to water deliveries and the average volume of those spills. In the San Diego region, reservoir releases are typically made only in response to water delivery requests. During situations of high inflows or high reservoir storage resulting from storms, water may spill from the reservoir in uncontrolled releases. Under Baseline 2015 demands and the current climate scenario, spills are relatively rare for San Diego region reservoirs, with Hodges having the most and largest spills. As demands increase in 2025 and 2050 projections, spills become slightly less frequent and smaller (Figure 21), likely as a result of lower reservoir storage providing more reservoir space to store high flows during storms. Comparing climate scenarios, there are no obvious trends with climate change scenarios.

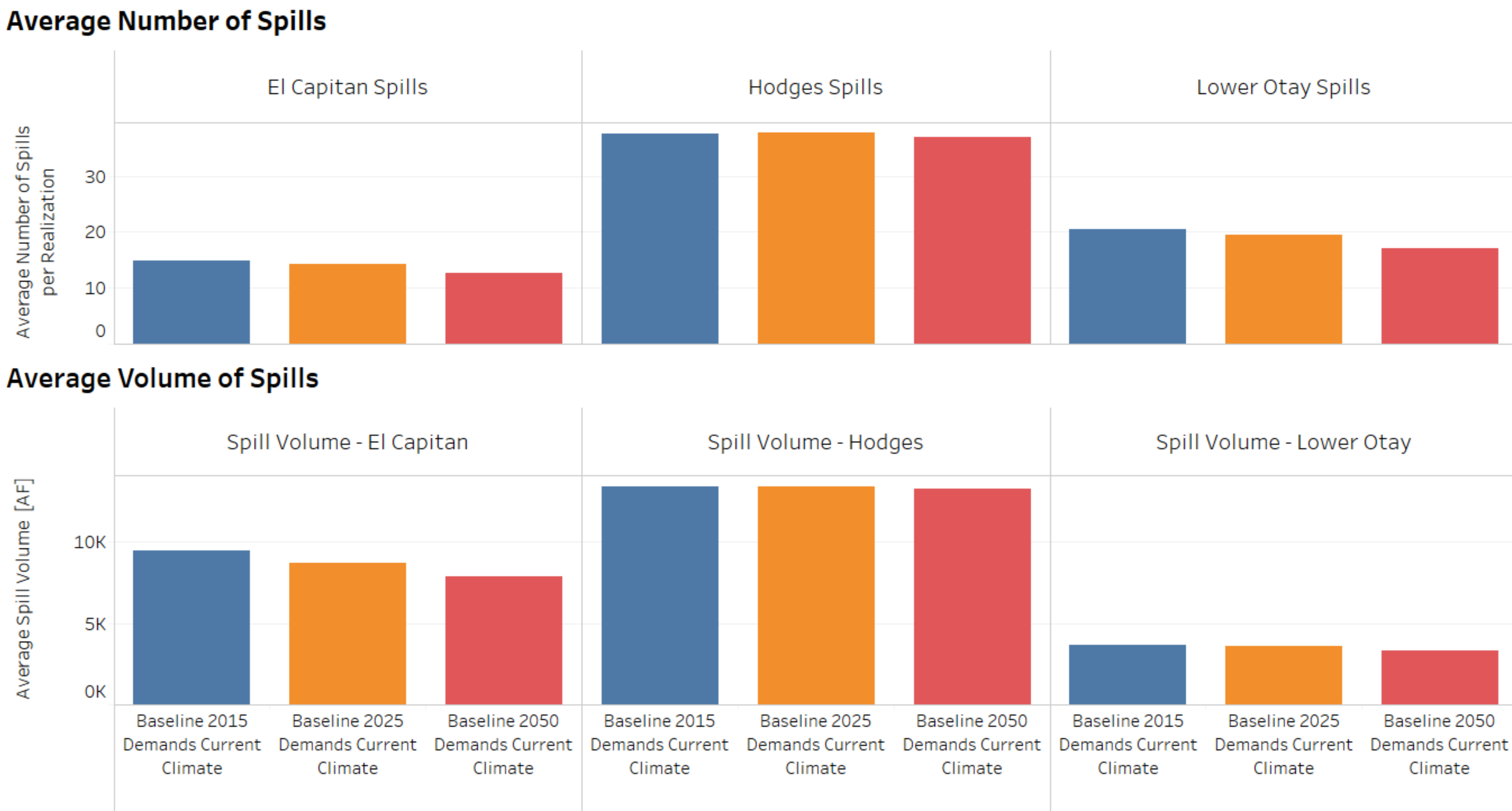


Figure 20. Average number and volume of spills for 2015, 2025, and 2050 demand scenarios with current climate

5.2.5. Environment

Impacts to environmental resources such as energy, greenhouse gases, fire, habitat, endangered species, biodiversity, ecosystems, and water quality are important considerations for water resources planning. No CWASim metrics were available to directly quantify environmental impacts; however, recent studies indicate how climate change may be expected to affect environmental resources in the San Diego region.

5.2.5.1. Energy and Greenhouse Gas Emissions

Anthropogenic greenhouse gas emissions have long been known to contribute to climate change, and water supply methods vary in the release of these emissions. A recent study (Stokes & Horvath, 2006) concluded that desalination had 2-5 times larger energy demand and caused 2-18 times more emissions than importing or recycling water due to the energy-intensity of the treatment process. While the Carlsbad Desalination plant is decreasing the potential adverse effects of climate change for the San Diego region by providing a reliable water source, the resulting increase in greenhouse gas emissions partially offsets the benefit of the desalinated water. As of 2008, and before planned upgrades that are projected to lower the carbon footprint of the Plant, the Carlsbad Desalination Project reported emissions of 97,165 metric tons of CO_2 per year. The water sector in general has yet to adopt a common carbon assessment methodology, making it difficult to compare the energy and emissions implications of adaptation strategies of the Carlsbad Project with other planned adaptation strategies in the San Diego region (Frijns, 2011).

Water resources and energy resources are interdependent. An immense amount of electricity is required to develop, treat, and transport water. And a large amount of water is required to produce that energy, regardless of the source (Sovacool, 2009); (Scott et al., 2011). Yet there is very little research available focusing on energy as the limiting factor, let alone adaptation and mitigation strategies (Racoviceanu et al., 2007).

Three of the main players in the San Diego water market have voluntarily taken on the responsibility of addressing the carbon impact of treating and supplying water. Poseidon Resources made a commitment in 2007 to render the Carlsbad Desalination Project net carbon neutral within 30 years and published a report summarizing the reduction strategy in 2008 (Poseidon Resources, 2007). The SDCWA voluntarily developed a Climate Action Plan with a goal of minimizing GHG emissions. The 2009 total GHG emissions for the agency was 5,837 metric tons with a target reduction of 15% by 2020, and the agency is on track to meet the state-aligned carbon reduction targets for 2035 (San Diego County Water Authority, 2015). The City of San Diego developed a Climate Action Plan with the intent of reducing greenhouse gas emissions. In 2015, City emissions were 17% below the 2010 baseline, well ahead of the target reduction in emissions set for 2020 (City of San Diego, 2016). The City of San Diego also developed a process to quantify energy use, energy intensity, and GHG emissions related to water management in order to identify energy saving opportunities, calculate greenhouse gas emission reductions associated with water conservation programs, and to inform climate mitigation strategies (City of San Diego, 2015).

5.2.5.2. Fire

The frequency of wildfires in the western U.S. is expected to increase in the next 30 years, and across the entire U.S. at the end of the century (Moritz et al., 2012). Ecosystems and watershed hydrology are expected to be impacted in the San Diego region due altered vegetative cover caused by wildfires and forest dieback. Coastal southern California is projected to have a longer fire season as a result of atmospheric circulation that controls the timing and extent of the Santa Ana winds (Miller & Schlegel, 2006). Lower moisture content is also expected to play a role in projected longer fire seasons as a reduction in fine fuel production will outweigh increased fuel flammability in low elevation grass and shrublands (Westerling & Bryant, 2008). Invasive species including the Gold Spotted Oak Borer *(Agrilus auroguttatus)* and the Shot Hole Borer *(Euwallacea sp.)* are contributing to the deaths of thousands of trees in San Diego County and are likely increasing the frequency and intensity of wildfires (Fire Safe Council of San Diego, 2017).

5.2.5.3. Habitat Loss/ Endangered and/or Threatened Species

The City of San Diego, through the Multiple Species Conservation Program, implemented the Multi-Habitat Planning Area (MHPA) in 1997. The MHPA was developed in cooperation with wildlife agencies, property owners, developers, and environmental groups. The MHPA delineates core biological resource areas and corridors targeted for conservation and covers approximately 56,831 acres furthering their commitment to habitat protection (City of San Diego, 1997).

In the same year, San Diego County also developed a Multi Species Conservation Plan (MSCP) for the purpose of providing large, connected preserve areas to provide protected habitat for rare, threatened and endangered species in the region. The MSCP is an agreement among landowners, local governments, and other stakeholders identifying the most critical area for threatened or endangered species and provides a plan for the general public benefit through open space conservation and access to natural preserves (San Diego County, 1997). The San Diego Management and Monitoring Program has implemented a strategic plan to inspect occurrences and determine management needs of 17 species of rare plants and to assess habitat issues and potential threats. The project will be used to develop specific management recommendations and prioritize funding (San Diego Management and Monitoring Program, 2017). San Diego County reported a net habitat gain of 1,234 acres in 2015 while the City of San Diego reported a net habitat gain of 40 acres in the same year (California Department of Fish & Wildlife, 2015).

Yet habit loss has been found to impact a number of species in the San Diego region. The Coastal California gnatcatcher (*Polioptila californica californica*), a small blue-gray songbird known to occur in the San Diego Bay Wildlife Refuge, is currently listed as threatened due to habitat loss and fragmentation as well as other management issues such as fire and nonnative plants. The Least Bell’s Vireo (*Vireo bellii pusillus*) bird and the Quino Checkerspot butterfly (*Euphydryas editha quino (=e. e. wrighti)*), both known to occur in the San Diego National Wildlife Refuge, are listed as endangered primarily due to loss of habitat driven by anthropogenic modification. The California Spotted Owl (*Strix occidentalis occidentalis*) is known to exist in the San Diego area and is currently under review to be federally listed as endangered due to habitat loss (U.S. Fish & Wildlife Service, 2016). The San Diego Cactus Wren *(C.b. sandiegenis)* bird, a subspecies of the Coastal Cactus Wren *(Campylorhynchus brunneicapillus)*, is presently listed as a California State Species of Special Concern due to anthropogenic habitat loss and fire (Solek & Szijj, 2004). The City of San Diego implemented a conservation and management plan for the years 2017 through 2021 for the Cactus Wren with the goal of rehabilitating habitat, improving connectivity between genetic clusters, and managing high risk anthropogenic predation of adults and nestlings (San Diego Management & Monitoring Program, 2017).

Other species in the San Diego region could be impacted by warming temperatures and decreased precipitation. The Joshua tree (*Yucca brevifolia*) is projected to have a substantially contracted range due to rapidly increasing temperatures and is expected to decline throughout the southern portion of the current range which includes San Diego County (Cole et al., 2011). Although not federally listed as threatened or endangered, the Torrey pine (*Pinus torreyana Parry*) is considered rare or endangered in California by the California Native Plant Society (Holland, 1986). The pine has a natural distribution including a mainland population in California near the Torrey Pines State Reserve in San Diego County, and another population on Santa Rosa Island off the coast of California. Due to low genetic variability, the Torrey pine has little capacity to respond to threats by natural selection, but has been known to adapt to harsh environments of poor soils and little moisture.

5.2.5.4. Native Species/Biodiversity/Ecosystems

Climate change has the potential to negatively impact many native species in the San Diego region. For example, the future bird assemblages in southern California are expected to have a lower species richness as well a low similarity between current and future bird assemblages (Wiens et al., 2009). This lower species richness could potentially provide important implications for wildlife management and could limit biodiversity. Similarly, freshwater ecosystems are expected to adapt to climate change, but the adaptation will likely entail a diminishment of native biodiversity (Allan et al., 2005). Warmer water temperatures in the San Diego region have the potential to exacerbate ecosystem health through an increase in invasive species (Pyke et al., 2008). Quagga mussels, an aquatic invasive species, have already been found in San Vicente Reservoir and Lake Dixon.

The California Department of Fish and Wildlife analyzed the impact of climate change on the natural and vegetation community in California and projected the impact to the year 2100. Vegetation was classified into 31 categories called ‘macrogroups’ covering 99.87% of the state’s natural terrestrial vegetation. The projected climate related impacts were organized in the following categories: 1) Low; 2) Moderate; 3) Mid-High; and 4) High (Thorne et al., 2016). A summary of the common and macrogroup names found in San Diego County as well as the corresponding mean conservative estimate of risk related to climate change is shown in Table 28.

Table 28. San Diego Region Natural and Vegetation Community Vulnerability Rank

Common Name	Macrogroup Name	Mean Vulnerability Rank
Great Basin Juniper-Pinyon	All mixed pinyon and juniper stands in trans-montane California	Mid-High
Coastal Sage Scrub	California Coastal Scrub	Mid-High

Common Name	Macrogroup Name	Mean Vulnerability Rank
California Grassland and Flowerfields	California Annual and Perennial Grassland	Mid-High
Wet Mountain Meadow	Western North America Wet Meadow and Low Shrub	Mid-High

Increases in temperature and drought likely have influenced an increase in insect outbreaks as climate change has appeared to have affected forest insect species range and abundance through changes in survival rates. Increases in life cycle development rates and the effects of host plant capacity to resist attack are also expected to impact ecosystem health (Ryan et al., 2008). Ecologically fragile coastlines are also in jeopardy of being damaged or destroyed due to rising sea levels caused by climate change. While rates of increase have been found to vary in California, the sea level is increasing almost everywhere across the state (Cayan et al., 2008) and is expected to rise along the Southern California coast at the same rate as the global estimates (Rahmstorf, 2007). Under moderate sea level rise scenarios, the San Diego Region is expected to experience a loss of recreational facilities and critical habitat including beaches and rocky shores. Some areas such as Cabrillo National Monument and Scripps Coastal Reserve are expected to lose much of their intertidal habitats as well since there is no room in these areas for species to move inward. This loss of habitat and species composition may also affect marine productivity and fisheries (California Climate Change Center, 2009).

San Diego area ecosystems have already been impacted by invasive species such as the Yellow Star Thistle (*Centaurea solstitialis*), which currently infests between 10-15 million acres in southern California, choking native plants and reducing biodiversity and wildlife habitat and forage. Another impact to the southern California ecosystem has been the Glassy-Winged Sharpshooter (*Homalodisca vitripennis*) which has infested six counties in southern California including San Diego County and is responsible for outbreaks of Pierce's disease. The impact of invasive species could be exacerbated in the region due to altered climate constraints, and the changes could decrease the effectiveness of chemical or biological agents used to control invasive species. Five possible consequences of climate change for invasive species include: 1) altered mechanisms of transport; 2) altered climatic constraints on invasive species; 3) altered distribution of existing invasive species; 4) altered impact of existing invasive species; and 5) altered effectiveness of management strategies for invasive species (Hellmann et al., 2008). These potential consequences emphasize the need for enhanced environmental monitoring and invasive-species management. The San Diego Association of Governments (SANDAG) in collaboration with the San Diego Management & Monitoring Program (SDMMP) published a report in 2012 identifying invasive species management strategies for the Crestridge Ecological Reserve and South Crest Properties including the following four tasks: 1) Invasive Species Mapping; 2) Covered Species Mapping; 3) Invasive Plant Control; and 4) Early Detection Plan. The report is part of SDMMP's mission to coordinate science-based, biological management and monitoring of lands in San Diego that have been conserved through various conservation planning and mitigation efforts (San Diego Management & Monitoring Program, 2012).

5.2.5.5. Water Quality

Local and regional efforts have been put in place by various agencies in the San Diego region to improve water quality. For example, the City of San Diego implemented a Municipal Code in 1994 to maintain the water quality of receiving waters by prohibiting non-stormwater discharges and reducing pollutants in discharges to the maximum extent possible (San Diego Municipal Code, 1994). The Think Blue campaign was also launched in 2001 to help educate residents, businesses, and industry leaders about the effects of stormwater pollution and provide ways to prevent that pollution from harming the environment (City of San Diego, 2017). The San Diego Public Utilities department has also created source water protection guidelines serving as a roadmap for sensible development, increasing the reliability of the water supply system, and reducing the cost of drinking water treatment through building upon existing land use, zoning, and building code regulations (City of San Diego Water Department, 2004). In 2015, the City published the fourth update to the Watershed Sanitary Survey to identify actual or potential origins of local source water contamination which might adversely affect the quality and treatability of water used as a domestic supply (City of San Diego, 2015). Regionally, Project Clean Water was initiated in 2000 to provide a broad and inclusive forum for exploring water quality issues of regional significance and has served as a resource to both governmental agencies and the general public (Project Clean Water, 2017).

In the San Diego region, abrupt nonlinear ecosystem changes have been observed due to increased regional aridity related to climate change. These changes have been found to degrade water quality due to sediment deposition behind reservoirs, altered mountain snowpack melt and runoff rates, as well as dust potentially transported from disturbed areas to distant mountains (Painter et al., 2007). As the climate warms, algae growth could potentially result in eutrophic conditions of lakes, degrading water quality and potentially altering species composition (Lettenmaier et al., 2008). The quality of water in Hodges Reservoir has been diminished due to eutrophic conditions resulting from algae production from nutrient loading as well as several other water quality impairments. In 2014, the City of San Diego Public Utilities Department, among other Lake Hodges stakeholders, prepared a strategic plan to decrease algae production while addressing nonattainment issues.

6. Conclusion

The key objectives of Task 2.3 of the San Diego Basin Study were to identify water supply and demand imbalances for current and future climate conditions, and current and future demands under baseline water system infrastructure within the Study Area. Impacts on water delivery, hydroelectric power, recreation, and flood control were described with metrics calculated from model simulations. Environmental impacts were described in a literature review in Section 5.2.5.

Water Delivery
Demands increase in the future due to demographic and economic changes and vary between Climate Scenarios. Baseline water deliveries increased to meet demands. Reliance on imported water purchased from MWD was also found to increase. Water shortages occurred more frequently and were found to be larger in magnitude under future demand scenarios. Treatment plant utilization is expected to increase under future demand scenarios with minimal difference between climate scenarios. Conveyance system limitations could contribute to water shortages.

Hydroelectric Power
Energy generation was found to increase slightly with increased water demand. As demands increase in the future, energy use is also expected to increase. The result is an expected increase in net energy consumption as more energy is required to treat and distribute water.

Recreation
Reservoir natural inflows were found to vary between years and within years. Boat ramps were found to typically remain accessible, yet may become inaccessible at some reservoirs from time to time.

Flood Control
The number and volume of flood releases or spills (not for water supply) were found to decrease in the future. This decrease is likely the by-product of lower reservoir storage volumes, which result in more available reservoir capacity to store larger flows during storm events.

7. References

Allan et al. (2005). Overfishing of Inland Waters. *BioScience*.

California Climate Change Center. (2009). *Climate Change-Related Impacts in the San Diego Region by 2050.*

California Deparment of Fish & Wildlife. (2015). *Summary of Habitat Losses and Gains.*

California State Legislature. (2008). The Metropolitan Water District Act. Office of the General Counsel of The Metropolitan Water District of Southern California.

Cayan et al. (2008). Climate Change Projections of Sea Level Extremes along the California Coast . *Climate Change*.

City of San Diego. (1997). *City of San Diego: MSCP Subarea Plan.* https://www.sandiego.gov/sites/default/files/legacy//planning/programs/mscp/pdf/subarea fullversion.pdf.

City of San Diego. (2015). *Urban Water Management Plan.*

City of San Diego. (2015). *Watershed Sanitary Survey.*

City of San Diego. (2016). *Climate Action Plan: 2016 Annual Report.*

City of San Diego. (2017, 05 09). Retrieved from https://www.sandiego.gov/thinkblue/

City of San Diego Public Utilities. (2014). *Lake Hodges Reservoir Water Quality Assessment Study: Final Conceptual Planning Report.*

City of San Diego Water Department. (2004). *Source Water Protection Guidelines for New Development.*

CMIP3. (2007). World Climate Research Programme (WCRP). *Coupled Model Intercomparison Project Phase 3 (CMIP 3) multi-model dataset*.

CMIP5. (2013). *Downscaled CHIP3 and CHIP5 Climate Projections.*

Cole et al. (2011). Past and ongoing shifts in Joshua tree distribution support future modeled range contraction. *Ecological Applications: Ecological Society of America*.

Department of Interior. (2007). *Interim Guidelines for the Operation of Lake Powell and Lake Mead.*

Fire Safe Council of San Diego. (2017, 05 04). Retrieved from http://firesafesdcounty.org/resources/tree-and-forest-health/

Frijns. (2011). Towards a common carbon footprint assessment methodology for the water sector. *Water and Environment Journal*.

Hellmann et al. (2008). Five Potential Consequences of Climate Change for Invasive Species. *Conservation Biology*.

Holland. (1986). Preliminary descriptions of the terrestrial natural communities of California.

Intergovernmental Panel on Climate Change. (2007). *Climate Change 2007: Synthesis Report.*

Lettenmaier et al. (2008). The effects of climate. *The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States*.

Metropolitan Water District of Southern California. (2016). *Integrated Water Resources Plan: 2015 Update (Report No. 1518).*

Miller & Schlegel. (2006). Climate change projected fire weather sensitivity: California Santa Ana wind occurrence. *Geophysical Research Letters: An AGU Journal* .

Moritz et al. (2012). Climate change and disruptions to global fire activity . *Ecosphere: An ESA Open Access Journal*.

Otay Water District. (2017, 06 09). *Rosarito Desalination*. Retrieved from Rosarito Desalination and Otay Mesa Conveyance and Disinfection System Project website: http://otaywater.gov/about-otay/water-information/desalination/rosarito-desalination/

Painter et al. (2007). Impact of disturbed desert soils on duration of mountain snow cover. *Geophysical Research Letters: An AGU Journal*.

Poseidon Resources. (2007). Carlsbad Desalination Plant. *Climate Action Plan*.

Project Clean Water. (2017, 05 09). Retrieved from http://www.projectcleanwater.org/

Pyke et al. (2008). Current Practices and Future Opportunities for Policy on Climate Change and Invasive Species. *Conservation Biology*.

QSA. (2003). *Quantification Settlment Agreement by and among Imperial Irrigation District, the Metropolitan Water District of Southern Califronia, and Coachella Valley Water District*.

Racoviceanu et al. (2007). Life-Cycle Energy Use and Greenhouse Gas Emissions Inventory for Water Treatment Systems. *Journal of Infrastructure Systems: Vol. 30, Issue 4*.

Rahmstorf. (2007). A Semi-Empirical Approach to Projecting Future Sea-Level Rise. *Science*.

Reclamation. (2012). *Colorado River Basin Water Supply and Demand Study.* U.S. Bureau of Reclamation.

Reclamation. (2016). *Reclamation Manual: Basin Studies Directives and Standards.* WTR 13-01.

Reclamation. (2016). *Sacramento and San Joaquin Rivers Basin Study*. U.S. Bureau of Reclamation .

Reclamation. (2012). *Colorado River Basin Water Supply and Demand Study.*

Ryan et al. (2008). The Effects of climate change on Agriculture, Land Resources, Water Resources, and Biodiversity in the U.S. . *Land Resources*.

San Diego County. (1997). *Multiple Species Conservation Program (MSCP) Plan.* http://www.sandiegocounty.gov/content/sdc/pds/mscp/overview.html.

