

FINAL

# Water System and Resources Plan 

Prepared for:<br>City of Pasadena<br>Water \& Power Department<br>150 South Los Robles Avenue, Suite 200<br>Pasadena CA 91101

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## EXECUTIVE SUMMARY

The Water System \& Resources Plan (WSRP) is a 25 year strategy that integrates investments for sustainable water resources with the infrastructure necessary to ensure high quality water service continues to be provided now and in the future. This is the first time that Pasadena Water and Power (PWP) has combined a long term resource plan and an infrastructure master plan that previously were two separate documents. This one comprehensive document provides the programmatic view of the entire water operations from the source to the customers' tap. The WSRP is proposed to be revisited every five years with an internal review every two to three years. This type of periodic review is intended to ensure that the WSRP addresses evolving issues and local, regional, state or federal considerations.

The WSRP evaluates the current and projected needs of the customers for potable and non-potable water that provides risk-based screening of alternatives to meet future demands with necessary infrastructure within the reasonable operational and financial constraints. Major considerations include water quality, greater dependency on local water, groundwater basin stability, reliability of the distribution system, affordability, climate change uncertainties, and legislative and regulatory requirements.

PWP developed the WSRP with an extensive input from a focused Stakeholder Advisory Committee (SAC) consisting of 14 members representing a cross section of the community and public input. The SAC met six times and in addition two public meetings were conducted. During the WSRP development process, periodic updates were provided to the Municipal Services Committee (MSC) and to the Environmental Advisory Commission (EAC). Youth from the Pasadena community were engaged in one workshop and one outreach event. This report is culmination of joint thinking and collaborative efforts of the community, elected and appointed public officials, subject matters experts and personnel from several City departments. Key recommendations include:

- Goal of 50/50 local and imported water supply versus the current $35 \%$ local supply and 65\% import.
- Lower the overall cost of water supply (as a commodity).
- Protection from unexpected interruption of imported water supply (earthquake, etc.)
- Accelerated catch up with the repairs/replacement of old pipes, groundwater pumps, reservoirs and other similar water distribution system components.
- Active engagement with legislative and regulatory entities to retain local control.

The projected cost to accomplish these recommendations is approximately $\$ 250$ million additional spending over a 25 year period. While this report outlays the policies and objectives, PWP will ensure the initiatives requiring capital costs align with the policies and objectives stated in the WSRP. It is possible, all objectives may not be met in the anticipated timeframe because of financial, operational or external constraints. However, PWP should achieve greater efficiencies, aggressively pursue grants and joint project opportunities with other agencies to reduce the overall cost impacts to its rate payers.

## Purpose of the Water System \& Resources Plan

Water is a distinctively personal necessity and a vital commodity that drives Pasadena's economy and gives life to the Pasadena community. Effectively managed utilities balance technical, financial and social values of the communities they serve. This plan intends to map resource choices linked to program guidance coupled to projects as a masterplan.
Devised with a comprehensive view and the support and input of key stakeholders, this WSRP is a long-term planning tool meant to ensure both a reliable supply of water and a resilient delivery system that underpins our community's continued success. This WSRP establishes water supply objectives, informs policy, shape decisions and guides implementation of long-term and short-term initiatives.
Serving as a financial model, this WSRP also outlines a hierarchy of priorities guiding funding for the backlog of repairs and renovations to address current deficiencies leveraged by projects which best satisfy the program goals. The plan incorporates a matrix of priorities and assessment techniques, including risk-based tools identifying projects with a high likelihood and high consequence of failure to be addressed in the next five years. Using this data, the WSRP defines the programs and projects within the City's Capital Improvement Program (CIP) that will ensure system resilience, as well as adaptive evaluation tools used to modify the five-year program in subsequent years.

This comprehensive plan strives to strike a balance among reliability, costs, and social values. It considers not only water quality, fire suppression, emergency response and disaster recovery, but also the long-held values of the customers, including affordability, sustainability, community trust, and environmental stewardship.

It is the goal of this WSRP to fully address all of these key considerations to reliably and responsibly serve PWP customers for decades to come.

## Pasadena's Rich Water History and Future

Pasadena is situated on an alluvial fan atop the Raymond Groundwater Basin which is sliced by surface water drainages. It was the combination of these two water sources that allowed for the establishment of the Pasadena community. Developing, protecting and defending natural water became Pasadena's civic obligation. Imported water from Metropolitan Water District of Southern California arrived in 1941, and these water entitlements remain essential to our current plan.
However, the vulnerability of imported water, combined with the variables of climate change, present new risks to Pasadena's supply. Without significant reinvestment and adaptation, the challenges Pasadena currently faces related to surface water and groundwater entitlements portend water reliability issues. To address this concern, and to buttress our community from the rising cost and uncertain future of imported water, this WSRP strives to use local resources to the fullest sustainable levels. We must also implement new policies to ensure these local supplies remain robust enough to carry the community through major emergencies that may disrupt imported water deliveries.

## State and Local Water Trends

Like many California communities, Pasadena continues to see population growth alongside declining water demand. Three factors drive this trend. First, the population is reducing or eliminating its irrigable land. With the majority of our water used for outdoor purposes, reduced irrigable area due to increased population density results in reduced water demand. Secondly, as communities age, water use declines. Finally, the state legislature and regulatory agencies have enacted laws and adopted policies to decrease water use. Unenforceable goals have been replaced with caps and penalties to ensure declines in municipal and industrial uses.

Locally, Pasadena's water use is likely to decline from 28,500 acre feet per year (AFY) to 23,500 AFY by 2030 consistent with several state mandates. Conservation programs that permanently harden demand and increase water efficiency hasten this reduction. At the same time, imported water will become increasingly expensive as costs continue to climb.

Reduced demand lessens the need to enlarge Pasadena's water resources; however, adequate water supplies for emergency and non-emergency purposes, improved quality and reliability remain highly valued in Pasadena and necessitate nimble deployment of the portfolio.

## Pathway for Pasadena

Pasadena's future water portfolio, outlined in this document, is dominated by two themes. First, groundwater is declining and must be revived to ensure emergency and peak-demand supply. Second, significant repair and replacement are needed to address water infrastructure that is beyond its reliable use. The relationship between these two themes is central. Establishing a sustainable groundwater basin is key to addressing climate change and the resulting variance in wet-year and dry-year scenarios. Even with steady precipitation, funding is needed to accelerate needed infrastructure repairs and replacement to ensure the groundwater basin is reliable. Fortunately, Pasadena has a path forward that joins available water resources with financial and social values.

## The Preferred Portfolio

Through a careful vetting process of analyses and engagement of stakeholders, PWP arrived at a preferred portfolio that strikes a balance between investing in infrastructure and groundwater supply. These goals allow for a portfolio that focuses on resiliency of the system and reliability of the supply while providing many additional benefits.

## Maximizing Local Supply

Full use of local water is a principal tenet of the WSRP. Planning ahead for reduced demand combined with leveraging groundwater rights, the preferred option allows for Pasadena's portfolio to be made of a sustainable blend of 50 percent local and 50 percent imported water.

As part of this WSRP, innovative water sources will be developed to serve the community. Small-scale and specialized projects may not contribute largely to PWP's water portfolio but are consistent with Pasadena's community values and support its quality of life. In many years, the local options may replace imported water as the primary source of water for Pasadena.

Also, matching water supplies to the best end use can eliminate expensive and unnecessary treatment. Surplus surface water or groundwater with nitrate levels exceeding the drinking water standards are expensive to transform into potable water. However, with less treatment, approximately 1,000 AFY of lower quality water could be used for irrigation of public spaces and recreational fields.

## Lower Costs

While water basin access and active sustainable practices require investments in production facilities and water resources, increased use of local supply reduces imported water expenses and decreases water loss. Water pipe improvement and better management practices also reduce water losses. In addition to reducing costs from lost water, the WSRP pathway reduces risk of service interruptions.

## Protection from Emergencies

Refocused efforts to create a sustainable ground water supply will also provide insurance against imported water interruptions during emergencies and peak weather-based demand. Conservation programs in conjunction with planned groundwater use will provide flexibility for variations in demand.
Planning for more weather extremes (wet-year/dry-year variance), policies for the Raymond Basin must come into sync with wholesale programs. In addition to recharge from local sources, the portfolio that was selected as preferred calls for the "banking" of imported water during wet years. Discount purchases for wet-year water, which can be stored in the basin, will insulate Pasadena and other basin pumpers from shortages and the price of imported water. Additionally, with reliable infrastructure to manage the use, storage and delivery of water, Raymond Basin pumpers can become partners and store other agencies' water to assist with the long-term recovery of the basin's water levels. As an added benefit, Metropolitan Water District and other water importers will experience periodic water availability surges when Pasadena and its Raymond Basin partners can tap into discounted water stored in the Basin for future use. These local and regional partnerships are considered a valued portfolio component by the community.

## Deferred Repairs and Replacement

Like many communities, Pasadena grew in spurts that trailed major events, such as World War I. From 1918 to 1930, for instance, Pasadena experienced rapid growth, and much of the water infrastructure from this period is the basis of today's system. Likewise, many of Pasadena's wells, reservoirs and pipes placed in service in these years have exceeded their useful lives and are performing at marginal or impeded levels. Of 18 wells in the system, only nine are active and frequently only six can operate. Reservoirs constructed at the turn of the $20^{\text {th }}$ century are not repairable to address leaks, water quality and seismic deficiencies. While the City has steadily invested to replace water distribution system components and addressed the worst pipes for many years, funding has not been sufficient to keep pace with needed replacements including the current backlog of \$250 million, funding for repairs and replacement (R\&R) of water system components is in excess of $\$ 400$ million during the next 25 years. Infrastructure funding of R\&R is about 20 percent of the water revenues, or $\$ 12$ million yearly. Funding at this level has not kept pace with failures, which has led to prioritizing distribution system repairs while deferring reservoir, well and other repairs.
PWP Water finances have recently stabilized, with modest reserves. Capital funds have been committed to the most urgent projects - replacing broken water lines. Several wells simply became unusable. Contamination rendered other wells unusable without blending or treatment. The lack of production from local groundwater shifted to additional expensive imported water and led to the City leasing pumping rights to other agencies.
The City's surface water rights have been redirected to spreading basins in the Arroyo Seco and Eaton Canyon. In recent years, failure of the Arroyo Seco intake structure and deficiencies in the spreading basins resulted in less than optimal use of the City's surface water and less recharge for the basin.
The preferred portfolio includes projects and establishes decision analytics to guide reinvestment of more than $\$ 400$ million of capital funding for $R \& R$ to address production, treatment, storage and related water system needs.

## Summary

Across the state and nation, as well as in Pasadena, water resource programs are transitioning to reflect social changes and address stressors such as availability, affordability, water quality and reduced water demands. Imported water is increasingly expensive and less reliable, yet the complex infrastructure comes with high fixed costs. Large shifts from independent supplies, as well as climate change and regulations, have lessened the availability of imported water. Declining confidence in reliability and reliance upon this large centralized system has spurred the development of alternative supplies by the other member agencies of Metropolitan Water District of Southern California (MWD).
These progressions encouraged Pasadena to shift its reliance from 65 percent imported water to a new goal of 50/50 local and imported water supply. This move towards local reliance will help insulate Pasadena from large swings in water supply availability, including large-scale disasters, drought or interruptions to imported water deliveries.

Local reliance depends on two principles; first is to match source with use. Local surface water and high nitrate groundwater is suited for irrigation with only minimal treatment, delivered via systems not requiring redundancy or robust standards of drinking water systems. Second, local reliance requires reinvestment in infrastructure and retooling of policies to manage and balance the Raymond Basin. Faced with 100 years of declining groundwater levels, despite adjudication and voluntary reductions in pumping, managing the Basin requires a focused effort to catch and recharge water. It also requires coordination with the Upper San Gabriel Basin and new approaches, such as banking and exchanges with other water agencies.
Investments in local water resource development must be made while also addressing the backlog of infrastructure repairs and replacements. Water storage reservoirs are old and deteriorating. Approximately 108 miles, or 21 percent, of the distribution system needs immediate replacement, and another 166 miles will require replacement during the next 25 years. In addition, existing water production and treatment facilities are inadequate to support Pasadena's locally reliant objective. Finally, the management systems to assign, track and manage the water utility also need to be retooled to conform to modern demands of regulatory and customer accountability.
Pasadena's water resources and capital improvement programs are challenged. This WSRP provides an integrated approach addressing deficiencies while advancing sustainability and resiliency. The current backlog of repairs has grown to $\$ 250$ million and continues to grow. This plan necessitates $\$ 10$ million of additional capital investment annually to check the decline and initiate the path towards a more reliable water system. Nearly half of this amount can be generated by efficiencies and alternative funding, such as grants and reductions of expensive imported water. Some rate impacts are unavoidable, these are estimated in the range of \$13 to $\$ 17$ per residential connection each month will be phased in during the course of this plan. Commercial connections will likely experience similar increases of $10 \%$ to $15 \%$.

The WSRP is intended to be an analytical decision tool providing analysis of water resource options with risks and benefits expressed in narrative that reflect the Community goals and priorities. It is the foundation which captures the decisions and provides the guidance for implementation of long-term strategies and short-term planning, integrated with the Master Plan which seeks to define the programs and projects within the rolling five year capital funding program. The WSRP, therefore, does not commit the City to any particular project. As projects are identified for actual implementation, the Community will be informed, and appropriate environmental review will be undertaken and approvals will be sought.

## 1. INTRODUCTION

The City of Pasadena (City) and surrounding area is a beautiful, thriving community that depends on PWP to provide reliable water with prudent investment in infrastructure and a proficient workforce.

Historically, PWP has relied upon two sources of water: local ground water (augmented by surface water recharge) from the Raymond Basin (Basin) and water imported by the Metropolitan Water District of


Pasadena is a beautiful community that depends on reliable water. Southern California (MWD).

The Basin is a 40-square-mile groundwater aquifer underlying the cities of Pasadena, Sierra Madre, Arcadia, Altadena, San Marino, and La Cañada-Flintridge. It is bound by the San Gabriel Mountains to the north, the San Rafael Hills to the west, and the Raymond Fault to the south and east. The Basin slopes to the south, with elevations from 1,500 feet above sea level at the toe of the San Gabriel Mountains to 500 feet at the Raymond Fault. Approximately 35 percent of the City's drinking water supply comes from groundwater that originates as surface water in the San Gabriel Mountains.

Pasadena holds the largest water pumping rights in the Basin, with an adjudicated right to pump 12,807 acre-feet of groundwater. The City also holds surface water rights, established pre-1914, to divert up to 25 cubic feet per second (cfs) or 16 million gallons per day from the Arroyo Seco stream and up to 8.9 cfs from the stream in Eaton Canyon.

The City imports the remaining 65 percent of its supply as a member agency of MWD. MWD imports water from the Sacramento-San Joaquin Delta (Delta) via the State Water Project (SWP), and from the Colorado River Aqueduct (CRA).

Two recent and substantial droughts, from 2006 to 2008 and 2011 to 2018, significantly impacted water resources within the state of California. These droughts, combined with the Colorado River basin's own historic drought, caused MWD to reduce the water allocations to its member agencies in response to State requirements and contributed to increased regulations for water use and groundwater management throughout the state of California.

Droughts, increased impervious surfaces, pumping and climate change all contributed to decreasing groundwater levels in the Raymond Basin. To maintain and increase groundwater levels, the Raymond Basin Management Board (RBMB) initiated a voluntary 30 percent reduction in production of groundwater rights for all pumpers in the Pasadena Subarea starting on July 1, 2009. In response to MWD water supply limitations and
reduced local groundwater, the City implemented both temporary and permanent citywide water restrictions since 2009.

In addition to these water supply concerns, PWP must address a backlog of aging infrastructure that directly impact its ability to reliably serve customers. Nearly half of the City's existing pipelines are over 80 years old and need rehabilitation or replacement. In recent years, several PWP wells have failed due to mechanical and water quality issues.

As droughts are likely to occur frequently in California, PWP is planning long-term solutions to continue to provide its customers adequate sustainable water supplies at reasonable rates.

PWP initiated this Water System and Resources Plan (WSRP) to update both the 2002 Water System Master Plan and the 2011 Water Integrated Resources Plan. These two documents were combined into one 25-year plan intending to improve the management and availability of local water supply, prioritize replacement and rehabilitation infrastructure, and set water conservation targets.

### 1.1 Planning Purpose and Context

Traditionally, water resources planning and system infrastructure planning are addressed using separate processes and documents as described below.

- Integrated water resources plans focus on water resources, and are generally used to define new projects and programs that provide access more sources of supply and/or volumes of future water supplies based on projected supply reliability and demands.
- Water master plans focus on assessing the condition and capacity of the distribution and storage infrastructure to meet the current and projected demands throughout a service area and to develop a list of capital improvement projects (CIPs) necessary to remedy any identified deficiencies.

This WSRP takes a holistic approach combining long-term water resources and infrastructure planning together for a 25 year window.
The WSRP is reliant upon previous planning documents including:

- Water Master Plan (PWP 2002)
- Seismic Vulnerability Assessment of the City of Pasadena Water System (G\&E Engineering Systems Inc. [G\&E] 2006)
- Water Integrated Resources Plan (WIRP) (PWP 2011)
- Recycled Water Planning Study (RMC 2012)
- 2015 Urban Water Management Plan (UWMP) (PWP 2015)
- MWD's Integrated Water Resources Plan, 2015 Update (2015 IRP Update) (MWD 2016)
- Raymond Basin Salt and Nutrient Management Plan (SNMP) (RBMB 2016)

This WSRP is the City's plan for long-term capital and water resources planning to address aging infrastructure and improve supply reliability. This document also outlines future programs and projects to take full advantage of existing water resources, develop new water supplies and provide safe and reliable water with superior customer service at reasonable rates.

### 1.2 Planning Approach and Process

This WSRP was developed in five steps that began in the fall of 2018 and extended through 2020 (Figure 1-1). This report is organized to reflect this multi-step process; each step is briefly described below.
Figure 1-1: WSRP Development Process

## Define Goals and Objectives (Chapter 3)



### 1.2.1 Define Goals and Objectives

Developing this WSRP began with defining the goals and objectives of how the City's water resources and infrastructure should look and function by 2045. These goals and objectives were developed in partnership among community stakeholders, policy makers and PWP to ensure that the WSRP reflects both technical needs and community values.

### 1.2.2 Assess Baseline and Needs

The next step was to assess the current condition of the City's water resources and system and identify any gaps relative to the goals established in step 1. The current condition baseline analysis evaluated existing production, distribution and storage infrastructure to determine potential risk of failure and any potential for efficiencies. The analysis considered historical and current water production, as well as water demands projected to 2045 . This data along with newer regulatory framework revealed a projected
baseline for supply reliability, which ensures the availability of water supply under drought or emergency conditions.

### 1.2.3 Identify Options

Thirty-six supply options and a series of infrastructure options were developed to assess gaps when comparing baseline conditions against future goals. Options included projects, programs and strategies to maintain existing supplies and infrastructure, and to improve or create new supplies and infrastructure. Some options considered during this step were screened out as technically or unfeasible for other reasons.

### 1.2.4 Develop and Evaluate Portfolios

Nine portfolios were built, initially using a combination of options that reflect the strategies for achieving WSRP goals and objectives. Three portfolios were eliminated to remove redundancies. The remaining six portfolios were compared against a water supply model with nine criteria prioritized by stakeholders and PWP. Portfolio F was selected as the highest ranked portfolio. Chapter 7 of this report includes more information about the evaluation process.

### 1.2.5 Create an Implementation Pathway

This step created an implementation plan describing the policies, scheduling, phasing, finances, tracking and adapting processes needed to implement the selected portfolio. To account for future uncertainty and changing conditions, the implementation plan includes adaptive management, flexibility and a method for assessing progress toward WSRP goals.

### 1.3 Stakeholder Coordination and Public Participation



Stakeholder Advisory members discuss water supply options and alternatives

A stakeholder advisory committee (SAC) was selected to aid the development of the WSRP. The SAC provided a range of additional perspectives, initial ideas and essential feedback on draft WSRP planning elements. The SAC includes a diverse group of people representing PWP's residential, commercial, institutional and large water customers. SAC members also represent a range of interests and experience, including leaders in the water industry, as well as the fields of environmental and social advocacy, education, technology, and economic development.

SAC helped to create the principles recommended for forming public policy for water supply and infrastructure development in the City.
Five meetings/workshops were held with SAC to provide feedback on the following topics:

- Goals and objectives - Workshop 1, October 17, 2018
- Strategies to address challenges and needs - Workshop 2, December 18, 2018
- Distribution and water resources options, alternative themes - Workshop 3, March 8, 2019
- Portfolio evaluation, trade-offs and selection - Workshop 4, June 28, 2019
- WSRP implementation - Workshop 5, September 18, 2019.

One final meeting was conducted on September 30, 2020 to share with SAC the draft report.
After release of the draft WSRP, a WSRP website was developed to provide information about the plan. The site includes an online feedback form to collect questions or comments from the general public.

PWP will present the WSRP to the Municipal Services Committee (MSC) and City Council for approval in fall of 2021.

