Inland Empire Utilities Agency
A MUNICIPAL WATER DISTRICT

AGENDA

SPECIAL MEETING/WORKSHOP OF THE BOARD OF DIRECTORS

WEDNESDAY, DECEMBER 5, 2018
8:00 A.M.
(PLEASE NOTE CHANGE IN TIME)
INLAND EMPIRE UTILITIES AGENCY*
AGENCY HEADQUARTERS
BOARD ROOM
6075 KIMBALL AVENUE
CHINO, CALIFORNIA 91708

CALL TO ORDER OF THE INLAND EMPIRE UTILITIES AGENCY BOARD OF DIRECTORS MEETING/WORKSHOP

FLAG SALUTE

PUBLIC COMMENT

Members of the public may address the Board on any item that is within the jurisdiction of the Board; however, no action may be taken on any item not appearing on the agenda unless the action is otherwise authorized by Subdivision (b) of Section 54954.2 of the Government Code. Those persons wishing to address the Board on any matter, whether or not it appears on the agenda, are requested to complete and submit to the Board Secretary a "Request to Speak" form which is available on the table in the Board Room. Comments will be limited to three minutes per speaker. Thank you.

ADDITIONS TO THE AGENDA

In accordance with Section 54954.2 of the Government Code (Brown Act), additions to the agenda require two-thirds vote of the legislative body, or, if less than two-thirds of the members are present, a unanimous vote of those members present, that there is a need to take immediate action and that the need for action came to the attention of the local agency subsequent to the agenda being posted.

1. CLOSED SESSION

A. PURSUANT TO GOVERNMENT CODE SECTION 54954.5 – PUBLIC EMPLOYMENT

1. General Manager

2. WORKSHOP PRESENTATION

A. CLIMATE CHANGE ACTION PLAN

3. ACTION ITEM

A. ADOPTION OF RESOLUTION NO. 2018-12-7, COMMENDING CITY OF CHINO COUNCIL MEMBER EARL ELROD FOR 20 YEARS OF PUBLIC SERVICE

Staff recommends that the Board adopt Resolution No. 2018-12-7, commending Council Member Earl Elrod for 20 years of public service with the City of Chino.

3. ADJOURN

*A Municipal Water District

In compliance with the Americans with Disabilities Act, if you need special assistance to participate in this meeting, please contact the Board Secretary (909) 993-1736, 48 hours prior to the scheduled meeting so that the Agency can make reasonable arrangements.

Proofed by: jh

Declaration of Posting

I, April Woodruff, Board Secretary of the Inland Empire Utilities Agency*, A Municipal Water District, hereby certify that a copy of this agenda has been posted by 5:30 p.m. at the Agency's main office, 6075 Kimball Avenue, Building A, Chino, CA on Thursday, November 29, 2018.

April Woodruff

April Woodruff

WORKSHOP

2A

Inland Empire Utilities Agency
A MUNICIPAL WATER DISTRICT

Date: December 5, 2018

To: The Honorable Board of Directors **From:** Halla Razak, General Manager KB for HHR

Committee:

Executive Contact: Kathy Besser, Executive Manager of Ext. Aff. & Policy Dev./AGM

Subject: Climate Change Action Plan

Executive Summary:

IEUA staff has developed a Climate Change Action Plan (CCAP) that describes the vision and direction needed to bolster IEUA's water management system and minimize its carbon footprint. The CCAP expands on previous planning efforts and provides a framework for environmentally conscious project development based on the anticipated effect of climate change on the water supply and demand in the IEUA service area and resulting Greenhouse Gas emissions impacts.

The CCAP establishes four main objectives that IEUA will pursue to develop an adaptable water management system that positively impacts climate change:

- Maximize local water supplies;
- Maintain health of groundwater aquifer;
- Maximize system efficiencies; and
- Measure performance.

Adoption of the CCAP will also strengthen IEUA's ability to pursue grant funds through the Clean Water State Revolving Fund Program.

Staff's Recommendation:

This is a workshop item on the Climate Change Action Plan.

Budget Impact *Budgeted (Y/N):* N *Amendment (Y/N):* N *Amount for Requested Approval:*

Account/Project Name:

Fiscal Impact (explain if not budgeted):

Full account coding (internal AP purposes only): - - - Project No.:
- - -

Prior Board Action:

None.

Environmental Determination:

Not Applicable

Business Goal:

The CCAP provides a framework for project development that directly aligns with several Agency Business Goals, including Water Reliability, Wastewater Management, and Environmental Stewardship.

Attachments:

Attachment 1 - PowerPoint
Attachment 2 - Climate Change Action Plan

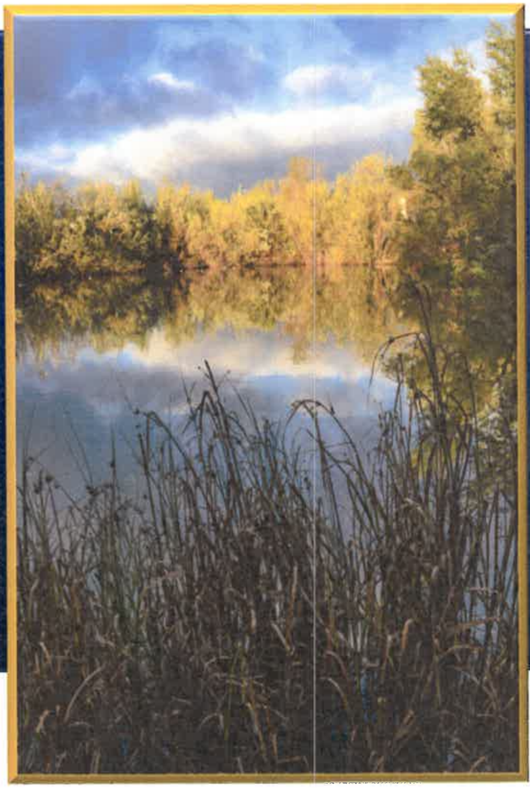
IEUA Climate Change Action Plan

Inland Empire Utilities Agency
A MUNICIPAL WATER DISTRICT

Jesse Pompa, P.E., PMP
December 2018

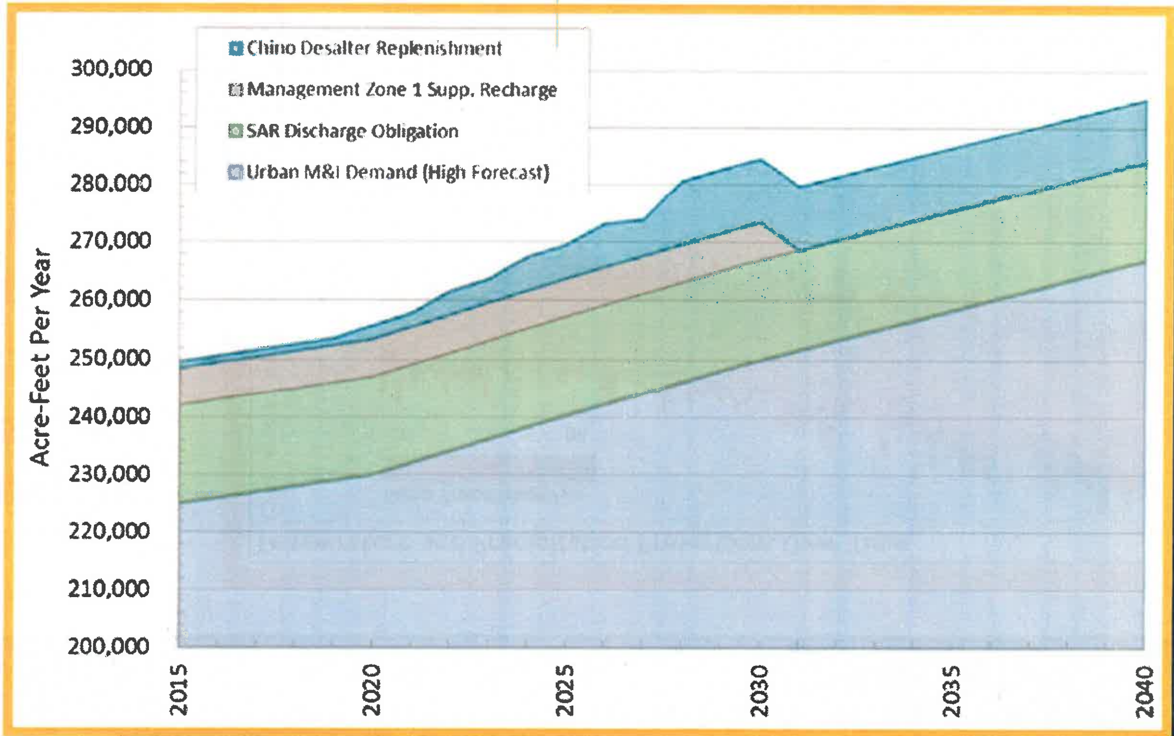
Background

- IEUA continues to be a leader in environmental stewardship.
- Improving regional water sustainability will help mitigate effects of climate change.



Regional Water Supply and Demand

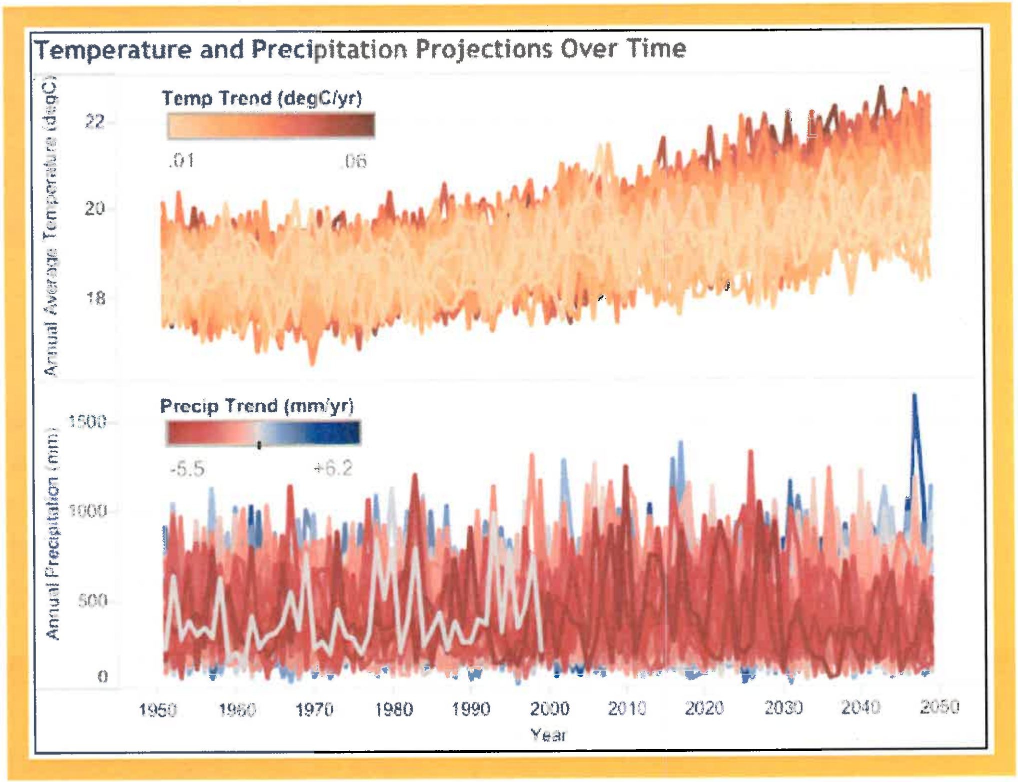
- Climate change will greatly impact IEUA's ability to meet regional water demands
- Increase in urban development, decrease in agricultural land in the region
- Increase in demand for wastewater treatment



Inland Empire Utilities Agency
A MUNICIPAL WATER DISTRICT

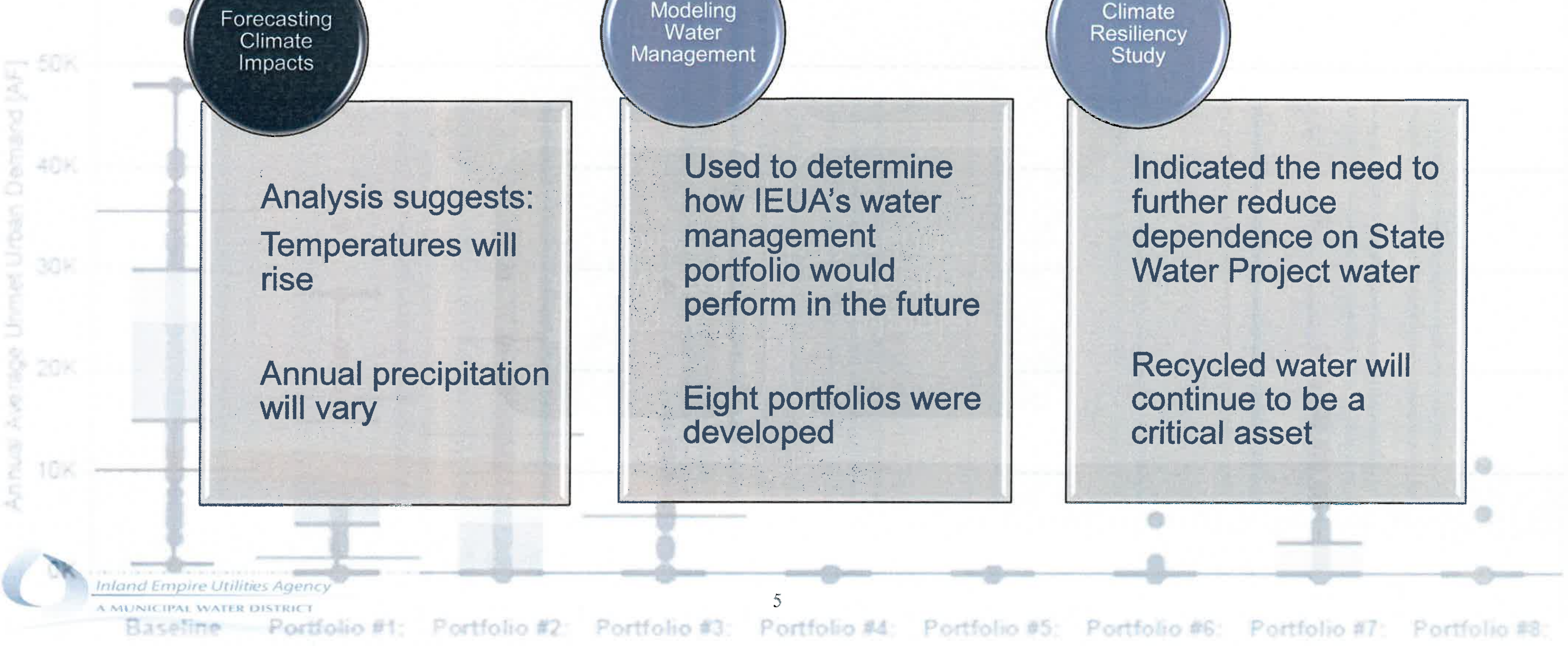
Preparing for Climate Change Impacts

- Planning Department efforts identified climate change impacts and response
  - Integrated Water Resources Plan
  - Urban Water Management Plan
  - Energy Management Plan
- Compilation of efforts into one plan defines path forward
  - Strengthens ability to receive state and federal funding



Temperature and Precipitation Projections Over Time

Improving Climate Resilience



Forecasting Climate Impacts

Analysis suggests:

Temperatures will rise

Annual precipitation will vary

Modeling Water Management

Used to determine how IEUA's water management portfolio would perform in the future

Eight portfolios were developed

Climate Resiliency Study

Indicated the need to further reduce dependence on State Water Project water

Recycled water will continue to be a critical asset

Goals and Objectives

- Maximize Local Water Supplies
- Maintain Health of Groundwater
- Maximize System Efficiencies
- Measure Performance

Maximize Local Water Supplies

Objectives

- Expand or improve infrastructure at IEUA sites to enhance capabilities for end-user application, storage or groundwater replenishment of recycled water.
- Enhance regional water reliability by pursuing projects that will increase local water production or storage.

Benefits

- Less reliance on the SWP supply offers more flexibility during drought periods and reduces electricity usage.
- The projects will aim to:
  - Improve water quality
  - Increase local water deliveries
  - Increase storage capabilities

Maintain Health of Groundwater Aquifer

Objectives

- Improve stormwater capture.
- Enhance groundwater replenishment capabilities.
- Improve water quality to protect public health, the environment and anticipated regulatory requirements.
- Enhance storage capabilities of storm, recycled or imported water.

Benefits

- Reduces electricity to convey RW or imported water to basins.
- Improves flexibility in the type/amount of water to basins.
- Ensures environmental compliance.
- Optimizes the use of existing assets, minimizing imports.

Maximize System Efficiencies

Objectives

- Expand energy efficiencies at IEUA facilities.
- Develop water use efficiency and/or conservation programs within the region.
- Pursue renewable resource recovery projects.

Benefits

- Reduces IEUA's GHG emissions.
- Optimizes water supply, promotes regional sustainability.
- Reduces IEUA's reliance on the electrical grid.

Measure Performance

Objectives

- Report GHG emissions annually through The Climate Registry and track energy efficiency of IEUA facilities.
- Track key performance indicators for recycled, storm and imported water usage within IEUA's management system.

Benefits

- Allows IEUA to determine the effectiveness of reduction measures.
- Enables IEUA to identify potential improvements to further advance the system.

QUESTIONS?

The Climate Change Action Plan provides a framework for project development that directly aligns with several Agency Business Goals, including ***Water Reliability***, ***Wastewater Management***, and ***Environmental Stewardship***.

2018

Climate Change Action Plan

Inland Empire Utilities Agency
A MUNICIPAL WATER DISTRICT

Table of Contents

Executive Summary

While climate change is a global concern with far-reaching impacts, regional and state agencies must assess their own ability to adapt to future changes. The state of California has responded to the anticipated environmental and economic effects of climate change by implementing statewide regulations that target reductions of Greenhouse Gas (GHG) emissions.

The Inland Empire Utilities Agency (IEUA) is a regional wastewater treatment agency and wholesale distributor of imported water in western San Bernardino County. IEUA is responsible for providing service to approximately 875,000 people over a 242-square mile area. This Climate Change Action Plan (CCAP) seeks to identify the local impacts of climate change and lay the groundwork for developing projects and management practices that will allow IEUA to continue providing reliable services to the region while remaining a steward to the environment.

IEUA has voluntarily reported and verified its GHG emissions since 2013. IEUA has also become a leader among public agencies nationwide by pursuing innovative renewable energy projects that promote sustainability and reduce demands on a strained electrical grid.

This CCAP expands on these initial steps to integrate studies that IEUA has conducted which focus on the potential impacts climate change will have on IEUA's water management system. These studies evaluated the anticipated water supply and demand in the IEUA service area over the next 20 years and identified components within IEUA's portfolio that can be improved to create a resilient system that is adaptable to climate change.

In conjunction with changes to IEUA's water management system, the CCAP also establishes measures that can steer IEUA toward a net-zero impact with regard to GHG emissions. Using this information, the CCAP establishes goals and objectives that will be used to develop future projects. These goals satisfy four main areas of need to achieve a flexible, effective water management system:

- Maximize recycled water production and usage;
- Maintain health of the groundwater aquifer;
- Maximize system efficiencies; and
- Measure performance.

Introduction

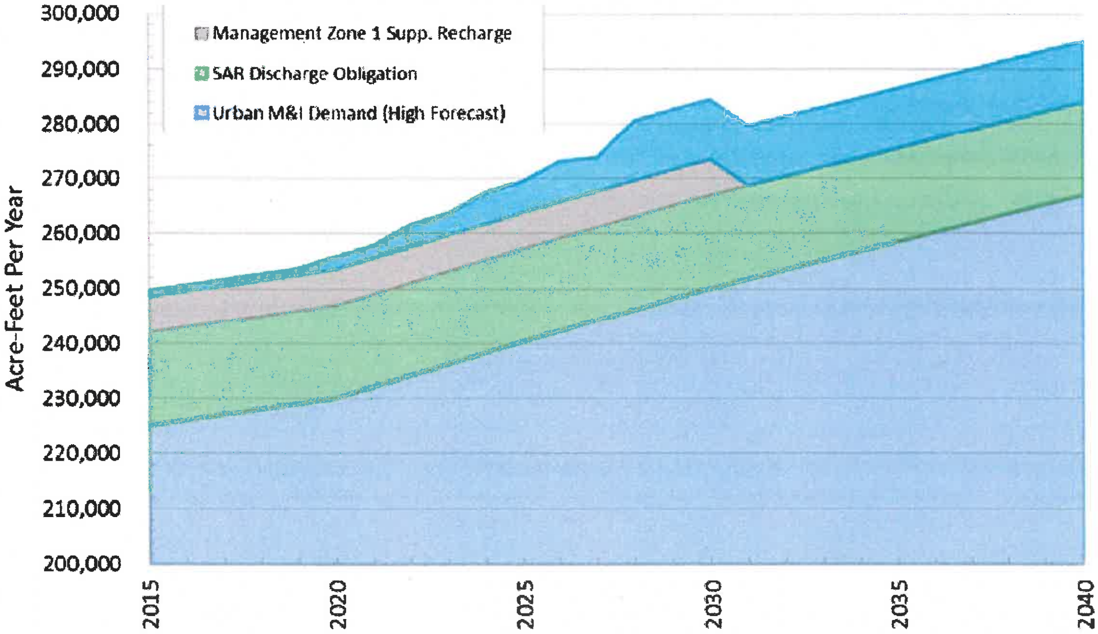
Global climate change has contributed to intense heat, rising sea levels and loss of sea ice. Although the sum of potential impacts due to climate change comes with some uncertainty, there is no doubt this change is expected to disturb the pattern for water demand as well as the availability for supplies. There are many ways a warmer climate is likely to affect water and wastewater management. Conditions in much of the western United States range from abnormally dry to extreme drought. The area is also experiencing a trend for reduced mountain snowpack with earlier melting runoff peaks in the spring. Temperatures are expected to rise, reducing soil moisture which will intensify summer heat waves. Due to increasing evapotranspiration through the warmer seasons, additional water resources may be needed to maintain proper irrigation and prevent the damaging effects of dry soil for the vegetation.

Regional Water Supply and Demand

Coupled with a projected steady population growth, the effects of climate change will greatly impact IEUA's ability to meet regional water demands. To accommodate the expected increase in urban demand, agricultural land has been converted for urban usages to meet the needs of the region. This shift will cause the percentage of water pumped for urban demand to increase over the next 25 years as the agricultural demand for water in these areas will diminish. As the regional economy continues to evolve, the demand for water and wastewater treatment will continue to increase; raising significant challenges and concerns to meet basic needs.

Strategic planning efforts are underway to shape the regional water management system in a way that can adapt to fluctuations in both demand

FIGURE 1. PROJECTED REGIONAL DEMANDS WITHIN IEUA SERVICE AREA THROUGH 2040



and supply as a result of climate change. IEUA's 2016 Integrated Water Resources Plan (IRP) evaluated the anticipated regional water demand through 2040, shown in Figure 1. These projections anticipate a continual increase in demand and include the total municipal and industrial demands as well as the amount of water needed to ensure regional sustainability by replenishing the groundwater aquifer and the Santa Ana River.

IEUA meets regional demand with supply from several sources, shown in Figure 2. These sources are all expected to be impacted by climate change, and each brings unique challenges to maintain their efficacy as a sustainable resource for meeting water needs.

Primary among these challenges will be IEUA's ability to increase the amount of local resources used to meet local needs. Reducing the region's reliance on imported water from the State Water Project (SWP), which is pumped from Northern California, will not only reduce GHG emissions from the energy-intensive water conveyance process, but it will also enhance the flexibility of IEUA's water management system in preparation for an uncertain climate future.

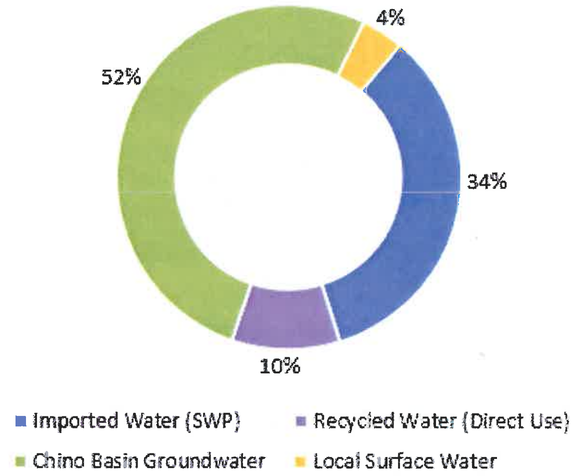


FIGURE 2. IEUA WATER SUPPLY SOURCES FOR FISCAL YEAR 2017/2018

It should be noted that increasing production from local resources should not be done without also balancing with equivalent groundwater replenishment. This CCAP provides a framework for developing a water management portfolio that is resilient enough to meet continually increasing demands in the face of unknown climate change impacts.

Improving Climate Resilience

Forecasting Climate Impacts

IEUA's location in the semi-arid, populous area of southwestern San Bernardino County has raised concerns regarding its ability to continue meeting regional water demands. These concerns were recently brought to the forefront when the region encountered extreme drought conditions. Although this drought appears to be consistent with long-term patterns of climate variability, its effects may be exacerbated by ongoing climate change. These effects may have a strong impact on the region's water supply and the length and magnitude of droughts, timing of precipitation, and temperature-driven demand. IEUA partnered with the RAND Corporation (RAND), a multi-disciplinary, non-partisan research organization and educational institution headquartered in Santa Monica, California, to evaluate how adaptive, integrative water management portfolios could improve IEUA's abilities to meet customer needs under a wide range of futures. The complete RAND Memorandum is included as Appendix 1.