San Diego County Water Authority. (2013). *2013 Regional Water Facilities Optimization and Master Plan.*

San Diego County Water Authority. (2015). Climate Action Plan.

San Diego County Water Authority. (2016). *Final 2015 Urban Water Management Plan.*

San Diego County Water Authority. (2017, 07 31). Retrieved from http://www.sdcwa.org/metropolitan-water-district-approves-water-supply-cutbacks-significant-rate-hike; http://www.sdcwa.org/mobile/drought-conditions.html

San Diego Management & Monitoring Progam. (2012). *Covered and Invasive Species Management: Crestridge Ecological Reserve and South Crest Properties.* https://portal.sdmmp.com/upload/projects/20160330_2357_99.pdf.

San Diego Management & Monitoring Program. (2017, 05 09). *https://portal.sdmmp.com/*. Retrieved from https://portal.sdmmp.com/tracker.php?Target=species&Species=917698&ActionStatus=&ManagementUnit=&ObjectiveType=&Year=&Preserve=&Short=Long&submit

San Diego Management and Monitoring Program. (2017, 05 04). *Rare Plant Inspect and Manage Monitoring 2014-2018*. Retrieved from https://portal.sdmmp.com/view_project.php?sdid=SDID_sarah.mccutcheon%40aecom.com_57cf0196dff76

San Diego Municipal Code. (1994, 03 08). *Chapter 4: Health and Sanitation*. Retrieved from http://docs.sandiego.gov/municode/MuniCodeChapter04/Ch04Art03Division03.pdf

SANDAG. (2013). *Series 13: 2050 Regional Growth Forecast.* Retrieved from http://www.sandag.org/index.asp?classid=12&subclassid=84&projectid=503&fuseaction=projects.detail

Scott et al. (2011). Policy and institutional dimensions of the water–energy nexus. *Energy Policy: Volume 39, Issue 10*.

Solek & Szijj. (2004). *The Coastal Scrub and Chaparral Bird Conservation Plan.* California Partners in Flight. Retrieved from http://www.prbo.org/calpif/htmldocs/scrub.html.

Sovacool. (2009). Running on empty: The electricity-water nexus and the US electric utility sector. *Energy LJ 30*.

Stokes & Horvath. (2006). Life Cycle Energy Assessment of Alternative Water Supply Systems. *The International Journal of Life Cycle Assessment*.

Taylor et al. (2012). An Overview of CMIP5 and the Experiment Design.

Thorne et al. (2016). A Climate Change Vulnerability Assessment of California's Terrestrial Vegetation. *California Department of Fish and Wildlife*.

U.S. Fish & Wildlife Service. (2016). ECOS: Environmental Conservation Online System.

Westerling & Bryant. (2008). Climate change and wildfire in California. *Climatic Change, 87(1)*.

Wiens et al. (2009). Niches, models, and climate change: Assessing the assumptions and uncertainties. *Proceedings of the National Academy of Sciences of the United States of America*.

Appendix A. Baseline Run Results

The following sections contain summaries of descriptive and impact metric results and associated graphs illustrating results. Descriptive results summaries are contained in blue boxes divided into four sections as described in Table A1. Impact metrics descriptions are in light green boxes. Impact results summaries are in dark green boxes divided as described in Table A1.

Table A1. Description of box contents

2015 Demands Current Climate Conditions	Summary of B2015-cc scenario
Current Climate Comparison between Demand Projections	Comparison between B2015-cc, B2025-cc, B2050-cc scenarios
Climate Change Scenario Comparison	Comparison between B2025-cc, -ct-2020s, -ww-2020s, -wd-2020s, -hw-2020s, and -hd-2020s scenarios. Comparison between B2050-cc, -ct-2050s, -ww-2050s, -wd-2050s, -hw-2050s, -hd-2050s scenarios.
Notes and Other Findings	Additional information

Table A2. List of Boxes

Box Name | Page

Baseline Run Descriptive Results

Baseline Run Descriptive Results - Water Deliveries

Box 1. Summary of Findings: Water Deliveries

Summary of Findings: Water Deliveries	
2015 Demands Current Climate Conditions	Imported water (QSA plus imported purchases) makes up the largest share of deliveries.
Current Climate Comparison between Demand Projections	• Deliveries increase to meet increasing demands. • No change in desalination or surface water. • Small changes in recycled water, groundwater, and desalination delivery volumes. • Large increases in imported MWD purchases
Climate Change Scenario Comparison	• Current climate deliveries are smaller than deliveries in climate change scenarios • For the 2020s, dry scenario deliveries are slightly larger than wet scenario deliveries • For the 2050s, wet scenario delivers are larger than dry scenario deliveries • Differences between scenarios are larger for 2050s climate than 2020s climate
Notes and Other Findings	None

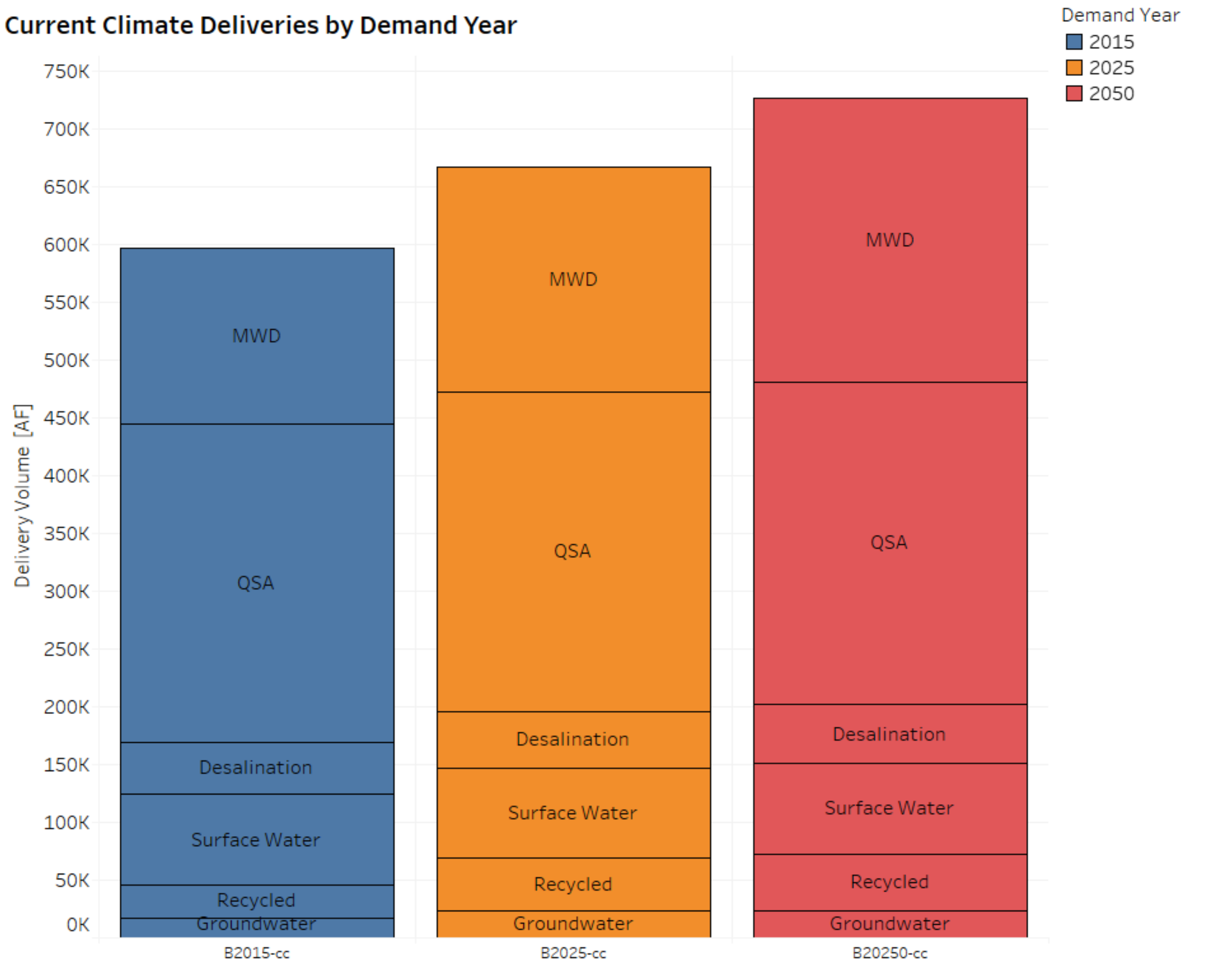


Figure A1. Water deliveries by supply type for 2015, 2025, and 2050 demands with current climate scenarios.

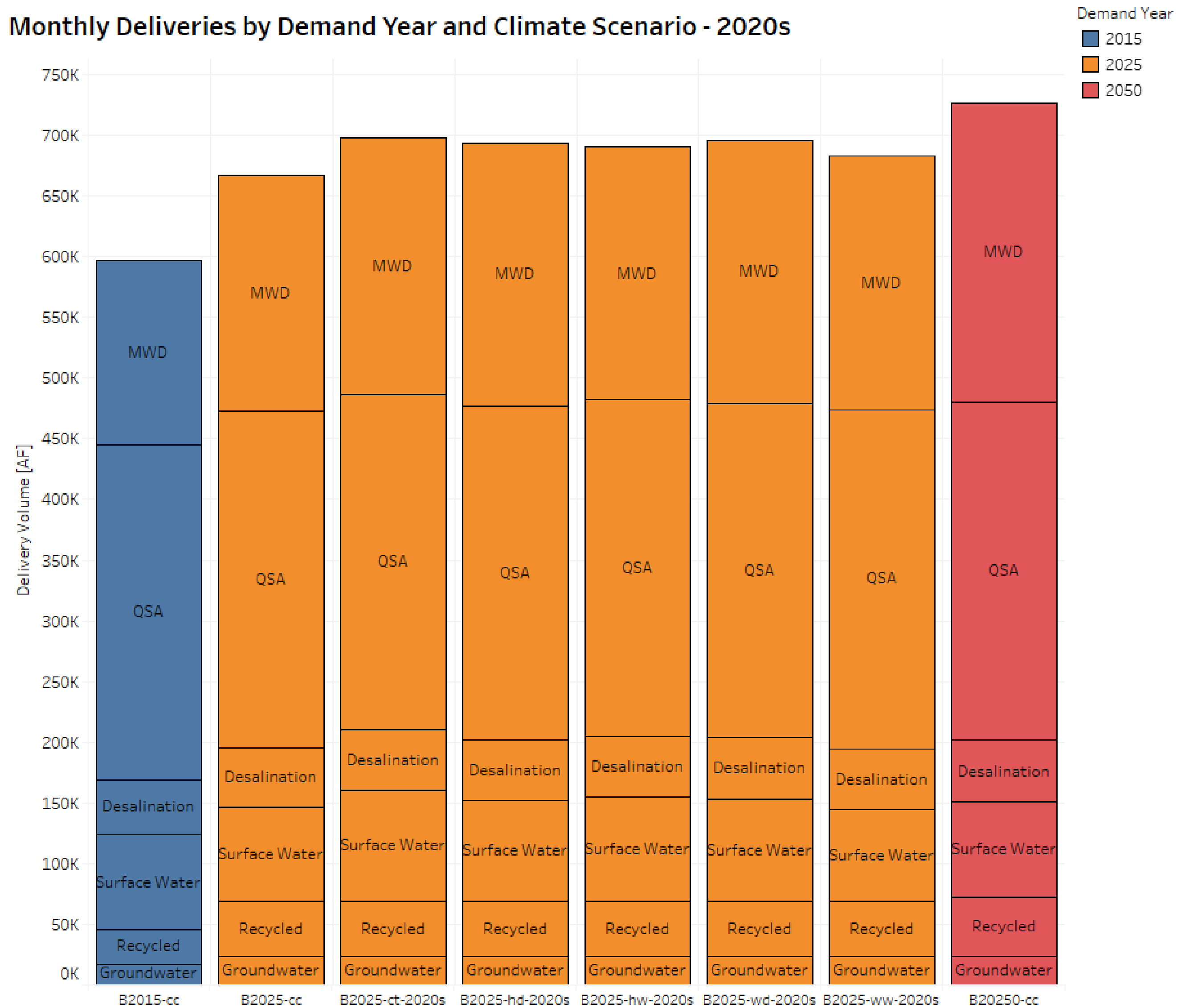


Figure A2. Total average delivery volumes for 2015, 20205, and 2050 demands with current climate and 2025 demands with climate change scenarios.

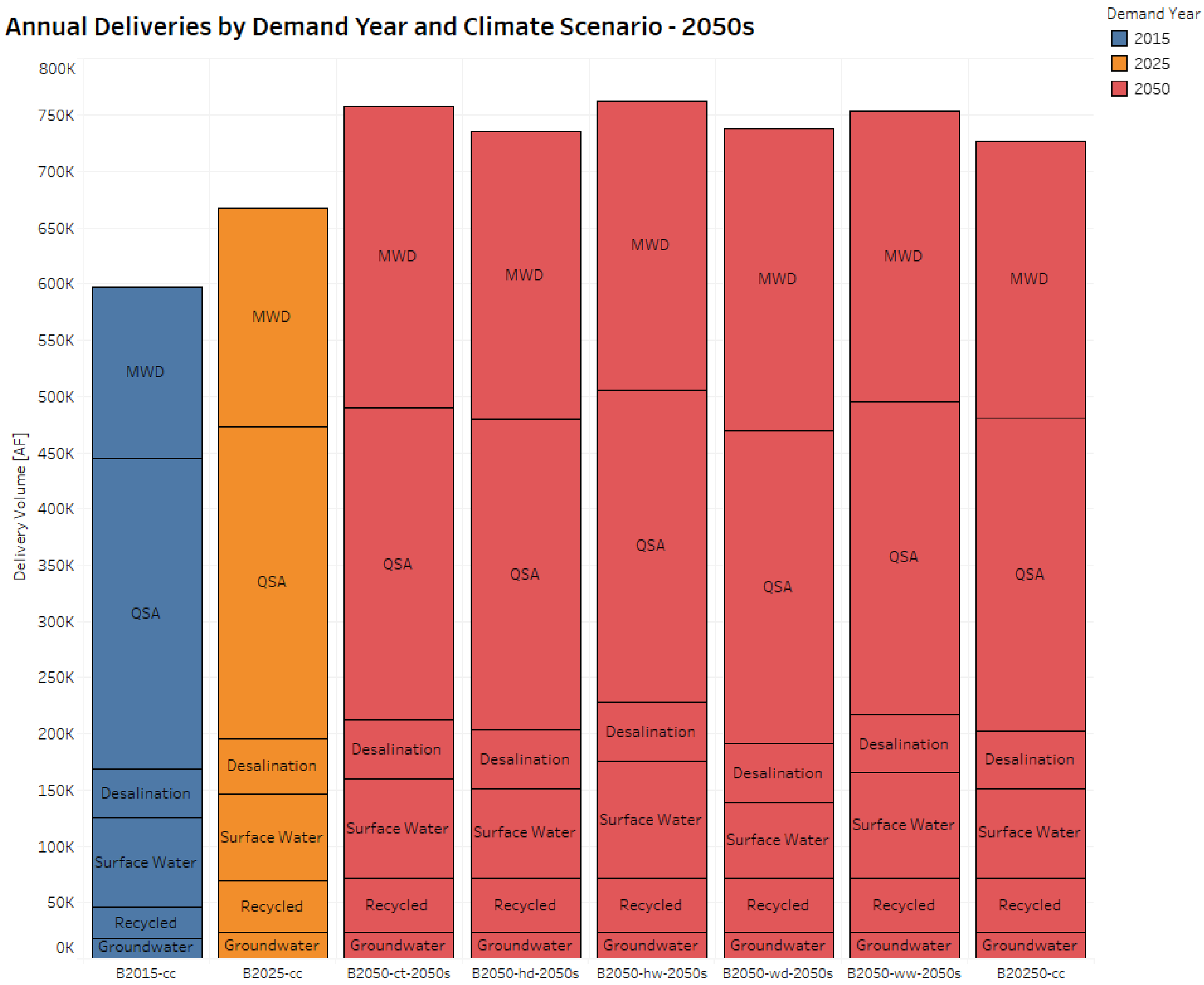


Figure A3. Total average delivery volumes for 2050 demands and 2050s climate change scenarios shown with current climate deliveries for 2015, 2025, and 2050 demand years.

Baseline Run Descriptive Results - Reservoir Operations

Box 2. Summary of Findings: Reservoir Operations

Summary of Findings: Reservoir Operations	
2015 Demands Current Climate Conditions	Reservoir storage generally peaks in March or April and declines through December for most reservoirs
Current Climate Comparison between Demand Projections	Storage • El Capitan and San Vicente have the largest storage difference between Demand years Releases • Releases generally follow the same pattern for all demand years
Climate Change Scenario Comparison	Storage • No significant difference between climate scenarios Releases • No significant difference between climate scenarios
Notes and Other Findings	None

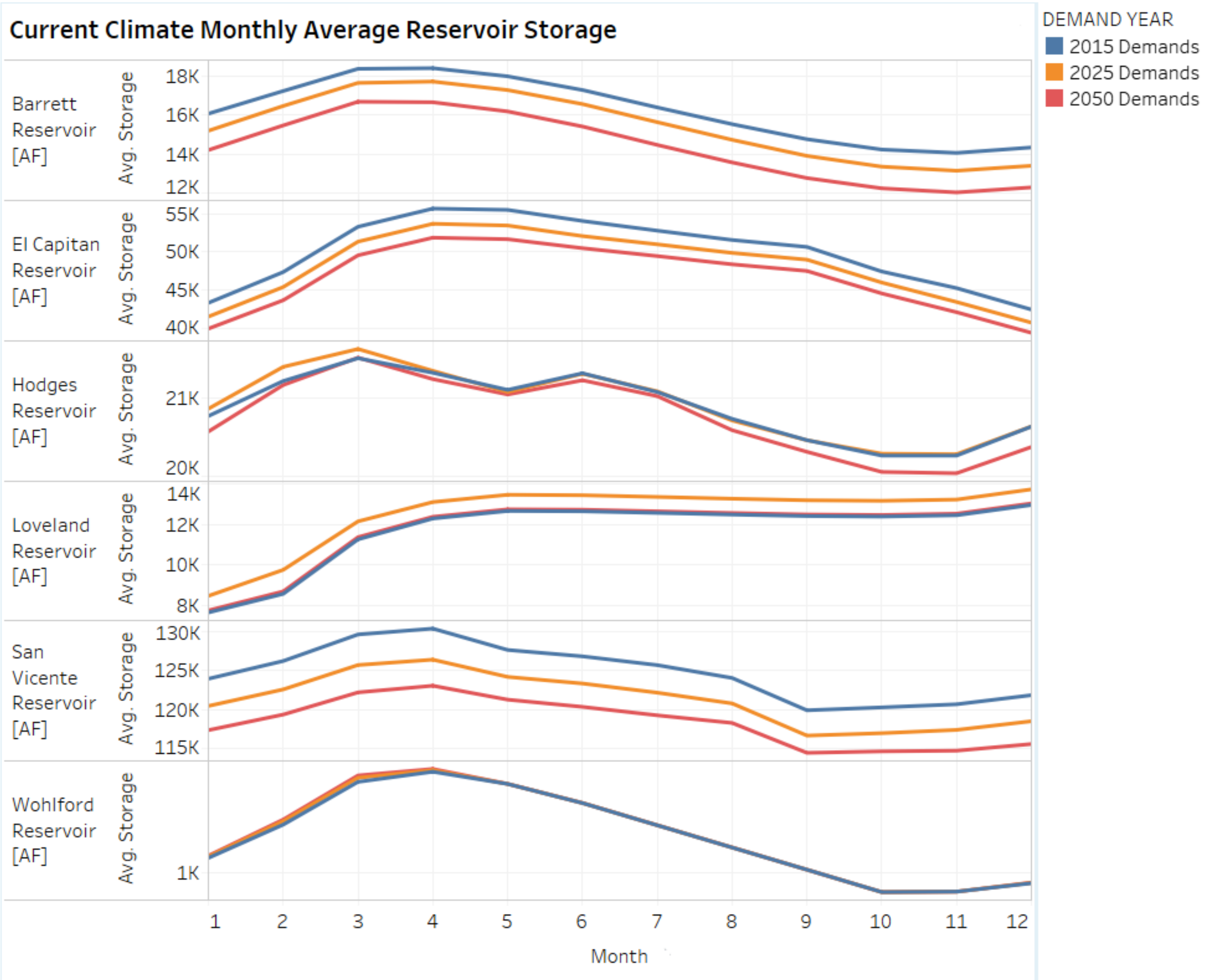


Figure A4. Monthly average reservoir storage for 2015, 2025, and 2050 demands with current climate.

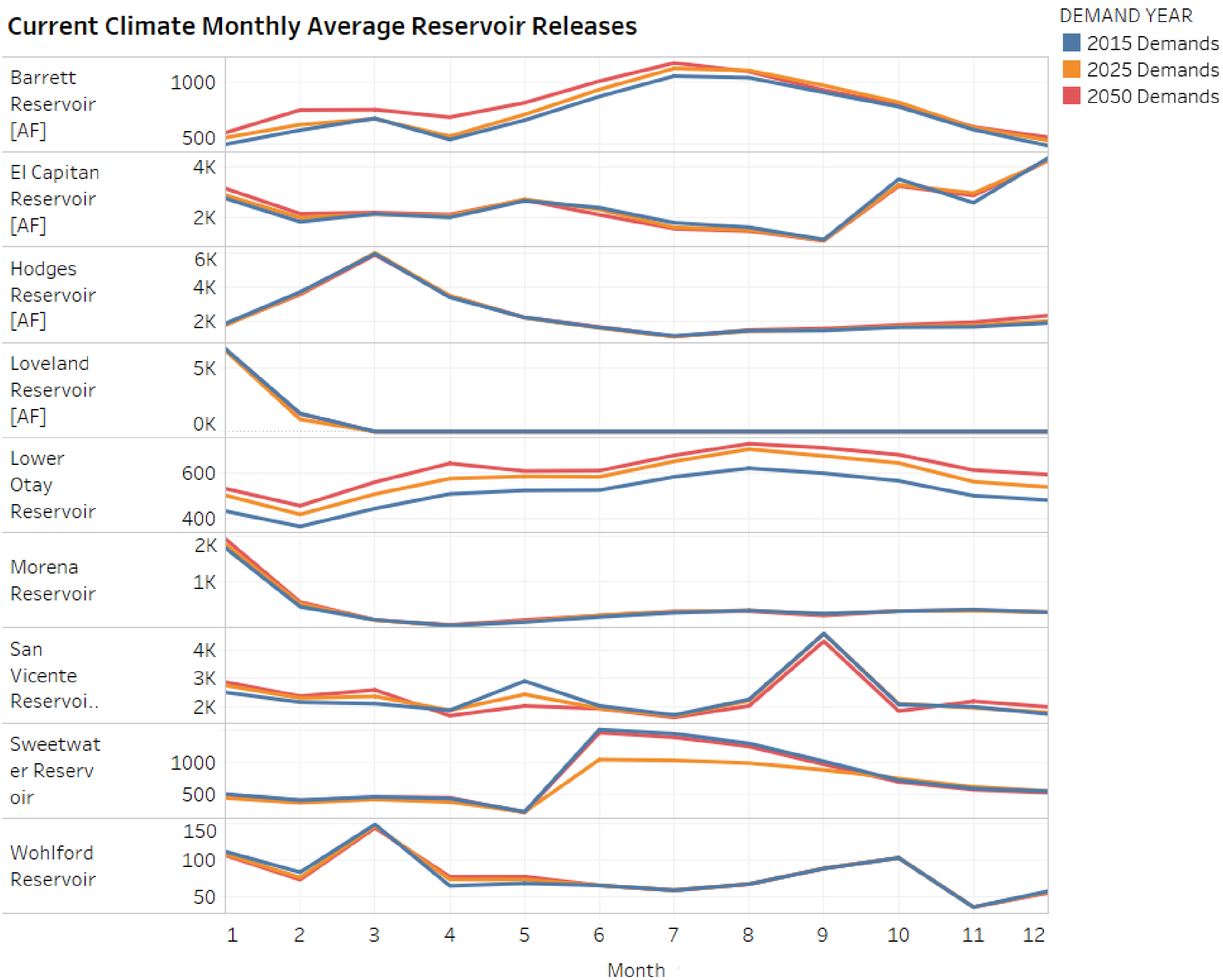


Figure A5. Monthly average reservoir releases for 2015, 2025, and 2050 demands with current climate.