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Stakeholder Advisory Committee Members
1. Margaret McAustin
    (Pasadena City Council Member/ Minicipal Services Committee Chair)
2. Shirly Barrett
    (Pasadena Unified School District)
3. Maximilian Christman
    (Caltech)
4. Michael X. Cook
(Kaiser Foundation Health Plan)
5. Brenda Goldstein
(Pasadena Resident)
6. Jim Green
(MWD)
7. Michael B. Hurley
(California Water Service)
8. Kim Luu
(Jet Propulsion Laboratory)
9. Ken Kules
    (Pasadena resident)
10.Paul Little
    (Pasadena Chamber of Commerce)
11.M. Michele Montano
    (Council for Watershed Health)
12.Charles Thomas
    (Outward Bound Adventures)
13.Morey Wolfson
    (Pasadena City Council's Environmental Advisory Commission)
14.Eugene Ruane
```


## 2. PASADENA WATER SYSTEM AND RESOURCES

### 2.1 Pasadena Water \& Power Water Service Area

Located at the base of the San Gabriel Mountains in Los Angeles County, the City of Pasadena (City) is home to approximately 150,000 people. The City is a place with scenic, cultural and academic landmarks that include the Arroyo Seco and Eaton Canyon, Rose Bowl, California Institute of Technology, Art Center College of Design, and NASA's Jet Propulsion Laboratory. It is a beautiful place to live and visit. Supporting its character, economy and diverse land uses requires a reliable water supply.
The City is situated between the Arroyo Seco to the west and Eaton Wash to the east, overlaying the Raymond Groundwater Basin. This combination of surface water and groundwater provided the basis for Pasadena's establishment and early
 development.

Pasadena's population has always been progressive and engaged in securing and protecting its water supplies. In the late 1890s, private water companies provided unreliable supply to the community. In 1912, to address this issue, the City began purchasing and consolidating water companies and created the Pasadena Water Department that later became Pasadena Water \& Power (PWP). Protecting the quality of its surface water supplies in the 1920s, the utility purchased portions of the Arroyo Seco and Eaton Wash watersheds.
PWP is a public utility managed as a City department that provides water and electricity to its customers. PWP's water service area is approximately 26 square miles, larger than the jurisdictional boundary of the City, and includes portions of Altadena, East Pasadena and areas of unincorporated Los Angeles County in East San Gabriel (Figure 2-1). Over 15 percent of the total population served by PWP is located outside of the City. The service area is bordered on the north by the remaining portion of Altadena and the Angeles National Forest, on the east by the cities of Arcadia and Sierra Madre, on the south by the cities of South Pasadena and San Marino, and on the west by the cities of Los Angeles, Glendale and La Cañada Flintridge.

### 2.1.1 Population and Employment

Recent population growth for the PWP water service area has been slow but steady. Between 1990 and 2019, the service area population increased from 146,840 to 168,650, representing an annual average growth rate of 0.5 percent.

Figure 2-1: PWP Service Area


According to the Southern California Association of Governments and population projections provided by the California Department of Finance, minimal population growth is expected through 2045 in PWP's service area (Southern California Association of Governments 2016; California Department of Finance 2018). Service area population is forecast to increase by 0.5 percent annually, resulting in approximately 22,000 additional residents over the next 25 years. The City's 2015 General Plan Update is consistent with those estimates (City 2015).

In addition to population, employment is also expected to increase at a rate of approximately 0.5 percent annually through the planning horizon of 2045. Table 2-1 presents projected population and employment rates for PWP's service area.

| Table 2-1 Population and Employment Projections |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :---: |
| Criteria | $\mathbf{2 0 2 0}$ | $\mathbf{2 0 2 5}$ | $\mathbf{2 0 3 0}$ | $\mathbf{2 0 3 5}$ | $\mathbf{2 0 4 0}$ | $\mathbf{2 0 4 5}$ |  |
| Population | 169,493 | 173,508 | 181,466 | 185,702 | 189,927 | 191,233 |  |
| Employment | 123,383 | 127,252 | 130,008 | 132,210 | 135,866 | 139,623 |  |

Source: Southern California Association of Governments 2016; California Department of Finance for Los Angeles County 2018.

### 2.1.2 Land Use

Land use in the PWP service area is largely low and medium density residential (Appendix A). High-density residential, commercial and mixed land uses are generally located along major corridors, such as Fair Oaks Avenue and Washington Boulevard, and in Special Districts such as Central Pasadena, East Colorado and South Fair Oaks. The 2015 General Plan Update explains that the long-term vision for growth in the City is to encourage development along major corridors (City 2015). Also, according to the 2015 General Plan Update, future growth will occur through urban infill, which means increasing the number of residential units or mixed-use units per acre, typically by replacing single-story structures with multi-story structures. Table 2-2 presents housing projections for PWP service area.

Table 2-2: Housing Projections

| Units/Persons | $\mathbf{2 0 2 0}$ | $\mathbf{2 0 2 5}$ | $\mathbf{2 0 3 0}$ | $\mathbf{2 0 3 5}$ | $\mathbf{2 0 4 0}$ | $\mathbf{2 0 4 5}$ |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Occupied Housing Units | 67,003 | 68,704 | 70,423 | 72,129 | 74,015 | 75,950 |
| Single Family Units | 37,046 | 37,561 | 38,398 | 39,507 | 40,199 | 40,903 |
| Multi-Family Units | 29,957 | 31,143 | 32,025 | 32,622 | 33,815 | 35,052 |
| Persons per Household | 2.47 | 2.47 | 2.52 | 2.52 | 2.51 | 2.51 |

Source: UWMP for data between 2020 and 2040, extrapolated to 2045 and the City's 2015 General Plan Update.

### 2.1.3 Climate

The City's climate characterized as Mediterranean. Temperatures are hot during the summer, and mild during the rest of the year. The average annual precipitation is 20 inches, slightly more than surrounding cities, as a result of its geographic location at the base of the San Gabriel Mountains. Between 1928 and 2018, precipitation varied between 5 and 48 inches per year. Approximately 75 percent of the average annual precipitation falls during the winter months of December through March. Table 2-3 shows historical monthly average precipitation and average high temperatures.

Table 2-3: Monthly Rainfall Data (1928-2018)

| Month | Average <br> Precipitation <br> (inches) | Average High <br> Temperatures <br> $(0 ~ F)$ |
| :---: | :---: | :---: |
| January | 4.0 | 68 |
| February | 4.4 | 70 |
| March | 3.1 | 72 |
| April | 1.5 | 76 |
| May | 0.4 | 79 |
| June | 0.1 | 84 |
| July | 0.05 | 89 |
| August | 0.1 | 91 |
| September | 0.3 | 89 |
| October | 0.7 | 82 |
| November | 1.7 | 74 |
| December | 3.1 | 67 |
| Annual | $\sim 20$ | $\sim 78$ |
|  |  |  |

Source: National Oceanic and Atmospheric Administration, Pasadena Station ID USC00046719, January 1928-October 2018

### 2.1.4 Hydrology

The PWP service area is within the Los Angeles River watershed and is divided across three tributaries. The western portion of the service area drains to the Arroyo Seco, and the eastern portion drains to Eaton Wash. The small drainage area in the central part of the service area is directed to the Alhambra Wash and Rubio Wash which, along with the Eaton Wash, join the Rio Hondo. Both the Rio Hondo and Arroyo Seco join the Los Angeles River beyond the boundaries of the service area.

Figure 2-2 shows the three drainage watersheds within PWP's water service area. PWP has diverted mountain runoff from Arroyo Seco to the Arroyo Seco Spreading Grounds since 1912 and from Eaton Wash to Eaton Wash Spreading Grounds since 1923. PWP owns and operates the Arroyo Seco Spreading Grounds while LA County Department of Public Works owns and operates the Eaton Wash Spreading Grounds.

The large aquifer underling the City and the surrounding areas is referred to as the Raymond Basin. The alluvial gravel, sand, and silt are the main water-bearing materials in the Raymond Basin. It yields water to groundwater wells from a few hundred to several thousand gallons per minute (gpm). The alluvium sit upon impervious bedrock. The alluvial valley slopes to the south, ranging in elevation from 2,000 feet above mean sea level (MSL) near the mountains to between 500 and 700 feet MSL at the Raymond fault. The fault acts as groundwater barrier along the southern boundary of the Basin.

During the urbanization of Pasadena impervious surfaces replaced the natural ground soils, dramatically reducing the ability of the soil to naturally recharge into the Basin. Additionally, channelizing the Arroyo Seco and Eaton Wash further reduced natural recharge. The first section of the canal of the Arroyo from Devil's Gate Dam past the Rose Bowl was completed in 1935 with soft bottom. After the 1938 floods, the channel was fully lined in concrete in Pasadena, except for a small area south of the dam and one below Colorado Street Bridge.

Figure 2-2: City Hydrologic Characteristics


### 2.2 Water Demands

Population, economy, climate and hydrology are all important factors in assessing water demand. As a result of a persistent droughts from 2006 to 2017, water use in California has been subject to mandatory conservation. Assembly Bill 1668 and Senate Bill 606 passed in 2018 establish caps on community water use and outline requirements for additional reductions in per capita water use. The balance of population and economic growth with increasing conservation must be considered when projecting future water demands in PWP's service area. PWP provides potable water to meet all demands in its service area. Some demands could be satisfied with non-potable supply, but PWP is lacking the distribution facilities to deliver non-potable water to its customers.

### 2.2.1 Past and Current Water Use

Water use is tracked by PWP's billing system, which categorizes customers into four primary types: residential (including single-family and multi-family residential), commercial and industrial, city accounts, and miscellaneous. The single-family residential
customers include individually metered houses, whereas the multi-family residential customers include apartments and condominiums are generally master-metered for the entire building or complex. Unless built to be in compliance with current regulations.*

System water losses in the distribution system prior to reaching customer meters ranges from 5 to 8 percent. Reducing water loss with replacement and rehabilitation of waterlines and valves increase drought resilience, saves energy, and defers the need for new supplies.

Water use varies due to weather and economic conditions. Pasadena's current total water use by major billing category from 2013 through 2018 is shown on Figure 2-3. Water demand during this period decreased through 2016 even though population increased during this same period, as described in Section 2.1.1. Single-family residential customers achieved more than 25 percent reduction. This decrease in water consumption is likely the result of the state's conservation measures implemented in 2014 to mitigate drought impacts, as well as social awareness, outreach campaigns by state and water agencies, the economy and weather.
Water demand has slightly increased since 2017 following the end of the drought and the relaxing of water use restrictions, yet remains well below historical levels.
Water use was approximately 28,000 acre-feet (AF) in 2019, with single-family and multifamily residential water use accounting for approximately 67 percent of PWP's overall water use and commercial and industrial uses accounting for 28 percent. The remaining 5 percent was water loss. The 2020 water use was approximately 28,500 AFY.

Figure 2-3: Water Use per Customer Class


In 2019, residential water use in the PWP service area was approximately 96 gallons per capita per day (GPCD). Single-family residential households consumed approximately

100 GPCD, which was twice the average use of 50 GPCD for multi-family residential homes. This difference is increased outdoor use at single-family residences.

Water use throughout the year follows seasonal trends, peaking in the hot, dry months of July through September. It is estimated that approximately 61 percent of annual residential water use is landscaping and other outdoor purposes (Appendix A).

### 2.2.2 Projected Water Demand

Forecasting water demand is important for identifying potential water supply shortfalls as well as to develop best strategies for supply choices. The analysis requires understanding of current land use, population and water consumption trends in the service area, as well as projected population growth, future development, and implementation of regulations influencing future water use. Appendix A describes the methodology used to forecast demand for this plan. Figure 2-4 shows current demand and three projected scenarios: Status Quo (high) demand, Meet Regulations demand, and Goal (low) demand. Current conservation savings from existing codes, ordinances and standards are included in all demand projections.

Status Quo (high) demand projection is the current water use projected for future years with current levels of conservation and regulation.

Meet Regulations (mid) projections are based on the Status Quo demand and applying the indoor and outdoor water use reductions imposed by Senate Bill (SB) 606 and Assembly Bill (AB) 1668. This demand projection includes indoor residential water use decrease from the current 57 GPCD to meet the target of 55 GPCD by 2025 and 50 GPCD by 2030 (approximately 1,400 AFY). The WSRP assumes Pasadena will also meet regulations and reduce outdoor water use by 2,100 AFY by 2030. Meeting regulations, Pasadena water demands will be approximately 25,000 AFY.
Goal (low) demand projections include sufficient water use to meet mandated indoor and outdoor regulations, plus an additional 10 percent outdoor conservation goal (approximately 1,500 AFY by 2030). The total water reduction under this projection is approximately 5,000 AFY by 2030 (approximately 23,500 AFY demands).
Compared to Status Quo, the Goal is a $18 \%$ reduction from 2020 to 2030. This level of conservation plus additional local water supply enhancements will help PWP meet the objective of $50 \%$ local and $50 \%$ imported water supplies.

Figure 2-4: Current and Projected Water Demands


## 2020 Demands 28,500 AFY



# 2030 Goal Demands 23,500 AFY 



### 2.3 Water Supply Sources

Pasadena's water supply originally included groundwater and local stream water. Historically, water from the Arroyo Seco and Eaton Canyon was captured and distributed directly to the service areas. In 1971, the John Behner Treatment Plant was constructed to treat surface water from the Arroyo Seco. State surface water regulations were tightened and PWP discontinued this use in 1993 and redirected stream water solely for groundwater recharge.

In the late 1920s, Pasadena focused on acquiring supplemental water from San Gabriel River and the Colorado River, initiating the creation of the MWD to build and operate the Colorado River Aqueduct (CRA). The California Department of Water Resources granted Pasadena permits to store and divert up to 4,000 AFY of flood flows from the San Gabriel

River. In 1934, Pasadena constructed Pine Canyon Dam (now Morris Dam). In 1935, the City sold the dam to MWD and discontinued diverting water when MWD began deliveries of Colorado River water in 1941.

Today, Pasadena's water supply consists of three main sources: local groundwater from the Raymond Basin, local surface water from the Arroyo Seco and Eaton Wash spread into Raymond Basin, and imported water purchased from MWD.

PWP supplies nearly 29,000 AFY of potable water to its customers each year. From 2000 to 2019, PWP's supply included $37 \%$ local groundwater, supplemented by surface water recharge, and $63 \%$ imported water. Figure 2.5 shows the historical water demands since 2000. Water demands have decreased by $25 \%$ over the last 20 years.

Figure 2-5: PWP Historical Water Production


## Imported Water

MWD is the nation's largest water wholesaler, providing an average of 1.34 billion gallons of water per day to 19 million consumers. MWD owns and operates the Colorado River Aqueduct (CRA), is one of twenty seven contractors of the California Department of Water Resources' (DWR's) State Water Project (SWP) and manages/owns groundwater and surface water storage and treatment facilities. Although the Colorado River is over allocated, water supplies via the CRA have historically been stable while the SWP has been considerably variable.

### 2.3.1 Imported Water Capacity and Quality

As a member agency of MWD, PWP has a long-term contract to purchase imported water. PWP only receives treated MWD water via five interconnections from MWD's Upper Feeder. Water delivered to PWP is normally treated at MWD's F.E. Weymouth Water Treatment Plant (Weymouth) in La Verne. During outages at Weymouth, PWP can receive treated water from MWD's Jensen Water Treatment Plant via one of the five connections. Sufficient connection capacity exists to meet total existing and projected PWP demands. However, while connection capacity is sufficient, reliability of this supply is insufficient. PWP would be unable to meet local demand in the event of a service disruption to MWD.

Currently, water delivered from Weymouth is a blend of SWP and CRA water, which have significantly different qualities. The main SWP water quality challenges are total organic carbon and bromide. These elements form disinfection byproducts during water treatment, which restricts MWD's ability to use SWP water at various times. In response, MWD has upgraded its treatment processes and is currently implementing multiple programs to mitigate quality issues with SWP raw water and to provide adequately treated water to PWP.

High salinity of Colorado River water is a significant quality issue, while salinity levels in SWP supplies are low. The blend of CRA water and SWP water at Weymouth helps to address salinity issues.

## Imported Water Reliability

MWD's 2015 IRP Update is the foundation for the imported water supply forecasts in this plan. That document concluded that MWD has sufficient supplies to meet projected demands from 2020 through 2040 under single dry-year and multiple dry-year conditions. MWD's analysis indicates hydrologic variability can trigger some level of shortages to be managed by strategic allocation. During past extended droughts, MWD has applied water allocations (i.e., reductions in water supply) to member agencies. Based on MWD's 2015 IRP Update, future water shortages could occur up to 15 percent of the projected 20 years (or 3 in 20 years). Shortages were estimated to be less frequent and of lower magnitude after the implementation of the Delta Conveyance Project which proposes to construct a tunnel to convey up to 6,000 cfs of water from the Sacramento River under the Sacramento-San Joaquin Delta to the intake for the SWP.
The State Water Project Delivery Capability Report, used by MWD for their reliability analysis, indicates increased reduction in water deliveries when compared to previous estimates because of environmental constraints and hydrologic changes due to climate change (DWR 2018). Multiple issues in the Bay-Delta region, where major SWP pumping facilities are located, include pumping restrictions to protect deteriorating levees and fish species under the Endangered Species Act and failures in the conveyance facilities south of the Delta. In the future, these reductions may be eliminated and the reliability may significantly increase.

MWD's 2015 IRP Update shows that MWD relies on its full apportionment of Colorado River water supply. Today the reliability of CRA supply is considered less certain as the water level in Lake Mead, a critical part of the system, has steadily declined. CRA has adopted a Colorado River Basin Drought Contingency Plan (Reclamation 2019) that would be triggered if Lake Mead levels reach a critical condition (i.e., 1,075 feet of elevation above mean sea level). This condition could reduce the CRA supply to MWD, creating shortage conditions for MWD and its member agencies.

### 2.3.2 Groundwater

Groundwater production is obtained from the Raymond Basin (section 2.3.2.1). The Basin is adjudicated and PWP has groundwater pumping rights within the Basin. In addition PWP is credited with extra rights for spreading surface water. PWP can also use the Basin for long-term supply storage as an emergency supply. To balance reliability and maximize groundwater production, PWP manages its pumping rights, spreading credits, and longterm storage.

### 2.3.2.1 Raymond Basin

The Raymond Basin is an alluvial valley approximately 40 square miles in area, supported by deposits of gravel, sands, silt and clay, with a capacity of more than 800,000 acre-feet of water. The Basin is bound by the San Gabriel Mountains to the north, the San Rafael Hills to the west, and the Raymond Fault to the south/southeast. The Basin is divided into three subareas: the Monk Hill subarea in the northwest, the Pasadena subarea in the center, and the Santa Anita subarea on the east. PWP pumping and storage rights are in the Monk Hill and Pasadena subareas.

Groundwater in the Basin generally flows from northwest to southeast, from areas of recharge at the base of the San Gabriel Mountains to areas of discharge along the Raymond Fault. The Raymond Fault acts as a leaky hydrologic barrier and defines the boundary between Raymond Basin and the Main San Gabriel Basin to the south. Approximately 6,000 to 10,000 AFY are estimated to leak from the Raymond Basin to the Main San Gabriel Basin along the eastern side of the Raymond Fault.
The Raymond Basin provides Pasadena vital emergency water supply. When MWD imported water is interrupted due to an emergency, such as drought, regulatory constraints, contamination or earthquake, groundwater is the only supply available to meet the City's water demands.

There are three main threats to the Basin. PWP is working to address with near-term actions: groundwater contamination, basin management practices, and regulatory overreach by the State.

PWP's established goal is to partner with other water agencies implementing specific projects in the Raymond Basin to reduce the loss of groundwater to the Main San Gabriel Basin, determine the current sustainable yield of the Raymond Basin, revise established
policy on Basin sustainability, and develop Basin protection policies and guidelines to be adopted by all other land users and pumpers in the Basin.

Figure 2-6: Raymond Groundwater Basin Subareas and PWP Well Locations


Note: Wells shown are those owned by PWP only; not all wells in the Basin.

### 2.3.2.2 Raymond Basin Management

## Raymond Basin Judgment

Raymond Basin was the first groundwater basin adjudicated in California in December 1944, to alleviate overdraft conditions. Under the adjudication, it was determined that 16 parties had the right to extract water. The court allocated the rights to each party. The decision is based on a judgment of "safe yield". The safe yield was determined to be 21,900 AFY but was modified in 1955 to 30,662 AFY. The authority to administer the Basin and resolve future disputes and make binding judgments is vested in a Basin Watermaster. The Watermaster is the Raymond Basin Management Board (RBMB), which represents the parties (pumpers) of the Judgement.

PWP's decreed right was set at 12,807 AFY, divided between the Monk Hill (4,464 AFY) and Pasadena (8,343 AFY) subareas. To address declining water levels, on July 1, 2009
the RBMB implemented a resolution that voluntarily reduced pumping from the Pasadena subarea. As a result, PWP's water pumping from the Pasadena subarea was decreased by 2,503 acre-feet (AF) to 10,304 AFY.

## Spreading Credits

PWP has pre-1914 rights to divert up to 25 cubic feet per second (cfs) of surface water from the Arroyo Seco and Millard Canyon streams and up to 8.9 cfs from the Eaton Wash. This surface water is used to recharge the Raymond Basin. The Judgment allows each pumper to take the surface water directly, or recharge the Basin and then pump a portion of the recharged


PWP has 18 wells, nine of them are currently active. volume in addition to their decreed rights.

Pumping credits from the spreading of surface water provided PWP an average of 1,850 AFY from 2001 to 2015, ranging from approximately 300 AF in dry years to 5,000 AF in wet years. PWP receives a pumping credit of 60 to 80 percent of the water recharged at the Arroyo Seco Spreading Grounds, and a credit of 80 percent of the water recharged at the Eaton Wash Spreading Grounds.

### 2.3.2.3 Groundwater Production

For the past five years, PWP's annual groundwater production averages approximately 11,000 AFY, which includes decreed rights and surface water spreading credits. Currently PWP has nine active wells. An additional nine wells are inactive due to contamination and other factors. Most of the operational wells are influenced by contamination which requires treatment or a sequence of blending with imported water to make them usable. Table 2-4 provides the pumping history for all wells that produced groundwater between 2014 and 2018. Additional details on well capacity and production are in Appendix B. Well locations are shown on Figure 2-6.

Table 2-4: $\quad$ Groundwater Pumped Between CY 2014-2018 (AF)

| Well | $\mathbf{2 0 1 4}$ | $\mathbf{2 0 1 5}$ | $\mathbf{2 0 1 6}$ | $\mathbf{2 0 1 7}$ | $\mathbf{2 0 1 8}$ | Average |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Arroyo | 2,115 | 2,125 | 2,196 | 2,145 | 1,931 | $\mathbf{2 , 1 0 0}$ |
| Ventura | 134 | 41 | 38 | 36 | 6 | $\mathbf{5 0}$ |
| Well 52 | 1,448 | 40 | 16 | 232 | 8 | $\mathbf{3 5 0}$ |
| Garfield | 98 | 627 | 0 | 1 | 0 | $\mathbf{1 4 5}$ |
| Sunset | 1 | 1,136 | 106 | 525 | 891 | $\mathbf{5 5 0}$ |
| Bangham | 986 | 508 | 1,299 | 1,524 | 1,407 | $\mathbf{1 , 1 4 5}$ |
| Chapman | 444 | 1,033 | 1,048 | 1,056 | 651 | $\mathbf{8 4 5}$ |
| Twombly | 1,430 | 2,291 | 2,969 | 2,683 | 1,791 | $\mathbf{2 , 2 3 5}$ |
| Wadsworth | 2,225 | 2,058 | 2,181 | 1,961 | 1,956 | $\mathbf{2 , 0 8 0}$ |
| Woodbury | 2,243 | 2,160 | 854 | 987 | 1,140 | $\mathbf{1 , 4 8 0}$ |
| Total | $\mathbf{1 1 , 1 2 5}$ | $\mathbf{1 2 , 0 2 0}$ | $\mathbf{1 0 , 7 0 7}$ | $\mathbf{1 1 , 1 5 0}$ | $\mathbf{9 , 7 8 2}$ | $\mathbf{1 1 , 0 0 0}$ |

Note: Garfield well is currently inactive a replacement well is programed for 2021.

### 2.3.2.4 Long-Term Storage

In 1992 and 1993, long-term storage policies were adopted that determined Basin groundwater storage capacity and allocated a storage volume of 96,500 AF to Basin pumpers. PWP's share of this storage volume is 38,500 AF. Current long-term storage for PWP is approximately 13,400 AF in the Monk Hill and 20,600 AF in the Pasadena subareas of the Raymond Basin. PWP can also lease storage to and from other agencies in the Basin.

### 2.3.2.5 Groundwater Quality

Water quality and operational challenges at PWP's wells has resulted in underproduction of water pumping rights and spreading credits.

Most of Pasadena's wells are contaminated with perchlorate, volatile organic compounds (VOCs) such as 1,2,3 - trichloropropane (1,2,3-TCP), and/or nitrates. Wells with nitrate concentrations above the drinking water standard are planned be used in the future to meet non-potable demands. PWP uses a combination of blending and treatment to deliver water to customers to meet water quality regulations established by the State Water Resources Control Board (SWRCB) and the United States (U.S.) Environmental Protection Agency (EPA).

The Jet Propulsion Laboratory (JPL) is a federally designated superfund site overseen by the US EPA and is located adjacent to PWP's service area. Information related to the site and clean-up is available at: https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0903438.

JPL paid for construction of the Monk Hill Water Treatment Plant (Monk Hill Plant) to remove VOCs and perchlorate from wells in the Monk Hill Basin, which was contaminated by past releases of rocket fuel and other chemicals to the environment. The Monk Hill Plant is designed to treat four wells (capacity of $7,000 \mathrm{gpm}$ ). However, due to declining groundwater levels, high nitrate levels and other factors, generally only two wells are in service.

### 2.3.2.6 Groundwater Reliability

Aging infrastructure and existing groundwater recharge facilities and governing practices confound groundwater pumping capacity in the area. Declining water levels in the basin are the main challenges for the water agencies relying on groundwater. PWP and the regional partners must implement new policies to improve groundwater quality and quantity in order to achieve the reliability goals of the basin. In addition, PWP has initiated new capital improvement projects and sought partnerships to pursue recharge efforts aimed towards the objective of a reliable groundwater supply in the future.

Historic Pasadena Area Groundwater Levels


Sownce RMBM Draf Oppartunites to Eqhiance Grouncwatier Levels in Pasadene Subarea.

### 2.3.3 Surface Water Diversion

The full amount of water available from PWP's diversion rights from the Arroyo Seco and Eaton Canyon is not typically realized due to stream flow variability, damage to PWP's existing diversion infrastructure, and capacity limitations of the spreading grounds.

Runoff from the Arroyo Seco is highly variable due to weather patterns. In wet years, runoff may exceed 40,000 AFY, most of which flows past Devil's Gate Dam to the Pacific Ocean. In dry years, runoff is less than 1,000 AFY. Runoff in the Arroyo Seco also is highly seasonal.
 On average, PWP's current recharge of approximately 2,500 AFY in the Arroyo Seco Spreading Grounds produces 1,500 AFY of water supply after RBMB credits are applied. Comparing historical data indicates that approximately 1,000 AFY of PWP's water pumping rights is underutilized due to damage to PWP's existing stream water diversion and the capacity of the spreading basins.

PWP measures flow for Eaton Canyon and collects data monthly at PWP's diversion point. RBMB provides a spreading credit based on metered outflows from Eaton Reservoir and flow downstream of the Eaton Canyon Spreading Grounds. The 10-year average spreading credits from Eaton Wash rights is approximately 750 AFY, ranging from 139 AFY in 2015 to 2521 AFY in 2006. LA County has recently made improvements to the Eaton Dam and enlarged the Eaton Spreading Grounds.

### 2.4 Water System Overview

PWP's water system consists of wells, pipelines, storage reservoirs, booster stations, pressure reducing stations, treatment facilities and interconnections with other water agencies (Table 2-5). A schematic of all facilities is presented in Appendix B.

Table 2-5: Water System Facilities

| Facility Type | Number |
| :--- | :--- |
| Storage reservoirs | 14 |
| Hydro-pneumatic tanks | 2 |
| Booster stations | 19 |
| Groundwater wells (total) | 18 |
| Groundwater wells (active) | 9 |
| MWD connections | 5 |
| Interconnections with other agencies | 27 |
| Pipelines (miles) | 510 |
| Pressure regulating stations | 30 |
| Centralized groundwater treatment facility | 1 (Monk Hill Plant) |
| Centralized disinfection facilities | 3 |
| Surface water treatment facility | 1 (inactive) |

PWP's water service area is divided into 23 pressure zones; 10 are gravity-fed by reservoirs, two are hydro-pneumatic zones, and 11 zones are fed from a higher-pressure zone using one or more pressure reducing stations. Pressure zones are separated by closed valves, check valves, pressure regulating stations, and booster stations. Pressure zone boundaries are shown on Figure 2-7. Additional details about the above-listed facilities are presented in Appendix B.

MWD imported water is treated and enters PWP's water distribution system through five interconnections. Groundwater pumped from PWP wells is disinfected and often blended to meet water quality standards before entering the distribution system, while the Monk Hill wells are also treated for VOCs and perchlorate.

### 2.4.1 Storage Infrastructure

PWP's total storage capacity is approximately 110 MG. This excludes the capacity of two reservoirs shared with neighboring water agencies - Altadena Reservoir, co-owned with Foothill Municipal Water District, and Sacred Heart Reservoir, co-owned with Valley Water Company. PWP portion is 33 percent of the 0.8 MG Sacred Heart Reservoir and

33 percent of the 1.2 MG Altadena Reservoir. Water stored in these reservoirs can be accessed in an emergency. Appendix B contains a summary of PWP's storage reservoirs, and their locations are shown on Figure 2-8.

Most pressure zones are pressurized by a single reservoir or two reservoirs adjacent to one another. Sunset zone has two reservoirs: Sunset and Jones. Sunset Reservoir is divided into two separate units, Sunset 1 and Sunset 2 . Well water is blended with MWD water before entering these units. Calaveras Zone has three reservoirs: Calaveras, Santa Anita and Thomas. The remaining pressure zones are served by one reservoir each.

Many of Pasadena's reservoirs are old and in need of repairs or upgrades to comply with codes and drinking water standards. Repair and replacement of reservoirs has become a compliance issue with State Department of Drinking Water regulators. The appurtenances connecting reservoir to the distribution system also need to be repaired and replaced. PWP provided an assessment of these facilities described in Chapter 4.

Final
Water System and Resources Plan
Figure 2-8: Reservoir Locations


### 2.4.2 Distribution Infrastructure

PWP's distribution system consists of approximately 510 miles of pipeline that range from 2 to 42 inches in diameter (Figure 2-9). Pipeline diameter and maintenance practices dictates its capacity to deliver water at an appropriate pressure which is an important element in the hydraulic analysis described in Chapter 4.

As shown in Table 2-6, over 50 percent of the system was installed between 1854 and 1949; about half of PWP's system is over 80 years old which is the life expectancy of water mains (Figure 2-10). The system's age, considered in the system assessment described in Chapter 4, is a factor that has contributed to and will continue to result in pipe breaks and non-revenue water loss.

Table 2-6: Pipeline Age Summary

| Period <br> (years) | Length <br> (miles) | Percent of the System <br> $(\%)$ |
| :---: | :---: | :---: |
| $1854-1924$ | 58 | 11 |
| $1925-1949$ | 169 | 33 |
| $1950-1974$ | 120 | 24 |
| $1975-1999$ | 56 | 11 |
| $2000-2018$ | 90 | 18 |
| Unknown | 17 | 3 |
| Total | 510 | $\mathbf{1 0 0}$ |

Pipe material affects durability (useful life) and the manner of failure. Pipes chemically interact with the soil and with the water. The material the pipe is made of and the installation techniques establish the useful life and certain conditions may result in health risks. A pipe may also lose capacity over time due to deposits inside of the pipe. Lined pipelines tend to limit buildup inside a pipe; however, only 30 percent of PWP's pipelines are lined. Pipe material, flow velocity, fire flow deficiency, risk and consequence of failure, along with age and break history, are some of the criteria that drive a pipe replacement program. Pipe breaks cause significant impacts on traffic, businesses and water quality, and can damage roads and community assets.

About 72 percent of PWP's pipelines are cast iron. The remaining distribution pipes are composed of ductile iron (20 percent), steel (3 percent), and concrete reinforced with steel (4 percent). Less than 1 percent of total pipe length in the system is composed of asbestos cement, concrete, galvanized steel, reinforced cement concrete/hume, and polyvinyl chloride (PVC). Appendix B shows distribution system pipelines colored by material throughout the PWP service area.
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Figure 2-9: Pipelines by Diameter


### 2.3.3.1 Booster Pump Stations

PWP operates 19 booster stations. Each booster station has from two to five pumps, which vary in size from 10 to 400 horsepower (hp). All booster stations have constantspeed pumps, which are less energy efficient and operationally less flexible than variable speed pumps. Details about each booster station are summarized in Appendix B, and Figure 2-11 shows booster pump station locations.

PWP has made major upgrades to several key booster stations, in the last 10 years. However many smaller booster stations still need some upgrades.

PWP is in a process of installing emergency generators for its booster stations to provide back-up power in case of emergencies. Without generators, smaller zones are more vulnerable to loss power which is a concern during wildfires.

Booster stations convey water to customers and to the storage reservoirs. Pump operations can be manually controlled to blend imported water with groundwater and to control levels and residence time in reservoirs. This is especially important to address water quality issues like nitrification.

### 2.3.3.2 Pressure Regulating Stations

There are 29 operational pressure regulating stations in PWP's water service area. Two additional pressure regulating stations are not in service and are only used for emergencies.

Appendix B summarizes details about all pressure regulating stations in the distribution system. Figure 2-12 shows pressure regulating station locations. PWP's pressure regulating stations are not anticipated to need significant repair or replacement, but data for these stations is noted in Chapter 4.

### 2.3.4 Inter-Agency Connections

The PWP water system is connected to neighboring water utilities through 27 interconnections. These interconnections allow PWP to obtain water from or provide water to surrounding cities and other water utilities. PWP has interconnections with the cities of Sierra Madre and South Pasadena, as well as, Foothill Municipal Water District, California American Water, Rubio Canyon Land \& Water Association, Kinneloa Irrigation District, Lincoln Avenue Water Company, and Valley Water Company. Most of these connections are used in case of emergency only, while others, such as with South Pasadena and Lincoln Avenue Water Company are used regularly. Appendix B summarizes information about these interconnections.
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## 3. WSRP GOALS AND OBJECTIVES

PWP's water system is a complex mix of natural resources and mechanical elements that are greatly affected by weather and climate and start below ground or hundreds of miles away. The system must satisfy essential health and safety requirement. Clean drinking water is indispensable to the social and economic foundations of the community.

Today, much of the system is beyond useful life or in disrepair and in need of costly renovations or replacements. A large backlog of work has been identified in Chapter 4. The WSRP establishes goals and objectives to improve local water resources, and prioritized the replacement and rehabilitation of the City's aging water infrastructure.

PWP and its stakeholders collaborated to develop targeted goals and objectives for the WSRP. Each goal is supported by specific objectives that define desired

## PWP Vision

PWP will be a valued community asset, an exceptional employer, a partner in Pasadena's prosperous future, and contribute to the quality of life in Pasadena.

## PWP Mission

PWP is committed to providing safe and reliable water and power with superior customer service at reasonable rates. outcomes in key areas. Collectively, they considered three key inputs: PWP's stated vision and mission (right), the existing water system and resources (summarized in Chapter 2), and community values (based on input received at stakeholder meetings).
These goals and objectives guide WSRP development in the following ways:

- Understanding any gaps between current conditions and future desired outcomes
- Evaluating how well potential solutions could help achieve desired outcomes
- Informing decisions about policies needed for the implementation


## Goal 1 - Develop and Manage Sustainable Water Supplies

To ensure sufficient water supplies are available in the future, Goal 1 recognizes the need to manage existing water resources sustainably and explore development of new supplies. The following four objectives define desired outcomes that align with this goal:

## Objective 1a - Improve Health of the Raymond Basin

Improve groundwater levels in the Basin and manage the quality of recharge and supply.

## Objective 1b - Efficiently Use Existing and Future Water Supplies

Manage demand to achieve less overall water use, use non-potable sources when appropriate, and increase groundwater storage to mitigate the high variability of surface supplies.

## Objective 1c - Adapt to a Changing Climate

Manage existing sources and develop new sources and management strategies to reduce vulnerability to extended droughts and other climate changes that increase both demand and frequency of wildfires.

## Objective 1d - Enhance Local Supplies and Support Regional Water Supply Programs

Achieve balance between local control of supply sources and regional collaboration to manage and develop supplies.

## Goal 2 - Provide Reliable Water Service

Providing reliable water service is the primary mission of PWP. This goal must be accomplished consistently under a variety of existing and changing conditions. While Goal 1 focuses on long-term sustainability of water supply, Goal 2 focuses on the ability to address near-term challenges and avoid and/or mitigate disruptions in the PWP water system. The following objectives define desired outcomes that align with this goal:

## Objective 2a - Improve Effectiveness of the Water Distribution System

Provide the right capacity and water pressures to all areas of PWP's service area by expanding, upsizing, rehabilitating and replacing infrastructure, as needed.

## Objective 2b - Ensure Water is Available to Meet Health and Safety Needs

Upgrade the distribution system storage infrastructure to ensure that water is available and can reach customers to meet their health, safety, and fire protection needs. Provide water quality treatment if necessary to maintain excellent water quality.

## Objective 2c - Optimize Water Distribution System Operational Efficiency

Provide the right capacities for treatment, storage, transmission and distribution of water, and provide the right equipment and instrumentation to minimize inefficiencies in water supply operations that could result in higher energy use and potential supply interruptions.

## Objective 2d - Enhance Resilience to Minimize Impacts to Customers During Emergencies

Develop local sources of supply and storage, and develop redundant distribution pathways and backup power to ensure water is available during emergencies.

## Goal 3 - Foster Watershed Stewardship and Environmental Health

Watershed and environmental health, both locally and areas where supply originates, plays an important role in maintaining the health and availability of water resources. Locally, watershed stewardship can maintain, and even increase, the volume of local
surface water available for direct use or recharge of the Basin. On a larger scale, decreasing the amount of energy used to produce and deliver water can reduce PWP's emissions of greenhouse gasses to the atmosphere. Goal 3 defines PWP's role in watershed stewardship and environmental health.

The following three objectives define desired outcomes that align with this goal:

## Objective 3a - Capture More Stormwater Runoff

Collaborate with agencies that have a mandate to implement stormwater management measures that improve water quality and potentially increase local supply through groundwater recharge or direct beneficial use in lieu of potable supply.
Objective 3b - Protect the Local Watersheds


Manage and protect the local Arroyo Seco and Eaton Wash watersheds to achieve greater stream flows and groundwater recharge. Develop a program to create and enhance habitat for the benefit of water resources by removal of invasive plants and encouraging native plant growth and sediment control.

## Objective 3c - Minimize PWP's Water System Operations Carbon Footprint

Consider opportunities to minimize energy use and greenhouse gas emissions related to accessing and distributing water supply to PWP's customers.

## Goal 4 - Support Pasadena's Quality of Life and Community Values

Water resources are integral with Pasadena's quality of life. The management of the resources should reflect the community and its values. The residents and businesses of Pasadena value the city's historic architecture intermixed with open green spaces, which are to be regarded and preserved as unique educational and recreational amenities for future generations. Goal 4 recognizes the balance of reducing water use while maintaining the quality of life. The following objectives define desired outcomes that align with this goal:

Objective 4a - Balance Water Use with Pasadena Aesthetics, Economic, Social and Recreational Needs

Balance water use efficiency, which provides environmental benefits associated with Goal 3, with the social benefits of water use and the sustainable preservation of quality of life in Pasadena.


Objective 4b - Promote Water Resources Educational Programs to Engage the Community and Foster Advocacy
Engage and educate the public about the conditions and actions required to provide reliable and clean water, and how they can become active participants in achieving WSRP goals.

Objective 4c - Promote Water System \& Resource Planning and Implementation Fair to Current and Future Generations

Adopt and promote planning policies that account for sustainability and its basic principle of meeting current needs without compromising the ability of future generations to meet theirs. Pursue outside grants and funding. Establish rates that support capital improvements without excessive debt ratio. Implement a replacement program that targets industry standards for life expectancy of equipment and facilities.


## 4. SUPPLY, DISTRIBUTION AND STORAGE ASSESSMENTS

Pasadena's water system and resources were outlined in Chapter 2. The goals and objectives of Chapter 3 are used to focus the specific WSRP assessment. The assessments identify gaps between current conditions and needed improvements to achieve the outcomes for developing WSRP options and solutions (Chapters 5 and 6).

### 4.1 Water Supply Reliability Assessment

Water reliability is impacted by numerous factors, including population, economic activity, land use, hydrologic fluctuations, climate change, constraints on distribution facilities, aging water systems, more stringent policies and regulations, natural disasters, and emergencies. An assessment of water supply reliability measures the extent to which a water system effectively meets current and projected water demands. In this WSRP, reliability is assessed in the context of these supply and demand pressures.

This WSRP quantifies potential water supply shortages under multiple constraints that may limit future water reliability. To analyze these elements, a systems model was developed to simulate water supply and demand balance and to quantify the long-term reliability of existing water supplies available to PWP through year 2045.

### 4.1.1 Analysis Approach

Comparing water supply and demand under variable conditions requires expanded analysis. Non-average conditions in the context of baseline assessment are related to hydrologic and weather variability impacting demand and most supplies. MWD-imported water supplies have historically been reliable but some levels of shortage do occur during extended droughts and the vulnerabilities disrupting the delta exports and the long aqueducts are increasingly probable. Local surface water varies significantly and impacts the consistency of recharge into spreading basins and spreading credits for pumping. Demand also varies with weather; hotter and drier years result in higher demand compared to cooler years. MWD's own simulations of supplies and reliability account for these non-average conditions and were used as the basis of this WSRP's analysis.

The PWP simulation model was developed using GoldSim software, an object-oriented platform used for visualizing and dynamically simulating complex systems. This systems model accounted for uncertainty and risk regarding future water supplies and helped evaluate PWP's ability to meet future service area needs.
Projected water demand identified in Chapter 2 served as the basis for this analysis. Using the annual water demand estimates, the model simulated monthly water demands. Monthly demand factors were applied to characterize water consumption throughout the year, with water demands peaking during dry summer months. The monthly demand factors are based on total historical production data for PWP from 2010 to 2018. The model also applied annual weather factors obtained from MWD's model database, which scales demands slightly up and down according to local weather. Key to the reliability
assessment is analysis of supply and demand under multiple hydrologic/weather conditions. The analysis uses historical data from 1922 to 2018 to evaluate future years under multiple hydrologic conditions. This allows the model to account for inherent variability and uncertainty in the system, which can occur at any time over the planning horizon. The method used applies to possible combinations of historical weather factors and future planning years, resulting in 86 future demand sequences. Climate change variables were not applied to future years.

Imported water supply availability was modeled from MWD's databases and simulation models. MWD also uses a method of multiple hydrology simulation in their reliability analysis and provided a matrix of reliability under each historical year applied to each future planning year.
To determine local supply availability, the model simulated local hydrology using historical data from the Arroyo Seco and Eaton Wash and accounted for diversion rights, spreading credits and adjudicated pumping rights as well as capacity constraints on existing facilities. This analysis was used to quantify the reliability of groundwater and surface water and determine the ability of the existing water supply portfolio to meet future water demands.

The analysis ultimately evaluates demands, local and imported supplies under variable conditions of hydrology and demand to determine reliability. Using this approach, reliability concerns can be presented as the percent of simulated years with shortage, as well as the average and maximum shortage that occurs.

### 4.1.2 Groundwater Supply

In the Monk Hill and Pasadena subareas of the Raymond Basin, PWP has adjudicated groundwater rights, additional groundwater pumping credits from spreading of surface water, and long-term storage credits. Total groundwater pumping is constrained by the pumping capacity of the active wells. The baseline analysis assumes that only the wells that are currently operating will be in operation in the future. Currently, Pasadena estimated pumping capacity is approximately 10,000 AFY. To meet groundwater pumping objectives, wells with capacity of $20 \%$ greater than pumping rights are required.

PWP's total adjudicated groundwater rights in the Basin are 12,807 AFY: 8,343 AFY in the Pasadena subarea and 4,464 AFY in the Monk Hill subarea (prior to the voluntary reduction described in Chapter 2).
To meet water demand in PWP's service area, the model prioritizes the use of groundwater rights, followed by spreading credits from surface water in the Arroyo Seco and Eaton Canyon, and finally imported water from MWD.

The model uses historical flow data for Eaton Wash, PWP's surface water diversion right of 8.9 cfs , and the existing structural diversion capacity of 200 cfs to simulate the water available for recharge in the Eaton Wash Spreading Grounds into the Pasadena subarea. This model applies an evaporation rate from the California Irrigation Management