RAND utilized a suite of general circulation models to generate a range of future climate projections for the IEUA service area. A total of

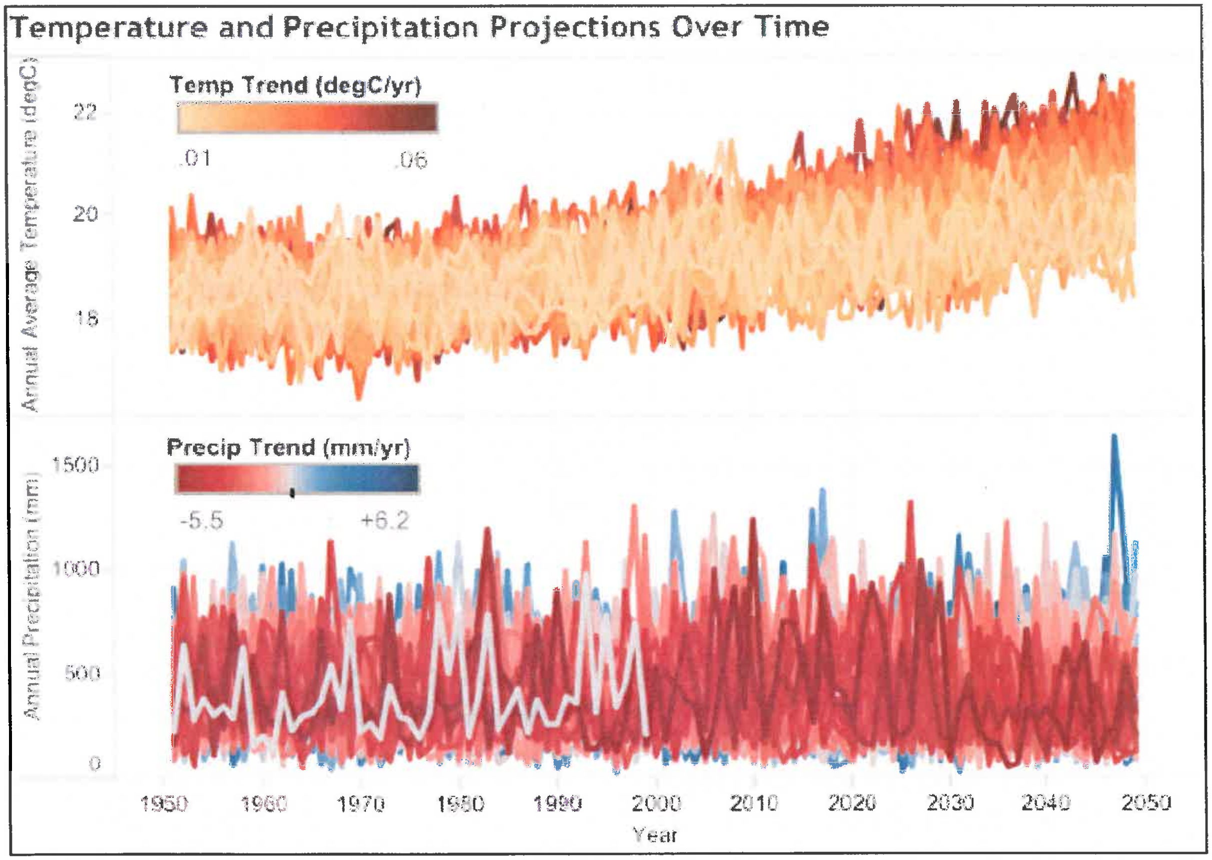


FIGURE 3. HISTORICAL AND FUTURE ESTIMATED ANNUAL AVERAGE TEMPERATURE AND PRECIPITATION FOR THE IEUA SERVICE AREA

106 projections were downscaled and analyzed to forecast the anticipated climate scenarios that IEUA's planning efforts will need to address.

The analysis suggests that temperatures within the IEUA service area will rise over the coming decades and that annual precipitation will continue to be highly variable, with no consensus on trends towards wetter or drier conditions. Using data from the 106 projections, RAND compiled and displayed the annual average temperature and total precipitation estimates from 1950 to 2050 for the IEUA service area, shown in Figure 3. The figure stresses the unpredictability of these variables, as temperatures began to steadily increase in the region beginning around the 1980s while precipitation followed an uncertain pattern over the same period. This information underscores the importance of identifying IEUA's water management options and portfolios to ensure that future demand can be met under a variety of different hydrologic circumstances that appear to point toward higher temperatures and unreliable rainfall.

Modeling Water Management

To determine how IEUA's water management portfolio would perform in the future, RAND conducted a study that used a mass balance model with estimated supply and demand values across the range of anticipated climate conditions.

The study consisted of a four-step process:

1. Compile information on a wide range of plausible water demand and supply futures reflecting climate change;
2. Develop a simple water management mass balance model to evaluate the performance of the IEUA system under a wide range of futures;
3. Create a portfolio development tool (PDT) to help IEUA planners and stakeholders compare attributes of different management options and develop portfolios for evaluation; and
4. Evaluate and compare how each proposed water management portfolio would enhance IEUA's ability to deliver urban water supplies in the future under different futures of climate and demand.

The 106 future climate projections allowed RAND to stress test the IEUA water management system in its ability to meet future demand. While it is impossible to predict, with certainty, what type of climatic change the region will encounter, having a diverse set of projections benefits planning efforts in the development of a robust, adaptable water supply system.

RAND developed the PDT used in the study with the input of IEUA and its member agencies. The PDT allowed users to review individual project attributes and determine the impact that these projects, in various combinations, would have on the regional water supply and demand.

Following collaborative discussions among the regional stakeholders, a list of eight portfolios was finalized and incorporated into the study, as shown in Table 1. These portfolios were then evaluated for their ability to meet regional demand under various conditions.

Portfolio Name	Portfolio Description
Portfolio #1	Maximize the Use of Prior Stored Groundwater
Portfolio #2	Maximize Recycled Water (Including External Supplies) and Local Supply Projects and Implement Minimal Water Efficiency
Portfolio #3	Portfolio 2 Plus Secure Supplemental Imported Water from MWD and Non-MWD Sources
Portfolio #4	Maximize Recycled Water (Including External Supplies) and Implement Moderate Water Efficiency
Portfolio #5	Portfolio 4 Plus Implement High Water Efficiency
Portfolio #6	Maximize Supplemental Water Supplies and Recycled Water Supplies
Portfolio #7	Maximize the Purchase of Imported Water from MWD and Implement Minimal-Moderate Level of Water Efficiency
Portfolio #8	Portfolio 7 Plus Maximize Recycled Water

TABLE 1. WATER MANAGEMENT PORTFOLIOS USED TO DETERMINE FUTURE CLIMATE RESILIENCY

Climate Resiliency Study Results

Despite uncertainty over the specific effect of climate change on IEUA's water supply, the various projections showed an overall tendency of future decreases in IEUA's supply sources. The largest potential impact on supply is the imported water that IEUA receives from the SWP through the Metropolitan Water District (MWD), which indicates a need to improve regional sustainability and reduced dependence on the SWP supply.

Figure 4 shows the performance of each portfolio and their ability to meet the varying demands set forth in the model. Portfolios 4, 5, 6, and 8 all met demands in over 90 percent of the demand scenarios. Based on these results, IEUA can develop a water management system that is resilient against climate change by focusing planning efforts on projects that maximize recycled water production and usage, implement water efficiency, and optimize supplemental water supplies.

Recycled water supplies, in particular, will prove to be a critical asset in bolstering a flexible management portfolio, as these supplies are:

- Not impacted by climate, making recycled water the region's most climate resilient water supply;
- Needed to maximize supplemental water for groundwater recharge;
- Generated locally and can be beneficially used by all agencies; and
- A supplemental water source for the entire region with infrastructure that can be intertied with that of neighboring agencies to optimize availability and use.

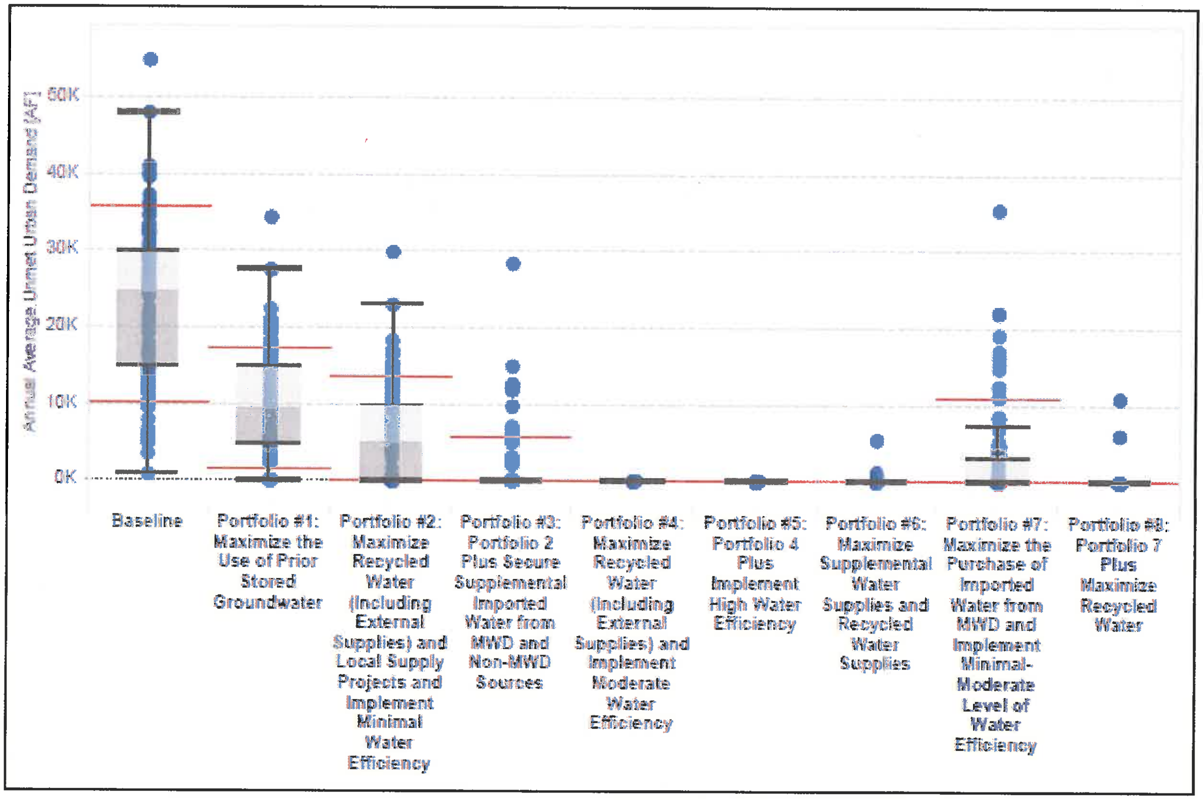


FIGURE 4. AVERAGE UNMET DEMAND (2036 - 2040) FOR IEUA PORTFOLIOS ACROSS CLIMATE PROJECTIONS FOR HIGH DEMAND SCENARIOS

Greenhouse Gas Emissions Impacts

Background

The California Global Warming Solutions Act of 2006 – also known as AB 32 – marked the beginning of an integrated climate change program. AB 32 set California's first GHG emissions target, which called on the state to reduce emissions to 1990 levels by 2020, and 40 percent below the 1990 levels by 2030. These targets represent benchmarks, consistent with prevailing climate science, charting an appropriate trajectory forward that is in line with California's role in stabilizing global warming below dangerous thresholds. California is on track to exceed its 2020 climate target while the economy continues to grow.

Greenhouse Gases emitted in the state are regulated by the California Air Resources Board (CARB). CARB has also developed the Climate Change Scoping plan, most recently updated in November 2017, which targets industries and large facilities with high global warming potential and mandates reduction measures to steadily decrease GHG emission levels. Wastewater treatment plants and composting facilities are not subject to the reduction measures addressed in the Scoping Plan. In addition, no IEUA facility emits GHGs at a level high enough to reach the regulated threshold for mandatory GHG reporting.

The Connection between Water and Energy

According to the Public Policy Institute of California (PPIC), California's water system accounts for nearly 10 percent of the state's GHG emissions and approximately 20 percent of statewide electricity use goes to pumping, treating, and heating water. The inextricable link between water and energy, termed, "the water-energy nexus," highlights the importance of enhancing water-use efficiency and drought resilience while at the same time focusing efforts on lowering energy usage. As the population grows and we adapt to climate change, the adoption of policies and technologies that enhance water and energy management will be essential.

IEUA GHG Emissions

In February 2014, IEUA became a member of The Climate Registry (TCR). TCR is a non-profit organization governed by the U.S. and Canadian provinces and territories. TCR designs and operates voluntary and compliance GHG reporting programs globally and assist organizations in measuring, verifying and reporting their carbon footprints for benchmarking and management purposes. It is the only voluntary greenhouse gas (GHG) registry supported by this level of government collaboration. TCR's reporting protocols align with international standards and provide a nexus between business, government and non-governmental organizations to share policy information and exchange best practices. Membership in TCR is voluntary and is a result of IEUA's aim to practice environmental stewardship as a regional leader. As a member of TCR, IEUA has committed to publicly report annual GHG emissions despite not being subject to mandatory reporting. IEUA has reported GHG emissions, as carbon dioxide equivalency, from its facilities to TCR each year since 2013. The reported emissions use TCR protocols to calculate the metric tons of carbon dioxide equivalents (MT CO_2e) emitted by IEUA facilities.

Both direct (emissions from equipment operated within IEUA facilities) and indirect (emissions associated with services procured by IEUA, such as purchased electricity) emissions were included in the reported values. It should be noted that the 2013-2015 emissions have been verified by TCR; the 2016 emissions have been reported and are in the process of being verified. As seen in Figure 5, the greatest source of GHG emissions in 2013 was purchased electricity by a dramatic margin. In 2016, GHG emissions from digester gas combustion were slightly higher than purchased electricity, and the two sources combined for over 90 percent of the total GHG emissions across all facilities.

The reason for such a drastic shift in digester gas combustion emissions can be attributed to the implementation of the food waste digestion process at IEUA's Regional Plant No. 5 Solids Handling Facility (RP-5 SHF). The food waste digestion process generated a new source of biogas, which means more local GHGs were emitted from its combustion. However, the food waste that was digested to create the biogas was diverted from landfills, where it would have resulted in higher global GHG emissions from long-distance hauling followed by years of methane generation. The power generation from the cogeneration engine that is fueled by the biogas explains the decrease in electricity purchases that IEUA made over the same period.

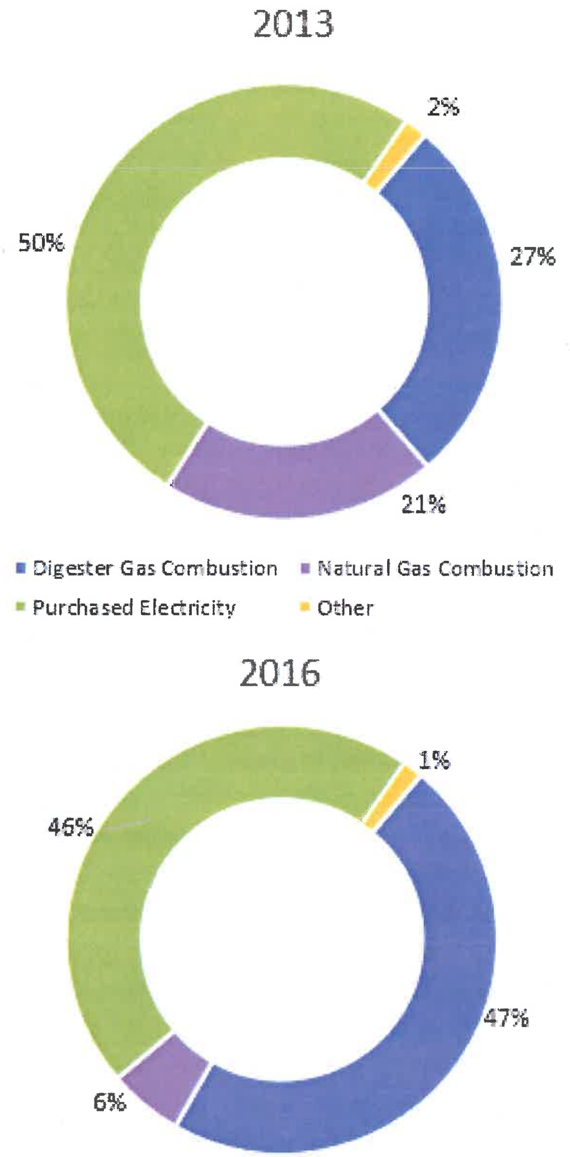


FIGURE 5. COMPARISON OF 2013 AND 2016 IEUA GHG EMISSIONS BY SOURCE

Note: The "Other" category is made up of emissions from heavy duty vehicles, IEUA fleet vehicles, biosolids hauling from treatment plants, emergency generators, and liquified petroleum gas combustion.

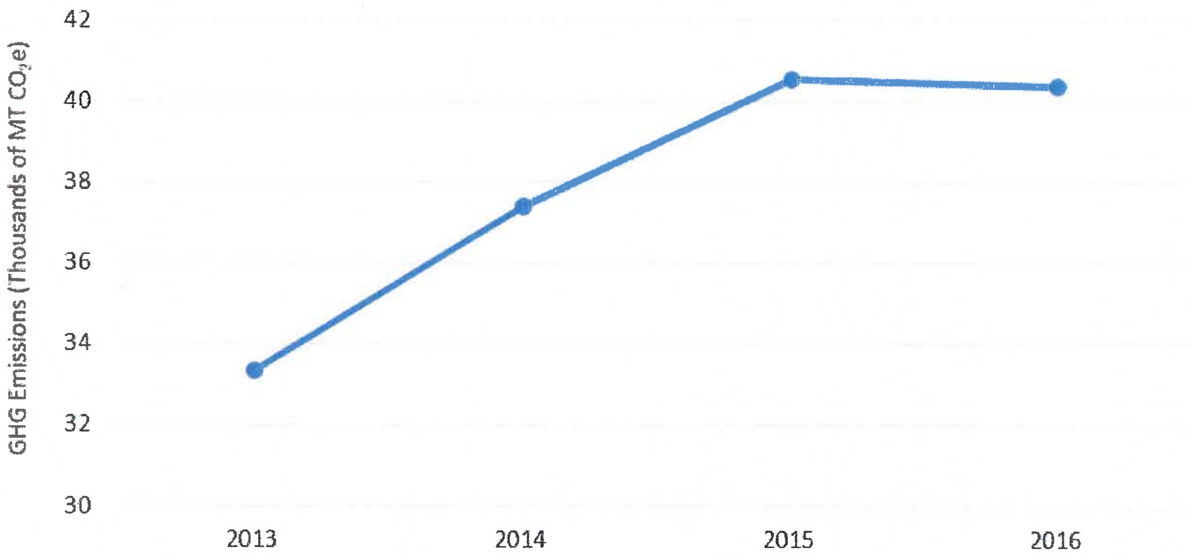


FIGURE 6. OVERALL IEUA GHG EMISSIONS FROM 2013 - 2016

Note: CO_2e is a way of measuring the global warming potential (GWP) of various greenhouse gases by using carbon dioxide (CO_2) as the reference so they can easily be compared. For example, one ton of methane is equal to 25 tons of CO_2e because it's GWP is 25 times that of CO_2.

Climate change is a global concern, and IEUA's reduction efforts must also be viewed through a global lens. More digester gas combustion not only results in more GHG emissions from IEUA facilities, but also less global GHG emissions.

It should be noted that the digester gas combustion emissions come from biogenic sources (GHGs that were recently contained in living organisms) and are therefore considered carbon neutral. TCR requires these emissions to be reported, though they are distinguished from anthropogenic (human-made) source emissions.

When the GHG emissions profiles are analyzed by facility (Figure 7) over the same period, it shows that emissions have remained relatively steady or decreased, with the exception of recycled water pumping and two treatment facilities: Regional Plant No. 1 (RP-1) and RP-5. Each of these three facilities were subject to specific energy projects between 2013 and 2016 that impacted the energy usage and GHG emissions of the facility.

RP-1: Due to digester gas cleaning challenges, the RP-1 fuel cell was shut down temporarily in the fourth quarter of 2013 and permanently removed from service in early 2014. This resulted in increases from two GHG emissions sources: 1) purchased electricity and 2) the biogas flare. Beneficial use of the biogas produced on site is vital in achieving future GHG reductions at the RP-1 facility.

RP-5: The food waste digestion process is located at the RP-5 SHF and began power generation in 2015. GHG emissions spiked as a result of the biogas consumption in the new process.

Recycled Water Pumping: Each year, IEUA has increased the amount of recycled water that is pumped to regional end users or groundwater replenishment basins. Pumping this water is an energy-intensive process, which requires more

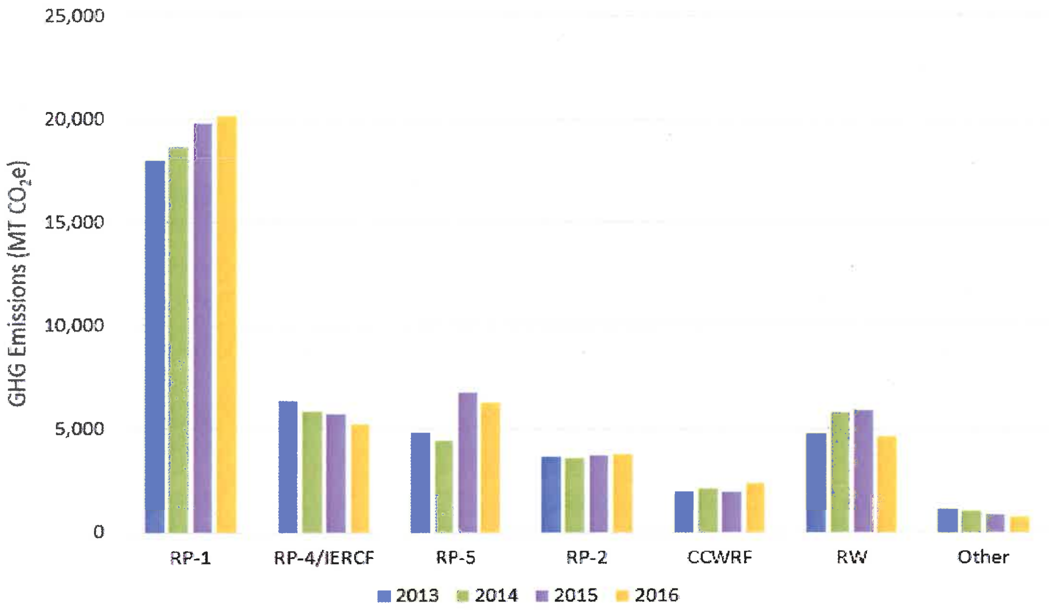


FIGURE 7. IEUA FACILITY GHG EMISSIONS FROM 2013 – 2016

Note: The "Other" category is made up of emissions from remote pumping and dechlorination stations, groundwater recharge sites, and administrative headquarters buildings.

purchased electricity or demand from renewable processes. Globally, more recycled water usage means less water is pumped from the SWP and a net reduction in statewide GHG emissions. Improved regional sustainability in response to climate change will necessarily increase the amount of recycled water pumping at IEUA.

GHG Reduction Goals

IEUA will continue to balance regional sustainability efforts with environmentally conscious energy management strategies to identify projects and objectives that holistically address climate change efforts. IEUA will pursue the following strategies to minimize its facilities' climate change impacts.

Pursue resource recovery: IEUA's current renewable portfolio can meet approximately 50 percent of the agency-wide power needs. Increasing this capability will reduce IEUA's impact on climate change and enhance environmental sustainability.

Report GHG Emissions: IEUA will continue to report its GHG emissions to TCR. Tracking emissions will allow for performance measurement. Rather than focusing on lowering IEUA's direct GHG emissions, potential projects will be evaluated on their potential to reduce global GHG emissions.

Increase energy efficiency: Optimizing facility processes and retrofitting equipment can result in less power demand on the electrical grid.

Reduce methane emissions: Short-lived climate pollutants (SLCPs) are powerful compounds that remain in the atmosphere for a much shorter period than longer-lived climate pollutants, such as CO_2. Methane (CH_4) has been identified as a SLCP and is a common byproduct of the wastewater treatment process. IEUA will strive toward optimizing resource recovery by pursuing projects that beneficially use the methane generated in the digestion process as a renewable source of power generation.

Project Goals and Objectives

Project Development

Each year, pursuant to terms within its Regional Sewage Services Contract, the IEUA submits a ten-year forecast of system capacity demands and capital projects called the Ten-Year Capital Improvement Plan (TYCIP). The TYCIP identifies projects that are needed for the rehabilitation, replacement, or expansion of facilities owned or operated by IEUA.

The TYCIP also serves as a roadmap to achieve IEUA's vision and goals based on the condition of facility assets and forecasted projections of water and wastewater needs.

Several planning documents, such as the Asset Management Plan, the Integrated Water Resources Plan, the Wastewater Facilities Master Plan, and the Urban Water Management Plan, have been developed with the intent of formulating the vision and projected needs of IEUA's facilities and the region it serves. This CCAP serves as an additional planning document that will establish goals and objectives for IEUA's future planning efforts.