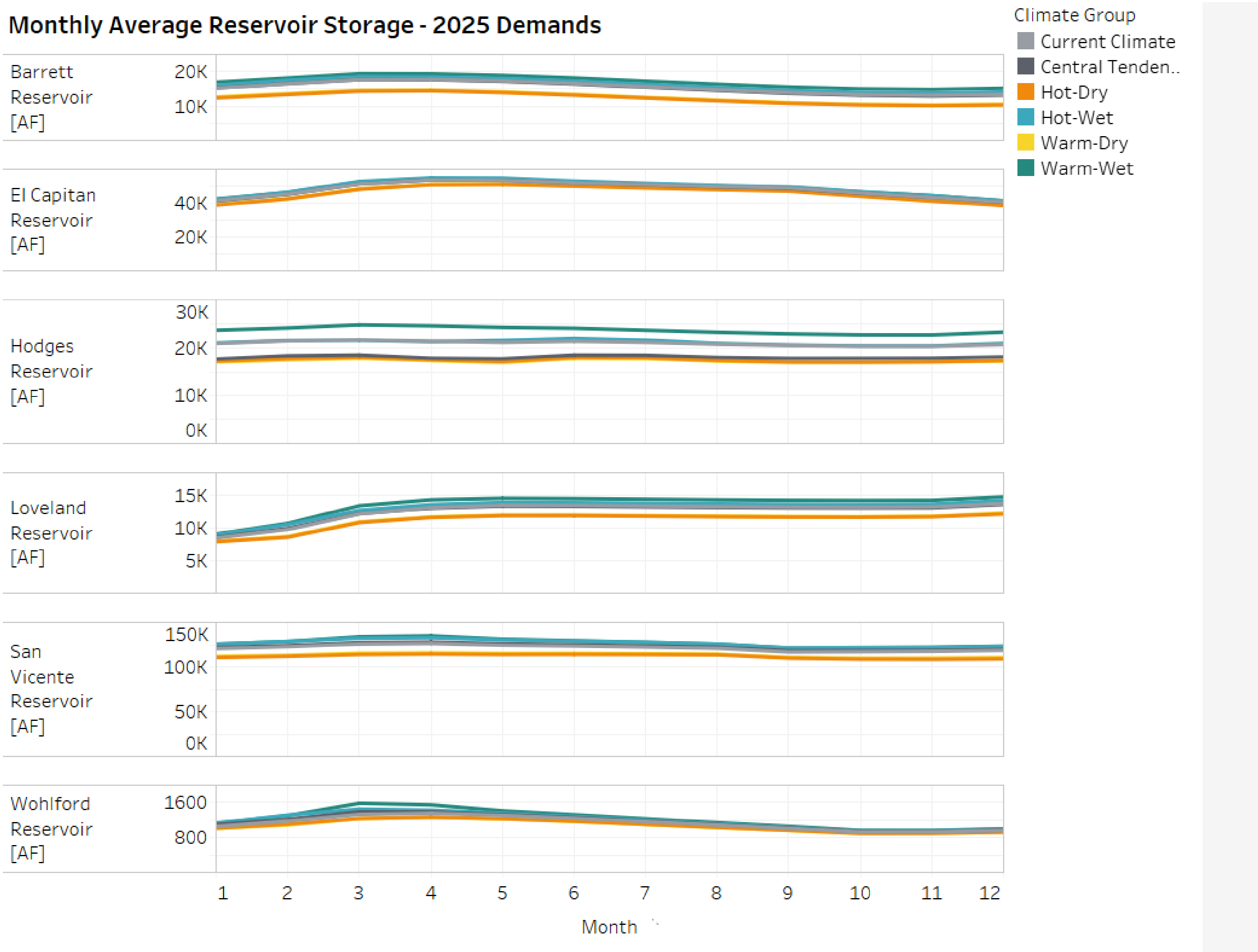


Figure A6. Monthly average reservoir storage for 2025 demands with current climate and 2020s climate scenarios.

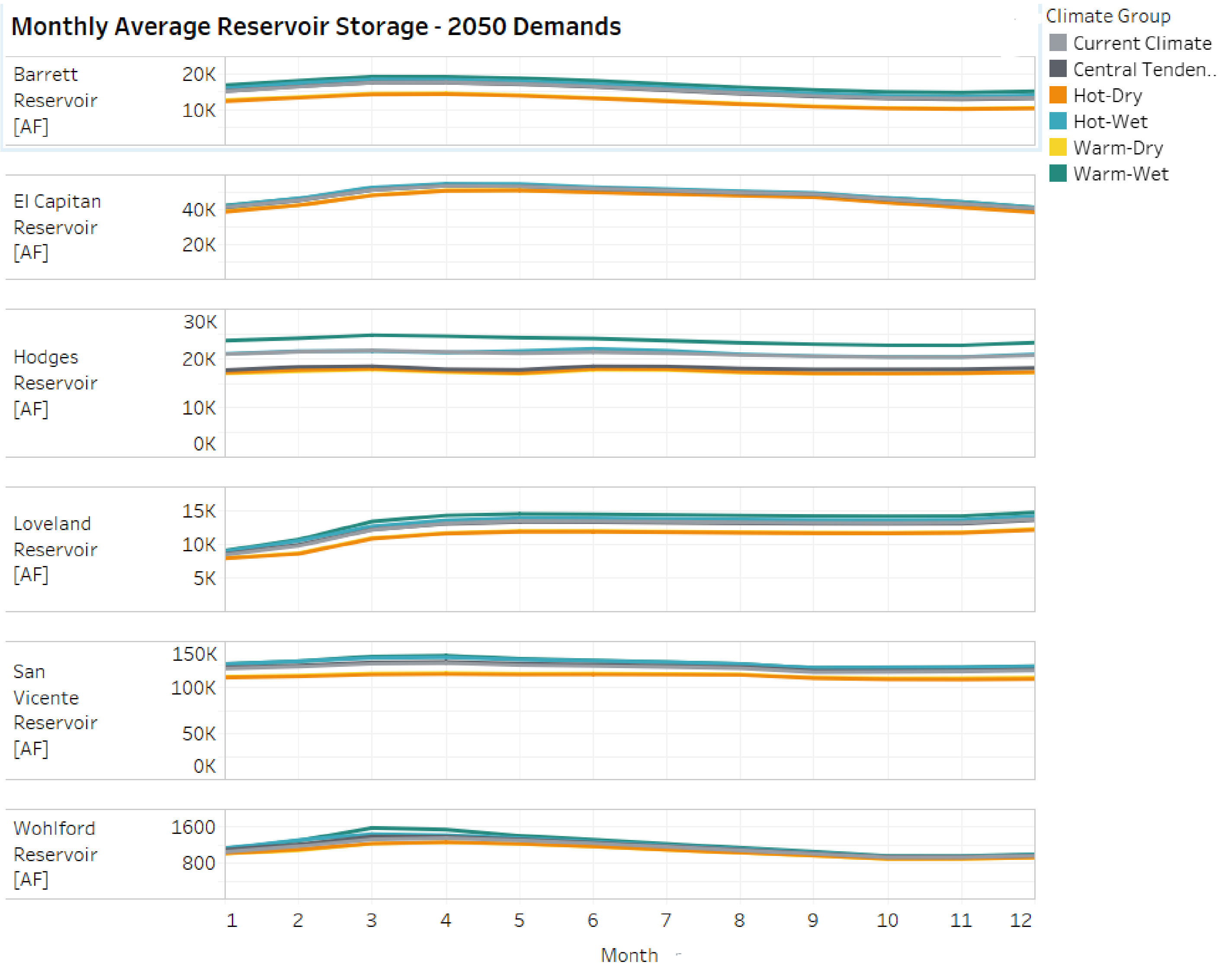


Figure A7. Monthly average reservoir storage for 2050 demands with current climate and 2050s climate scenarios.

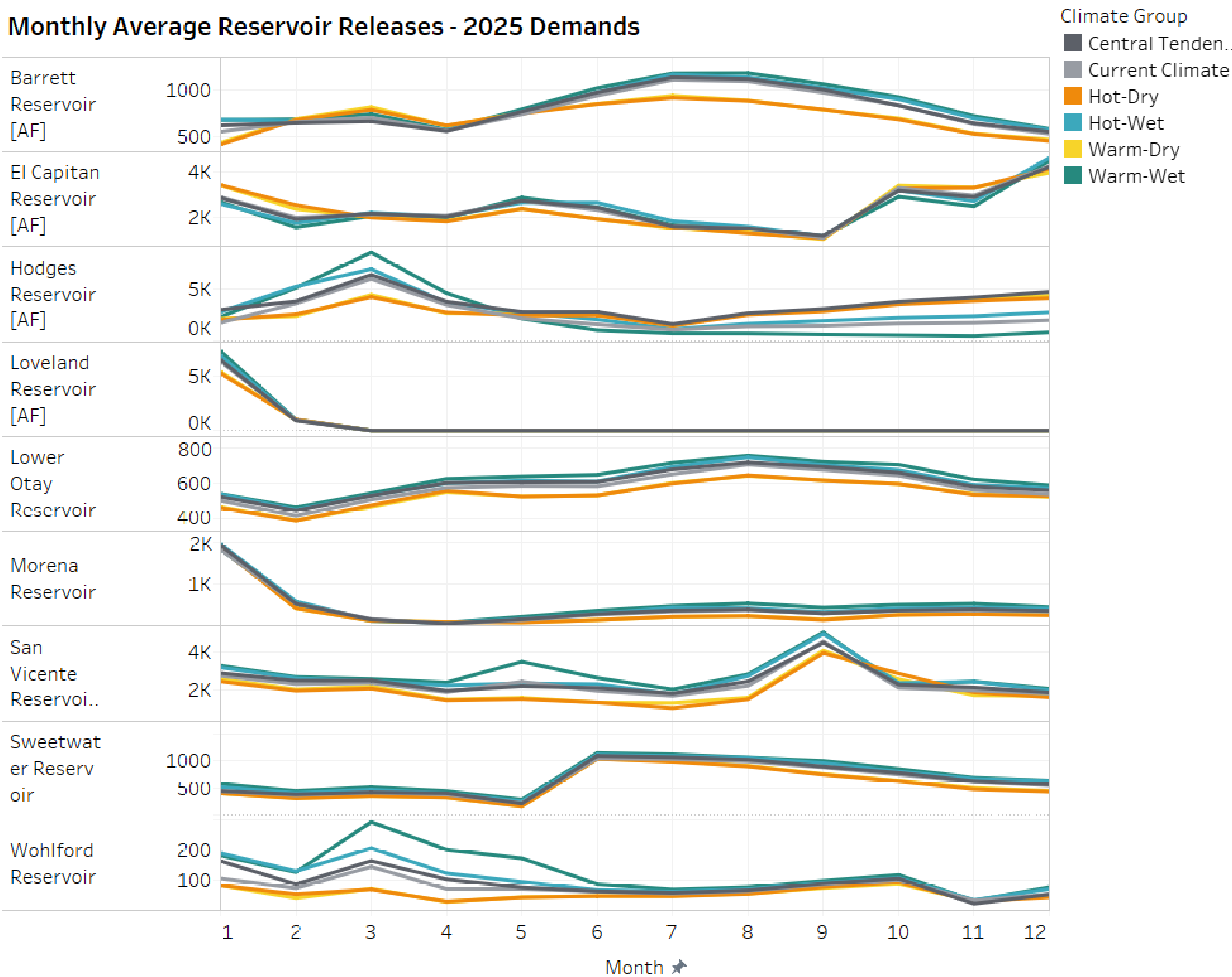


Figure A8. Monthly average reservoir releases for 2025 demands with current climate and 2020s climate change scenarios.

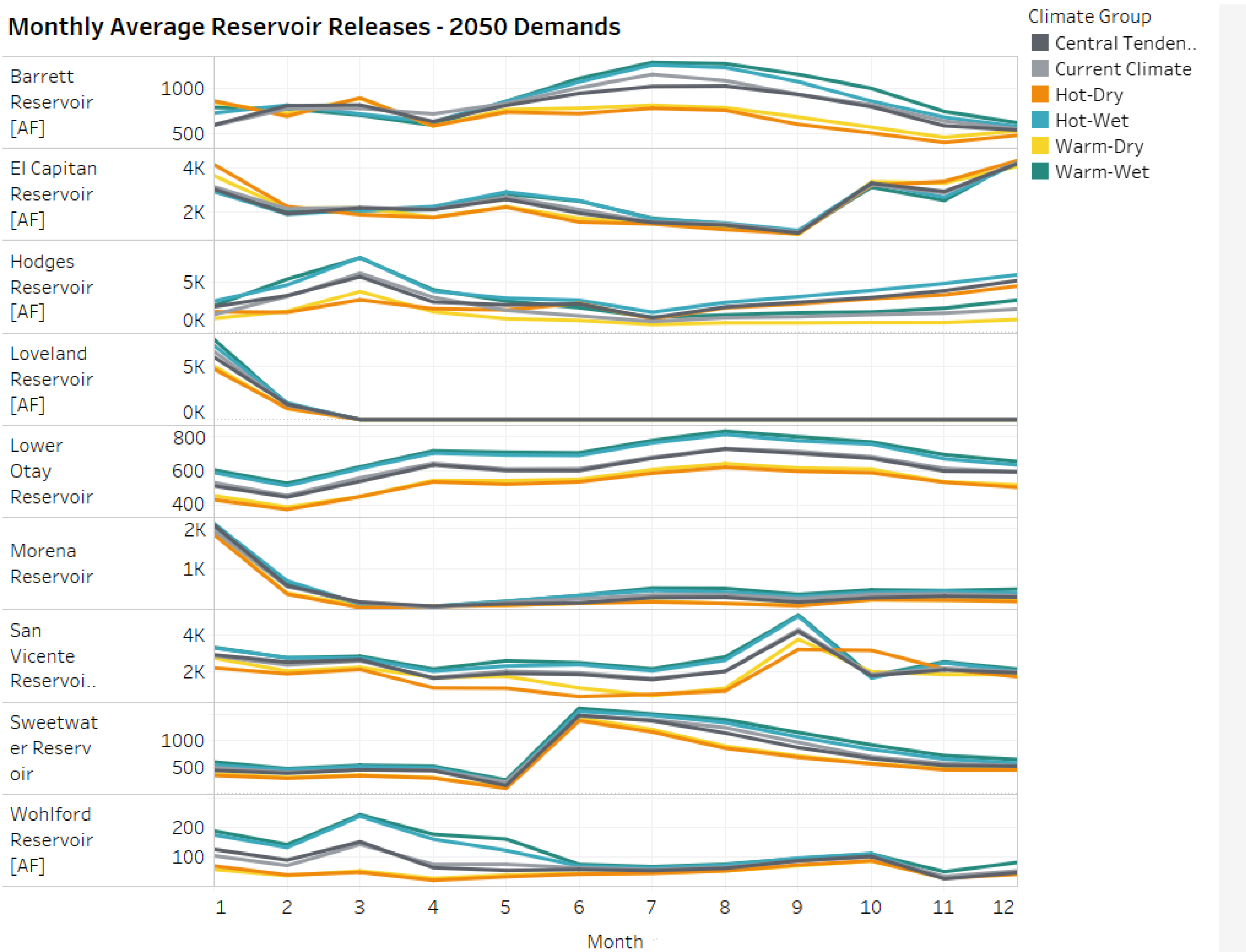


Figure A9. Monthly average reservoir releases for 2050 demands with current climate and 2050s future climate scenarios.

Baseline Run Descriptive Results - Conveyance Operations

Box 3. Summary of Findings: Conveyance Operations

Summary of Findings: Conveyance Operations	
2015 Demands Current Climate Conditions	The MWD Untreated pipeline has the highest volume of flow and the 30-inch pipeline has the lowest volume.
Current Climate Comparison between Demand Projections	• Pipeline flow increases as the as the demand increases for Pipeline 4 Just South of TOV WTP, MWD Treated Pipeline, and MWD Untreated Pipeline • Crossover Pipeline flow volumes are similar in all demand scenarios • The 30-inch Pipeline flow decreases between the 2015 and 2025 demand scenarios, but increases in the 2050 scenario
Climate Change Scenario Comparison	• Minimal differences in pipeline flow between climate scenarios
Notes and Other Findings	None.

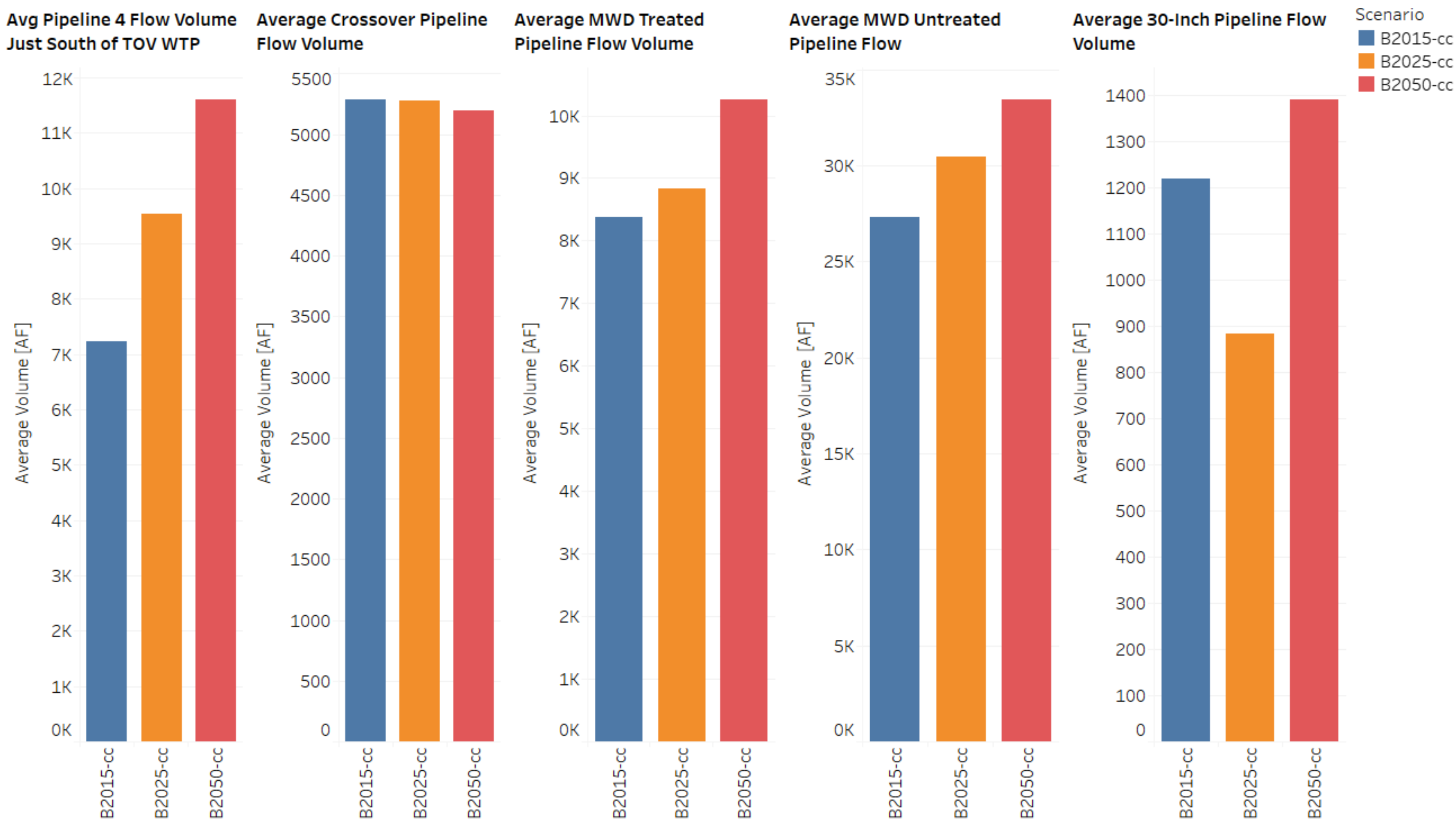


Figure A10. Monthly average pipeline flow with current climate infrastructure and future projected demand scenarios.

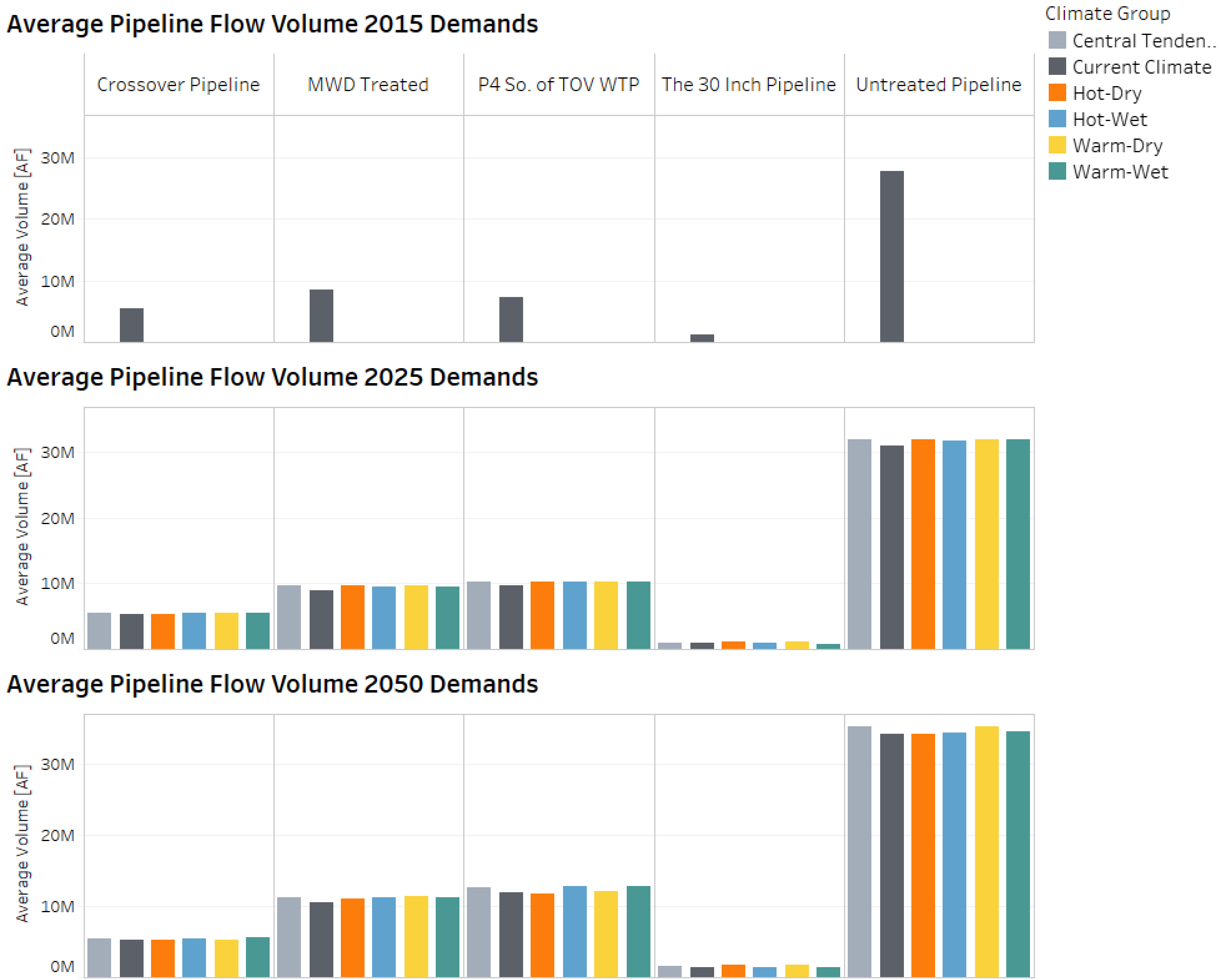


Figure A11. Monthly average pipeline flow with all climate group infrastructure and future projected demand scenarios.