Information System (CIMIS) and an infiltration of 1.1 feet per day as defined in the 2011 Final PWP Groundwater Technical Memorandum (RMC 2011).

A 20 percent administrative loss is applied to the volume of water recharged in Eaton Wash Spreading Grounds to calculate the spreading credits available to PWP.

Similarly, the model uses historical flow data for Arroyo Seco stream, PWP's surface water diversion right of 25 cfs , and the existing structural diversion capacity of 18 cfs to simulate the water available for recharge in the Arroyo Seco Spreading Basins into the Monk Hill subarea. The model incorporates an evaporation rate estimated by CIMIS and an infiltration rate of 2.7 feet per day (RMC 2011). PWP receives spreading credits of 60 to 80 percent of the diverted water spread in the basins in the Monk Hill subarea. To calculate this, a 30 percent administrative loss was used for spreading credits available to PWP in the Monk Hill subarea.

In addition to the groundwater rights and spreading credits, PWP has long-term storage of groundwater in the Monk Hill and Pasadena sub-areas. PWP's current long-term storage is approximately $20,000 \mathrm{AF}$.

The model can be run under two separate scenarios as follows:

- Model assumes current wells are maintained during the planning period, preserving existing pumping capacity
- Model assumes existing operational wells deteriorate over time with the corresponding capacity loss
For more information regarding the model inputs and data used in the GoldSim model, refer to Appendix C.


### 4.1.3 Imported Water Supply

Demands that are not met with groundwater are then met with imported water from MWD. The model incorporated a matrix of imported water reliability projections provided by MWD's 2015 IRP Update (MWD 2015). Reliability of MWD's imported water has been less certain in recent years due to intense droughts and environmental restrictions. The imported water reliability matrix projections first estimated by MWD assumed that California WaterFix would be implemented. In 2018, DWR withdrew proposed permits for California WaterFix as a result of nine appeals alleging the project was inconsistent with the Delta Plan's coequal goals of providing a more reliable water supply for California and protecting, restoring and enhancing the Sacramento-San Joaquin Delta ecosystem. DWR is now pursuing a new environmental review and planning process for the proposed Delta Conveyance Project, which is now a single-tunnel solution to upgrade Sacramento-San Joaquin Delta conveyance. For WSRP modeling, California WaterFix was excluded from MWD's reliability matrix, resulting in decreased imported water reliability. The reliability matrix showing forecast reliability for future planning years and for historical hydrology years is presented in Appendix C.

The results of the GoldSim model indicate that during most modeled years, MWD's supply is expected to be fully reliable. During significantly dry years, MWD's supply will result in some shortage. During a droughtrelated cutback, MWD allocates available imported water according to the Water Supply Allocation Plan (Plan). For this WSRP, a simplified version of the Plan has been programmed into the model. Per the Plan MWD will allocate a specific reduction to each of its member agencies based on their need.

As shown in Appendix C, imported
 water will have full reliability (i.e., no allocation) in 91 percent of the years considered. During the remaining 9 percent of modeled years, imported water would experience various levels of shortage, from 0.6 to 15.3 percent of MWD's total available supplies.

### 4.1.4 Surface Water Supply

Surface water is a supplemental inflow to the Basin, and therefore a significant asset. Arroyo Seco and Eaton Wash diversion rights can be used for groundwater recharge or direct use as a potable or non-potable supply. Arroyo Seco surface flows have been used in the past as drinking water supply with treatment at PWP's John L. Behner Water Treatment Plant, which was constructed to treat 8 cfs of Arroyo runoff. The plant was shut down in 1993 due to the new more stringent `surface water treatment regulations.

The local hydrology of Arroyo Seco and Eaton Wash was also evaluated. To maximize diversion rights from Arroyo Seco additional projects were identified and to be implemented. Figure 4-1 shows a 9-year period of actual diversions and available flow up to PWP's water rights from Arroyo Seco, illustrating that higher diversions are possible. Chapter 5 and Chapter 7 present options and portfolios developed to consider use of the additional supply.

Figure 4-1: Arroyo Seco Historical Spreading and Available Flows


Stormwater is another potential future source of local supply and the major replenishment source for stream water. Chapter 5 describes stormwater options that could recharge the Basin and provide a sustainability benefit.

Stormwater as a supply option depends on many factors, such as location of the retention, infiltration or diversion structures in the urban watershed, and the number of these structures. In general, stormwater is highly contaminated and expensive to treat to useable standards. Protecting groundwater from contaminates contained in stormwater is an objective of the Wellhead protection program. Chapter 5 describes the stormwater options that were evaluated as a supply.

### 4.1.4.1 Surface Water Quality

The 2009 Station Fire in the Angeles National Forest in the upper Arroyo Seco watershed, and the 2010 and 2011 wind storms that followed damaged PWP's diversion facilities. Prior to the fire, the headworks structure diverted stream flows to adjacent sedimentation basins which provided less turbid water for the infiltration basins. The storms brought debris from the watershed damaging the headworks and reducing the available flows and degraded the water quality. As a result, PWP has reduced the spreading at Arroyo Seco until the facilities are repaired. PWP is in the process of preparing an environmental impact report for the Arroyo Seco Canyon Project that would restore the intake and improve the spreading basins.

Los Angeles County is currently removing the sediment from the Station Fire retained at Devil's Gate Dam and should be complete by 2022.

Spreading operations in Eaton Canyon are not as vulnerable to fires because Eaton Dam is upstream of the diversion intake structure. Most of the debris and sedimentation is captured at the dam and does not reduce diversion. The spreading of surface flows allows for natural treatment through infiltration into the groundwater aquifer.
While the Eaton Wash drainage area ( 9.5 square miles) is smaller than the Arroyo Seco drainage area ( 31.9 square miles), the capacity of the Eaton Wash Spreading Grounds is 10 times larger than the Arroyo Seco Spreading Grounds capacity.

### 4.1.4.2 Tunnel Water

In the late 1880s, three tunnels (Devil's Gate, Richardson and Wilson) were constructed to capture spring water considered surface water underflow. Used for water supply since 1912, Richardson and Wilson tunnels have been out of service since the 1940s. Devil's Gate tunnel was used for irrigation at Brookside Golf Course, from the 1970s to late 1990s. The City has pre-1914 water rights to capture and divert some of the tunnel water. PWP also has a permit from SWRCB to capture 238 AFY water percolating in Devil's Gate tunnel. Wilson tunnel is piped to the Brookside Golf Course largest lake. The tunnels have been dry since summer 2013.

Chapter 5 explored using tunnel water for potable and non-potable use.

### 4.1.5 Climate Change Considerations

Climate change impacts are considered in analysis through MWD reliability results for SWP and CRA in their 2015 IRP Update. At the time of that analysis, MWD's reliability of supply from the Colorado River was not forecast to change due to the climate, even though the Colorado River basin as a whole was forecast to be impacted. Reliability of SWP supply is expected to be impacted by climate change based on different climate change forecasts (DWR 2018). A detailed description of climate impact analysis for MWD supplies is included in MWD's 2015 IRP Update.
Local climate change impacts are expected but they are difficult to predict. The U.S. Department of the Interior Bureau of Reclamation's (Reclamation) Los Angeles County Basin Study (Reclamation 2016) predicts a potential increase in basin-wide annual precipitation due to climate change, although the variability of storms could see higher peaks and lower flows. The study also indicates that higher temperatures would be offset by wetter years (Reclamation 2016).

### 4.1.6 Reliability Results

Water supply reliability is evaluated in terms of potential deficits under multiple hydrologic and weather conditions. Demands in the PWP service area are not increasing over the planning period. Thus, potential deficits are the result of shortages during extended droughts or disruptions to the imported water supply. Therefore, WSRP stakeholders and PWP have established objectives related to resiliency during emergencies to offset any deficits.

## Reliability Under Non-Emergency Conditions

Groundwater was assessed as a resource by comparing its current production to potential production based on water rights. The limiting factor in groundwater production is the total capacity of the wells currently in operation. Current capacity is approximately 13,800 AFY assuming year-round consistent pumping, while the adjudicated rights are 12,807 AFY. At this capacity, only about 1,000 AFY of spreading credits (or long-term storage) could be pumped in any year above the adjudicated rights. A modeling scenario was run with an increased pumping capacity to approximately $17,500 \mathrm{AFY}$ to explore the potential for additional spreading credits. Results consistently showed the potential to use 1,000 AFY more spreading credits in 12 out of 25 years of the planning period, 2,000 AFY more in seven out of 25 years, and 4,000 AFY more spreading credits in five out of 25 years. The benefits of rehabilitating existing wells or drilling new wells to maximize spreading credits is indicated by these numbers, and specific options are described in Chapter 5.

Totaling groundwater (including spreading credits from surface water diversions) and imported water compared to demand (scaled by weather) revealed the reliability under non-emergency conditions. Model results indicate Pasadena will experience no supply deficits in average or non-drought years.

The model projects that between 2020 and 2045, PWP will meet its service area water demand approximately 91 percent of the time. For the remaining 9 percent of the time the projected water supply shortage will be approximately 1,000 to $1,500 \mathrm{AFY}$.

Most agencies are able to manage supply shortages of 10 percent with temporary conservation measures. Additional investment needed to pursue additional supply and production solutions based on these forecasted deficits needs to be accomplished in the context of level of service discussions.
This reliability analysis assumes existing wells are maintained and that investment in replacement production capacity is sustained over the planning period.

## Reliability Under Regional Seismic Emergency Conditions

This analysis considered a 7.8 magnitude earthquake along the southern San Andreas Fault (U.S. Geological Survey [USGS] 2008), which is assumed to cut imported supply for 12 to 24 months. An event of this magnitude could damage the CRA and the SWP and cause interruptions in supplies. It would require at least six months of work to restore
some capacity to the CRA and an additional three to five years to restore the CRA to full capacity. An earthquake of this magnitude would also impact the SWP East Branch, causing a 12- to 24 -month interruption in SWP deliveries. SWP deliveries would be reduced by 50 percent in the first year under this scenario, and 20 percent in the subsequent four years.

This WSRP assumes a seismic emergency scenario with a one-year or larger interruption of imported supply. The estimated deficit of 12,000 AFY assumes the earthquake happens around year 2030 under average weather conditions. An earthquake occurring after 2030 under hot or dry year conditions would create a higher deficit. During this condition, Pasadena would need additional ground water production from wells which are not constructed.

### 4.2 Wells Assessment

An assessment of PWP's wells was completed, based on current PWP facility records and water quality reports, and supplemented with information gathered during interviews with PWP operations and engineering personnel. Table 4-1 summarizes the deficiencies identified at each well during the assessment. Planning for future wells, PWP will need to assume wells are functional at an $80 \%$ level, requiring construction of $20 \%$ additional capacity to the desired peak groundwater production to satisfy the City demands during an extended disruption of MWD supplies.
Currently, PWP does not have emergency generators at any well. Local water cannot be produced during a power outage. Due to the large well motors, auxiliary energy sources are large in size. Smaller mobile generators currently being purchased by PWP will work for small wells and boosters, but must be operated in series for the larger pumps. Permanent generators are recommended with the construction of new groundwater wells.

## Table 4-1: Well Water Quality Deficiencies

## Well

## Water Quality Detections

Active Wells

| 1 | Arroyo | Perchlorate, carbon tetrachloride (CTC), trichloroethylene (TCE), <br> tetrachloroethene (PCE), and 1,2,3-trichloropropane (1,2,3-TCP) |
| :--- | :--- | :--- |
| 2 | Bangham | Nitrate, perchlorate, TCE, PCE, and 1, 2, 3-TCP |
| 3 | Chapman | Nitrate |
| 4 | Sunset | Nitrate, perchlorate, TCE, PCE, cis-1,2-Dichloroethylene (c-1,2- <br> DCE) and 1,2,3-TCP |
| 5 | Twombly | Nitrate |
| 6 | Ventura | Nitrate, perchlorate, TCE, PCE and 1,2,3-TCP |
| 7 | Wadsworth | Nitrate, PCE, TCE and 1,2,3-TCP |
| 8 | Well 52 | Nitrate, perchlorate, TCE and PCE |
| 9 | Woodbury | Nitrate, perchlorate and 1,2,3-TCP |
|  | Inactive | Wells |



Sheldon Well is in a process of rehabilitation

Of PWP's 18 wells, nine wells are currently active. The remaining wells are inactive due to water quality or mechanical issues.

Many of the equipment deficiencies are high priority and related to old equipment; others are lower priority related to infrastructure resiliency and energy efficiency. The lower priority issues are discussed further in Sections 4.6 and 4.7. In addition, few of the existing sites are suitable to drill new or replacement wells.

### 4.3 Water System Capacity

Water distribution systems are interconnected pipelines, reservoirs, wells and booster stations that convey water from the water sources to customers. PWP's service area includes over 500 miles of pipelines, 18 wells ( 9 active), five MWD interconnections, 29 interconnections with neighboring agencies, reservoirs at 14 locations with total storage of $110 \mathrm{MG}, 21$ booster stations, two hydro pneumatic tanks, 23 pressure zones and 29 pressure regulating stations that reliably deliver potable water to PWP's customers for drinking, irrigation and firefighting.

To determine if the PWP water system is capable of providing uninterrupted, pressurized water supply to customers 24 hours a day, a hydraulic model prepared for PWP's water system was used. The modeling analysis simulated PWP's complicated system and operational processes under current and future supply and demand conditions to determine if demands in all pressure zones can be met with the existing infrastructure.

### 4.3.1 Analysis Approach

PWP's water system hydraulic model was developed in 2016. The process used to develop and calibrate the model is included in the May 2017 Carollo Hydraulic Model Calibration Report, Appendix D.

The six criteria used in the evaluation of current and projected future water demands are summarized in the Table 4-2 below. The criteria are based on typical planning principles and industry standards for similar systems, selected to reflect local and state codes and regulations with PWP input. The existing system was evaluated for system pressures, adequacy of pressure zones, and reliability to meet current and future demands.

Table 4-2: Distribution System Evaluation Criteria

| Description | Value |  | Units |
| :--- | :---: | :--- | :--- | | Demand <br> Conditions |
| :--- |
| 1. System Pressure |
| Maximum (Max.) pressure |


| Description | Value | Units | Demand Conditions |
| :---: | :---: | :---: | :---: |
| 4. Booster Station Capacity (per pressure zone) |  |  |  |
| Reliability with the largest unit out of service | Meet MDD largest pump out of service |  | MDD |
| Reliability during power outage | Meet MDD with one substation out of service at a time |  | MDD |
| Reliability for restoring emergency storage | Restore $10 \%$ of zone's emergency storage in 3 days |  | MDD |
| 5. Storage Volume (per pressure zone) |  |  |  |
| Operational | $30 \%$ of MDD | Million gallons (MG) | MDD |
| Firefighting (FF) | Highest FF requirement | MG | MDD |
| Emergency | 50\% of MDD | MG | MDD |
| 6. Water Supply |  |  |  |
| Important source out of service | Meet demands with all MWD connections out of service for 7 days |  | MDD |
| Important source out of service | Meet demands with all groundwater wells out of service for 7 days |  | MDD |

### 4.3.2 Current Capacity

The capacity of the water system infrastructure was assessed for current supplies and demands. Scenarios were run in the hydraulic model (described in Appendix E) to determine whether the evaluation criteria listed in Table 4-2 are met.

Figure 4-2 shows pipelines with fire flow deficiency, indicating that there may be insufficient water flow over for the time required to fight a fire, or capacity deficiency, meaning there is insufficient pressure in the pipe. Approximately 5,100 feet ( 1 mile) of pipelines with capacity deficiency and 89,000 feet ( 17 miles) of pipelines with fire flow deficiency were identified during the assessment. The capacity deficiency and most fire flow deficiencies can be corrected by upsizing the diameter of the deficient pipelines.

However, oversizing pipes frequently leads to water quality problems. Alternating water supply scenarios may also alter the water pressures and flow rates within the model.
Table 4-3 summarizes pipe lengths with a modeled flow deficiency by pressure zone. Because these are modeled flow deficiencies, PWP needs to complete additional investigation to identify specific pipeline replacement projects. For example, the Annandale, Annandale Reduced, Allen Reduced 2, and Mirador pressure zones may require some pipes to be upsized. In the Eagle Rock pressure zone, capacity and fire flow projects are triggered by small diameter pipes feeding water to fire hydrants; upsizing these pipes would allow for larger flows.
The Calaveras Reduced West pressure zone shows over half of the pipe length as having a hydraulic deficiency. Further investigation may be needed to determine whether certain parts of the zone have the appropriate booster stations serving them. Remaining pressure zones that indicate a high percentage of pipeline as having a flow deficiency include Lida and Mirador Reduced pressure zones, both of which have dead end lines, which are essentially the end of the line at water mains, which tends to reduce water pressure.

Table 4-3: Pipeline with Deficiency by Pressure Zone, Current Demands

| Pressure Zones | Total Length Pipe (feet) | Pipe w/ Modeled Deficiency (feet) | Pipe with Deficiency (Percent) |
| :---: | :---: | :---: | :---: |
| 1. Allen | 35,650 | 0 | 0 |
| 2. Allen Hydro | 2,340 | 170 | 7 |
| 3. Allen Reduced 1 | 22,620 | 0 | 0 |
| 4. Allen Reduced 2 | 9,500 | 1,430 | 15 |
| 5. Annandale | 32,000 | 3,000 | 9 |
| 6. Annandale Red. | 2,850 | 1,800 | 64 |
| 7. Calaveras | 608,600 | 14,700 | 2 |
| 8. Calaveras Reduced East | 7,800 | 600 | 8 |
| 9. Calaveras Reduced West | 14,200 | 7,300 | 52 |
| 10. Don Benito | 16,200 | 0 | 0 |
| 11. Don Benito Reduced | 8,600 | 0 | 0 |
| 12. Eagle Rock | 87,900 | 7,850 | 9 |
| 13. Gould | 22,200 | 300 | 1 |
| 14. Gould Reduced | 51,200 | 7,900 | 15 |
| 15. Lida | 15,700 | 5,200 | 33 |
| 16. Mirador | 12,800 | 70 | 1 |
| 17. Mirador Reduced | 1,300 | 600 | 47 |
| 18. Murray | 4,000 | 0 | 0 |
| 19. Sheldon | 536,400 | 10,600 | 2 |
| 20. Sierra Madre Villa | 85,400 | 5,200 | 6 |
| 21. Sierra Madre Villa Reduced | 21,300 | 4,000 | 19 |
| 22. Sunset | 1,060,000 | 22,600 | 2 |
| 23. Sunset Reduced | 6,400 | 750 | 12 |
| Total | ~2,700,000 | ~94,000 | 4 |

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Figure 4-2: Modeled Flow Deficiencies under Current Conditions


### 4.3.3 Future Capacity

Distribution system capacity was assessed for projected future supplies and demands to the year 2045. Demands were adjusted in the model by using the projected incremental decreases in demand per capita and adjustments for the overall service area as presented in Chapter 2. Duty factors (which are volumes of water per land use area) for each parcel in the water system were assigned based on the overall demand projections and designated land use, including single family residential, multi-family residential, and combined commercial, industrial and institutional land uses. This method assumes that the primary method of growth in the service area is increased densification, considering that PWP's service area is largely built out and that there are no major areas producing disproportionately higher levels of demand in the system.

Based on these demands and the six evaluation criteria listed in Table 4-2, the hydraulic model was run to identify areas with flow deficiencies under future demands, and assumes that deficiencies noted under existing demands were addressed. The results of modeling flow deficiencies in the future are shown on Figure 4-3, and indicate pipelines with fire flow deficiency or capacity deficiency identified in the hydraulic model. Table 4-4 lists pipelines with flow deficiency by pressure zone. Approximately 1,700 feet of pipelines were identified with flow deficiency that need to be upsized, which indicates that once flow deficiencies for current demands are addressed, few projects will be needed to address flow deficiencies for future demands.

Table 4-4: Pipeline with Flow Deficiency by Pressure Zone, Future Demands

| Pressure Zone | Total Length <br> Pipe (feet) | Pipe with <br> Deficiency (feet) | Pipe with <br> Deficiency (percent) |
| :--- | ---: | ---: | ---: |
| Annandale | 32,000 | 1,070 | 3 |
| Calaveras | 608,600 | 650 | $<1$ |
| Sheldon | 536,400 | 5 | $<1$ |

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Aged pipes have a higher likelihood of failure.

### 4.4 Pipeline Assessment

This WSRP used a risk-based approach to identify and rank pipelines for replacement within PWP's service area. Because pipes are buried and difficult to inspect visually, this approach uses known parameters to approximate the condition of pipelines. For the purposes of this assessment, "failure" means that the pipeline cannot convey the volume of water needed to meet demand due to various reasons, such as corrosion, cracking or collapse of the pipeline. For each pipeline, the likelihood of failure (i.e., how likely a pipeline is to fail by 2045) and the consequence of failure (i.e., the impact of the failed pipeline on customers and the surrounding area) is determined based on known criteria. Scores, developed for the likelihood of failure and consequence of failure for each pipeline, are used to calculate an overall level of risk score based on the following formula:

Level of Risk $=$ Likelihood of Failure $x$ Consequence of Failure

### 4.4.1 Likelihood of Failure

The likelihood of failure of PWP's water distribution pipelines was approximated using three criteria:

- Age - PWP service area has over 200 miles of pipeline installed 80 years ago or more (shown on Figure 2-10 and Figure 4-7). Pipelines beyond 80 years old have a higher likelihood of breakage and a higher priority for replacement than newer pipes.
- Modeled hydraulic flow deficiency - Pipelines with a hydraulic deficiency based on existing demands, as determined by hydraulic modeling, are also a priority for replacement. The flow deficiencies identified through the modeling are shown in Figure 4-2.
- Break history - Pipelines with a history of breaks are a priority for replacement as these pipelines may have demonstrated a higher likelihood of failure. For the purposes of this analysis, pipelines located within 200 feet of a past main break were assumed to have a higher future likelihood of failure. Figure $4-5$ shows the locations of pipeline breaks in 2018.
Likelihood of failure score was developed by using the age, hydraulic deficiency, and break history of the pipelines. Scientific tools such as metallurgy reports or acoustic soundings are also used to determine the suitability for additional service. A likelihood of failure score was assigned to each pipeline segment based on the number of criteria met, Table 4-5. These likelihood of failure scores shape priorities for pipeline replacement.
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Legend

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Figure 4-4: Pipelines Aged 80 Years or Older

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## Table 4-5: Likelihood of Failure Scoring

| Likelihood <br> of Failure <br> Score |  |
| :---: | :--- |
| 1 | Meets all of these conditions: <br> - History of breakage <br> - Age (greater than 80 years) <br> - Modeled hydraulic flow deficiency identified |
| 2 | Meets two of these conditions: <br> - Age (greater than 80 years) <br> - Modeled hydraulic flow deficiency identified <br> - History of breakage |
| 3 | Meets one of these conditions: <br> - Age (greater than 80 years) <br> - Modeled hydraulic flow deficiency <br> - History of breakage |
| 9 | - Pipes in good condition with no hydraulic deficiencies are not considered for <br> the analysis |
| 2 |  |

Figure 4-6 is a map showing the likelihood of failure scores assigned to each pipeline. Most pipe segments met at least one of the criteria, but few segments met all three criteria. The pipe segments that met at least one criteria and received likelihood of failure scores of one, two or three appear to be distributed evenly, with no particular concentration in a specific area. Listed below are excerpt of a metallurgy report.

## Conclusions

Based on the results of the evaluation, V\&A presents the following conclusions for PWP to consider.

- The pipe sample exhibited heavy corrosion (graphitization) on its interior and exterior surfaces, which was likely the cause of the approximate 1 -inch by 0.75 -inch perforation on the pipe.
- The nominal pipe wall thickness appears to be 0.38 inches, which is consistent with 6 -inch-diameter Class 22 CIP (spun-cast). A cross section near the perforation showed approximately 0.125 -inch pipe wall loss on both the interior and exterior surfaces of the pipe ( $66 \%$ pipe wall loss).
- Laboratory test results:
- Macroscopic examination of a cross section did not show inclusions, porosity, or other defects.
- Chemical composition is consistent with grey cast iron.
- Ring test and Talbot strip do not meet ASA A21.6 or ASA A21.8 requirements.
- Charpy Impact tests indicate that the material is susceptible to brittle fracture.
- Rockwell hardness tests meet ASA A21.6 requirements.
- Microscopy indicates a microstructure consistent with grey cast iron, and, in particular, spun-cast pipe rather than pit-cast pipe.
The pipe reach from which this sample was pulled had failed (remaining service life of 0 years).
While this is a small sample size of similar pipes that may be in service, it is likely that piping
installed around the same time and subjected to similar loading and exposure conditions is also nearing the end of its service life.
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### 4.4.2 Consequence of Failure

The consequence of failure of PWP's water distribution pipelines was estimated using the following six criteria:

- Located near a critical care hospital - A pipeline failure near a hospital would impact the ability of the hospital to care for patients, may flood the hospital and block the incoming patients' access.
- Located in a business district - Business districts within the city are generally areas with high traffic also bus routes. A pipeline failure can flood the area, interrupt business and block traffic.
- Pipeline over 12 inches in diameter - Pipelines over 12 inches in diameter carry high volumes of water. A large pipeline failure can flood the area in a short amount of time while disrupting service to a significant number of customers.
- The only pipe serving a pressure zone or area - If a single pipe delivering water to a pressure zone or area fails, the customers in that area or pressure zone may not receive water and increases the vulnerability to water quality and fire response.
- The only pipe conveying water from a well to the distribution system - If a single pipe conveying water from a well to the distribution system fails, that supply would not be available to serve customers, and other sources of supply (wells or imported water) would be required to meet demand.
- Pipeline in a fire risk area - PWP service area is surrounded by hills and mountains, defined as fire risk areas. Los Angeles County fire hazard zones and portions of PWP's service area overlap. A pipeline failure in these areas can impact the ability to fight fires near homes and businesses.

Figure 4-7 provides the location where each of these conditions occurs. Consequence of failure scores were assigned to each pipe segment based on potential severity, as shown in Table 4-6. Pipe segments that do not meet the above criteria are still considered to have a small consequence of failure because all pipelines serve customers within the PWP service area.

Table 4-6: Consequence of Failure Scoring

| Score | Criteria |
| :---: | :--- |
| 1 | - Pipeline is adjacent to Huntington Hospital OR |
|  | - Pipeline overlaps with major business district OR <br>  <br>  <br> - Pipeline is above 12-inch diameter OR |
| 2 | - Pipe 12-inch dia.or less \& single pipe feeding a zone/area |
| 3 | - Pipeline is within a within a fire risk area |
| 3 | Remaining pipelines |

### 4.4.3 Results

The likelihood of failure and consequence of failure scores applied to each pipe segment are multiplied to obtain a relative risk score to prioritize the pipeline replacements. The risk scores are shown on Figure 4-9 and summarized in Table 4-7, lower scores (1, 2, 3 and 4) indicate more critical risk. Pipelines with critical, extreme and high score will be scheduled for replacement before pipelines with medium and low risks. Table 4-7 also provides the total length of pipelines within each category of risk.

Table 4-7: Pipeline Risk Score Summary

| Score | Relative <br> Risk Level | Pipeline <br> Length <br> (feet) | Pipeline <br> Length <br> (miles) | PWP Pipeline <br> Network <br> (percent) |
| :---: | :---: | ---: | ---: | ---: |
| $1-2$ | Critical | 29,400 | 6 | 1 |
| $3-4$ | Extreme | 226,200 | 43 | 8 |
| 6 | High | 313,400 | 59 | 12 |
| 9 | Medium | 875,000 | 166 | 33 |
| $>9$ | Low | $1,250,000$ | 237 | 46 |
|  | Total | $\sim \mathbf{2 , 7 0 0 , 0 0 0}$ | $\mathbf{5 1 0}$ | $\mathbf{1 0 0}$ |

In Figure 4-9, the pipelines with a critical and extreme relative risk level are clustered in downtown Pasadena due to a combination of factors in that area, including old pipes, past pipeline breaks, hydraulic deficiency, and proximity to Huntington Hospital and the business district. This analysis was completed to identify high priority areas of the pipeline network for replacement or rehabilitation, as opposed to identifying specific pipe segments. Other factors considered in the decision to replace specific pipelines include new pipe breaks, metallurgy reports, coordination with roadwork, future developments, new sources of supply, or other scenarios.
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|  |  |  |
| :---: | :---: | :---: |



### 4.5 Above-Ground Infrastructure

Assessments of reservoirs, booster stations and pressure reducing stations were completed to determine the condition and potential hydraulic capacity deficiencies of these facilities. The assessments were completed using the processes described below.

### 4.5.1 Condition Assessment

The condition assessment was based on a combination of inspections, existing facility assessments and interviews with PWP operations and engineering personnel. Based on this analysis, recommendations were developed for infrastructure improvements.

### 4.5.2 Hydraulic Assessment

The hydraulic assessment was completed using a spreadsheet model using demand and supply from the hydraulic model, existing capacity, and booster station capacity criteria listed in Table 4-2. The capacity surplus or deficit was determined within each pressure zone, and any areas of deficit were analyzed to determine whether surplus from higher pressure zones could be used to offset the deficit. Based on this analysis, recommendations were developed for above-ground infrastructure within each pressure zone.

The assessment determined that pressure reducing stations do not have any deficiencies.

### 4.5.3 Storage Reservoirs

An evaluation of each storage reservoir within PWP's service area was completed based on data provided by PWP, including a seismic vulnerability assessment for all facilities (G\&E Engineering 2006), dive inspection reports, and interviews with operators and engineering personnel. The State Department of Drinking Water has also identified deficiencies likely requiring several reservoirs to be replaced or upgraded. The current condition of each storage reservoir was determined and the deficiencies are summarized in Table 4-8. Because PWP has an excess of storage capacity, abandonment of some sites may be warranted to reduce the burden of needed repairs and O\&M costs.

Table 4-8: Reservoir Condition Deficiencies

| Reservoir | Deficiencies Noted |
| :--- | :--- |
| Allen | - <br>  <br>  <br> - |
| Annandale | Replace roof |

A hydraulic assessment was performed for each pressure zone to determine whether the existing reservoirs can provide sufficient storage under existing and future conditions based on the operational criteria described in Section 4. 2. A summary of the required and available storage is provided in Appendix E by pressure zone, and indicates that PWP has a surplus storage capacity for the system as a whole of 60 MG under existing conditions, and 58 MG under future conditions. While some pressure zones show a storage deficit, most are connected to higher pressure zones with a pressure sustaining valve that allows water in excess of pressure setting to flow automatically from the higherpressure zone to the lower-pressure zone to meet demand. Only one zone with a deficit
is not connected to a higher-pressure zone - Eagle Rock pressure zone located in the southwestern part of PWP's service area. To address this deficiency, a pressure sustaining valve could be installed at the Eagle Rock Booster Station to allow for supply from higher pressure zones to automatically flow to the Eagle Rock Pressure Zone. This upgrade is addressed in Chapter 6.

While many of the above referenced deficiencies are high priority related to equipment failure, such as reservoir cracking with leaks, torn liners, root intrusion, and leaking or corroded pipes, other deficiencies are relegated to later years such as minor building, or seismic upgrades, pump replacements and site security upgrades, are lower priority related to infrastructure resiliency/redundancy, and energy efficiency. These lower priority issues are discussed in Sections 4.6 and 4.7.

### 4.5.4 Booster Stations

Each booster station was evaluated based on data provided by PWP, including recent and future upgrades, the seismic vulnerability assessment for all facilities (G\&E Engineering 2006), and interviews with operators and engineering personnel regarding condition and upgrades needed for booster stations. The current condition of each booster station was determined; Table 4.9 summarizes the major deficiencies noted.


Table 4-9: Booster Station Condition Deficiencies

| Booster Station | Deficiencies Noted |
| :--- | :--- |
| Ventura | - Minor building and electrical repairs |
|  | - Emergency generator connector <br>  <br> - Electrical repairs |
| Glorietta | - Replace pumps <br>  <br>  <br>  <br>  <br> - Piping and valve upgrades <br>  <br> - Minor building modifications and seismic upgrades |
| Wilson | - Piping upgrades |


| Booster Station | Deficiencies Noted |
| :--- | :--- |
| Allen Hydro-pneumatic | - No deficiencies noted |
| Murray Hydro-pneumatic | - No deficiencies noted |
| Arroyo | - Upgrade completed in 2020 |
| Ross | - Upsize pumps, add standby |
|  | - Upgrade piping |
|  | - Replace electrical service and equipment |


| Booster Station | Deficiencies Noted |
| :--- | :--- |
| Thomas | - Replace electrical service |
|  | - Suction piping upgrade |
|  | - Emergency generator connector |
| Linda Vista | - Replace electrical service and equipment |
|  | - Replace flow meter |
|  | - Smergency generator connector |
|  | - No deficiencies noted |
| Annandale | - Replace pump |
| Devil's Gate | - Emergency generator connector |
|  | - Seismic upgrades (anchor equipment) |

A hydraulic assessment was performed for each pressure zone to determine whether the booster stations can provide sufficient supply under existing and future conditions based on operational criteria described in Section 4.2. The assessment shows that the service area as a whole has sufficient capacity to provide service to all pressure zones. A summary of the required and available booster station capacities is provided in Appendix E.

### 4.6 Water System Resiliency and Redundancy

This WSRP assesses the ability of PWP's water system to respond to disruptions due to emergencies. Disruptions may occur for a variety of reasons, such as earthquakes, power outages, fires or tampering, and could impair water operations for days, weeks, or even months. As discussed in Chapter 3, PWP has set an objective to enhance resilience and minimize impacts to customers during emergencies.


Windsor Reservoir seismic retrofit has been completed

The resilience assessment for aboveground infrastructure was completed using the same process as discussed in Section 4.5. Table 4-8 and Table 4-9 summarize all deficiencies, including those related to emergency resilience. Several improvements are necessary to ensure continued service. PWP reservoirs that were not seismically retrofitted, for instance, could fail during a major earthquake and cause interruptions to service and localized flooding. Building modifications or site security improvements are needed for PWP to continue to provide water to its customers after a major earthquake. Other needs include connectors for emergency generators, equipment anchors, and building and security improvements at booster station sites. These upgrades will be discussed further in Chapter 6.
PWP's pipeline network has control valves installed to close pipeline sections for repairs of possible pipeline breaks without disruption to other customers in the system. Maintaining these valves, as well as installing appropriate valves on new pipelines, is important for water systems during emergency or repair situations. Since control valves are currently installed on the existing system at reasonable locations, the addition of new valves was not assessed. However, a significant number of nonfunctioning valves has been noted in the PWP valve maintenance program. It was also noted that the system lacks emergency generator or redundant power sources leaving boosters and pressure zones vulnerable to unexpected or preemptive energy outages. PWP's wells were assessed and recommended emergency generators to ensure continued production during power outages, and are included in the assessment described in Section 4.2.

### 4.7 Water System Energy Efficiency

The production, treatment and distribution of water are energy-intensive. Certain upgrades can improve energy efficiency (or the amount of energy required to produce, treat and distribute a certain volume of water), which in turn would decrease costs, extend
the life of existing infrastructure, reduce greenhouse gas emissions, and improve overall customer relations. Installation of photovoltaic panels to power water production and distribution facilities can also provide these benefits.

Booster stations and wells were assessed for potential energy efficiency upgrades based on information provided by PWP personnel as to how the system was operated (e.g., use of throttled valves) as well as evidence of excessive noise or vibrations, out-of-alignment conditions, wear on pumps, poor pump efficiency, poor hydraulics, etc. The deficiencies noted under this category are included in Table 4-8 and Table 4-9. Upgrades to address energy efficiency are discussed further in Chapter 6.

## 5. WATER SUPPLY AND PRODUCTION OPTIONS

A series of water supply and production options were considered to serve PWP's projected water demands (Chapter 2), address supply reliability concerns (Chapter 4), and meet the goals and objectives of the WSRP (Chapter 3). Chapter 5 describes the process to develop the water supply and production options, as well as details of each option.

### 5.1 Options Development

The development of water supply and production options builds upon existing project concepts, water supply plans and feasibility studies. As a first step, the supply and production options developed in the 2011 WIRP were examined based on current water resource conditions, and either updated or removed from further consideration. Additional concepts from previous planning studies are also updated and included. Workshops with PWP personnel and stakeholders helped to develop additional supply and production concepts. Finally, PWP's existing supply and production operations are included as baseline supply options. Initially, 36 supply and production concepts were considered.

Planning level analysis was conducted to estimate costs and volumes of supply for each option. The costs and volumes were calculated based on assumptions of existing infrastructure and any new infrastructure needed to implement an option. The existing infrastructure included PWP's production infrastructure and infrastructure owned by other water agencies. The sources of supply and existing infrastructure referenced in this chapter are shown in Figure 5-1.

For each option identified were three supply scenarios: average yield (average supply available over a 10-year period); drought yield (supply available during droughts, which typically occur three out of every 10 years); and emergency yield (supply available during a supply interruption, such as an imported water interruption due to an earthquake).

Capital, operations and maintenance (O\&M), and unit costs were estimated for each supply option in 2019 dollars. Volumes for each option were based on the available supply and the assumed capacity of existing and proposed infrastructure (e.g., capacity of diversions, wells, or treatment systems). The full list of the options is provided in Appendix F.

Figure 5-1: Existing Supply and Conveyance Facilities


While an initial list of 36 options was developed, not all options were feasible under current or reasonable future water resources extending to 2045. A threshold screening removed or modified any infeasible options for the following reasons:

- Option does not meet the Basin's groundwater quality objectives (i.e., recharge with recycled water is limited due to the salt and nutrient assimilative capacity approved in the Raymond Basin's Salt \& Nutrient Management Plan (SNMP).
- Option is very similar to another option that may be more desirable (i.e., satellite treatment of wastewater at Eaton Wash Spreading Grounds would allow for higher recharge volumes than at Arroyo Seco Spreading Grounds).
- Option would not provide a sufficient volume of water (i.e., capture of stormwater may be limited due to sub-watershed area and recharge credits).

The initial screening eliminated four options.

### 5.2 Options

The 32 options, listed in Table 5-1, are organized by the source of supply (supply category), with the options describing how the water will be conveyed, produced, and/or treated to meet demands. Each option is given a code that indicates the water source followed by a consecutive number. Those options ending in a zero (0) represent current baseline supply and production strategies or in a process of implementation.

Table 5-1: Water Supply and Production Options

| Supply Category | Code | Supply and Production Option Name |
| :---: | :---: | :---: |
| Imported Water | IW-0 | Treated water imported from MWD |
|  | IW-1 | Agricultural spot market or long-term transfer |
|  | IW-2 | Pasadena Groundwater Storage Program |
|  | IW-3 | External groundwater banking |
|  | IW-4 | Raw imported water pipeline connecting to San Gabriel Valley Municipal Water District's (SGVMWD's) Devil Canyon-Azusa Feeder and Carson recycled water (RW) pipelines |
| Local Surface Water | LSW-0 | Arroyo Seco Canyon Project |
|  | LSW-1a | Arroyo Seco to Eaton Canyon raw water pipeline |
|  | LSW-1 | Arroyo Seco Pump Back Project |
|  | LSW-4 | Re-open and upgrade Behner WTP to use Arroyo Seco water for drinking |
|  | LSW-5 | Natural infrastructure |
| Los Angeles Glendale Water Reclamation Plant (LAG) | LAG-1 | Phase 1 non-potable reuse using LAG RW |
|  | LAG-3a | Advanced treatment of RW from LAG for recharge |
|  | LAG-3b | Advanced treatment of RW from LAG for direct use |
| Non-Potable Water | NP-1 | Tunnel water to Brookside Golf Course |
|  | NP-3 | Local Non-Potable Project |
|  | NP-5 | Satellite plant to treat wastewater near the Eaton Wash Spreading Grounds |
|  | NP-6 | Wastewater and stormwater supply capture at Glenarm Power Plant |
| Greywater | Grey-1 | Greywater Program |

Supply Category $\quad$ Code $\quad$ Supply and Production Option Name

| Desalination | Desal-1 | Ocean desalination |
| :---: | :---: | :---: |
| Stormwater | SW-1 | Infiltration galleries |
|  | SW-2 | Altadena Drain diversion to Arroyo Seco Spreading Grounds |
|  | SW-3 | Centralized stormwater capture and conveyance to Eaton Wash for recharge |
|  | SW-4 | Decentralized stormwater recharge, Tier 1 |
|  | SW-5 | Decentralized stormwater recharge, Tier 2 |
| Water Use Efficiency | WUE-0 | Conservation programs to meet future regulations |
|  | WUE-1 | Conservation programs to meet future regulations plus $10 \%$ additional outdoor conservation |
|  | WUE-2 | Conservation programs to meet future regulations plus 25\% additional outdoor conservation |
| Groundwater | GW-0 | Well rehabilitation and replacement projects, importance level 1 |
|  | GW-00 | Well rehabilitation and replacement projects, importance level 2 |
|  | GW-2a | Add nitrate treatment to the Monk Hill wells |
|  | GW-2b | Add nitrate, perchlorate and VOCs treatment to the Sunset wells |
|  | GW-3 | Connect high nitrate wells to a non-potable system |

The symbols used in the flow charts are shown in Table 5-2. Gray symbols represent water supply and production infrastructure, blue symbols represent groundwater basin, green symbols represent supply sources, and orange symbols represent water demands.

Table 5-2: Flow Chart Key

| Symbol | Key |
| :---: | :---: |
|  | Wells |
|  | Reservoir |
|  | Treatment plant |
|  | Supply sources |
|  | End user (water demands) |

### 5.2.1 Imported Water Options

PWP purchases approximately 18,000 AFY of treated imported water from MWD's Weymouth treatment plant via five connections from the Upper Feeder pipeline. The options assume continued and increased MWD purchases and other forms of conveying imported water not currently used by PWP. The major water conveyance facilities that MWD relies on are the California Aqueduct and the Colorado River Aqueduct as shown on Figure 5-2.

## Treated Imported Water from MWD (IW-0)

PWP has an agreement with MWD to buy a predetermined amount of water at a Tier 1 treated volumetric rate. Purchases in excess of this limit are made at a higher Tier 2 rate, which includes MWD's cost of accessing additional, more costly supplies. Under this option, PWP would purchase whatever amount of imported water is necessary to meet demand after local supplies have been produced. Therefore, this option has an increasing cost if PWP buys supplies at the Tier 2 rate. This option would not require any additional infrastructure as it would rely on MWD. The amount of Tier 1 water that PWP could purchase from MWD varies (i.e., imported water would be more limited in a drought as
opposed to an average or wet year) as projected in the MWD 2015 IRP Update. Similarly, the emergency yield is specific to the type of emergency. A severe earthquake, for example, could decrease PWP's ability to purchase MWD water. Additionally, MWD rates are projected to increase steadily in the future as a result of the Delta Conveyance Project and other programs currently being initiated.

## Agricultural Spot Market or Long-Term Transfer (IW-1)

An agricultural spot market or a long-term transfer with agricultural water rights holders could also augment PWP's access to imported water supplies. A market transfer is the transfer of water rights for a single year, often used to offset the impacts of a severe drought year, while a long-term transfer occurs for a period of time usually longer than a year. The agricultural transfer would require agreements with the agricultural water rights holder and MWD conveyance and treatment. Similar to IW-0, this option would rely on existing infrastructure. The expected yield during a drought or an emergency would be specific to the expected water shortage level. The cost for implementing this project would vary by transfer. However, participating in these purchases place PWP in competition with MWD for these purchases.

Figure 5-2: Major Water Conveyance Facilities in California


Source: Metropolitan Water District of Southern California

## Pasadena Groundwater Storage Program (IW-2)

Option IW-2 requires a partnership between PWP and MWD to recharge imported water in the Basin. Water from MWD could be recharged and stored in the groundwater basin using in lieu pumping, and spreading credits. A conceptual diagram of this option is presented in Figure 5-3. To implement this program, PWP needs an agreement with MWD to store surplus imported water available in wet years. The program would use existing MWD infrastructure. The maximum imported water recharge volume is expected to average $8,350 \mathrm{AF}$ for three years, for a total of $25,000 \mathrm{AF}$, and could be pumped over two years (12,500 AFY). It is assumed that this project would have up to a 1 percent loss per year if water is stored for five years, resulting in a yield of 23,750 AF which may replace imported water in dry years or during emergencies.

Figure 5-3: Pasadena Groundwater Storage Program Flow Chart


## External Groundwater Banking (IW-3)

Option IW-3 would implement external groundwater banking through a partnership with a banking program outside of the Basin to store surplus SWP water during wet years. An agreement with MWD to deliver banked water to PWP in dry years is required. This option is feasible if the bank has access to SWP conveyance infrastructure, enabling PWP can use SWP and MWD conveyance. External groundwater banking is assumed to only be possible in connection with the SWP, as there were no external groundwater banks identified that are connected to the CRA. This program assumes up to 1,100 AFY of banked supplies over three consecutive years during a period of drought, assuming that dry years occur three out of every 10 years. This option is a drought supply not expected to provide an emergency yield. A map with the general location of some of the water
banks operating in Central and Southern California and their respective storage capacity is shown in Figure 5-4.

Figure 5-4: External Water Banks with Access to the SWP