Based on the information presented in this CCAP, IEUA has identified key areas that should be addressed to create a resilient water and

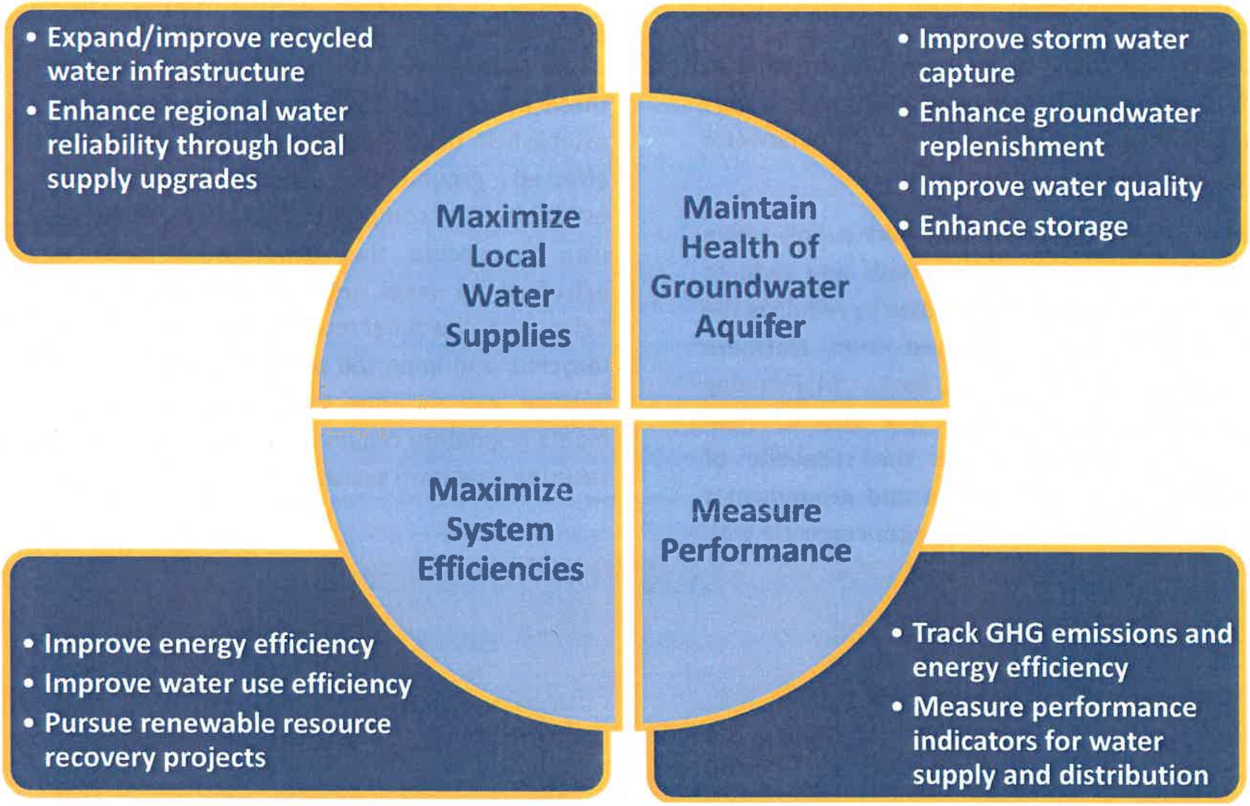


FIGURE 8. IEUA PROJECT GOALS TO MITIGATE THE EFFECTS OF CLIMATE CHANGE

wastewater management system that also contributes to GHG emission reductions. Specific objectives within these areas will be established and used to develop projects that will prepare IEUA's system for the effects of climate change while also minimizing the system's impact on the environment. The goals and objectives are described in greater detail below.

Maximize Local Water Supplies

IEUA's wastewater treatment facilities currently produce Title 22-compliant recycled water that can be used by end users for irrigation purposes or conveyed to groundwater replenishment basins to recharge the Chino Basin aquifer. Increased recycled water production and usage within the Chino Basin will ensure less reliance on the SWP, thereby reducing the significant power needs associated with pumping water from Northern California.

Objective: Expand or improve infrastructure at IEUA sites to enhance capabilities for end user application, storage, or groundwater replenishment of recycled water.

Benefit: Less reliance on the SWP supply offers flexibility during drought periods and reduces electricity usage across the state by reducing the amount of water conveyed from Northern California to the Chino Basin. Maintaining modern facilities reduces the risk of non-compliance and enhances the reliability of recycled water for end use and groundwater replenishment. As assets age concurrently with increasingly stringent regulatory requirements, improvements must be made to the wastewater treatment plants to ensure effective treatment.

Objective: Enhance regional water reliability by pursuing projects that will increase local water production or storage.

Benefit: Pursuing projects within the region or surrounding areas that aim to improve water quality, increase local water deliveries, or increase storage capacities will add to the reliability and resiliency of the IEUA water management system and reduce dependence on the SWP.

Maintain Health of Groundwater Aquifer

Historically, much of the Chino Basin was home to agricultural use and dairy farms, which resulted in high levels of salts and nitrates in the groundwater aquifer. As part of an Optimum Basin Management Plan (OBMP) to address these concerns, the Chino Basin Watermaster established desalination facilities to treat the affected groundwater in the basin and established a comprehensive basin recharge plan to ensure that groundwater that is extracted to meet regional demand is also balanced with aquifer replenishment with storm, recycled, and imported water. Maintaining this balance and ensuring that the basin's water meets regulatory requirements is imperative in securing long term sustainability.

Objective: Improve storm water capture through improvements to the groundwater replenishment system infrastructure.

Benefit: Because precipitation within the Chino Basin is highly variable and often scarce, storm water capture is a valuable commodity. Replenishment of the groundwater aquifer with storm water reduces the need and associated electricity used to convey recycled and/or imported water to the recharge basins.

Objective: Enhance groundwater replenishment capabilities within the Chino Basin through infrastructure upgrades.

Benefit: Increasing groundwater replenishment improves regional sustainability and facilitates hydraulic control of the basin. Upgrading the replenishment system infrastructure can improve flexibility in the type or amount of water conveyed to the recharge basins. Increased flexibility is a key component to establishing an adaptable water distribution system that can meet demands of an uncertain climate.

Objective: Improve water quality to protect public health, the environment, and anticipated regulatory requirements.

Benefit: Effective pollutant removal ensures continued environmental compliance and uninterrupted service to end users, which is paramount to operating a reliable water management system.

Objective: Enhance storage capabilities of storm, recycled, or imported water through expansion of existing infrastructure or collaboration with surrounding water systems.

Benefit: Increasing water storage during years of high precipitation will bring the flexibility needed to withstand periods of drought. Working with other water systems in the area can benefit the entire region, optimizing the use of assets and minimizing the need for energy-intensive water imports.

Maximize System Efficiencies

The concept of the water-energy nexus highlights the inextricable relationship between water and energy. Simply put, generating power requires significant amounts of water, and treating and conveying water requires a significant amount of power. As a water agency taking a leadership role in environmental stewardship, IEUA identifies the need to optimize its management and both water and power.

Objective: Improve energy efficiencies at IEUA facilities.

Benefit: Wastewater treatment and recycled water conveyance are very energy-intensive processes. Strategic management and regular performance assessments of these systems can identify opportunities to save on energy usage. Less demand on the energy utilities will result in fewer GHG emissions into the atmosphere.

Objective: Develop water use efficiency and/or conservation programs within the region.

Benefit: Reducing reliance on supplemental water supplies can not only be achieved through infrastructure improvements, but also through decreasing the water demand within the region. Development and implementation of regional water conservation programs that educate on the importance of water efficiency or incentivize reduced usage can be an effective way to optimize the water supply and progress toward regional sustainability.

Objective: Pursue renewable resource recovery projects, with an emphasis on renewable power generation and beneficial use of resources.

Benefit: IEUA has a diverse renewable energy portfolio across its treatment plants, including 3.5 MW of solar, a 1 MW wind turbine, and a 1.5 MW cogeneration engine fueled by biogas generated from anaerobically digested food waste. The clean power generated from these processes can combine to account for 50 percent of IEUA's electricity needs, which results in a significant demand reduction from the electrical grid. IEUA's portfolio also integrates battery storage systems that can displace up to 4 MW of demand from the grid during peak periods. Expansion of this portfolio will reduce GHG emissions associated with combustion of fossil fuels that are associated with power generation at large-scale utility power plants. Future portfolio expansion may not be limited to on-site resources. For instance, diversion of regional organic waste for anaerobic digestion introduces a new renewable stream into IEUA facilities and results in a reduction of global GHG emissions.

Measure Performance

Improvements in overall system management can only be verified if key performance indicators are effectively tracked. Increasing water and energy efficiency requires comparison against baselines or previous periods, and the efficacy of these project goals will not be proven until sufficient performance data has been collected and analyzed.

Objective: Report GHG emissions annually through The Climate Registry and track energy efficiency of IEUA facilities.

Benefit: Annual tracking of IEUA's GHG emissions profile and energy efficiency will allow IEUA to determine the effectiveness of implemented reduction measures. Using this information, planning efforts can focus on projects that will have the greatest impact on emissions reductions.

Objective: Track key performance indicators for recycled, storm, and imported water usage within IEUA's management system.

Benefit: Using this performance data, IEUA can identify potential improvements to the system to optimize water usage and supply with the goal of reducing the energy needed to convey water into and within the region.

Appendices

Appendix 1 – RAND Memorandum: “Evaluating Options for Improving the Climate Resilience of the Inland Empire Utilities Agency in Southern California”

Appendix 1:

RAND Memo "Evaluating Options for Improving Climate Resilience of the Inland Empire Utilities Agency in Southern California"

Project Report

Evaluating Portfolios for Improving the Climate Resilience of the Inland Empire Utilities Agency in Southern California

Abbie H. Tingstad, David G. Groves, and James Syme (RAND Corporation)
Elizabeth Hurst and Jason Pivovaroff (Inland Empire Utilities Agency)

May 2016

Preface

The Inland Empire Utilities Agency (IEUA) and RAND worked together in 2003-2005 to demonstrate and evaluate how new approaches to decisionmaking under uncertainty could help a water utility evaluate the potential threats of climate change in their long-term planning. This work was performed outside IEUA's planning process and was documented in several RAND reports and scientific journal articles (Groves, Davis, *et al.*, 2008; Groves, Knopman, *et al.*, 2008; Groves, Lempert, *et al.*, 2008). In 2015, IEUA asked RAND to help it re-evaluate its water management system under a range of future conditions reflecting climate change and other drivers for its Integrated Resources Plan (IRP). This report documents the tools developed and analysis performed during 2015 for this effort. Questions or comments about this report should be sent to the project leaders, David Groves (groves@rand.org) and Abbie Tingstad (tingstad@rand.org).

Table of Contents

Figures

Tables

Abbreviations

BCSD	Bias-Corrected Statistically Downscaled
CMIP	Coupled Model Intercomparison Project
FWOA	Future Without Action
GCM	General Circulation Model
GHCND	Global Historical Climatology Network Database
IEUA	Inland Empire Utilities Agency
IRP	Integrated Resources Plan
MWD	Metropolitan Water District of Southern California
NOAA	National Oceanographic and Atmospheric Administration
PDT	Portfolio Development Tool
RDM	Robust Decision Making
SAR	Santa Ana River
SEI	Stockholm Environment Institute
UWMP	Urban Water Management Plan
WCRP	World Climate Research Programme
WEAP	Water Evaluation and Planning System
WEI	Wildermuth Environmental Inc.

Introduction

Water managers continue to face challenges related to climate non-stationarity (Milly *et al.*, 2008) in their long-term planning. Even when water supplies appear sufficient to meet present and short-term demand, uncertain future changes in temperature and precipitation make decisions about investments to ensure longer-term supply sufficiency difficult. In Southern California, the recent drought has refocused attention on water resources in this semi-arid, populous area. Although this drought appears to be consistent with long-term patterns of climate variability, its effects may be exacerbated by ongoing climate change, which is anticipated to have a strong effect on the region, including on its water supplies (e.g., with respect to the length and magnitude of droughts, timing of precipitation, and temperature-driven demand) (Diffenbaugh *et al.*, 2015; Mao *et al.*, 2015; Shukla *et al.*, 2015)

Adaptive management plans are designed to evolve over time in response to new information regarding future conditions. This type of flexible approach is becoming increasingly favored in the water management community as a mechanism for planning under uncertainty. Integrative approaches, which help facilitate adaptive plans, focus on combining a variety of management options, rather than a single type of solution.

The Inland Empire Utilities Agency (IEUA), a water management agency in Southern California, recently partnered with the RAND Corporation, a multi-disciplinary, non-partisan research organization and educational institution headquartered in Santa Monica, California, to evaluate how adaptive, integrative water management portfolios could improve IEUA's abilities to meet customer needs under a wide range of futures. This analysis was used to support the development of its Integrated Resources Plan (IRP). The purpose of the IRP is to evaluate the resiliency of water resources in the IEUA's service area over the next twenty-five years and to evaluate alternative management portfolios for ensuring water deliveries to urban users. The IRP results will be used to recommend regional strategies and identify preferred water supply projects that, in turn, will help the IEUA and its member agencies to apply for grants and loans to implement new projects. RAND supported IEUA's IRP by developing a tool for constructing and visualizing different portfolios for water management investments and actions, and enabling an analysis of *status quo* and potential future water management activity success in meeting future urban water demand under different demand and climate change-impacted water supply conditions. This follows RAND's previous work supporting the IEUA's 2005 Urban Water Management Plan (UWMP) (Groves, Knopman, *et al.*, 2008; Groves, Lempert, *et al.*, 2008).

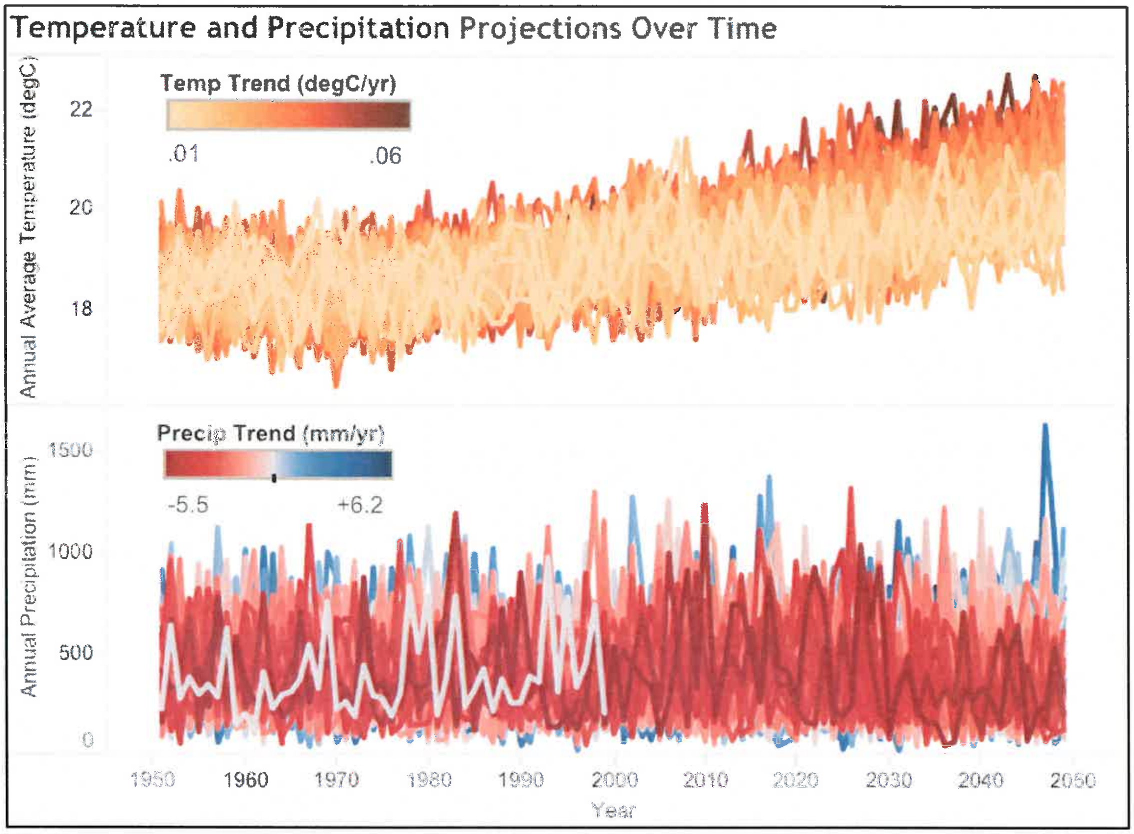
Current water demands in the IEUA service area are serviced by groundwater from the Chino Basin in addition to local surface supplies, recycled water, and imported water from Northern California via Metropolitan Water District of Southern California (MWD). In addition, IEUA implements water efficiency projects, such as low-flow toilet rebate programs. Depending on different estimates of future infrastructure water efficiency, this "baseline" supply (current and planned supplies from groundwater and other sources plus savings from water efficiency projects) is likely sufficient, or very nearly so, for meeting future demand assuming climatic conditions remain similar to those experienced in recent history. However, IEUA wanted to explore how shifts in stationarity assumptions through climate change, along with possible changes in demand, could impact its future water supplies and demands, and what water management projects could help meet future demand under uncertain future temperature and precipitation conditions.

A suite of global climate models suggests that temperatures over the IEUA service area will rise over the coming decades and that annual precipitation will continue to be highly variable, with no consensus on trends towards wetter or drier conditions. Figure 1 displays the annual average temperature and total precipitation estimates from 1950 to 2050 for the IEUA service area based on 106 downscaled projections of climate from a range of general circulation models (GCMs).[1] The temperature increases seen beginning around the 1980s and the uncertainty associated with local precipitation underscores the importance of carrying out an analysis of IEUA water management options and portfolios to ensure that future demand can be met under a variety of different hydrologic circumstances against the backdrop of rising temperatures.

---

[1] Note that GCMs are not expected to simulate the precise interannual fluctuations of the historical period, because stochastic forces and sequences of events that are unresolvable by numerical models drive such historical variability. Instead, GCMs are validated based on their ability to characterize the statistical characteristics of historical climate, such as maximum and minimum temperatures or precipitation.

Figure 1: Estimates of historical and future annual average temperature and total precipitation for the IEUA service area



To support this analysis we developed (1) a simple mass balance water management model to estimate future supplies and demand across different futures and (2) a decision support tool to help IEUA planners and stakeholders to compare attributes of different management options and develop portfolios for evaluation. We then used these tools with IEUA to evaluate how the IEUA system would perform across a wide range of supply and demand futures and compare how different management portfolios would ensure that IEUA would meet its goals across these futures. Due to the limited scope of this effort, we did not attempt to evaluate the cost-effectiveness or finer details (e.g., implementation potential at specific locations) of the different water management projects. We also did not conduct statistical analysis to determine the specific climatic conditions most conducive to different portfolio success or failure in meeting urban water demand, nor did we consider uncertainties related to budget and/or other factors that could impact our results.

Methods

In this section we describe our study in terms of a four-step process, which generally follows a Robust Decision Making (RDM) approach (see Appendix 1 for more detail on RDM):

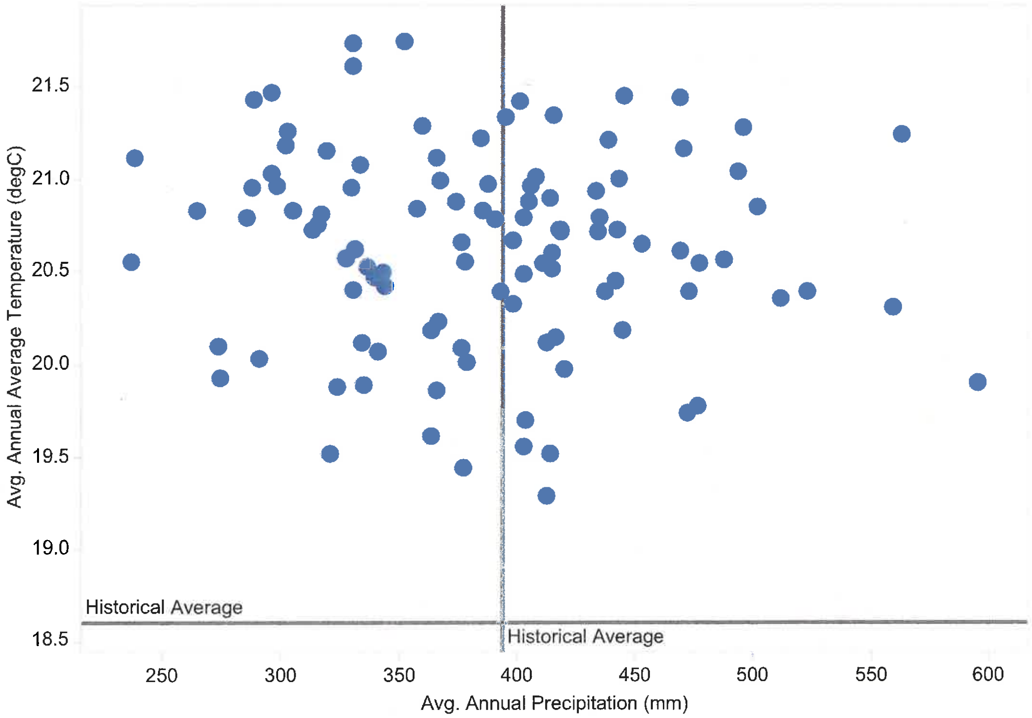
1. Compile information on a wide range of plausible water demand and supply futures reflecting climate change
2. Develop a simple water management mass balance model to evaluate the performance of the IEUA system under a wide range of futures;
3. Develop a portfolio development tool to help IEUA planners and stakeholders to compare attributes of different management options and develop portfolios for evaluation; and
4. Evaluate and compare how each proposed water management portfolio would enhance the IEUA's ability to deliver urban water supplies in the future under different futures of climate and demand.

In the following section we describe the key results.

Step 1 – Compile Water Supply and Demand Futures

The study considered how the IEUA system would perform under the 106 projections of future climate displayed in Figure 1. These were downloaded from an archive of downscaled global climate model simulations, described in Appendix 2. These 106 projections of future climate were integral to our ability to stress test the IEUA water management system in its ability to meet future demand. Each projection represents a plausible climate future in our analysis. Although we cannot know with certainty what type of climatic change the future holds, having a diverse set of projections enables development of management alternatives that could be robust in adapting to a range of different conditions. Figure 2**Error! Reference source not found.** plots the average annual temperature and precipitation from 2040-2049 for this set of climate projections.

Figure 2: Average annual temperature and precipitation over the Inland Empire Utilities Agency service area from 106 climate projections (2040-2049)



All the climate projections show higher average annual temperatures from 2040 – 2049 than the historical average (1951 – 1999). This is consistent with observed and projected changes around the world (IPCC, 2014). About half of the climate projections show higher precipitation and half show lower precipitation. Specifically, annual average precipitation varies between 237 mm/year to 595 mm/year, or between 60 percent and 151 percent of the historical record. This uncertainty in precipitation trends reflects the difficulty in modeling the complex atmospheric and oceanic processes that govern precipitation patterns in the Southwest United States and the stochasticity of these processes (Peterson *et al.*, 2013). Although these projections do not indicate whether the climate will get drier or wetter in the coming decades in the IEUA service area, they do provide a useful test bed of plausible climate conditions within which to stress test water management plans. Dry conditions could challenge the ability of the system to meet user demand whereas wet conditions could turn additional investments in new supplies into unnecessary expenditures.

Scientists have confidence that the projections in Figure 2 are suggestive of future climate conditions that are impacted by higher greenhouse gas concentrations in the atmosphere. One reason is that these climate models, when evaluated for historical periods of time (e.g. 1950 – 2000), estimate past variability that is similar to the observed historical values. To illustrate this, **Error! Reference source not found.** Figure 3 shows the historical, observed annual average temperature and annual total precipitation from 1951 – 1999 for the IEUA service area (blue line on the left), along side the maximum and minimum projected annual average temperature from the 106 climate scenarios for the same time period (box charts on the right). The models, when "backcasting" the same historical time period, estimate a range of maximum and minimum temperatures that are inclusive of the historical observed maximum and minimum temperature. **Error! Reference source not found.**Figure 4 shows the same comparison for annual total precipitation. Once again, the observed and modeled maxima and minima appear to have some overlap, which provides confidence that the models are able to provide some realism in their representation of the climate system.