Baseline Impacts

Baseline Impacts - Water Delivery

Baseline Impacts - Water Delivery - Shortage

Box 4. Impact Metric Description: Shortage Volume

Impact Category: Water Delivery Metric: Shortage Volume	
What it Measures	Measures the magnitude of regional demand that is unable to be met by the available supplies and/or limited by conveyance system capacity.
Meaning of Larger or Smaller Values	Non-zero values of supply shortage metrics indicate that supplies are insufficient to meet demands or that conveyance system capacity limits deliveries. Larger values indicate larger supply-demand imbalances or capacity limitations.
Why it is Measured	Shortages indicate that demands cannot be met by the available supplies due to an imbalance between water supply and demand or limits of the conveyance system.

Box 5. Impact Metric Description: Shortage >20 KAF for 2 years

Impact Category: Water Delivery Metric: Shortage >20 KAF for 2 years	
What it Measures	Measures the number of times in a run when the shortage is greater than 20 TAF for two years in a row
Meaning of Larger or Smaller Values	Larger values indicate more frequent shortages that cannot be mitigated by operational or management actions
Why it is Measured	Shortages indicate that demands cannot be met by the available supplies due to an imbalance between water supply and demand or limits of the conveyance system.

Box 6. Summary of Findings: Shortage

Summary of Findings: Supply Shortage	
2015 Demands Current Climate Conditions	No shortages greater than the 20,000 AF shortage threshold.
Current Climate Comparison between Demand Projections	• Increasing shortage magnitude and volume between 2015, 2025, and 2050 demand years. • Some shortages in the 2050 demand year exceed the shortage threshold.
Climate Change Scenario Comparison	• More and larger shortages in the dry climate scenarios (wd, hd) versus wet climate scenarios (ww, hw) • Current climate shortages within a demand year are comparable to the wet climate scenario shortages, yet smaller than dry climate scenario shortages.
Notes and Other Findings	None.

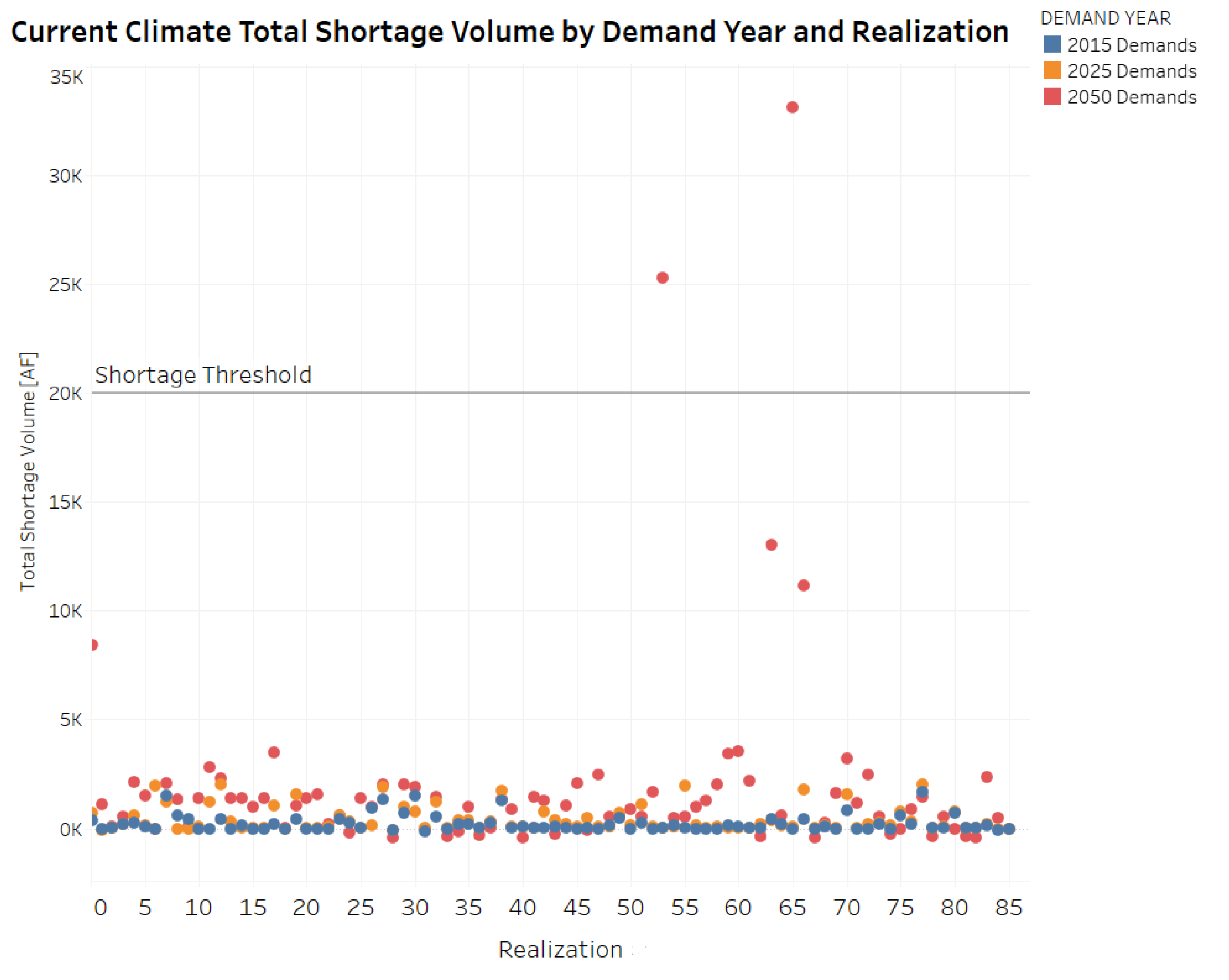


Figure A12. Time series of current climate shortage volume by demand year.

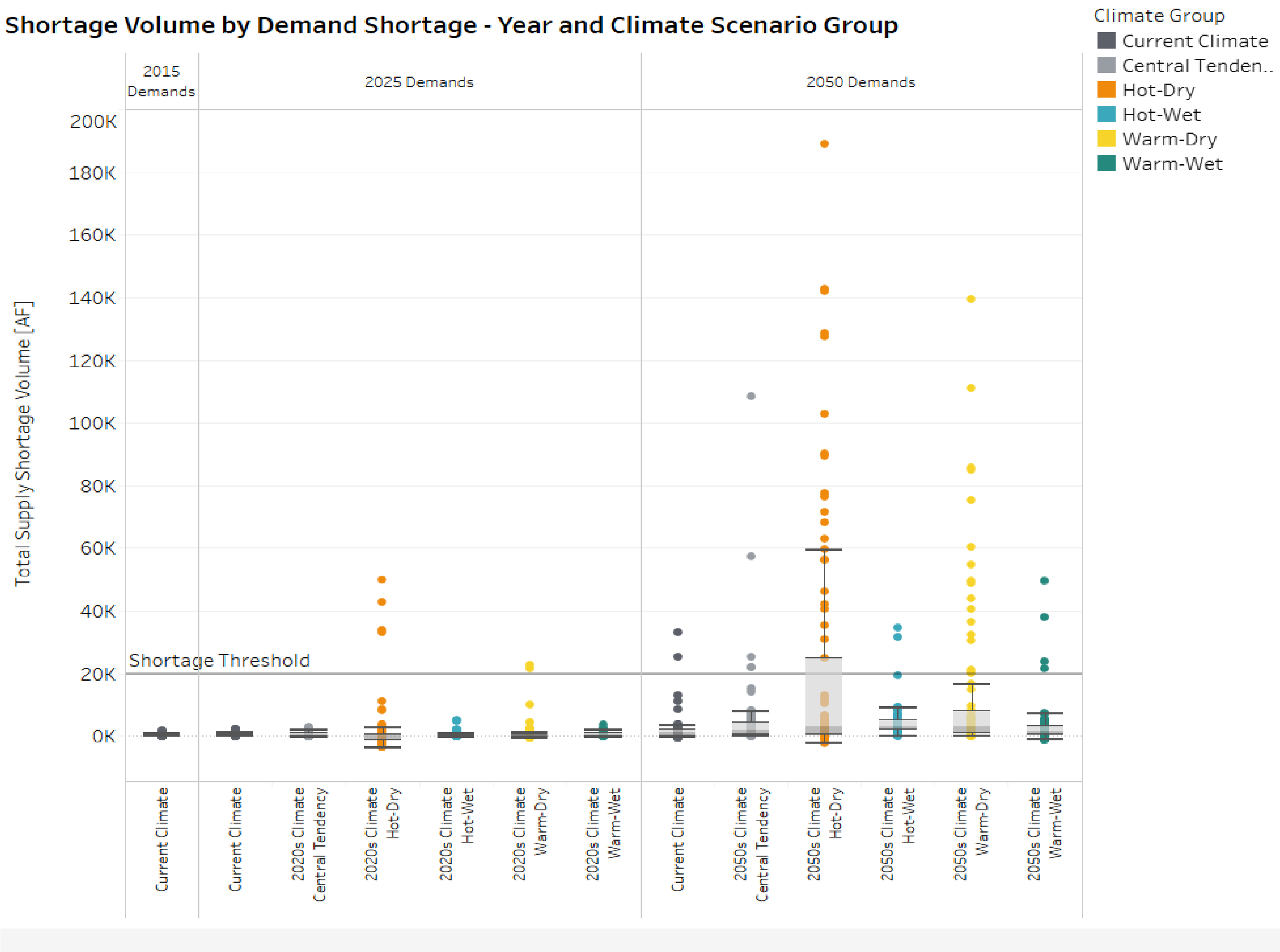


Figure A13. Shortage volume by demand year and climate scenario.

Baseline Impacts - Water Delivery - Diversification

Box 7. Impact Metric Description: Supply Diversification

Impact Category: Water Delivery Metric: Supply Diversification	
What it Measures	Measures the percentage of supply from local storage releases, groundwater, recycled water, Carlsbad Desalination Plant, imported QSA water, and imported water purchases.
Meaning of Larger or Smaller Values	Comparing between scenarios, larger values of supply diversification indicate greater reliance on that supply type. Because diversification is measured as a percentage, any change in one of the diversification metrics will result in a corresponding change to another diversification metric.
Why it is Measured	There is interest in shifting the water supply in San Diego to less reliance on imported supply and more reliance on local supply. San Diego has historically relied primarily on imported water, but imported supplies could be impacted by changing climatic, political, and management conditions in the source basins. Local water supplies may be vulnerable to climate change, but are controlled within the region. Desalination is a local supply that is less vulnerable to climate change.

Box 8. Summary of Findings: Diversification

Summary of Findings: Diversification	
2015 Demands Current Climate Conditions	Imported and QSA water make up the largest percentage of supply, followed by local storage releases.
Current Climate Comparison between Demand Projections	• Increasing percentage of supply provided by imported water and recycled water. • Decreasing percentage of supply from local storage releases, Carlsbad Desalination Plant, and QSA water as those supplies are fully utilized in all scenarios.
Climate Change Scenario Comparison	• Drier scenarios have larger reliance on imported water than wetter scenarios • In the 2050 Demand scenario, local storage increases for the wet scenarios
Notes and Other Findings	• Groundwater, recycled water, Carlsbad Desalination Plant, and imported QSA water volumes are fixed, so increases in demand have minimal effect on Carlsbad supply volume.

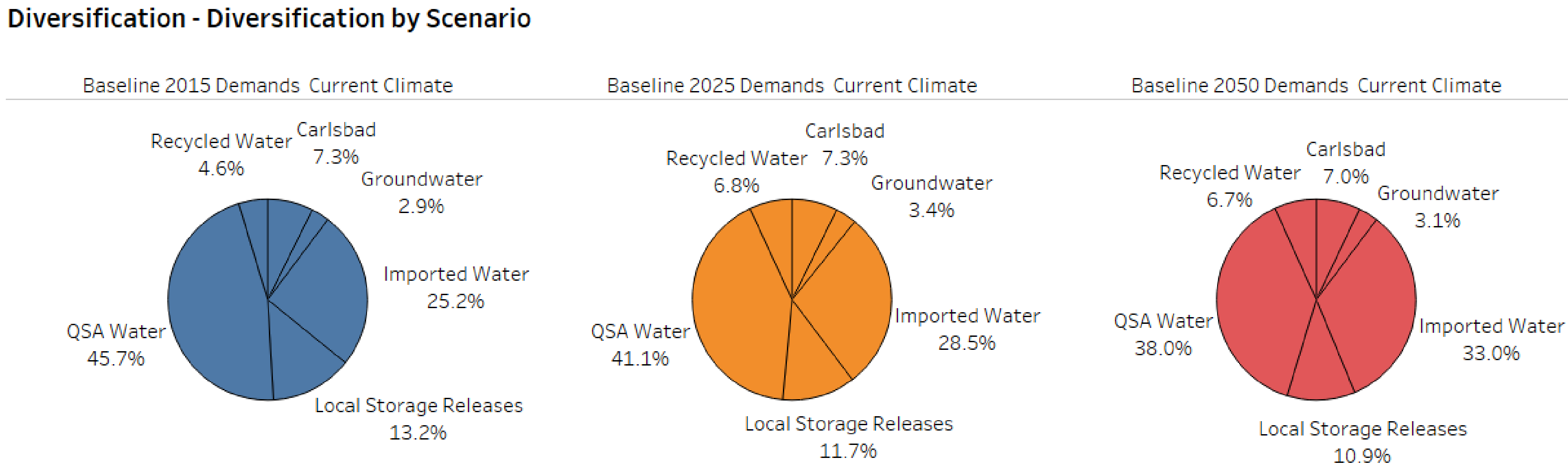


Figure A14. Supply diversification by demand year.

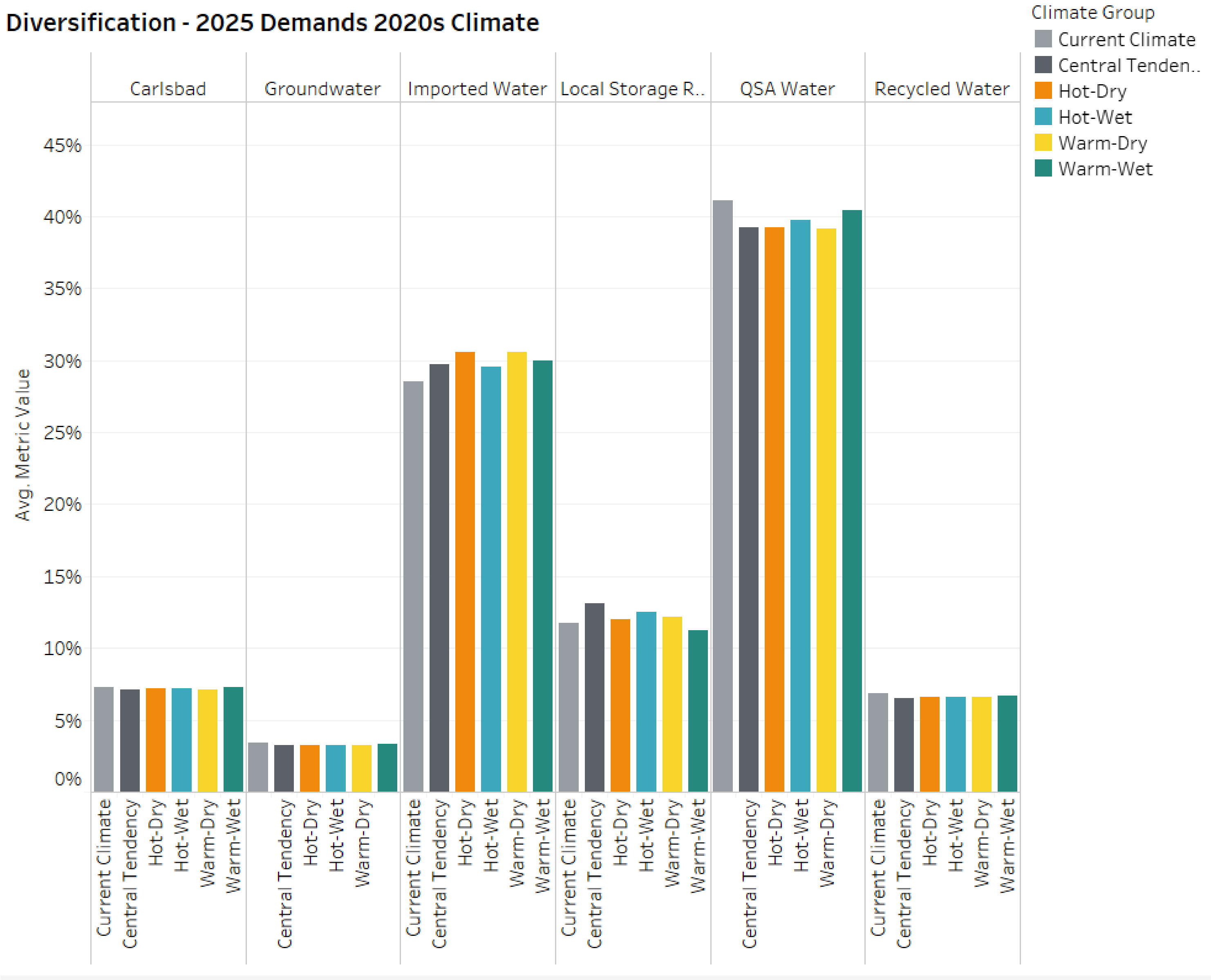


Figure A15. Diversification by supply type and scenario for 2025 demands and 2020s climate.

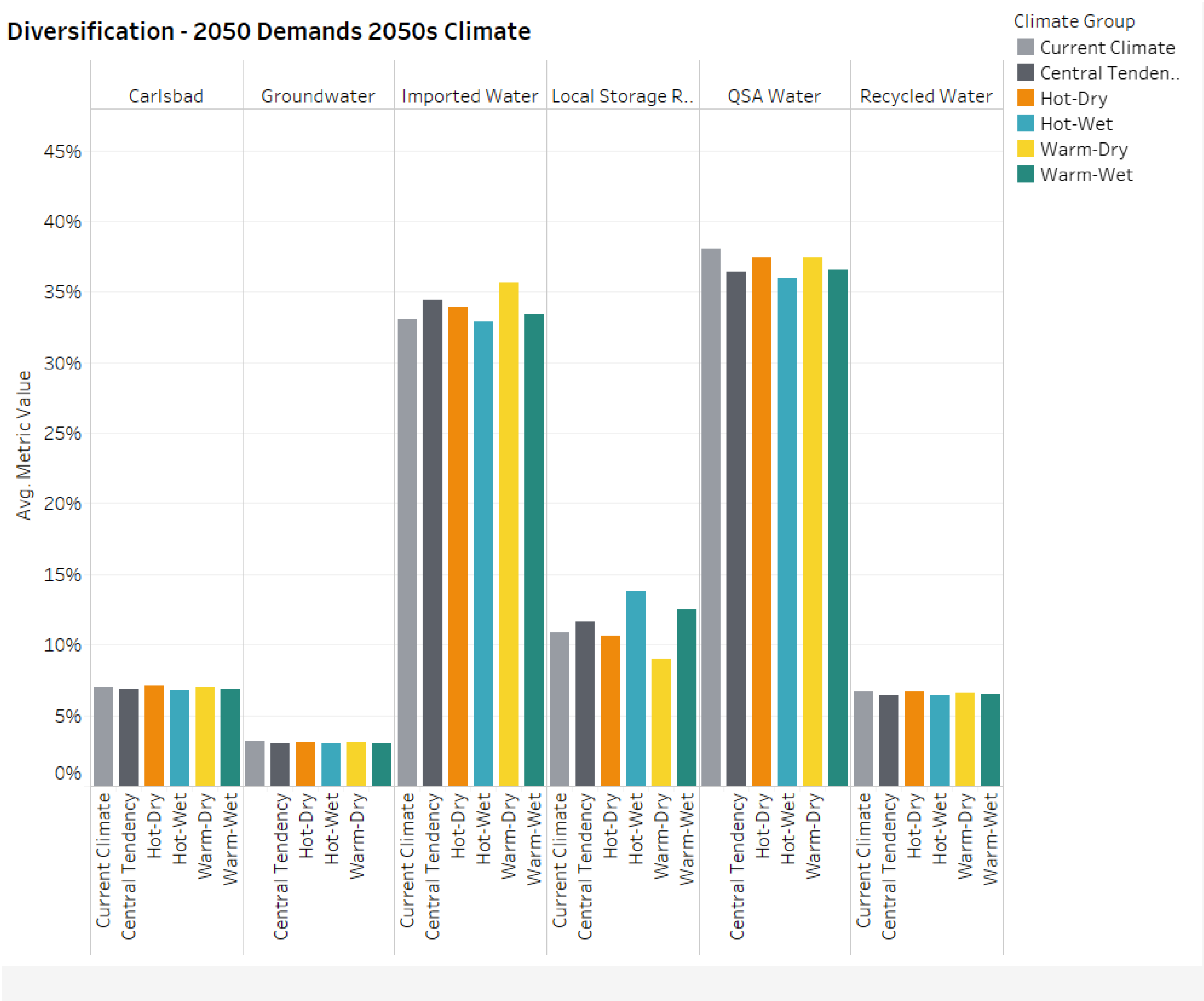


Figure A16. Diversification by supply type and scenario for 2050 demands and 2050s climate.