Raw Imported Water Pipeline Connecting to SGVMWD's Devil Canyon-Azusa Feeder and Carson Recycled Water Pipelines (IW-4)
Option IW-4 partners with the foothill water agencies to construct new facilities to deliver raw imported water to recharge areas in the Basin. The existing Devil Canyon-Azusa Feeder pipeline owned by the SGVMWD (a SWP contractor) could extend from its current end in Azusa to spreading grounds in the San Gabriel Basin and eventually to the existing Eaton Wash Spreading Grounds in the Pasadena subarea (see Figure 5-5). This project could be supplied with water from MWD or other contractors. Imported water would be delivered six months a year, yielding approximately 1,000 AFY for recharge into the Raymond Basin. Assuming that pumping of this water occurs in the same year it is recharged, there will be no losses. This option would yield an average of 1,000 AFY, although during droughts imported water may not be available. To implement this project, PWP needs agreements with SGVMWD, MWD, Los Angeles County and RBMB. PWP would also need to construct new pipeline and a new well.

Figure 5-5 Devil Canyon-Azusa Feeder and Eaton Wash Spreading Grounds


### 5.2.2 Local Water Supply

Surface runoff from the San Gabriel Mountains is a local water source for Pasadena. Surface water recharges in the Monk Hill and Pasadena subareas and produces spreading credits for groundwater pumping. PWP has the water rights to divert up to 25 cfs from Arroyo Seco stream and 8.9 cfs from Eaton Wash. Due to limited spreading basin capacity and damage to the intake structure, PWP is unable to use its full water rights from Arroyo Seco. To maximize surface water diversion rights and restore groundwater levels in the Basin, PWP can implement a combination of projects.

## Arroyo Seco Canyon Project (LSW-0)

This project will remove the existing Arroyo Seco headworks, restore the area, and replace the diversion structure to allow PWP to fully utilize its surface water rights. The project includes a new sedimentation basin and four acres of new spreading basins. The project is expected to recharge approximately 1,000 AFY of surface water, which would provide approximately 800 AFY in groundwater pumping credit in the Monk Hill subarea. To pump the recharged water, a new well may be needed if pumping capacity is not available in the existing system. The location of this project is shown in Figure 5-6.

Figure 5-6 Arroyo Seco Canyon Project


## Arroyo Seco to Eaton Canyon Raw Water Pipeline (LSW-1a)

Option LSW-1a proposes to use existing and new pipelines and pump station, to convey Arroyo Seco stream water following storm events from the reservoir pool behind Devil's Gate Dam to the Eaton Wash Spreading Grounds, as shown in Figure 5-7. To pump the recharged water, a new well may be needed if pumping capacity is not available in the existing system. This project was originally proposed by Los Angeles County. The project can recharge approximately 1,070 AFY in the Pasadena subarea (860 AFY supply credit).

Figure 5-7 Arroyo Seco to Eaton Canyon Raw Water Pipeline Flow Chart


## Arroyo Seco Pump Back Project (LSW-1)

Option LSW-1 proposes to recharge the Monk Hill subarea with surface water from the Arroyo Seco stream collected from behind Devil's Gate Dam. The project includes installation of a new pumping system and controls at the dam and a new pipeline to the Arroyo Seco spreading basins. Implementation of this project would result in an average 1,000 AFY of surface water recharged in the Monk Hill subarea. This project can be implemented after Los Angeles County completes the Devil's Gate Dam Sediment Removal Project.

## Re-Open and Upgrade Behner Water Treatment Plant to Use Arroyo Seco Water for Drinking (LSW-4)

Option LSW-4 proposes to upgrade the Behner WTP (out of service since 1991) as a 2 cfs plant yielding 860 AFY of drinking water. Behner WTP would treat raw water from Arroyo Seco for direct potable use. Nearly all of the water treated at Behner WTP can be used as drinking water supply. Untreated (backwash) water would recharge the groundwater in the Arroyo Seco Spreading Grounds. This project would use the existing diversion infrastructure from the Arroyo Seco to the Behner WTP. A schematic of LSW-4 is shown in Figure 5-8.

Figure 5-8: Re-Open Behner Water Treatment Plant for Drinking


## Natural Infrastructure (LSW-5)

Option LSW-5 seeks to increase stormwater recharge in the watershed 5\% by implementing Arroyo Seco watershed management improvements. This option includes removing invasive species, planting native plants and sediment control. Native plants consume less water and are typically more fire resistant than invasive species. Fires negatively affect stream flow. This project does not require new infrastructure. PWP intends to partner with local NGO's and LA County to better manage vegetation in the watershed. Implementation of this project is expected to recharge up to 200 AFY of stormwater in the Monk Hill subarea. With a supply credit of $60 \%$, the yield of this project is 120 AFY. PWP is currently preparing a plan for regular maintenance and management of the watershed, including removal of noninvasive species and habitat enhancement.


### 5.2.3 Recycled Water from Los AngelesGlendale Water Reclamation Plant (LAG-WRP)

The LAG-WRP is co-owned by the cities of Los Angeles and Glendale, and maintained by the Los Angeles Sanitation District. PWP has an existing contract to purchase up to 6,000 AFY of recycled water from the LAG-WRP to offset potable water demands.

## Phase 1 Non-Potable Reuse using LAG-WRP Recycled Water (LAG-1)

Option LAG-1 includes a new non-potable infrastructure to deliver tertiary treated and disinfected recycled water from the LAG-WRP to Pasadena for landscape irrigation and other non-potable uses identified in the Recycled Water Planning Study (RMC 2012) as Phase 1. The construction would include new pipelines, storage reservoirs, pressure reducing facilities and four customer connections (see Figure 5-9). This project would provide an average, drought, and emergency yield of approximately 700 AFY.
Water Supply and Production Options

|  |  |  |  |
| :---: | :---: | :---: | :---: |

## Advanced Treatment of Recycled Water from LAG-WRP for Recharge (LAG-3a)

Option LAG-3a would take advanced treated water from the LAG-WRP and recharge it into the Eaton Wash Spreading Grounds. This project would construct advanced treatment facilities to treat wastewater to advanced standards at either the LAG-WRP or within PWP's service area. If the treatment facilities are constructed within PWP's service area, the additional cost of brine disposal must be included. LAG-3a would also require construction of a new pipeline pump station and storage reservoir to convey the treated water to the Eaton Wash Spreading Grounds. To pump the recharged water, a new well is needed to augment the existing system. LAG-3a would recharge approximately 3,200 AFY in the Pasadena subarea, and yield 2,600 AFY in pumping credits.

## Advanced Treatment of Recycled Water from LAG-WRP for Direct Potable Use (LAG-3b)

LAG-3b would construct advanced treatment at the LAG-WRP or in the PWP service area to treat recycled wastewater to potable water standards, and construct pipelines, a pump station and reservoirs to convey the water to the Pasadena service area. If the treatment facilities are constructed within PWP's service area, the additional cost of brine disposal must be included. This option requires higher treatment of the water than LAG-3a supplies. It is estimated that this project would result in an average potable supply yield of 3,200 AFY.

### 5.2.4 Other Sources of Non-Potable Water

All water demands in the PWP service area are currently met with potable water. However, some water uses, such as irrigation, do not require drinking quality water. Matching water quality to uses can often eliminate excess water treatment. The options below explore the potential for using local supplies without additional treatment to more efficiently meet non-potable demands.

## Tunnel Water to Brookside Golf Course (NP-1)

Devil's Gate, Richardson and Wilson tunnels were constructed in the 1880's to capture water that seeps into the ground from the Arroyo Seco stream.

Option NP-1 would use Devil's Gate and Richardson tunnel water for irrigation at Brookside Golf Course, as shown in Figure 5-10. To implement this project include the two existing tunnels, a new booster pump station, new pipeline, and water storage. Tunnel water would produce 433 AFY, which would offset Brookside's water demand currently met with potable water. Tunnel water has historically stopped flowing during droughts. The tunnels have been dry since summer 2013. This project is included as a part of NP-3 (below), and therefore is mutually exclusive with NP-3.

Figure 5-10: Tunnel Water for Irrigation to Brookside Golf Course


## Local Non-Potable Project (NP-3)

Option NP-3 would construct a local non-potable system that uses tunnel water and highnitrate groundwater. Potential irrigation customers include schools, parks, golf courses, and other landscaped areas. Existing infrastructure used for implementation of this project include Devil's Gate and Richardson Tunnels (similar to Option NP-1), This project would also require pipelines (new or existing), storage, customer connections, and existing wells with high nitrates. This option in conjunction with GW-3 would result in an average yield of 1,000 AFY.

Figure 5-11: Local Non-Potable Project Flow Chart


## Satellite Plant to Treat Wastewater near the Eaton Wash Spreading Grounds (NP-5)

This option proposes to construct a 0.5-million gallon per day satellite plant to treat raw wastewater from the Los Angeles County Sanitation District's sewer system near Eaton Canyon. The new satellite plant would treat the wastewater to tertiary levels, and convey treated effluent to Eaton Wash Spreading Grounds for recharge. The project assumes that the effluent would have total dissolved solids (TDS) concentration that comply with the Raymond Basin TDS objectives. This option assumes that the satellite plant would produce approximately 560 AFY for groundwater recharge, resulting in pumping credits of 450 AFY (Foothill Municipal Water District 2012).

## Wastewater and Stormwater Supply Capture at Glenarm Power Plant (NP-6)

Option NP-6 proposes to divert local wastewater collected in Pasadena's sewer system and stormwater collected in Pasadena's stormwater system in the vicinity of the Glenarm Power Plant to a new satellite water reclamation treatment plant, as shown in Figure 5.12. The blended water would then be treated to tertiary levels (based on the lower wastewater quality), and conveyed to the power plant and water customers near the power plant for non-potable use. This option would require a satellite treatment plant, stormwater diversion infrastructure, and pipeline to convey wastewater and stormwater, and would provide an average yield of 200 AFY.

## Figure 5-12: Wastewater \& Stormwater Supply Capture at Glenarm Power Plant



Flow Chart

### 5.2.5 Greywater (Grey-1)

Residential wastewater is comprised of greywater and sewage. Sewage is the wastewater that comes from toilets, dishwashers and other sources with high organic content, whereas residential greywater comes from washing machines, bathtubs, showers, and bathroom and kitchen sinks. Nearly all domestic wastewater within PWP's service area is currently discharged to a sewer system. Greywater could be re-routed onsite for landscape irrigation.

PWP's greywater program would require new policies and increased rebates to encourage greywater use. New infrastructure required to implement this program include household greywater collection systems and onsite drip irrigation systems. Because water use is likely to remain constant during wet and dry periods, this program would have a constant average yield of 150 AFY. These projections assume approximately 4,000 homes, or 10 percent of single-


Greywater from sinks, showers, and washing machines can be used for outdoor irrigation family homes, will convert 40 percent of indoor water use to greywater.

### 5.2.6 Ocean Desalination (Desal-1)

Desalination is the treatment process that removes salts and minerals from brackish groundwater or saline ocean water to make water suitable for human consumption and industrial use. Desalination plants are typically found along coastal cities with access to seawater. To obtain access to desalinated water PWP would partner with coastal agencies that receive imported water from MWD and have ocean desalination projects. PWP would enter into an exchange agreement with a coastal agency to receive their allocation of MWD's treated imported water. In return, the coastal agency would reduce their imported water purchases and use more desalinated water to meet their demands. The project may require a new ocean desalination plant if the partnering agency does not already have one in operation. The project could produce up to 5,000 AFY.

### 5.2.7 Stormwater

Stormwater runoff from urban areas has increased over time as a result of increased impervious surfaces that have reduced the ability for precipitation to percolate into the ground. The use of stormwater as a source to augment local supplies can provide both water quality and supply benefits. Stormwater within the PWP service area, is collected in storm drains that discharge into storm channels which eventually reach the ocean. Realizing stormwater is an important local asset, agencies throughout the region have developed Enhanced Watershed Management Plans (EWMPs) to address and manage stormwater runoff. The Upper Los Angeles River Watershed EWMP addresses potential projects and concepts that can capture and directly use or infiltrate stormwater within Pasadena and the Basin.

Stormwater management can be accomplished with both centralized and decentralized projects. Centralized projects have typically larger flows and convey water to one central location, whereas decentralized projects are smaller and generally integrated in localized landscaping.

## Infiltration Galleries (SW-1)

An infiltration gallery is an underground system that expedites percolation of water into the ground. This concept proposes to install five acres of infiltration galleries under the parking lots along South Lake Avenue, shown in Figure 5.13, that would capture stormwater falling on the parking lots through catch basins that drain to the infiltration gallery below. The infiltration galleries would recharge approximately 9 AF of stormwater in an average year (based on the average rainfall over the 5 -acre area covered by the parking lots). Infiltration of stormwater could only result in a pumping credit of 10.5 percent. Based on PWP's right to 42 percent of the Raymond Basin Operating Safe Yield multiplied by the assumption that 25 percent of the infiltrated water percolates to the basin (PWP 2011), this would result in an average yield of 1 AFY.

Figure 5-13: Infiltration Galleries along South Lake Avenue


## Altadena Drain Diversion to the Arroyo Seco Spreading Grounds (SW-2)

Option SW-2 would direct stormwater from the Altadena Drain into the Arroyo Seco Spreading Grounds. The drain captures stormwater from an area of approximately 1,000 acres and flows near the spreading grounds. A treatment pond is needed prior to allowing this water to enter the groundwater. A new well may also be needed in the existing system. In an average year, the Altadena Drain diversion is expected to recharge approximately 285 AF into the Monk Hill subarea and yield 170 AFY for potable demands.

## Centralized Stormwater Capture and Conveyance to Eaton Wash for Recharge (SW-3)

Option SW-3 would capture stormwater around Rubio Wash and divert it for recharge in the existing Eaton Wash Spreading Grounds shown in Figure 5-14. This option would require new pipeline and a pump station. To pump the recharged water, a new well may be needed in the existing system. In an average year, approximately 420 AFY would be recharged in the Pasadena subarea, resulting in a groundwater pumping credit of 340 AFY for potable demands, based on the 80 percent supply credit that PWP receives for recharging to Eaton Wash Spreading Grounds (PWP 2011).

Figure 5-14: Centralized Stormwater Capture and Recharge at Eaton Wash


## Decentralized Stormwater Recharge, Tier 1 (SW-4)

Option SW-4 includes on-site stormwater capture projects that would collectively meet 50 percent of the EWMP goal to recharge the stormwater in Raymond Basin. The projects include green streets and low impact development (LID) projects and programs, such as ordinances, commercial LID, public LID, and residential LID.
To pump recharged water, a new well may be needed if pumping capacity is not available in the existing system. Based on average historic precipitation, SW-4 would recharge approximately 2,200 AFY and yield 230 AFY, assuming groundwater pumping credit of 10.5 percent.

## Decentralized Stormwater Recharge, Tier 2 (SW-5)

Option SW-5 includes on-site stormwater capture projects that would collectively meet 100 percent of the EWMP goal to recharge the stormwater in the Basin. Based on average historic precipitation. SW-5 would recharge approximately 4,300 AF and produce an average yield of 452 AFY, assuming groundwater pumping credit of 10.5 percent. These projects are not identified and would require significant investment and on-going O\&M.

### 5.2.8. Water Use Efficiency

All of the previous water supply options augment the water supplies available to PWP. Water use efficiency options implement demand management solutions that create a "conserved supply" instead of increasing supplies to meet demands. Water use efficiency involves adoption of programs and policies to use less water. PWP's 2015 UWMP includes long-term conservation practices that have been implemented in the service area. In May 2018, Assembly Bill 1668 and Senate Bill 606 became state law requiring a


Demonstration gardens provide Pasadena residents with information on how to convert to drought tolerant landscaping. reduction in indoor and outdoor water use. In an effort to stretch existing water supplies, the water efficiency bills mandate that indoor water use is reduced to 55
gallons-per-capita-per-day (GPCD) by year 2025 and to 50 GPCD by year 2030. Outdoor water use will be determined by DWR in the future. It is assumed that increased conservation will be required. Water suppliers like PWP will be responsible for the enforcement. For more details on water use efficiency options see Appendix A.

## Conservation Programming to Meet Future Regulations (WUE-0)

Option WUE-0 is a baseline water-use efficiency program that would help residential customers within the PWP service area reduce indoor and outdoor water use as it would be required by future state law. PWP estimates that the required decrease in indoor water use would need to be 1,400 AFY and the decrease in the outdoor water use would need to be 2,100 AFY (total of 3,500 AFY) by year 2030. To meet this target, a combination of passive and active conservation measures, such as rebates, public outreach and ordinances, will be implemented.

## Conservation Programming to Meet Future Regulations Plus 10 Percent Additional Outdoor Conservation (WUE-1)

Option WUE-1 would reduce water use as outlined in Option WUE-0 with an additional 10 percent reduction of outdoor use $(1,500)$. WUE-1 would decrease water demand by approximately 5,000 AFY using a combination of conservation measures, such as landscape conversions from turf to drought tolerant native plants. Indoor water use will be maintained at 50 GPCD as this is the minimum water use for health and safety.

## Conservation Programming to Meet Future Regulations Plus 25 Percent Additional Outdoor Conservation (WUE-2)

Option WUE-2 is a water-use efficiency program that would reduce indoor water use as outlined in Option WUE-0 with an additional 25 percent reduction in outdoor water use (4,000 AFY). Option WUE-2 would decrease water demand by 7,500 AFY using a combination of passive and active conservation measures specified under Option WUE-0, with increased landscape replacements, automated irrigation systems, and a water budget-based rate structure.

### 5.2.8 Groundwater

Local groundwater provides approximately


Public outreach is a key tool in reducing water demand in PWP's service area 35 percent of PWP's water demands. Groundwater pumping is controlled by the adjudicated water rights, spreading credits and long-term storage. Deteriorating infrastructure and water quality problems have made it difficult for PWP to use its full groundwater rights. Rehabilitation of existing wells, construction of new wells, treating contaminated wells and using groundwater with high nitrates for non-potable uses will allow PWP to fully use its groundwater from the Basin.

PWP is working with the RBMB and Main San Gabriel Basin to implement management practices and programs to stabilize groundwater levels in the Raymond Basin.

## Well Rehabilitation and New Well Replacement Projects, Importance Level 1 (GW-0)

Option GW-0 focuses projects to rehabilitate wells and replace old wells as identified during the well assessment (Chapter 4). Rehabilitation projects will repair existing infrastructure to improve reliability, while well replacement will construct new wells when it is not cost effective to rehabilitate an old well. The age of most of PWP wells renders rehabilitation as infeasible. Importance levels were assigned for rehabilitation and replacement projects based on several criteria, including how critical the well is, the repair history, and the need to upsize/downsize the equipment to meet demands. In general, Importance Level 1 projects address deficiencies affecting the pumping of a well that are considered critical, and Importance Level 2 projects improve the well efficiency and are needed to maintain the well operation.

This option also implements Importance Level 1 projects that improve resiliency and redundancy (including seismic upgrades and retrofits), improve energy efficiency, and address issues related to the site, security or building. Level 1 projects that are considered
critical to maintaining existing pumping capacity for potable use by drilling new wells, replacing well pumps and motors, and/or replacing the electrical and control systems.

Improvements would be made to several wells, identified in Table 5-3, so PWP can maintain historical pumping levels; without these projects, groundwater production would continue to decrease. This option would maintain an average groundwater pumping capacity of 12,700 AFY, assuming groundwater supplies are available.

## Table 5-3: Well Projects, Importance Level 1

| Well Name | Projects (Importance Level 1) |
| :--- | :--- |
| Garfield | - Drill and equip new well at this site <br> - PWP is in a process of abandoning the old well due to age and <br> contamination |
| Sunset | - Abandon due to age, production issues and contamination <br>  <br> - Replace with new well in Pasadena sub-area |
| Villa | - Replace pump, motor and motor control center <br> - Replace flowmeter <br> - Install new site control panel <br> - Major building modifications |
| Chapman | - Install generator connector <br> - Eliminate air |
| Twombly | - Install generator connector |
| Wadsworth | - Pressure sustaining/regulating valve <br> - Install generator connector |
| Woodbury | - Replace motor control center |

## Well Rehabilitation and Equipment Replacement Projects, Importance Level 2 (GW-00)

Option GW-00 would implement well rehabilitation and replacement projects to address deficiencies classified as Importance Level 2 to improve functioning of the infrastructure. Improvements include upgrading well discharge pipes, replacing electrical service, installing/replacing flowmeters, and installing new control panels at well sites. These improvements would only be required if Options GW-2 and GW-3 described in the subsequent sections are implemented.

Option GW-00 would also implement Importance Level 2 projects identified to improve resiliency and redundancy, including seismic upgrades, retrofits and energy efficiency improvements, and address issues related to the site security or building.

These improvements are assumed to be required in addition to Option GW-0 improvements. Improvements would be made at Bangham, Chapman, Villa, and Windsor wells, as identified in Table 5-4. Well 52 and Ventura upgrades would only be implemented if nitrate treatment is installed.

Table 5-4: Well Projects, Importance Level 2

| Well Name | Projects (Importance Level 2) |
| :--- | :--- |
| Ventura | - Install generator connector <br>  <br>  <br>  <br> - |
| Weill 52 | Requires nitrate treatment and major building <br> modifications |
| Windsor | - Seismic upgrades |
| - Requires nitrate treatment |  |

## Nitrate Treatment to the Monk Hill Wells (GW-2a)

Option GW-2a would add nitrate treatment to Well 52 or Ventura well in the Monk Hill subarea. The existing Monk Hill WTP, shown on Figure 2-6, treats the Monk Hill wells for perchlorate and VOCs to comply with drinking water standards. This project would produce an average potable yield of up to $2,400 \mathrm{AFY}$ by returning to service two of the Monk Hill wells.

## Nitrate, Perchlorate and Volatile Organic Compounds Treatment to the Sunset Wells (GW-2b)

An MCL is a standard set by the U.S. Environmental Protection Agency or California Division of Drinking Water that specifies the maximum contaminant level allowed in drinking water. Option GW-2b includes centralized treatment of the Sunset wells that currently require blending to meet MCLs. Nitrate, perchlorate and VOC treatment would be implemented for the Garfield, Villa, Sunset and Bangham wells or their replacements. This project would produce an average groundwater yield of 3,500 AFY to meet potable demands in absence of MWD water for blending.

## Connect High Nitrate Wells to a Local Non-Potable System (GW-3)

Option GW-3 proposes to connect the wells with high nitrate concentration to a local nonpotable system. This option allows beneficial use of groundwater without treating the water beyond the quality needed for its intended use. This option is included in Option NP-3. Depending on non-potable demands, this project in conjunction with NP-3 could produce an average water yield of 1,000 AFY.

## 6. WATER DISTRIBUTION AND STORAGE OPTIONS

The assessments described in Chapter 4, list water distribution and storage deficiencies. This chapter describes how to address those deficiencies. Instead of providing an extensive list of individual projects as common in traditional master plans, the WSRP describes programmatic options reflecting a level of importance derived from the analysis (Chapter 4) to be used as the 5 year projection in the annual budgeting process.

### 6.1 Options Development

The process for developing water distribution and storage options, illustrated in Figure 6-1, begins by grouping the different elements of infrastructure into categories of storage (reservoirs only) and distribution which include booster stations and pipelines.

Figure 6-1: Storage and Distribution Options Development Process


Specific projects were identified to address deficiencies best fulfilling the options. Costs for each project were estimated based on industry standards or local experience for each project type and scale. The projects were grouped into five categories and then were consolidated for each program level.

The projects are organized into the following five categories:

- Rehabilitation and Replacement - Projects to repair existing infrastructure or replace it if it is more cost effective than repairing. Some equipment is critical to water delivery and cannot be taken offline for an extended length of time. These projects are divided into critical projects (Importance Level 1) and needed projects (Importance Level 2) as described in Section 6.2.
- Expansions Needed to Meet Future Demands - Projects to ensure sufficient pressure and flow in the distribution system as demands increase over time.
- Energy Efficiency - Projects that will reduce the energy to produce, treat and distribute water.
- Resiliency and Redundancy - Projects that will improve the ability to respond to a disruption to the distribution and/or storage infrastructures in emergency or natural disasters.
- Site/Security/Building - Projects that will address issues in buildings or area surrounding and protecting equipment.

Projects in the storage and distribution categories provide an estimated cost of each category as shown in Table 6-1. For example, one option in the table is the critical Rehabilitation and Replacement Projects, Importance Level 1. This option is identified to address deficiencies of storage infrastructure, and has an estimated total cost of $\$ 33$ million. By integrating projects into programmatic options, PWP can make decisions based on a general level of investment and have more flexibility to select projects for its capital improvement program that better reflect changes in conditions and needs from year to year.

## Table 6-1: $\quad$ Storage and Distribution Options

| Option Categories | Storage (\$) | Distribution (\$) |
| :--- | ---: | ---: |
| Rehabilitation \& Replacement, Importance Level 1 | $33,000,000$ | $116,100,000$ |
| Rehabilitation \& Replacement, Importance Level 2 | $1,700,000$ | $177,100,000$ |
| Expansions to Meet Future Demand | Not applicable | 340,000 |
| Energy Efficiency | 300,000 | 250,000 |
| Resiliency and Redundancy | $7,100,000$ | 440,000 |
| Site/Security/Building | 630,000 | 230,000 |

### 6.2 Options Descriptions

The storage and distribution options developed for this WSRP are summarized below, and include the estimated project costs shown in Table 6-1 at programmatic levels.

### 6.2.1 Rehabilitation and Replacement

Rehabilitation and replacement projects intended to prevent infrastructure failure to ensure continued water service to PWP's customers. These projects include rehabilitating or replacement of mechanical equipment (pumps and motors, piping, reservoirs, and valves), electrical equipment (master control centers and electrical service), and controls (flowmeters and control panels).
Project importance levels were assigned based on how critical the project is, history of repairs, and need to upsize equipment to meet demand or pressure requirements. In general, Importance Level 1 projects address deficiencies that would have immediate and major impact on water system operations, and are considered critical; Importance Level 2 projects would improve and maintain functioning infrastructure and would be considered as needed.

## Storage Infrastructure Rehabilitation and Replacement

Projects to address deficiencies in storage facilities are summarized in Table 6-8; detailed information about estimated costs and importance levels are in Appendix G. The locations of each reservoir listed below are also shown on Figure 2-8.

Storage rehabilitation and replacement Importance Level 1 projects are estimated to cost $\$ 33$ million, and Importance Level 2 projects to cost $\$ 1.7$ million.

## Distribution System Rehabilitation and Replacement



Over half of the pipeline system is in need of rehabilitation or replacement

Rehabilitation and replacement projects identified to address deficiencies in the distribution system are summarized in in Appendix G. The locations of the booster stations are shown on Figure 2-11. The rehabilitation and replacement of the booster stations is summarized in Table 6-9. While specific projects were identified for each booster, pipeline rehabilitation and replacements were identified based on the risk assessment described in Chapter 4.

The most critical pipeline replacements summarized in Table 6-2 show that approximately 108 miles of pipeline ( 21 percent of the total system) were identified as Importance Level 1, while 166 miles of pipeline (33 percent of the total system) were identified as Importance Level 2 and need to be replaced to maintain the distribution system. Replacement of critical pipelines classified as Importance Level 1 is expected to take place during the first 10 years at 10 to 11 miles of pipeline per year, while the less critical pipeline replacements classified as Importance Level 2 (needed) are expected to take place over 15 years at 10 to 11 miles per year from year 2030 to 2045.

Table 6-2: Pipeline Rehabilitation and Replacement Program

| Criteria | Pipeline Rehab and Replacement Program |  |
| :--- | ---: | ---: |
|  | Importance Level 1 | Importance Level 2 |
| Pipe Length (miles) | 108 | 166 |
| Percent of Distribution System | 21 | 33 |
| Years to Replace | 10 years | 15 years |

Projects are summarized by Importance Level, and shown in Appendix G. Importance Level 1 critical projects are estimated at \$113,800,000, and Importance Level 2 Projects are estimated at $\$ 174,900,000$.

## Rehabilitation and Replacement Options Summary

There are five rehabilitation and replacement options grouped in the two importance levels summarized in Table 6-3. There are also distribution system improvements needed to meet future demand. Expanding reservoirs and booster stations to meet future demand were not identified based on hydraulic modeling results.

Table 6-3: Rehabilitation and Replacement Options

| Option | Storage (dollars) | Distribution (dollars) |
| :--- | :--- | :--- |
| Rehabilitation and Replacement, <br> Importance Level 1 | $33,000,000$ | $116,100,000$ |
| Rehabilitation and Replacement, <br> Importance Level 2 | $1,700,000$ | $177,100,000$ |

### 6.2.2 Expansions Needed to Meet Future Demand

Projects to expand the pipeline network to meet future demand were developed based on hydraulic modeling, and include projects to upsize or change the existing system, but do not include installation of new pipelines. An additional 1,720 feet (approximately 0.3 miles) of pipeline improvements are needed to meet future demand. Reservoirs and booster stations can meet future demands without expansion, based on hydraulic modeling results.

| Table 6-4: |  | Expansions Needed to Meet Future Demand Options |
| :--- | :--- | :--- |
| Option | Storage | Distribution (dollars) |
| Expansions to Meet Future Demand | Not applicable | 340,000 |

### 6.2.3 Water System Energy Efficiency

The water system energy efficiency option is a group of projects that can reduce the amount of energy needed to produce, store and distribute water. The projects include improvements to operational features at booster stations and installation of solar photovoltaic systems at some sites.

## Storage Infrastructure Energy Efficiency

One project is identified to improve energy efficiency by installing a solar photovoltaic system at Sheldon Reservoir. The estimated cost is \$300,000.

## Distribution System Energy Efficiency

Projects to improve energy efficiency in the distribution system are summarized in Appendix G. Energy efficiency projects were only identified for booster stations and not for pipelines, as pipelines on their own do not use energy. While these upgrades are similar to the rehabilitation and replacement projects described in Section 6.2.2, the recommendations in Section 6.2.2 are designed to prevent failure of infrastructure, while upgrades described here are not vital to infrastructure function.

## Energy Efficiency Options Summary

Estimated costs for two energy efficiency options are summarized in Table 6-5 below.
Table 6-5: Energy Efficiency Options

| Option | Storage (dollars) | Distribution (dollars) |
| :--- | :--- | :--- |
| Energy Efficiency | 300,000 | 250,000 |

### 6.2.4 Water System Resiliency and Redundancy

Water system resiliency projects will improve PWP's ability to respond to physical disruption of distribution and storage infrastructure, such as earthquakes, that could impact water service. Projects and estimated costs below are based on recommendations of the 2006 G\&E Seismic Vulnerability Assessment, and are updated based on projects that have been completed.

## Storage Infrastructure Resiliency

Resiliency projects to address deficiencies in storage infrastructure are summarized in Appendix G. Projects to improve resilience for storage infrastructure are estimated to cost \$7,100,000.

## Distribution System Resiliency and Redundancy

Resiliency projects identified to address deficiencies in the distribution system are summarized in Appendix G. Resiliency projects were only identified for booster stations and not for pipeline projects. In total, projects to improve resilience of the distribution system are estimated to cost $\$ 440,000$.

## Resiliency and Redundancy Options Summary

Estimated costs for the two resiliency and redundancy options (storage resiliency and redundancy option and distribution resiliency and redundancy option) are summarized in Table 6-6.

Table 6-6: Resiliency and Redundancy Options

| Option | Storage (dollars) | Distribution (dollars) |
| :--- | :--- | :--- |

Resiliency and Redundancy $7,100,000$ 440,000

### 6.2.5 Site/Security/Building Improvements

Site, security and building improvements address deficiencies in buildings housing aboveground infrastructure, security and other on-site issues not directly related to equipment.

## Storage Infrastructure Site/Security/Building Improvements

Site/security/building improvements identified to address deficiencies at storage infrastructure are summarized in Appendix G. The estimated costs for these projects is \$630,000.

## Distribution System Site/Security/Building Improvements

Site/security/building improvement projects identified to address deficiencies at distribution system infrastructure are summarized in Appendix G. This category of projects does not apply to pipelines, as they are underground. Improvements to storage infrastructure sites, security or buildings are estimated to cost \$230,000.

## Site/Security/Building Improvement Options Summary

The site/security/building improvements are summarized in Table 6-7. In total, there are two options that roll up to the site/security/building improvement projects identified above.

Table 6-7: Site/Security/Building Improvement Options

| Option | Storage (dollars) | Distribution (dollars) |
| :--- | :--- | :--- |
| Site/Security/Building Improvements | 630,000 | 230,000 |

### 6.3 Summary of Distribution and Storage Projects

Tables 6-8 and 6-9 summarize improvements at reservoirs and booster stations. These projects, along with pipeline rehabilitation and replacement and expansion, would be used to build up to the programmatic options summarized in Table 6-1.
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| Table 6-8: Reservoir Rehabilitation and Replacement Projects |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Reservoir | Rehabilitation and Replacement | Energy Efficiency | Resiliency and Redundancy | Site/Security/ Building |
| Allen | - Piping upgrades | - None | - Seismic upgrades | - Replace roof <br> - Building modifications |
| Calaveras | - None | - None | - Install seismic valves <br> - Seismic upgrades | - Minor building modifications |
| Don Benito 1 and 2 | - Piping upgrades | - None | - Seismic upgrades | - Building modifications |
| Eagle Rock | - Piping upgrades | - None | - None | - Replace roof |
| Gould East and West | - Piping upgrades | - None | - Seismic upgrades | - None |
| Jones | - Piping upgrades <br> - Reservoir lining/ recoating | - Bifurcate tank | - Seismic upgrades | - None |
| Lida | - Replace reservoir | - None | - None | - None |
| Mirador | - Piping upgrades | - None | - Seismic upgrades | - None |
| Santa Anita | - Possible replacement | - None | - Install seismic valves <br> - Seismic upgrades | - Major building modifications <br> - Replace roof |
| Sheldon 1 and 2 | - Piping upgrades | - Install solar photovoltaic system | - Install seismic valves | - None |

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> Table 6-9: Booster Station Rehabilitation and Replacement Projects
> Building
> Efficiency
> piping upgrades
> and Replacement
> - none
> Booster Station
> Atlanta
> Craig service
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| Booster Station | Rehabilitation and Replacement | Energy Efficiency | Resiliency and Redundancy | Site/Security/ Building |
| :---: | :---: | :---: | :---: | :---: |
| Glorietta | - replace pump and motor (60-150 hp) <br> - replace pump and motor (300+hp) <br> - piping upgrades | - none | - install generator connector <br> - seismic upgrades | - minor building modifications |
| Jones | - piping upgrades | - none | - seismic upgrades | - none |
| Lida | - none | - none | - install generator connector | - none |
| Linda Vista | - replace MCC <br> - replace electrical service <br> - install/replace flowmeter | - none | - install generator connector <br> - seismic upgrades | - none |
| Ross | - replace pump and motor (60-150 hp) <br> - piping upgrades <br> - replace MCC <br> - replace electrical service <br> - replace building | - none | - none | - none |
| Rutherford | - none | - piping upgrades | - install generator connector | - none |

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| Booster Station | Rehabilitation and Replacement | Energy Efficiency | Resiliency and Redundancy | Site/Security/ Building |
| :---: | :---: | :---: | :---: | :---: |
| San Rafael | - replace pump and motor (up to 50 hp <br> - replace pump and motor (60-150 hp) <br> - piping upgrades <br> - HVAC system <br> - replace MCC <br> - replace electrical service | - piping upgrades | - install generator connector <br> - seismic upgrades | - building modifications |
| Santa Anita | - replace pump and motor (200-250 hp) <br> - replace MCC <br> - replace electrical service | - piping upgrades | - install generator connector <br> - seismic upgrades | - major building modifications |
| Thomas | - replace electrical service | - piping upgrades | - install generator connector | - none |
| Ventura | - none | - none | - install generator connector | - major building modifications (install HVAC system new louvers, air flow and dust control) |

## 7. WATER SYSTEM AND RESOURCES PORTFOLIOS

To meet multiple goals and objectives, six water system and resources portfolios were established that combine supply and production, distribution, storage and other solutions into strategies. Each portfolio use unique combinations of water resource options including surface water, groundwater, imported water, stormwater and non-potable water. Options focused on water supply and production were combined with projects and programs to upgrade PWP's water system, including distribution, storage and other CIPs.

In packaging and evaluating portfolios to meet complex water resources and CIP challenges while achieving goals of the WSRP, the following were incorporated:

- Technical analysis that explored system-wide issues and solutions
- Consideration of multiple benefits and prioritization of evaluation criteria
- Processes that brought together decision-makers and stakeholders
- Processes that identified key decision points
- Exploration of risks, reliability and resiliency

The following terms are defined as use in each portfolio:

- Water Supply and Production - Identifying and accessing a water resource (imported, local, potable and non-potable), producing supply from that source (pumping, diversion and treatment), and the conservation of the supply due to its efficient use.
- Distribution System - The network of pipelines and the associated pump stations to distribute treated water within the PWP service area.
- Storage Infrastructure - Potable water storage reservoirs.
- Other CIPs - Projects and programs not included under the above categories, such as a new customer information (billing) system, community demonstration gardens, supervisory control and data acquisition system (SCADA) improvements, upgrades to the water quality lab and other buildings, and site security.
- Option - Projects and programs for rehabilitation and replacement in water supply and production, distribution and storage.
- Portfolio - A group of projects and programs that includes multiple elements of supply and production, distribution, storage and other CIP elements. and one portfolio will be selected as preferred and will be used to recommend future CIP development.
- Evaluation Criteria - A series of criteria that allows decision-makers to assess the performance of portfolios to meet WSRP goals.
- Sub-Criteria - Sub-criteria with assigned metrics aligned with the evaluation criteria that further explain the meaning of the criteria and provide more detail in defining what is being measured.
- Metrics - Variables that can be scored associated with each of the sub-criteria and criteria.

The evaluation process steps for analysis and recommendation are shown on Figure 7-1.
Figure 7-1: Portfolio Evaluation Process


### 7.1 Building Portfolios

The approach for developing WSRP portfolios was based on the use of themes. Themes organize concepts and help select options that are consistent with those concepts. Themes can also be seen as a way to reflect basic ideals or strategies for PWP's water system and future resources. This WSRP created the following six portfolios.

- Portfolio A - Staus Quo and Stormwater Capture. Continue the status quo in addition to some planned projects.
- Portfolio B - Maximize MWD Supply/Minimize Local Projects. Minimal investments locally, and increased use of MWD imported water over time.
- Portfolio C - Maximize Local Supplies. Reduce reliance on MWD imported water and increase development of local supply sources.
- Portfolio D - Maximize Sustainable Sources and Practices. Focus on sustainability and environmental stewardship to select options.
- Portfolio E - Maximize Direct Use of Stormwater and Recycled Water. Implement options that will maximize direct use of local supplies.
- Portfolio F - Sustainable Groundwater, Conservation, Stormwater Capture. Implement options that use local water for potable and non-potable supplies. This portfolio received the highest overall score and was selected for implementation in the next 25 years.

Portfolios were developed beginning with different combinations of supply and production options, and adding in distribution and storage options and the Other CIP options. The Other CIP options were included in each portfolio to capture items that may not be included but may be important to effective operations and maintenance.

Once combined, individual options were modified to remove redundancies, refine supply volumes and optimize infrastructure. For example, a portfolio that relies heavily on imported water will not include components associated with producing more local supply. Decisions about investments in distribution and storage are independent and were treated as variations which become part of any portfolio. The rate of investment to replace the aging network of pipelines, for example, is a decision to be made during the CIP development all portfolios.

### 7.2 Overview of Portfolios

Each portfolio has a different combination of Supply and Production, Distribution and Storage options. Since there is only one Other CIP option considered vital to a functioning utility, it is included in all portfolios. Options mandated by regulations are also included in all portfolios.

## Other CIP Option

Chapters 5 and 6 of this WSRP described a number of options related to supply and production, distribution system and storage infrastructure, but there are a number of other projects and programs necessary for the efficient and effective operation of the water utility. Examples include:

- Improvements to the water quality lab
- New customer information (billing) system
- Community demonstration gardens
- Automated metering infrastructure (AMI)
- Building improvements
- SCADA system

Since these items can change from year to year, one option was used to represent "Other CIP," and was given a general cost

### 7.2.1 Portfolio A - Status Quo and Stormwater Capture

Portfolio A assumes continuation of the status quo in addition to some planned projects, meaning that PWP continues using its current supplies and continues with the same level of storage and distribution system repairs, replacements and maintenance. This portfolio assumes no investment in new supply or production options.

Table 7-1 lists the options included in Portfolio A, and estimated capital costs.

Figure 7-2: Components of a WSRP Portfolio


Table 7-1: Portfolio A - Status Quo and Stormwater Capture


### 7.2.2 Portfolio B - Maximize MWD Supply/Minimize Local CIP

Portfolio B includes only minimal investments made locally and increased reliance on imported water from MWD. This portfolio assumes that no new local supply projects will be implemented. As imported water use will be maximized, projects to rehabilitate and replace wells will not be implemented, and wells will be taken offline as they reach the end of their service life. In this portfolio, over time PWP becomes completely reliant on imported water.

All critical and needed rehabilitation and replacement options for the storage and distribution system are included in Portfolio B, which assumes that PWP invests in maintaining existing storage and distribution infrastructure. While reduced local investments will be made, PWP will rely entirely on MWD for supply reliability and resiliency.

Table 7-2 lists the options included in Portfolio B and their estimated capital costs.

Table 7-2: Portfolio B - Maximize MWD Supply/Minimize Local CIP


## Distribution

| Distribution Program Components | Capital Cost |  |
| :--- | ---: | ---: |
| Distribution Rehabilitation and Replacement, Importance Level 1 |  | $\$ 116,100,000$ |
| Distribution Rehabilitation and Replacement, Importance Level 2 |  | $\$ 177,100,000$ |
|  | Total | $\$ \mathbf{\$ 2 9 3 , 2 0 0 , 0 0 0}$ |
| Storage |  |  |
|  | Storage Program Components | Capital Cost |
| Storage Rehabilitation and Replacement, Importance Level 1 |  | $\$ 33,000,000$ |
| Storage Rehabilitation and Replacement, Importance Level 2 | $\$ 34,700,000$ |  |
|  |  |  |
| Other CIP | Capital Cost |  |
|  | Total | $\$ 15,000,000$ |
| Other CIP Components |  |  |

### 7.2.3 Portfolio C - Maximize Local Supplies

Portfolio C minimizes reliance on MWD imported water and maximizes local supplies. This portfolio includes increased groundwater production, increased local surface water recharge, groundwater storage, stormwater capture and maximizing use of non-potable resources. The increase in local supply use would require improvements to the groundwater production and construction of treatment plants to remove nitrate, perchlorate and other chemicals.

As Portfolio C increases reliance on local supplies, it is assumed that PWP will implement all necessary rehabilitation and replacement projects identified for the storage and distribution system to ensure continued reliable water delivery to customers. In addition, options to expand the distribution system to meet future demands and options to improve resiliency in storage and distribution infrastructure will be implemented.
Table 7-3 lists the options included in Portfolio C, and their estimated capital costs.

## Table 7-3: Portfolio C - Maximize Local Supplies



## Distribution

| Distribution Program Components | Capital Cost |
| :---: | :---: |
| Distribution Rehabilitation and Replacement, Importance Level 1 | \$116,100,000 |
| Distribution Rehabilitation and Replacement, Importance Level 2 | \$177,100,000 |
| Expansions Needed to Meet Future Demands | \$340,000 |
| Distribution Resiliency and Redundancy | \$440,000 |
| Total | 293,980,000 |
| Storage |  |
| Storage Program Components | Capital Cost |
| Storage Rehabilitation and Replacement, Importance Level 1 | \$33,000,000 |
| Storage Rehabilitation and Replacement, Importance Level 2 | \$1,700,000 |
| Storage Resiliency and Redundancy | \$7,100,000 |
| Total | \$41,800,000 |
| Other CIP |  |
| Other CIP Components | Capital Cost |
| Other CIP Components | \$15,000,000 |
| Total | \$15,000,000 |

### 7.2.4 Portfolio D - Maximize Sustainable Sources and Practices

Portfolio D focuses on sustainability and environmental stewardship while selecting options to build the portfolio. The portfolio includes supply and production options that match water quality to its end use, and using non-potable water (drinking water wells with nitrate levels exceeding the drinking water standards, tunnel water or home greywater systems) for irrigation.