Figure 3: Observed historical annual temperature record for the IEUA service area from 1951 – 1999 (left) compared to the distribution of predicted maximum and minimum temperatures across the 106 climate scenarios for the same historical time period (right)

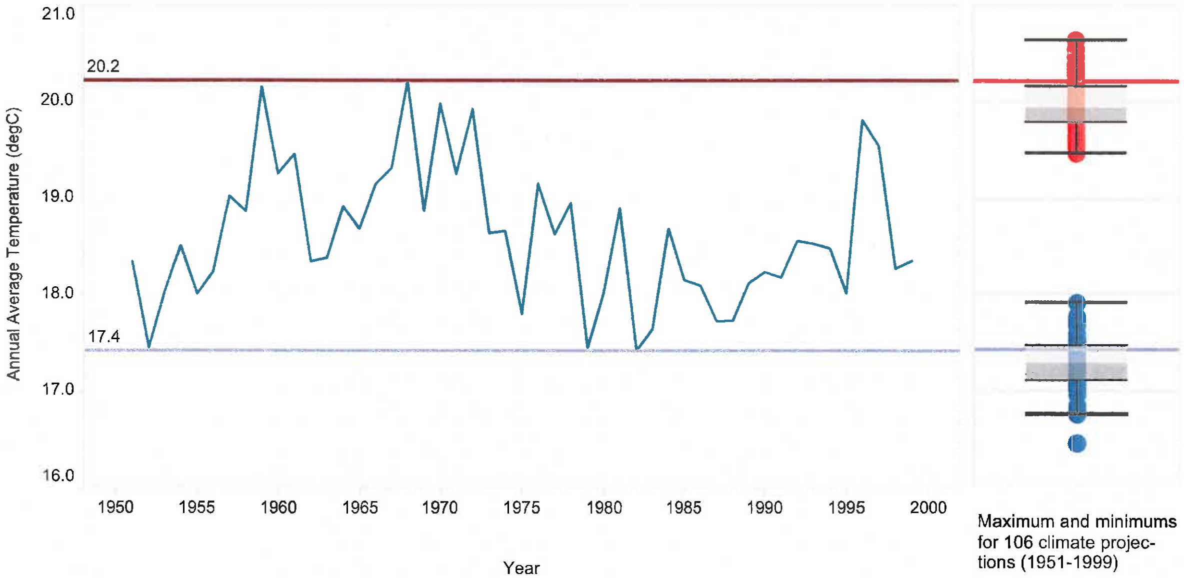
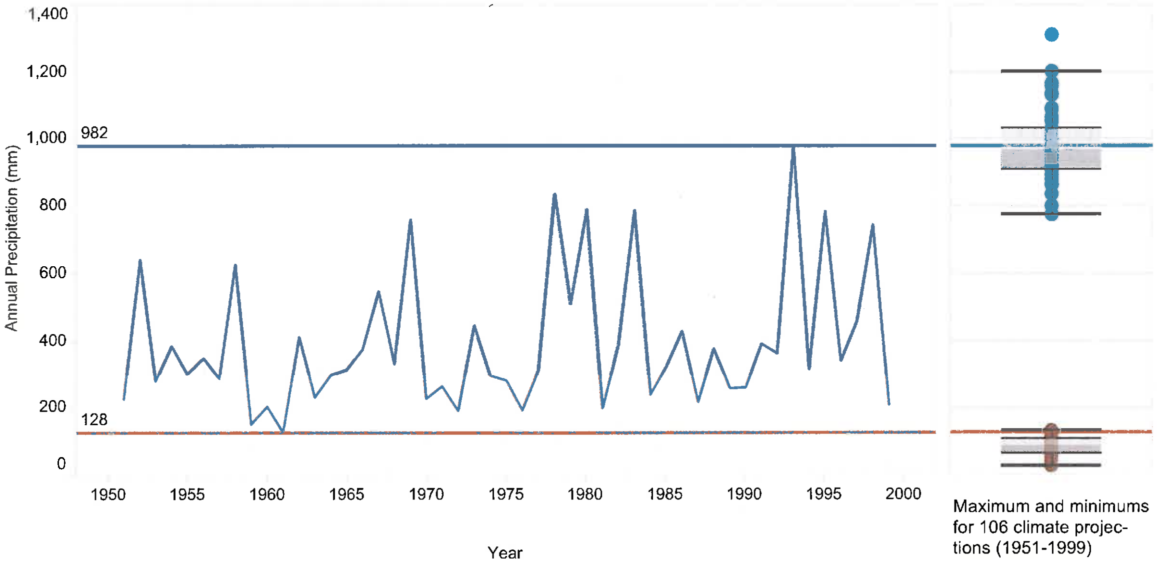
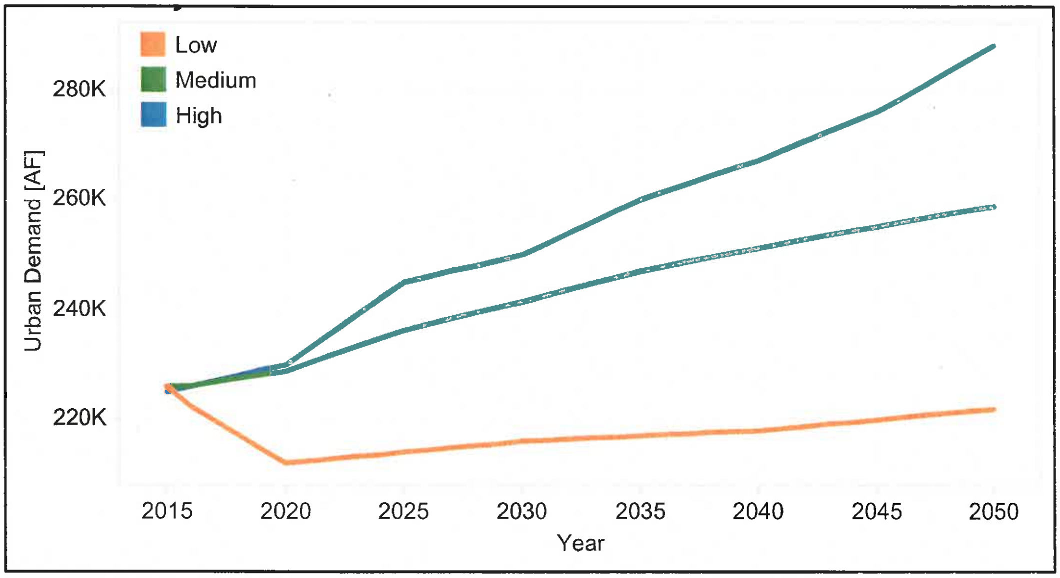


Figure 4: Observed historical annual total precipitation record for the IEUA service area from 1951 – 1999 (left) compared to the distribution of predicted maximum and minimum precipitation across the 106 climate scenarios for the same historical time period (right)



In addition to future climate, this work also examined impact of future demand. IEUA supplied two projections of future demand—a low and high demand estimate. A middle projection was then estimated within the water management model by specifying indoor and outdoor water use rates that were between those used for the high and low demand estimate. Figure 5 **Error! Reference source not found.**shows these three demand scenarios under conditions of no climate change. It also shows unmet demand under historical climate conditions.

Figure 5: IEUA demand scenarios under no climate change



Step 2 – Develop Water Management Mass Balance Model

RAND developed a water management model developed for the IEUA service area using a simulation platform called the Water Evaluation and Planning system (WEAP) (Yates *et al.*, 2005). The purpose of this model was to help understand how the IEUA system would perform under a wide range of futures. In brief, WEAP enables integration of physical hydrologic processes with management of water demands and supplies using a link-and-node representation of a water management system, as constructed by a user. The WEAP model was used primarily to evaluate projected annual urban demands, sources of supply, and unmet demands.

RAND previously developed a WEAP model for the IEUA service area (Groves, Lempert, *et al.*, 2008) based on information available during the 2003-2005 time period. For the present study, RAND developed a new WEAP model based primarily on IEUA's latest spreadsheet-based information about current water supplies and demands, and annual projections of them through 2050. See Appendix 2 for more detail.

Absent available detailed analyses of how climate change could affect each element of IEUA's water supply portfolio, RAND worked with the best available data to develop some approximations using basic models (details below) for how different supplies and demand would change under different assumptions and projections of climate conditions. These analyses were developed as a first step towards a more comprehensive assessment of IEUA resilience to climate change, and were vetted by IEUA water managers. For the purposes of this initial work, these approximations provided sufficient insights into the potential impacts of climatic changes on supply and demand to facilitate deliberation over the usefulness of different types of water management projects.

Below is a summary of the basic regression and other mathematically-simple models that were developed to estimate the impacts of climatic changes on the following elements of the IEUA system (see Appendix 2 for details):

- *Local surface supplies, storm water, and replenishment supplies*: two regression models of historical annual local surface supplies and annual climate were used to estimate future local surface supplies based on projections of temperature and precipitation. These models were applied to estimate local surface supplies, available storm water supplies, and non-MWD replenishment supplies.
- *Groundwater safe yield*: Projections of future safe yield under different trends in climate conditions were developed by Wildermuth Environmental Inc. (WEI) and provided to IEUA and the study team. The current long-term sustainable yield of the groundwater basin was then modified for each climate projection based long-term precipitation trend perturbation factors derived from the WEI analysis.
- *Imported supplies via Metropolitan Water District*: A simple linear model of supply availability over time from Northern California via MWD was used to modify IEUA's contractually available supply from MWD. Two different climate response rates were evaluated that effectively assumed a 17 percent and 34 percent reduction in imported available water by 2040.
- *Water demand*: Demand climate adjustment factors were developed using IEUA calculations of the sensitivity of demand to climate using MWD-MAIN. These factors were used together with the climate scenarios (annual average temperature and precipitation) to adjust the demand annually.

By imbedding these models into the WEAP model, we estimated future local surface water production, groundwater sustainable yield and replenishment, outdoor urban demand, and possible adjustments to water imports under changing climate. This WEAP model was used to both test baseline supply resiliency to climate change as well as determine expected benefits from new water management projects.

Step 3 – Develop a Portfolio Development Tool

With inputs from the IEUA and its member agencies, RAND created a Portfolio Development Tool (PDT) using the visualization software platform Tableau. The purpose of this activity was to support the second step of our analysis by creating a user-friendly interface through which the IEUA and its member agencies could explore a variety of water management projects and develop portfolios that included one or more projects. The PDT enables users to review individual project attributes—both quantitative (i.e., how much water they produce) and qualitative (e.g., whether they contribute to different IEUA regional goals)—and determine how combinations of these projects together would increase future supplies, moderate demand, and meet qualitative, regional goals.

IEUA and RAND used the PDT to support a series of meetings between the IEUA and member agencies and a workshop co-run with member agency representatives to create different adaptive, integrative portfolios for increasing future water supplies. After discussing the individual projects and their attributes in detail, each stakeholder (including IEUA staff, member agencies, and the Chino Basin Watermaster) was invited to design portfolios with varying emphases. The PDT not only assisted in the development of the portfolios used in the analysis, but also fostered more general discussion about the types of projects each stakeholder saw as beneficial and the impacts of different plausible future demand and supply scenarios. IEUA finalized a set of 8 portfolios for the IRP (Table 1). Most of the portfolios in Table 1 represent groups of projects that several stakeholders were interested in, and/or alternative emphases in water project management that were useful to explore in order to understand how the system would perform in the future. The IEUA IRP includes more detailed description and rationale for these portfolios.

Table 1: Management portfolios developed using the Portfolio Development Tool

Portfolio Name	Portfolio Description
Portfolio #1	Maximize the Use of Prior Stored Groundwater
Portfolio #2	Maximize Recycled Water (Including External Supplies) and Local Supply Projects and Implement Minimal Water Efficiency
Portfolio #3	Portfolio 2 Plus Secure Supplemental Imported Water from MWD and Non-MWD Sources
Portfolio #4	Maximize Recycled Water (Including External Supplies) and Implement Moderate Water Efficiency
Portfolio #5	Portfolio 4 Plus Implement High Water Efficiency
Portfolio #6	Maximize Supplemental Water Supplies and Recycled Water Supplies
Portfolio #7	Maximize the Purchase of Imported Water from MWD and Implement Minimal-Moderate Level of Water Efficiency
Portfolio #8	Portfolio 7 Plus Maximize Recycled Water

Step 4 – Evaluate Different Management Portfolios Across Futures of Climate and Demand

The study team next used the WEAP model to "stress test" the resiliency of the IEUA service area's baseline water supplies, and baseline supplies plus the different future water management project portfolios, under different climate and demand futures. These evaluations considered urban demand, supplies, and unmet demand from 2015 to 2050 for each of the 106 climate change projections as well as a projection that repeated historical climate conditions. Impacts of these 107 climate futures on IEUA's baseline supplies and proposed portfolios to augment supplies were examined in the context of the three future demand scenarios, as well as assumptions about the strength of climate change on imports, and the sensitivity of local supplies to temperature. In sum, IEUA's baseline supplies and each augmentation portfolio were tested against 1,284 futures (107 climate projections x 3 demand scenarios x 2 regressions to estimate climate impacts on local supplies x 2 levels of climate impact on water imports). The necessary computing capacity was obtained via Amazon Web Service, which enabled the WEAP model to be run hundreds of times simultaneously.

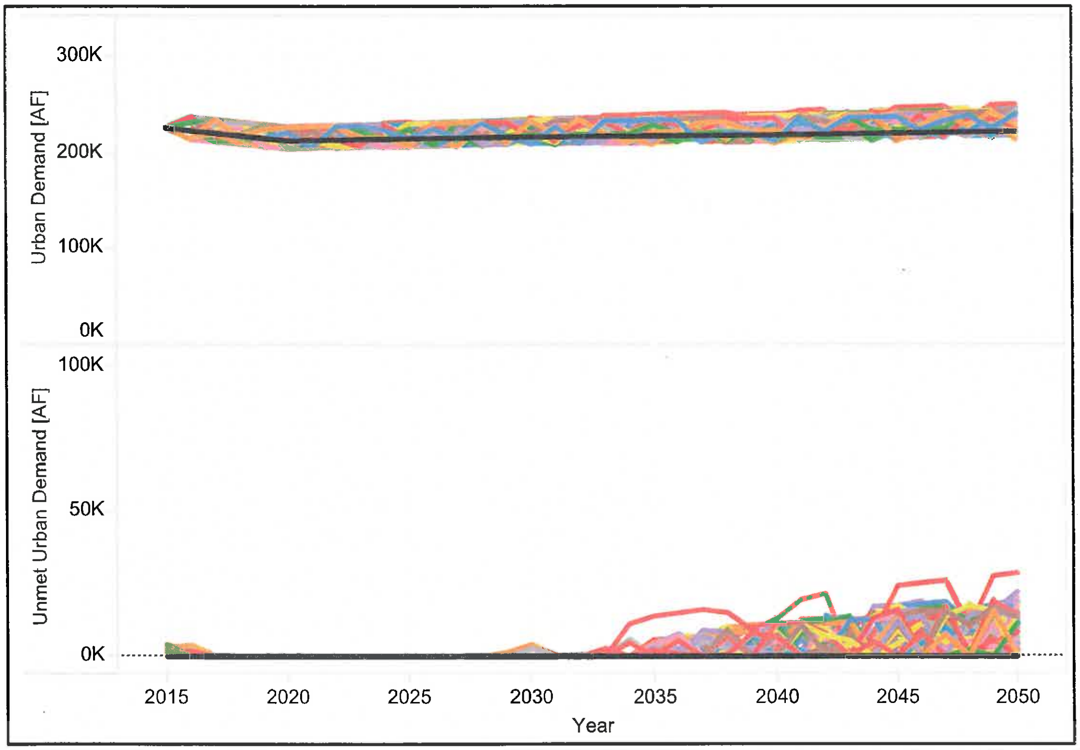
Results

In this section, we summarize the results of our analysis of IEUA's system under the wide range of climate and demand futures.

IEUA baseline supplies may be insufficient to meet future demand

We first explored how well IEUA baseline supplies were able to meet future demand under varying climatic conditions using the WEAP model. We found that, under the low demand scenario, supplies were sufficient under historical climate and mostly sufficient through mid-century with climate change (Figure 6). After 2035, some shortages begin to appear. The figure below shows results that assume the strongest effect of climate on imports, and that temperature changes affect local supplies. See Appendix 2 for more detail.

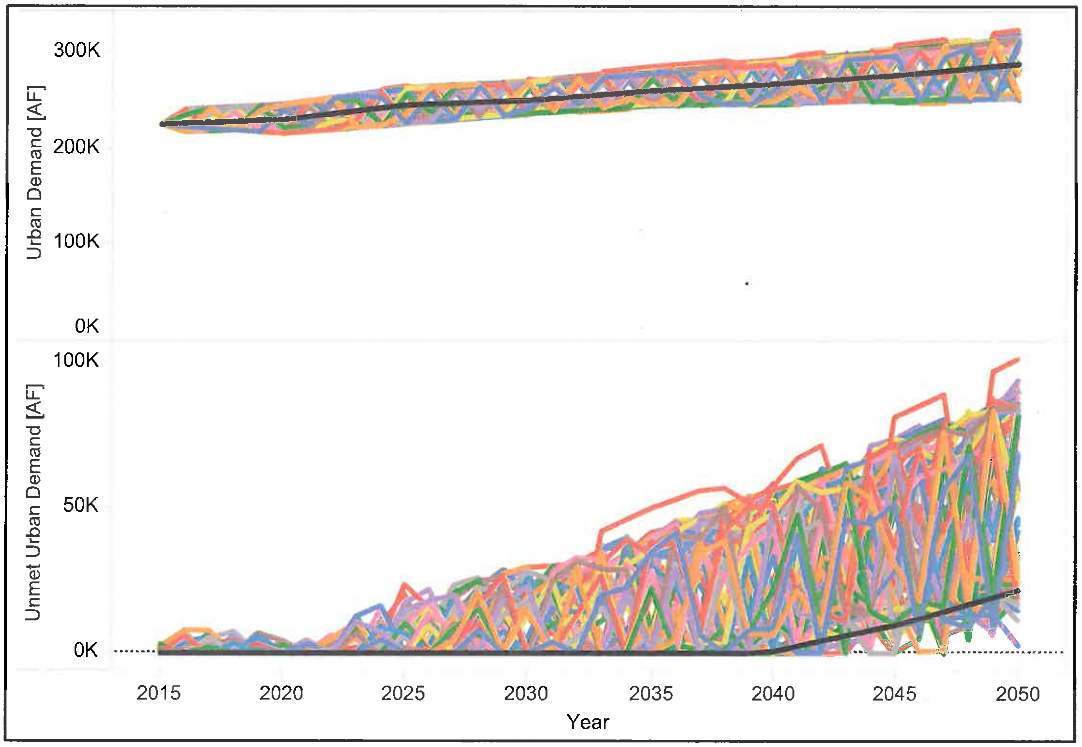
Figure 6: Unmet demand for IEUA service area by climate change scenario over time (low demand scenario)



Note: Colored lines correspond to the individual 106 climate scenarios. The black lines correspond to the historical climate scenario.

However, supplies do not appear sufficient to meet demand in the medium (not shown) and high demand scenarios as early as 2016, with the level of unmet demand ramping up significantly after 2020. Under the high demand scenario, unmet demand is nonzero even under historical climate conditions (Figure 7).

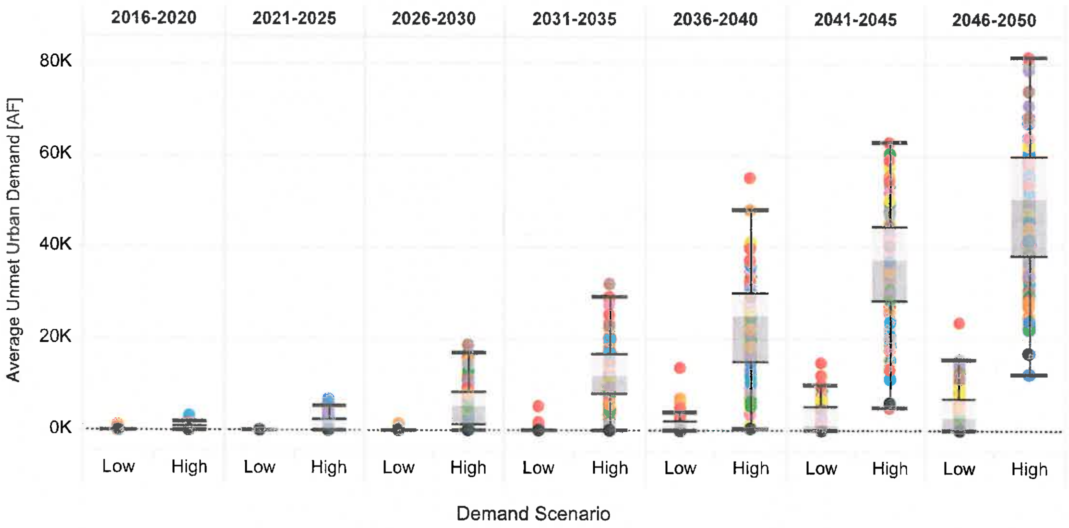
Figure 7: Unmet demand for IEUA service area by climate change scenario over time (high demand scenario)



Note: Colored lines correspond to the individual 106 climate scenarios. The black lines correspond to the historical climate scenario.

Figure 8 summarizes the results shown above by 5-year period. For the 2036-2040 period, which essentially reflects the end of IEUA's IRP timeframe, there is virtually no unmet demand for half of the 106 climate projections under the low demand scenario. In contrast, under the high demand scenario, which was used in the IRP, the median result for unmet demand is about 25 TAF/year, and there is unmet demand in most of the future climates considered. Note that the IEUA IRP reports the 75th percentile unmet demand results as a characterization of the majority of plausible futures. The 75th percentile results are seen in the figure as the top of the shaded boxes.

Figure 8: Summaries of unmet demand across climate scenarios by demand scenario and 5-year period

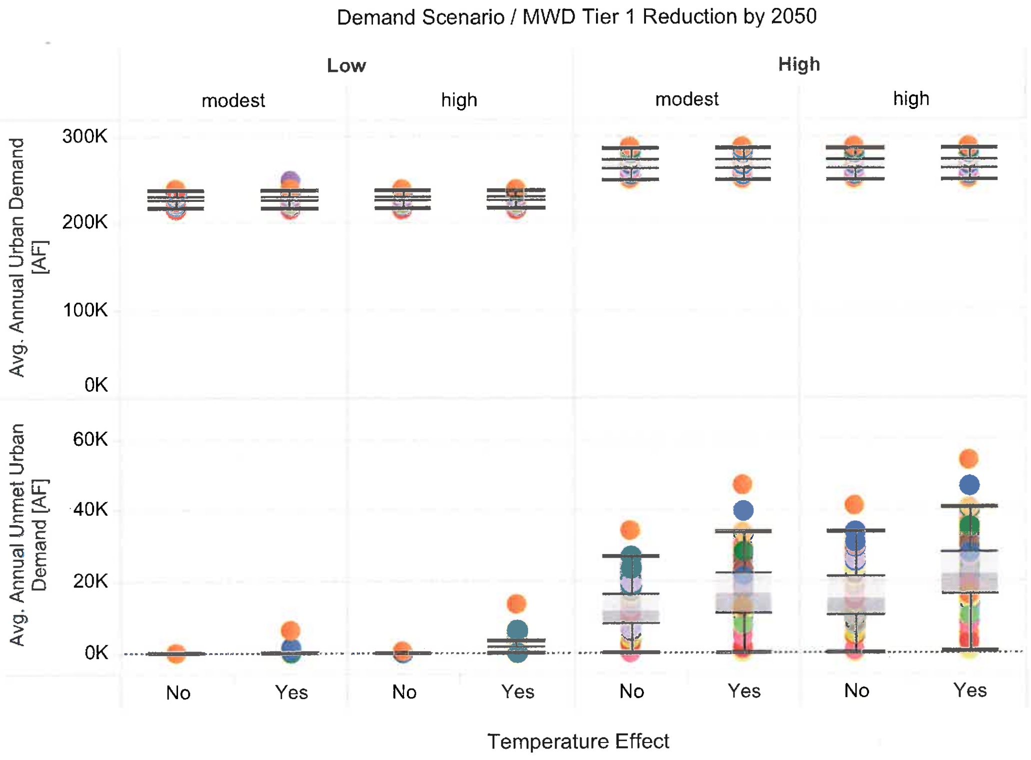


Note: Colored dots correspond to the individual 106 climate scenarios. The black dots correspond to the historical climate scenario. The boxes show the 25th, median, and 75th quartile results, with the vertical stems indicates 1.5 times the 25th-75th quartile range.

RAND also investigated how the results vary with different assumptions about how much MWD supplies might decline over time in response to climate change, and whether or not local supplies, stormwater, and non-MWD replenishment supplies will fluctuate due to temperature in addition to precipitation (see Appendix 2 for more detail). Figure 9 compares the range of unmet demands for the 2036 – 2040 period under different assumptions about temperature effects on local supplies and climate change on MWD supplies. For the low demand scenario, the assumptions appear to have little effect on the unmet demand results across the climate scenarios. For the high demand scenario, however, there are some modest changes. The effect of going from modest to high climate impact on MWD supplies is about equal to the effect of including the temperature impacts on local, stormwater, and replenishment water supplies. For both types of uncertainties, however, the effects on the results are modest, and are much smaller in scale than differences in results between demand scenarios.

For the IRP, IEUA selected the assumptions that (1) climate change would have a high impact on MWD supplies and that (2) there would be temperature effects on local, stormwater, and replenishment supplies in order to be able to plan for more stressing future situations. These assumptions were made to ensure that IEUA has sufficient resources and necessary infrastructure under a wide range of plausible futures.

Figure 9: Average urban demand and unmet demand (2036 – 2040) across climate scenarios (boxes), demand scenarios (Low, Wide), climate effects on MWD supplies (modest, high), and temperature effects on local, stormwater, and replenishment supplies (No, Yes)



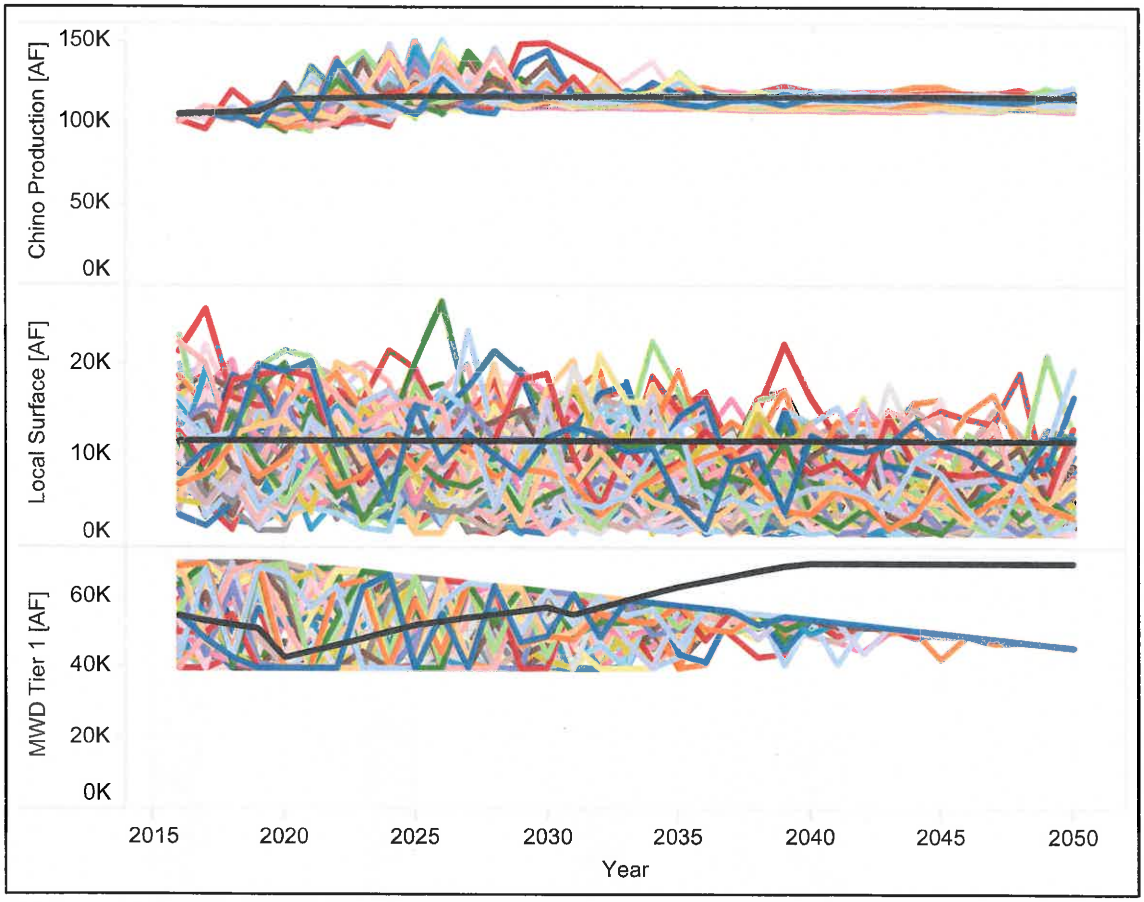
Note: Colored dots correspond to the individual 106 climate scenarios. The black dots correspond to the historical climate scenario. The boxes show the 25th, median, and 75th quartile results, with the vertical stems indicates 1.5 times the 25th-75th quartile range.