Baseline Impacts - Water Delivery - Pipeline Utilization

Box 9. Impact Metric Description: High Pipeline Utilization Summer Count

<table>
<tr><th colspan="2">Impact Category: Water Delivery
Metric: High Pipeline Utilization Summer Count</th></tr>
<tr><td>What it Measures</td><td>Measures the number of days that pipeline flow exceeds 95% of capacity during the summer for four pipeline locations:
• Pipeline 4 just south of Twin Oaks Valley WTP, which serves treated water to Carlsbad, Vista, and Vallecitos member agencies
• Pipeline 3 30-inch interconnect, which conveys untreated water near Murray Reservoir
• Crossover Pipeline, which conveys untreated water
• MWD Delivery Point treated water conveyed through Pipelines 1, 2, and 4
• Untreated</td></tr>
<tr><td>Meaning of Larger or Smaller Values</td><td>Larger numbers of days indicate that high summer pipeline utilization is more frequent.</td></tr>
<tr><td>Why it is Measured</td><td>High pipeline utilization is important because it indicates that pipeline capacity may be limiting water deliveries. Summer is when water usage is typically highest and pipeline capacity is most likely to be a limiting factor in water deliveries. Exceeding 95% of capacity is expected during the summer.</td></tr>
</table>

Box 10. Summary of Findings: Pipeline Utilization

Summary of Findings: Pipeline Utilization	
2015 Demands Current Climate Conditions	No days with flows above 95% capacity for Pipeline 3 30-inch interconnect, Pipeline 4 just South of TOV, Crossover, or Treated Pipeline. Untreated Pipeline had a count of 37 days.
Current Climate Comparison between Demand Projections	• In the 2025 demand scenario, there were no instances of high pipeline utilization for Pipeline 3 30-inch, Pipeline 4 just South of TOV, or Treated Pipeline. • Untreated Pipeline had an average of 69 days of exceedance, and Crossover Pipeline had a minimal count. • In the 2050 demand scenario, Untreated Pipeline had an average of 84 exceedance days. Crossover Pipeline and Pipeline 3 30-inch had minimal counts. The Pipeline Just South of TOV and the Treated Pipeline had no exceedances.
Climate Change Scenario Comparison	• There were no instances of high pipeline utilization for Pipeline 3 30-inch or the Pipeline 4 just South of TOV for the 2025 demands. The Treated Pipeline had no instances for either the 2025 or 2050 demands. • Untreated and Crossover pipelines had high pipeline utilization in both 2025 and 2050 demand scenarios under current climate conditions. Pipeline 3 30-inch and Pipeline 4 had minimal utilization for 2050 demands. • Dry scenarios have larger numbers of exceedances than wet scenarios.
Notes and Other Findings	None.

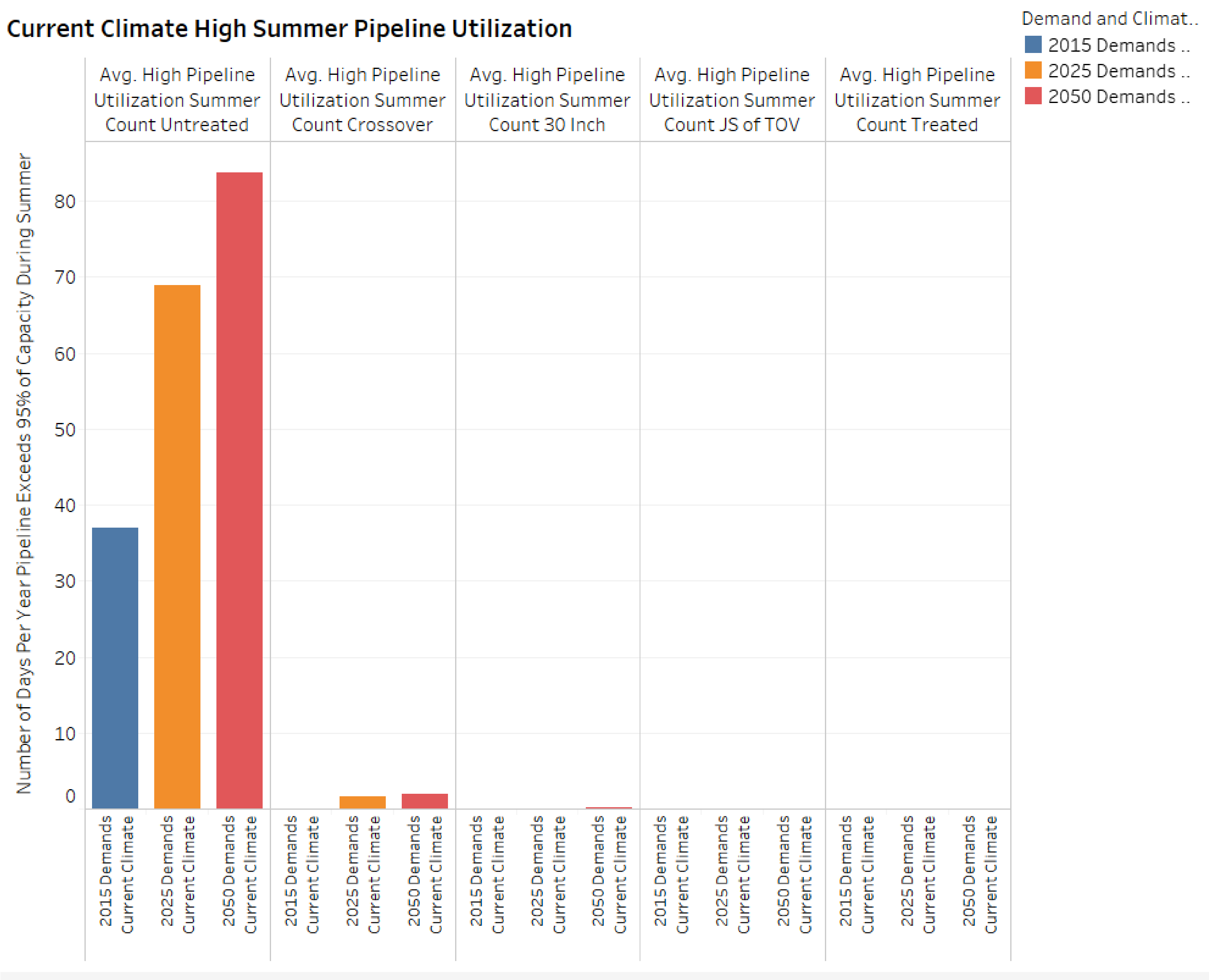


Figure A17. Number of days of high summer pipeline utilization by time period.

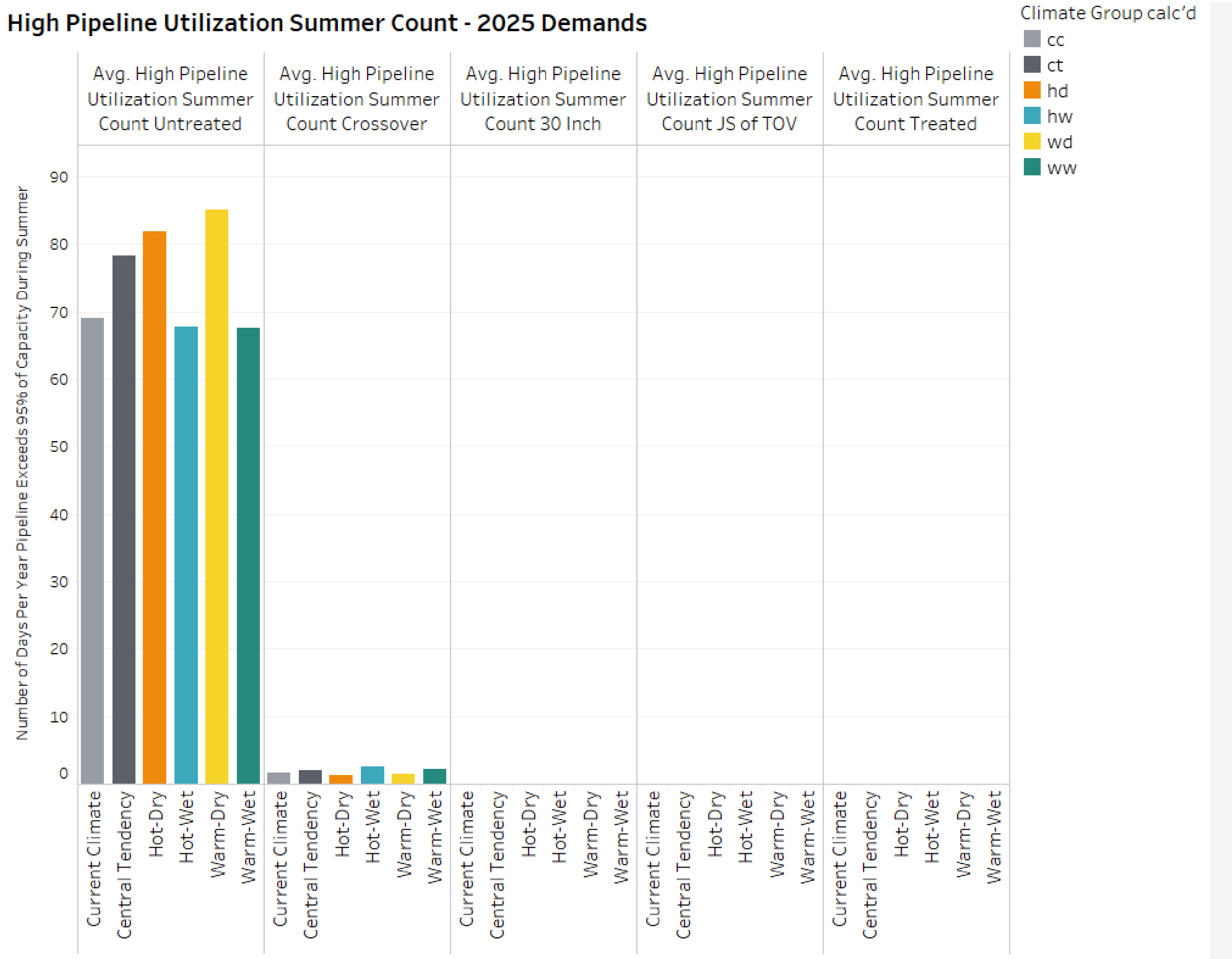


Figure A18. Number of days of high summer pipeline utilization by climate scenario group.

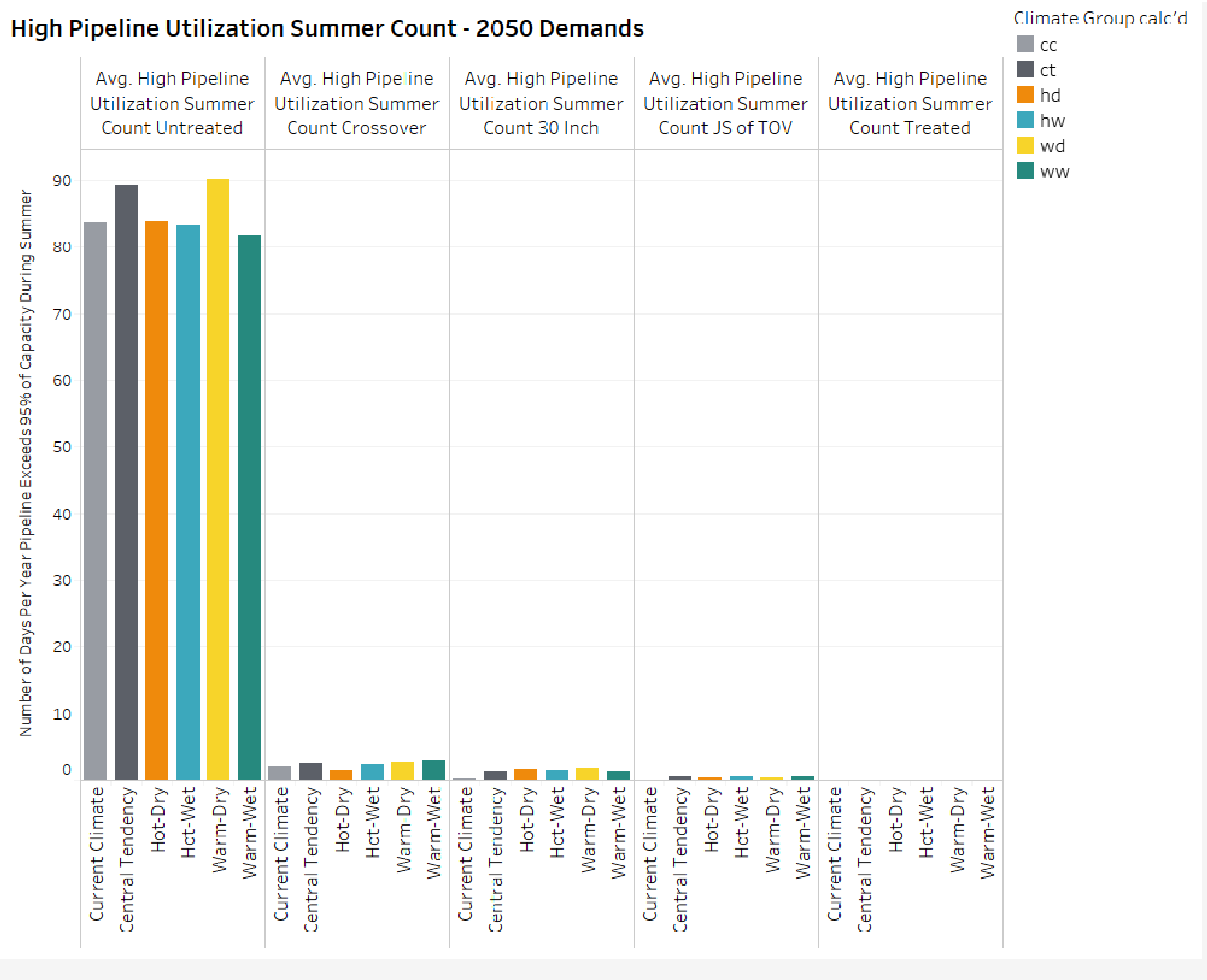


Figure A19. Number of days of high summer pipeline utilization by climate scenario group.

Baseline Impacts - Water Delivery - Pump Station Utilization

Box 11. Impact Metric Description: Pump Station Utilization

Impact Category: Water Delivery Metric: Pump Station Utilization	
What it Measures	Measures the number of times per year that pump station exceeds 95% of capacity for 70% of pumping days for the following pump station locations: • San Vicente; 70% of pumping days = 107 days • P2A; 70% of pumping days = 171 days
Meaning of Larger or Smaller Values	Larger numbers of days indicate that pump station maximum utilization is more frequent.
Why it is Measured	Pump station utilization is important because it indicates that a large number of days in excess of 95% capacity could warrant the need for future pump stations.

Box 12. Summary of Findings: Pump Station Utilization

Summary of Findings: Pump Station Utilization	
2015 Demands Current Climate Conditions	No occurrences of greater than 95% pump station usage were found for either of the two pump stations analyzed (San Vicente Pump Station or P2A Pump Station) under the 2015 demands scenario.
Current Climate Comparison between Demand Projections	No occurrences of greater than 95% pump station usage were found for either of the two pump stations analyzed (San Vicente Pump Station or P2A Pump Station) under the 2025 or 2050 demands scenarios
Climate Change Scenario Comparison	The B2025-ww scenario had a 2 occurrences of greater than 95% pump station usage for the San Vicente Pump Station.
Notes and Other Findings	The P2A Pump Station had no occurrences of greater than 95% pump station usage for any of the climate or demand scenarios.

Baseline Impacts - Water Delivery - Treatment Plant Utilization

Box 13. Impact Metric Description: Annual Treatment Plant Utilization

Impact Category: Water Delivery Metric: Annual Treatment Plant Utilization	
What it Measures	Measures WTP usage on an annual basis. Values are reported as the percentage of average annual treatment plant flow compared to treatment plant capacity.
Meaning of Larger or Smaller Values	Larger percentages indicate greater usage of the WTP averaged across the year
Why it is Measured	Surface water and untreated imported water must first be treated before it can be used, so treatment plants could be a bottleneck in the water supply system if their capacity is not large enough to support the demand for water.

Box 14. Impact Metric Description: Seasonal Treatment Plant Utilization

Impact Category: Water Delivery Metric: Seasonal Treatment Plant Utilization	
What it Measures	Measures WTP usage during the summer (June through September). Values are reported as the percentage of average seasonal treatment plant flow compared to treatment plant capacity.
Meaning of Larger or Smaller Values	Larger percentages indicate greater usage of the WTP during the summer
Why it is Measured	Surface water and untreated imported water must first be treated before it can be used, so treatment plants could be a bottleneck in the water supply system if their capacity is not large enough to support the demand for water. Summer is when water usage is typically highest and WTP capacity is most likely to be a limiting factor in water deliveries

Box 15. Impact Metric Description: Imported Treatment Plant Utilization

Impact Category: Water Delivery Metric: Imported Treatment Plant Utilization	
What it Measures	Measures WTP usage for treating imported water. Values are reported as the percentage of treatment plant flow that is made up of imported water.
Meaning of Larger or Smaller Values	Larger percentages indicate greater usage of the WTP for treating imported water.
Why it is Measured	Untreated imported water must first be treated before it can be used, so treatment plants could be a bottleneck in the water supply system if their capacity is not large enough to support the demand for water.

Box 16. Impact Metric Description: Local Treatment Plant Utilization

Impact Category: Water Delivery Metric: Local Treatment Plant Utilization	
What it Measures	Measures WTP usage for treating local surface water. Values are reported as the percentage of treatment plant flow that is made up of local surface water.
Meaning of Larger or Smaller Values	Larger percentages indicate greater usage of the WTP for treating local surface water.
Why it is Measured	Local surface water must first be treated before it can be used, so treatment plants could be a bottleneck in the water supply system if their capacity is not large enough to support the demand for water.

Box 17. Summary of Findings: Treatment Plant Utilization

Summary of Findings: Annual Treatment Plant Utilization	
2015 Demands Current Climate Conditions	2015 annual utilization ranges between 24-87% with a system-wide average of 53%
Current Climate Comparison between Demand Projections	• Annual usage increases for most plants between 2015, 2025, and 2050. • Weese increases for 2025 demands, then decreases for 2050 below 2015 demands. • Badger and Purdue decrease for 2025 demands, then increase in 2050. • Escondido decreases for both 2025 and 2050 demands.
Climate Change Scenario Comparison	• Minimal differences between climate scenarios except Twin Oaks, which shows slightly lower utilization in the dry scenarios than the wet scenarios for 2050 demands. • The 2050 hot-wet scenario shows higher average treatment plant utilization than all other climate change scenarios.
Notes and Other Findings	Badger WTP shows a drastic jump for the hot-wet scenario during 2050 demands.

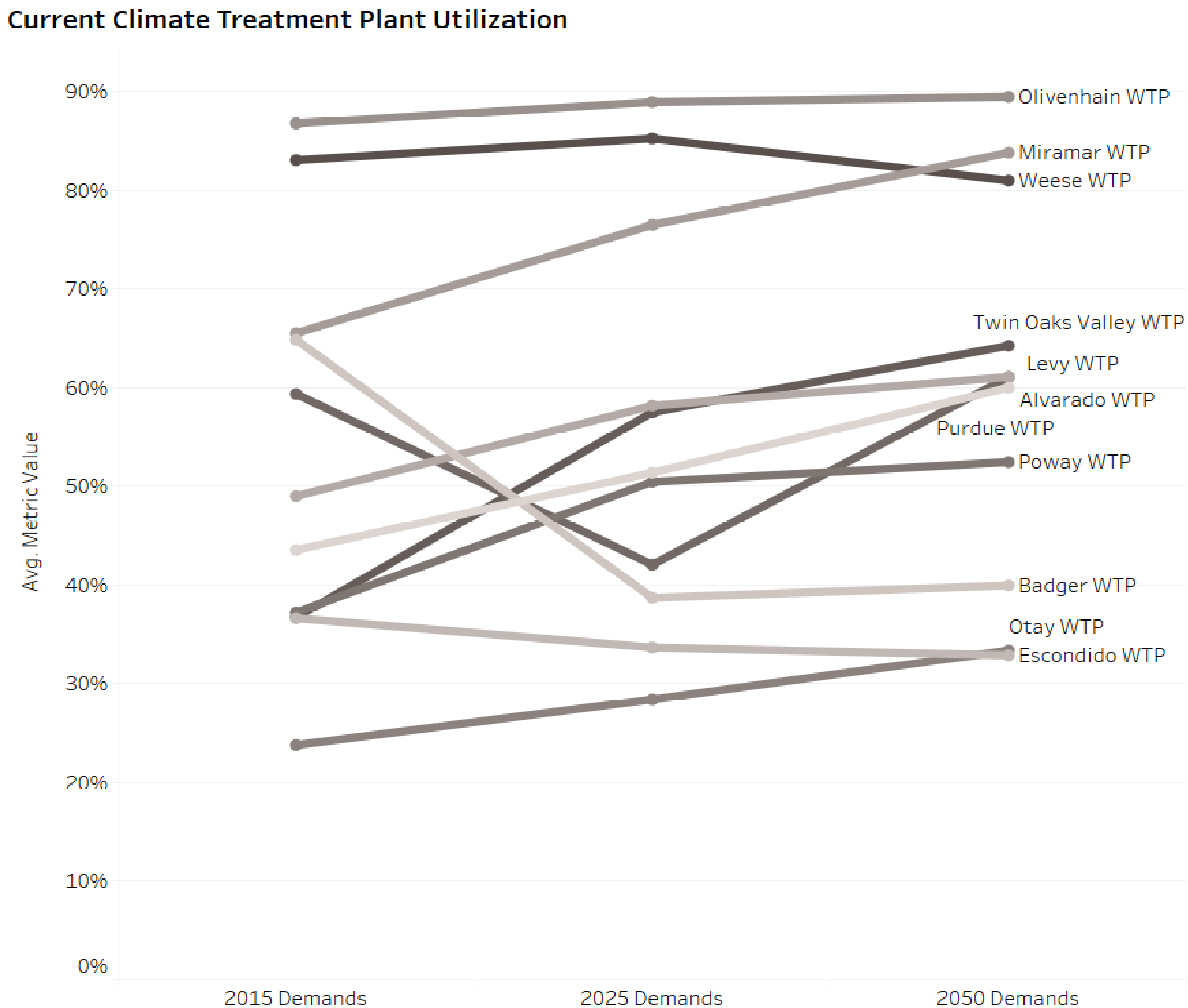


Figure A20. Treatment plant utilization by time period.