Energy use directly correlates to the production of greenhouse gases, which contribute to climate change. Since importing water through the SWP and CRA and treating wastewater effluent at LAG-WRP are energy intensive, Portfolio D includes more local, less energy intensive supplies.

Similar to Portfolio C, Portfolio D includes improvements to groundwater production to maximize groundwater pumping, including rehabilitation and replacement projects, and construction of treatment plants to remove nitrate and organics. As the best way to reduce energy consumption and greenhouse gas production is to use less water, this portfolio includes a high level of water use efficiency (Option WUE-2), in keeping with the theme of sustainable practices.

To increase the reliance on local supplies PWP would invest further in the storage and distribution systems to ensure continued delivery reliability to customers. All critical and
needed rehabilitation and replacement options will be implemented for the storage and distribution infrastructure, in addition to implementing the option to expand the distribution system to meet future demands. Portfolio D also includes the option to enhance local resiliency to supply disruption by implementing projects to improve distribution system and storage infrastructure resiliency.

Table 7-4 lists the options included in Portfolio D, and estimated capital costs.
Table 7-4: Portfolio D - Maximize Sustainable Sources and Practices


| Distribution |  |  |
| :---: | :---: | :---: |
| Distribution Program Components |  | Capital Cost |
| Distribution Rehabilitation and Replacement, Importance Level 1 |  | \$116,100,000 |
| Distribution Rehabilitation and Replacement, Importance Level 2 |  | \$177,100,000 |
| Expansions Needed to Meet Future Demands |  | \$340,000 |
| Distribution Resiliency and Redundancy |  | \$440,000 |
| Distribution Energy Efficiency |  | \$250,000 |
|  | Total | \$294,230,000 |
| Storage |  |  |
| Storage Program Components |  | Capital Cost |
| Storage Rehab/Replacement, Importance Level 1 |  | \$33,000,000 |
| Storage Rehab/Replacement, Importance Level 2 |  | \$1,700,000 |
| Storage Resiliency and Redundancy Projects |  | \$7,100,000 |
|  | Total | \$41,800,000 |
| Other CIP |  |  |
| Other CIP Components |  | Capital Cost |
| Other CIP Components |  | \$15,000,000 |
|  | Total | \$15,000,000 |

### 7.2.5 Portfolio E - Maximize Direct Use of Stormwater and Recycled Water

Supply and production options that maximize stormwater and recycled water for irrigation and potable use are included in this portfolio, particularly local supplies for recharge and direct use, low-cost stormwater projects, and tunnel water. This portfolio includes options to purchase imported water rights when the market is favorable, and use advanced treated recycled water for direct potable use. Investment in water use efficiency is minimized due to the high cost of implementing high levels of conservation. Portfolio E includes investment in local groundwater production and treatment to allow for maximizing of groundwater rights and use of recharged water.

Portfolio E includes investments in the distribution and storage systems to maintain reliable delivery in the future. All rehabilitation and replacement projects for storage and distribution infrastructure would be implemented, as well as projects to expand the distribution system to meet future demands.

Table 7-5 lists the options included in Portfolio E, and estimated capital costs.

Table 7-5: Portfolio E - Maximize Direct Use of Stormwater and Recycled Water


| Distribution |  |  |
| :---: | :---: | :---: |
| Distribution Program Components |  | Capital Cost |
| Distribution Rehabilitation and Replacement, Importance Level 1 |  | \$116,100,000 |
| Distribution Rehabilitation and Replacement, Importance Level 2 |  | \$177,100,000 |
| Expansions Needed to Meet Future Demands |  | \$340,000 |
|  | Total | \$293,540,000 |
| Storage |  |  |
| Storage Program Components |  | Capital Cost |
| Storage Rehabilitation and Replacement, Importance Level 1 |  | \$33,000,000 |
| Storage Rehabilitation and Replacement, Importance Level 2 |  | \$1,700,000 |
|  | Total | \$34,700,000 |
| Other CIP |  |  |
| Other CIP Components |  | Capital Cost |
| Other CIP Components |  | \$15,000,000 |
|  | Total | \$15,000,000 |

### 7.2.6 Portfolio F - Sustainable Groundwater, Conservation, Stormwater Capture

Portfolio F emphasizes the Basin as an asset for recharge and potable production, and as a source of non-potable supply. This portfolio maximizes use of local surface water as a non-potable source. This option also implements a non-potable system that uses Arroyo Seco water, tunnel water and high nitrate groundwater for irrigation and recharge. Portfolio F also implements a groundwater storage program to store imported water for use during droughts or emergencies, and to further maximize use of the Basin. As a result of increased recharge, several options are included to upgrade groundwater production, including rehabilitation and replacement of wells, and construction of nitrate and organics treatment facilities. Finally, this option assumes that the outdoor water conservation will be $10 \%$ greater than what the future regulations will require.

Options to improve storage and distribution infrastructure are kept to the level required to maintain reliable delivery into the future, meaning all rehabilitation and replacement projects would be implemented at storage and distribution infrastructure, as well as projects to expand the distribution system to meet future demands.

This portfolio received the highest score and was selected for implementation.
Table 7-6 lists the options included in Portfolio F and estimated capital costs.

## Table 7-6: Portfolio F - Sustainable Groundwater, Conservation, Stormwater Capture

| Category |  | Capital Cost |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Supply \& Production |  | \$76,300,000 | \$41,800,000 |  |
| Distribution |  | \$293,980,000 |  | - Supply and |
| Storage |  | \$41,800,000 |  |  |
| Other CIP |  | \$15,000,000 |  |  |
| Total |  | 427,080,000 |  | - Storage |
| Supply and Production |  |  |  |  |
| Option |  | Supply and Production Program Components |  | Capital Cost |
| IW-0 | Treated Imported Water from MWD |  |  | 0 |
| IW-2 | Pasadena Groundwater Storage Program |  |  | \$16,000,000 |
| LSW-0 | Arroyo Seco Canyon Project |  |  | \$7,400,000 |
| LSW-1a | Arroyo Seco to Eaton Canyon Raw Water Pipeline |  |  | \$6,600,000 |
| LSW-1 | Arroyo Seco Pump Back Project |  |  | \$4,000,000 |
| LSW-5 | Natural infrastructure |  |  | 0 |
| NP-3 | Local Non-Potable Project |  |  | \$10,000,000 |
| WUE-1 | Conservation Programs to Meet Future Regulations Plus 10\% Additional Outdoor Conservation |  |  | \$12,000,000 |
| Base GW | Current Groundwater Production |  |  | 0 |
| GW-0 | Well Projects, Importance Level 1 |  |  | \$6,500,000 |
| GW-00 | Well Projects, Importance Level 2 |  |  | \$400,000 |
| GW-2a | Add Nitrate Treatment to the Monk Hill Wells |  |  | \$7,500,000 |
| GW-2b | Nitrate, Perchlorate and VOC Treatment to the Sunset Wells |  |  | \$2,900,000 |
| GW-3 | Connect High Nitrate Wells to a Local Non-Potable System - in conjunction with NP-3 |  |  | \$3,000,000 |
|  |  |  |  |  | \$76,300,000 |


| Distribution Program Components |  | Capital Cost |
| :---: | :---: | :---: |
| Distribution Rehabilitation and Replacement, Importance Level 1 |  | \$116,100,000 |
| Distribution Rehabilitation and Replacement, Importance Level 2 |  | \$177,100,000 |
| Expansions Needed to Meet Future Demands |  | \$340,000 |
| Distribution Resiliency and Redundancy |  | \$440,000 |
|  | Total | \$293,980,000 |
| Storage |  |  |
| Storage Program Components |  | Capital Cost |
| Storage Rehabilitation and Replacement, Importance Level 1 |  | \$33,000,000 |
| Storage Rehabilitation and Replacement, Importance Level 2 |  | \$1,700,000 |
| Storage Resiliency and Redundancy |  | \$7,100,000 |
| Total |  | \$41,800,000 |
| Other CIP |  |  |
| Program Components |  | Capital Cost |
| Other CIP Components |  | \$15,000,000 |
|  | Total | \$15,000,000 |

### 7.3 Evaluation Process

As this WSRP has multiple goals and objectives (discussed in Chapter 3), a multi-criteria evaluation method was designed to compare portfolios and to test each portfolio's ability to achieve those goals and objectives. Essential to this method is defining criteria and metrics to assess portfolio performance. This method scores each portfolio on various criteria, accounting for the relative importance of criteria to compute an aggregated final score. Portfolios are then compared by that single comprehensive score to make planning decisions. Criteria and sub-criteria were developed based on the objectives established at project onset with stakeholders and PWP.

### 7.3.1 Criteria

In applying a multi-criteria evaluation method, the number of criteria must be manageable, and criteria must adhere to basic principles. Criteria need to exhibit the following traits:

- Understandable - Decision-makers need to know what is being measured. The use of sub-criteria is common as a way to explain criteria in more detail.
- Quantifiable by quantitative or qualitative methods - At least one metric needs to be established for each criteria or sub-criteria. If no quantitative method is feasible to score a portfolio, a qualitative scale based on objective information needs to be established.
- Non-redundant - Each criteria, sub-criteria and metric needs to measure a distinct element of the portfolio.

Sub-criteria, shown in Table 7-7, are used not only to help better define the criteria, but also to account for water supply and production elements, and elements related to capital investments in the water system. For example, the Supply Reliability and Resiliency criteria includes three sub-criteria that distinguish between the reliability of sources on a long-term basis, their reliability in an extended emergency and the ability of the water system to sustain or quickly resume a level of service under short-term emergencies and shutdowns.

An additional key element in this analysis is the weight, or relative importance, assigned to criteria. In addition, sub-criteria weightings reflect relative importance within each criteria. Table 7-7 presents the metrics and weights for the criteria and sub-criteria used in this analysis. Weights are also shown on Figure 7-9. These weights were developed using a simple weighting exercise completed by stakeholders and PWP, the results of which are provided in Appendix H.
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| \# | Criteria | Criteria Weight (\%) | Sub-Criteria | SubCriteria Weight | Metric |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | Supply <br> Reliability and Resiliency | 18 | 1a) Long-Term Reliability | 37\% | Percent of time demand is met |
|  |  |  |  |  | Average shortage |
|  |  |  | 1b) Long-Term Disruption Resiliency | 26\% | Shortage during disruptions - 12 to 24 months |
|  |  |  | 1c) Emergency Resilience | 37\% | Redundancy score (derived from resulting distribution system in each alternative) |
| 2 | Health and Safety | 21 | 2a) Water Quality (Potable) | 50\% | Change in salinity of groundwater basin |
|  |  |  |  |  | Nitrate or VOC treatment implemented |
|  |  |  | 2b) Level of Service / Risk of Failure | 50\% | Dollar value of distribution and storage improvements, or percent of overall R/R invested |
| 3 | Environmental Stewardship | 10 | 3a) Water Quality (enviro) | 50\% | Volume of urban runoff captured |
|  |  |  | 3b) Energy Efficiency / Carbon Footprint | 50\% | Dollar value of "energy efficiency" improvements |
|  |  |  |  |  | Carbon footprint/energy intensity of new sources |
| 4 | Cost | 11 | 4a) Unit cost | 50\% | Unit cost of portfolio |
|  |  |  | 4b) Capital cost | 50\% | Capital cost of portfolio |
| 5 | Self-Sufficiency | 11 | 5a) Local Portfolio | 50\% | Percent of supply portfolio derived locally |
|  |  |  | 5b) Effect Basin Management | 50\% | Recharge to pump ratio |
| 6 | Regional Collaboration | 4 | n/a | n/a | Number of new partnerships or agreements |

## Table 7-7: Criteria, Sub-Criteria and Weights Used in the Evaluation of Portfolios

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| \# | Criteria | Criteria <br> Weight <br> (\%) | Sub-Criteria |  | Sub- <br> Criteria <br> Weight |
| :--- | :--- | :---: | :--- | :---: | :--- |

Figure 7-3: Portfolio Evaluation Criteria Weightings


### 7.3.2 Evaluation and Scoring

After portfolio evaluation criteria and metrics were developed, a point system was created to provide a numerical scoring mechanism for each metric. After the portfolios were scored for each metric, the sub-criteria weightings were applied, and sub-criteria scores were summed to generate an overall point score for each criteria. Criteria weightings were applied to these scores and summarized to generate a single score for each portfolio. Referred to here as a "decision score," this number represents the overall performance of each portfolio. Performance in this context is the ability of each portfolio to achieve objectives established during the planning period. The point system and resulting scores for each portfolio are provided in Appendix H.

This multi-criteria evaluation was conducted using tools and information developed specifically for this WSRP, and are described in Appendix H. Evaluation results (i.e., the total score for each portfolio) became the key input for decision-making.

Figure 7-4 illustrates the steps involved in the evaluation process discussed in this chapter and previous chapters, from forming portfolios through evaluation and selection of the preferred portfolio.

Figure 7-4: Overall Evaluation Process


### 7.4 Portfolio Ranking Results

Once completed, evaluation results are most helpful to decision makers when they highlight the differences between portfolios in their ability to meet WSRP objectives. Each portfolio holds different degrees of reliability, cost effectiveness, local control, water quality protection, etc. This section presents the evaluation results based on each portfolio's overall score. A more detailed comparison of results is provided in Appendix H .

Figure 7-5 presents the total score for each portfolio, with each color in a bar representing one criteria. In each case, the more of a given color representing a criteria, the higher the portfolio scores for that criteria. Figure 7-5 shows not only which portfolios score well, but why.

Portfolios A and B are noticeably lower in overall scoring relative to the other four portfolios, even as these portfolios have the best scores under the cost criteria. These two portfolios do not implement options to increase use of local supplies, nor do they implement the level of system improvements that increase reliability and resiliency. While this leads to better cost, it also leads to poorer performance under all other criteria.
Also notable on Figure 7-5 are the highest scoring portfolios. Portfolios C and F are similar in total score, given their reliance on local supply over imported water. While Figure 7-5 presents a useful way to view overall scores and generally compare performance under specific criteria, in order to select a single preferred portfolio, additional analysis was completed to better understand nuances. This analysis is described in Section 7.5.

Figure 7-5: Portfolio Scoring Results


### 7.5 Selecting a Portfolio

This WSRP process was designed to include discussions and evaluation of results internally with PWP and stakeholders to scrutinize and interpret these multi-criteria evaluation results. For a planning project with the importance and relevance of the WSRP, an aggregated numerical index from quantitative analysis cannot dictate a final decision alone, even though it represents an invaluable parameter for decision-making.

To facilitate decision-making, individual and combined scores were used in a tradeoff analysis to present and discuss the pros and cons of portfolios with stakeholders. The basis of any tradeoff analysis is the comparison of two criteria (typically graphically) to observe the relationship between them. Figure 7-6 illustrates a generic tradeoff curve, indicating how to interpret them. Generally, the top-right area of the chart is the quadrant where the best portfolios will fall, while the bottom-left quadrant will include the least desirable portfolios. In the example in Figure 7-6, the purple portfolio is clearly less desirable than the green portfolio, because the green portfolio achieves a greater reliability at a better cost.

Figure 7-6: Generic Tradeoff Curve


Figure 7-7 applies Portfolios A through F in this trade-off matrix. The $x$ axis is a composite of criteria for cost-effectiveness and complexity, given that they exhibit a highly correlated response in the evaluation. Comparing these two against all of the remaining criteria combined highlighted obvious trade-offs.

Portfolios A and B, while more cost-effective and simpler to implement as they do not involve any new supply projects, score poorly under all other criteria due primarily to their higher reliance on imported water. This leads to the overall low scores of Portfolios A and $B$ shown on Figure 7-5. The remaining portfolios, while more complicated and costly due to the number of new supply projects and system improvements included, are more wellrounded in terms of the other criteria.

Figure 7-7: Portfolio Cost-Effectiveness and Complexity vs. All Other Criteria


The next trade-off comparison, shown in Figure 7-8, compares cost versus reliability. Given that Portfolios A and B were clearly underperforming as compared to the remaining four portfolios, the focus of this trade-off is on Portfolios C, D, E and F. The comparison of cost versus reliability shows that Portfolios C, E and F all have similar cost scores, but vary in terms of reliability. Portfolio E earned a lower reliability score compared to Portfolios C and F due to fewer projects that will store water in the Basin and no implementation of projects to improve system resiliency, meaning that there will be a greater disruption to supplies in an emergency. Also shown in Figure 7-8 is the cost of Portfolio D as compared to the other portfolios. Portfolio D received a poor score under the cost criteria. This is due to implementation of options that, while more sustainable and environmentally friendly, such as greywater systems, urban stormwater capture and high levels of conservation, are more expensive than other options. In addition, Portfolio D is also less reliable than Portfolios $C$ and $F$ as it implements fewer options that would help PWP respond to a supply emergency.

Figure 7-8: Portfolio Cost vs. Reliability


Based on the above two trade-off analyses, Portfolios C and F out-perform all other portfolios. While they implement many of the same options, certain differences lead to trade-offs between criteria, specifically environmental stewardship and flexibility versus reliability and community values. Figure 7-9 shows that while Portfolio C received better scores under the environmental stewardship and flexibility criteria, Portfolio F received better scores under the reliability and community values criteria. The differentiation between these two portfolios can be seen when weightings are applied, where the high
weighting applied to reliability results in Portfolio F receiving a higher overall score than Portfolio C.

Overall, while Portfolios C and F have similar cost-effectiveness and complexity scores, Portfolio F outscores Portfolio C in all other criteria. Portfolio F is also lower in capital costs by approximately $\$ 90$ million, which can represent a significant advantage not measured in this analysis but in terms of implementation. Portfolio F also introduces nonpotable supply for non-potable demands, making use of existing resources.

Results of ranking and tradeoff analysis were presented to stakeholders in a workshop setting with significant discussion about specific elements of the different portfolios and their performance. Portfolio F was selected as the preferred portfolio for implementation in the coming years. Portfolio F was judged to best meet WSRP objectives, as described further in Chapter 8 as it relates to portfolio implementation.

Figure 7-9: Portfolio Environmental/Flexibility vs. Reliability/Community Values


## 8. IMPLEMENTATION

As discussed in Chapter 7, Portfolio F - Maximize Value of the Groundwater Basin and Non-Potable Supplies was selected as the preferred portfolio. This preferred portfolio reflects a backlog of rehabilitation and replacement projects, and to meet 12 to 24 months of demand in the event of an MWD imported water interruption. This portfolio focuses on the use of the Basin for storage and maximizing local supplies. This approach is implemented by aligning treatment levels to end uses through a local non-potable project.

The preferred portfolio was optimized based on feedback from the stakeholder group to ensure it aligns with community values, as well as modeling to ensure water is delivered efficiently and reliably. The preferred portfolio options are summarized below, and are described in more detail in Chapters 5 and 6 . The preferred portfolio consists of existing supply and production options, including current groundwater production and imported MWD water, plus options that will require capital improvements and new programs.

Table 8-1: Preferred Portfolio Options

| Option | Summary | Capital <br> Cost |
| :--- | :--- | ---: |
| Supply and Production | Continue purchase of treated imported water <br> from MWD. No new facilities, no capital costs. | 0 |
| Treated, imported <br> water from MWD | Recharge imported water in the Basin via new <br> ASR wells, in lieu pumping during wet periods | Million |
| Pasadena GW Storage <br> Program | Replace diversion structure, build 3 acres of <br> spreading basins and 1 sedimentation basin. | Million |
| Arroyo Seco Canyon <br> Project | Use existing and new pipelines and construct a <br> new pump station to convey Arroyo Seco stream <br> water following storm events from the reservoir <br> pool behind Devil's Gate Dam to the Eaton Wash <br> Spreading Grounds. | Million |
| Arroyo Seco to Eaton <br> Canyon Raw Water <br> Pipeline | Install a new pump system and controls at the <br> dam, and a new pipeline from the Devil's Gate | \$4 <br> Dam to Arroyo Seco Spreading Grounds to pump <br> stream water stored behind the dam. |
| Arroyo Seco Pump <br> Back Project | Construct a local non-potable system that uses <br> tunnel water and high-nitrate groundwater for <br> non-potable use. Includes the connection of high <br> nitrate wells. | Million |
| Local Non-Potable |  |  |
| Project |  |  |


| Natural Infrastructure | Arroyo Seco watershed management improvements to increase water percolation. An ongoing program with only O\&M costs. | 0 |
| :---: | :---: | :---: |
| Conservation Program <br> - Meet Regulations <br> Plus 10\% Outdoor <br> Decrease | Implement new conservation programs to meet future regulations, plus 10 percent additional outdoor conservation. | \$12 <br> Million |
| Current Groundwater Production | No new facilities are necessary for this option, and there are no capital costs. | 0 |
| Well Rehabilitation and Replacement Program, Importance Level 1 | Critical projects, \& projects to improve resiliency \& redundancy, energy efficiency \& site/security/building will be made at seven wells. | $\$ 6.5$ <br> Million |
| Well Rehabilitation and Replacement Program, Importance Level 2 | Not critical projects for operation of the wells, or to improve resiliency \& redundancy, energy efficiency \& site/ security / building to six wells. | \$0.4 <br> Million |
| Nitrate Treatment for the Monk Hill Wells | Nitrate treatment to one of two of the Monk Hill wells. | $\begin{gathered} \$ 7.5 \\ \text { Million } \end{gathered}$ |
| Nitrate, Perchlorate and VOC Treatment to the Sunset Wells | Add centralized treatment for the Sunset wells. | $\begin{gathered} \$ 2.9 \\ \text { Million } \end{gathered}$ |
| Distribution |  |  |
| Distribution <br> Rehabilitation and Replacement Program, Importance Level 1 | Critical projects to repair \& replace pipelines and booster stations made on 108 miles of pipeline and 5 boosters. | \$116.1 <br> Million |
| Distribution <br> Rehabilitation and Replacement Program, Importance Level 2 | Not critical projects to rehabilitate \& replace 166 miles of pipelines \& 10 booster stations. | \$177.1 Million |
| Distribution Improvements to Meet Future Demands | Projects to expand the distribution system to meet future demands. | $\$ 0.3$ <br> Million |
| Distribution Resiliency and Redundancy Improvement Program | Improvements to 13 booster stations to improve the ability to respond to a physical disruption to distribution (earthquakes), \& impact water service. | \$0.4 <br> Million |


| Storage |  |  |  |  |
| :--- | :--- | :---: | :---: | :---: |
| Storage R\&R Program, <br> Importance Level 1 | Critical projects, including Sunset Reservoir <br> replacement. | $\$ 33$ <br> Million |  |  |
| Storage Rehabilitation <br> and Replacement <br> Program, Importance <br> Level 2 | Not critical projects to repair and replace <br> reservoirs, including Lida Reservoir replacement. | $\$ 1.7$ <br> Million |  |  |
| Storage Resiliency and <br> Redundancy <br> Improvement Program | Improvements to 10 reservoirs to improve the <br> ability to respond to a physical disruption to <br> storage infrastructure \& impact water service. | $\$ 7.1$ <br> Million |  |  |
| Other CIP | Other projects and programs necessary for the <br> efficient and effective operation of the water <br> utility. | $\$ 15$ <br> Million |  |  |
| Other CIP <br> Components |  |  |  |  |

While in the past PWP has relied only on groundwater and imported water, the preferred portfolio includes use of local non-potable water for irrigation. PWP will need additional funding higher than the current 5 -year CIP to fund distribution and storage infrastructure rehabilitation and replacement programs. The implementation plan presented here includes the following four components:

- Policies - Policies are necessary to provide the overarching strategies to support implementation of the selected portfolio that will be adopted by the City Council. Policies are supported by specific enabling statements.
- Scheduling and Phasing - Scheduling and phasing of when options will be implemented, including near-term (2020-2024), mid-term (2025-2030), and longterm (2030-2045) time periods.
- Finances and Funding - Potential funding needed to implement the selected portfolio, including CIP needs, sources of outside funding, financing of debt, and funding of operations and maintenance costs.
- Tracking and Adapting - The WSRP must have a process for measuring progress of its implementation and performance. The process should be adaptable to both internal and external changes in conditions.


### 8.1 Policies

Successful implementation of the preferred portfolio will require adoption of a set of policies and enabling statements that will provide the foundational support to meet WSRP goals and objectives. Policies are defined as overarching strategies that provide the
political support necessary to implement key aspects of the WSRP program. The policies will be adopted by the City Council as part of adopting the WSRP, and align with the goals and objectives defined in Chapter 3. Since policies are more general, enabling statements provide specifics within policy categories that support each policy.

Figure 8-1 lists WSRP policies and enabling statements developed based on the goals and objectives defined in Chapter 3, the implementation needs of the preferred portfolio, and input from the stakeholder advisory committee.

Figure 8-1: Policies and Enabling Statements

## Policy 1: Protecting and developing local water supplies

- Managing surface flows and groundwater for the highest and best use
- Promoting beneficial use sources in the local water cycle, both natural and urban


## Policy 2: Maximizing the value and improving the health of Raymond Basin

- Securing and restoring groundwater quality and production
- Investing in recharge and recovery solutions
- Improve management and control strategies for local and adjacent basins


## Policy 3: Promoting the efficient and beneficial use of resources

- Implementing a comprehensive non-potable program
- Achieving indoor and outdoor conservation goals
- Operating efficiently
- Capitalizing on local, clean energy potential


## Policy 4: Investing in infrastructure to sustain an excellent level of service

- Funding the gap in infrastructure rehabilitation and replacement needs
- Funding emergency resilience strategies
- Adopting asset management principles


## Policy 5: Prioritizing customer relations and fiscal stewardship

- Evolving the current rate model into a service-based rate model
- Providing transparent fiscal stewardship
- Fostering a culture of public education and engagement


## Policy 6: Facilitating inter-departmental and regional cooperation

- Supporting watershed and inter-basin stewardship and regional planning
- Partnering on regional system connections and resource development


## Policy 7: Investing in our people

- Creating great jobs and careers for our employees
- Providing opportunites for development, engagement and recognition
- Planning for generational equity


### 8.2 Phasing Schedule and Considerations

The project team has developed a phased implementation strategy that lays out recommended near- to mid-term schedules for each of the options included under Portfolio F. This schedule, provided in Figure 8-2, incorporates timeframes for planning, design, permitting and environmental review and construction/implementation of each option. Options that are already underway or address critical infrastructure needs have been scheduled to begin in the near-term. Options that have not yet gone through the planning and/or design phases, or are less time critical, are set to be implemented in the mid- to long-term time period. Continued purchase of imported MWD water and natural infrastructure are not included on this schedule as no capital expenditures are required to implement them.

Certain challenges and assumptions must be considered to ensure successful implementation of Portfolio F. For example, rehabilitation/replacement projects and the conservation program rely on consistent implementation over the course of several years to be successful. Table 8-2 provides a listing of these considerations.

As options move toward implementation, these considerations will be reviewed to determine how this schedule may need to be updated, and how options will be incorporated into future CIPs.
Final
Water System and Resources Plan

Table 8-2: Implementation Considerations Option Considerations

| Option | Considerations |
| :--- | :--- |
| Pasadena Groundwater <br> Storage Program | - Requires an ability to come to agreement with <br>  <br> - MWD to obtain imported water in wet years |
|  | Dependent on RBMB allowing long-term storage <br> - <br> for replenishment water |
|  | Imported water volume to be recharged could be <br> constrained by salt and nutrient limits set in the |
| Basin Salt and Nutrient Management Plan |  |


| Option | Considerations |
| :---: | :---: |
| Sunset Nitrate, Perchlorate and VOC Treatment | - Requires permits from regulatory agencies |
| Distribution Projects, Importance Level 1 | - Assumes pipeline replacement at 10-11 miles/year <br> - Assumes boosters projects spaced out |
| Distribution Projects, Importance Level 2 | - Assumes pipeline replacement at 10-11 miles/year <br> - After Importance Level 1 projects |
| Distribution Improvements to Meet Future Demands | - Demands should be re-assessed in future years for new developments throughout the City |
| Distribution Resiliency and Redundancy | - Implementation of all recommendations in the Seismic Vulnerability Assessment (G\&E 2006) |
| Storage Projects, Importance Level 1 | - Sunset Reservoir replacement in the near-term |
| Storage Projects, Importance Level 2 | - Assumes remaining reservoir upgrades to take place following Level 1 |
| Storage Resiliency and Redundancy | - Assumes all recommendations in the Seismic Vulnerability Assessment (G\&E 2006) implemented |
| Other CIP Components | - As needed projects during CIP development |

### 8.3 Financing and Funding

The phasing schedule provided in Section 8.2 allows for an estimation of the financing and funding required to implement the preferred portfolio, which has a total estimated cost of $\$ 430$ million (in 2019 dollars). The following discussion and charts lay out the annual funding and financing necessary to implement the preferred portfolio. In each chart, one bar represents an annual dollar amount for the near term (2020-2024). Midterm years are represented by an average annual bar for the 5 -year increments of 20252029 and 2030-2034. Long-term years are represented by an average annual bar for the 5 -year increments of 2035-2039, and 2040-2044.

Figure $8-3$ shows the annual capital expenditures needed to implement each category of options (i.e., supply and production, distribution, storage and other CIP). The capital expense required each year is estimated based on the capital cost of each option applied over the schedule described in Section 8.2. The capital needs chart reflects the time needed to ramp up projects, and considers that more capital funds are needed in the near term to implement the preferred portfolio. In addition, the chart reflects steady implementation of distribution system rehabilitation and replacement options, and other CIP components over the long-term.

Figure 8-3: Estimated Capital Needs for the Preferred Portfolio


To address capital needs, PWP expects to use a combination of rate revenues, including future rate increases and outside funding (i.e., grants and low-interest loans). The remaining capital needs will be financed Existing rate revenue, generated from the current rate structure, provides an estimated $\$ 12$ million per year for PWP to use for capital expenditures. Outside funding is assumed to pay for 10 percent of the CIP. A future rate revenue increase of 5 percent over five years is also assumed, allowing for an additional $\$ 3$ million per year by 2029. The existing rate, outside funding and future increased rate revenue, defined here as direct funds, will not be sufficient to address all capital funds for implementing the WSRP. The remaining portion, totaling $\$ 62.4$ million, is expected to be paid for through debt financing.

While the above chart illustrate the annual capital expenditures needed to implement the preferred portfolio, financing a portion will mean that debt will be incurred and payments will be made over time, as opposed to pay-as-you-go financing, when capital projects are paid for as they are implemented. Figure 8.4 illustrates how expenditures to implement the preferred portfolio might look if the financed portion is paid off at a 3 percent interest rate over 30 years. The blue-gray portion of the bars represent direct annual funding (equivalent to all of the green portion of the bars on Figure 8-3), with the additional red
hashed areas representing the new CIP debt service from financing. PWP will evaluate funding and financing options as projects move forward to determine the best pathway for WSRP implementation.

Figure 8-4: Projected Annual Capital Revenue Requirements, Including Debt Service


The above capital revenue requirement and debt service chart reflect only the expenditures expected to pay for the new capital projects in the preferred portfolio. In addition to the direct revenue and debt service associated with the Preferred Portfolio, PWP will need to continue to pay existing CIP debt service and address ongoing maintenance of infrastructure beyond rehabilitation and replacement needs currently identified, called asset management allowance. Figure 8.5 shows the additional funding needs of existing CIP debt service (pink cross-hatched areas), and the future asset management allowance in gray. Taken together with the preferred portfolio CIP, annual revenue requirement will range between $\$ 19$ and $\$ 27$ million.

Figure 8-5: Projected Annual Capital Revenue Requirements, Including Debt Service and Asset Management Allowance


### 8.4 Adaptive Management and Performance Tracking

WSRP implementation will be a long-term process, and is expected to face uncertainty in the future. While the WSRP was developed under certain assumptions that account somewhat for uncertainty, conditions may change and alter how the WSRP is implemented. Figure 8.6 provides examples of internal and external conditions that may influence the way the WSRP is implemented (i.e., where internal conditions are influences in PWP's organization or service area, and where external conditions are influences from outside PWP's organization or service area).

Figure 8-6: Potential Conditions Impacting WSRP Implementation


The preferred portfolio is a current understanding of the best combination of solutions to meet goals and objectives, and should be adaptable to future conditions. As conditions change, PWP's performance must be measured on progress in meeting goals and objectives, as opposed to implementation of specific projects or programs described in the preferred portfolio.

Several considerations identified in Section 8.2 need to be met when implementing the preferred Portfolio F. As PWP moves forward with implementation, these considerations will be tracked to see how changing conditions may affect the decision to move forward with each option.

PWP will apply an adaptive management approach as a tool to ensure successful implementation of the WSRP. Adaptive management is a flexible management strategy that employs monitoring and experience to inform decision making in the face of uncertainty. Adaptive management will allow PWP to periodically assess how internal and external conditions have changed at key decision points, and determine if and how implementation should change to achieve WSRP goals and objectives.

As part of developing this WSRP, tools and models were developed that can inform implementation of the preferred portfolio, including the following:

- Infrastructure upgrade workbook tool - The infrastructure upgrade workbook tool lists projects needed at each reservoir, booster station and well. Each project has a planning level cost and importance level that automatically rolls into the categories that define the storage and distribution options. PWP staff can change the projects, costs or importance levels to update the storage and distribution options and use the information to inform CIP development.
- GoldSim systems model - The GoldSim systems model simulates PWP's supply and production to account for uncertainty and risk of future water supplies, and helps to evaluate the ability to meet future needs. Should reliability of supplies or
major system changes occur, the GoldSim model can be updated to reflect these changes and provide updated reliability projections.
- Hydraulic model - PWP's hydraulic model provides information on whether the PWP water system is capable of providing uninterrupted, pressurized water to customers 24 hours a day. Changes to PWPs storage or distribution facilities can be incorporated to determine if demands can be met in all pressure zones.
- Portfolio summary and evaluation workbook tool - The portfolio summary and evaluation workbook tool lists of the options included in each portfolio and their capital costs. In addition, the tool includes the portfolio evaluation criteria, weightings and scoring calculations. Should conditions change and require changes to the criteria weightings or even the makeup of the preferred portfolio, the workbook can be updated to summarize these changes and determine how the portfolio compares to other portfolios.

For example, in the near-term, an emergency condition such as a key infrastructure failure may require a reprioritization of the rehabilitation and replacement schedule to meet that immediate need. Longer-term adaptation may result from changing community priorities or climate change impacts, resulting in a need to prioritize evaluation criteria, thereby changing options in the preferred portfolio.

Finally, PWP will track progress implementing the WSRP based on metrics that align with goals and objectives. Instead of prescribing language to be used, PWP will provide a progress report that uses specific statements indicating the projects implemented and the metrics achieved that support each of the specific WSRP objectives.

PWP will be able to continue to use this WSRP into the future by allowing for regular review and updating on an annual and multi-year cycles. Based on the timing shown in Figure 8.7, PWP will assess changing conditions and use the results of the adaptive management process to guide creation of annual budgets, scheduling and phasing of projects and programs, and revisions to goals, objectives and evaluation criteria weighting.

Figure 8-7: Review and Update Cycles


### 8.5 Summary

Pasadena's water resources and capital improvement programs are challenged. This WSRP provides an integrated approach of addressing deficiencies while positioning the City water program towards reliability and resiliency while facing a future of uncertainty.
Water resources programs are transitioning to reflect social changes and addressing stressors such as availability, affordability, water quality. Water use is also responding due to a variety of reasons. Overall water supply no longer grows proportional to population. Water regulations will continue to drive water consumption downward while contributing to the cost of water going upward. Costs for potable water will continue to rise and supplies of new water will not come from additional dams or big projects, it is adapting and using the existing resources more effectively to promote and sustain our community. Pasadena is positioned to capture new water which in the past was not financially viable while seemingly limitless imported water was less expensive.
Imported water is increasingly expensive and less reliable in any single year. Infrastructure to import expansive demand is laden with expensive fixed charges that must be recouped. As larger agencies are shifting to local supplies, the burden remains on agencies dependent upon imported water. This creates incentives for Pasadena to redevelop its groundwater reserves to buffer droughts and provide for emergency supplies. In addition, the infrastructure investments necessary to meet this challenge place Pasadena in position to shift its reliance on imported water from $65 \%$ to $50 \%$ which will provide increased resiliency and reduce annual expenses.

Local reliance is dependent upon two principles. First is to match the sources of water with the best use. Local surface water or high nitrate ground water is suited for irrigation with only minimal treatment and delivery systems that lack the redundancy and robust standards of drinking water system. Second, local reliance requires reinvestment and retooling the policies for managing and balancing the Raymond Basin. With 100 years of decline despite of adjudication and voluntary reductions to pumping, managing the Basin requires a deliberate effort to catch and infiltrate water, additionally it requires coordination with the Upper San Gabriel Basin and new approaches such as banking and exchanges with other water suppliers in the region.

Investments in local reliance can be made while addressing the large backlog of local infrastructure. Water storage reservoirs in the City are old and failing to the degree which regulators intervened to require replacement commitments from the City. In addition, reservoirs lack updates, including roofing systems and adequate seismic protections. Approximately 108 miles or $21 \%$ of the distribution system is in need of immediate replacement and another 166 miles is anticipated to require replacement during the next 25 years. The water production and treatment facilities are substantially inadequate to engage in managing Raymond basin. Finally, the management systems to assign, track and managed the water utility also need to be retooled to conform to modern demands of regulatory and customer expectations.

The WSRP can be implemented successfully and consistent with City policy. It is scheduled and phased in manageable pieces, financially affordable, and adaptable to
changing conditions. The implementation will allow PWP to meet the overarching goals and objectives laid out at the outset of this effort.

## 9. GLOSSARY

This glossary is provided to help readers understand WSRP-specific technical terms and abbreviations. These are not final or definitive descriptions of any term.
active conservation Water savings from water conservation, such as replacement of residential and commercial building fixtures, outdoor and indoor water efficient devices, greywater systems, drought tolerant landscapes, and turf removal.
adaptive management
Flexible management strategy that uses monitoring techniques and professional judgment or experience to inform decision making during uncertainty.
adjudication
administrative loss
advanced treatment
agricultural spot market transfer
allocation
alluvial
artificial recharge

Legal case that has been heard and decided by a judge. In the context of an adjudicated groundwater basin, landowners or other parties have turned to the courts to settle disputes over how much groundwater can be extracted by each party.
Administrative loss is the percentage of the total amount of water spread that does not receive a spreading credit used when calculating spreading credits. See spreading credit.

Treatment of wastewater beyond conventional wastewater treatment processes. Advanced treatment yields reclaimed or recycled water.

Transfer of water rights for a single year; often used to offset the impacts of a severe drought year.

Reduction in water supplies distributed during extended drought periods.
Clay, silt, sand or gravel deposited by flowing water in a riverbed, flood plain or delta.

Process of spreading water on land to increase water percolation into a groundwater basin, or the process of injecting water through aquifer storage and recovery (ASR) wells directly into the groundwater basin.

Assembly Bill 1668
asset management allowance
automated metering infrastructure (AMI)
average day demand
average year average yield banking (water)
baseline demand
basin subarea
booster station
bromide

California WaterFix Proposed project (by the California Department of Water Resources in 2016) to build two large tunnels to convey water beneath the Delta. California WaterFix was replaced by the Delta Conveyance Project. See Delta Conveyance Project.

| capital | Financial resources that organizations can use to fund <br> operations and purchases of machinery, equipment, and <br> other resources. |
| :--- | :--- |
| capital expenditures | Funds spent by organizations to repair or replace fixed assets <br> such as property, land, buildings, or equipment. |
| capital improvement |  |
| projects | Projects that build, maintain or improve assets. |
| carbon tetrachloride | Chemical used in fire extinguishers, as refrigerants, and as a <br> cleaning agent. Due to safety concerns, this chemical is no <br> longer used. In humans, exposure to high concentrations can <br> affect the central nervous system and harm the liver and <br> kidneys. Prolonged exposure can be fatal. |
| Valve that allows fluids to flow through it in only one direction. |  |


| Drought Contingency Plans | Plans signed by the United Stated Department of the Interior's Bureau of Reclamation and representatives from all seven Colorado River Basin states to reduce risks from drought and protect the Colorado River. |
| :---: | :---: |
| drought yield | Water supply available during drought years that typically occur in three out of every 10 years. |
| dry year | A hydrological year with below-average precipitation. |
| dry weather runoff | Urban water runoff that enters a drainage system, such as car washing and lawn irrigation. |
| effluent | Water partially or completely treated or in its natural state, flowing from a water treatment plant. |
| emergency yield | Water supply available during a supply interruption or emergency, such as the delivery of imported water after an earthquake. |
| Endangered Species Act | A 1973 federal law that provides a program for the conservation of threatened and endangered plants and animals and the habitats in which they are found. |
| Enhanced Watershed Management Plans | Plans that guide municipalities throughout Los Angeles to simultaneously comply with storm water discharge water quality mandates, improve the water quality of rivers, creeks and beaches, and address current and future regional water supply challenges. |
| fire flow | Water flow over a specified length of time sufficient to fight a fire. |
| gallons per capita per day | The number of gallons of water used per person per day. |
| geographic information system (GIS) | A digital system for gathering, managing, and analyzing data about positions on the Earth's surface. A geographic information system integrates many types of data. It also analyzes spatial location and organizes layers of information into visualizations by generating maps. |
| grey water | Wastewater from washing machines, bathtubs, showers, and bathroom and kitchen sinks. |
| groundwater | Water beneath the land surface that fills pore spaces of alluvium or the rock formation in which it is located. |
| groundwater right | See decreed right. |

headworks structure
heating ventilation air conditioning (HVAC)
high demand
hydropneumatic

Importance Level 1

Importance Level 2
imported water
infiltration gallery

Integrated Water
Resources Plan

Likelihood of Failure
long-term transfer
low demand
low impact development
maximum day demand

Structure that diverts Arroyo Seco stream flow into the sediment basins to reduce debris upstream of water intake structure.

Equipment used to provide heating and cooling services to a building.

A water demand projection calculated similarly to baseline demand, assuming that PWP service area will only achieve 50 percent of the total passive conservation projected in PWP's 2015 Urban Water Management Plan.
A system of pumps and a pressure tank that maintains water pressure.

Projects that address deficiencies that may affect the primary mission of infrastructure and are considered critical.

Projects that would improve functioning and maintains infrastructure.

Water imported from outside the water agency to supplement local supplies and to meet water demands.
Structure constructed to expedite surface water percolation to a groundwater basin.

Planning document that provides a holistic approach to water resources management by assessing water supply and water demand.

How likely a pipeline is to fail by year 2045.
Transfer of water rights for a period of time, usually longer than a year.

Water demand projection that uses the baseline demand (see baseline demand) and all passive conservation reduction estimates. This projection assumes indoor residential water use will decrease to meet a target of 55 gallons per day per capita by 2025 and 50 gallons per day per capita by 2030, as mandated in Senate Bill 606 and Assembly Bill 1668.

Systems or construction practices that replicate natural systems and minimize impact on development sites.

Highest demand in a 24-hour period in any specified year.
maximum contaminant level (MCL)
motor control center (MCC)
multi-family residential
municipal separate storm sewer systems
natural recharge
nitrate
nitrification
non-potable
operations and maintenance
outfall

The maximum level of a drinking water constituent allowed in drinking water under the state and federal law. MCLs are established by the US EPA and State which are legally enforceable standards that apply to public water systems.
An assembly to control some or all electric motors from a central location.