Figure 10 shows the major climate-dependent supplies used to meet demand over time for the 106 climate projections and historical record. The top panel shows these results for Chino Basin groundwater. The figure shows that during the next 15 years, when supplies generally exceed demand, there is a range of groundwater supply use, depending on the demand and availability of cheaper local surface supplies. The increased use during some years reflects deferred use of these supplies during wet years. Around 2030, increasing demand, coupled with declining surface supplies, groundwater supply becomes more stable at the maximum amount available. The slight range of use across the climate scenarios in the out years reflects the different climate effects on safe yield—which is small.

Local supply, some types of which are relatively low-cost (notably excluding recycled and desalted water), fluctuates due to its availability. Figure 10 shows significant variability as well as a tendency for declining amounts of supply, as compared to the typical IEUA assumption of stable supplies based on historical yields (the solid black line). These results reflect the projected warming conditions for all climate scenarios and variability in projected precipitation.

Lastly, the bottom panel of Figure 10 shows use of MWD Tier 1 water (water supplied at the lowest cost tier) over time across the 106 climate projections and historical (black line). Future use under assumptions of historical climate declines initially as other supplies are developed. After 2020, however, IEUA increasingly relies on the assumed available MWD Tier 1 supply to meet growing demands. By 2040, all cheaper supplies are completely utilized and MWD Tier 1 supply is used at its maximum level. Note that 2040 is the year in which shortages are also shown to begin (see Figure 7). There is significant interannual variability in the use of MWD Tier 1 supplies across the futures, in response to variable demands and other supplies. In many years, Tier 1 use reaches the maximum available amount. Per the assumptions about climate's impact on available MWD supplies, the maximum amount available begins to decline in 2020. In those years and scenarios in which the MWD Tier 1 use is at this declining maximum level, there is also unmet demand as seen in Figure 7.

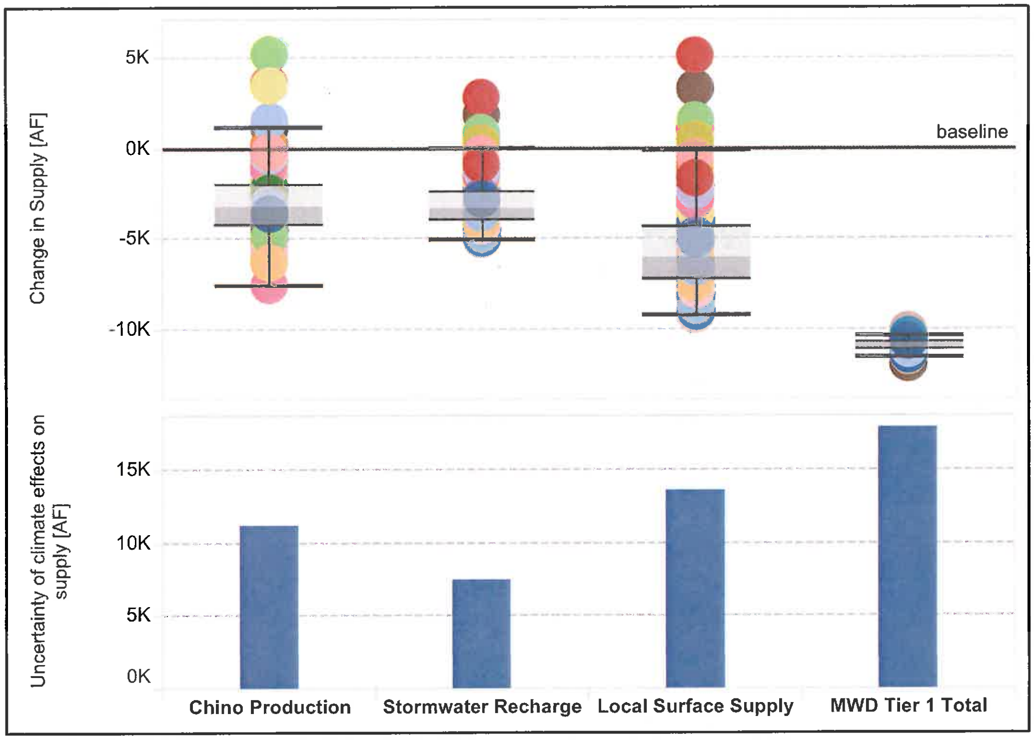
Figure 10: Baseline supply ability to meet IEUA service area in the high demand scenario by climate projection



While there is uncertainty over how climate change might affect IEUA's supplies, the climate scenarios used, combined with assumptions made in this analysis, show a tendency for supply reductions. The top panel of Figure 11 shows that for most scenarios, supplies are lower than they would be under historical climate conditions. The largest potential impact on supply is on MWD imported supply—with all climate scenarios showing a decline in accordance with the assumption that MWD supplies could experience a gradual decline in response to climate change. The second most impacted supply is on local surface supply, with a median decline of about 5 TAF/year. The overall effect on groundwater production is small, consistent with the assumptions about climate's effect on safe yield.

The bottom panel of Figure 11 shows the range in use of future supplies across the climate scenarios. For the resources that are utilized fully due to their lower cost, such as Chino groundwater and local surface supplies, the variability reflects the range of climate impacts on these supplies. For these, the larger range of uncertainty is seen in the local supplies. The range in uses of MWD Tier 1, however, reflects the range of availability of the less expensive supplies—not any assumptions of climate effects on MWD supplies. As described above, the only climate effect on MWD Tier 1 availability is specified through a steady decline in supply availability.

Figure 11: Impacts of climate on IEUA supplies across climate futures (colored dots) (2036-2040) (top) and uncertainty in the magnitude of climate impacts uncertainty (bottom)



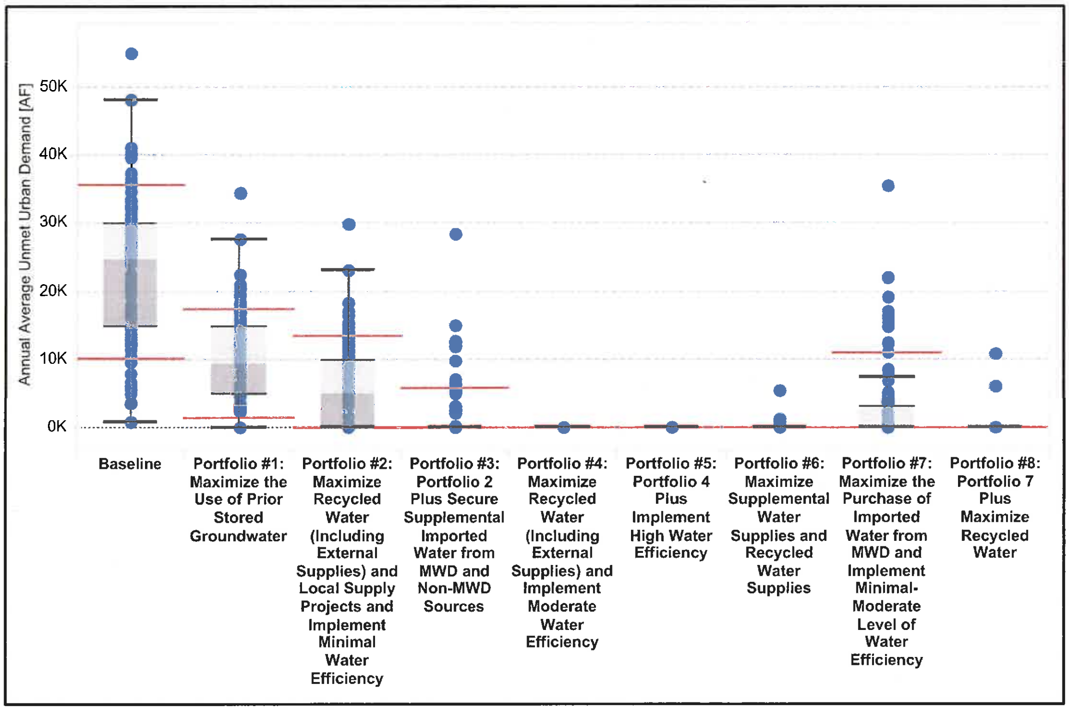
Note: Colored dots correspond to the individual 106 climate scenarios. The black dots correspond to the historical climate scenario. The boxes show the 25th, median, and 75th quartile results, with the vertical stems indicates 1.5 times the 25th-75th quartile range. The blue bars indicate the range of supply outcomes across the climate scenarios (excluding the historical simulation shown by the black dot).

Management strategies that focus on efficiency and maximizing use of recycled and imported water help close future gaps between supply and demand

Through interactions with member agencies and other stakeholders and facilitated by use of the PDT, the IEUA converged on the choice of the seven portfolios listed in Table 1, consisting of different water management actions aimed at closing the future gap between supply and demand, and meeting other regional goals.

Using the WEAP model and the same climate projections used to "stress test" the IEUA baseline water supplies, we evaluated how well each of the eight portfolios would meet demand in the future. Figure 12 summarizes the performance of the baseline strategy and the eight portfolios in terms on unmet demand from 2036 – 2040. All portfolios lead to an improvement in unmet demand over the baseline supply. Portfolio 1, which uses previously stored groundwater, reduces unmet demand by more than half for the median climate scenario. Portfolio #2, which increases use of recycled water and external supplies as well as implements additional efficiency, eliminates unmet demand for more than 25 percent of scenarios and reduces the median unmet demand to below 10 TAF. Portfolio #3 improves upon portfolio #2 by adding additional imports—all but eliminating unmet demand. Portfolio #7 combines moderate efficiency with increased imports to eliminate unmet demand in more than half of the scenarios. Lastly, four portfolios—#4, #5, #6, and #8—eliminate unmet demand in at least 90 percent of the scenarios. The first two do so by significantly increasing efficiency—effectively ensuring that demand follow the low growth demand trajectory. The other two (#5 and #8) improve performance by maximizing recycled water use while also increasing imported water supplies.

Figure 12: Average unmet demand (2036 – 2040) across climates projections for high demand projection and different IEUA portfolios



Conclusion

This study helped IEUA evaluate how its system would perform across a wide range of future climate and demand futures. This information confirmed that the region could be vulnerable to plausible climatic changes, particularly if demand increases along a higher trajectory. These identified "vulnerabilities" also guided IEUA and its stakeholders in developing eight portfolios of management options. The analysis then compared these portfolios and found that portfolios that include additional water use efficiency and maximizing use of local resources—such as recycled wastewater and stormwater capture—can significantly increase the robustness of IEUA's system, providing confidence that IEUA will meet its long-term goals. This work also demonstrated the value of interactive, analysis based decision support tools. Both the Portfolio Development Tool and the WEAP water management model served as important tools that IEUA planners used to develop and refine their IRP.

These findings were highly useful to IEUA in the development of its IRP, and IEUA management considered this work a "game changer" (Davis, *personal communication*). Specifically, by identifying the key vulnerabilities and evaluating different options for improving the robustness of IEUA's system, IEUA was able to quantify the value of efficiency and local supply strategies in reducing the risk of future supply shortfalls in IEUA's service area. Further, the work provided reassurance that their region could be sufficiently prepared for a future with uncertain shifts in climate. By engaging in this process, IEUA has not only identified how and when changes in temperature and precipitation could impact its water supplies, but also how demand influences the delicate balance between supply and demand. Both the timing of surges in unmet demand and the types of management actions that could help mitigate anticipated gaps in supply helped to inform the development of IEUA's IRP in a way that encourages adaptation and the use of integrative plans.

This study provides an important foundation for IEUA's long-term planning. Additional analysis, however, could assist IEUA in identifying key climate and demand triggers that would indicate when additional IRP management projects would need to be implemented or brought on line. Adding such adaptive elements to IEUA's long-term plan can help ensure IEUA is prepared for more stressing future conditions while also avoiding over building in the case that conditions change more gradually over time or in ways that can be addressed with IEUA's current system.

Appendix 1 – Robust Decision Making

This work is guided by the Robust Decision Making (RDM) (Groves and Lempert, 2007; Lempert *et al.*, 2003) analytical framework. RDM is an approach that seeks to determine what plans reduce risk over a range of assumptions, thereby facilitating deliberation among stakeholders that may have differing values and expectations about the future (Lempert, 2013). The process involves iterative steps including stakeholder interactions, modeling, and statistical analysis that facilitate interactions and shape decision-maker discussions around which factors lead to plan success or failure and the identification of robust solutions – those that perform well under a range of futures—rather than a single "best" solution (Hallegatte *et al.*, 2012; Lempert *et al.*, 2006).

The RDM approach runs models on tens to thousands of different sets of assumptions to describe how plans perform in a range of plausible futures. Analysts then use visualization and statistical analysis of the resulting large database of model runs to help decision-makers distinguish future conditions in which their plans will perform well from those in which they will perform poorly (Bryant and Lempert, 2010). RDM has been used in a range of contexts, to include water management, flood risk assessment, and sea level rise planning (Groves *et al.*, 2013, 2014; Herman *et al.*, 2015; Tingstad *et al.*, 2013).

This particular work did not follow a full RDM approach due to time and resource constraints. It did use deliberation with stakeholders to identify portfolios for use in the analysis and employed many different futures to assess which of those portfolios appeared most robust across a range of plausible conditions. However, this work did not mine the resulting statistical database of portfolios and how they perform under each plausible future in order to understand which conditions cause portfolios to perform particularly well or poorly. This could be the focus of future work with IEUA.

Many RDM analyses are conceptually organized using a framework called "XLRM", where key uncertainties (X), policy levers or strategies (L), relationships or models (R), and metrics or outcome measures (M) are summarized in a quad chart. The principal considerations around which this project is organized are summarized in XLRM format below (Table A-1).

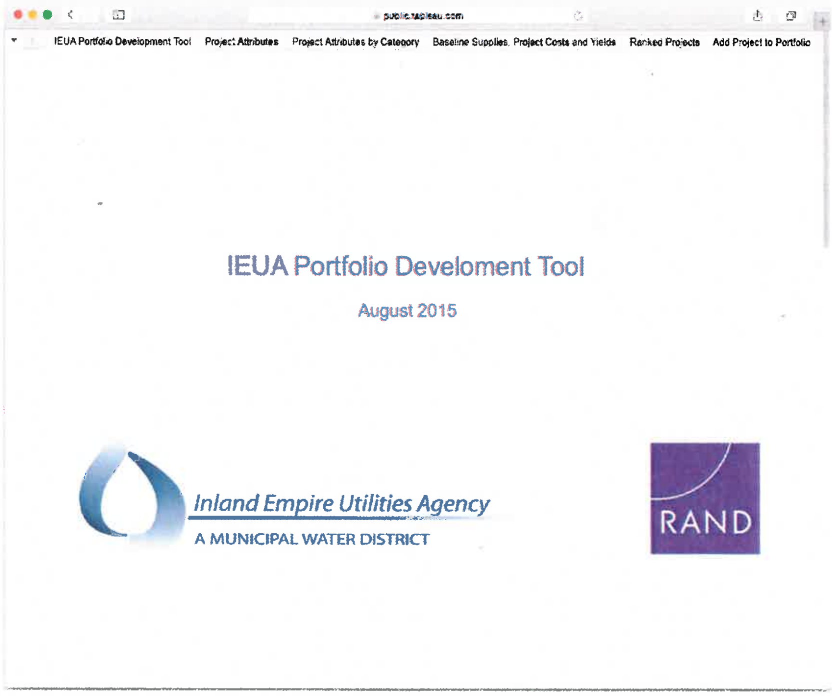
Table A-1: Summary of uncertainties, projects, models, and outcome measures considered

Uncertainties (X)	Projects (L)
Climate conditions Demand	75 different projects in categories • Chino Basin projects (13) • Imported Water Direct, Imported Water Recharge (14) • Imported Water Recharge (3) • Imported Water Recharge / Recycled Water (4) • Local Surface (2) • Other Groundwater (1) • Recycled Water (16) • Stormwater (6) • Stormwater, Recharge, Imported Water Recharge, Recycled Water (4) • Water Use Efficiency (10) • Chino Basin Groundwater, Recycled Water, Imported Water (2)
Models (R)	**Performance Metrics (M)**
WEAP IEUA IEUA Portfolio Development Tool	Demand Sources of supply to meet demand Unmet demand

Appendix 2 – Portfolio Development Tool

This appendix describes the IEUA Portfolio Development Tool (PDT) developed by RAND (Figure), with input from IEUA on its function, design, and input data. The PDT is a decision support tool designed to help IEUA and its member agencies assemble different portfolios of water management options that could help ensure the IEUA meets future water demands. IEUA used the PDT to develop a set of portfolios that were then evaluated across different climate and demand scenarios using a water management model described in Appendix 3. Although the information within and specific design of the PDT are specific to IEUA's needs, the visualization platform and methodological process could be used in the context of any water agency with similar needs for long-range planning under uncertain future conditions.

Figure A-1: Title screen for the Portfolio Development Tool



IEUA Portfolio Develoment Tool

August 2015

The PDT was developed using Tableau (www.tableausoftware.com)—a business analytics and visualization software package. All the data used to develop the PDT were provided to RAND by IEUA, and the PDT was deployed via the Internet for IEUA and stakeholders. In the series of figures below, we walk through each of the PDT's visualizations. Once again, the design and data shown here are specific to IEUA, but this type of tool could be configured to support decision-making within numerous types of organizations.

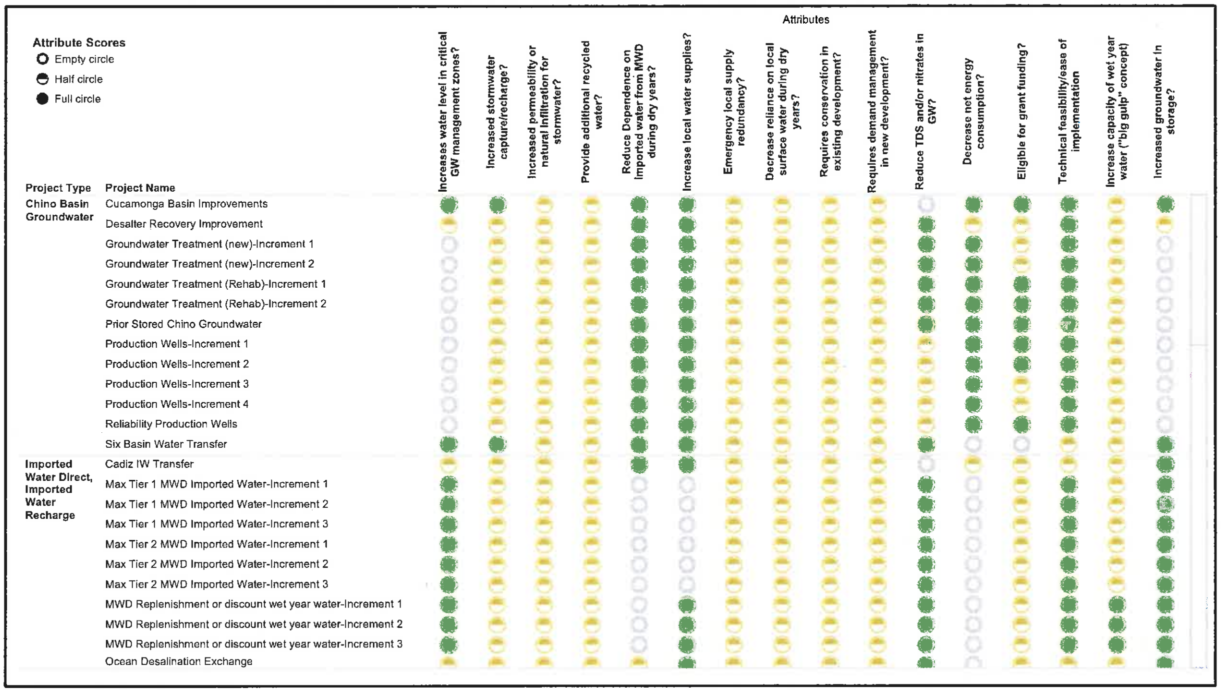
Overview of the Portfolio Development Tool

The PDT's main function is to help the user develop a portfolio of management options (or projects) that meets specified near-term and long-term water supply and demand targets. To do this, the user first specifies the projects that he or she wishes to consider. Next, the user specifies the near-term and long-term targets. The PDT then identifies the projects that would best achieve the targets from the set of eligible projects using a cost effectiveness criterion. In this context cost effectiveness is expressed in terms of levelized cost—or average cost per unit of new supply or demand reduction. Lastly, the PDT summarizes the included projects, their overall attributes, their cumulative yields, and their cumulative costs.

Portfolio Development Tool Visualizations

Figure A-2 shows one visualization used to concisely display qualitative information about the attributes of different water management projects. Here, each row pertains to a different project, organized by type, with each column indicating one of 16 qualitative attributes related to IEUA's future goals (e.g., increasing water levels in critical groundwater management zones, increasing stormwater capture and associated groundwater recharge). Filled circles indicate that projects help meet certain goals, half circles indicate that a projects have no impact on goals, and open circles indicate that projects detract from efforts to meet goals. IEUA, in consultation with its member agencies, developed these qualitative metrics and evaluated them for the different projects. More information on these can be found in the IRP. The visualization below provided a reference for IEUA and member agencies used this tab to contrast how well different types of and individual projects helped meet goals.