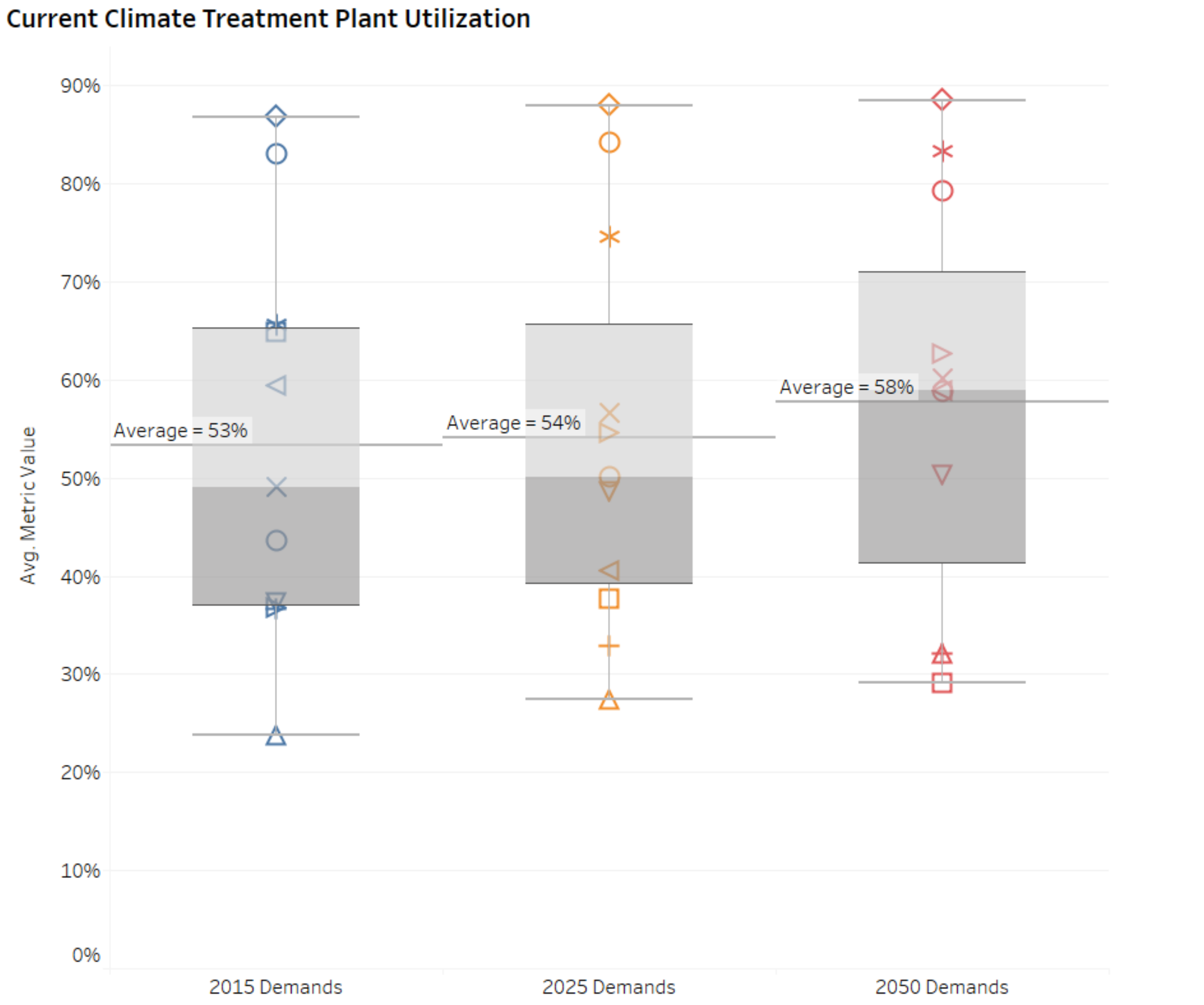


Figure A21. Current climate treatment plant utilization. Boxplots show median and quartiles, and whiskers extend to 1.5 times the IQR.

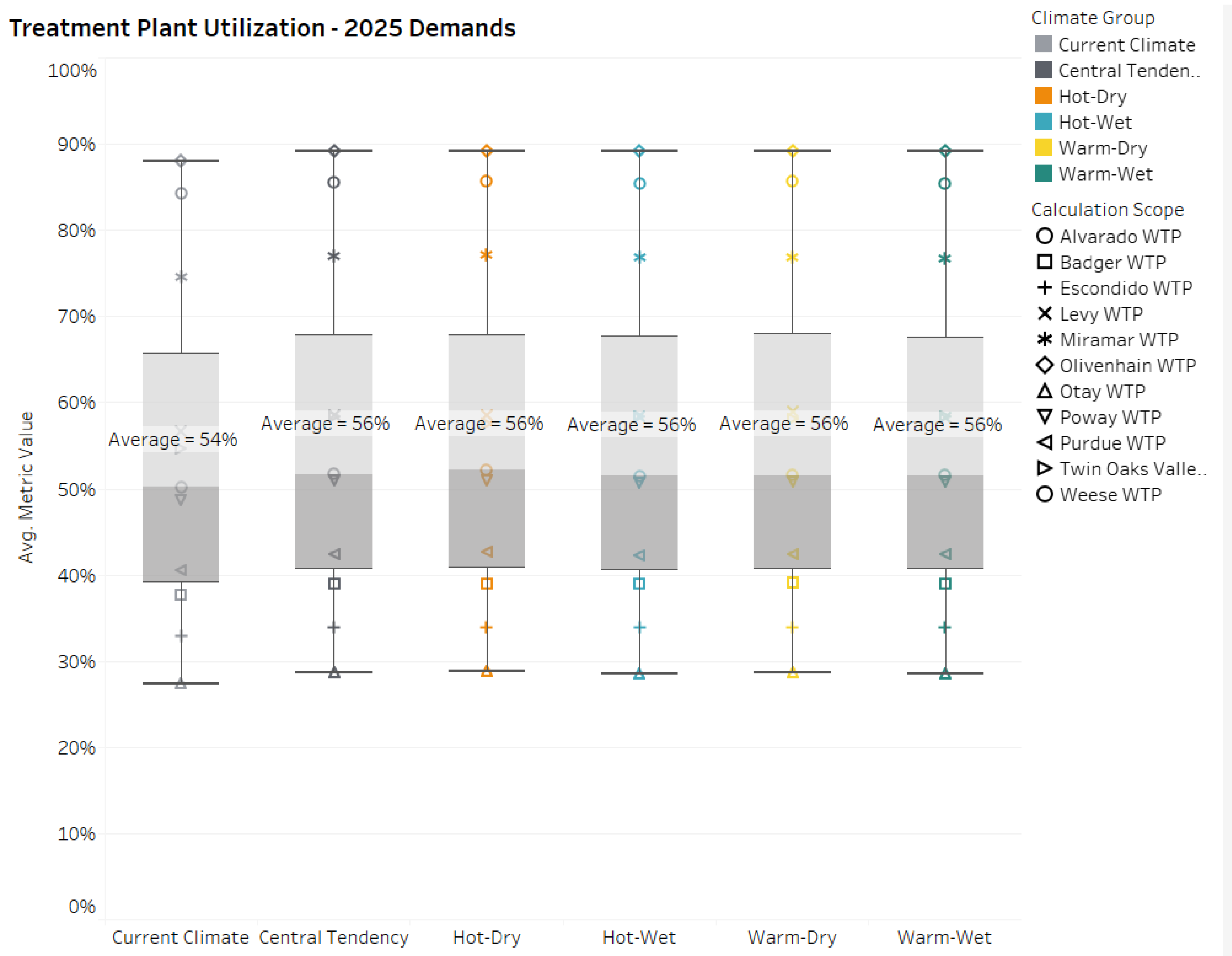


Figure A22. Treatment plant utilization, 2025 demands, 2020s climate. Boxplots show median and quartiles, and whiskers extend to 1.5 times the IQR.

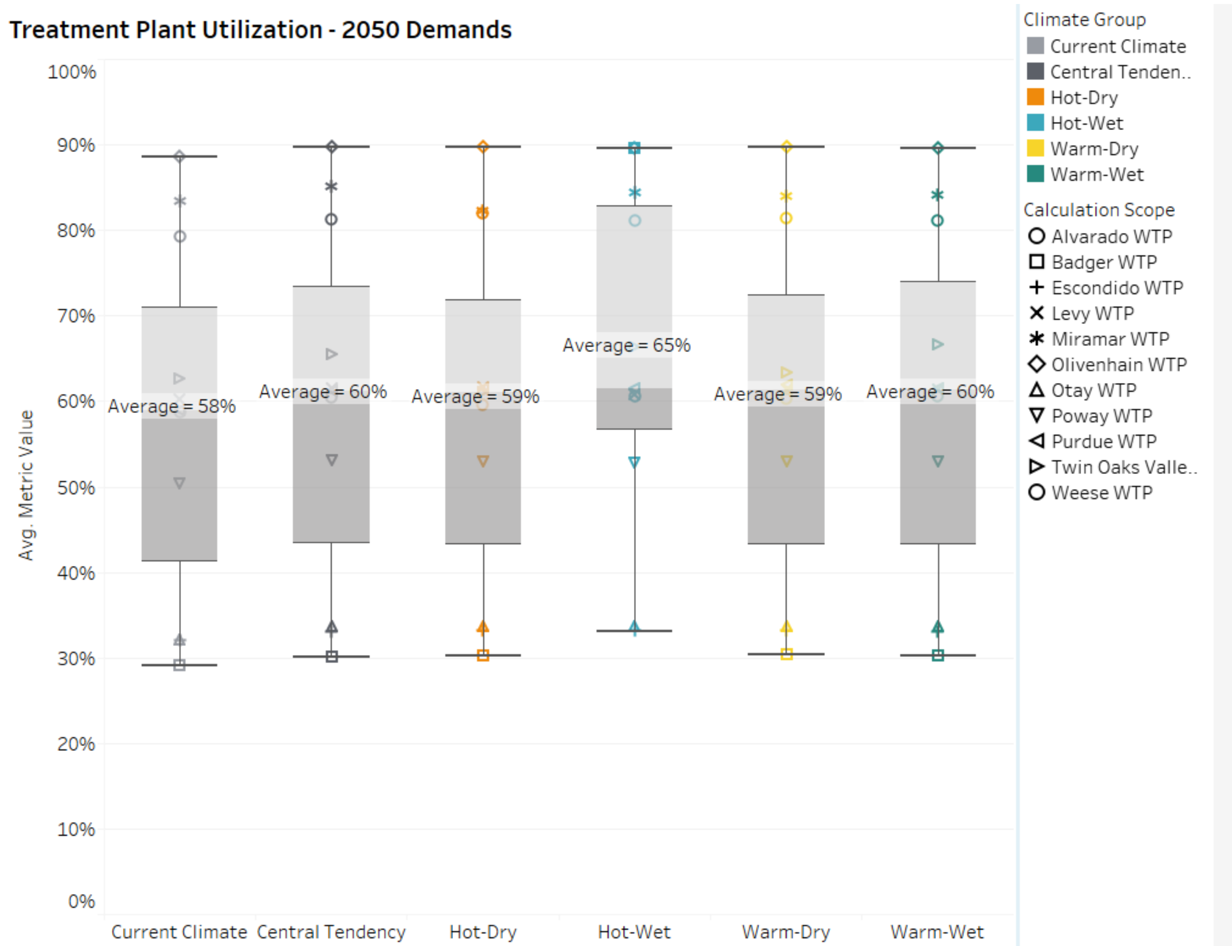


Figure A23. Treatment plant utilization, 2050 demands, 2050s climate. Boxplots show median and quartiles, and whiskers extend to 1.5 times the IQR.

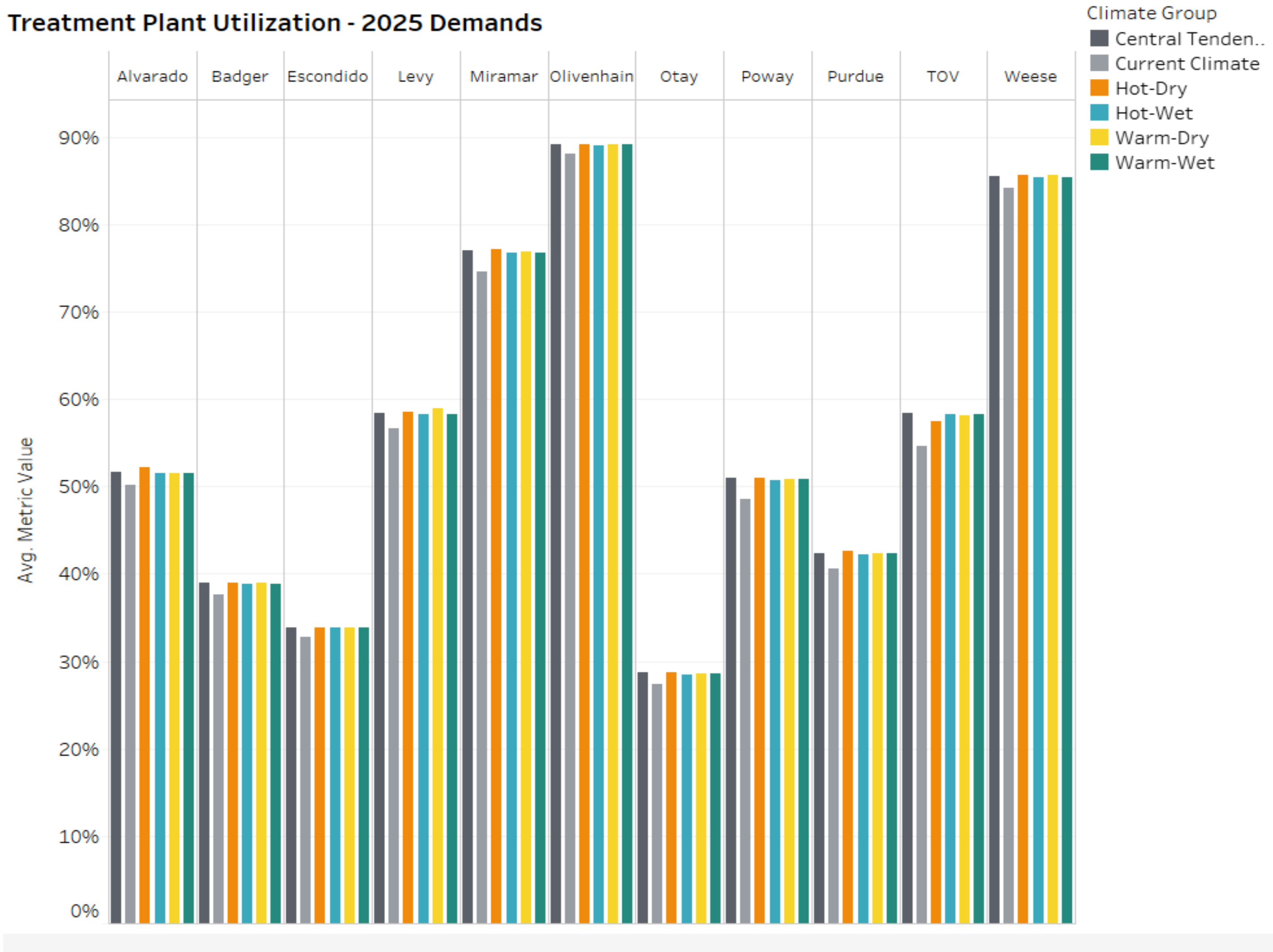


Figure A24. Treatment plant utilization by climate scenario, 2025 demands.

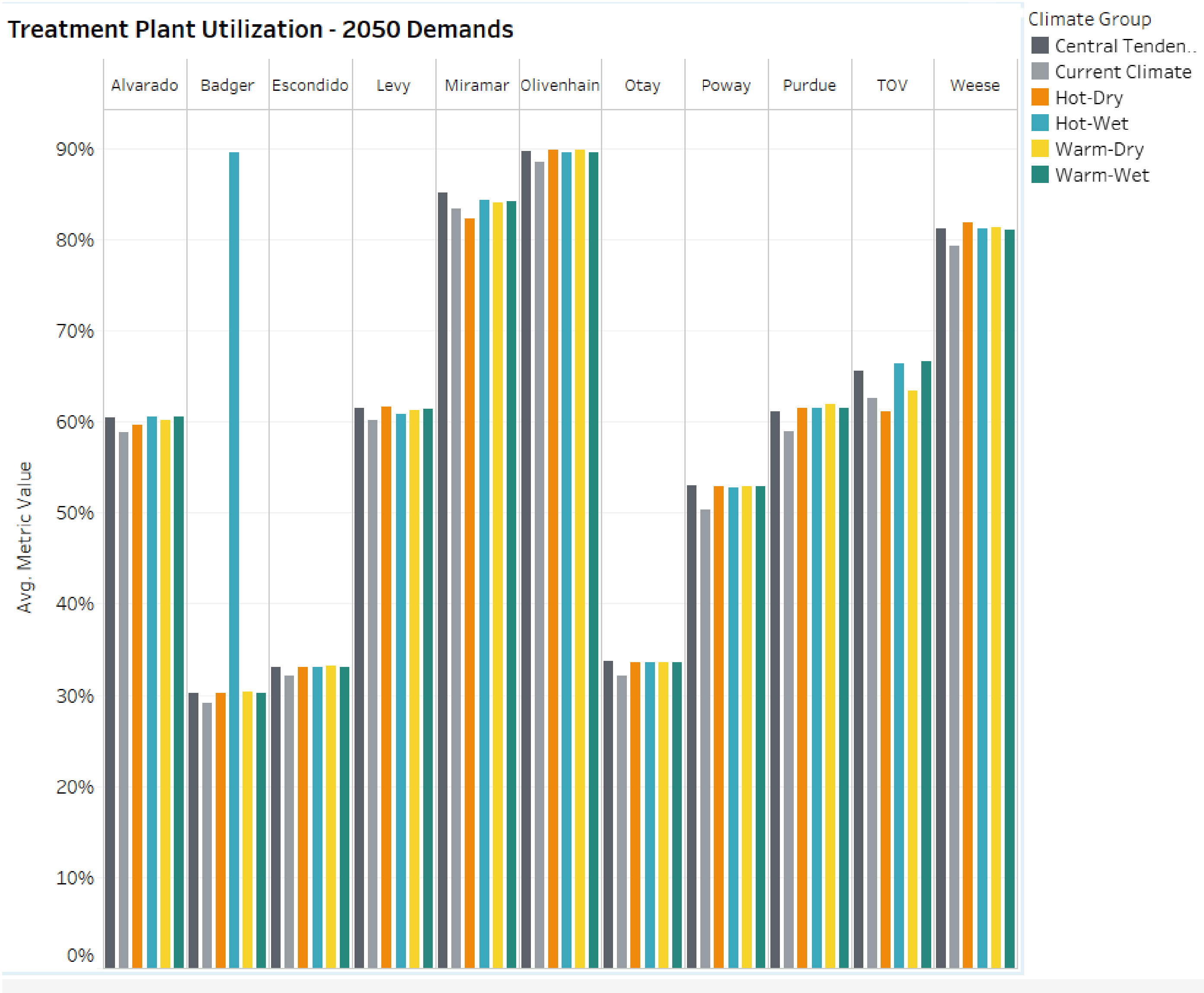


Figure A25. Treatment plant utilization by climate scenario, 2050 demands.

Baseline Impacts - Water Delivery - Reservoir Storage

Box 18. Impact Metric Description: End of September Storage

Impact Category: Water Delivery Metric: End of September Storage	
What it Measures	Measures the volume remaining in local reservoirs at the end of September for Hodges, El Capitan, San Vicente, Lower Otay, Olivenhain, and Other reservoirs. Volume includes storage in all modeled reservoir pools.
Meaning of Larger or Smaller Values	Smaller values indicate lower storage remaining at the end of September.
Why it is Measured	End of September storage is important because it is at the end of the peak demand season. It approximates the amount of water remaining in the reservoir after meeting demands. This water is available to be carried over in the reservoir for water supply in the next year.

Box 19. Summary of Findings: Reservoir Storage

Summary of Findings: Reservoir Storage	
2015 Demands Current Climate Conditions	San Vicente has the largest storage volume
Current Climate Comparison between Demand Projections	• Total end of September storage decreases for El Capitan, Olivenhain, and San Vicente between 2015 and 2050 demands. • Lower Otay decreases slightly from 2015 to 2050 while Hodges remains the same for all years. • Other Reservoirs increase for 2025, then decrease in 2050.
Climate Change Scenario Comparison	• Dry scenarios have lower end of September storages than wet scenarios in most cases. • Current climate scenarios generally have lower end of September storages than wet scenarios, but higher than dry scenarios and central tendency scenarios.
Notes and Other Findings	None.

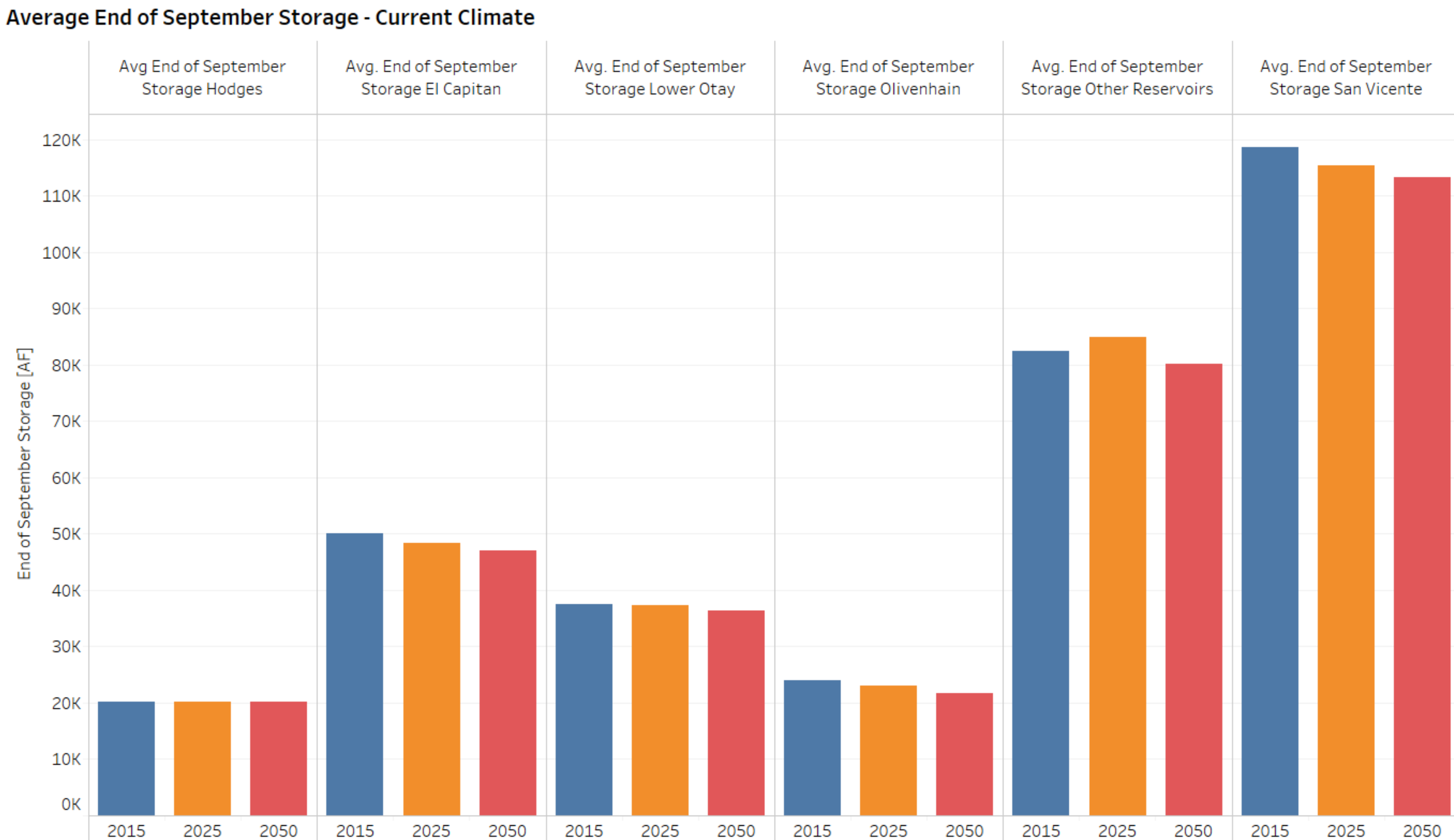


Figure A26. Average end of September reservoir storage by time period.