A building used as a residence by multiple families. Multiple separate housing units for residential inhabitants are contained in one building or several buildings in one complex.
A conveyance or system of conveyances that has the following characteristics:

- Owned by a state, city, town, village, or other public entity that discharges to waters of the U.S.
- Designed or used to collect or convey stormwater
- Not a combined sewer
- Not part of a sewage treatment plant, or publicly owned treatment works

Natural replenishment of an aquifer generally from snowmelt and runoff through seepage from the ground surface.
Organic compounds found in fertilizers and eroded natural deposits. Nitrate in water supplies poses health hazards for infants and pregnant women (and animals). High nitrate levels in drinking water can result in methemoglobinemia, commonly known as "blue baby syndrome," which is a condition characterized by reduced ability of the blood to carry oxygen to organs and tissue.

The process by which bacteria in soil and water oxidize ammonia and ammonium ions to form nitrites and nitrates.

Water that is not of drinking quality, but may be used for many other purposes (such as irrigation, cooling).

Activities necessary for maintaining and operating a building or structure, system, equipment, and to help occupants and users to perform their intended function.

Location point where wastewater or stormwater flows from a conduit, stream, or drainage ditch into natural waters.
overdraft
passive conservation
peak hour demand
perchlorate
potable
pounds per square inch
pressure regulating
/sustaining valve
pressure zones
pump station (PS)
radionuclides
rate revenue
Raymond Basin Judgment

Raymond Basin
Management Board
recharge A natural or artificial process that increases infiltration of water into a groundwater basin.

| reclaimed (recycled) water | The end product of wastewater reclamation. Reclaimed water must meet water quality requirements for biodegradable materials, suspended matter, toxicants, and pathogens. |
| :---: | :---: |
| reliability | The ability to meet varying water demands and dependable operation of the water system during adverse conditions. |
| reservoir | Artificial lake, pond, or impoundment where water is collected and stored for use. |
| residence time | Average length of time during which a substance remains in a given location. |
| runoff | Surface flow of water from an area; the total volume of surface flow during a specified time. |
| Salt and Nutrient Management Plan | Assesses impact on groundwater quality and promotes a basin-wide approach to management of salts and nutrients in groundwater. |
| sedimentation basin | Pond to capture runoff water with sediment or other debris. A sedimentation basin allows runoff to stand still, allowing sediment or other debris to settle out of the water via gravity. |
| Senate Bill 606 | See Assembly Bill 1668. |
| sewage | Waste water that comes from toilets, dishwashers, and other sources having high organic content. |
| single-family residential | Home on its own lot that is a single dwelling unit intended for one family. |
| spreading credits | Groundwater pumping credits obtained from spreading operations. These credits are assigned in addition to adjudicated groundwater rights. |
| spreading grounds | A surface facility, often a large pond, used to increase the rate of infiltration of water into a groundwater basin. |
| spreading operations | Process of diverting surface water, imported water, or recycled water into spreading basins to recharge a groundwater basin. |
| State Water Project (SWP) | A water storage and delivery system of reservoirs, aqueducts, power plants and pumping plants that are operated by the California Department of Water Resources (DWR). The State Water Project is to distribute water supplies from the Sacramento/San Joaquin Delta to Southern California. |

$\left.\begin{array}{ll}\begin{array}{l}\text { State Water Project } \\ \text { Delivery Capability } \\ \text { Report }\end{array} & \begin{array}{l}\text { Report issued by the DWR that estimates the current SWP } \\ \text { delivery capability and incorporates all current regulatory } \\ \text { requirements for SWP and Central Valley Project operations. }\end{array} \\ \text { stormwater } & \begin{array}{l}\text { Precipitation that falls from the sky, including rain, hail, and } \\ \text { snow. }\end{array} \\ \text { stormwater runoff } & \begin{array}{l}\text { Rainwater or melted snow that flows over land or impervious } \\ \text { surfaces, such as streets, parking lots, and other sites, and } \\ \text { does not soak into the ground. }\end{array} \\ \text { supervisory control } \\ \text { and data acquisition } \\ \text { (SCAD) } & \begin{array}{l}\text { System of software and hardware components that allow } \\ \text { supervision and control of the water system both locally and } \\ \text { remotely. }\end{array} \\ \text { systems model } & \begin{array}{l}\text { A conceptual model that describes and represents a water } \\ \text { system. }\end{array} \\ \text { Table A Amount } & \begin{array}{l}\text { Amount of water listed in Table A of the contract between the }\end{array} \\ \text { State Water Project and its contracting agencies. The Table }\end{array}\right\}$

| total dissolved solids | Quantitative measure of the residual minerals dissolved in <br> (TDS) <br> water that remain after evaporation of a solution expressed in <br> milligrams per liter or in parts per million. |
| :--- | :--- |
| total organic carbon | Amount of carbon found in an organic compound; often used <br> as a non-specific indicator of water quality. |
| tradeoff curve | Decision-making tool that visualizes relationships between <br> conflicting parameters. A tradeoff curve graph demonstrates <br> which qualities are lost in return for gains in other aspects. |
| trichloroethylene | Clear, colorless liquid that is used as a solvent, as an <br> intermediate for refrigerant manufacture and as a spotting |
| agent in dry cleaning facilities. Trichloroethylene is |  |
| carcinogenic to humans. |  |
| Synthetic compound used as an industrial solvent and as a |  |

## Water Supply

Allocation Plan
water treatment plant wastewater treatment plant
water use efficiency
watershed
wellhead treatment
wet year
wholesaler

MWD's plan to allocate available imported water supplies during a significantly dry year or during a severe drought that results in some shortage of imported supplies.

Facility that treats water for potable use.
Facility that treats wastewater by removing solids and pollutants, breaks down organic matter, and restores the oxygen content of treated water before it is returned to the environment or used for irrigation and other non-potable uses.

Term that describes water demand management solutions that create a conserved water supply.

An area of land that water drains to specific rivers and streams. Also known as a drainage basin.
A water treatment plant for a specific groundwater well that provides treatment to contaminated groundwater supplies.

A hydrological year with above-average precipitation.
An agency that delivers water to its member agencies and typically does not serve individual customers. Often member agencies have limited water sources of their own and rely on a wholesaler to meet water demands.
degree(s) Fahrenheit
Assembly Bill
acre-feet
acre-feet per year
aquifer storage and recovery
cubic feet per second
California Irrigation Management Information System
capital improvement projects
consequence of failure

| CRA | Colorado River Aqueduct |
| :---: | :---: |
| CTC | carbon tetrachloride |
| DCE | dichloroethylene |
| DWR | California Department of Water Resources |
| EPA | United States Environmental Protection Agency |
| EWMP | Enhanced Watershed Management Plans |
| GIS | geographic information system |
| GPCD | gallons per capita per day |
| HVAC | heating ventilation air conditioning |
| IRP | Integrated Water Resources Plan |
| Judgment | Raymond Basin Judgment |
| LAG-WRP | Los Angeles Glendale Reclamation Plant |
| LID | low impact development |
| LoF | Likelihood of Failure |
| MCC | motor control center |
| MCL | maximum-contaminant level |
| MG | million gallons |
| MWD | Metropolitan Water District of Southern California |
| NP | non-potable |
| PCE | tetrachloroethylene |
| PWP | Pasadena Water \& Power |
| RBMB | Raymond Basin Management Board |
| Reclamation | United States Department of the Interior Bureau of Reclamation |
| SCAG | Southern California Association of Governments |
| SGVMWD | San Gabriel Valley Municipal Water District |
| SNMP | Salt and Nutrient Management Plan |
| SW | storm water |
| SWP | State Water Project |
| SWRCB | State Water Resources Control Board |
| TCE | Trichloroethylene |


| TCP | trichloropropane |
| :--- | :--- |
| TDS | total dissolved solids |
| U.S. | United States |
| USGS | United States Geological Survey |
| UWMP | Urban Water Management Plan |
| VOC | volatile organic compound |
| WIRP | Water Integrated Resource Plan |
| WSRP | Water System and Resources Plan |
| WTP | Water Treatment Plant |
| WUE | water use efficiency |

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## Appendix A <br> Water Demand Forecast

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## APPENDIX A. WATER DEMAND FORECAST

Appendix A provides a detailed description of the current demands and the methodology used to project demands, including the following:

- Land use and demographic projections: Overview of current land use and how land use changes are expected to change demand for water in the future
- Demand forecast: Provides the methodology used to forecast demand to year 2045 based on 2015 demands


## Land Use and Demographic Projections

Population growth in the Pasadena area is not expected to increase significantly between 2015 and 2045, and assumes average growth of only 0.5 percent per year. Table A-1 presents the housing projections for PWP service area.

Table A-1: Housing Projections

|  | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Occupied Housing Units | 67,003 | 68,704 | 70,423 | 72,129 | 74,015 | 75,950 |
| Single Family Units | 37,046 | 37,561 | 38,398 | 39,507 | 40,199 | 40,903 |
| Multi-Family Units | 29,957 | 31,143 | 32,025 | 32,622 | 33,815 | 35,052 |
| Persons per Household | 2.47 | 2.47 | 2.52 | 2.52 | 2.51 | 2.51 |

Current land use in the PWP water service area is shown in Figure A-1, while General Plan land use (with a planning horizon of 2035) is shown in Figure A-2. Current land use in the PWP service area is predominantly single family residential, multi-family residential and commercial land uses are concentrated in areas along major transportation corridors. Pasadena is considered to be largely built-out. Areas designated as parks in the General Plan are designated as government in the current land use database. To account for this in the analysis, only summary land uses were considered (single family residential, multifamily residential, commercial, industrial, institutional, and parks).
Water System and Resources Plan

Water System and Resources Plan
Figure A-2: General Plan Land Use


## Demand Forecast

Forecasting water demands establishes a range for demand conditions then identifying applies water supply portfolios to address the likely scenarios. These shape strategies addressing potential deficiencies or best options. Performing this analysis requires evaluating the current land use, population, water consumption trends, and regulations.

The demand forecast used the following methodology:

1. Obtain data and forecast for housing and commercial/industrial land uses for PWP's service area, including projected population growth.
2. Estimate average unit water use factors and duty factors for single-family, multi-family, and commercial/industrial billing categories.
3. Account for weather variability, economic recession, and extraordinary conservation achieved in recent years as a result of droughts by adjusting the water use trends.
4. Maintain existing conservation into the future and apply estimated future watter supply regulations to obtain water use factors.
5. Apply water use factors, and percentages to their respective categories as forecasted, to estimate future water use.

The projected water demand presented in WSRP builds upon the existing projection established in the 2015 PWP Urban Water Management Plan (UWMP) and relies on the following data sources:

- California Department of Finance (DOF) and Southern California Association of Governments (SCAG): Provide current and projected region demographics, including annual estimates of population, employment, and housing units for cities and counties in California
- General Plan for the City of Pasadena: Provides framework for land use development within the City of Pasadena's boundaries and strategies for long-term growth
- Metropolitan Water District's (MWD) Integrated Resources Plan (IRP) and 2015 MWD UWMP: Provide forecasted demands, key demographic data, and passive conservation for each of its member agencies, including PWP's service area
- PWP's billing system: Provides historical and current water demands in the service area to determine trends and average water use by land use category

The water demand projection presented in the 2015 PWP UWMP reflect a baseline demand for and is consistent with, regional planning efforts such as MWD's regional plans and Pasadena's General Plan. Baseline demand for PWP was projected in the 2015 PWP UWMP as follows:

- Single-Family Residential and Multi-family Residential: Water use data and data on SFR and MFR units were used to estimate average unit water use factors for SFR and MFR billing categories for 2007 (pre-recession) and 2010 through 2015.
- Commercial/Industrial: The land-based duty factor (AFY/Acre) was computed using current land use and water use data for the billing category. The General Plan indicated that the total square footage for commercial/industrial will be 46.5 million or an additional 11 million square feet.
- Municipal/Institutional: A percentage of total water use for this category was computed and then applied to the forecast.
- Total Water Losses: Water losses using the AWWA method are between 5 to 8 percent of water use. This percentage was assumed to remain consistent.

Current indoor residential water use within the PWP service area is 57 gpcd calculated using residential water billing data for two wet months, February and March 2019, assuming 10 percent of the total water is used outdoor. The current indoor water use is estimated at 11,000 AFY or approximately $39 \%$ of the total water use. To comply with the recent water-use efficiency legislation, the low demand projection assumes that indoor residential water use within the PWP service area will be decreased by 2 gpcd to 55 gpcd by year 2025 , and by 7 gpcd to 50 gpcd by year 2030 (1,400 AFY).

PWP service area has approximately 6,700 acres of landscaped area that is currently irrigated based on 2006 infrared imaging. The current outdoor use is estimated based on the state Model Water Efficient Landscape Ordinance (MWELO) calculations for moderate water use for the Pasadena area evapotranspiration zone. The current annual water use in PWP service area is approximately 28,500 . The estimated annual outdoor water use is $17,500 \mathrm{AFY}$, or approximately $61 \%$ of the total water use.

At the time of the publication of this report California has not established outdoor conservation objectives. However, to estimate the water use reduction to meet the future outdoor water conservation requirements, PWP included high irrigation efficiency in the MWELO calculations. As a result PWP could be required to reduce outdoor water use to approximately 16,000 AFY (a reduction of 1,500 AFY). To comply with current indoor and future outdoor water use requirements PWP must reduce its annual water use by approximately 3,500 AFY by the year 2030.

The water demand projections are shown in Figure A-3:

1. Status Quo - the current water use projected for future years based on population increase with current levels of conservation. The 2010 through 2019 data was used for the demand projections adjusted for weather variability, economic recession, and extraordinary conservation measures.
2. Meet Regulations - Status Quo demands reduced to meet California's Assembly Bill (AB) 1668 and Senate Bill (SB) 606 requirements.

Final
3. Goal - meet regulations plus an additional 10\% outdoor conservation (approximately 1,500 AFY by 2030) in anticipation additional regulatory reductions being proposed.

Figure A-3: Water Demand Projections


| Water Use <br> and <br> Projections <br> Meet <br> Regulations <br> (AFY) | 2020 | 2030 | 2045 | 2020 to 2030 <br> Reduction |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Indoor | 11,000 | 9,600 | 9,740 | 1,400 | $\mathbf{1 3 \%}$ |
| Outdoor | 17,500 | 15,400 | 16,211 | 2,100 | $\mathbf{1 2 \%}$ |
| TOTAL | $\mathbf{2 8 , 5 0 0}$ | $\mathbf{2 5 , 0 0 0}$ | $\mathbf{2 5 , 9 5 1}$ | $\mathbf{3 , 5 0 0}$ | $\mathbf{1 2 \%}$ |

## Appendix B System Schematics and Maps

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APPENDIX B. WATER SYSTEM SCHEMATICS AND MAPS
Appendix B contains the following information regarding PWP's storage and distribution assessment:
Table B-1: Pressure Zones ..... 2
Figure B-1: Water System Hydraulic Profile Schematic ..... 3
Figure B-2: Pressure Zone Locations ..... 4
Table B-2: Reservoirs ..... 5
Table B-3: Summary of Pipeline by Diameter ..... 6
Table B-4: Pipelines ..... 7
Figure B-3: Pipelines by Diameter ..... 8
Figure B-4: Pipelines by Age ..... 9
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Table B-5: Booster Pump Station Descriptions ..... 11
Table B-6: Pressure Regulating Stations ..... 13
Table B-7: Inter-Agency Connections ..... 16
Table B-8: Wells ..... 17

## Table B-1: Pressure Zones

| Pressure Zone | Hydraulic Grade Line (ft MSL) |
| :--- | :---: |
| 1. Allen | 1,480 |
| 2. Allen Hydro | 1,658 |
| 3. Allen Reduced East | 1,295 |
| 4. Allen Reduced West | 1,300 |
| 5. Annandale | 1,301 |
| 6. Annandale Reduced | 1,171 |
| 7. Calaveras | 1,209 |
| 8. Calaveras Reduced East | 1,065 |
| 9. Calaveras Reduced West | 1,117 |
| 10. Don Benito | 1,432 |
| 11. Don Benito Reduced | 1,290 |
| 12. Eagle Rock | 1,132 |
| 13. Lida | 1,439 |
| 14. Millard/Gould | 1,434 |
| 15. Millard/Gould Reduced | 1,365 |
| 16. Mirador | 1,598 |
| 17. Mirador Reduced | 1,332 |
| 18. Murray Hydro | 1,320 |
| 19. Sheldon | 1,050 |
| 20. Sierra Madre Villa | 785 |
| 21. Sierra Madre Villa Reduced | 705 |
| 22. Sunset | 945 |
| 23. Sunset Reduced | 780 |
|  |  |

Water System and Resources Plan


Figure B-2: Pressure Zone Locations

Table B-2: Reservoirs

| Reservoir | Year Installed | Capacity (MG) | Pressure Zone Served | Bottom Elevation <br> (ft) | High Water Elevation (ft) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1. Allen | 1930 | 4.1 | Allen | 1,459 | 1,480 |
| 2. Annandale | 1926 | 0.64 | Annandale | 1,283 | 1,301 |
| 3. Calaveras | 1925 | 10 | Calaveras | 1,189 | 1,209 |
| 4. Don Benito 1 | 1958 | 0.7 | Don Benito | 1,403 | 1,432 |
| Don Benito 2 | 1958 | 0.7 | Don Benito | 1,403 | 1,432 |
| 5. Eagle Rock | 1923 | 0.95 | Eagle Rock | 1,115 | 1,132 |
| 6. Gould East | 1991 | 1.5 | Gould | 1,412 | 1,434 |
| Gould West | 1991 | 1.5 | Gould | 1,412 | 1,434 |
| 7. Jones | 1949 | 50 | Sunset | 918 | 945 |
| 8. Lida | 1948 | 0.43 | Lida | 1,421 | 1,439 |
| 9. Mirador | 1928 | 1.0 | Mirador | 1,578 | 1,598 |
| 10. Santa Anita | 1948 | 4.22 | Calaveras | 1,187 | 1,207 |
| 11. Sheldon 1 | 1919 | 6.73 | Sheldon | 1,033 | 1,050 |
| Sheldon 2 | 1938 | 5.1 | Sheldon | 1,032 | 1,050 |
| 12. Sunset 1 | 1888 | 5.58 | Sunset | 929 | 945 |
| Sunset 2 | 1900 | 9.85 | Sunset | 929 | 945 |
| 13. Thomas | 1952 | 1.4 | Calaveras | 1,184 | 1,200 |
| 14. Windsor | 1926 | 4.75 | Calaveras | 1,142 | 1,154 |

Table B-3: Summary of Pipeline by Diameter

| Diameter (inches) | Total Length (feet) | Total Length <br> (miles) | Percentage of <br> Total Length (\%) |
| :---: | :---: | :---: | :---: |
| $\leq 2$ | 43,000 | 8 | $2 \%$ |
| 3 | 538 | 0.1 | $0.1 \%$ |
| 4 | 118,000 | 22 | $4 \%$ |
| 6 | $1,048,000$ | 198 | $40 \%$ |
| 8 | 714,000 | 135 | $27 \%$ |
| 10 | 16,000 | 3 | $1 \%$ |
| 12 | 478,000 | 90 | $18 \%$ |
| 14 | 1,100 | 0.2 | $0.1 \%$ |
| 16 | 106,000 | 20 | $4 \%$ |
| 18 | 914 | 0.2 | $0.1 \%$ |
| 20 | 69,000 | 13 | $3 \%$ |
| 24 | 60,000 | 11 | $2 \%$ |
| 30 | 8,300 | 2 | $0.3 \%$ |
| 36 | 29,900 | 6 | $1 \%$ |
| 42 | 205 | 0.1 | $0.1 \%$ |
| Total | $\sim \mathbf{2 , 7 0 0}$ | $\mathbf{0 0 0}$ | $\sim 510$ |

Table B-4: Summary of Pipelines by Material

| Materials | Total Length <br> (feet) | Total Length <br> (miles) | Percentage (\%) |
| :---: | :---: | :---: | :---: |
| Cast Iron | $1,959,000$ | 370 | $72.4 \%$ |
| Concrete | 105 | 0.0 | $<0.01 \%$ |
| Concrete Steel Reinforced | 97,600 | 18.5 | $3.7 \%$ |
| Ductile Iron | 521,800 | 98.8 | $19.6 \%$ |
| Galvanized Steel | 21,600 | 4.1 | $0.8 \%$ |
| Reinforced Cement <br> Concrete / Hume | 3,700 | 0.7 | $0.1 \%$ |
| PVC | 2,400 | 0.5 | $0.1 \%$ |
| Steel | 72,100 | 13.7 | $2.7 \%$ |
| Transite/Asbestos Cement | 13,860 | 2.6 | $0.5 \%$ |
| Unknown or blank | 2,400 | 0.4 | $0.01 \%$ |
| Total | $\boldsymbol{\sim 2 , 7 0 0 , 0 0 0}$ | $\sim 510$ | $\mathbf{1 0 0 \%}$ |

Water System and Resources Plan
Figure B-3: Pipelines by Diameter

Water System and Resources Plan

Water System and Resources Plan
Figure B-5: Pipelines by Material

Final

| Water System and Resources Plan |  |  |  |  |  |  | Water System Schematics and Maps |
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| Table B-5: Booster Pump Station Descriptions |  |  |  |  |  |  |  |
| Booster Station | Year Built/ Last Major Upgrade | Pump No. | Year Installed | Suction Zone/Discharge Zone | Design Capacity (gpm) | $\begin{aligned} & \text { Design } \\ & \text { TDH (feet) } \end{aligned}$ | Motor HP |
| 1. Ventura | 2010 | 1 | 2010 | Wells to MHWTP/Windsor Reservoir | 2800 | 270 | 250 |
|  |  | 2 | 2010 | Wells to MHWTP/Windsor Reservoir | 2800 | 270 | 250 |
|  |  | 3 | 2010 | Wells to MHWTP/Windsor Reservoir | 2800 | 270 | 250 |
| 2. Glorietta | 1948/2010 | 1 | 1990 | Sunset/Calaveras | 3600 | 273 | 300 |
|  |  | 2 | 1991 | Sunset/Calaveras | 4250 | 274 | 400 |
|  |  | 3 | 2002 | Sunset/Sheldon | 3600 | 111 | 150 |
| 3. Jones | 1949/2012 | 1 | 2013 | Sunset/Sheldon | 2200 | 160 | 125 |
|  |  | 2 | 2012 | Sunset/Sheldon | 1000 | 135 | 50 |
|  |  | 3 | 1989 | Sunset/Calaveras | 1800 | 265 | 150 |
|  |  | 4 | 2015 | Sunset/Calaveras | 1600 | 286 | 150 |
| 4. Wilson | 1930/2013 | 1 | 2013 | Sunset/Sheldon | 4500 | 147 | 250 |
|  |  | 2 | 1991 | Sunset/Sheldon | 4500 | 147 | 200 |
|  |  | 3 | 1995 | Sunset/Calaveras | 2200 | 303 | 200 |
|  |  | 4 | 2015 | Sunset/Calaveras | 2200 | 305 | 250 |
|  |  | 5 | 2013 | Sunset/Calaveras | 2200 | 303 | 250 |
| 5. Allen Hydro | 1930/2014 | 1 | 2014 | Allen/Allen Hydro | 150 | 180 | 10 |
|  |  | 2 | 2014 | Allen/Allen Hydro | 150 | 180 | 10 |
|  |  | 3 | 2014 | Allen/Allen Hydro | 150 | 180 | 10 |
| 6. Murray Hydro | 2016 (Replaced) | 1 | 2016 | Calaveras/Murray Hydro Tank | 150 | 140 | 10 |
|  |  | 2 | 2016 | Calaveras/Murray Hydro Tank | 150 | 140 | 10 |
|  |  | 3 | 2016 | Calaveras/Murray Hydro Tank | 150 | 140 | 10 |
| 7. Arroyo | 1936/2019 | 1 | 1991/1999 | Calaveras/Gould (Millard) | 320 | 288 | 40 |
|  |  | 2 | 2016 | Calaveras/Gould (Millard) | 750 | 290 | 75 |
| 8. Ross | 1958 | 1 | 1957 | MWD P-5/Eagle Rock | 700 | 200 | 50 |
|  |  | 2 | 1985 | MWD P-5/Eagle Rock | 700 | 200 | 50 |
| 9. Eagle Rock | 1926 | 1 | 2011 | Eagle Rock/Annandale | 325 | 248 | 30 |
|  |  | 2 | 1987 | Eagle Rock/Annandale | 500 | 265 | 50 |
| 10.P-1 Booster |  | 2000 | 2000 | MWD P-1/Sunset |  |  |  |
| asadena Water \& Power |  |  |  | B-11 |  |  | November 2020 |

Final
Water System and Resources Plan

Final

| Water System and Resources Plan |  |  |  | Water System Schematics and Maps |
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|  | Table B-6: Pressure Regulating Stations |  |  |  |
| Name/Location | Dia. (inch) | Setting (psi) | Inlet Zone | Outlet Zone |
| 1. Valley View \& Cartwright Reg Station | 4 | 51 | Calaveras | Calaveras Red. E |
|  | 6 | 46 | Calaveras | Calaveras Red. E |
| 2. Cartwright \& Hastings Ranch Drive | 2 | 56 | Calaveras | Calaveras Red. E |
|  | 6 | 50 | Calaveras | Calaveras Red. E |
| 3. Riviera Drive \& Pine Bluff Drive | 4 | 46 | Calaveras | Calaveras Red. E |
|  | 2 | 57 | Calaveras | Calaveras Red. E |
| 4. Reg Station at Chapman Well (Halstead @ Chapman) | 4 | 45 | Sunset | Sierra Madre Villa |
|  | 4 | 40 | Sunset | Sierra Madre Villa |
|  | 6 | 35 | Sunset | Sierra Madre Villa |
|  | 6 | 30 | Sunset | Sierra Madre Villa |
| 5. Rosemead and Huntington Drive | 4 | 67 | Sierra Madre Villa | Sierra Madre Villa Red. |
|  | 4 | 62 | Sierra Madre Villa | Sierra Madre Villa Red. |
|  | 6 | 57 | Sierra Madre Villa | Sierra Madre Villa Red. |
| 6. Colorado Blvd \& Sierra Madre Villa | 4 | 44 | Sunset | Sierra Madre Villa |
| 7. Foothill Blvd and Sierra Madre Villa | 6 | 29 | Sunset | Sierra Madre Villa |
| 8. Michillinda Ave n/o Foothill Blvd | 6 | 45 | Sunset | Sierra Madre Villa |
|  | 6 | 50 | Sunset | Sierra Madre Villa |
| 9. Bradley St. and New York Drive | 8 or 6 | 75 | Calaveras | Sheldon |
|  | 4 | 70 | Calaveras | Sheldon |
|  | 8 or 6 | 65 | Calaveras | Sheldon |
| 10. Madre St s/o Del Mar Blvd | 4 | 40 | Sunset | Sierra Madre Villa |
|  | 4 | 35 | Sunset | Sierra Madre Villa |
| 11. California Blvd w/o Eaton Wash | 6 | 78 | Sunset | Sierra Madre Villa |
|  | 4 | 83 | Sunset | Sierra Madre Villa |
| 12. Madre St $\mathrm{n} / \mathrm{o}$ Huntington Drive | 6 | 62 | Sierra Madre Villa | Sierra Madre Villa Red. |
|  | 2 | 67 | Sierra Madre Villa | Sierra Madre Villa Red. |
| 13. Sidney Reg Station s/o California Blvd | 2 | 71 | Sunset | Sierra Madre Villa |
|  | 6 | 76 | Sunset | Sierra Madre Villa |
|  |  |  |  |  |
| Pasadena Water \& Power |  |  |  | November 2020 |



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29.Sinaloa n/o Meadowbrook
Final

| Water System and Resources Plan |  |  |  | Water System Schematics and Maps |
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| Table B-7: Inter-Agency Connections |  |  |  |  |
| General Location | Address | From | To | Pressure Zone |
| 1. FMWD | Rosemont Ave. n/o Washington Blvd | Pasadena | Foothill Municipal Water District (FMWD) | Calaveras |
| 2. Linda Vista/FMWD | Rosemont Ave. n/o Washington Blvd | FMWD | Pasadena | Calaveras |
| 3. Rosemead Blvd | 227 S. Rosemead Blvd | Pasadena | East Pasadena Water Co. | Sierra Madre Villa |
| 4. Ranch Top Road | 3650 Ranch Top Rd | Pasadena | Kinneloa Irrigation District (KID) | Don Benito |
| 5. Lamanda Reservoir/East | 60 Sierra Madre Blvd | Pasadena | Cal-American Water Co. | Sunset |
| 6. Calaveras Reservoir | 88 E. Calaveras Ave | Lincoln Avenue Water Co. (LAWC) | Pasadena | Calaveras |
| 7. Loma Alta Dr | 1902 Loma Alta Dr | Rubio Canyon Land \& Water (Rubio) | Pasadena | Allen Hydro |
| 8. Murray Res Pkwy | 3410 Fairpoint Street | KID | Pasadena | Calaveras |
| 9. Paloma St | Arroyo Spreading Grounds | Pasadena | Pasadena Spreading | Sunset |
| 10.Allen Ave \& Homewood | 2561 Allen Ave. | Pasadena | Rubio | Allen |
| 11.Canyon Crest Dr | 3425 Florecita Dr | LAWC | Pasadena | Millard |
| 12. New York Dr | 2765 New York Dr | Pasadena | KID | Calaveras |
| 13.Columbia St | 36 Columbia St | Pasadena | City of South Pasadena (South Pas) | Sunset |
| 14.Oak Knoll Dr | 888 S. Oak Knoll Dr | Pasadena | Cal-American Water Co. | Sunset |
| 15. Windsor \& Mountain View | Mountain View Rd e/o Windsor Ave | Pasadena | Lincoln | Gould |
| 16.La Canada/ Pasadena | 1542 Inverness Dr | Valley Water Co. | Pasadena | Lida |
| 17. Arroyo Blvd \& Zanja St | 1260 Arroyo Blvd | Calaveras Zone | Sheldon Zone | Sheldon |
| 18.Kinneloa Outpost/East | 1776 Kinneloa Canyon Rd | KID | Pasadena | Calaveras |
| 19.Kinneloa Outpost/West | 1777 Kinneloa Canyon Rd | Pasadena | KID | Calaveras |
| 20.Glenarm Plant | $60 \mathrm{E}$. State St | Pasadena | South Pasadena | Sunset |
| 21. Michillinda \& Mariposa | Mariposa Ave s/o Michillinda Ave | Pasadena | City of Sierra Madre | Sheldon |
| 22. Michillinda/ Grandview | Grandview Ave s/of Michillinda | City of Sierra Madre | Pasadena | Calaveras |


|  | Well | Water Quality Detections |
| :---: | :---: | :---: |
|  | Active Wells in Service |  |
| 1 | Arroyo | Perchlorate, carbon tetrachloride (CTC), trichloroethylene (TCE), tetrachloroethene (PCE), and 1,2,3-trichloropropane (1,2,3-TCP) |
| 2 | Bangham | Nitrate, perchlorate, TCE, PCE, and 1, 2, 3-TCP |
| 3 | Chapman | Nitrate |
| 4 | Sunset | Nitrate, perchlorate, TCE, PCE, cis-1,2-Dichloroethylene (c-1,2DCE) and 1,2,3-TCP |
| 5 | Twombly | Nitrate |
| 6 | Ventura | Nitrate, perchlorate, TCE, PCE and 1,2,3-TCP |
| 7 | Wadsworth | Nitrate , PCE, TCE and 1,2,3-TCP |
| 8 | Well 52 | Nitrate, perchlorate, TCE and PCE |
| 9 | Woodbury | Nitrate, perchlorate and 1,2,3-TCP |
|  |  | Inactive Wells |
| 1 | Copelin | Nitrate, perchlorate, TCE, PCE, and DCE |
| 2 | Sheldon | Nitrate and PCE |
| 3 | Craig | Nitrate and perchlorate |
| 4 | Eaton | Under influence of surface water |
| 5 | Garfield | Nitrate, perchlorate |
| 6 | Jourdan | Nitrate, PCE, TCE and DCE |
| 7 | Monte Vista | Nitrate, perchlorate, 1, 2, 3-TCP, and CTC |
| 8 | Villa | Nitrate, perchlorate, and TCE |
| 9 | Windsor | Nitrate, perchlorate, TCE, PCE and CTC |

## Appendix C Water Supply Reliability Analysis

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## Appendix C: Water Supply Reliability Analysis

Appendix C provides a detailed description of the GoldSim modeling framework and the methodology used to conduct the water supply reliability analysis for the PWP Water System and Resources Plan (WSRP).

## 1. GOLDSIM MODEL

A water resources assessment was conducted for Pasadena Water and Power (PWP) using GoldSim software, a graphical platform used for visualizing and dynamically simulating complex systems that evolve over time. Models in GoldSim are built by drawing a diagram of the system with various "elements" that represent the components of the system being modeled, data, and relationships between the data. One of the main advantages of GoldSim is that it provides probabilistic simulation features to quantitively represent the inherent variability and uncertainty present in the system, allowing the user to evaluate how the system is likely to change over time. The model is also capable of comparing alternative scenarios and portfolios, effectively allowing users to preemptively quantify risks and to make strategic decisions that minimize that risk.

### 1.1 PWP Supply Reliability and Resiliency GoldSim Model

Though GoldSim is not specifically a water resources modeling tool, it is well suited for water resources and commonly applied to water resources settings. A GoldSim model was used to quantify the Supply Reliability and Resiliency of future water supplies available to PWP, as identified in the PWP WSRP. The modeling platform was selected to enable PWP to simulate the baseline conditions and various water resources options and full WSRP portfolios and use the simulation results to evaluate the most cost-effective portfolio that will meet the supply reliability and resiliency needs of PWP. The model simulated the WSRP portfolios for a 25 -year planning horizon.

### 1.1.1 Questions the Model is Programmed to Answer

The PWP Supply Reliability and Resiliency GoldSim Model informed the PWP WSRP. Specifically, the model was used to answer questions related to the current and expected water supply reliability and resiliency. The model determined the future operational yield and reliability of the system under baseline conditions and nine portfolios that implement various water supply projects and programs. The model simulated expected water supplies with dynamic hydrologic factors and various projected demands on a monthly basis.

### 1.1.2 Modeling Method

The model utilized an index sequential method to quantify long-term reliability. In other words, the model imposed existing hydrology data to the 26-year planning period (2020 to 2045) until each recorded hydraulic year was applied to each planning year. The model incorporated imported water reliability projections and water allocations provided by

MWD's 2015 Integrated Water Resources Plan, which also uses an index sequential method. These projections were revised under the assumption that the California Water Fix will be replaced by implementation of the Delta Conveyance project.

To determine how much water enters the underlying groundwater basin, the model simulated the local hydrology of the region. Limitations such as historical Arroyo Seco and Eaton Wash stream flows, PWP's surface water diversion rights, pumping rights in the Monk Hill and Pasadena subareas, groundwater recharge and associated pumping credits, and system capacity constraints for existing wells, diversions, and other facilities were all accounted for in the model.

Key to index sequential simulation is the definition of a future period onto which the historical period is imposed. In the WSRP assessment, the planning period corresponds to 2020 to 2045 and the historical period runs from 1922 to 2018. The simulation model uses local hydrological data from 1922 to 2018 and imposes it on the 25-year planning period (2020 to 2045) until each recorded hydrology year is applied to each planning year. This allows the model to account for the inherent variability and uncertainty present in the system and predicts how likely the system is to change over time. Each sequence of 2020 to 2045 under a specific hydrology history is called a "realization". The model thus has 96 realizations.

Model results are probabilistic, meaning that output results show 1) How many years will have a supply deficit, and 2) What is the extent of the water supply deficit. The percent of time demand is met and average shortage under the baseline conditions and each of the six water supply portfolios are shown in Chapter 7.

## 2. MODEL ORGANIZATION

### 2.1 GoldSim Model Elements

The systems model is organized into six containers. A container is an element that acts like a "box" or a "folder" into which other elements can be placed. It can be used to create hierarchical models, "top-down" models and organize models in which the level of detail increases farther into the containment hierarchy. The GoldSim model uses containers to organize PWP's water supplies in discrete and manageable sectors. The model is divided into six containers: Data, Water Demand ("Demand"), Water Supplies ("Supplies"), Alternative Project Switches ("AlternativeSwitches"), Supply Reliability and Resiliency Final Results ("Final_Results"), and a Mass Balance ("Mass_Balance") to ensure that all water supply inputs equal all water supply outputs. A general model diagram showing the relationship between the containers is shown Figure C-1.

Figure C-1: PWP Supply Reliability and Resiliency GoldSim Model Diagram


GoldSim offers a wide variety of elements from which the user can construct models. The major elements used to construct this specific model within the various containers identified in Figure $\mathrm{C}-1$ include:

- Data Elements: Elements intended to represent a constant input. A Data element can represent both values and conditions (i.e. True/False), and can represent a single scalar value, an array ( 1 -dimensionsl), or matrix (2-demensional) data. This model extensively uses this element for constants, rates, capacities, etc.
- Time Series Elements: Data elements with time histories of data. This element is used for historical demand and hydrology. Data can be both time shifted or run in an index-sequential mode over multiple realizations.
- Reservoir Elements: GoldSim includes reservoirs elements with preprogrammed rules for operating simple systems. Reservoirs allow the user to specify simple or dynamic values for the upper and lower levels, and the withdrawal rate. The spreading basins, groundwater basins, and long-term water storage in this model use this element.
- Integrator Elements: Elements that integrate rates. These are used to integrate and track information, such as accumulated flows for mass balance calculations. This GoldSim model uses this element for mass balance calculations.
- Expression Elements: A function element produces a single output by calculating user-specified mathematical expressions or equation. Expression elements are used extensively for model logic.
- Allocator Elements: Allocate an incoming signal to a number of outputs according to a specified set of demands and priorities. Typically, the signal will be a flow of water, distributed among a series or prioritized demands. This model uses this element in all of the spreading basin outflow elements to preserve the mass balance.
- Lookup Table Elements: A function element that allows the user to create a 1, 2, or 3-dimensional lookup table. Used, for example, for lake election-capacity tables. This model uses this element for some of the model logic, such as the pump curves.


### 2.2 Model Components

### 2.2.1 Data Container

The Data Container provides the basis for the model. Elements within the container identify the start year ("Start_Year") and simulation year ("Sim_Year") for the model. These elements are not intended to be modified by the model user.

### 2.2.2 Water Demand Container

The Water Demand Container identifies the current and projected water needs for PWP. Because water consumption is variable and dependent on the existing environment, the model incorporates all the possible conditions that could impact water consumption in the future. The "Demand_Proj" element defines the "Baseline Demand", "High Demand", and "Low Demand" projections developed as part of the PWP WSRP (see Section 2). The model user can alternate the demand scenario by modifying the demand series element ("Demand_Series") that specifies which scenario the model will simulate. This container also applies weather variability factors that influence demands both on a monthly basis ("Monthly_Demand_Factor") and on an annual basis ("WeatherFactor"). Monthly factors cause demands to peak in dry months, and annual factors cause demands to peak in drought years. These factors are applied to both potable ("D_Weather") and nonpotable ("D_NonPotable_Weather") demands. The weather factors were obtained from MWD for Pasadean with similar characteristics in southern California and are not intended to be modified by the user. The model user may turn on the Water Use Efficiency (WUE) program that reduces demand projections for both the potable (i.e. indoor) and nonpotable (i.e. outdoor) water demands (see Section 2).

### 2.2.3 Water Supplies Container

For organization purposes, the Water Supplies Container is further subdivided into seven sub-containers that allow the model user to better manipulate each of the discrete water supplies available to PWP. The seven sub-containers include: groundwater supplies ("Groundwater Supplies"), imported water supplies ("ImportedSupplies"), alternative direct non-potable water supplies ("Alt_DirectNonPotableSupplies"), alternative direct potable water supplies ("Alt_DirectPotableSupplies"), alternative banked and water transfers ("Alt_BankedTransfer"), alternative WUE ("Alt_WUE"), and additional local storage programs ("Alt_AdditionalLocalStorage").

### 2.2.3.1 Groundwater Supplies Container

The Groundwater Supplies Container simulates current and projected groundwater supplies in the Raymond Basin and is further subdivided into the Pasadena and Monk Hill Subarea containers. Though these two Subareas are modeled in two different containers, the general structure for modeling these two Subareas is very similar. Elements that are
designated with an "MH" or "AS" refer to Monk Hill Subarea or Arroyo Seco, and elements that are designated with a "P" or "EW" refer to Pasadena Subarea or Eaton Wash.

Within each subarea, PWP is entitled to: 1) an adjudicated groundwater right, 2) additional groundwater extraction credits from spreading of surface water diversions, and 3) longterm storage credits. Total groundwater extractions from these three rights and credits are constrained by the sum of the pumping capacity of the active wells in the Subarea. Three pumping capacity expression elements constrain pumping in each Subarea, with priority given to adjudicated rights, then spreading credits, followed by long-term storage. No additional pumping is possible once the pumping capacity has been met.

The adjudicated right ("Subarea_Adjudication") is a static data element determined by the adjudication judgement that is replenished every year. Adjudication groundwater rights are modeled as a reservoir ("Subarea_Adjudication_Pool"). Pumping from this pool is constrained by the total pumping capacity ("Subarea_Avg_AnnualPumpingCapacity") in the subarea and the total water demand in the PWP service area.

Following the adjudicated right, PWP is entitled to spreading credits that are determined by surface water diversions and spreading. For the Pasadena Subarea, Eaton Wash surface flows are diverted and spread in the Eaton Wash Spreading Grounds. For the Monk Hill Subarea, Arroyo Seco surface flows are diverted and spread in the Arroyo Spreading Grounds. Available surface water diversions are projected with an expression element that incorporates historical surface water flows for each stream ("Stream_Flow"), and is constrained by PWP's diversion rights ("Stream_DiversionRights"), the structural diversion capacity ("Stream_DiversionCapacity"), and spreading capacity ("SpreadingBasin_SpreadingCapacity"). Each spreading basin is modeled by a reservoir with inflows defined as the surface water diversions and outflows defined as the infiltration rate and evaporation rate. The infiltration rate ("SpreadingBasin_InfiltrationRate") is then used as an input to the credit pool expression element that calculates the spreading credits available to PWP after applying a predetermined administrative groundwater loss ("SpreadingBasin_Admin_Losses") for the subarea. The remaining credits ("SpreadingBasin_CreditPool") are the inflow to the spreading credits pool reservoir element ("SpreadingBasin_SpreadingCreditsPool"). Pumping from this pool is constrained by 1) the pumping capacity in the subarea minus the volume pumped in the adjudicated right; and 2) the total water demand in the PWP service area minus the adjudication water supplies.

Arroyo Seco flow data were obtained from the United States Geological Survey (USGS) for the years 1910 through 2018 (Station 1109800). Eaton Wash flow data were also obtained from USGS for the years 1918 through 1966 and extrapolated through 2018 (Station 11101000). Figure C-2 shows the historical Arroyo Seco and Eaton Wash hydrographs.

Figure C-2: Arroyo Seco and Eaton Wash Hydrographs


Finally, the long-term groundwater storage is a reservoir element ("Subarea_LongTerm_Storage") constrained by the remaining water demand and pumping capacity after the groundwater extractions earned from the spreading credits. The long-term groundwater storage was provided by PWP.

Alternative water supply projects that either maintain or rehabilitate existing pumping facilities or augment pumping capacity are all elements that directly modify the annual pumping capacity expression element ("SpreadingBasin_Avg_AnnualPumping Capacity"). Alternative water supply projects that either 1) increase capacity for groundwater recharge, or 2) increase water supplies for recharge (either through surface water diversions or recycled water) directly modify inflows to or recharge within the Arroyo Seco or Eaton Wash Spreading Grounds ("Alt_GW_EW_Recharge" or "Alt_GW_AS_Recharge"). Some projects also increase the surface diversion flows from Arroyo Seco or Eaton Wash.

### 2.2.3.2 Imported Water Supplies Container

The Imported Water Supplies container simulates PWP's imported water supplies. It calculates monthly imported water supplies using an imported water allocation expression ("InitialMnAllocation") and an imported water reliability matrix obtained from MWD and
modified to account for recent events with the CalWater Fix project ("IRP_Reliability"). Additional expressions in the container ensure that water is allocated on a monthly rather than annual basis and that imported water supplies are constrained by demands.

The WSRP is a "needs based" allocation, meaning that allocations are based in part on local supply availability, so that member agencies that are more dependent on MWD do not experience disparate shortages at the retail level when compared to other member agencies. The elements used in the WSRP calculation are:

- Regional Shortage Level: The WSRP allocates shortages of MWD supplies over 10 Levels.
- Wholesale Minimum Allocation: The WSRP provides a minimum level of MWD water supplied to each member agency before adding the Retail Impact Adjustment.
- Maximum Retail Impact Adjustment: The WSRP provides a maximum possible adjustment based on a member agency that is $100 \%$ dependent on MWD at the retail level. To determine a final value, the maximum Retail Impact Adjustment is multiplied by the member agency's percent dependence on MWD.

The percent allocation for each future year under each hydrology of the past is the key output from MWD's model called "IRP Sim". The WSRP assessment used output from IRP Sim specifically for Pasadena. The complete reliability matrix is included below in Table C-1.

Table C-1: Reliability Matrix from MWD for Pasadena, Extended to 2018, Without California Water Fix


### 2.2.3.3 Alternative Direct Non-potable and Potable Water Supplies

The Alternative Direct Non-potable Water Supplies container includes NP-1, NP-2, NP-3, NP-6, LAG-1, Grey-1, and GW-3. These projects directly meet non-potable water demands. The Alternative Direct Potable Water Supplies container includes LSW-4, LAG3b, and Desal-1. These projects directly meet potable water demands. Every supply option alternative has an element that specifies a start date of January $1^{\text {st }}, 2020$ ("ProjectCode_StartYear"). The alternative options are also defined by the expected water supply ("ProjectCode_Supply"). Both the start date and the expected supply can be modified by the user. Supply options that fluctuate with wet periods and droughts are also defined by a drought capacity element ("ProjectCode_DroughtCapacity") and a year type expression ("ProjectCode_Supply_YearType"). In the model, a drought was defined as the $75^{\text {th }}$ percentile for water supplies, or a weather factor greater than 1.04. Similarly, a wet year was defined with a weather factor less than 0.98.

### 2.2.3.4 Alternative Banked and Water Transfers and Additional Local Storage Programs

The Alternative Banked and Water Transfers container includes IW-3 and IW-1, and the Additional Local Storage Program container includes IW-2. These alternatives have an element that specifies a start date of January $1^{\text {st }}, 2020$ ("ProjectCode_StartYear") but can be modified by the user. IW-1 is also defined by the expected water supply ("ProjectCode_Supply"). IW-2 and IW-3 are modeled as reservoirs ("ProjectCode_Supply") constrained by the bank capacity ("ProjectCode_BankCapacity"), inflows ("ProjectCode_Addition"), and outflows ("ProjectCode_Withdrawal") as defined in the PWP WSRP.

### 2.2.3.5 Alternative Water Use Efficiency Programs

The Alternative Water Use Efficiency Program container includes WUE-0, WUE-1, and WUE-2. These alternatives have an element that specifies a start date of January 1, 2020 ("ProjectCode_StartYear") but can be modified by the user. This component of the model calculates indoor water use ("Indoor_Use"), outdoor water use ("Outdoor_Use"), and per capita indoor water use ("WUE_0_IndoorGPCD") using population projections and demand projections defined in the PWP WSRP. Percent water use reductions are defined for each alternative ("WUE_0_IndoorReduction" or "ProjectCode_OutdoorReduction"), and these are used to calculate demand reductions for each option ("ProjectCode_Supply"). Note that WUE-1 and WUE-2 are supplementary to WUE-0 and turning these on will automatically trigger WUE-0. Water conservation from these options is treated as a supply and directly reduces water demands defined in the Water Demand Container.

### 2.2.4 Alternative Project Switches

The Alternative Project Switches container includes an element for each of the projects selected for potential implementation by PWP in collaboration with local stakeholders. Each element allows the model user manually to activate or deactivate each of the water resources options alternatives identified as part of the PWP WSRP. Each project element
is a binomial element where a " 0 " will deactivate the water supply project, and a " 1 " will activate the water supply project. Note that because of the nature of the projects, exceptions apply for GW-0 and GW-00. Portfolios that only select GW-0 should indicate a "1" for GW-0 and a " 0 " for GW-00, portfolios that identify both GW-0 and GW-00 should denote a "0" for both projects, and portfolios that neither select GW-0 nor GW-00 should indicate a "1" for both projects.

### 2.2.5 Supply Reliability and Resiliency Final Results Container

The Final Results container calculates water supply shortages based on the simulated water demands and supplies. The total demand is reduced by each project's expected water supply ("Final_ProjectCode") in a successive manner to calculate the remaining demand ("D_After_ProjectCode"). Water supply use is constrained by the remaining water demand, meaning that water supply use does not exceed water demands. The predetermined order of water supplies employed to meet demands are as follows: 1) water use efficiency projects, 2) nonpotable water supply projects, 3) groundwater adjudication allocation supplies, 4) Eaton Wash groundwater spreading credits, 5) Arroyo Seco groundwater spreading credits, 6) nonpotable groundwater supplies, 7) long-term groundwater storage supplies, 8) direct potable water supply projects excluding imported water projects, 9) imported water supply allocation, and 10) alternative imported water supply projects. The remaining demand is equal to the supply shortage.

## 3. MODEL SIMULATIONS

For the PWP WSRP, the model simulated expected supply reliability using the baseline demand projection and realization \#66. A realization is a single model run within a Monte Carlo simulation that represents one possible path the system could follow through time. In this model, realization \#66 represents the path with the highest expected supply shortages. It represents the hydrology sequence from 1987 to 2016 and includes the 1987-1992 drought and the 2011-2016 drought. The Supply Reliability and Resiliency derived from the simulated supply shortages are summarized in Chapter 4 of the PWP WSRP.

Final

## Appendix D Hydraulic Model

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# Pasadena Water System and Resources Plan APPENDIX D 




PASADENA WATER AND POWER
WATER SYSTEM HYDRAULIC MODEL CALIBRATION HYDRAULIC MODEL CALIBRATION REPORT

## FINAL

May 2017

# PASADENA WATER AND POWER <br> WATER SYSTEM HYDRAULIC MODEL CALIBRATION 

## HYDRAULIC MODEL CALIBRATION REPORT

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## LIST OF ABBREVIATIONS

| APN | Assessor's Parcel Number |
| :--- | :--- |
| Carollo | Carollo Engineers, Inc. <br> cfs |
| Cubic Feet per Second |  |
| City | City of Pasadena |
| EPA | Environmental Protection Agency |
| EPS | Extended Period Simulation |
| fps | Feet Per Second |
| ft/kft | Feet Per Thousand Feet |
| GIS | Geographic Information System |
| GUI | Graphical User Interface |
| HGL | Hydraulic Grade Line |
| IDSE | Initial Distribution System Evaluation |
| MG | Million Gallons |
| mgd | Million Gallons Per Day |
| MSL | Mean Sea Level |
| OOS | Out of Service |
| PWP | Pasadena Water \& Power |
| PRV | Pressure Reducing Valve |
| psi | Pounds Per Square Inch |
| SCADA | Supervisory Control and Data Acquisition |
| WTP | Water Treatment Plant |

If you wish to see the entire calibration report please contact PWP at 626-744-4409