Figure A-2: Summary of how a sample of IEUA potential projects would help meet qualitative goals



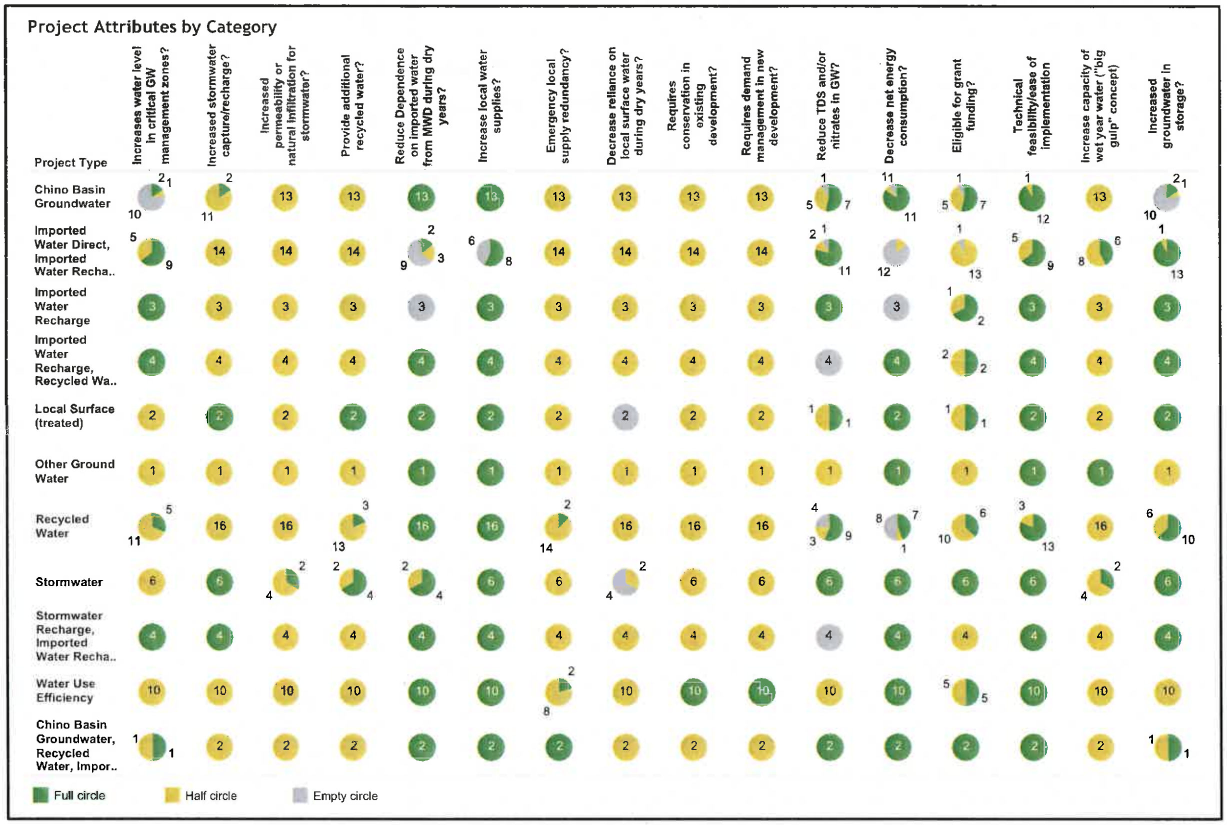
Attribute Scores
○ Empty circle
◓ Half circle
● Full circle

Attributes

Project Type	Project Name	Increases water level in critical GW management zones?	Increased stormwater capture/recharge?	Increased permeability or natural infiltration for stormwater?	Provide additional recycled water?	Reduce Dependence on imported water from MWD during dry years?	Increase local water supplies?	Emergency local supply redundancy?	Decrease reliance on local surface water during dry years?	Requires conservation in existing development?	Requires demand management in new development?	Reduce TDS and/or nitrates in GW?	Decrease net energy consumption?	Eligible for grant funding?	Technical feasibility/ease of implementation	Increase capacity of wet year water ("big gulp" concept)	Increased groundwater in storage?
Chino Basin Groundwater	Cucamonga Basin Improvements	●	●	◓	◓	●	●	◓	◓	◓	◓	○	●	●	●	◓	●
	Desalter Recovery Improvement	◓	◓	◓	◓	●	●	◓	◓	◓	◓	●	◓	◓	●	◓	◓
	Groundwater Treatment (new)-Increment 1	○	◓	◓	◓	●	●	◓	◓	◓	◓	●	●	◓	●	◓	○
	Groundwater Treatment (new)-Increment 2	○	◓	◓	◓	●	●	◓	◓	◓	◓	●	●	◓	●	◓	○
	Groundwater Treatment (Rehab)-Increment 1	○	◓	◓	◓	●	●	◓	◓	◓	◓	●	●	●	●	◓	○
	Groundwater Treatment (Rehab)-Increment 2	○	◓	◓	◓	●	●	◓	◓	◓	◓	●	●	●	●	◓	○
	Prior Stored Chino Groundwater	○	◓	◓	◓	●	●	◓	◓	◓	◓	●	●	●	●	◓	○
	Production Wells-Increment 1	○	◓	◓	◓	●	●	◓	◓	◓	◓	◓	●	●	●	◓	○
	Production Wells-Increment 2	○	◓	◓	◓	●	●	◓	◓	◓	◓	◓	●	●	●	◓	○
	Production Wells-Increment 3	○	◓	◓	◓	●	●	◓	◓	◓	◓	◓	●	◓	●	◓	○
	Production Wells-Increment 4	○	◓	◓	◓	●	●	◓	◓	◓	◓	◓	●	◓	●	◓	○
	Reliability Production Wells	○	◓	◓	◓	●	●	◓	◓	◓	◓	◓	●	●	●	◓	○
	Six Basin Water Transfer	●	●	◓	◓	●	●	◓	◓	◓	◓	●	○	○	◓	◓	●
Imported Water Direct, Imported Water Recharge	Cadiz IW Transfer	◓	◓	◓	◓	●	●	◓	◓	◓	◓	○	◓	◓	◓	◓	●
	Max Tier 1 MWD Imported Water-Increment 1	●	◓	◓	◓	○	○	◓	◓	◓	◓	●	○	◓	●	◓	●
	Max Tier 1 MWD Imported Water-Increment 2	●	◓	◓	◓	○	○	◓	◓	◓	◓	●	○	◓	●	◓	●
	Max Tier 1 MWD Imported Water-Increment 3	●	◓	◓	◓	○	○	◓	◓	◓	◓	●	○	◓	●	◓	●
	Max Tier 2 MWD Imported Water-Increment 1	●	◓	◓	◓	○	○	◓	◓	◓	◓	●	○	◓	●	◓	●
	Max Tier 2 MWD Imported Water-Increment 2	●	◓	◓	◓	○	○	◓	◓	◓	◓	●	○	◓	●	◓	●
	Max Tier 2 MWD Imported Water-Increment 3	●	◓	◓	◓	○	○	◓	◓	◓	◓	●	○	◓	●	◓	●
	MWD Replenishment or discount wet year water-Increment 1	●	◓	◓	◓	○	●	◓	◓	◓	◓	●	○	◓	●	●	●
	MWD Replenishment or discount wet year water-Increment 2	●	◓	◓	◓	○	●	◓	◓	◓	◓	●	○	◓	●	●	●
	MWD Replenishment or discount wet year water-Increment 3	●	◓	◓	◓	○	●	◓	◓	◓	◓	●	○	◓	●	●	●
	Ocean Desalination Exchange	◓	◓	◓	◓	◓	●	◓	◓	◓	◓	●	○	◓	◓	◓	●

Figure A-3 displays the same IEUA qualitative goals as in the previous screenshot (above), but summarizes their values within the different project categories. This shows, for example, how many projects within the more general category of "Chino Basin Groundwater" add to, detract from, or have neutral effects on different goals. This assists decision makers in identifying which categories have the most projects that might contribute to the achievement of particular goals.

Figure A-3: Summary of how well projects in different categories meet various IEUA qualitative goals



IEUA has considerable supplies to meet current and future needs already. These are highlighted in the top panel of Figure A-4, and include groundwater, recycled water, imported water, conservation measures, and other sources. The color bars indicate when these sources come online, and most are already available. (Note that those that come online in the future are already planned for implementation and are thus not considered in the portfolios directly.) IEUA and member agencies requested this view of the baseline supplies because it serves as a useful perspective upon which to layer projects to bring additional future supplies. Below the baseline supply panel are the different potential projects, sorted by general categories, and with information about cost and amount of supply each is estimated to provide. Note that not all projects are visible in this screen shot.

Figure A-4: Summary of baseline supplies, estimated new project supply amounts, and new project costs

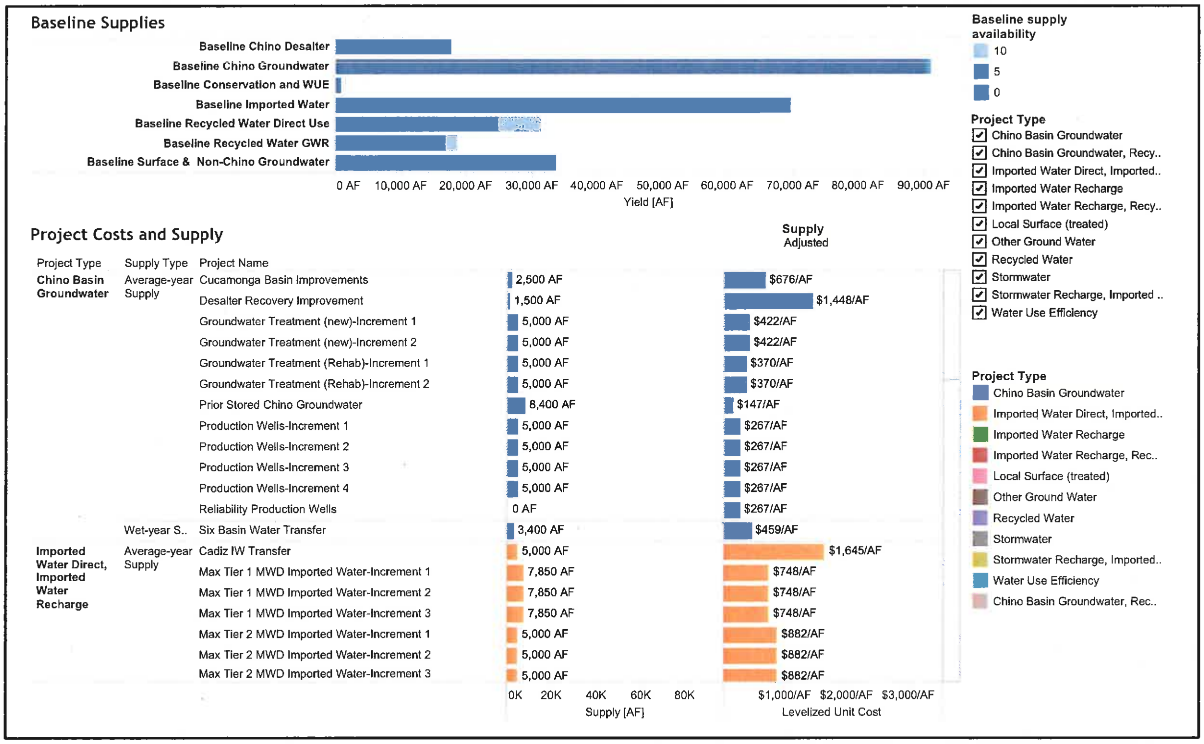
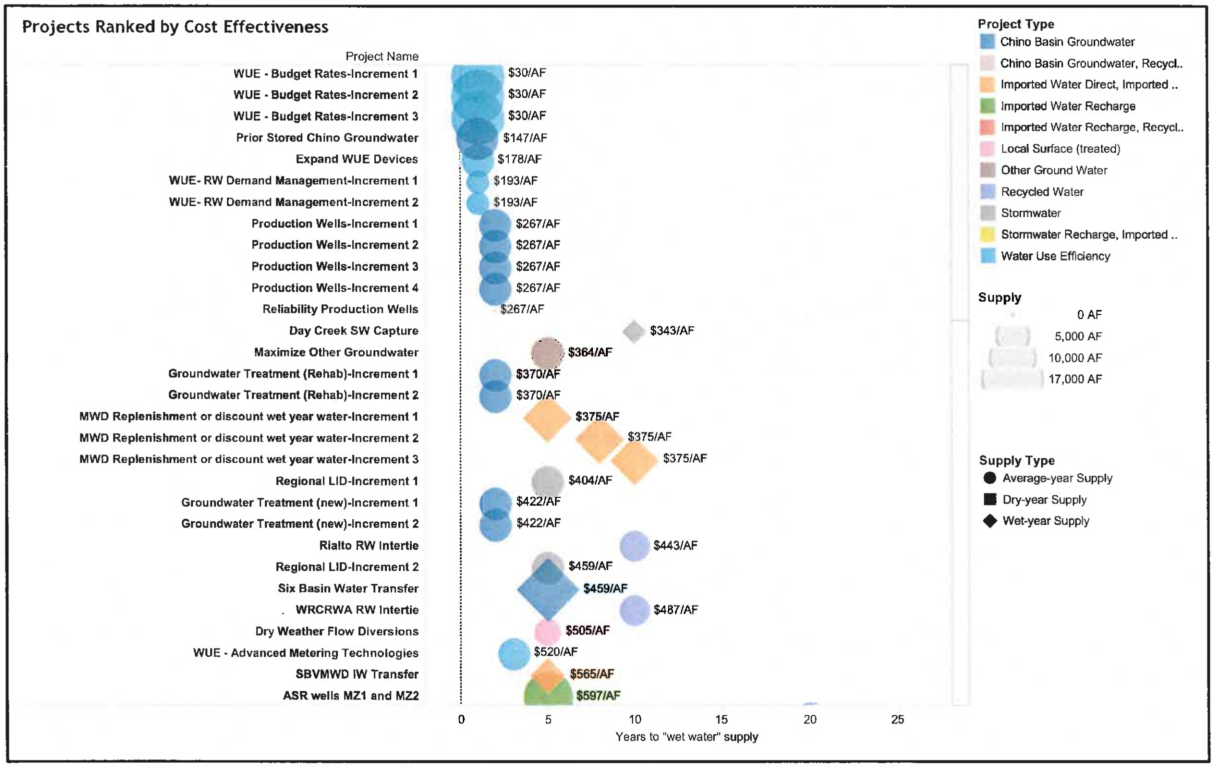


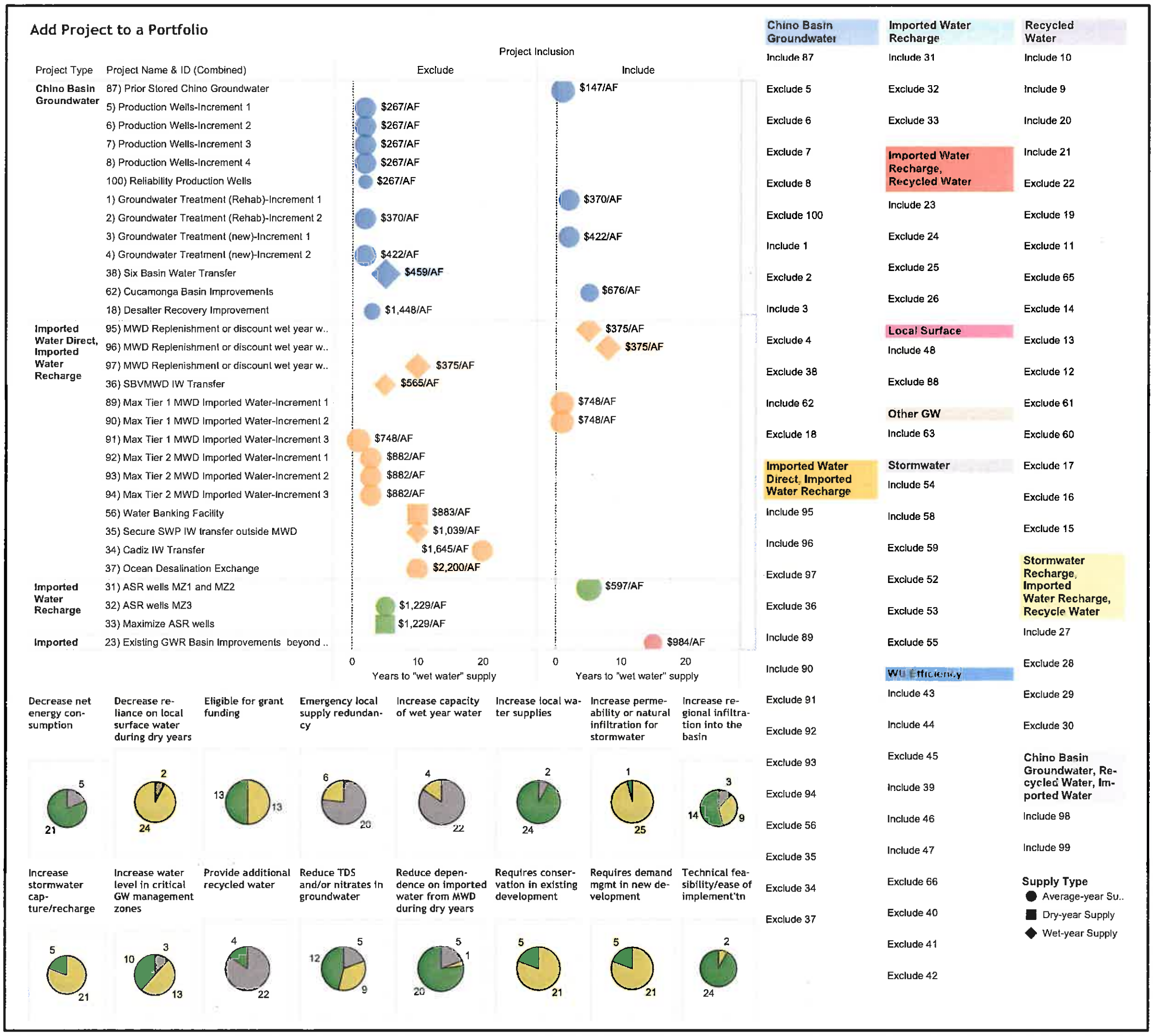
Figure A-5 displays all the projects, sorted by preliminary estimates of per unit water cost (these have yet to be finalized). Symbol coloring indicates its category, size indicates its estimated volume; horizontal position indicates the number of years until which the project produces enough water to add to the supply IEUA distributes to stakeholders; the text label indicates its cost; and its symbol indicates whether the water is available during any given year or only under particularly wet or dry conditions. This view was useful for stakeholders to compare projects, and general categories of projects, by supply amount, timing, and cost.

Figure A-5: Project cost per acre-foot, with information on project type, supply amount, supply type, and number of years to "wet water" supply



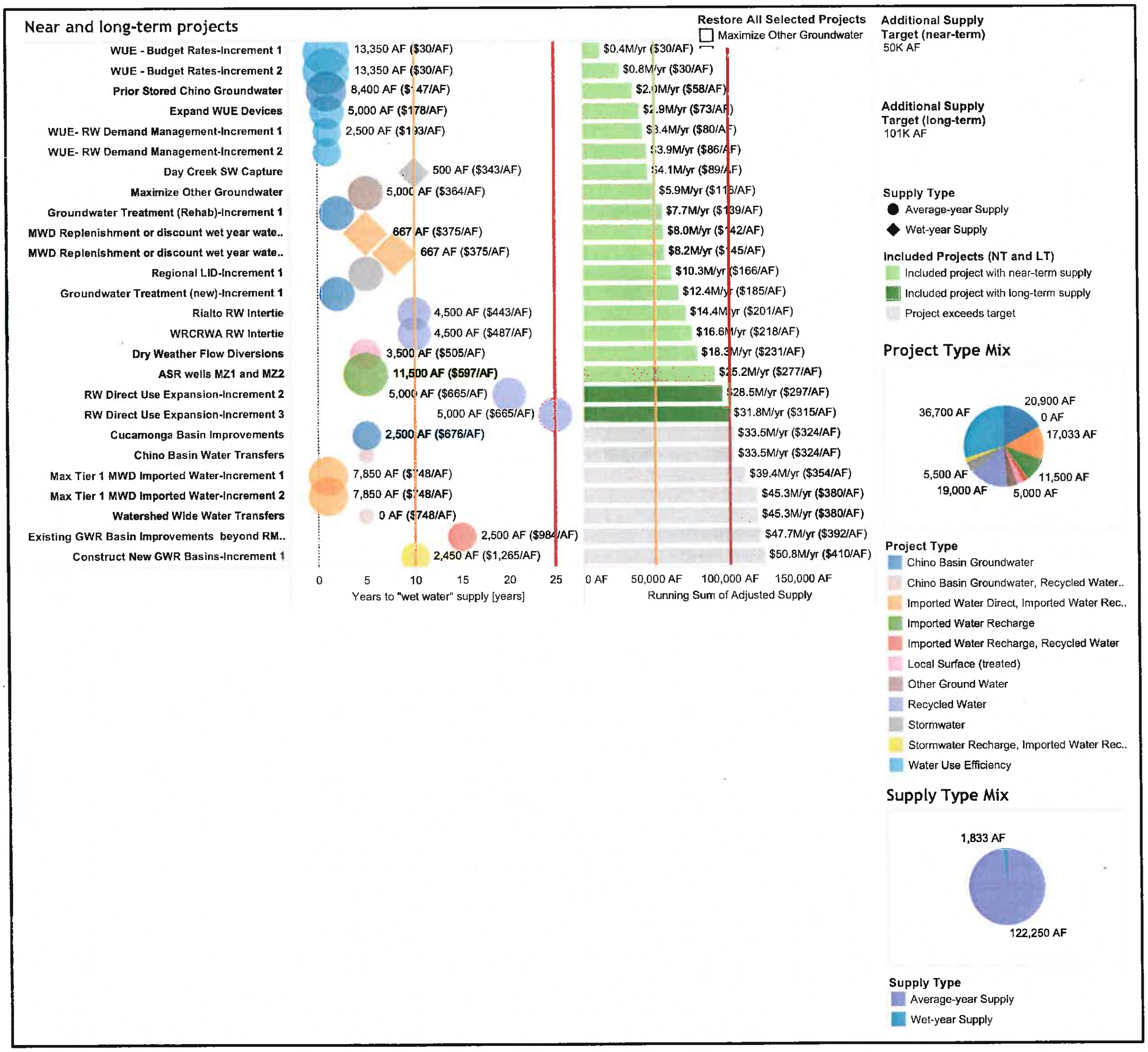
The next figures show how IEUA and member agencies were able to use the tool to create different potential portfolios of water management projects. Figure A-6 shows a tab in which the user is able to select individual projects to be considered in a portfolio. The user can exclude or include a project with a single click of the toggles on the right side of the screen shot. Projects' inclusion, category, cost, and years to wet water supply are tracked in real time on the left side of the screen. Aggregate summaries of the project attribute measures are shown as pie charts at the bottom of the screen. In this figure, a subset of projects is selected for inclusion, and only some projects are shown in the figure. In the tool, the user is able to scroll to see projects from all project categories.

Figure A-6: Portfolio building tab enabling user to include and exclude specific projects in real time and visually track different project categories, costs, and years to "wet water" supply



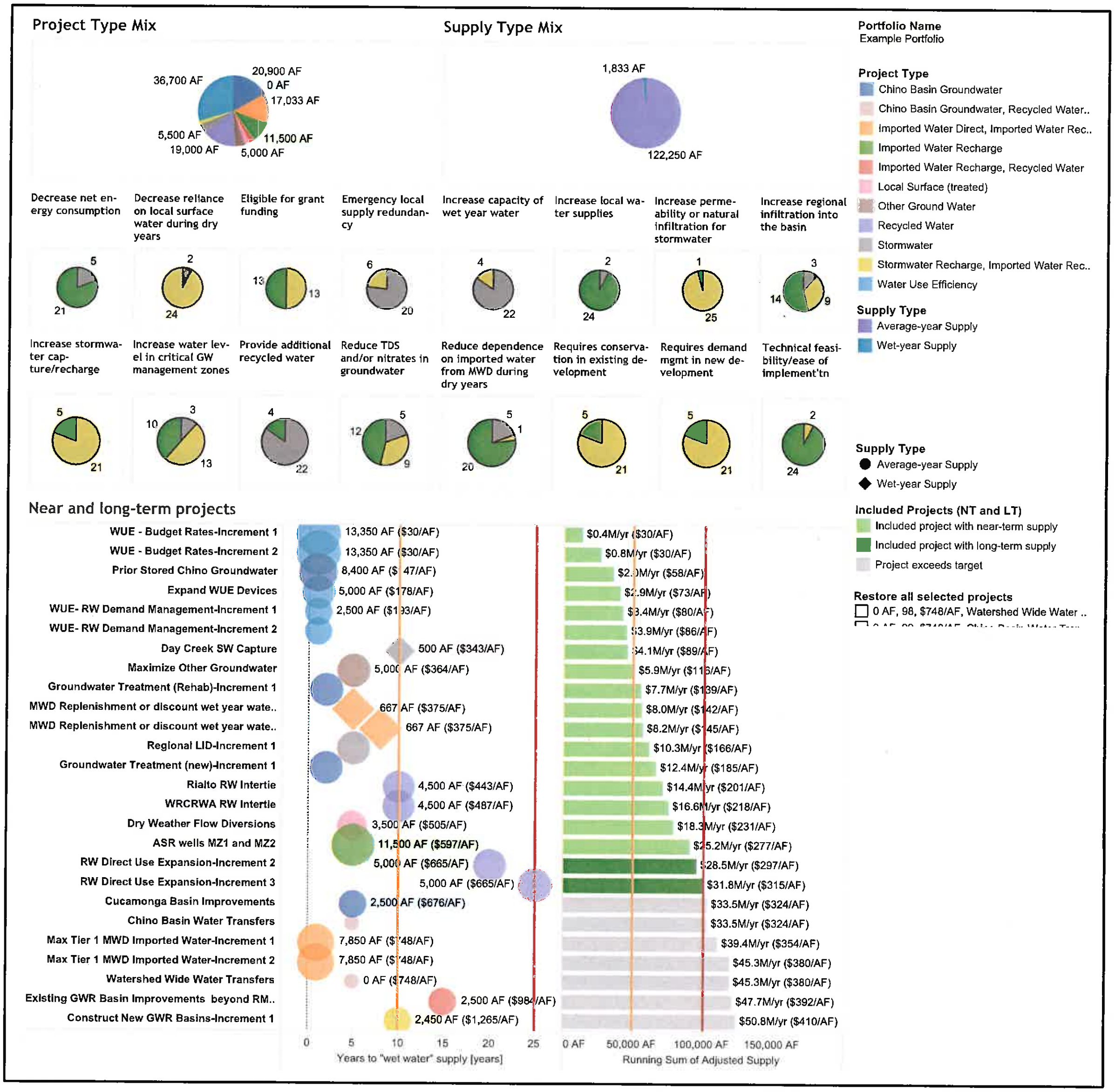
The next visualization (Figure A-7) takes the projects included in the previous screens and sorts them by cost effectiveness and availability to meet user-specified near-term (year 10) and long-term (year 25) targets. In this example, the near-term target is set to 50 TAF, whereas the long-term target is set to 101 TAF. On the left, projects are shown ordered by cost effectiveness. The bar chart to the right shows the cumulative new supply or demand reduction. Projects that meet the near-term or long-term targets are shaded green, indicating that they are included in the final portfolio. The projects shaded dark green are only available to meet long-term demand. On the right, a pie chart summarizes the mixture of projects used to meet the supply targets and the type of projects with respect to availability (all year, wet year, or dry year).

Figure A-7: Example portfolio with information on projects included therein, and how well projects meet supply goals



Lastly, Figure A-8 provides another summary of the defined portfolio. This includes a summary of the supply and project category information in Figure , but also displays summaries of the project attributes—suggesting how well a particular portfolio meets different IEUA qualitative goals. IEUA and member agencies were able to use this display as a final summary chart for each portfolio they explored.