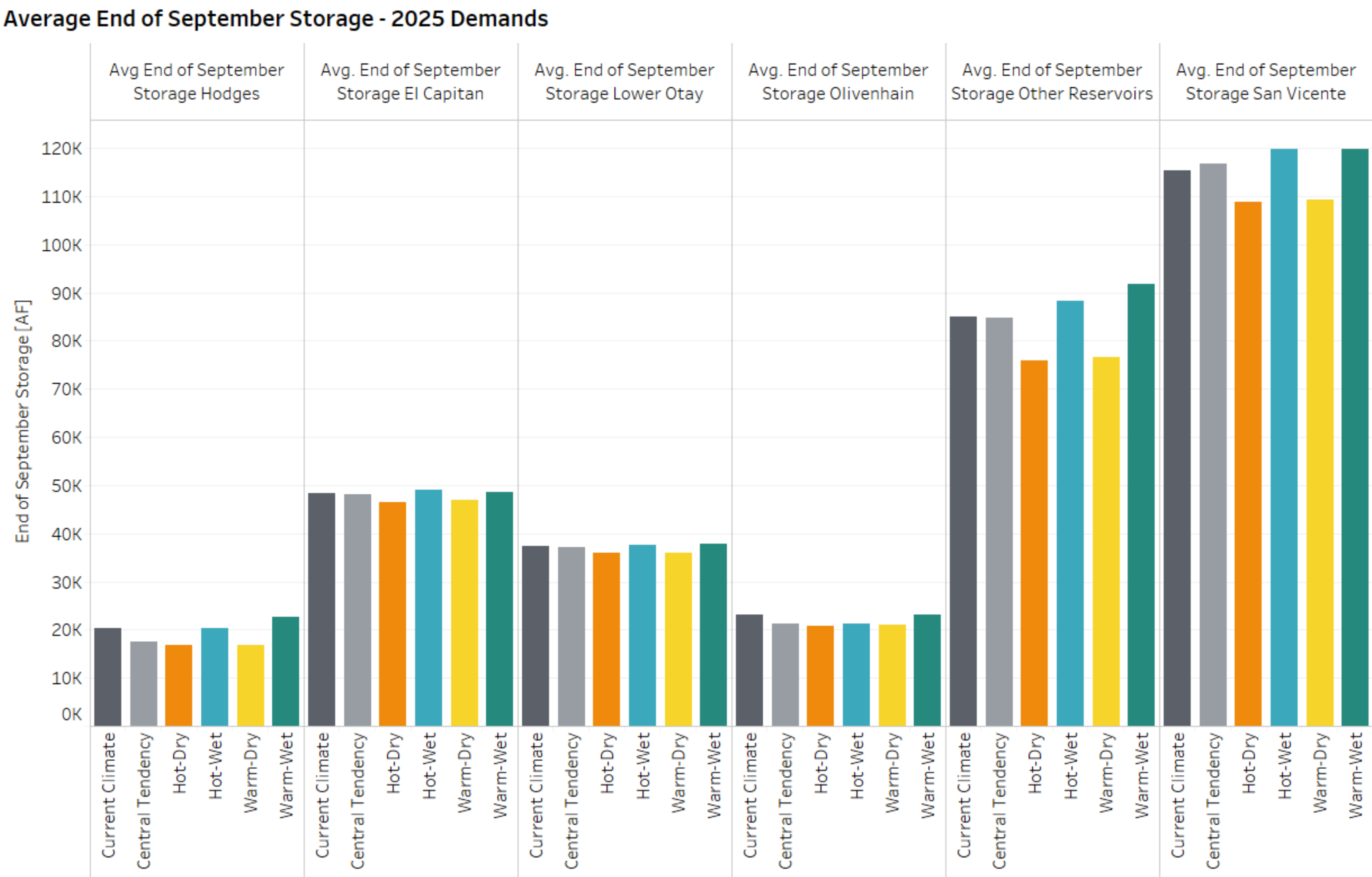


Figure A27. Average end of September reservoir storage by climate scenario group.

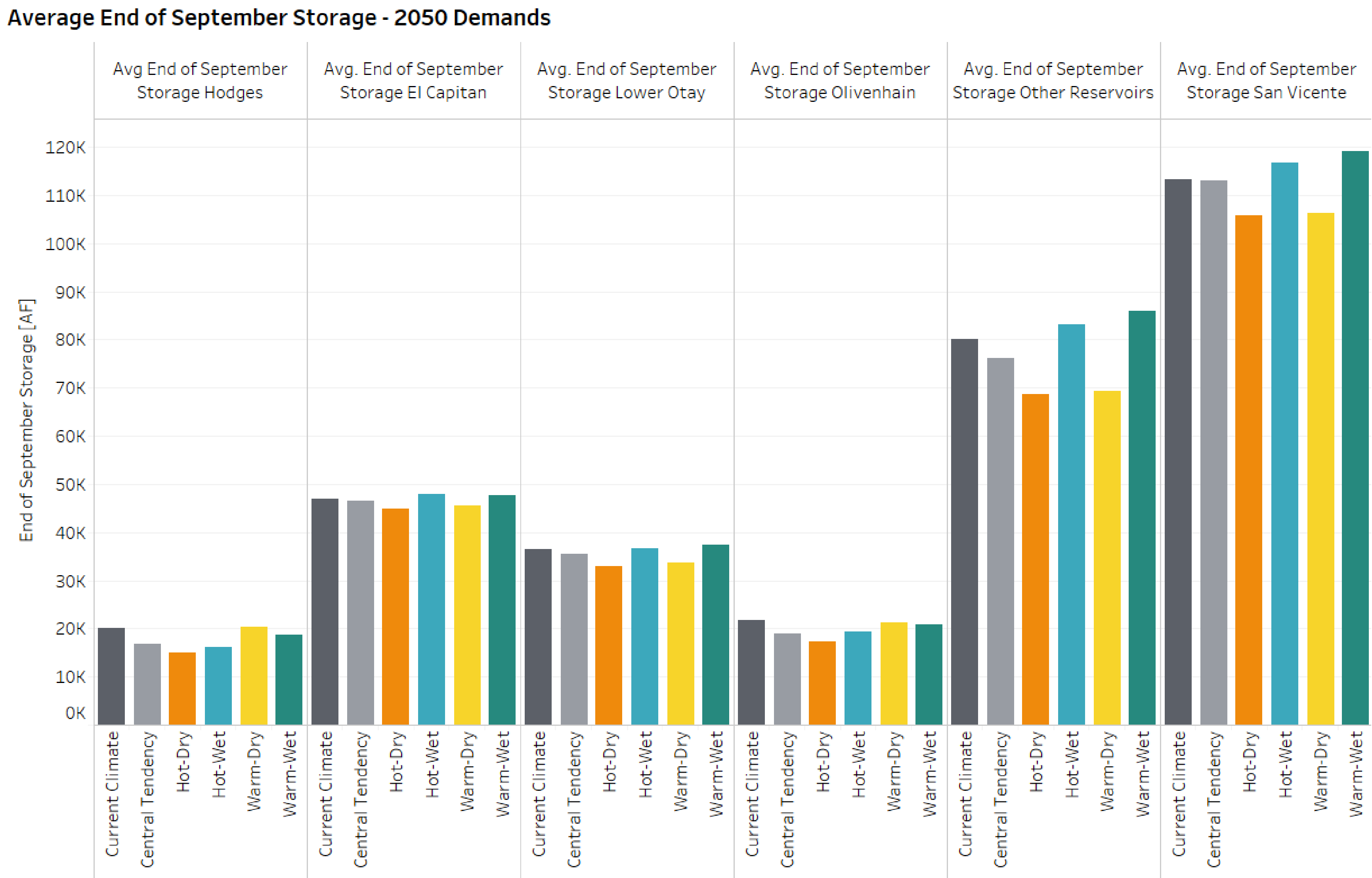


Figure A28. Average end of September reservoir storage by climate scenario group.

Baseline Impacts - Hydroelectric Power

Box 20. Impact Metric Description: Annual Power Generation

Impact Category: Hydroelectric Power Metrics: Annual Power Generation	
What it Measures	Measures the power generated by Water Authority facilities
Meaning of Larger or Smaller Values	Larger values of generation indicate that there are larger flows through hydropower facilities and result in larger offsets to consumption.
Why it is Measured	Hydropower generation can offset some of the power needed to convey and treat water. Consumption that is not offset must be purchased or generated by another method.

Box 21. Impact Metric Description: Annual Power Consumption

Impact Category: Hydroelectric Power Metric: Annual Power Consumption	
What it Measures	Measures the power consumed to treat and deliver water
Meaning of Larger or Smaller Values	Larger values of consumption indicate higher energy usage to treat and deliver water. May be due to larger water demands and/or use of more energy-intensive water supply sources.
Why it is Measured	Hydropower generation can offset some of the power needed to convey and treat water. Consumption that is not offset must be purchased or generated by another method.

Box 22. Impact Metric Description: Annual Net Power

Impact Category: Hydroelectric Power Metric: Annual Net Power	
What it Measures	Measures the difference between power consumed and generated. Power generation is subtracted from power consumption, so values represent the amount of additional power that must be generated or purchased to supply water.
Meaning of Larger or Smaller Values	Larger values indicated larger amounts of power purchased or generated by non-hydropower sources.
Why it is Measured	Hydropower generation can offset some of the power needed to convey and treat water. Consumption that is not offset must be purchased or generated by another method.

Box 23. Summary of Findings: Hydroelectric Power

Summary of Findings: Hydroelectric Power	
2015 Demands Current Climate Conditions	Average total annual energy consumption for water treatment, desalination, pumping, groundwater, and recycled water is larger than average annual energy generation.
Current Climate Comparison between Demand Projections	Small increases in generation (due to increased water flow through hydro facilities) and large increases in consumption (due to additional water demands).
Climate Change Scenario Comparison	• Minimal differences between scenario groups. • Dry scenarios are slightly lower than wet scenarios for both generation and consumption.
Notes and Other Findings	Hydropower metrics are estimates and may not capture all generation and consumption by member agencies.

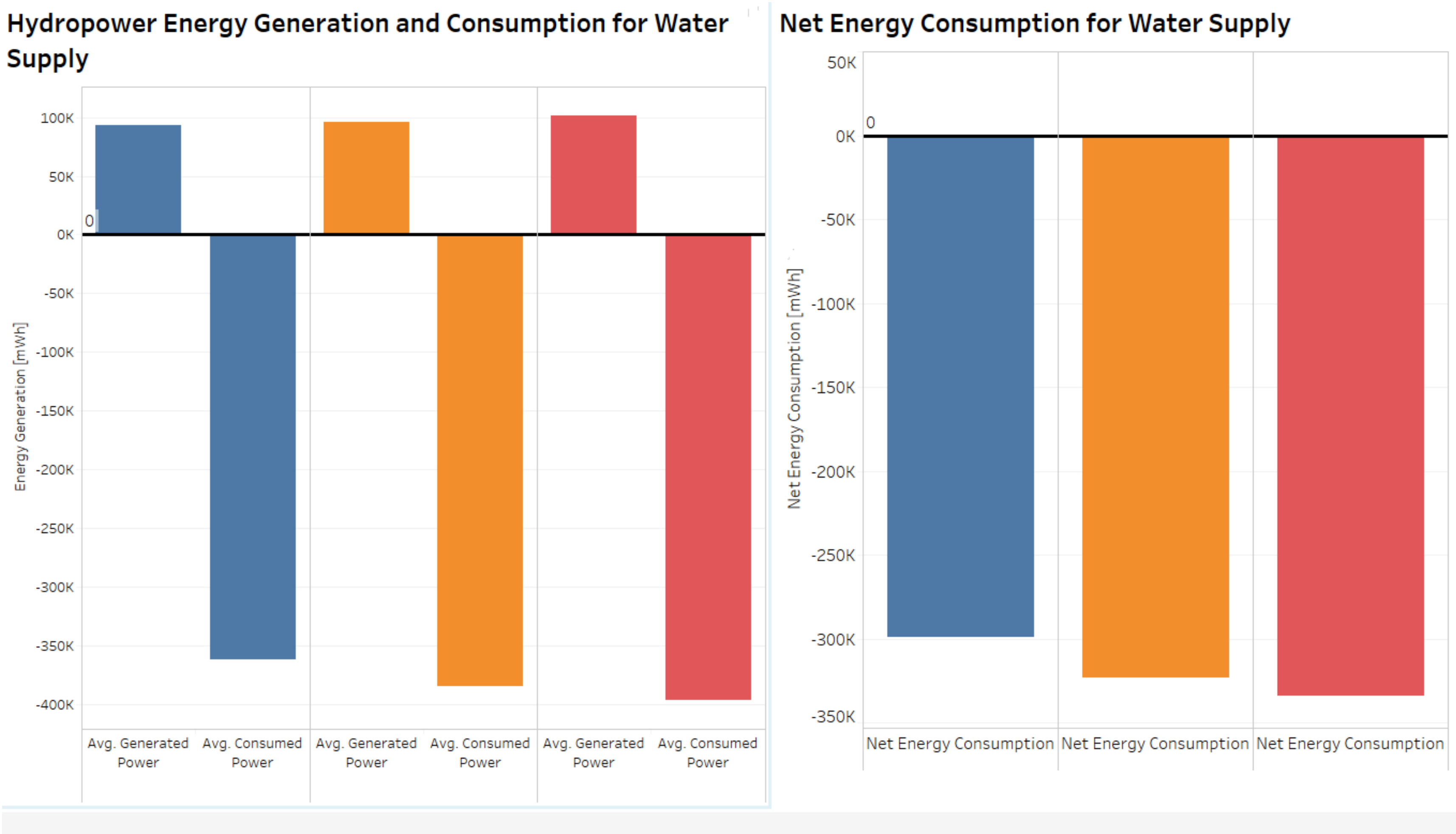


Figure A29. Energy generation and consumption by time period.

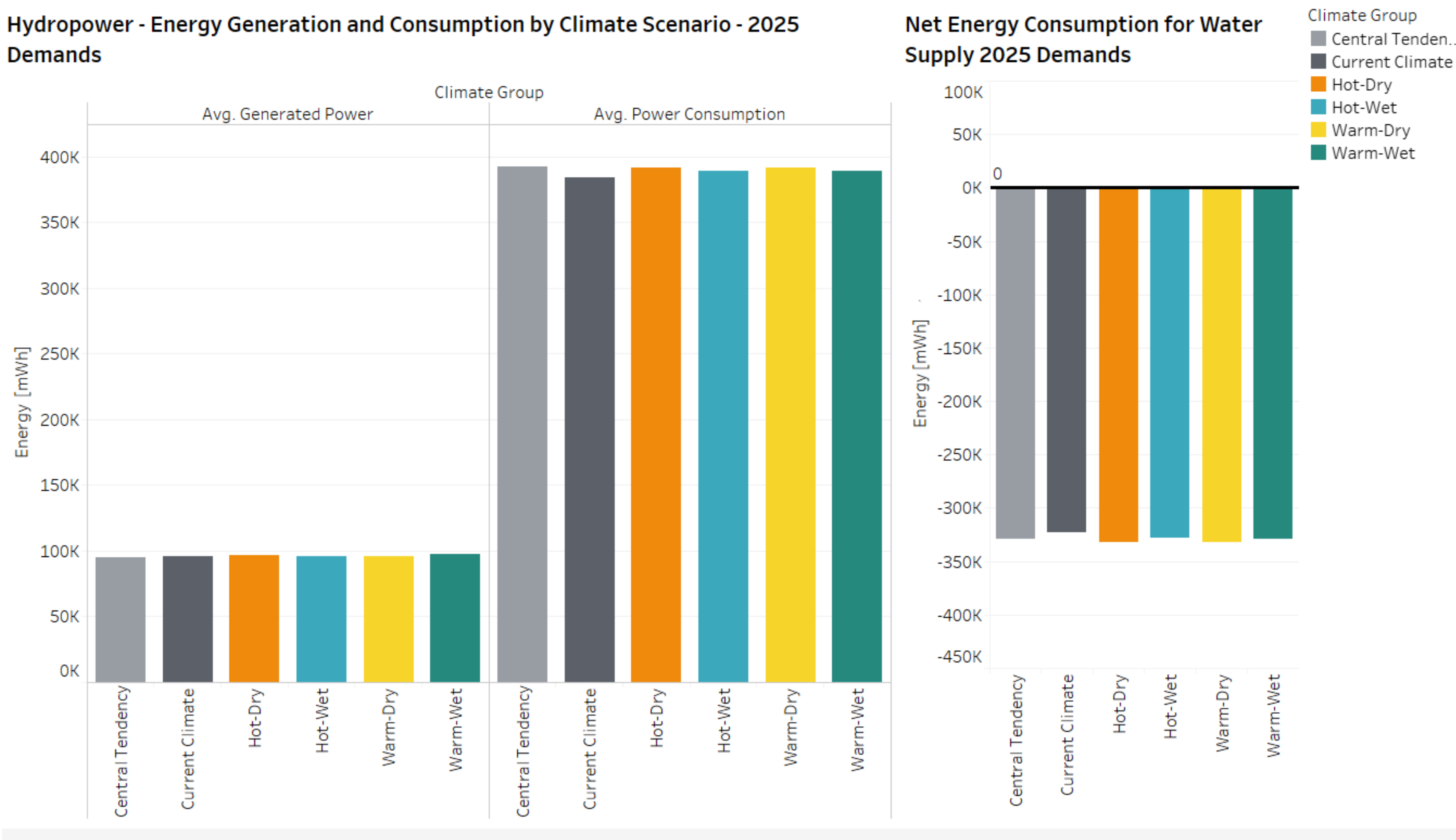


Figure A30. Energy generation and consumption by climate scenario group-2025 Demands.

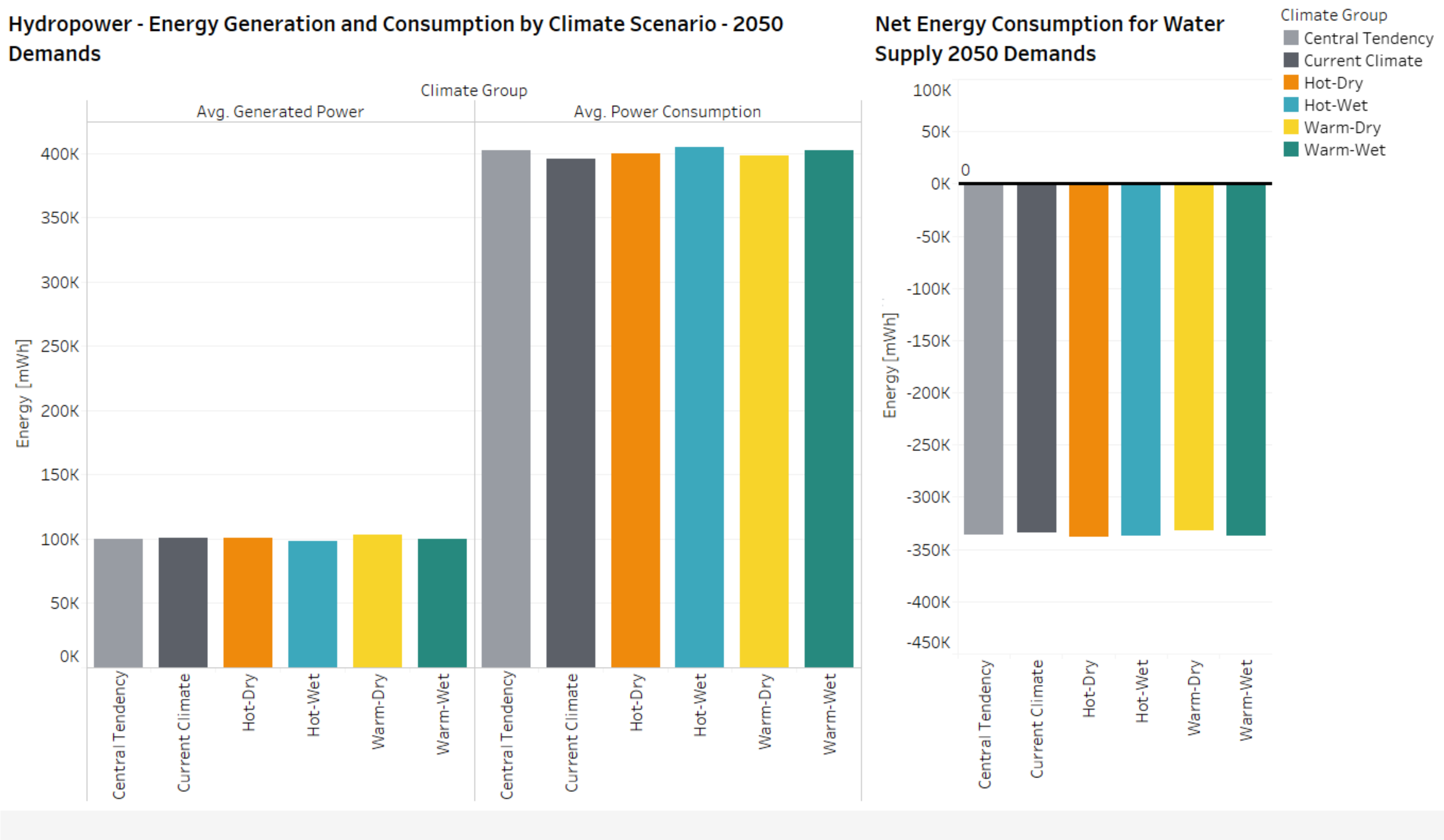


Figure A31. Energy generation and consumption by climate scenario group-2050 Demands.

Baseline Impacts - Recreation

Box 24. Impact Metric Description: End of September Elevation

Impact Category: Recreation Metric: End of September Elevation	
What it Measures	Measures the end of September reservoir elevation, which can be compared to other elevations, such as boat ramp elevations
Meaning of Larger or Smaller Values	Larger values mean elevation is higher and boat ramps are more likely to be accessible
Why it is Measured	Reservoir elevation affects boat ramp accessibility, which is an indicator of recreation opportunities.