## Appendix E Distribution System Analysis

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## APPENDIX E. DISTRIBUTION SYSTEM ANALYSIS

Appendix E provides information on the process used as part of the Water System and Resources Plan (WSRP) to assess PWP's distribution system capacity

The distribution system capacity analysis used the hydraulic model to evaluate system pressures, adequacy of pressure zones, and reliability. Tables E-1 and E-2 list each scenario run (using the scenario title as listed in the model), demand conditions, pipe set, and purpose for running the scenario under current and future demands. Note that the hydraulic model assumes that the supply portfolio used is unchanged from the baseline described in the WSRP, relying on existing groundwater wells and imported water connections. Figure E-1 provides the resulting hydraulic deficiencies under current conditions, while Figure E-2 provides additional hydraulic deficiencies under future conditions (assuming hydraulic deficiencies under existing conditions are addressed). Both of these figures assume a minimum pipe roughness coefficient of 80.

In addition to the pipeline network assessment performed using hydraulic modeling, a hydraulic assessment was performed to analyze the capacity of reservoirs and booster stations under current and future conditions. This hydraulic assessment was completed using a spreadsheet exercise that incorporated demand within each pressure zone, reservoir storage capacity, booster station capacity, supply inputs within each pressure zone and capacity requirements for reservoirs and booster stations within each pressure zone. Demand and supply within each pressure zone was exported from the hydraulic model. The capacity surplus or deficit was determined within each pressure zone, then any areas of deficit were analyzed to determine whether surplus from higher pressure zones could be used to offset the deficit. Based on this analysis, recommendations were developed for above-ground infrastructure improvements.

Tables E-3 and E-4 provide a summary of the booster station capacity by pressure zone for current and future demands, as well as the service-area wide total, with and without MWD imported water supply. These results indicate that, while some pressure zones show negative values, the service area as a whole has sufficient booster station capacity to provide service to all pressure zones, and that neighboring pressure zones have capacity to support zones with insufficient capacity.

Tables E-5 and E-6 provide a summary of the storage reservoir capacity, indicates that PWP has a surplus storage capacity for the system as a whole. While some individual pressure zones show a storage deficit, most are connected to zones of higher pressure via a pressure sustaining valve (PSV) that allows for the automatic cascading of water from the higher-pressure zone to the lower-pressure zone to meet demand. The only zone with a deficit that isn't connected to a higher-pressure zone is the Eagle Rock Pressure Zone located in the southwestern part of PWP's service area.

Table E-1: Hydraulic Modeling Scenarios Run Using Current Demands

| Scenario | Demand Conditions | Pipe Set | Purpose |
| :---: | :---: | :---: | :---: |
| $\begin{aligned} & \text { EX_ADD_ASSESSM } \\ & \text { ENT } \end{aligned}$ | ADD | Existing pipes | Check for maximum pressure violations |
| $\begin{aligned} & \text { EX_MDD_ASSESSM } \\ & E N \bar{T} \end{aligned}$ | MDD (includes PHD) | Existing pipes | Check for minimum pressure and maximum velocity violations. |
| EX_MDD_FF_ASSE SSMENT | MDD | Existing pipes | Check for fire flow availability and related deficiencies. |
| MDD_FF_MIN_C-80 | MDD | Existing pipes with minimum Hazen Williams factor set to 80 | Check for fire flow availability and related deficiencies. |
| MDD_FF_MIN_C-90 | MDD | Existing pipes with minimum Hazen Williams factor set to 90 | Check for fire flow availability and related deficiencies. |
| EX_CIP_DEV_ADD | ADD | Existing pipes + projects to address existing deficiencies | Develop projects and confirm projects address identified deficiencies. |
| EX_CIP_DEV_MDD | MDD (includes PHD) | Existing pipes + projects to address existing deficiencies | Develop projects and confirm projects address identified deficiencies. |
| $\begin{aligned} & \text { EX_CIP_DEV_MDD_ } \\ & \mathrm{FF}_{-} \end{aligned}$ | MDD | Existing pipes + projects to address existing deficiencies | Develop projects and confirm projects address identified deficiencies. |
| $\begin{aligned} & \text { EX_CIP_DEV_MDD_ } \\ & \text { FF_C-80 } \end{aligned}$ | MDD | Existing pipes + projects to address existing deficiencies | Develop projects and confirm projects address identified deficiencies. |
| $\begin{aligned} & \text { EX_CIP_DEV_MDD_ } \\ & \text { FF_C-90 } \end{aligned}$ | MDD | Existing pipes + projects to address existing deficiencies | Develop projects and confirm projects address identified deficiencies. |

Table E-2: Hydraulic Modeling Scenarios Run Using Future Demands

| Scenario | Demand Conditio ns | Pipe Set | Purpose |
| :---: | :---: | :---: | :---: |
| FUT_ADD_ASSESS MENT | ADD | Future pipes (assumes existing pipes + all projects to address existing deficiencies) | Check for maximum pressure violations under future demands conditions |
| FUT_MDD_ASSESS MENT | MDD <br> (includes PHD) | Future pipes | Check for minimum pressure and maximum velocity violations with under future demands conditions. |
| FUT_MDD_ASSESS MENT | MDD | Future pipes | Check for fire flow availability and related deficiencies under future demand conditions. |
| FUT_CIP_DEVELOP MENT | MDD <br> (includes PHD) | Future pipes + projects to address future deficiencies | Develop projects and confirm projects address identified deficiencies. |
| FUT_NEW_SUPPLY _PORTTFOLIO | MDD | Future pipes | Check for minimum pressure and maximum velocity violations with new supply portfolio and future demands. |
| FUT_NEW_SUPPLY _ADD_ASSESS | ADD | Future pipes | Check for maximum pressure violations with new supply portfolio and future demands. |
| FUT_NEW_SUPPLY _ADD_MWD_OOS | ADD | Future pipes | Check system ability to meet demands for 7 days under future demand conditions with new supply portfolio and all MWD connections out of service. |
| FUT_NEW_SUPPLY _ADD_WELLS_OOS | ADD | Future pipes | Check system ability to meet demands for 7 days under future demand conditions with new supply portfolio and wells out of service. |
| FUT_NEW_SUPPLY _MDD_WELLS_OOS | MDD | Future pipes | Check system ability to meet demands for 7 days under future demand conditions with new supply portfolio and wells out of service. |

Final
Water System and Resources Plan
Figure E-1: Modeled Flow Deficiencies under Current Conditions



Final
Water System and Resources Plan
Figure E-2: Modeled Flow Deficiencies under Future Conditions


Table E-3: Booster Station Capacity Analysis Results under Current Demands

| Pressure <br> Zone | Available <br> Capacity w/ <br> MWD* (gpm) | Available <br> Capacity w/o <br> MWD* (gpm) | Max Day <br> Demand <br> Exst (gpm) | Difference <br> w/ MWD <br> (gpm) | Difference <br> w/o MWD <br> (gpm) |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Allen | 2,200 | 2,200 | 1,198 | 1,002 | 1,002 |  |  |  |  |  |  |
| Allen Hydro | 300 | 300 | 9 | 291 | 291 |  |  |  |  |  |  |
| Annandale | 1,225 | 1,225 | 603 | 622 | 622 |  |  |  |  |  |  |
| Calaveras | 23,000 | 23,000 | 8,980 | 14,020 | 14,020 |  |  |  |  |  |  |
| Don Benito | 560 | 560 | 306 | 254 | 254 |  |  |  |  |  |  |
| Eagle Rock*** | 3,400 | 2,700 | 1,282 | 2,118 | 1,418 |  |  |  |  |  |  |
| Lida | 400 | 400 | 206 | 194 | 194 |  |  |  |  |  |  |
| Gould | 1,000 | 1,000 | 802 | 198 | 198 |  |  |  |  |  |  |
| Mirador | 815 | 815 | 111 | 704 | 704 |  |  |  |  |  |  |
| Murray Hydro | 300 | 300 | 37 | 263 | 263 |  |  |  |  |  |  |
| Sheldon | 13,300 | 13,300 | 7,897 | 5,403 | 5,403 |  |  |  |  |  |  |
| Sunset** | 33,032 | 7,000 | 15,011 | 18,020 | $-8,012$ |  |  |  |  |  |  |
| Total |  |  |  |  |  |  | $\mathbf{8 7 , 2 5 2}$ | $\mathbf{6 0 , 5 2 0}$ | $\mathbf{3 6 , 4 4 5}$ | $\mathbf{5 0 , 8 0 7}$ | $\mathbf{2 4 , 0 7 5}$ |
| * Total capacity minus the largest pump in the pressure zone |  |  |  |  |  |  |  |  |  |  |  |
| **Includes Woodbury, Wadsworth, Twombly, and Chapman wells. Also includes | P-1, P-2, and |  |  |  |  |  |  |  |  |  |  |
| P-3 MWD connections in w/ MWD capacity |  |  |  |  |  |  |  |  |  |  |  |
| ***P-5 MWD connection not included as it is the largest pump in the zone in w/ MWD capacity |  |  |  |  |  |  |  |  |  |  |  |

Table E-4: Booster Station Capacity Analysis Results under Future Demands

| Pressure Zone | Available Capacity w/ MWD* (gpm) | Available <br> Capacity w/o MWD* (gpm) | $\begin{gathered} \text { Max Day } \\ \text { Demand } \\ 2045 \text { (gpm) } \end{gathered}$ | Difference w/ MWD (gpm) | Difference w/o MWD (gpm) |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Allen | 2,200 | 2,200 | 1,258 | 942 | 942 |
| Allen Hydro | 300 | 300 | 11 | 289 | 289 |
| Annandale | 1,225 | 1,225 | 645 | 580 | 580 |
| Calaveras | 23,000 | 23.000 | 9,540 | 13,460 | 13,460 |
| Don Benito | 560 | 560 | 324 | 236 | 236 |
| Eagle Rock*** | 3,400 | 2,700 | 1,332 | 2,068 | 1,368 |
| Lida | 400 | 400 | 230 | 170 | 170 |
| Gould | 1000 | 1,000 | 878 | 122 | 122 |
| Mirador | 815 | 815 | 131 | 684 | 684 |
| Murray Hydro | 300 | 300 | 39 | 261 | 261 |
| Sheldon | 13,300 | 13,300 | 8,383 | 4,917 | 4,917 |
| Sunset** | 33,032 | 7,000 | 15,808 | 17,224 | -8,808 |
| Total | 87,252 | 60,520 | 38,579 | 48,673 | 21,941 |
| * Total capacity minus the largest pump in the pressure zone |  |  |  |  |  |
| **Includes Woodbury, Wadsworth, Twombly, and Chapman wells. Also includes P-1, P-2, and P-3 MWD connections in w/ MWD capacity |  |  |  |  |  |
| ***P-5 MWD connection not included as it is the largest pump in the zone in w/ MWD capacity |  |  |  |  |  |

Final
Water System and Resources Plan

| Water System and Resources Plan |  |  |  |  |  |  |  |  | Distribution System Analysis |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Table E-5: Reservoir Hydraulic Capacity Analysis Results under Current Demands |  |  |  |  |  |  |  |  |  |  |
|  | Existing Demand |  |  | Storage Requirements (MG) |  |  |  |  |  |  |
| Pressure Zone | Average Day Demand (mgd) | Maximum Day Demand (mgd) | Highest Zone FF Requirement | Fire Flow (Highest FF Req) | Operational (30\% of MDD) | $\begin{gathered} \text { Emergency } \\ \text { (50\% of } \\ \text { MDD) } \end{gathered}$ | Storage Required | Storage Available (MG) | Surplus/ Deficit | Sufficient Storage? |
| Allen Hydro* | 0.01 | 0.01 | Single-Family Res $1,500 \mathrm{gpm} / 2$ hours | 0.18 | 0.004 | 0.01 | 0.19 | 4.10 | 3.91 | Yes |
| Allen <br> (w/ Allen Red. 1 and 2) | 0.90 | 1.72 | Commercial $3,000 \mathrm{gpm} / 3$ hours | 0.54 | 0.52 | 0.86 | 1.92 | 4.10 | 2.18 | Yes |
| Annandale (w/ Annandale Red.) | 0.45 | 0.87 | Multi-Family Res $1,500 \mathrm{gpm} / 2$ hours | 0.18 | 0.26 | 0.43 | 0.87 | 0.64 | -0.23 | No |
| Calaveras <br> (w/ Calaveras Red. East and West) | 6.73 | 12.93 | High Schools $4,000 \mathrm{gpm} / 4$ hours | 0.96 | 3.88 | 6.47 | 11.31 | 20.40 | 9.09 | Yes |
| Don Benito (w/ Don Benito Red.) | 0.23 | 0.44 | Commercial $3,000 \mathrm{gpm} / 3$ hours | 0.54 | 0.13 | 0.22 | 0.89 | 1.40 | 0.51 | Yes |
| Eagle Rock | 0.96 | 1.85 | Commercial $3,000 \mathrm{gpm} / 3$ hours | 0.54 | 0.55 | 0.92 | 2.02 | 0.95 | -1.07 | No |
| Lida | 0.15 | 0.30 | Single-Family Res $1,500 \mathrm{gpm} / 2$ hours | 0.18 | 0.09 | 0.15 | 0.42 | 0.43 | 0.01 | Yes |
| Gould (w/ Gould Red.) | 0.60 | 1.15 | JPL $4,000 \mathrm{gpm} / 4$ hours | 0.96 | 0.35 | 0.58 | 1.88 | 3.00 | 1.12 | Yes |
| Mirador (w/ Mirador Red.) | 0.08 | 0.16 | Multi-Family Res $1,500 \mathrm{gpm} / 2$ hours | 0.18 | 0.05 | 0.08 | 0.31 | 1.00 | 0.69 | Yes |
| Murray Hydro** | 0.03 | 0.05 | Single-Family Res $1,500 \mathrm{gpm} / 2$ hours | 0.18 | 0.02 | 0.03 | 0.22 | 20.40 | 2.18 | Yes |
| Sheldon | 5.92 | 11.37 | City Hall $5,000 \mathrm{gpm} / 5$ hours | 1.5 | 3.41 | 5.69 | 10.60 | 11.83 | 1.23 | Yes |
| Sunset (w/ Sunset Red, Sierra Madre Villa, Sierra Madre Villa Red.) | 11.24 | 21.62 | PCC <br> $4,000 \mathrm{gpm} / 4$ hours | 0.96 | 6.49 | 10.81 | 18.25 | 65.33 | 47.08 | Yes |
| Total | 27.30 | 52.48 |  | 6.90 | 15.74 | 26.24 | 48.88 | 109.09 | 60.20 |  |
| * Allen Hydro receives available storage from Allen reservoir pressure zone <br> ** Murray Hydro receives available storage from Calaveras pressure zone |  |  |  |  |  |  |  |  |  |  |

Final
Water System and Resources Plan

| Water System and Resources Plan |  |  |  |  |  |  |  |  | Distribution System Analysis |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Table E-6: Reservoir Hydraulic Capacity Analysis Results under Future Demands |  |  |  |  |  |  |  |  |  |  |
|  | 2045 Demand |  |  | Storage Requirements (MG) |  |  |  |  |  |  |
| Pressure Zone | Ave. Day Demand (mgd) | $\begin{aligned} & \text { Max. Day } \\ & \text { Demand } \\ & \text { (mgd) } \\ & \hline \end{aligned}$ | Highest Zone FF Requirement | Fire Flow (Highest FF Req) | $\begin{aligned} & \text { Operational } \\ & \text { (30\% of } \\ & \text { MDD) } \\ & \hline \end{aligned}$ | $\begin{aligned} & \text { Emergency } \\ & \text { (50\% of } \\ & \text { MDD) } \end{aligned}$ | Storage Required | Storage Available (MG) | Surplus/ Deficit | Sufficient Storage? |
| Allen Hydro* | 0.01 | 0.02 | Single-Family Res 1,500 gpm/2 hours | 0.18 | 0.006 | 0.01 | 0.20 | 4.10 | 3.90 | Yes |
| Allen <br> (w/ Allen Red. 1 and 2) | 0.95 | 1.81 | Commercial 3,000 gpm/3 hours | 0.54 | 0.54 | 0.91 | 1.99 | 4.10 | 2.11 | Yes |
| Annandale <br> (w/ Annandale Red.) | 0.48 | 0.92 | Multi-Family Res $1,500 \mathrm{gpm} / 2$ hours | 0.18 | 0.28 | 0.46 | 0.92 | 0.64 | -0.28 | No |
| Calaveras <br> (w/ Calaveras Red. East and West) | 7.15 | 13.73 | High Schools 4,000 gpm/4 hours | 0.96 | 4.12 | 6.87 | 11.94 | 20.40 | 8.46 | Yes |
| Don Benito (w/ Don Benito Red.) | 0.24 | 0.47 | Commercial $3,000 \mathrm{gpm} / 3$ hours | 0.54 | 0.14 | 0.24 | 0.92 | 1.40 | 0.48 | Yes |
| Eagle Rock | 1.00 | 1.92 | Commercial 3,000 gpm/3 hours | 0.54 | 0.58 | 0.96 | 2.08 | 0.95 | -1.13 | No |
| Lida | 0.17 | 0.33 | Single-Family Res 1,500 gpm/2 hours | 0.18 | 0.10 | 0.17 | 0.44 | 0.43 | -0.01 | No |
| Gould (w/ Gould Red.) | 0.66 | 1.26 | JPL <br> 4,000 gpm/4 hours | 0.96 | 0.38 | 0.63 | 1.97 | 3.00 | 1.03 | Yes |
| Mirador (w/ Mirador Red.) | 0.10 | 0.19 | Multi-Family Res $1,500 \mathrm{gpm} / 2$ hours | 0.18 | 0.06 | 0.10 | 0.33 | 1.00 | 0.67 | Yes |
| Murray Hydro** | 0.03 | 0.06 | Singlei-Family Res 1,500 gpm/2 hours | 0.18 | 0.02 | 0.03 | 0.23 | 20.40 | 20.17 | Yes |
| Sheldon | 6.28 | 12.07 | City Hall 5,000 gpm/5 hours | 1.5 | 3.62 | 6.04 | 11.16 | 11.83 | 0.67 | Yes |
| Sunset (w/ Sunset Red, Sierra Madre Villa, Sierra Madre Villa Red.) | 11.84 | 22.77 | PCC <br> 4,000 gpm/4 hours | 0.96 | 6.83 | 11.39 | 19.18 | 65.33 | 46.15 | Yes |
| Total | 28.91 | 55.55 |  | 6.90 | 16.67 | 27.78 | 51.34 | 109.09 | 57.75 |  |
| * Allen Hydro receives available storage from Allen reservoir pressure zone |  |  |  |  |  |  |  |  |  |  |
| Pasadena Water \& Power |  |  |  |  |  |  |  |  |  | ovember 2020 |

## Appendix F Water Supply and Production Options

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|  | Supp | er and Powe and Product | er Water Option | Sys ions | and Resources Plan |  |  |  |  |  | 19 do |  |  |  |  |  | Appendix F No | Page 1 of 6 ember 2020 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| \# | No. | Name | Supply Source | $\begin{aligned} & \text { Use } \\ & \text { Cate } \end{aligned}$ | Description | $\begin{gathered} \text { Rechar } \\ \text { ge } \end{gathered}$ | Supply credits | Averag e Yield | Drought Yield | $\begin{aligned} & \text { Emerg } \\ & \text { ency } \end{aligned}$ | Capital or <br> Program Cost (\$) | Annual capital cost (\$/year) | $\begin{gathered} \text { O\&M } \\ \operatorname{Cost}(\$ / y r) \end{gathered}$ | Water <br> Purchas | Groundwat | Unit Cost | Assumptions and Notes | Sources |
| 1 | IW-0 | Treated imported water from MWD | $\begin{aligned} & \text { MWD } \\ & \text { imported } \\ & \text { water } \end{aligned}$ | Direct | Treated imported water purchased from MWD. | n/a | n/a |  |  | Specific to the type of emergen cy | n/a | n/a | n/a | \$ 1,444 | n/a | \$1,500 | Costs are projected to increase at approximately $2.5 \%$ per year for CIP implementation (excluding inflation), and therefore are based on the average estimated cost from 2018 to 2045, and include the WaterFix. The costs of $\$ 1,444 / \mathrm{AF}$ is an average for the planning period. Our model will use the time series of costs. | 2018-19 and 2019/20 Proposed Biennial Budget, Ten-Year Financial Forecast |
| 2 | IW-1 | Agricultural Spot Market or Long-Term Transfer | Ag water nolder holder | Direct | Spot market rights transfer or longterm transfer | n/a | 100\% | n/a | Specific to expected shortage level. Determined by the Analysis. | Specific to the type of emergen cy | \$ | \$ - | \$ | \$ 1,600 | \$0 | \$1,600 | Costs assumed to increase at approximately $3 \%$ per year, and therefore are based on the average estimated cost from 2018 to 2045, and include the WaterFix. The costs of $\$ 1,536 / \mathrm{AF}$ is an average for the planning period. Our model will use the time series of costs. If a "No Ca Water Fix" scenario is analyzed, costs will be increased at a $5 \%$ rate. | 2018-19 and 2019/20 Proposed Biennial Budget, Ten-Year Financial Forecast |
| 3 | IW-2 | Pasadena Groundwater Storage Program | $\underset{\substack{\text { Mmported } \\ \text { water }}}{\text { MWD }}$ | $\begin{gathered} \text { Recha } \\ \text { rge } \end{gathered}$ | Enter into agreement with MWD to store imported water in Raymond Basin | $\begin{gathered} 8,350 \text { for } \\ 3 \text { years } \\ (\sim 25,000 \\ \text { AF total } \\ \text { Put }) \end{gathered}$ | $\begin{gathered} 95 \%- \\ 10 \% \\ (-1 \% \text { loss } \\ \text { for } 5 \text { yrs }) \end{gathered}$ | n/a | $\begin{gathered} 23,750 \text { to } \\ 25,000 \end{gathered}$ | $\begin{gathered} 23,750 \\ \text { to } \\ 25,000 \end{gathered}$ | \$16,000,000 | \$1,040,000 | \$ 320,000 | \$ 1,071 | \$200 | \$1,900 | -Eastside Well Collector component has already been constructed, and therefore is removed from capital - Jourdan well is expected to be abandoned; assuming an additional new well will will be needed in its place. <br> - Put and take through new wells. - Assumes that a blend of SWP and Colorado River water will be recharged, and will meet the SNMP quality requirements - Nitrate treatment unnescessary as wells will be placed away from high nitrate areas. | 2011 WIRP Appendix E Table E-1. Groundwater options meeting information about specific wells. |
| 4 | IW-3 | External groundwater banking | Imported water from groundwa ter bank | Direct | Partner in a groundwater banking program to store SWP bank water through the MWD delivery and treatment system (e.g. Semitropic, Kern, IRWD). | n/a | n/a | n/a expected to be a drought supply | $\left.\begin{gathered} 1,100 \text { per } \\ \text { year over } 3 \\ \text { years } \end{gathered} \right\rvert\,$ | 0 | \$ 2,000,000 | \$ 130,000 | \$ 520,000 | Included in O\&M | n/a | \$2,000 | This would only work if the out-of-basin bank could access the SWP (i.e. not a paper exchange). Drought supply, not emergency. | 2011 WIRP Appendix E Table E-1 2014 Semitropic Rate Structure for Customers |
| 5 | IW-4 | Raw Imported <br> Water <br> Pipeline Connecting to SGVMWD's Devil CanyonAzusa Feeder \& Carson Recycled Water Pipelines | $\begin{gathered} \text { Imported } \\ \text { water } \end{gathered}$ | $\begin{gathered} \text { Recha } \\ \text { rge } \end{gathered}$ | Partner with foothill water agencies to construct new raw imported water to recharge areas in Raymond Basin. Project known as the San Gabrie//Raymond Basin Feeder, and would extend the existing Devil Canyon-Azusa Feeder Pipeline, owned by the San Gabrial Valley Municipal Water District (a State Water Project contractor), to the San Gabriel Basin and Raymond Basin for groundwater replenishment. Phase 1 would extend the pipeline from Azusa to the Santa Anita and Sierra Madre Spreading Grounds. | 1,000 | $\begin{array}{\|c\|} 100 \% \\ \text { (pumping } \\ \text { is the } \\ \text { same year } \\ \text { as } \\ \text { recharge) } \end{array}$ | 1,000 | 0 | 1,000 | \$26,000,000 | \$1,690,000 | \$60,000 | \$ 964 | \$200 | \$2,900 | - Assumes 12 cfs to Eaton Spreading <br> Grounds, 6 months of the year <br> - Imported water cost equal to $90 \%$ of MWD <br> untreated water cost. <br> - Costs include Phases 1 and 2 <br> - Costs include construction of 1 new wells, assuming capacity isn't available in the existing system. <br> - Note that partnerships will be necessary for realize the unit cost. | Foothill Water Coalition http://www.foothillwc.or g/proj.html\#Raymond Foothill MWD Water Resources Plan Alterantives Screening Report, January 2009 |
| 6 | LSW-0 | Arroyo Seco Canyon Project | $\begin{gathered} \text { Arroyo } \\ \text { Seco } \\ \text { Surface } \\ \text { Water } \\ \text { diversion } \\ \text { rights } \end{gathered}$ | $\begin{gathered} \text { Recha } \\ \text { rge } \end{gathered}$ | The Arroyo Seco Canyon Project will remove the Arroyo Seco Headworks structure and restore the area, replace the PWP diversion structure, and construct a new sedimentation basin, 3 acres of additional spreading basins, a new recreational parking lot, and an access road. Portions of the project expected to contribute to water supply are the new diversion structure and spreading basins. This project will be completed in 4 years. | 1000 | 80\% | 800 | 100 | 450 | \$7,400,000 | \$480,000 | \$60,000 | \$ | \$200 | \$900 | Supply volumes are based on additional recharge expected with new spreading grounds. <br> Supply recharged based on existing recharge at Arroyo Seco of 1,940 AFY (5year rolling average) to the 13.1 acre basin, and scaled to the size of the 3 acre basin. (Tables 5-1 and 5-2 of the Groundwater Replenishment Technical Assessment) Costs reflect new spreading grounds plus new diversion facility. Assumes PWP will be able to negotiate a higher credit percentage than used for the existing spreading grounds. | - Arroyo Seco Canyon Project email - SW Options Workshop (2/7) |


| $\begin{aligned} & \mathrm{Pas} \\ & \text { Wa } \end{aligned}$ | adena W er Supply | er and Powe and Product | er Water tion Opti | Syst ions | and Resources Plan |  |  |  |  |  | 10 |  |  |  |  |  | Appendix No | Page 2 of 6 vember 2020 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| \# | No. | Name | Supply Source | $\begin{gathered} \text { Use } \\ \text { Cate } \end{gathered}$ | Description | $\begin{gathered} \text { Rechar } \\ \text { ge } \end{gathered}$ | $\begin{aligned} & \text { Supply } \\ & \text { credits } \end{aligned}$ | Averag e Yield | $\begin{gathered} \text { Drought } \\ \text { Yield } \end{gathered}$ | $\begin{aligned} & \text { Emerg } \\ & \text { ency } \end{aligned}$ | $\begin{aligned} & \text { Capital or } \\ & \text { Program Cost (\$) } \end{aligned}$ | $\begin{aligned} & \text { Annual capital } \\ & \text { cost (\$/year) } \end{aligned}$ | $\begin{gathered} \text { O\&M } \\ \operatorname{Cost}(\$ / \mathrm{yr}) \end{gathered}$ | $\begin{aligned} & \text { Water } \\ & \text { Purchas } \end{aligned}$ | Groundwat | $\begin{aligned} & \text { Unit } \\ & \text { Cost } \end{aligned}$ | Assumptions and Notes | Sources |
| 7 | LSW-1a | Arroyo Seco to Eaton Canyon Raw Water Pipeline | $\begin{aligned} & \text { Arroyo } \\ & \text { Seco } \\ & \text { SWash } \end{aligned}$ | $\begin{gathered} \text { Recha } \\ \text { rge } \end{gathered}$ | Project to use existing old and new pipelines and a new pump to move Atorm events from the reservoir pool behind Devil's Gate Dam to the Eaton Spreading Grounds. This project was originally proposed by LA County and put on hold because it would have delayed the Drive road improvements to New York | 1,070 | 80\% | 860 | 200 | 860 | \$6,600,000 | \$430,000 | \$100,000 | \$ . | \$200 | \$800 | Credits: 627 AFY <br> Would count against Pasadena's 25 cfs right to divert Arroyo Seco Canyon water Either/or with the Arroyo Seco Pump Back project County pulled the original project. | - FINAL Devil's Gate to Eaton Water Conservation Pipeline Feasibility Copy - Devil's Gate Dam and Reservoir WC Project website Devirs Gate to Eaton PASADENA NOW devils-gate-Eaton-canyon-pipeline - GW and RW Options Workshop (1/31) |
| 8 | LSW-1 | Arroyo Seco Pump Back Project | $\begin{gathered} \text { Arroyo } \\ \text { Seco } \\ \text { Sash } \end{gathered}$ | $\begin{gathered} \text { Recha } \\ \text { rge } \end{gathered}$ | Project consists of developing a new pipeline from the Devil's Gate Dam to the Arroyo Seco spreading basins and installing new pumping system and controls at the dam. 1,000 AFY could be used for recharge. | 1,000 | 60\% | 600 | 0 | 0 | \$4,000,000 | \$260,000 | \$200,000 | \$ . | \$200 | \$1,000 | -Assumes that the project increases pumping credits and LA County will pay for the pump and the pumping power - Costs provided in "FW: Arroyo Seco Pump Back System" include cost for both the piping and spreading ground enlargement. pumping additional water | - Arroyo Seco Pump Back <br> FW Arroyo Seco <br> Pump Back System <br> - SW Options <br> Workshop (2/7) |
| 9 | LSW-4 | Re-Open and Upgrade Behner WTP to use Arroyo Seco water for drinking | Arroyo Secro Surace Wheter diversion rights | $\left\|\begin{array}{c\|c\|} \text { Direct } \\ \text { potal } \\ \text { euse } \end{array}\right\|$ | Bring Behner WTP capacity back online to treat water for potable use, with excess Arroyo Seco water to be sent to spreading basins. | n/a | n/a | 860 | 500 | Specific to the type of emergen cy | \$7,100,000 | \$460,000 | \$360,000 | \$ |  | \$1,000 | Yield assumes surface diversions will first be sent to the new treatment plant before being sent to existing spreading areas. | 2011 WIRP Appendix E Table E-1 |
| 10 | LSW-5 | Natural infrastructure | Arroyo weco wateshe a in addition diversion diver rights | $\begin{gathered} \text { Recha } \\ \text { rge } \end{gathered}$ | Manage land (invasive species and sediment control) in the Arroyo Seco watershed to increase overa recharge within the natural watershed by up to $5 \%$. | 200 | 60\% | 120 | 40 | n/a | \$0 | \$0 | \$50,000 |  | \$200 | \$600 | Land management would result in an increase of $5 \%$ in natural recharge. | Need reference. |
| 11 | LAG-1 | Phase 1 Nonpotable Reuse using LAG-WRP Recycled Water | $\begin{gathered} \text { LAG- } \\ \text { LFRPR } \\ \text { teraiary } \\ \text { treated } \\ \text { recycled } \\ \text { water } \end{gathered}$ | $\begin{array}{\|c} \text { Direct } \\ \text { non } \\ \text { porab } \\ \text { pouse } \end{array}$ | Construct facilities to deliver recycled water from the LAG-WRP to Pasadena to serve non-potable demands. This is the Phase 1 Project in the PWP Recycled Water Planning Study. | n/a | n/a | 700 | 700 | 700 | \$14,400,000 | \$940,000 | \$30,000 | \$ 829 | n/a | \$2,200 | Phase 1 core project from the PWP Recycled Water Feasibility Study, but does not include tunnel water as this is a separate option in the WSRP (NP-1). | PWP Recycled Water Feasibility Study. 5\% Design Cost. |
| 12 | LAG-2 (screen ed out) | Phase 1 recycled water program plus recharge recycled water from LAG-WRP at Eaton Wash |  | $\begin{array}{\|c} \text { Recha } \\ \text { rge } \end{array}$ | Construct facilities for Phase 1 of the NPR program, and facilities to deliver recycled water from the AG-WRP to Eaton Wash Spreading Grounds (405 AFY) and for non-potable use (700 AFY) | 405 | 80\% | 1,000 | 1,000 | 1,000 | \$14,400,000 | \$940,000 | \$30,000 | \$829 | \$200 | \$1,880 | Raymond Basin SNMP sets assimilative capacity limits that will limit the amount of tertiary treated recycled water from LAG to 405 AFY. Recommend screening out. Infeasible due to SNMP assimilative capacity limits. | $\begin{aligned} & \text { PWP Groundwater } \\ & \text { Replenishent } \\ & \text { Technical Assessment } \end{aligned}$ |


| Pasadena Water and Power Water System and Resources Plan Water Supply and Production Options |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Appendix F Page 3 of 6 November 2020 |  |
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| \# | No. | Name | Supply Source | Use Cate | Description | Rechar ge | Supply credits | Averag e Yield | Drought Yield | Emerg ency | Capital or Program Cost (\$) | Annual capital cost (\$/year) | $\begin{gathered} \text { O\&M } \\ \text { Cost }(\$ / y r) \end{gathered}$ | Water Purchas | Groundwat | Unit Cost | Assumptions and Notes | Sources |
| 13 | LAG-3a | Advanced Treatment of Recycled Water from LAG-WRP for Recharge | LAGWRP advanced treated recycled water | $\begin{gathered} \text { Recha } \\ \text { rge } \end{gathered}$ | Use advanced treated water from LAG for recharge. Option would construct a distribution system to convey tertiary treated water from the LAG-WRP to Pasadena, a brine disposal system that connects to either the LA BOS or LACSD systems, an advanced water treatment plant in the Pasadena area, and a distribution system to convey the advanced treated water to Eaton Wash Spreading Grounds, and monitoring wells. Project would use an abandoned pipe as part of the conveyance to Eaton Spreading | 3,200 | 80\% | 2,600 | 2,600 | 2,600 | (1) | \$ $\$ 1,420,000$ |  | \$ 829 | \$200 | \$3,000 | Assumes advanced treatment system constructed to treat tertiary water in the PWP service area. <br> This would be an either/or with NP-1 Would include the existing pipeline too. Based on Option EW4 in the PWP Groundwater Replenishment Technical Assessment (2010). Capital cost reduced to account for reuse of abandoned pipe. | GW and RW Options Workshop (1/31) <br> PWP Groundwater Replenishment Technical Assessment |
| 14 | LAG-3b | Advanced Treatment of Recycled Water from LAG-WRP for Direct Use | LAGWRP advanced treated recycled water | Direct potabl e use | Use advanced treated water from LAG for direct use. Option would construct a distribution system to convey tertiary treated water from the LAG-WRP to Pasadena, a brine disposal system that connects to either the LA BOS or LACSD systems, an advanced water treatment plant in the Pasadena area, and a connection to the potable water distribution system. | n/a | n/a | 3,200 | 3,200 | 3,200 | \$15,800,000 | \$1,030,000 | \$3,620,000 | \$ 829 | \$0 | \$2,300 | Assumes advanced treatment system constructed to treat tertiary water This would be an either/or with NP-1 Would include the existing pipeline too. Cost to upgrade LAG-WRP to advanced treatment plus conveyance facilities to PWP service area. | GW and RW Options Workshop (1/31) <br> Central Los Angeles County Regional Water Recycling Project Technical Memorandum |
| 15 | NP-1 | Tunnel Water to Brookside Golf Course | Devil's <br> Gate <br> Tunnel and Richardso n Tunnel | Direct nonpotabl e use | Use tunnel wells for irrigation at Brookside Golf Course. Option includes the use of Devil's Gate Tunnel (238 AFY of supply) and Richardson Tunnel (195 AFY). Included in NP-3. | n/a | n/a | 433 | 0 | 0 | \$1,100,000 | \$71,557 | \$30,000 | \$ | n/a | \$200 | PWP has water rights to 238 AFY of tunnel water. Assumes 433 AFY available on average (from the PWP Recycled Water Plannign Study, Table 4-20). This is included as a part of NP-3, and therefore is mutually exclusive. | 2011 WIRP Appendix E <br> 2012 PWP Recycled Water Planning Study |
| 16 | NP-2 | Arroyo Seco Diversions from Channel to Brookside Golf Course | Arroyo Seco stream water diversion | Direct nonpotabl e use | Divert Arroyo Seco to Brookside golf course for irrigation to capture additional water that cannot be recharged. | n/a | n/a | 550 | 0 | 550 | \$6,500,000 | \$420,000 | \$210,000 | \$ - | n/a | \$1,100 | 771 AFY of surface water expected to be available for the project in an average year, but Golf Course demand is approximately 550 AFY. This is included as a part of NP-3, and therefore is mutually exclusive. | 2011 WIRP Appendix E Table E-1 |
| 17 | NP-3 | Local NonPotable Project | Tunnel water rights \& well water with nitrate levels above the drinking water MCLs | Dire ct nonpota ble use for irrig atio n | Construct a non-potable system that uses tunnel water and high nitrate well water as an irrigation supply. The system will serve non-potable demands for irrigation (Muir High School, Robinson Park, Victory Park, Pasadena High School, Brookside Park and Golf Course, Brenner Park, Villa Park, McDonald Park, Eaton Golf Course, Marshall Fundamental and other schools and landscaped areas in Pasadena. | 500 | 80\% | 1400 | 500 | 1400 | \$10,000,000 | \$650,000 | \$73,000 | \$ - | \$200 | \$700 | Note that volumes and cost estimates are very high level, and will need to be confirmed. <br> NP-3 overlaps with NP-1 and NP-2. Would only do one. | 2011 WIRP Appendix E <br> 2012 PWP Recycled Water Planning Study |
| 18 | NP-4 (screen ed out) | Satellite plant to treat wastewater near the Arroyo Seco Spreading Grounds | Local wastewat er | Recha rge | Construct a 0.25 mgd satellite plant (including MBR) to extract and treat wastewater from the LACSD Joint Outfall, and construct shallow infiltration galleries beneath the athletic fields at John Muir High School. Will recharge approximately 280 AFY. (Alternative A-6 in the Foothill study) | 280 | 60\% | 200 | 200 | 200 | \$7,500,000 | \$490,000 | \$130,000 | \$ - | \$200 | \$3,100 | Recommend screening out due to potential impacts to the plume. Otherwise, would need to consider groundwater treatment. | FMWD Water Recycling - Project Alternative Analysis |

Pasadena Water and Power Water System and Resources Plan
Water Supply and Production Options

 to meet the goals of the ULAR EMWP, and
scaled according to the cost of each component.

- Assumes 10 rain events per year
- Assumes 1 new

$\underset{\text { Cost }}{\text { Unit }}$

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| Pasadena Water and Power Water System and Resources Plan Water Supply and Production Options |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Appendix F Page 6 of 6 November 2020 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  |  |  |  | 2019 dollars |  |  |  |  |  | November 2020 |  |
| \# | No. | Name | Supply Source | $\begin{aligned} & \text { Use } \\ & \text { Cate } \\ & \hline \end{aligned}$ | Description | $\begin{gathered} \text { Rechar } \\ \text { ge } \end{gathered}$ | Supply credits | Averag <br> e Yield | Drought Yield | $\begin{gathered} \text { Emerg } \\ \text { ency } \end{gathered}$ | Capital or Program Cost (\$) | Annual capital cost (\$/year) | $\begin{gathered} 08 \mathrm{M} \\ \operatorname{Cost}(\$ / \mathrm{yr}) \end{gathered}$ | Water Purchas | Groundwat | $\begin{aligned} & \text { Unit } \\ & \text { Cost } \end{aligned}$ | Assumptions and Notes | Sources |
| 33 | GW-00 | Well rehab and equipment replacement projects, importance level 2 | Groundw ater | Direct <br> potabl <br> e use <br> or non <br> potabl <br> e <br> depen <br> ding <br> on well <br> and <br> option <br> triggeri <br> ng the <br> rehab <br> below | Implement improvements to maintain pumping capacity by implementing projects to upgrade piping, replace electrical service, install/replace flowmeters, install new pressure monitoring, install new site control panels at wells. These improvements will only be required if the options below (GW2, GW3) are used. These improvements have been assigned an importance level of 2 . Option will also implement projects listed as "importance level 2" and categorized as improvements to energy efficiency. | n/a | n/a | 1,600 | 1,600 | 1,600 | \$400,000 | \$30,000 | n/a. <br> Assuming <br> current <br> is O \&ufficient. | n/a | \$200 | \$200 | Assumes groundwater will be available. | Facilities upgrades workbook |
| 34 | GW-2a | Add nitrate treatment to the Monk Hill wells | Groundw ater | Direct <br> potabl <br> euse <br> (after <br> GAC <br> treatm <br> ent at <br> Monk <br> WTP) | Add wellhead treatment for Nitrate to Wells 52 and Ventura to be able to send to Monk Hill WTP for additional treatment. This option is mutually exclusive with GW-3 for Ventura and well 52 | n/a | n/a | 2,400 | 2,400 | 2,400 | \$7,500,000 | \$490,000 | \$490,000 | n/a | \$200 | \$600 |  | PWP staff at GW and RW Options Workshop (1/31) |
| 35 | GW-2b | Add Nitrate, Perchlorate \& Volatile Organic Compounds Treatment to the Sunset Wells | Groundw ater | $\begin{aligned} & \text { Direct } \\ & \text { potabl } \\ & \text { e use } \end{aligned}$ | Add wellhead treatment to wells pumping in areas of plumes currently using blending to meet water quality requirements. | n/a | n/a | 3,500 | 3,500 | 3,500 | \$2,900,000 | \$190,000 | \$150,000 | n/a | \$200 | \$300 | Volumes are based on operating capacity by pumping zone (sunset area of the Pasadena Subbasin $=3,500 \mathrm{AFY}$ out of the adjudication of 5,000 AFY) | PWP staff at GW and RW Options Workshop (1/31) |
| 36 | GW-3 | Connect high nitrate wells to a local nonpotable system | Groundw ater | Direct nonpotab | Using high nitrate wells for nonpotable uses would allow for the beneficial use of groundwater without over-treatment. This option is mutually exclusive with GW-2a for Ventura and well 52 (Sheldon and Copelin will not be treated for potable) | n/a | n/a | 3,200 | 3,200 | 3,200 | \$3,000,000 | \$200,000 | \$200,000 |  | \$200 | \$300 | Wells identified by PWP for NPR system: Ventura, Sheldon, Copelin Assumes groundwater will be available. Project assumed to be a part of NP-3. | PWP staff at GW and RW Options Workshop (1/31) |

## Appendix G Water Distribution and Storage Options

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APPENDIX G. WATER DISTRIBUTION AND STORAGE OPTIONS
Appendix G contains detailed information regarding projects to address deficiencies identified at reservoirs, booster stations and pipelines, as well as the summary costs that are rolled up to create the distribution and storage options.
Summary Storage and Distribution Options ..... Page 1
Standardized Projects, Costs and Importance Levels ..... Page 2
Pipeline Risk Levels and Assessment. ..... Page 3
Reservoir Projects ..... Page 4
Booster Station Projects ..... Page 18

PWP 2020 WSRP
Summary Storage and Distribution Options
Appendix G Page 1

| Category | Importance | Storage | Distribution | Total |
| :---: | :---: | :---: | :---: | :---: |
| Mechanical | 1 | \$0 | \$1,075,000 | \$1,075,000 |
|  | 2 | \$500,000 | \$950,000 | \$1,450,000 |
|  | 3 | \$0 | \$100,000 | \$100,000 |
|  | Subtotal | \$500,000 | \$2,125,000 | \$2,625,000 |
| Electrical | 1 | \$0 | \$950,000 | \$950,000 |
|  | 2 | \$0 | \$800,000 | \$800,000 |
|  | 3 | \$0 | \$350,000 | \$350,000 |
|  | Subtotal | \$0 | \$2,100,000 | \$2,100,000 |
| Controls | 1 | \$0 | \$0 | \$0 |
|  | 2 | \$0 | \$10,000 | \$10,000 |
|  | 3 | \$0 | \$0 | \$0 |
|  | Subtotal | \$0 | \$10,000 | \$20,000 |
| Overall Facility Replacement | 1 | \$33,000,000 |  | \$33,300,000 |
|  | 2 | \$1,200,000 |  | \$1,200,000 |
|  | 3 | \$0 |  | \$0 |
|  | Subtotal | \$34,200,000 |  | \$34,500,000 |
| Rehab/ Replacement | 1 | \$33,000,000 | \$116,113,600 | \$149,113,600 |
|  | 2 \& 3 | \$1,700,000 | \$177,111,800 | \$178,361,800 |
|  | 3 | \$0 | \$450,000 | \$450,000 |
|  | Subtotal | \$34,700,000 | \$293,675,400 | \$328,375,400 |
| Capacity exp. based on future demands | n/a | \$0 | \$343,800 | \$343,800 |
| Energy Efficiency | 1 | \$0 |  | \$0 |
|  | 2 | \$0 |  | \$0 |
|  | 3 | \$300,000 |  | \$550,000 |
|  | n/a | \$300,000 | \$250,000 | \$550,000 |
| Resiliency/ Redundancy (incl. seismic) | 1 | \$0 |  | \$0 |
|  | 2 | \$7,054,000 |  | \$7,338,000 |
|  | 3 | \$0 |  | \$157,000 |
|  | n/a | \$7,054,000 | \$441,000 | \$7,495,000 |
| Site / Security / Building | 1 | \$0 |  | \$0 |
|  | 2 | \$534,000 |  | \$609,000 |
|  | 3 | \$100,000 |  | \$250,000 |
|  | n/a | \$634,000 | \$225,000 | \$859,000 |
| All | TOTAL | \$42,688,000 | \$294,485,200 | \$336,723,200 |

Standardized Projects, Costs and Importance Level
Appendix G Page 2

Pipeline Risk Level
PWP 2020 WSRP Appendix G Page 3
le

| Likelihood of Failure |  |  |
| :---: | :---: | :---: |
| A | 1 | Poor condition due to break history AND age (>80 years) AND flow d |
|  | 2 | Meets two of these conditions: Age (>80 years), flow deficiency, poor |
|  | 3 | Meets one of these conditions:Age (>80 years), flow deficiency, poor |
|  | 9 | Pipes in good condition and with no hydraulic deficiencies are not cons |
| Consequence of failure |  |  |
| B | 1 | - Pipeline adjacent to Huntington Hospital OR <br> - Pipeline overlaps with major business district OR <br> - Pipeline is above 12-in. (assume to include pipelines from Met) $\underline{O R}$ <br> - 12-in or smaller, if single pipe feeding a zone or area |
|  | 2 | - Single pipe from a well OR <br> - Within fire risk area |
|  | 3 | Pipe network, residential area |


| Risk Score Calculation: $\mathbf{C = A x}$ B |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| \# | Risk Score <br> (C) | Relative Risk Level | Feet Pipe | Miles Pipe | \% of pipe | Years to Replace at 5 miles/year |  | Est. Cost (\$200/LF) | Importance Level | $A \times B$ |
| 1 | 1-2 | Critical | 29,417 | 6 | 1\% | 1.1 | 0.6 | \$5,883,400 | Level 1 | 1x1, 1x2 |
| 2 | 3-4 | Extreme | 226,172 | 43 | 8\% | 8.6 | 4.3 | \$45,234,400 | Level 1 | $1 \times 3,3 \times 1$ |
| 3 | 6 | High | 313,354 | 59 | 12\% | 11.9 | 5.9 | \$62,670,800 | Level 1 | 2x3, $3 \times 2$ |
| 4 | 9 | Medium | 874,509 | 166 | 33\% | 33.1 | 16.6 | \$174,901,800 | Level 2 | $3 \times 3,9 \times 1$ |
| 5 | $>9$ | Low | 1,233,929 | 234 | 46\% | 46.7 | 23.4 | \$246,785,800 |  | 9x2, $9 \times 3$ |
|  |  | Total | 2,677,381 | 507 | 100\% | 101 | 51 | \$535,476,200 |  |  |
| Capacity expans - meet future demands |  |  | 1,719 | 0.3 |  |  |  | \$343,800 |  |  |

Pipeline Risk Assessment GIS Processing Detail

| Criteria | GIS Processing | Shapefile | Indic |  |
| :---: | :---: | :---: | :---: | :---: |
| Likelihood of Failure |  |  |  |  |
| Poor condition, breaks | Pipe is within 200 ft of main break | Brk200ft | 1 if conditions met, | otherwise 0 |
| >80 years old | YR_INST field > 0 and < 1940 | Age 80yrs | 1 if conditions met, | otherwise 0 |
| Flow deficiency | CAP_Proj_8 recom improvements | FlowDefic | 1 if conditions met, | otherwise 0 |
| Consequence of Failure |  |  |  |  |
| Near critical care hospital | Pipes by Huntington Memorial Hospital | Hospital | 1 if conditions met, | otherwise 0 |
| Within business district | Pipe 50-feet from business district | BusDist | 1 if conditions met, | otherwise 0 |
| Pipeline > 12" dia. | Diameter > 12 | Over12inch | 1 if conditions met, | otherwise 0 |
| Single pipe in a zone with diameter = or <12" | Processing visually completed | SPZone | 1 if conditions met, | otherwise 0 |
| Fire risk area | Pipe in fire risk area (maps by PWP) | FireRisk | 1 if conditions met, | otherwise 0 |
| Single pipe from a well | Single pipe from a well to distribution system | SPWell | 1 if conditions met, | otherwise 0 |

Allen Reservoir
PWP 2020 WSRP
Appendix G Page 4

| Category |  | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{gathered} \mathrm{E} \\ \mathrm{q} \\ \mathrm{u} \\ \mathrm{i} \\ \mathrm{p} \\ \mathrm{~m} \\ \mathrm{e} \\ \mathrm{n} \\ \mathrm{t} \end{gathered}$ | Mechanical | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$0 | 1 |
|  |  | Piping Upgrades | 1 | EA | \$50,000 | \$50,000 | 2 |
|  |  | Repair Reservoir Cracking |  | EA | \$0 | \$0 | 2 |
|  |  | Repair Reservoir Lining/Recoating |  | EA | \$0 | \$0 | 2 |
|  |  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
|  | Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  |  | Replace MCC |  | EA | \$125,000 | \$0 | 1 |
|  |  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
|  | Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  |  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency |  | none | 1 | EA | \$0 | \$0 | 3 |
|  |  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 3 |
|  |  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
| Resiliency/ Redundancy (incl. seismic) |  | none |  | EA | \$0 | \$0 | 3 |
|  |  | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  |  | Install Generator Connector |  | EA | \$5,000 | \$0 | 2 |
|  |  | Seismic Upgrades | 1 | EA | \$381,000 | \$381,000 | 2 |
| Site / Security / Building |  | Replace Allen Reservoir Roof | 40,500 | per SF | \$10 | \$405,000 | 2 |
|  |  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  |  | Minor Building Modifications | 1 | EA | \$25,000 | \$25,000 | 3 |
|  |  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility Replacement |  | none | 1 | EA | \$0 | \$0 | 3 |
|  |  | Replace Reservoir |  | per gal | \$3 | \$0 | 1 |
|  |  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 |
| Level 1 <br> Level 2 <br> Level 3 <br> All Projects: |  |  |  |  |  |  - <br> $\$$ 836,000 <br> $\$$ 25,000 <br> $\$$ 861,000 |  |

Annandale Reservoir
PWP 2020 WSRP
Appendix G Page 5

| Unit Cost | Total <br> Cost | Importance <br> Level |
| :---: | :---: | :---: |
| $\$ 0$ | $\$ 0$ | 3 |
| $\$ 50,000$ | $\$ 0$ | 1 |
| $\$ 25,000$ | $\$ 0$ | 1 |
| $\$ 125,000$ | $\$ 0$ | 3 |
| $\$ 100,000$ | $\$ 0$ | 1 |
| $\$ 0$ | $\$ 0$ | 2 |
| $\$ 10,000$ | $\$ 0$ | 3 |
| $\$ 5,000$ | $\$ 0$ | 2 |
| $\$ 75,000$ | $\$ 0$ | 2 |
| $\$ 0$ | $\$ 0$ | 3 |
| $\$ 50,000$ | $\$ 0$ | 3 |
| $\$ 50,000$ | $\$ 0$ | 3 |
| $\$ 0$ | $\$ 0$ | 3 |
| $\$ 25,000$ | $\$ 0$ | 2 |
| $\$ 5,000$ | $\$ 0$ | 2 |
| $\$ 0$ | $\$ 0$ | 2 |
| $\$ 25,000$ | $\$ 0$ | 3 |
| $\$ \mathbf{2 5 , 0 0 0}$ | $\$ \mathbf{2 5 , 0 0 0}$ | $\mathbf{3}$ |
| $\$ 100,000$ | $\$ 0$ | 3 |
| $\$ 0$ | $\$ 0$ | 3 |
| $\$ 5,000$ | $\$ 0$ | 1 |


Don Benito 1 \& 2 Reservoir
PWP 2020 WSRP Appendix G Page 7
 All Projects: \$ 1,615,000
Eagle Rock Reservoir
PWP 2020 WSRP
Appendix G Page 8

| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Mechanical | Piping Upgrades | 1 | EA | \$50,000 | \$50,000 | 2 |
|  | Repair Reservoir Cracking |  | EA | \$0 | \$0 | 2 |
|  | Repair Reservoir Lining/Recoating |  | EA | \$0 | \$0 | 2 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace MCC |  | EA | \$125,000 | \$0 | 1 |
|  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install /Replace Flowmeter |  | EA | \$10,000 | \$0 | 2 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | none | 1 | EA | \$0 | \$0 | 3 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
| Resiliency/ Redundancy (incl. seismic) | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector |  | EA | \$5,000 | \$0 | 2 |
|  | Seismic Upgrades |  | EA | \$0 | \$0 | 2 |
| Site / Security / Building | none |  | EA | \$0 | \$0 | 3 |
|  | Replace Eagle Rock Reservoir Roof | 10,400 | per SF | \$10 | \$104,000 | 2 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  | Minor Building Modifications |  | EA | \$25,000 | \$0 | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Reservoir |  | per gal | \$3 | \$0 | 1 |
| Level 1 $\$$ - <br> Level 2 $\$$ 154,000 <br> Level 3 $\$$ - <br> All Projects: $\$$ $\mathbf{1 5 4 , 0 0 0}$ |  |  |  |  |  |  |

Gould East and West Reservoirs
PWP 2020 WSRP 6 әбed ๑ x!puәdd $\forall$
 Leme

 $\begin{array}{cl}\text { Level 1 } & \$ 0 \\ \text { Level 2 } & \$ 141,000 \\ \text { Level 3 } & \$ 0 \\ \text { All Projects: } & \mathbf{\$ 1 4 1 , 0 0 0}\end{array}$

Jones Reservoir
PWP 2020 WSRP Appendix G Page 10


Mirador Reservoir
PWP 2020 WSRP


## Importance Level

 \begin{tabular}{|l|}\hline 1 <br>
\hline 1
\end{tabular}

  NF .on . $m$ (๓)
 $-$
效 $\$ 0$
$\$ 150,000$
$\$ 0$
$\$ 150,000$
Santa Anita Reservoir
PWP 2020 WSRP
Appendix G Page 13
Sheldon 1 \& 2 Reservoir PWP 2020 WSRP
Appendix G Page 14

| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| E Mechanical <br> q  <br> u  | none |  | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$0 | 1 |
|  | Piping Upgrades | 1 | EA | \$50,000 | \$50,000 | 2 |
|  | Repair Reservoir Cracking |  | EA | \$0 | \$0 | 2 |
|  | Repair Reservoir Lining/Recoating |  | EA | \$0 | \$0 | 2 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace MCC |  | EA | \$125,000 | \$0 | 1 |
|  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install /Replace Flowmeter |  | EA | \$10,000 | \$0 | 2 |
|  | Install New Pressure Monitoring |  | EA | \$5,000 | \$0 | 2 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | none |  | EA | \$0 | \$0 | 3 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
|  | Install Solar PV System | 1 | EA | \$300,000 | \$300,000 | 3 |
| Resiliency/ Redundancy | none |  | EA | \$0 | \$0 | 3 |
|  | Install Seismic Valve Actuators | 2 | EA | \$25,000 | \$50,000 | 2 |
| Site / Security / Building | none | 1 | EA | \$0 | \$0 | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  | Minor Building Modifications |  | EA | \$25,000 | \$0 | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility <br> Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Reservoir |  | per gal | \$3 | \$0 | 1 |
|  | Drill and Equip New Well |  | EA | \$3,000,000 | \$0 | 1 |
|  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 |

Sunset 1 \& 2 Reservoirs
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|  | N | N | N | - | $\cdots$ | $\leftharpoondown$ | N | $\cdots$ | N | N | $\cdots$ | $\cdots$ | $\cdots$ | $\cdots$ | N | N | N | N | $\cdots$ | $\cdots$ | $\cdots$ | $\cdots$ | $\leftharpoondown$ | $\leftharpoondown$ | $\leftharpoondown$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $$ | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 10 \\ & \infty \end{aligned}$ | $10$ | $\left\lvert\, \begin{aligned} & 0 \\ & \infty \end{aligned}\right.$ | $\left\lvert\, \begin{aligned} & 0 \\ & \infty \end{aligned}\right.$ | $\left\lvert\, \begin{aligned} & 0 \\ & \infty \end{aligned}\right.$ | $\left\|\begin{array}{\|c\|} \hline 0 \\ \infty \end{array}\right\|$ | $\left\lvert\, \begin{aligned} & \circ \\ & \leftrightarrow \end{aligned}\right.$ | $\left\|\right\|$ | $\left\lvert\,\right.$ | $\left\|\begin{array}{\|c\|} \hline 0 \\ \infty \end{array}\right\|$ | $0$ | $\left\lvert\, \begin{aligned} & \circ \\ & \leftrightarrow \end{aligned}\right.$ | $\mid$ | $\left\|\begin{array}{l} 0 \\ \infty \end{array}\right\|$ | $\mid$ | $\left\lvert\, \begin{gathered} 0 \\ \infty \end{gathered}\right.$ |  | $\left\|\begin{array}{l} 0 \\ 0 \\ 0 \\ N \\ \underset{N}{N} \\ \underset{\sim}{2} \end{array}\right\|$ | $\left\lvert\, \begin{array}{\|c\|} \hline- \\ \infty \end{array}\right.$ | $\left\|\begin{array}{\|c\|} \hline 0 \\ \infty \end{array}\right\|$ | o | $\left\lvert\, \begin{aligned} & 0 \\ & \infty \end{aligned}\right.$ | $\left\|\begin{array}{\|c\|} \hline 0 \\ \infty \end{array}\right\|$ | $\left\|\begin{array}{l} \circ \\ \infty \end{array}\right\|$ | 앙 |
| $\begin{aligned} & \text { \# } \\ & 0 \\ & 0 \\ & \vdots \\ & \end{aligned}$ | $\left\lvert\, \begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & \infty \\ & \infty \end{aligned}\right.$ | $\odot$ | $\|\odot\|$ | $\left\|\begin{array}{c} 0 \\ 0 \\ 0 \\ 1 \\ N \\ N \\ \infty \end{array}\right\|$ | $\left\lvert\, \begin{aligned} & 0 \\ & \infty \end{aligned}\right.$ |  | $\left\|\begin{array}{c} 8 \\ 8 \\ 8 \\ - \\ \frac{8}{\infty} \end{array}\right\|$ | $\left\|\begin{array}{l} 0 \\ \leftrightarrow \end{array}\right\|$ |  |  |  |  | $\left\|\begin{array}{c} \circ \\ 0 \\ 0 \\ 0 \\ 1 \\ \hline \end{array}\right\|$ | $\|\odot\|$ | $\left\lvert\, \begin{gathered} 8 \\ 0 \\ \mathrm{~N}^{2} \\ \mathrm{~N} \\ \mathrm{\leftrightarrow} \end{gathered}\right.$ | $\left\lvert\, \begin{gathered} 0 \\ 8 \\ 0 \\ 10 \\ 0 \\ \hline- \end{gathered}\right.$ |  | $\left\lvert\, \begin{aligned} & 8 \\ & 0 \\ & 0 \\ & \mathbf{N} \\ & \mathbf{N} \\ & \underset{\infty}{2} \end{aligned}\right.$ | $\mid$ | $\left\lvert\, \begin{gathered} 0 \\ 0 \\ 0 \\ 10 \\ \underset{\sim}{2} \\ \infty \end{gathered}\right.$ | $\left\|\begin{array}{c} \circ \\ 0 \\ 0 \\ \stackrel{n}{n} \\ \underset{\leftrightarrow}{\infty} \end{array}\right\|$ | 앙 | $\underset{\infty}{m}$ |  | $\left\|\begin{array}{c} 0 \\ 8 \\ 0 \\ 10 \\ 10 \end{array}\right\|$ |
|  | $\mathbb{\square}$ | ய | ய | $\|\llbracket\|$ | ய | ய | ய | ய | ய | $\mid \amalg$ | ய | ய | ய | $\|\llbracket\|$ | ய | あ | ய | $\mathbb{\square}$ |  | ய | ய | ய | $\left\|\begin{array}{l} \overline{0} \\ 0 \\ \overline{0} \\ \dot{0} \end{array}\right\|$ | $\underset{\square}{4}$ | 号 |