Figure A-8: Example project portfolio summary, including how well projects meet IEUA qualitative goals



Appendix 3 – Water Management Model and Assumptions

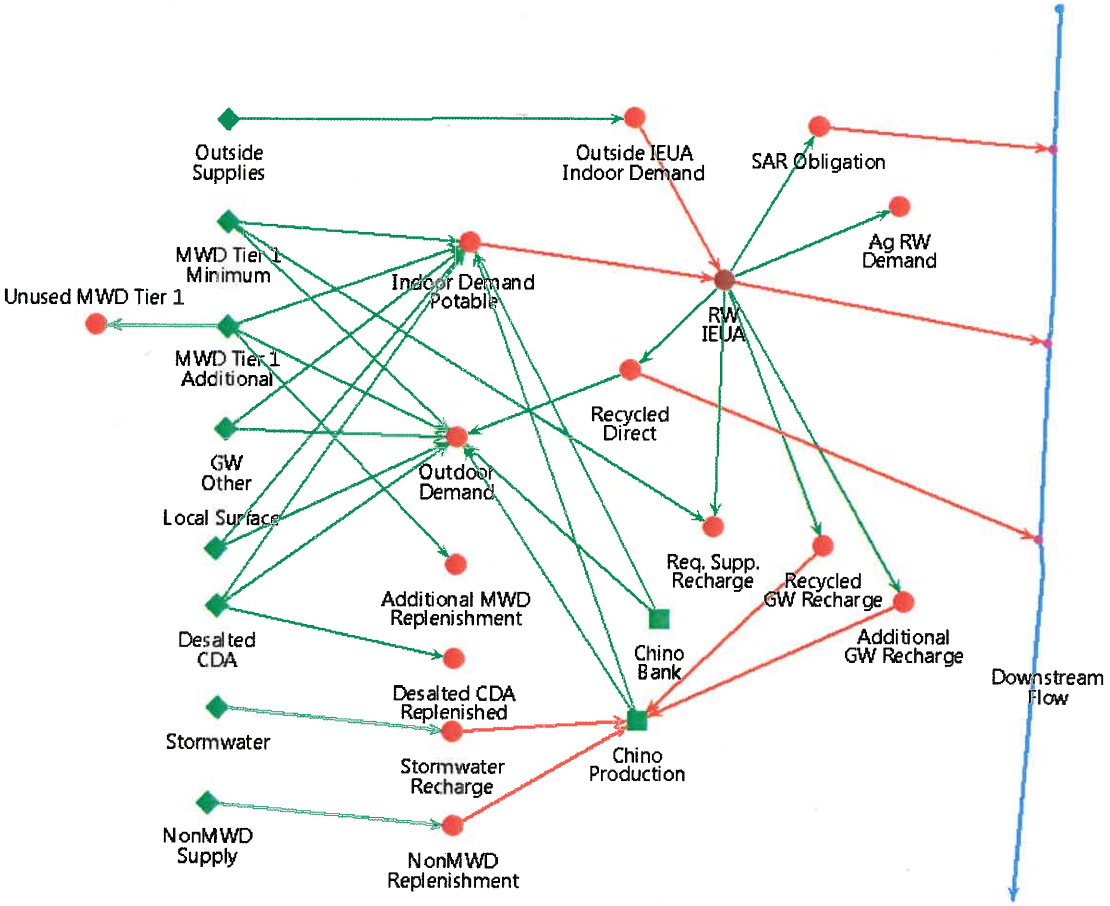
Model Overview

The study team built a model of the IEUA water management system, based on tabular monthly and annual information on historical and projected IEUA water supplies and demands provided by IEUA. The model includes simple relationships and data on estimated future climate conditions to evaluate water supply and demand balance conditions under alternative futures. Lastly, using the Portfolio Development Tool (see Appendix 2), the model evaluates how different water management portfolios would improve performance over these futures.

The model is built in the Water Evaluation And Planning (WEAP) system, developed by the Stockholm Environment Institute (SEI) (Yates *et al.*, 2005). The WEAP IEUA water management model represents the IEUA system through a set of arcs and nodes. Nodes represent locations of water inflows, storage (surface or groundwater), outflows, or demand. Arcs represent conveyance, either natural or constructed, between different nodes.

The IEUA WEAP model calculates how water demand would be met by various supplies based on a system of supply preferences and priorities for each demand node. The model schematic shows the connectivity of water flows among the nodes via the arcs within the model (Figure A-9). The schematic is not intended to represent the specific locations of IEUA system elements, but rather show their connectivity. Table A-2 lists and describes the demand and supply nodes shown in the model schematic. More details on select demands and supplies are provided in the sections below.

Figure A-9: Schematic of the WEAP model of the Inland Empire Utilities Agency service area



Note: RW = recycled water; Ag = agricultural; SAR = Santa Ana River; MWD = Metropolitan Water District of Southern California; CDA = Chino Desalter Authority; GW = Groundwater.

Table A-2: IEUA WEAP model supply and demands

Node Name	Description
Demand	
Indoor Demand Potable	Indoor demand for potable (non recycled) water
Outdoor Demand	Outdoor demand for potable and recycled water
Recycled Direct	Total recycled water demand for outdoor use; met demand passes through to Outdoor Demand node or downstream flow if unneeded
Recycled GW Recharge	Demand for groundwater replenishment water; passes to Chino Production node
Additional GW Recharge	Demand for additional groundwater replenishment as specified by water management strategies; passes to Chino Production node
Outside IEUA Indoor Demand	Demand for water outside IEUA that is provided to IEUA for recycling via RW IEUA node

SAR Obligation	Santa Ana River flow obligation; met by recycled water
Ag RW Demand	Agricultural water demand in IEUA service area met with recycled water
Supplies	
MWD Tier 1 Minimum	Specified annual minimum Tier 1 MWD imports (about 40 TAF)
MWD Tier 1 Additional	Additional annual Tier 1 MWD imports, constrained by contract with MWD
Local Surface	Water supplies obtained from watersheds within the IEUA boundary
Desalted CDA	Desalted brackish groundwater from the Chino Desalter Authority facilities
Chino Production	Groundwater from the Chino Basins
GW Other	Groundwater from sources outside the Chino Basin
Stormwater	Additional runoff from storms captured and treated for use
NonMWD Supply	External sources of water used for groundwater replenishment

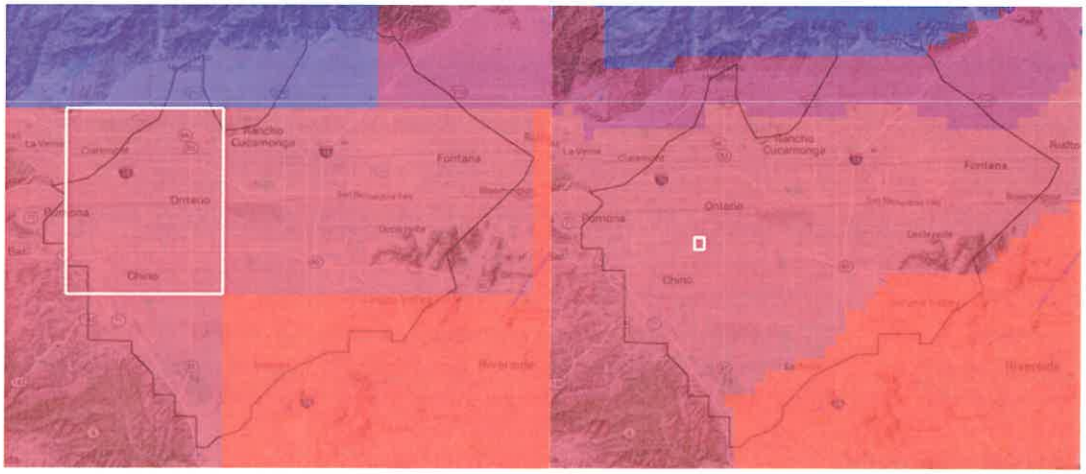
Climate Scenarios

The study uses downscaled climate data from general circulation models as the basis for a wide range of plausible future climate conditions. Historical and projected climate data from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset were downloaded from the Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections archive (Maurer *et al.*, 2007).[2] Climate data retrieved from this archive included bias-corrected statistically downscaled (BCSD) global climate model (GMD) monthly mean temperature and total precipitation observations and projections for 36 CMIP3 simulations and 70 CMIP5 model runs for years 1950-2050 (Brekke *et al.*, 2013). Note, however, that observed BCSD data were available only for years 1950-1999. These gridded climate data represented the gridded area bounded by latitudes 34.0N and 34.125N and longitudes 117.625W and 117.5W, roughly centered at Ontario International Airport (Figure A-10).

---

[2] Data is available online at: http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/.

Figure A-10: Geographic scale of climate sources for CMIP-3 data (left) and CMIP-5 date (right)



Key Demands

Indoor Potable

Indoor potable demand is calculated as the population within the IEUA service area times an annual water use rate. IEUA, assisted by A&N Technical Services, specified the high and low demand scenario by varying annual water use rates. The middle demand scenario is user definable by setting the indoor and water use rates for 2050. Indoor potable demand does not vary by climate.

Table A-3: Indoor potable demand parameters for historical data and scenario projections

Model Parameter	2010 (data)	2014 (data)	2020 (projection)	2050 (projection)
Population (people)	813,695	847,587	896,533	1,249,091 (all)
Water Use rates (gal/person/year)	26,061	23,981	24,090 (high) 22,959 (low)	24,017 (high) 17,082 (low)
Water Use/Demand (taf/year)	65.1	62.4	66.3 (high) 63.2 (low)	92.1 (high) 65.5 (low)

Outdoor

Outdoor demand is calculated as the population within the IEUA service area times an annual water use rate. IEUA, assisted by A&N Technical Services, specified the high and low demand scenario by varying annual water use rates. The middle demand scenario is user definable by setting the nominal outdoor and water use rates for 2050.

IEUA performed a series of sensitivity analyses of urban outdoor demand and weather conditions. By 2040, IEUA estimated that one dry year would increase demand by 5.6 percent. Similarly, a one wet year would decrease outdoor demand by 5.6 percent. A longer period of dry weather (3-years) would increase demand by 8.9 percent. Separately IEUA estimated the long-term effect of warming on outdoor demand. They found that for each degree temperature increase (in Celsius), outdoor demand would increase by percent. Together these factors were applied to the climate scenarios to estimate how outdoor demand could change due to weather in the future.

Outdoor demand varies by three outdoor water demand factors that are applied depending up the projected precipitation difference from historical (or perturbation), as shown in A-4. The outdoor water demand factors were derived from IEUA analysis.

Table A-4: Climate effect factors on outdoor water demand

Precipitation Condition	Perturbation Threshold	Outdoor Water Demand Factor
Very dry	-5 cm/year	-0.089
Dry	0 cm/year	-0.056
Wet	+ 25 cm/year	+0.56

Agricultural Recycled Water Demand

Agricultural recycled water demand is specified based on IEUA projections and does not vary by climate. This demand declines from about 10,000 AF in 2015 to 2,000 AF by 2025 and then remains constant through 2050. This is due to the transition of agricultural land to urban use.

SAR Obligations

IEUA's Santa Ana River (SAR) obligations are specified to be 17,000 AF/year per IEUA agreement.

Key Supplies

Local Surface Supplies

Total monthly local surface supplies within the IEUA management boundary for water years (July through June) 2010 through 2015 were provided by IEUA member agencies and represent the amount of water that is diverted, not total stream flow. To estimate these total local surface water supplies under different climate scenarios, relationships between climate variables and surface supply were derived using historical data. These relationships were then used to estimate future supplies under each climate scenario included in the analysis. Several different regression models were evaluated, and two models were found to reasonably represent the relationship between historical climate and historical supplies. One included both temperature and precipitation variables and the other only precipitation.

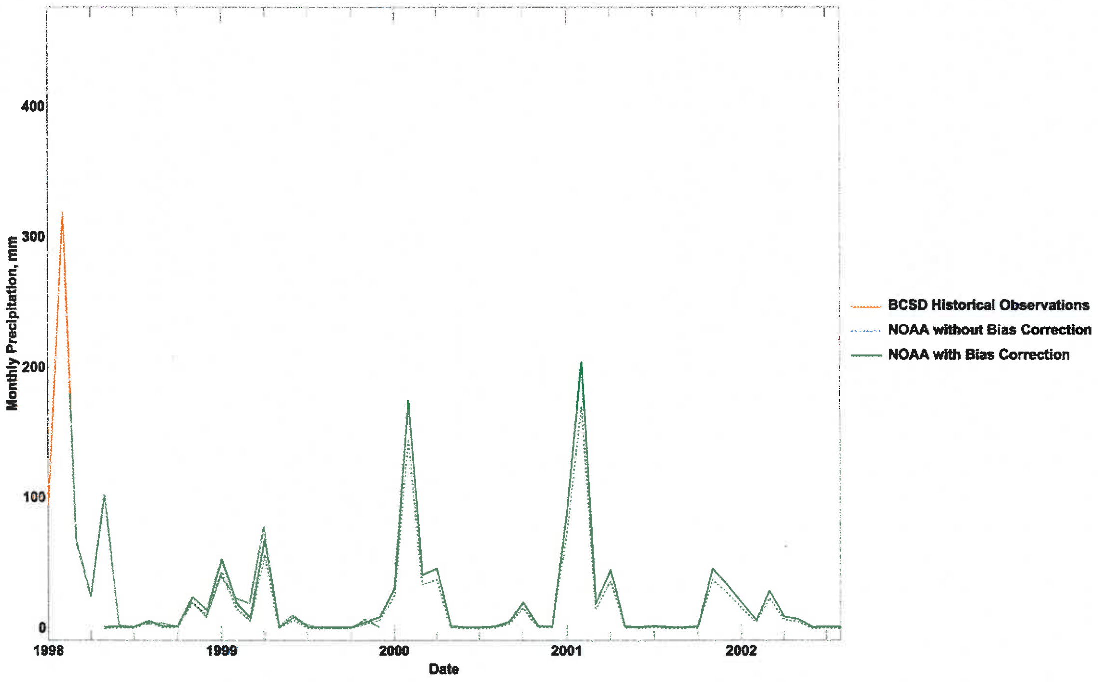
At the time of the analysis, the gridded BCSD historical climate observations were available only between 1950 and 1999. Therefore, to compare climate observations to the surface supply results for 2010 to 2015 an additional proxy data set for the 2010 to 2015 period was developed. Specifically, we used weather station observation at Ontario International Airport[3] (coordinates 34.05N, 117.61667W) contained in the Global Historical Climatology Network Database (GHCND) (Menne *et al.*, 2012), maintained by the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center. The Ontario International Airport observation station reports monthly total precipitation and mean temperature observations from 1998 to present day.

We compared the monthly mean NOAA observed data to the monthly mean BCSD observed data for the overlapping period of May 1998 to June 2015. As expected we found very strong relationships for both monthly temperature and precipitation, although the NOAA observations were generally slightly drier than the BCSD data. We calculated a correction factor that we subsequently applied to the NOAA observed data to generate bias corrected datasets. Figure A-11 shows a comparison of BCSD observed precipitation, NOAA observed monthly precipitation, and NOAA bias-corrected precipitation. This figure shows the strong relationship between the NOAA and BCSD datasets during the overlapping period of 1998 to 2000 and the very slight adjustment that was made to the NOAA data for months from 2000 and later.

---

[3] This station has Station ID GHCND:USW00003102 with latitude/longitude coordinates 34.05N, 117.61667W.

Figure A-11: Comparison of BCSD, NOAA, and NOAA bias corrected monthly precipitation data on overlapping dates



NOAA bias corrected temperature and precipitation data, which were available until June 2015, were used in a linear regression model to assess relationships of monthly mean temperature and mean precipitation to total observed IEUA surface supplies. Additionally, given that a significant component of surface supply is due to melting snow pack, the potential of a delayed precipitation signal was evaluated. Four regressions were considered to estimate stream flow: (1) precipitation alone, (2) temperature alone, (3) precipitation and temperature, and (4) precipitation and a 12-month moving average of temperature. These regressions were analyzed with various lag times—applied to both temperature and precipitation—ranging from 0 to 6 months to search for a significant signal; a lag time of three months was found to have the lowest p-value among for all regressions and appeared to best reflect observed stream flow patterns. Note that the minimum p-value found with a lag time of 0 months was ≈ 0.429, while the p-values of the three best-fitting regression models at a lag time of three months were < 0.005. Shown below in Figure A-12 is a comparison of each of the four regressions considered—each mapped over the NOAA bias corrected precipitation and/or temperature data—against observed surface flows. Figure A-13 shows the same models aggregated to annual totals.

Figure A-12: The four regression models versus observed flows

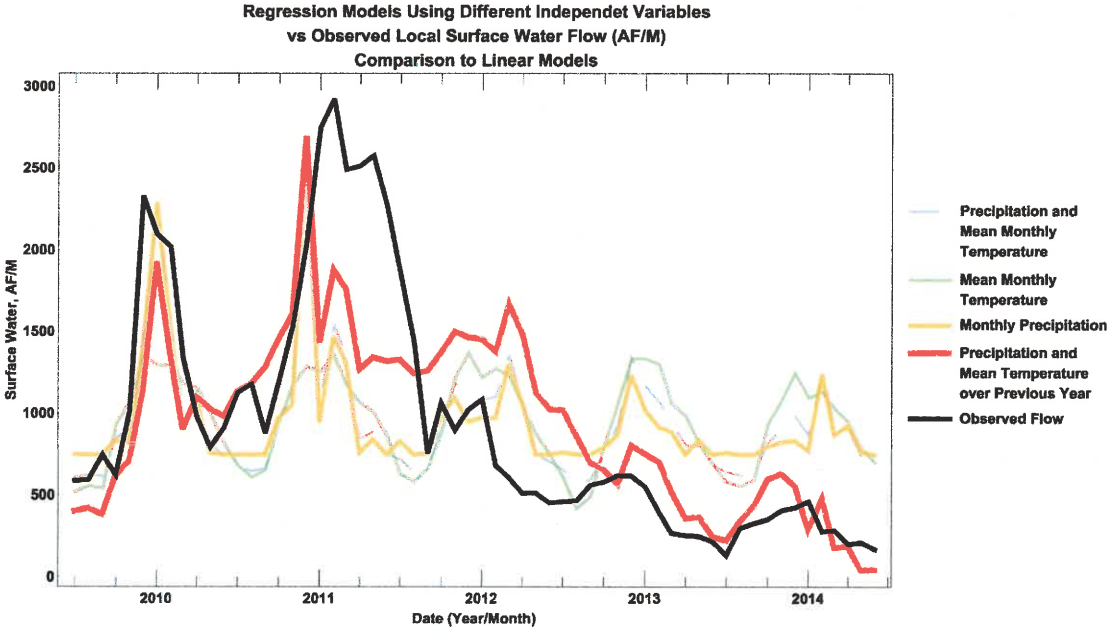
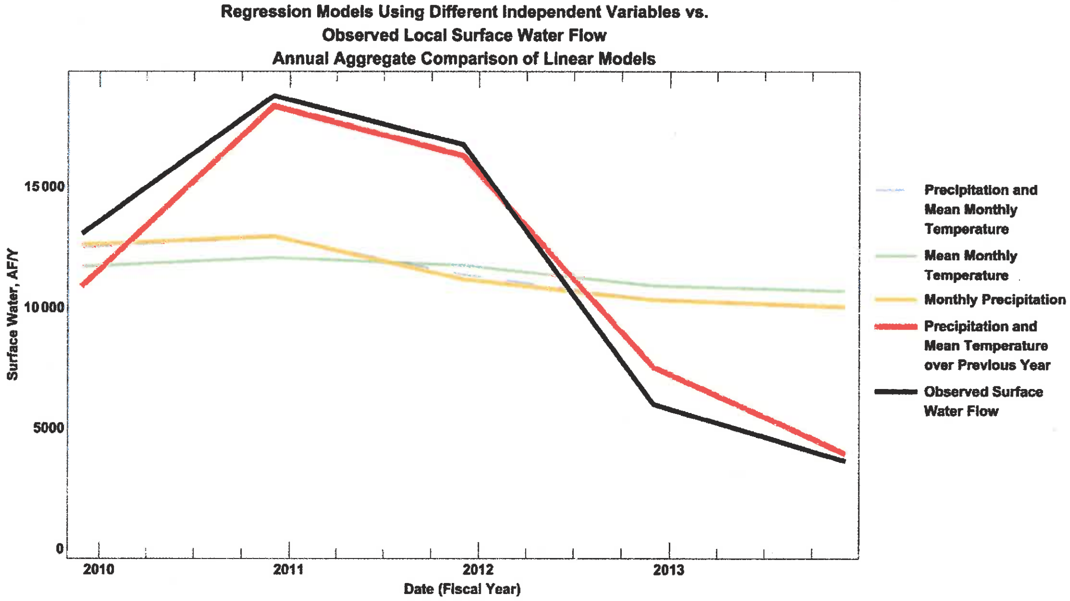


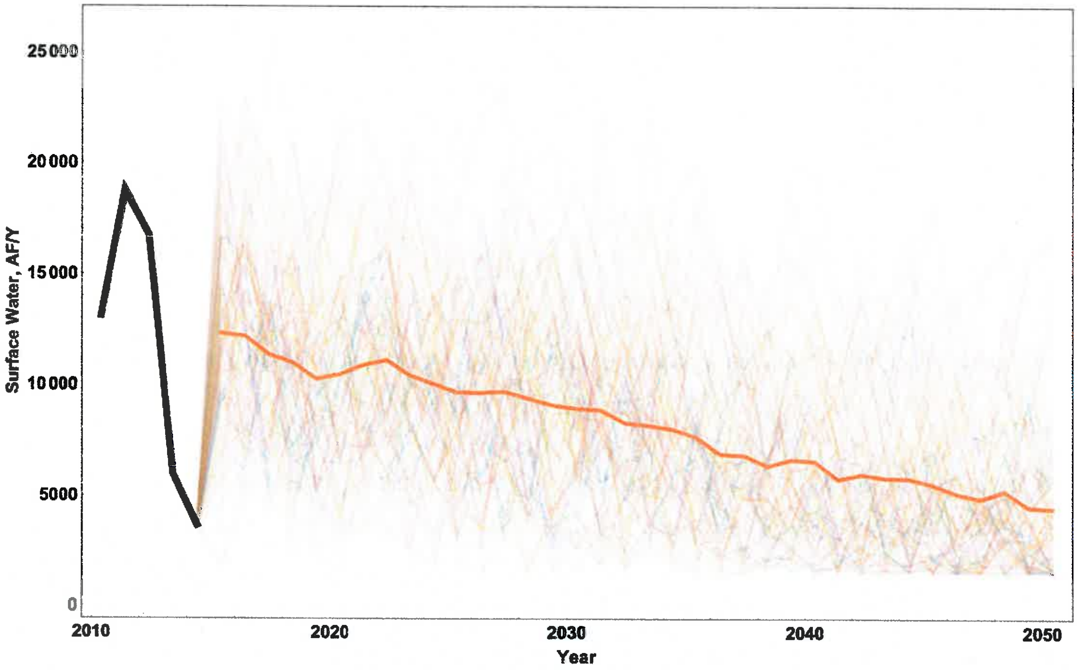
Figure A-13: Four regression models averaged annually



The regression model using precipitation and the mean temperature of the previous year (a moving average of twelve months) appears to generally follow the downward trend, while the precipitation only model, while accounting for much of the same variance, does not reflect the monthly downward trend in flow shown in Figure A-13.

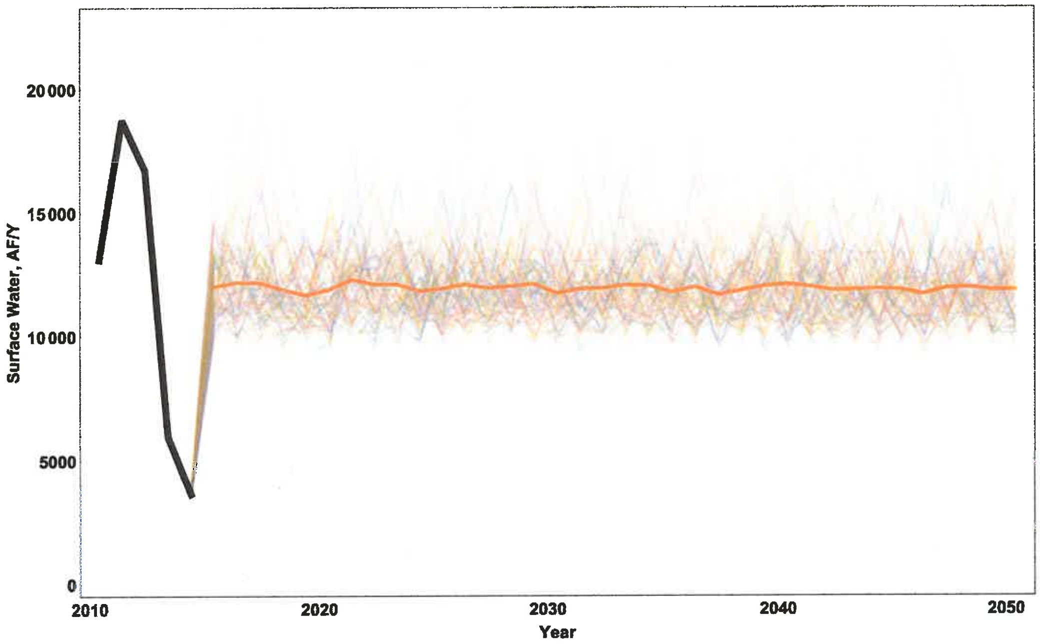
Figure A-14 shows estimates of surface supplies over time based on the precipitation and temperature regression applied to a larger set of 343 climate scenarios. The orange line shows the mean estimate across all climate scenarios. Estimates generated using the precipitation only model are shown below in Figure A-15.

Figure A-14: Annual projected IEUA surface supplies using the Precipitation and Temperature regression model



Note: Black line is the historical surface supply. Orange line is the mean estimate of future surface supply.

Figure A-15: Annual projected IEUA surface supplies using the Precipitation regression model



Note: Black line is the historical surface supply. Orange line is the mean estimate of future surface supply.