Box 25. Summary of Findings: Recreation

Summary of Findings: Recreation	
2015 Demands Current Climate Conditions	Hodges, El Capitan, and San Vicente are generally above the elevation of the lowest boat ramp. Lower Otay operates near or below the lowest boat ramp elevation frequently. End of September elevations sometimes drop below the boat ramp at Lower Otay.
Current Climate Comparison between Demand Projections	Minimal differences between 2015, 2025, and 2050 demand projections under current climate.
Climate Change Scenario Comparison	• Minimal differences between most climate change scenario groups. • Minor difference between scenario groups at Lake Hodges.
Notes and Other Findings	None

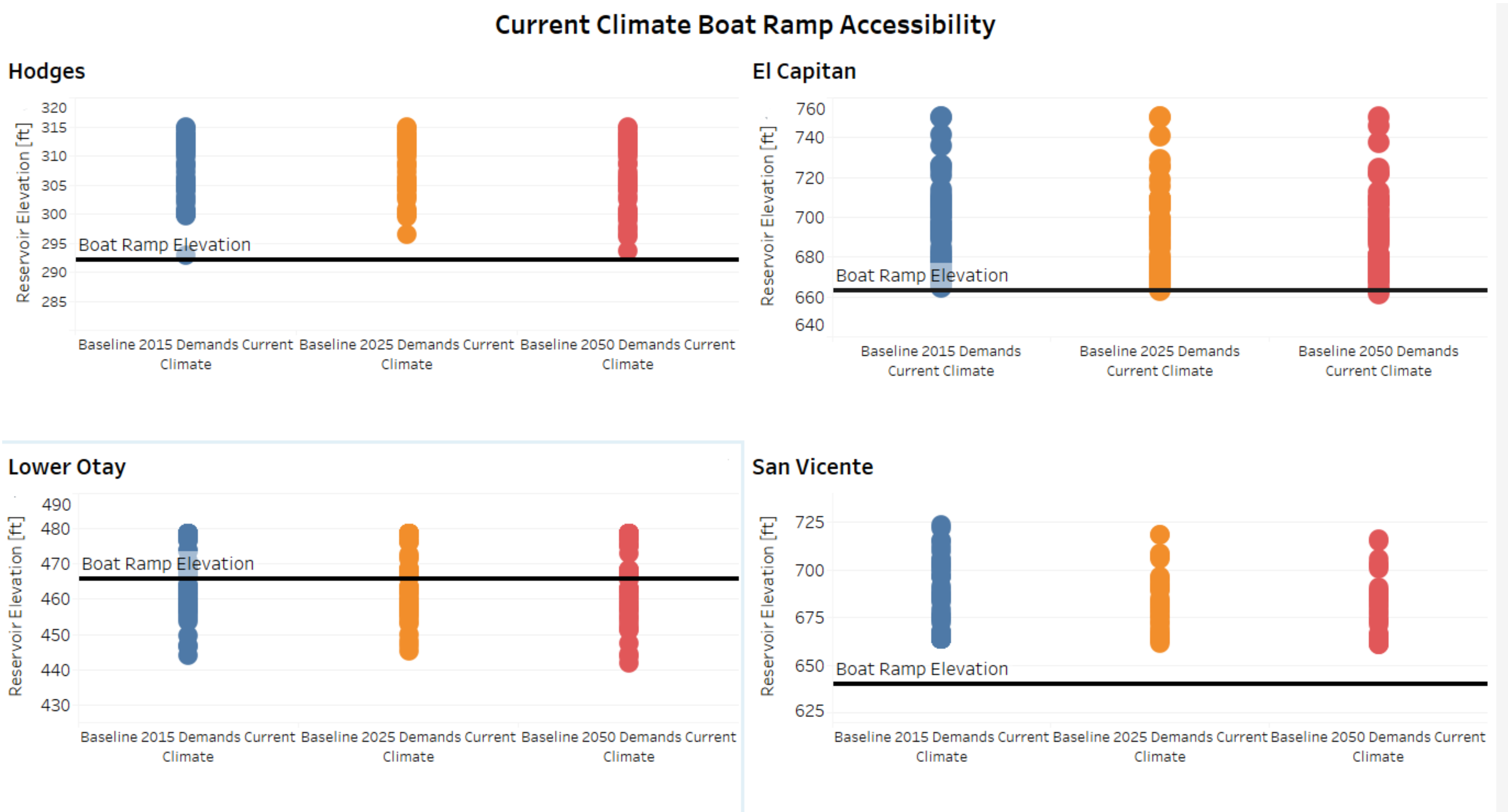


Figure A32. Reservoir and boat ramp elevations by time period.

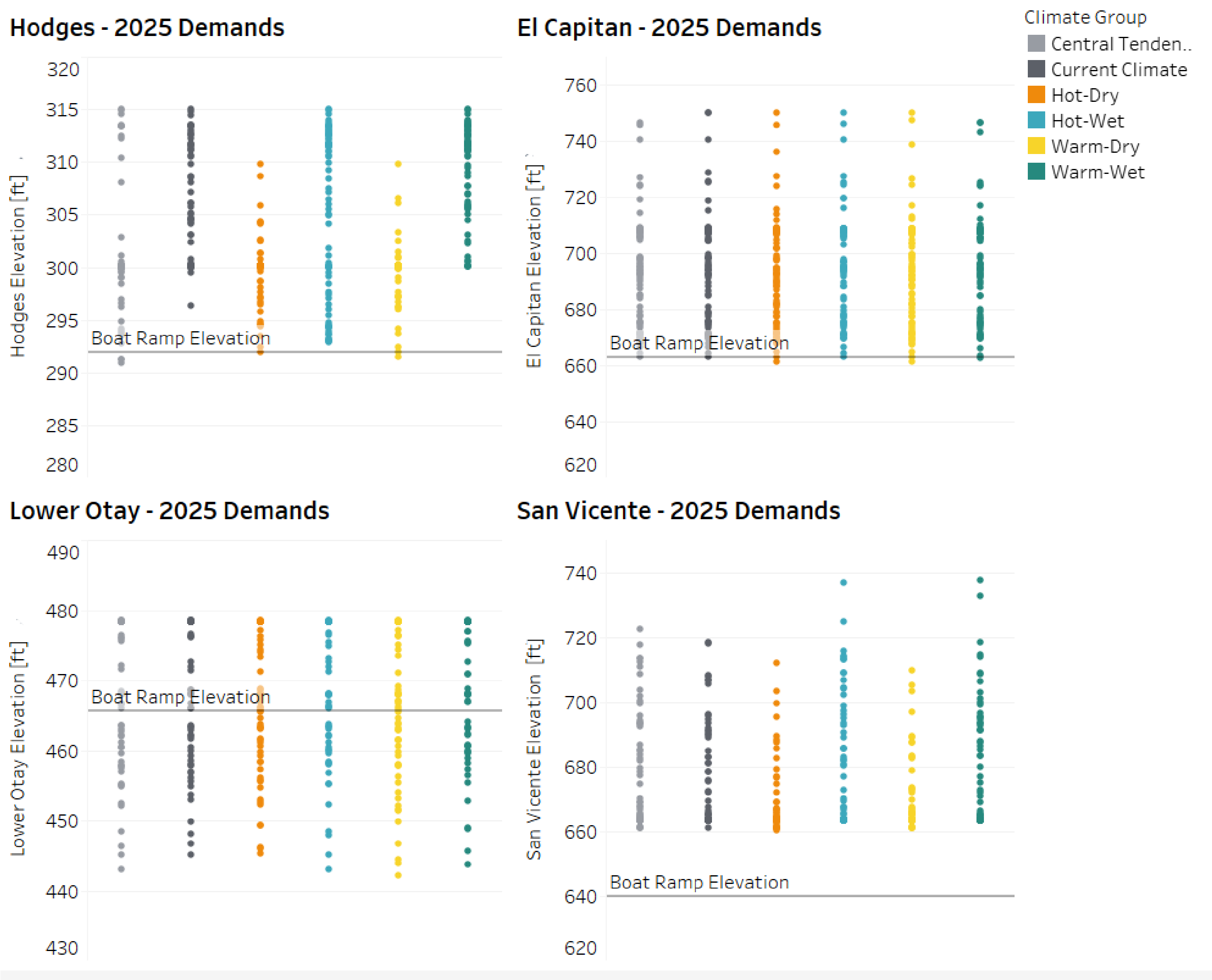


Figure A33. Reservoir and boat ramp elevations by climate scenario group, 2025 Demands.

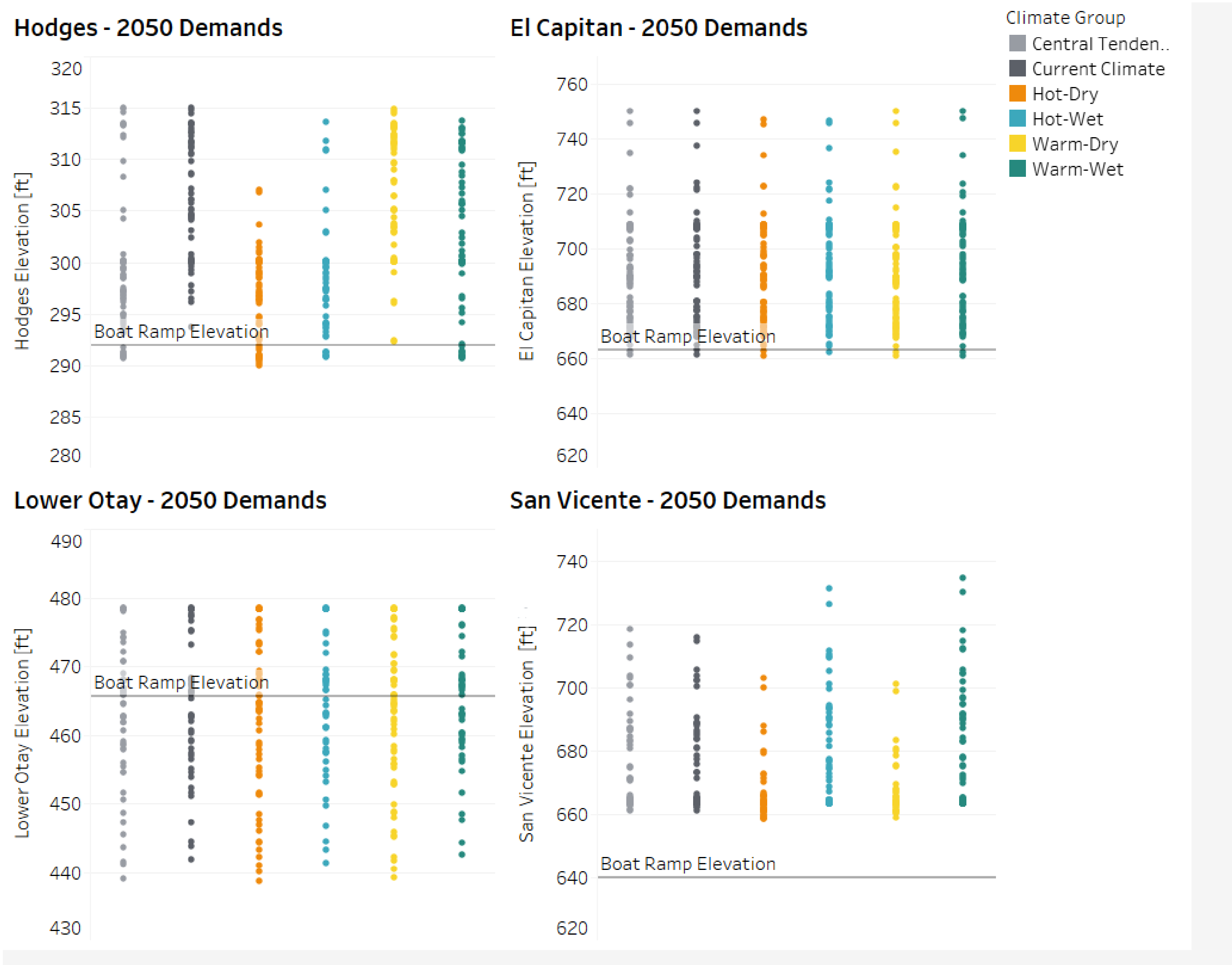


Figure A34. Reservoir and boat ramp elevations by climate scenario group, 2050 Demands.

Baseline Impacts - Flood Control

Box 26. Impact Metric Description: Number of Days with Spills

Impact Category: Flood Control Metric: Number of Days with Flood Spills	
What it Measures	Measures the number of days when water was spilled from a reservoir spillway
Meaning of Larger or Smaller Values	Larger numbers of days with spills indicate higher frequency of flood situations
Why it is Measured	Spills from these reservoirs are indicative of flood situations because water used for water supply purposes is spilled via pipes rather than through spillways. There are no minimum outflows from the reservoirs. If flood spills occur often, it may indicate an opportunity to store additional water for water supply.

Box 27. Impact Metric Description: Annual Volume Released

Impact Category: Water Delivery Metric: Annual Volume Released	
What it Measures	Measures the volume spilled from the reservoir during the year
Meaning of Larger or Smaller Values	Larger volumes indicate larger volumes of water that could not be stored in the reservoir
Why it is Measured	Spills from these reservoirs are indicative of flood situations because water used for water supply purposes is released via pipes rather than through spillways. There are no minimum outflows from the reservoirs. Flood spill volumes could represent an opportunity to capture additional local water supply.

Box 28. Summary of Findings: Flood Control

Summary of Findings: Flood Control	
2015 Demands Current Climate Conditions	Hodges has largest average number of spills per year and the largest average spill volume. No spills occur from Olivenhain or San Vicente.
Current Climate Comparison between Demand Projections	El Capitan, Hodges, and Lower Otay have stable or decreasing total average spill volume between demand projections under current climate.
Climate Change Scenario Comparison	El Capitan, Hodges and Lower Otay have larger numbers of spills and larger spill volumes in the wet scenarios than the dry scenarios
Notes and Other Findings	Flood control metrics are currently only available for El Capitan, Hodges, Lower Otay, Olivenhain, and San Vicente.

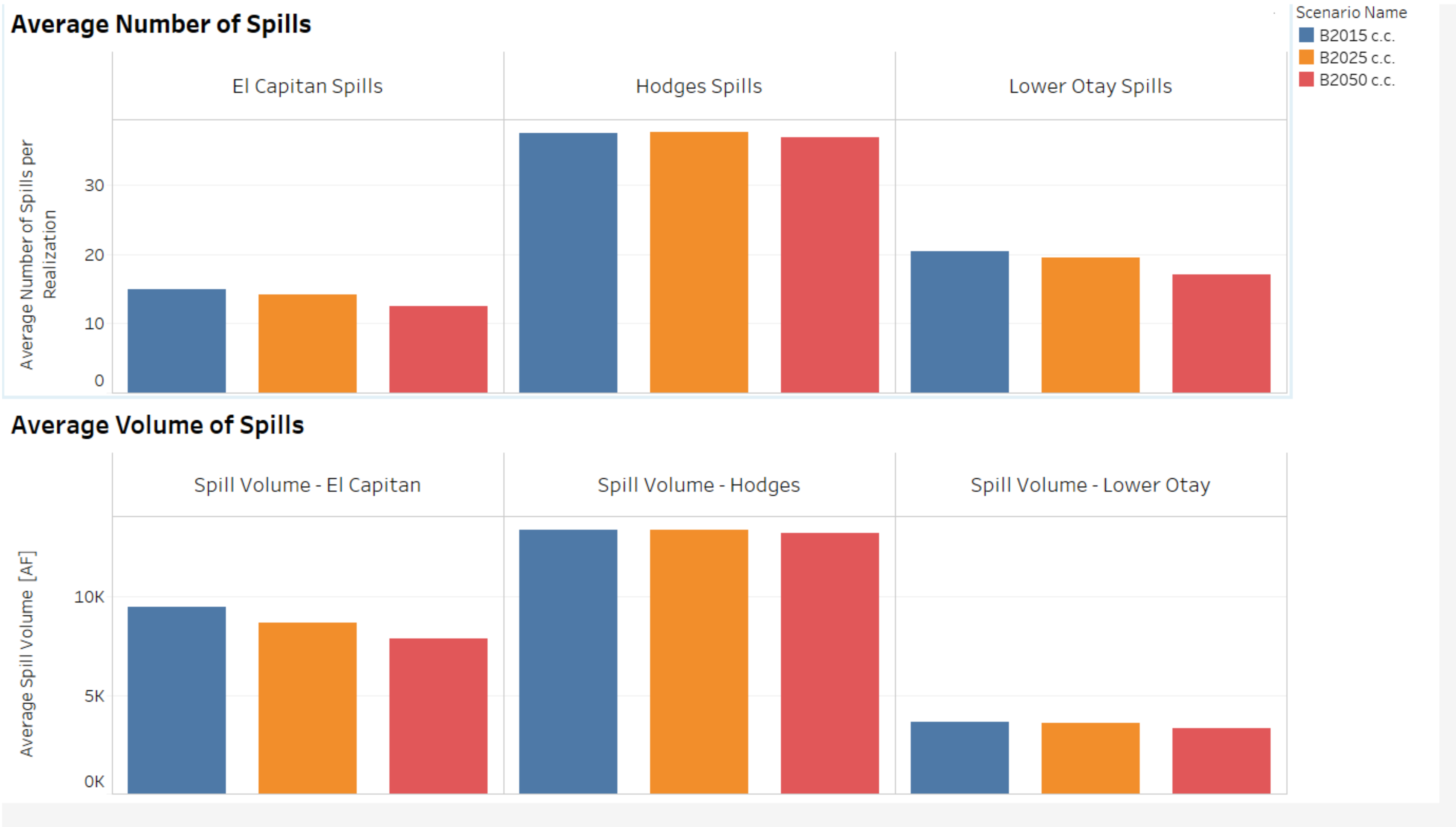


Figure A35. Average number and volume of flood spills by demand year.

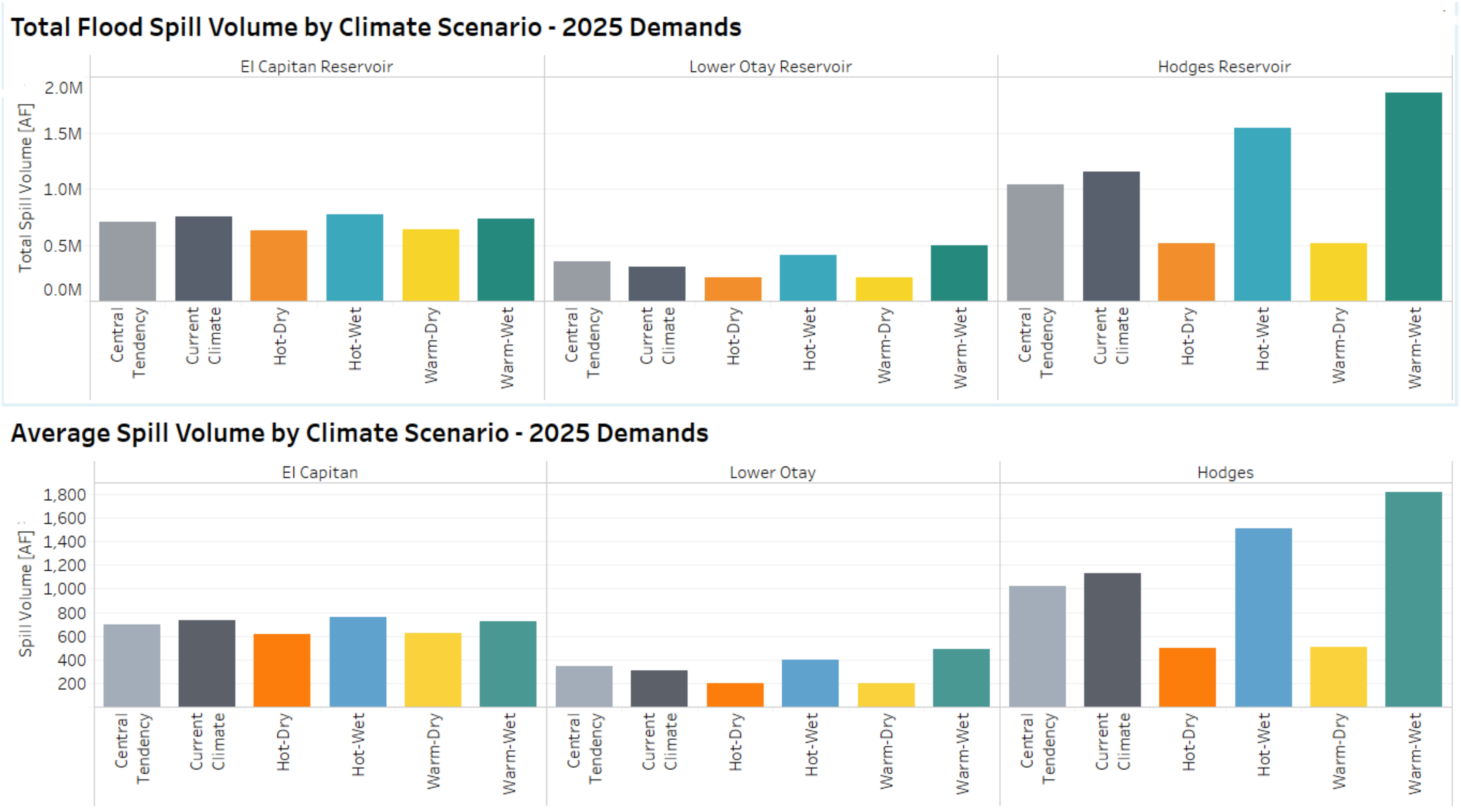


Figure A36. Average number and volume of spills per year by climate scenario group - 2025 Demands.

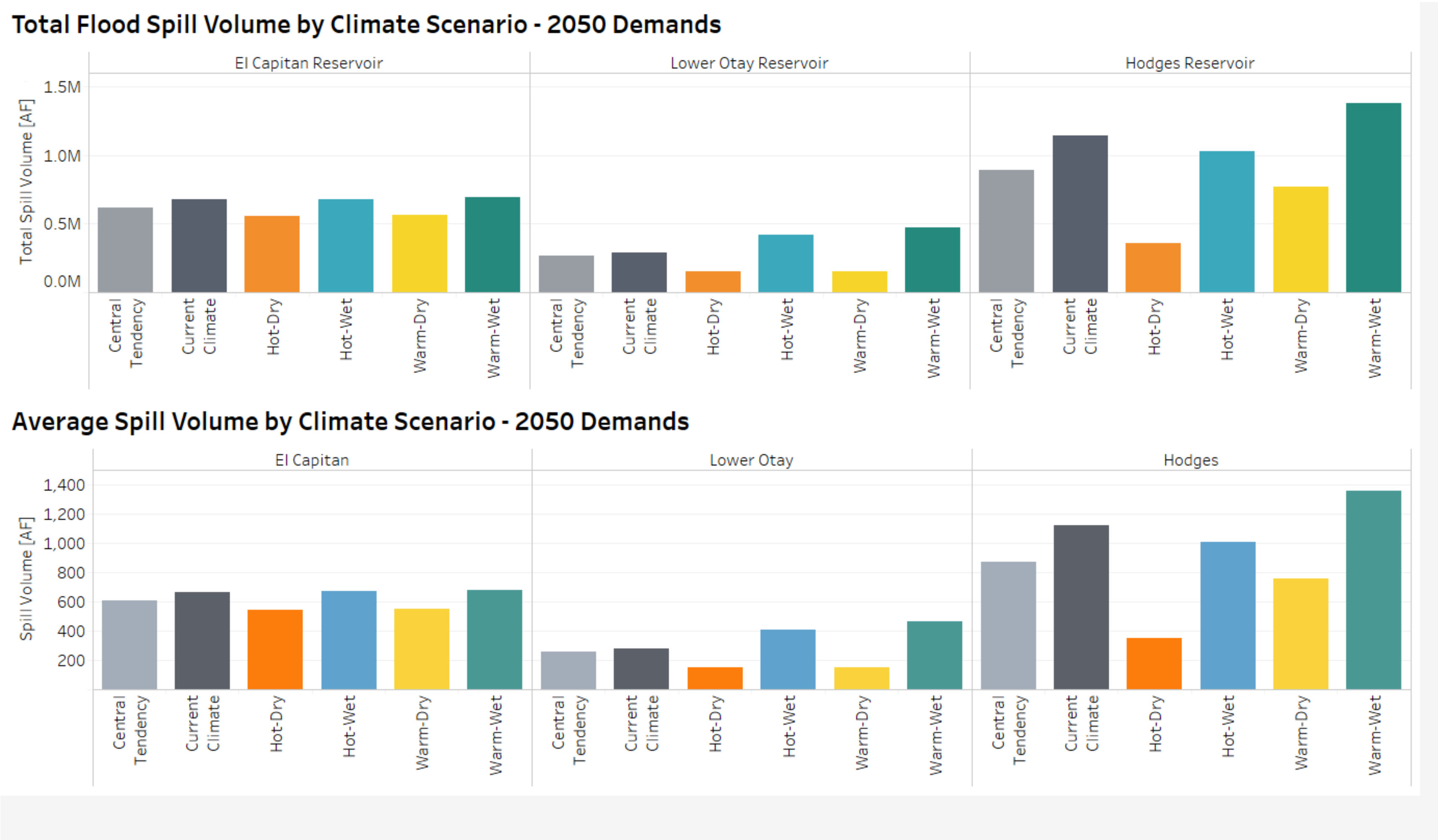


Figure A37. Average number and volume of spills per year by climate scenario group - 2050 Demands.