Stormwater

Additional stormwater used for Chino Basin groundwater replenishment is projected to increase from effectively 0 to 6,400 AF by 2020. The historical stormwater recharge has been included in the Chino Basin groundwater supply as provided from WEI to avoid double counting. Any "new" stormwater supply could be from projects constructed under the 2013 Recharge Master Plan Update prepared by the Chino Basin Water Master. In absence of more detailed information on how future stormwater would vary with respect to precipitation, we assume that the same relationship between weather (temperature and precipitation) and local supplies apply to the projected stormwater. To do this we apply the same regression formula developed for surface water supply to the baseline stormwater supply as well as any additional stormwater supply specified as part of a water management strategy.

Imports via Metropolitan Water District

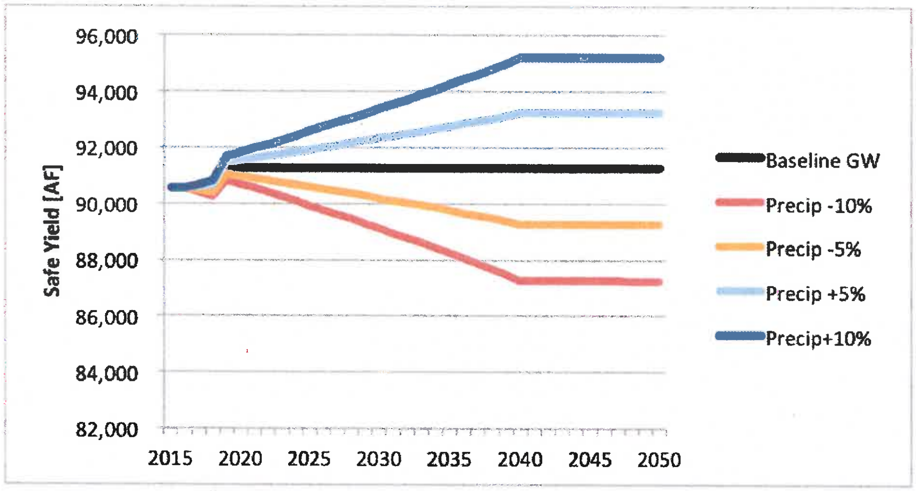
IEUA purchases water from MWD. Tier 1 water is generally used to meet urban indoor and outdoor demands. According to its contract with MWD, IEUA must purchase at least 39,835 AF/year. Additional Tier 1 water, up to a total of 93,283 AF/year, is also typically made available to IEUA and is purchased when needed for direct use or groundwater replenishment. The baseline assumption for available additional Tier 1 water is 26,600 AF/year, for a total of just under 67,000 AF/year.

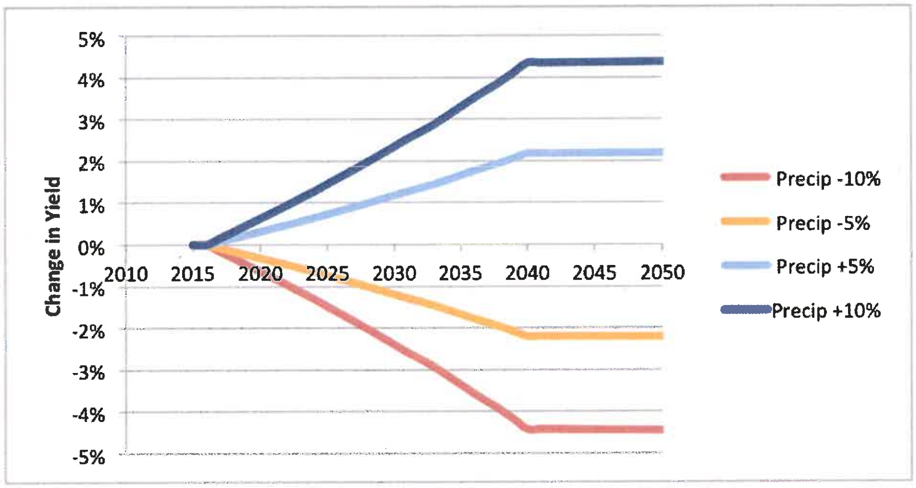
For this study, we evaluated two possible levels of climate effect on additional Tier 1 water. In both cases, the total amount available declines beginning in 2021 through 2050. In one scenario, we assume additional Tier 1 water declines by 40 percent. In the other scenario, we assume declines of 80 percent. Note that these two level of water declines imply a total reduction in MWD Tier 1 water from 62,600 AF in the without climate change condition to 51,960 (for the 40 percent decline in additional supplies) and to 41,320 (for the 80 percent decline in additional supplies).

Chino Groundwater Basin

IEUA's share of Chino Basin's sustainable groundwater yield is set through actions of the Chino Basin Water Master. Under current basin conditions, the amount of groundwater available to the appropriators within the IEUA service area is 91,266 AF. A modeling analysis by Wildermuth Environmental Inc. determined the sensitivity of IEUA's allowable production as a function of long-term precipitation trends (Figure). These data show that across the four scenarios evaluated, the safe yield would decline 0.44 percent for each 1 percent decline in long-term precipitation.

Figure A-16: Safe yield over time for the baseline and four trends in precipitation (top); change in safe yield (as compared to 2015 across four trends in precipitation (bottom)





We then modified the Chino Basin safe yield by the product of the long-term precipitation trend and the empirically derived scaling factor. For example, groundwater safe yield would be reduced 4.4 percent by 2040 for a climate scenario that exhibits a long-term precipitation trend of -10 percent.

Key Simulation Results

The WEAP IEUA model simulates annual water supply and demand from 2010 to 2015. For this analysis, the key outputs reviewed included:

- Urban indoor and outdoor demand
- Supplies used to meet urban demand
- Unmet urban demand
- Recycled water inflows and outflows
- Chino Basin inflows and outflows

This section shows results for these outputs from the WEAP IEUA model for a single simulation—high demand scenario and historical climate.

Figure A-17 shows annual indoor potable demand and outdoor demand—both potable and recycled. Note that indoor demand gradually increases each year, whereas outdoor demand varies year-to-year. The outdoor demand variation is due to the historical climate used in this simulation.

Figure A-17: Urban indoor and outdoor demand for high demand scenario and historical climate

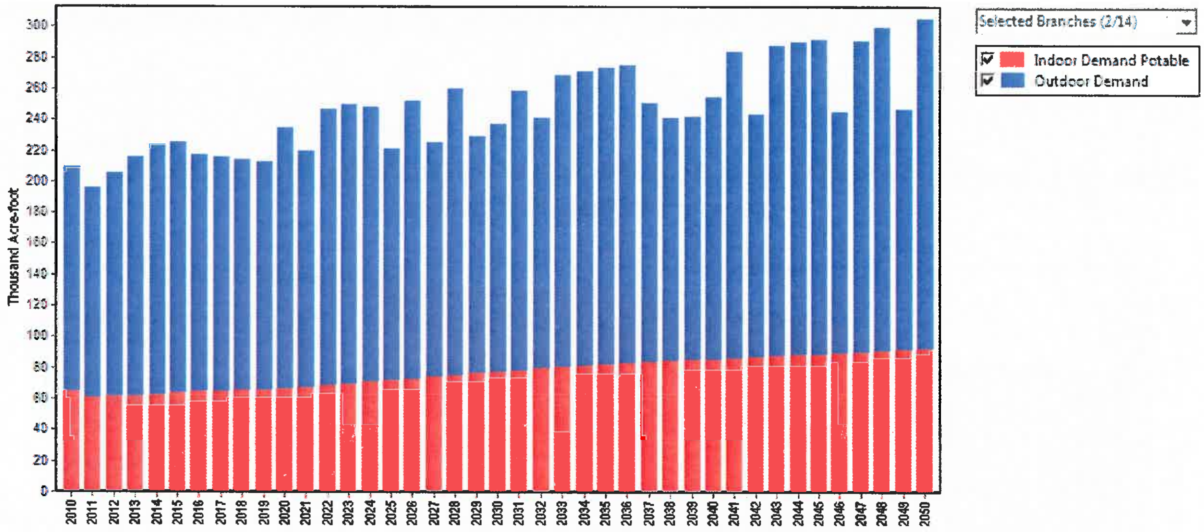


Figure A-18 shows the mixture of supplies used to meet the demands in Figure . The largest source is Chino groundwater supplies. MWD Tier 1 supplies (minimum and additional) provide significant water. Lastly, recycled water provides about 20 percent of the supply.

Figure A-18: Supplies used to meet demand for high demand scenario and historical climate

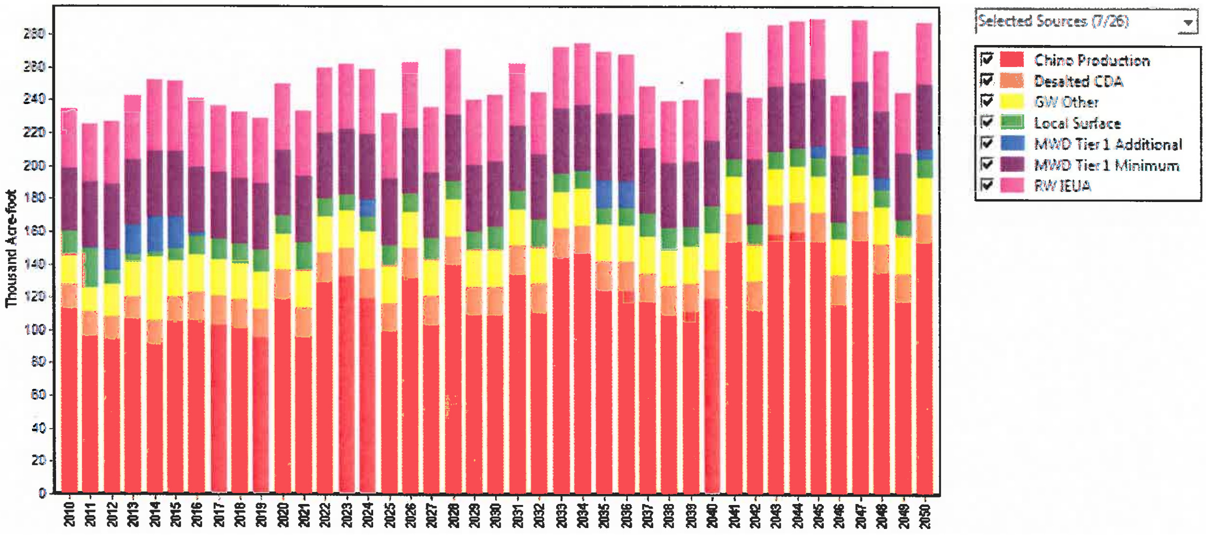


Figure A-19 focuses on the recycled water portion of the IEUA system. The top bars show the inflows—return flow from IEUA indoor demand and some small amount of wastewater from outside the IEUA service area. The bottom bars show the destinations for the recycled water supply including: outdoor urban use (Recycled Direct), agricultural use (Ag RW Demand), the Santa Ana River (SAR Obligation and Downstream Flow), recharge to the Chino Basin (Req.

Supp. Recharge and Recycled GW Recharge, Additional GW Recharge). Note that Downstream Flow represents more available recycled water than is needed to meet demand for recycled water. In simulations with low urban demand, there is no excess recycled water and instead shortages.

Figure A-19: Sources of recycled water (top) and uses of recycled water (bottom) for high demand scenario and historical climate

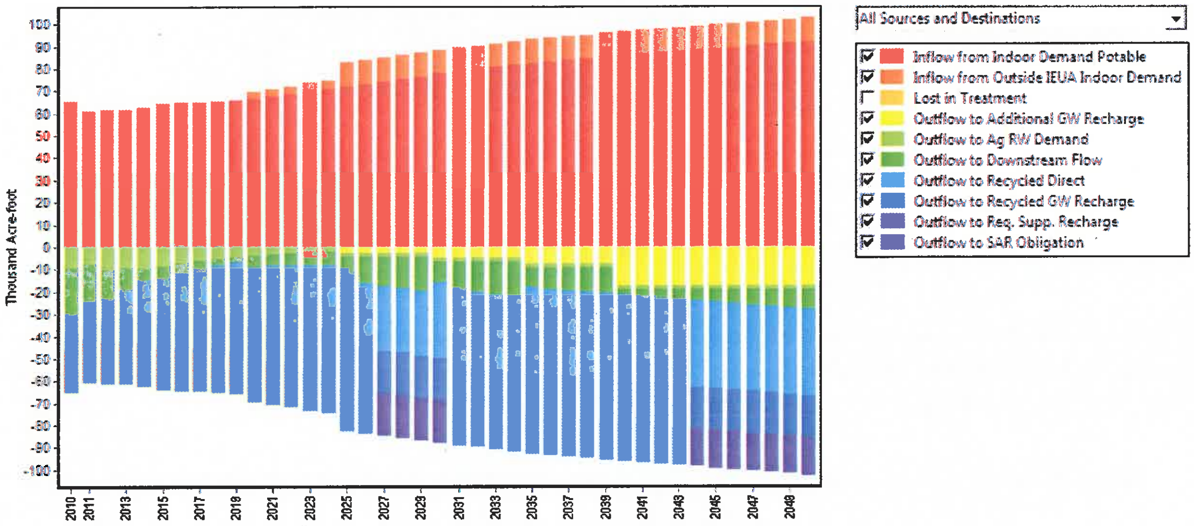
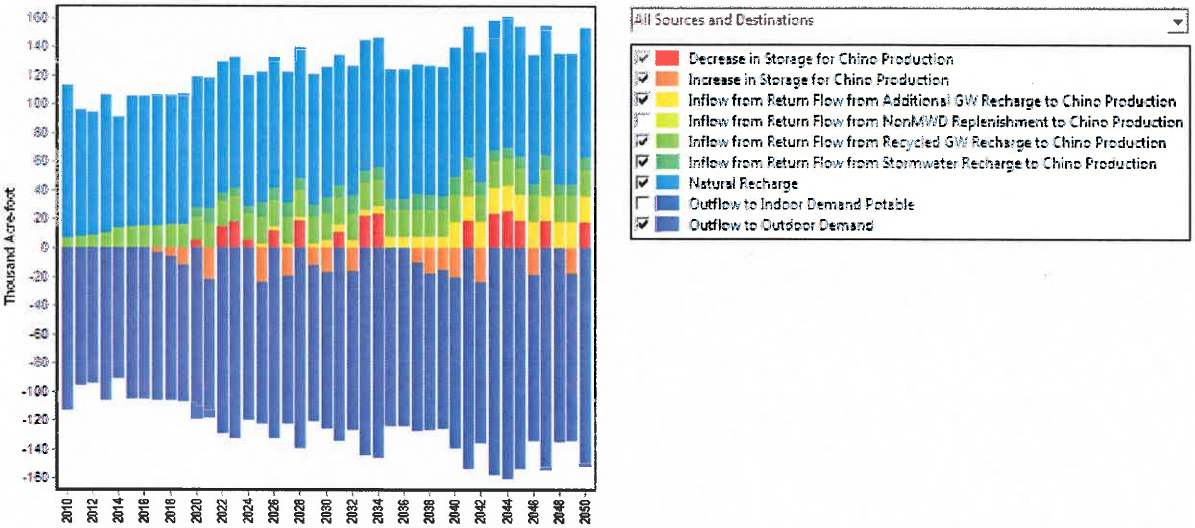


Figure shows the inflows and outflows to the Chino Groundwater Basin. Natural Recharge is the largest source, but one can see how the different replenishment sources increase the inflows over time. The primary use of groundwater is to meet outdoor demands.[4] There is some modest increase and decrease in storage over the years.

---

[4] In reality, potable water for indoor and outdoor use are served using common water mains. The partitioning of supplies to indoor and outdoor potable use in the model reflects the priority structure used to ensure that shortages, if any, are experienced by outdoor uses first.

Figure A-20: Inflows (top) and outflows (bottom) to the Chino Basin for high demand scenario and historical climate



References

Brekke, L.D., B.L. Thrasher, E.P. Maurer, and T. Pruitt, 2013. Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with Preceding Information, and Summary of User Needs. U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center, Denver, CO. http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/techmemo/downscaled_climate.pdf.

Bryant, B.P. and R.J. Lempert, 2010. Thinking inside the Box: A Participatory, Computer-Assisted Approach to Scenario Discovery. Technological Forecasting and Social Change 77:34–49.

Davis, M., 2016. Personal communication via e-mail on 03-21-16.

Diffenbaugh, N.S., D.L. Swain, and D. Touma, 2015. Anthropogenic Warming Has Increased Drought Risk in California. Proceedings of the National Academy of Sciences of the United States of America 112:3931–6.

Groves, D.G., M. Davis, R. Wilkinson, and R.J. Lempert, 2008. Planning for Climate Change in the Inland Empire. Water Resources IMPACT 10:14–17.

Groves, D.G., J.R. Fischbach, E. Bloom, D. Knopman, and R. Keefe, 2013. Adapting to a Changing Colorado River. RAND Corporation, Santa Monica, CA. http://www.rand.org/content/dam/rand/pubs/research_reports/RR100/RR182/RAND_RR182.pdf. Accessed 9 Dec 2013.

Groves, D.G., J.R. Fischbach, D. Knopman, D.R. Johnson, and K. Giglio, 2014. Strengthening Coastal Planning: How Coastal Regions Could Benefit from Louisiana's Planning and Analysis Framework. Santa Monica, CA. http://www.rand.org/pubs/research_reports/RR437.html.

Groves, D.G., D. Knopman, R.J. Lempert, S.H. Berry, and L. Wainfan, 2008. Presenting Uncertainty about Climate Change to Water-Resource Managers: A Summary of Workshops with the Inland Empire Utilities Agency. RAND Corporation, Santa Monica, CA.

Groves, D.G. and R.J. Lempert, 2007. A New Analytic Method for Finding Policy-Relevant Scenarios. Global Environmental Change 17:73–85.

Groves, D.G., R.J. Lempert, D. Knopman, and S. Berry, 2008. Preparing for an Uncertain Future Climate in the Inland Empire – Identifying Robust Water Management Strategies. RAND Corporation, Santa Monica, CA. http://www.rand.org/pubs/documented_briefings/DB550.html.

Hallegatte, S., A. Shah, R. Lempert, C. Brown, and S. Gill, 2012. Investment Decision Making Under Deep Uncertainty: Application to Climate Change. World Bank, Washington, DC.

Herman, J.D., P.M. Reed, H.B. Zeff, and G.W. Characklis, 2015. How Should Robustness Be

Defined for Water Systems Planning under Change? Journal of Water Resources Planning and Management 141:04015012.

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Core Writing Team, R. K. Pachauri, and L. A. Meyer (Editors). IPCC, Geneva, Switzerland.

Lempert, R., 2013. Scenarios That Illuminate Vulnerabilities and Robust Responses. Climatic Change 117:627–646.

Lempert, R.J., D.G. Groves, S.W. Popper, and S.C. Bankes, 2006. A General, Analytic Method for Generating Robust Strategies and Narrative Scenarios. Management Science 52:514–528.

Lempert, R.J., S.W. Popper, and S.C. Bankes, 2003. Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis. RAND Corporation, MR-1626-RPC, Santa Monica, Calif. http://www.rand.org/pubs/monograph_reports/MR1626.

Mao, Y., B. Nijssen, and D.P. Lettenmaier, 2015. Is Climate Change Implicated in the 2013-2014 California Drought? A Hydrologic Perspective. Geophysical Research Letters 42:2805–2813.

Maurer, E.P., L. Brekke, T. Pruitt, and P.B. Duffy, 2007. Fine-Resolution Climate Projections Enhance Regional Climate Change Impact Studies. Eos Transactions AGU 88:504.

Menne, M.J., I. Durre, B. Korzeniewski, S. McNeal, K. Thomas, X. Yin, S. Anthony, R. Ray, R.S. Vose, B. E.Gleason, and T.G. Houston, 2012. Global Historical Climatology Network - Daily (GHCN-Daily), Version 3. doi:10.7289/V5D21VHZ.

Milly, P.C.D., J. Betancourt, M. Falkenmark, R.M. Hirsch, Z. W., Kundzewicz, D.P. Lettenmaier, and R.J. Stouffer, 2008. Stationarity Is Dead: Whither Water Management? Science 319:573–574.

Peterson, T.C., R.R. Heim, R. Hirsch, D.P. Kaiser, H. Brooks, N.S. Diffenbaugh, R.M. Dole, J.P. Giovannettone, K. Guirguis, T.R. Karl, R.W. Katz, K. Kunkel, D. Lettenmaier, G.J. McCabe, C.J. Paciorek, K.R. Ryberg, S. Schubert, V.B.S. Silva, B.C. Stewart, A. V. Vecchia, G. Villarini, R.S. Vose, J. Walsh, M. Wehner, D. Wolock, K. Wolter, C.A. Woodhouse, and D. Wuebbles, 2013. Monitoring and Understanding Changes in Heat Waves, Cold Waves, Floods, and Droughts in the United States: State of Knowledge. Bulletin of the American Meteorological Society 94:821–834.

Shukla, S., M. Safeeq, A. AghaKouchak, K. Guan, and C. Funk, 2015. Temperature Impacts on the Water Year 2014 Drought in California. Geophysical Research Letters 42:4384–4393.

Tingstad, A.H., D.G. Groves, and R.J. Lempert, 2013. Paleoclimate Scenarios to Inform Decision Making in Water Resource Management: Example from Southern California's Inland Empire. Journal of Water Resources Planning and Management 10.1061/(A. doi:10.1061/(ASCE)WR.1943-5452.0000403.

Yates, D., J. Sieber, D. Purkey, and A. Huber-Lee, 2005. WEAP21—A Demand-, Priority-, and Preference-Driven Water Planning Model: Part 1: Model Characteristics. Water

International 30:487–500.

ACTION
ITEM

3A

Inland Empire Utilities Agency
A MUNICIPAL WATER DISTRICT

Date: December 5, 2018

To: The Honorable Board of Directors **From:** Halla Razak, General Manager for HHR

Committee:

Executive Contact: Steven J. Elie, Board President

Subject: Adoption of Resolution No. 2018-12-7, Commending City of Chino Council Member Earl Elrod for 20 Years of Public Service

---

Executive Summary:

Council Member Earl Elrod was elected to the Chino City Council in 1998, is serving his fifth term and has served as Mayor Pro Tem twice. Council Member Elrod has served on the Regional Sewerage Policy Committee for eight years, serving as Chair for two years. Council Member Elrod has also served on the Planning Commission for eight years, the Chino Parks Commission for three years, and on the San Bernardino County Grand Jury from 1997 to 1998. Council Member Elrod has served on numerous boards and advisory groups including the Street Committee and Economic Development Subcommittee, and Housing Committee. The Council Member has called the Chino community home for 64 years and has supported various organizations including the Chino Basque Club, Chino Fair Association, and Chino Boxing Foundation.

The Inland Empire Utilities Agency's Board of Directors would like to publicly extend its most sincere appreciation to Council Member Earl Elrod for his 20 years of dedicated public service as a Council Member of the City of Chino.

Staff's Recommendation:

Adopt Resolution No. 2018-12-7, commending Council Member Earl Elrod for 20 years of public service with the City of Chino.

Budget Impact *Budgeted (Y/N):* Y *Amendment (Y/N):* N *Amount for Requested Approval:*

Account/Project Name:

N/A

Fiscal Impact (explain if not budgeted):

Full account coding (internal AP purposes only): - - - Project No.:
- - -

Prior Board Action:

Environmental Determination:

Not Applicable

Business Goal:

Attachments:

Attachment 1 - Resolution No. 2018-12-7

RESOLUTION NO. 2018-12-7

RESOLUTION OF THE BOARD OF DIRECTORS OF INLAND EMPIRE UTILITIES AGENCY*, SAN BERNARDINO COUNTY, CALIFORNIA, COMMENDING COUNCIL MEMBER EARL ELROD FOR 20 YEARS OF PUBLIC SERVICE WITH THE CITY OF CHINO

COUNCIL MEMBER EARL ELROD

WHEREAS, Council Member Earl Elrod is retiring from the City of Chino after 20 years of exemplary service; and

WHEREAS, Council Member Earl Elrod was elected to the Chino City Council in 1998; and

WHEREAS, Council Member Earl Elrod has served his fifth term and previously served as Mayor Pro Tem twice; and

WHEREAS, Council Member Earl Elrod has served on the Regional Sewerage Policy Committee for eight years, serving as Chair for two years; and

WHEREAS, Council Member Earl Elrod has served on the Planning Commission for eight years from 1990 to 1998, on the Chino Parks Commission from 1977 to 1980, and on the San Bernardino County Grand Jury from 1997 to 1998; and

WHEREAS, Council Member Earl Elrod has served on numerous boards and advisory grounds including the Streets Committee and Economic Development Subcommittee, and Housing Committee; and

WHEREAS, Council Member Earl Elrod has supported various organizations including the Chino Basque Club, Chino Fair Association, and Chino Boxing Foundation.

NOW, THEREFORE, BE IT RESOLVED, that the Inland Empire Utilities Agency's Board of Directors does hereby publicly extend its most sincere appreciation to Council Member Earl Elrod for his 20 years of dedicated public service as a Council Member of the City of Chino. His exemplary work ethic and dedication to the City and the residents of Chino are to be commended.

ADOPTED this 5th day of December, 2018.

Steven J. Elie, President of the Inland Empire Utilities Agency* and of the Board of Directors thereof

ATTEST:

____
Jasmin A. Hall, Secretary/Treasurer of the
Inland Empire Utilities Agency* and of the
Board of Directors Thereof

STATE OF CALIFORNIA)
)SS
COUNTY OF SAN BERNARDINO)

I, Jasmin A. Hall, Secretary/Treasurer of the Inland Empire Utilities Agency*, DO HEREBY CERTIFY that the foregoing Resolution being No. 2018-12-7, was adopted at a regular Board Meeting on December 5, 2018, of said Agency by the following vote:

AYES:

NOES:

ABSTAIN:

ABSENT:

Jasmin A. Hall
Secretary/Treasurer of the Inland Empire
Utilities Agency* and of the Board of
Directors thereof

---

*A Municipal Water District