| 7 <br>  <br>  <br> $\frac{1}{0}$ <br> 0 | $\leftharpoondown$ |  |  |  | $\sigma$ |  |  | $\sigma$ |  |  |  |  |  |  |  |  |  | $\leftharpoondown$ | F |  |  | $\sigma$ |  |  |  | $\begin{array}{cl}\text { Level 1 } & \$ \\ \text { Level } 2 & \$ 292,000 \\ \text { Level } 3 & \$ 0 \\ \text { All Projects: } & \$ 292,000\end{array}$

Windsor Reservoir
PWP 2020 WSRP Appendix G Page 17

| Category |  | Project | Quantity | Unit | Unit Cost | Total Cost |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | \(\left.\begin{array}{c}Importance <br>

Level\end{array}\right]\)
Ventura Booster Appendix G Page 18

| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| E  <br> q Mechanical <br> u  | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$0 | 1 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 2 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace MCC |  | EA | \$125,000 | \$0 | 1 |
|  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install /Replace Flowmeter |  | EA | \$10,000 | \$0 | 2 |
|  | Install New Pressure Monitoring |  | EA | \$5,000 | \$0 | 2 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | none | 1 | EA | \$0 | \$0 | 3 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
| Resiliency/ Redundancy (incl. seismic) | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector | 1 | EA | \$5,000 | \$5,000 | 2 |
|  | Install Gen. Connector on MH Wells |  | EA | \$5,000 | \$0 | 2 |
|  | Seismic Upgrades |  | EA | \$0 | \$0 | 2 |
| Site / Security / Building | Minor Building Modifications |  | EA | \$25,000 | \$0 | 3 |
|  | Major Building Modifications | 1 | EA | \$75,000 | \$75,000 | 2 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Reservoir |  | per gal | \$3 | \$0 | 1 |
|  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 | All Projects: \$80,000

Glorietta Booster Appendix G Page 19

| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| E  <br> q  <br>   <br> M  | Replace Pump and Motor 60-150 HP | 1 | EA | \$100,000 | \$100,000 | 1 |
|  | Replace Pump and Motor 200-250 HP |  | EA | \$150,000 | \$0 | 1 |
|  | Replace Pump and Motor 300+ HP | 2 | EA | \$200,000 | \$400,000 | 2 |
|  | Piping Upgrades | 1 | EA | \$50,000 | \$50,000 | 2 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace MCC |  | EA | \$125,000 | \$0 | 1 |
|  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 3 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
| Resiliency/ Redundancy (incl. seismic) | none |  | EA | \$0 | \$0 | 3 |
|  | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector | 1 | EA | \$5,000 | \$5,000 | 2 |
|  | Install Gen. Connector on MH Wells |  | EA | \$5,000 | \$0 | 2 |
|  | Seismic Upgrades | 1 | EA | \$48,000 | \$48,000 | 2 |
| Site / Security / Building | none |  | EA | \$0 | \$0 | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  | Minor Building Modifications | 1 | EA | \$25,000 | \$25,000 | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Reservoir |  | per gal | \$3 | \$0 | 1 |
|  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 |


| Appendix G Page 20 |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| Mechanical | Replace Pump and Motor 200-250 HP |  | EA | \$150,000 | \$0 | 1 |
|  | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$0 | 1 |
|  | Piping Upgrades | 1 | EA | \$50,000 | \$50,000 | 2 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace MCC |  | EA | \$125,000 | \$0 | 1 |
|  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install /Replace Flowmeter |  | EA | \$10,000 | \$0 | 2 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 3 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
| Resiliencyl Redundancy (incl. seismic) | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector |  | EA | \$5,000 | \$0 | 2 |
|  | Install Gen. Connector on MH Wells |  | EA | \$5,000 | \$0 | 2 |
|  | Seismic Upgrades | 1 | EA | \$44,000 | \$44,000 | 2 |
| Site / Security / Building | none | 1 | EA | \$0 | \$0 | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Reservoir |  | per gal | \$3 | \$0 | 1 |
|  | Drill and Equip New Well |  | EA | \$3,000,000 | \$0 | 1 |
|  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 |

Ross Booster
Category
Appendix G Page 21

|  | － |  | $\leftharpoondown$ | N |  | $\checkmark$ | $\checkmark$ | m | N | N | $\cdots$ | m | m | m | N | N | m | m | m | $\cdots$ | $\checkmark$ | $\checkmark$ |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{aligned} & \stackrel{\rightharpoonup}{\omega} \\ & 0 \\ & 0 \\ & \stackrel{0}{0} \\ & \stackrel{0}{0} \end{aligned}$ | $\left.\begin{aligned} & 0 \\ & \hline 0 \\ & 0 \\ & 0 \\ & \hline 8 \\ & 0 \\ & 0 \\ & 0 \end{aligned} \right\rvert\,$ | $0$ | $\mid \infty$ | $\begin{aligned} & 8 \\ & \hline 0 \\ & 0 \\ & 6 \\ & \frac{1}{6} \end{aligned}$ | 0 | $\begin{aligned} & \mathrm{O} \\ & \hline 0 \\ & 0 \\ & 0 \\ & N \\ & N \\ & \hline \end{aligned}$ |  |  | $\bigcirc$ | $\bigcirc$ | O | O | O | O | $\bigcirc$ | $\bigcirc$ | $\bigcirc$ | $\bigcirc$ | $\bigcirc$ | $\bigcirc$ | $\bigcirc$ | $\left\|\begin{array}{l} 0 \\ \hline 0 \\ 0 \\ \hline 8 \\ \hline \\ 0 \\ 0 \end{array}\right\|$ | － |
| $\begin{aligned} & \stackrel{\rightharpoonup}{0} \\ & 0 \\ & 0 \\ & \stackrel{H}{5} \end{aligned}$ | $\begin{aligned} & 0 \\ & \hline 8 \\ & 0 \\ & 0 \\ & \hline 8 \\ & \hline 8 \end{aligned}$ | $\begin{array}{\|l} 8 \\ 8 \\ 0 \\ 0 \\ \frac{10}{6} \\ \hline \end{array}$ | $\left.\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & N \\ & 0 \end{aligned} \right\rvert\,$ | $\begin{aligned} & 9 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & \infty \end{aligned}$ | $\begin{gathered} 0 \\ 8 \\ 0 \\ N \\ N \\ N \end{gathered}$ |  | $\begin{aligned} & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & \hline 8 \end{aligned}$ | $0$ |  |  | $0$ | $\begin{gathered} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{gathered}$ | $\left\|\begin{array}{c} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 6 \end{array}\right\|$ | $0$ | $\left\|\begin{array}{c} \mathrm{O} \\ 0 \\ 0 \\ 10 \\ \mathrm{~N} \\ \mathrm{O} \end{array}\right\|$ |  |  |  | 8 <br> 8 <br> 8 <br> 8 | $\bigcirc$ | $\underset{\leftrightarrow}{\infty}$ | $\left.\begin{array}{\|l\|} \hline 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ \infty \\ \infty \end{array} \right\rvert\,$ | O |
|  | $\mid \underset{\mathbf{W}}{\|c\|}$ | $\|\underset{山}{\mid}\|$ | $\mid \underset{山}{\mid}$ | $\mathbb{\Psi}$ | $\mid \underset{\mathrm{u}}{ }$ | $\|\underset{山}{\mathbb{W}}\|$ | $\mid \underset{\mathbf{w}}{\mid}$ | $\mid \underset{\Psi}{\mid}$ | $\mid \underset{山}{\Psi}$ | $\overleftrightarrow{山}$ | $\underset{4}{\boldsymbol{w}}$ | $\underset{山}{4}$ | $\|\underset{山}{\Psi}\|$ | $\underset{\sim}{\mathbb{4}}$ | $\underset{山}{\mid}$ | $\mid \underset{山}{\mid}$ | $\|\underset{山}{\Psi}\|$ | $\|\underset{山}{\mid}\|$ | $\|\underset{山}{\mid}\|$ | $\|\mathbb{\Psi}\|$ | $\begin{array}{\|l\|} \hline \frac{\pi}{0} \\ \frac{0}{0} \\ \hline \end{array}$ | ¢ | 号 |
| 7 <br>  <br>  <br> 0 <br> 0 | $\cdots$ |  |  | $\cdots$ |  | N | N | － |  |  | － |  |  |  |  |  |  |  |  | $\tau$ |  | － |  |

All Projects：\＄1，200，000
PWP 2020 WSRP
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Wilson booster was upgraded.
Allen Hydropneumatic
PWP 2020 WSRP
Appendix G Page 23
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$\stackrel{\geqq}{\leftrightharpoons}$ EA per gal

| Category |  | Project | Quantity |
| :---: | :---: | :---: | :---: |
| $\begin{gathered} \mathrm{E} \\ \mathrm{q} \\ \mathrm{u} \\ \mathrm{i} \\ \mathrm{p} \\ \mathrm{~m} \\ \mathrm{e} \\ \mathrm{n} \\ \mathrm{t} \end{gathered}$ | Mechanical | none | 1 |
|  |  | Replace Pump and Motor up to 50 HP |  |
|  |  | Pressure Sustaining/Regulating Valve |  |
|  | Electrical | none | 1 |
|  |  | Replace MCC |  |
|  |  | Replace Electrical Service |  |
|  | Controls | none | 1 |
|  |  | Install /Replace Flowmeter |  |
|  |  | Install New Pressure Monitoring |  |
|  |  | Install New Site Control Panel |  |
| Energy Efficiency |  | none | 1 |
|  |  | Replace Pump and Motor up to 50 HP |  |
|  |  | Piping Upgrades |  |
| Resiliency/ Redundancy (incl. seismic) |  | none | 1 |
|  |  | Install Seismic Valve Actuators |  |
|  |  | Install Generator Connector |  |
|  |  | Seismic Upgrades |  |
| Site / Security / Building |  | none | 1 |
|  |  | Site Security Upgrades |  |
|  |  | Major Building Modifications |  |
| Overall Facility Replacement |  | none | 1 |
|  |  | Replace Reservoir |  |
|  |  | Replace Booster |  | Replace Booster

Allen Hydropneumatic tank was upgraded
Murray Hydropneumatic
PWP 2020 WSRP
Appendix G Page 24

Murray Hydropneumatic tank was upgraded
Arroyo Booster

| Appendix G Page 25 |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| Mechanical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 1 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace MCC |  | EA | \$125,000 | \$0 | 1 |
|  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install /Replace Flowmeter |  | EA | \$10,000 | \$0 | 2 |
|  | Install New Pressure Monitoring |  | EA | \$5,000 | \$0 | 2 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 3 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
| Resiliency/ Redundancy (incl. seismic) | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector |  | EA | \$5,000 | \$0 | 2 |
|  | Seismic Upgrades |  | EA | \$0 | \$0 | 2 |
| Site / Security / Building | none | 1 | EA | \$0 | \$0 | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Reservoir |  | per gal | \$3 | \$0 | 1 |
|  | Replace Booster |  | per HP | \$5,000 | \$ - | 1 |

Arroyo Bosster was upgraded
Eagle Rock Booster
PWP 2020 WSRP
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| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Mechanical | Replace Pump and Motor up to 50 HP | 2 | EA | \$50,000 | \$100,000 | 1 |
|  | Replace Pump and Motor 60-150 HP |  | EA | \$100,000 | \$0 | 1 |
|  | Piping Upgrades | 1 | EA | \$50,000 | \$50,000 | 2 |
|  | Pressure Sustaining/Regulating Valve | 1 | EA | \$25,000 | \$25,000 | 1 |
| Electrical | none |  | EA | \$0 | \$0 | 3 |
|  | Replace MCC | 1 | EA | \$125,000 | \$125,000 | 1 |
|  | Replace Electrical Service | 1 | EA | \$100,000 | \$100,000 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install /Replace Flowmeter |  | EA | \$10,000 | \$0 | 2 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency <br> Resiliency/ Redundancy (incl. seismic) | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$0 | 3 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
|  | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector |  | EA | \$5,000 | \$0 | 2 |
|  | Install Gen. Connector on MH Wells |  | EA | \$5,000 | \$0 | 2 |
|  | Seismic Upgrades | 1 | EA | \$5,000 | \$5,000 | 2 |
| Site / Security / Building | none | 1 | EA | \$0 | \$0 | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Reservoir |  | per gal | \$3 | \$0 | 1 |
|  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 |

P-1 Booster

| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| E  <br> q Mechanical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 1 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace MCC |  | EA | \$125,000 | \$0 | 1 |
|  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install /Replace Flowmeter |  | EA | \$10,000 | \$0 | 2 |
|  | Install New Pressure Monitoring |  | EA | \$5,000 | \$0 | 2 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 3 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
| $\qquad$ | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector |  | EA | \$5,000 | \$0 | 2 |
|  | Seismic Upgrades |  | EA | \$0 | \$0 | 2 |
| Site / Security / Building | none | 1 | EA | \$0 | \$0 | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Reservoir |  | per gal | \$3 | \$0 | 1 |
|  | Replace Booster |  | per HP | \$5,000 | \$ - | 1 |

Santa Anita Booster

| Santa Anita Booster |  |  |  |  | PWP 2020 WSRP Appendix G Page 28 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| Mechanical | none |  | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 1 |
|  | Replace Pump and Motor 60-150 HP |  | EA | \$100,000 | \$0 | 1 |
|  | Replace Pump and Motor 200-250 HP | 2 | EA | \$150,000 | \$300,000 | 1 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace MCC | 1 | EA | \$125,000 | \$125,000 | 1 |
|  | Replace Electrical Service | 1 | EA | \$100,000 | \$100,000 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | none |  | EA | \$0 | \$0 | 3 |
|  | Piping Upgrades | 1 | EA | \$50,000 | \$50,000 | 3 |
| Resiliencyl Redundancy (incl. seismic) | none |  | EA | \$0 | \$0 | 3 |
|  | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector | 4 | EA | \$5,000 | \$20,000 | 2 |
|  | Seismic Upgrades | 1 | EA | \$4,000 | \$4,000 | 2 |
| Site / Security / Building | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  | Minor Building Modifications |  | EA | \$25,000 | \$0 | 3 |
|  | Major Building Modifications | 1 | EA | \$100,000 | \$100,000 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 |

## All Projects: \$699,000

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| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Mechanical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 1 |
|  | Replace Pump and Motor 60-150 HP |  | EA | \$100,000 | \$0 | 1 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 2 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace MCC |  | EA | \$125,000 | \$0 | 1 |
|  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
| n n Controls | none | 1 | EA | \$0 | \$0 | 3 |
| t Controls | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$0 | 3 |
|  | Piping Upgrades | 1 | EA | \$50,000 | \$50,000 | 3 |
| Resiliencyl Redundancy (incl. seismic) | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector | 1 | EA | \$5,000 | \$5,000 | 2 |
|  | Install Gen. Connector on MH Wells |  | EA | \$5,000 | \$0 | 2 |
|  | Seismic Upgrades | 1 | EA | \$4,000 | \$4,000 | 2 |
| Site / Security / Building | none | 1 | EA | \$0 | \$0 | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 |

## All Projects: \$ 59,000

San Rafael Booster
PWP 2020 WSRP
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| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Mechanical | Replace Pump and Motor up to 50 HP | 1 | EA | \$50,000 | \$50,000 | 1 |
|  | Replace Pump and Motor 60-150 HP | 2 | EA | \$100,000 | \$200,000 | 1 |
|  | Replace Pump and Motor 200-250 HP |  | EA | \$150,000 | \$0 | 1 |
|  | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$0 | 1 |
|  | Piping Upgrades | 2 | EA | \$50,000 | \$100,000 | 2 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | HVAC | 1 | EA | \$50,000 | \$50,000 | 3 |
|  | Replace MCC | 2 | EA | \$125,000 | \$250,000 | 1 |
|  | Replace Electrical Service | 1 | EA | \$100,000 | \$100,000 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | Replace Pump and Motor 200-250 HP |  | EA | \$150,000 | \$0 | 3 |
|  | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$0 | 3 |
|  | Piping Upgrades | 1 | EA | \$50,000 | \$50,000 | 3 |
| Resiliencyl Redundancy (incl. seismic) | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector | 1 | EA | \$5,000 | \$5,000 | 2 |
|  | Seismic Upgrades | 1 | EA | \$82,000 | \$82,000 | 2 |
| Site / Security / Building | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  | Minor Building Modifications | 1 | EA | \$25,000 | \$25,000 | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 |

Lida Booster
Category
PWP 2020 WSRP
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| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Mechanical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 1 |
|  | Replace Pump and Motor 60-150 HP |  | EA | \$100,000 | \$0 | 1 |
|  | Replace Pump and Motor 200-250 HP |  | EA | \$150,000 | \$0 | 1 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install /Replace Flowmeter |  | EA | \$10,000 | \$0 | 2 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 3 |
|  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
| Resiliency/ Redundancy (incl. seismic) | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector | 1 | EA | \$5,000 | \$5,000 | 2 |
|  | Seismic Upgrades |  | EA | \$0 | \$0 | 2 |
| Site / Security / Building | none | 1 | EA | \$0 | \$0 | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 |

Rutherford Booster
PWP 2020 WSRP
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| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Mechanical | none | 1 | EA | \$0 | \$ | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$ | 1 |
|  | Replace Pump and Motor 60-150 HP |  | EA | \$100,000 | \$ | 1 |
|  | Replace Pump and Motor 200-250 HP |  | EA | \$150,000 | \$ | 1 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$ | 1 |
| Electrical | none | 1 | EA | \$0 | \$ | 3 |
|  | Replace MCC |  | EA | \$125,000 | \$ | 1 |
|  | Replace Electrical Service |  | EA | \$100,000 | \$ | 2 |
| Controls | none | 1 | EA | \$0 | \$ | 3 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$ | 2 |
| Energy Efficiency | Replace Pump and Motor 200-250 HP |  | EA | \$150,000 | \$ | 3 |
|  | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$ | 3 |
|  | Piping Upgrades | 1 | EA | \$50,000 | \$ 50,000 | 3 |
| Resiliency/ Redundancy (incl. seismic) | Install Seismic Valve Actuators |  | EA | \$25,000 | \$ | 2 |
|  | Install Generator Connector | 1 | EA | \$5,000 | \$ 5,000 | 2 |
|  | Install Gen. Connector on MH Wells |  | EA | \$5,000 | \$ | 2 |
|  | Seismic Upgrades |  | EA | \$0 | \$ | 2 |
| Site / Security / Building | none | 1 | EA | \$0 | \$ | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$ | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$ | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$ | 3 |
|  | Replace Booster |  | per HP | \$5,000 | \$ | 1 |

Craig Booster
PWP 2020 WSRP
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| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Mechanical | Replace Pump and Motor up to 50 HP | 2 | EA | \$50,000 | \$100,000 | 3 |
|  | Replace Pump and Motor 60-150 HP |  | EA | \$100,000 | \$0 | 1 |
|  | Replace Pump and Motor 200-250 HP |  | EA | \$150,000 | \$0 | 1 |
|  | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$0 | 1 |
|  | Piping Upgrades | 1 | EA | \$50,000 | \$50,000 | 2 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| Electrical | Replace MCC | 1 | EA | \$200,000 | \$200,000 | 3 |
|  | Replace Electrical Service | 1 | EA | \$100,000 | \$100,000 | 3 |
| Controls | none | 1 | EA | \$0 | \$0 | 3 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Pump and Motor 200-250 HP |  | EA | \$150,000 | \$0 | 3 |
|  | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$0 | 3 |
| Resiliencyl Redundancy (incl. seismic) | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  | Install Generator Connector | 1 | EA | \$5,000 | \$5,000 | 2 |
|  | Install Gen. Connector on MH Wells |  | EA | \$5,000 | \$0 | 2 |
|  | Seismic Upgrades | 1 | EA | \$157,000 | \$157,000 | 3 |
| Site / Security / Building | none | 1 | EA | \$0 | \$0 | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$0 | 3 |
|  | Replace Booster |  | per HP | \$5,000 | \$0 | 1 |

Thomas Booster
PWP 2020 WSRP
Appendix G Page 34



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\＄255，000
Linda Vista Booster
PWP 2020 WSRP
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| Category | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Mechanical | none | 1 | EA | \$0 | \$ | 3 |
|  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$ | 1 |
|  | Piping Upgrades |  | EA | \$50,000 | \$ | 2 |
|  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$ | 1 |
| Electrical | Replace MCC | 1 | EA | \$200,000 | \$ 200,000 | 2 |
|  | Replace Electrical Service | 1 | EA | \$100,000 | \$ 100,000 | 2 |
| Controls | Install /Replace Flowmeter | 1 | EA | \$10,000 | \$ 10,000 | 2 |
|  | Install New Pressure Monitoring |  | EA | \$5,000 | \$ - | 2 |
|  | Install New Site Control Panel |  | EA | \$75,000 | \$ | 2 |
| Energy Efficiency | none | 1 | EA | \$0 | \$ | 3 |
|  | Replace Pump and Motor 300+ HP |  | EA | \$200,000 | \$ | 3 |
|  | Piping Upgrades |  | EA | \$50,000 | \$ | 3 |
| Resiliency/ Redundancy (incl. seismic) | Install Seismic Valve Actuators |  | EA | \$25,000 | \$ | 2 |
|  | Install Generator Connector | 4 | EA | \$5,000 | \$ 20,000 | 2 |
|  | Seismic Upgrades | 1 | EA | \$9,000 | \$ 9,000 | 2 |
| Site / Security / Building | none | 1 | EA | \$0 | \$ | 3 |
|  | Site Security Upgrades |  | EA | \$25,000 | \$ | 3 |
|  | Major Building Modifications |  | EA | \$100,000 | \$ | 3 |
| Overall Facility Replacement | none | 1 | EA | \$0 | \$ | 3 |
|  | Replace Reservoir |  | per gal | \$3 | \$ | 1 |

Annandale Booster

| Category |  | Project | Quantity | Unit | Unit Cost | Total Cost | Importance Level |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| E Mechanical |  | none | 1 | EA | \$0 | \$0 | 3 |
|  |  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 1 |
|  |  | Pressure Sustaining/Regulating Valve |  | EA | \$25,000 | \$0 | 1 |
| i | Electrical | none | 1 | EA | \$0 | \$0 | 3 |
| p |  | Replace MCC |  | EA | \$125,000 | \$0 | 1 |
| p |  | Replace Electrical Service |  | EA | \$100,000 | \$0 | 2 |
| m | Controls | none | 1 | EA | \$0 | \$0 | 3 |
| e |  | Install /Replace Flowmeter |  | EA | \$10,000 | \$0 | 2 |
| n |  | Install New Pressure Monitoring |  | EA | \$5,000 | \$0 | 2 |
| t |  | Install New Site Control Panel |  | EA | \$75,000 | \$0 | 2 |
| Energy Efficiency |  | none | 1 | EA | \$0 | \$0 | 3 |
|  |  | Replace Pump and Motor up to 50 HP |  | EA | \$50,000 | \$0 | 3 |
|  |  | Piping Upgrades |  | EA | \$50,000 | \$0 | 3 |
| Resiliency/ Redundancy (incl. seismic) |  | none | 1 | EA | \$0 | \$0 | 3 |
|  |  | Install Seismic Valve Actuators |  | EA | \$25,000 | \$0 | 2 |
|  |  | Install Generator Connector |  | EA | \$5,000 | \$0 | 2 |
|  |  | Seismic Upgrades |  | EA | \$0 | \$0 | 2 |
| Site / Security / Building |  | none | 1 | EA | \$0 | \$0 | 3 |
|  |  | Site Security Upgrades |  | EA | \$25,000 | \$0 | 3 |
|  |  | Major Building Modifications |  | EA | \$100,000 | \$0 | 3 |
| Overall Facility Replacement |  | none | 1 | EA | \$0 | \$0 | 3 |
|  |  | Replace Reservoir |  | per gal | \$3 | \$0 | 1 |
|  |  | Replace Booster |  | per HP | \$5,000 | \$ - | 1 |


$\left.$| Category |  | Project | Quantity | Unit | Unit Cost | Total Cost |
| ---: | :--- | :--- | ---: | ---: | ---: | ---: | | Importance |
| :---: |
| Level | \right\rvert\,

## Appendix H Portfolio Evaluation Details

## APPENDIX H. PORTFOLIO EVALUATION DETAILS

Appendix H contains detailed information referenced in Chapter 7, including:

- Summary table of options included in each portfolio
- Criteria weighting exercise
- Description of the scoring scales for all metrics
- Information on the process used to analyze portfolio reliability and resiliency
- Detailed comparison of portfolios
- Full collection of scores for all portfolios


## H. 1 SUPPLY AND PRODUCTION OPTIONS USED IN PORTFOLIOS

Selection of supply and production options to include in each of the portfolios, discussed in Chapter 7, was based on the main themes selected to be the basis of each portfolio. Table H-1 provides a table that shows the supply and production options included in each portfolio (indicated by the coloring in of the cell).

As shown in the table, most options discussed in Chapter 5 of the WSRP were included in a portfolio. The large number and variety of options meant that it was possible to build portfolios to meet future demand without having to implement all options. Therefore, options that may achieve similar results were weighed against each other in terms of cost, reliability and the overall theme of the portfolio to determine which option would be implemented, For example, ocean desalination was not included in any of the portfolios as implementation of this option would require PWP to enter into partnership with another agency that would take the desalinated ocean water in exchange for imported water rights. Given that this would be similar to directly increasing imported water use either through more purchases from Metropolitan or rights purchase, options to directly increase imported water were selected due to their ease of implementation.
Water System and Resources Plan
Table H-1: Supply and Production Options Included Under Each Theme

| \# | $\begin{array}{c}\text { Water Supply Options }\end{array}$ | $\begin{array}{c}\text { B. } \\ \text { A. PWP } \\ \text { Pivot }\end{array}$ | $\begin{array}{c}\text { C. } \\ \text { Maximize } \\ \text { MWD } \\ \text { Supply }\end{array}$ | $\begin{array}{c}\text { Daximize } \\ \text { Local } \\ \text { Supplies }\end{array}$ | $\begin{array}{c}\text { E. Maximize } \\ \text { Sustainable } \\ \text { Sources }\end{array}$ | $\begin{array}{c}\text { Maximize } \\ \text { Direct Use } \\ \text { of SW and } \\ \text { RW }\end{array}$ |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
| Value GW/ |  |  |  |  |  |  |
| Non- |  |  |  |  |  |  |
| potable |  |  |  |  |  |  |$]$

Water System and Resources Plan

| \# | Water Supply Options | A. PWP Pivot | B. Maximize MWD Supply | C. Maximize Local Supplies | D. Maximize Sustainable Sources | E. <br> Maximize Direct Use of SW and RW | F. Max Value GW/ Nonpotable |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| LAG-3a | Advanced Treatment of Recycled Water from LAG-WRP for Recharge |  |  |  |  |  |  |
| LAG-3b | Advanced Treatment of Recycled Water from LAG-WRP for Direct Use |  |  |  |  |  |  |
| NP-1 | Tunnel Water to Brookside Golf Course |  |  |  |  |  |  |
| NP-2 | Arroyo Seco Diversions from Channel to Brookside Golf Course |  |  |  |  |  |  |
| NP-3 | Local Non-Potable Project |  |  |  |  |  |  |
| NP-5 | Satellite Plant to Treat Wastewater near the Eaton Wash Spreading Grounds |  |  |  |  |  |  |
| NP-6 | Wastewater and Stormwater Supply Capture at Glenarm Power Plant |  |  |  |  |  |  |
| Grey-1 | Greywater Program |  |  |  |  |  |  |
| Desal-1 | Ocean Desalination |  |  |  |  |  |  |
| SW-1 | Infiltration Galleries |  |  |  |  |  |  |
| SW-2 | Altadena Drain Diversion to the Arroyo Seco Spreading Grounds |  |  |  |  |  |  |
| SW-3 | Centralized Stormwater Capture and Conveyance to Eaton Wash for Recharge |  |  |  |  |  |  |

Water System and Resources Plan

| \# | Water Supply Options | A. PWP Pivot | B. Maximize MWD Supply | C. Maximize Local Supplies | D. <br> Maximize Sustainable Sources | E. <br> Maximize Direct Use of SW and RW | F. Max Value GW/ Nonpotable |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| SW-4 | Decentralized Stormwater Recharge, Tier 1 |  |  |  |  |  |  |
| SW-5 | Decentralized Stormwater Recharge, Tier 2 |  |  |  |  |  |  |
| WUE-0 | Conservation Programming to Meet Future Regulations |  |  |  |  |  |  |
| WUE-1 | Conservation Programming to Meet Future Regulations Plus 10\% Additional Outdoor Conservation |  |  |  |  |  |  |
| WUE-2 | Conservation Programming to Meet Future Regulations Plus 25\% Additional Outdoor Conservation |  |  |  |  |  |  |
| Base GW | Current Groundwater Production |  |  |  |  |  |  |
| GW-0 | Well Rehabilitation and New Well Replacement, Importance Level 1 |  |  |  |  |  |  |
| GW-00 | Well Rehabilitation and Equipment Replacement, Importance Level 2 |  |  |  |  |  |  |
| GW-2a | Monk Hill Wells Nitrate Treatment |  |  |  |  |  |  |
| GW-2b | Nitrate, Perchlorate and Volatile Organic Compounds Treatment of the Sunset Wells |  |  |  |  |  |  |
| GW-3 | Connect High Nitrate Wells to a Local Non-Potable System |  |  |  |  |  |  |

## H. 2 CRITERIA WEIGHTING EXERCISE

Criteria weightings were determined based on a weighting exercise completed by PWP and stakeholders. The exercise used "forced pair weighting", which is a head-to-head comparison of pairs of criteria. PWP staff and stakeholders were provided with all possible pairs of criteria, and, for each pair, asked to select the criterion they felt was most important. The number of times a criterion was selected to be more important was counted. These counts were then used to develop a weighting percentage for each criterion based on the percent of time the criterion was selected as being more important than another. The results for each individual completing the exercise were calculated and summarized to create the chart shown in Figure $\mathrm{H}-1$.

Figure $\mathrm{H}-1$ presents the results of the weighting exercise. The dots on Figure $\mathrm{H}-1$ indicate the average weight of each criteria, while the lines indicate the spread of results from individuals (where the upper and lower extents indicate the highest and lowest weighting based on individual weighting exercise results). As shown below, no criteria had more than approximately $10 \%$ of difference in weighting above or below the average, and no results indicated a criteria weighting of higher than $22 \%$. It was decided to use the average results of the PWP and stakeholder weighting activity as the criteria weighting for the portfolios.

Figure H-1: Results of Criteria Weighting Exercise


## H. 3 SCORING METRICS AND POINT SYSTEM

An integrated planning approach such as the one used in the WSRP that includes stakeholder participation and the formal assessment of non-traditional metrics, naturally elevates the complexity of the planning effort. Systems models are valuable tools to conduct the analysis and support the decision-making process in these, more complex, projects. The WSRP used a GoldSim systems model (described in Section 4) as the primary analytical tool, coupled with cost estimating and additional technical information. These tools and analysis steps were used in the evaluation of portfolios. The GoldSim model was used to generate the values needed to score for the most critical metrics: cost and reliability. Table H-2 shows the sources for the scores in each of the metrics used in assessing a portfolio, as well as the point system used to score each metric. In general, points from one to five were given to each criteria based on the qualitative or quantitative measure indicated.
Water System and Resources Plan
Portfolio Evaluation Details

## Table H-2: Metrics and Tools or Method Used to Score Portfolios

| Criteria \& SubCriteria | Metric | Description | Points |
| :---: | :---: | :---: | :---: |
| Criteria 1: Supply Reliability and Resiliency |  |  |  |
| 1a. Long-Term Reliability | Percent of time demand is met | Quantitative (GoldSim) | $\begin{aligned} & 5=\text { Demand met } 100 \% \text { of time } \\ & 4=95 \%-100 \% \text { of time } \\ & 3=90 \%-94 \% \\ & 2=85 \%-89 \% \\ & 1=<85 \% \text { of time } \end{aligned}$ |
|  | Average Shortage | Quantitative (GoldSim) | $\begin{aligned} & 5=\text { No shortage } \\ & 4=500 \text { AFY shortage } \\ & 3=1,000 \text { AFY shortage } \\ & 2=1,500 \text { AFY shortage occurs } \\ & 1=2,000 \text { AFY shortage occurs } \end{aligned}$ |
| 1b. Long-Term Disruption Resiliency | Shortage During Disruptions of Metropolitan of 24 months | Quantitative (GoldSim) | $5=10 \%$ shortage or less with a 12-month IW disruption <br> $4=20 \%$ shortage <br> $3=30 \%$ shortage <br> $2=40 \%$ shortage <br> $1=$ greater than $40 \%$ shortage with a 12 -month IW disruption |
| 1c. Emergency resilience | Redundancy score (derived from resulting distribution system in each alternative) | Qualitative | 5 = Redundancy-related improvements are implemented <br> 1 = No redundancy-related improvements made |
| Criteria 2: Health and Safety |  |  |  |
| 2a. Water quality (Potable) | Change in salinity of groundwater basin close to MCL | Quantitative | 5 = Salinity loading to basin unchanged or reduced <br> 4 = Significant salinity loading from imported water recharge |
|  | Nitrate or VOC treatment implemented | Qualitative | 5 = Nitrate AND VOC treatment implemented <br> 3 = Nitrate OR VOC treatment implemented <br> 1 = No additional groundwater treatment implemented |

Water System and Resources Plan

| Criteria \& SubCriteria | Metric | Description | Points |
| :---: | :---: | :---: | :---: |
| 2b. Level of service / risk of failure | Dollar value of "rehab/replacement" distribution and storage improvements, or percent of overall R/R invested | Quantitative | 5 = Level 1 and 2 "rehab/ replacement" improvements implemented <br> 3 = Level 1 "rehab/ replacement" improvements implemented 1 = No "rehab/ replacement" improvements implemented |
| Criteria 3: Environmental Stewardship |  |  |  |
| 3a. Water quality (environmental) | Volume of urban runoff captured | Quantitative | $\begin{aligned} & 5=2000+\text { AFY urban runoff captured } \\ & 4=1000-2000 \text { AFY } \\ & 3=500-1000 \text { AFY captured } \\ & 2=<500 \text { AFY captured } \\ & 1=0 \text { AFY captured } \end{aligned}$ |
| 3b. Energy efficiency / carbon footprint | Dollar value of "energy efficiency" distribution improvements | Quantitative | $5=\$ 350,000$ (all energy efficiency improvements implemented) <br> 3 = up to \$175,000 (50\% of energy efficiency improvements implemented) <br> 1 = up to $\$ 87,500$ ( $25 \%$ of energy efficiency improvements implemented) |
|  | Carbon footprint or energy intensity of new sources | Quantitative | 5 = New sources have a low carbon footprint or energy intensity (local sources) <br> 3 = One new source implemented that is considered to have a high carbon footprint or energy intensity (i.e. recycled water or imported water) <br> 1 = Two or more new sources implemented that are considered to have a high carbon footprint or energy intensity (i.e. recycled water and imported water) |
| Criteria 4: Cost |  |  |  |
| 4a. Unit cost | Unit cost of portfolio in average year | Costs based on modeled portfolio volumes | $\begin{aligned} & 5=\text { Unit cost is equal to or lower than } \$ 1,000 / \mathrm{AF} \\ & 4=\text { Unit cost is } \$ 1,000 / \mathrm{AF} \text { to } \$ 1,200 / \mathrm{AF} \\ & 3=\text { Unit cost is } \$ 1,200 / \mathrm{AF} \text { to } \$ 1,300 / \mathrm{AF} \\ & 2=\text { Unit cost is } \$ 1,300 / \mathrm{AF} \text { to } \$ 1,400 / \mathrm{AF} \end{aligned}$ |

Water System and Resources Plan

| Criteria \& SubCriteria | Metric | Description | Points |
| :---: | :---: | :---: | :---: |
|  |  |  | 1 = Cost is higher than Tier 1 treated imported water (\$1,400/AF or more) |
| 4b. Capital cost | Capital cost of portfolio | Quantitative | $\begin{aligned} & 5=\text { Capital cost less than } \$ 200 \mathrm{M} \\ & 4=\text { Capital cost less than } \$ 300 \mathrm{M} \\ & 3=\text { Capital cost less than } \$ 400 \mathrm{M} \\ & 2=\text { Capital cost less than } \$ 500 \mathrm{M} \\ & 1=\text { Capital cost }>\$ 500 \mathrm{M} \end{aligned}$ |
| Criteria 5: Self-Sufficiency |  |  |  |
| 5a. Local portfolio | Percent of supply portfolio derived locally | Quantitative | $\begin{aligned} & 5=>80 \% \text { of supply portfolio derived locally } \\ & 4=60-80 \% \text { of derived locally } \\ & 3=40-60 \% \text { of derived locally } \\ & 2=20-40 \% \text { of derived locally } \\ & 1=<20 \% \text { derived locally } \end{aligned}$ |
| 5b. Effective basin management | Recharge to Pump Ratio | Quantitative. Does not include imported water storage program (no "leave behind") | $\begin{aligned} & 5=1: 3 \text { ratio of recharge to pumping or better } \\ & 4=1: 4 \text { to } 1: 6 \\ & 3=1: 6 \text { to } 1: 8 \text { ratio of recharge to pumping } \\ & 2=1: 8 \text { to } 1: 10 \\ & 1=1: 11 \text { or higher ratio of recharge to pumping } \end{aligned}$ |
| Criteria 6: Regional Collaboration |  |  |  |
| n/a | Number of supply partnerships | Quantitative | $\begin{aligned} & 5=\text { several } \\ & 3=\text { few partnerships } \\ & 1=\text { only Met } \end{aligned}$ |
| Criteria 7: Ease of Implementation/Complexity |  |  |  |
| n/a | Qualitative 'time to implement' score based on permits, institutional arrangements, CEQA, and other considerations | Quantitative | $5=0-2$ projects to be implemented that will require additional permits, institutional arrangements, CEQA, etc. <br> $3=2-4$ projects <br> $1=4+$ projects |

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| Criteria \& SubCriteria | Metric | Description | Points |
| :---: | :---: | :---: | :---: |
| Criteria 8: Flexibility/Adaptability |  |  |  |
| 8a. Flexibility of Operations | Number of interconnections | Quantitative | $5=2$ or more new interconnections with other agencies <br> $3=1$ new interconnections with other agencies <br> 1 = No new interconnections |
| 8b. Adaptability on Implementation | Qualitative Score for Scalability and Phasing | Qualitative | 5 = Projects can be scaled or phased, several flexible projects <br> 3 = No new projects <br> 1 = Projects cannot be scaled or phased |
| Criteria 9: Community Values/Quality of Life |  |  |  |
| 9a. Efficient Use of Resources | Volume of WUE and nonpotable direct use (WUE needs to be "middle of the road") | Quantitative | 5 = Mid or Low WUE and Max Non-Potable <br> 4 = Mid Low WUE and Mid Non-Potable <br> 3 = Max WUE and Low or Mid Non Potable <br> 2 = Low or Max WUE and Low Non Potable <br> 1 = Low WUE and No Non Potable |
| 9b. Aesthetics and Character | Qualitative score for greening, urban canopy and environmental improvement | Does it improve greening, urban canopy and environmental improvement | 5 = Projects in place to maintain green areas and/or capture stormwater to improve surface water quality 1 = Projects not expected to increase or maintain greenspace and/or improve the environment |

## H. 4 PORTFOLIO RELIABILITY AND RESILIENCY EVALUATION

The basis of the reliability analysis described in Chapter 4, for the baseline condition, was applied to analyze the reliability of each portfolio. The GoldSim model provided output for each portfolio's supply-demand balance for each of the planning years (2020 to 2045) under multiple hydrology conditions. With this output, the metrics of percent of time demands are met and the average shortage when shortages happen were derived. The emergency condition with no MWD supply for 12 months was also computed from the GoldSim model output. The long-term supply from each source combined into the overall portfolio in the model simulation was used with cost estimating information for the computation of the overall unit cost (\$ per AF) of each portfolio. Cost estimating provided some of the other key metrics, while a qualitative scale based on objective information was developed for each of the remaining metrics.

## H. 5 EVALUATION RESULTS

The analysis of portfolios reflects the difference they have related to the criteria for evaluation, and in turn, related to the objectives of the WSRP. Portfolios have different degrees of reliability, cost effectiveness, local control, water quality protection, etc. While the multi-criteria ranking method results in a comprehensive single score, the comparison of portfolios for a single criterion (such as long-term disruption resiliency, effective basin management, cost to PWP, etc.) is a useful exercise informing decision-making.

While the multi-criteria ranking method results in a comprehensive single score, the comparison of portfolios for a single criterion (such as long-term disruption resiliency, effective basin management, cost to PWP, etc.) is a useful exercise informing decisionmaking.

## H.5.1 Portfolio Reliability and Costs

Results indicate that all portfolios are consistently reliable on a long-term basis, with all portfolios being able to meet demands at least 85\% of the years analyzed (2020 to 2045 under multiple hydrology conditions). Some deficits, however, are as high as 3,400 AFY, with average deficits of 1,800 AFY. Those maximum deficits correspond to about $10 \%$ of demand. Figure $\mathrm{H}-2$ shows the percent of time with deficit and the size of the maximum deficits for each portfolio.

Figure H-2: Portfolio Long-Term Reliability


In terms of resiliency under an extended disruption (see description of the Great ShakeOut seismic scenario in Chapter 4) where imported supply is not available for 12 months, the difference in reliability is much more pronounced. Portfolios that rely heavily on MWD supplies present large shortages that would be likely unmanageable over a period of 12 months or longer. Figure H-3 presents the results of the resiliency under an extended disruption, with the bars representing the deficit that would be observed if MWD imported water supplies were not available during a 12 months period.

Figure H-3: Resiliency under an Extended Disruption


The capital costs and unit costs of portfolios are an important criterion in decision-making, beyond the multi-criteria method score and it is of interests to stakeholders, decisionmakers and rate payers in general. Figure H-4 presents the capital and unit costs for all
portfolios. A high capital costs for a portfolio does not necessarily translate into a proportionally high unit costs, since the cost of imported supply (which has no capital costs) is significantly higher than some other supplies included in some portfolios. The unit cost presented in Figure $\mathrm{H}-4$ and used in the multi-criteria ranking calculations includes the capital and O\&M of all projects in a portfolio as well as the costs of imported water and the costs of pumping the local groundwater.

Figure H-4: Capital and Unit Costs for All Portfolios


## H.5.2 Portfolio Performance for Other Criteria

Along with reliability and costs, the Health and Safety criterion and the Self Sufficiency criterion were considered very important for decision-making based on the weighting exercise discussed above. Portfolios C, D, E and F are the better performing portfolios for the Health and Safety criterion, as shown in Figure H-5, which presents the qualitative scores on a scale of 1 to 5 used in the ranking. Two sub-criteria are shown in Figure H-5:

- Level of Treatment of Nitrates and VOCs in Groundwater: This score is assigned based on the treatment of these constituents that is provided by the portfolio. The score is not an output of the systems model but rather assigned based on the capital projects included in the portfolio directly targeting treatment for these pollutants
- Level of Service and Risk of Failure for the overall treated water system: this score is assigned based on the dollar value of rehabilitation/replacement and other improvements in the distribution and storage components of the portfolio.

Figure H-5: Health and Safety Scores for All Portfolios


Portfolios C, D and F are the best performing portfolios for the Self Sufficiency criterion as shown in Figure H-6. This criterion includes two sub-criteria:

- Pump-to-Recharge Ratio: score is defined by quantifying the annual pumping and the annual recharge, both on an average basis and computing the ratio to reflect how much of the pumping is supported by artificial recharge. It should be noted that this does not imply that artificial recharge is necessarily required in Raymond Basin. As explained in detail in Chapter 4, the basin has an estimated yield that can be supported by natural recharge. This criterion focuses on artificial recharge as a component of portfolios due to the fact that several of them increase pumping considerably above the decreed rights for PWP, which is allowed in the Raymond Basin as long as recharge is provided.
- Local Supply: This score is simply based upon the amount of local supply that is provided locally compared to the total demand.

Figure H-6: Self-Sufficiency Scores for All Portfolios


## H. 6 PORTFOLIO SCORES

The table on the following pages contains the full collection of scores for all portfolios.

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| Criteria (Weight) | (Weight) Sub-Criteria | Metric | Points | Portfolio A: Status Quo \& Stormwater Capture |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Data | Points | Score |
| 1. <br> Supply Reliability \& Resiliency / 19\% | 1a. (37\%) LongTerm Reliability | \% of time demand met | $\begin{aligned} & 5=100 \% ; 4=95 \%-99 \% ; 3=90 \%- \\ & 94 \% ; 2=85 \%-89 \% ; 1=<85 \% \end{aligned}$ | 85\% | 2 | 0.3 |
|  |  | Average shortage | $\begin{aligned} & 5=\text { No shortage; } 4=500 \mathrm{AFY} ; 3= \\ & 1,000 \mathrm{AFY} ; 2=1,500 \mathrm{AFY} ; 1= \end{aligned}$ | 1,794 AFY | 2 |  |
|  | 1b. (26\%) LongTerm D. <br> Resiliency | 24 months no MWD | $5=<10 \%$ shortage w/ 12-mo imported water disruption; $4=20 \%$; $3=30 \% ; 2=40 \% ; 1=>40 \%$ | 17411 AFY | 1 |  |
|  | 1c. (37\%) Em Resilience | Redundancy from distr. s. | 5 = Redundancy improvements (RI) made, 1 = No RI made | Distrib. \& storage RI not made | 1 |  |
| 2. <br> Health and Safety / 21\% | 2a. (25\%) Water Quality (WQ): Potable | GW salinity incr. to MCL | 5 = Salinity unchanged or reduced 4 = Significant salinity loading | No change in salinity | 5 | 0.6 |
|  |  | NO3 or VOC treatment | 5 = NO3 \& VOC treatment; 3 = NO3 or VOC treatm.; $1=$ No treatm. | No treatment implemented | 1 |  |
|  | 2b. (75\%) Service Level / Failure Risk | RR impr. cost , or \% of RR invested | 5 = Levels $1 \& 2$ rehab/ replacement $(R R)$ improvements; 3 = Level 1 RR; $1=$ No RR impr | Level 1 RI implemented | 3 |  |
| 3. <br> Enviro Stewardshp / 10\% | $\begin{gathered} \text { 3a. (50\%) } \\ \text { Envirom. WQ } \end{gathered}$ | SW captured | $\begin{aligned} & \text { 5:>2000 AFY; 4: 1000-2000 AFY; 3: } \\ & \text { 500-1000 AFY; 2:<500 AFY; 1: } 0 \\ & \hline \end{aligned}$ | 0 AFY stormwater captured | 1 | 0.1 |
|  | 3b. (50\%) <br> Energy Eff / Carbon Footprint | Energy effic. Improv.- EEI | $\begin{aligned} & 5=\$ 350 \mathrm{~K} \text { (all EEI); 3= up to } \$ 175 \mathrm{~K} \\ & (50 \%) ; 1=\text { up to } \$ 87.5 \mathrm{~K}(25 \%) \end{aligned}$ | No EEI implemented | 1 |  |
|  |  | Carbon footprint /energy intensity | 5=Low carbon footpr./energy intensity (CF/EI); 3= High CF/EI; 1=>1 sources w/high CF/EI | High energy \& carbon, IW | 1 |  |
| 4. <br> Cost / 11\% | 4a. (50\%) <br> Unit Cost | Unit cost in ave. year | $\begin{aligned} & 5=<\$ 1,000 / \mathrm{AF} ; 4=<\$ 1,200 / \mathrm{AF} ; \\ & 3=<\$ 1,300 / \mathrm{AF} ; 2=<\$ 1,500 / \mathrm{AF} ; \\ & 1=>\text { Tier } 1 \text { (\$1,500/AF) } \end{aligned}$ | \$1,000 | 5 | 0.5 |
|  | 4b. (50\%) Capital Cost | Capital cost of portfolio | $\begin{aligned} & 5=<\$ 200 \mathrm{M} ; 4=<\$ 300 \mathrm{M} ; 3=< \\ & \$ 400 \mathrm{M} ; 2=<\$ 500 \mathrm{M} ; 1=>\$ 500 \mathrm{M} \end{aligned}$ | \$197,900,000 | 5 |  |
| 5. (11\%) SelfReliance | $\begin{aligned} & \text { 5a. (50\%) Local } \\ & \text { Portfolio } \end{aligned}$ | \% local supplies | $\begin{aligned} & 5=>80 \% \text { local; } 4=60-80 \% ; 3=40- \\ & 60 \% ; 2=20-40 \% ; 1=<20 \% \end{aligned}$ | 60\%-80\% | 4 | 0.3 |
|  | 5b. (50\%) Eff. <br> Basin Mngmnt | Recharge to pump ratio | $\begin{aligned} & 5=1: 3 \text { ratio or better; } 4=1: 4-1: 6 ; 3 \\ & =1: 6-1: 8 ; 2=1: 8-1: 10 ; 1=>1: 10 \end{aligned}$ | $\begin{gathered} 2,070: 15,400, \\ \text { or } 1: 13 \end{gathered}$ | 1 |  |
| 6.(4\%) Regional Collabor | n/a | Number of supply partnerships | 5 = several; 3 = few partnerships 1 = only MWD | MWD only | 1 | 0.0 |
| 7. (6\%) Complexity | n/a | Time score: permits, agrmnts, CEQA | $5=0-2$ projects to be implemented that require permits, arrangements, CEQA <br> $3=2-4$ projects; $1=4+$ projects | No new projects that would require time to implement | 5 | 0.3 |
| 8. Flexibility (8\%) | 8a. (50\%) Op. <br> Flexibility | \# intercontns | $\begin{aligned} & 5=>2 \text { new interconnections (IC); } 3 \\ & =1 \text { new IN.; } 1=\text { No new IC } \end{aligned}$ | No new interconnections | 1 | 0.2 |
|  | 8b. (50\%) <br> Adaptability | Score for Scalability and Phasing | 5 = Projects scaled/phased, flexible; 3 = No new projects; 1 = No scaled or phased projects | No new projects | 3 |  |
| 9. (11\%) Comm values/ quality of life | 9a. (50\%) Eff Resources Use | Volume of WUE \& NP direct use | 5= Mid WUE/Max Non-Potable (NP); 4= Mid WUE/Mid NP; 3= Max WUE/Mid NP; 2= Max WUE/Low NP; 1= Low WUE/No NP | Low WUE and No NP | 1 | 0.1 |
|  | 9b. (50\%) Aesthetics | Urb. canopy \& env impr. score | 5=Maintain green areas, capture SW, improve surface WQ; 1 = No environment improvement | No new projects | 1 |  |
| Pasadena Water and Power |  |  |  |  |  | 2.3 |

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| Criteria (Weight) | (Weight) Sub-Criteria | Metric | Points | Portfolio B: Maximize MWD Supply/ Minimize Local CIP |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Data | Points | Score |
| 1. <br> Supply Reliability \& Resiliency / 19\% | 1a. (37\%) LongTerm Reliability | \% of time demand met | $\begin{aligned} & 5=100 \% ; 4=95 \%-99 \% ; 3=90 \%- \\ & 94 \% ; 2=85 \%-89 \% ; 1=<85 \% \end{aligned}$ | 85\% | 2 | 0.3 |
|  |  | Average shortage | 5 = No shortage; 4 = 500 AFY; 3 = 1,000 AFY; 2 = 1,500 AFY; 1 = | 1,848 AFY | 2 |  |
|  | $\begin{array}{\|c\|} \hline \text { 1b. }(26 \%) \text { Long- } \\ \text { Term D. } \\ \text { Resiliency } \\ \hline \end{array}$ | 24 months no MWD | 5 =<10\% shortage w/ 12-mo imported water disruption; 4 = 20\%; $3=30 \% ; 2=40 \% ; 1=>40 \%$ | 18, 071 AFY | 1 |  |
|  | 1c. (37\%) Em Resilience | Redundancy from distr. s. | 5 = Redundancy improvements (RI) made, 1 = No RI made | Distrib. \& storage RI not made | 1 |  |
| $\begin{gathered} 2 . \\ \text { Health and } \\ \text { Safety / } 21 \% \end{gathered}$ | 2a. (25\%) Water Quality (WQ): Potable | GW salinity incr. to MCL | 5 = Salinity unchanged or reduced 4 = Significant salinity loading | Increase salinity imported water | 5 | 0.6 |
|  |  | NO3 or VOC treatment | 5 = NO3 \& VOC treatment; 3 = NO3 or VOC treatm.; 1 = No treatm. | No additional GW treatment | 1 |  |
|  | 2b. (75\%) Service Level / Failure Risk | RR impr. cost , or \% of RR invested | 5 = Levels $1 \& 2$ rehab/ replacement (RR) improvements; 3 = Level 1 RR; 1 = No RR impr | Level 1 RR implemented | 3 |  |
| 3. <br> Enviro <br> Stewardshp <br> / 10\% | 3a. (50\%) <br> Envirom. WQ | SW captured | $\begin{aligned} & \text { 5:>2000 AFY; 4: 1000-2000 AFY; 3: } \\ & \text { 500-1000 AFY; 2:<500 AFY; 1: } 0 \end{aligned}$ | 0 AFY stormwater captured | 1 | 0.1 |
|  | 3b. (50\%) <br> Energy Eff / <br> Carbon <br> Footprint | Energy effic. Improv.- EEI | $\begin{aligned} & 5=\$ 350 \mathrm{~K} \text { (all EEI); } 3=\text { up to } \$ 175 \mathrm{~K} \\ & (50 \%) ; 1=\text { up to } \$ 87.5 \mathrm{~K}(25 \%) \end{aligned}$ | No EEI implemented | 1 |  |
|  |  | Carbon footprint /energy intensity | 5=Low carbon footpr./energy intensity (CF/EI); 3= High CF/EI; 1=>1 sources w/high CF/EI | High reliance on imported water | 1 |  |
| 4. <br> Cost / 11\% | 4a. (50\%) Unit Cost | Unit cost in ave. year | $\begin{aligned} & 5=<\$ 1,000 / \mathrm{AF} ; 4=<\$ 1,200 / \mathrm{AF} ; \\ & 3=<\$ 1,300 / \mathrm{AF} ; 2=<\$ 1,500 / \mathrm{AF} ; \\ & 1=>\text { Tier } 1(\$ 1,500 / \mathrm{AF}) \end{aligned}$ | \$1,000 | 5 | 0.4 |
|  | 4b. (50\%) <br> Capital Cost | Capital cost of portfolio | $\begin{aligned} & 5=<\$ 200 \mathrm{M} ; 4=<\$ 300 \mathrm{M} ; 3=< \\ & \$ 400 \mathrm{M} ; 2=<\$ 500 \mathrm{M} ; 1=>\$ 500 \mathrm{M} \end{aligned}$ | \$363,600,000 | 3 |  |
| 5. (11\%) <br> Self- <br> Reliance | 5a. (50\%) Local Portfolio | \% local supplies | $\begin{aligned} & 5=>80 \% \text { local; } 4=60-80 \% ; 3=40- \\ & 60 \% ; 2=20-40 \% ; 1=<20 \% \end{aligned}$ | Shift to all MWD water | 1 | 0.1 |
|  | 5b. (50\%) Eff. <br> Basin Mngmnt | Recharge to pump ratio | $\begin{aligned} & 5=1: 3 \text { ratio or better; } 4=1: 4-1: 6 ; 3 \\ & =1: 6-1: 8 ; 2=1: 8-1: 10 ; 1=>1: 10 \end{aligned}$ | Shift to all MWD water | 1 |  |
| 6.(4\%) <br> Regional Collabor | n/a | Number of supply partnerships | 5 = several; 3 = few partnerships <br> 1 = only MWD | No partnerships or agreements | 1 | 0.0 |
| 7. (6\%) <br> Complexity | n/a | Time score: permits, agrmnts, CEQA | $5=0-2$ projects to be implemented that require permits, arrangements, CEQA <br> $3=2-4$ projects; $1=4+$ projects | No new projects to implement | 5 | 0.3 |
| 8. Flexibility (8\%) | 8a. (50\%) Op. <br> Flexibility | \# intercontns | $\begin{aligned} & 5=>2 \text { new interconnections (IC); } 3 \\ & =1 \text { new IN.; } 1=\text { No new IC } \end{aligned}$ | No new interconnections | 1 | 0.1 |
|  | 8b. (50\%) <br> Adaptability | Score for Scalability and Phasing | 5 = Projects scaled/phased, flexible; 3 = No new projects; 1 = No scaled or phased projects | Shifting to all MWD - no impl. flexibility | 2 |  |
| 9. (11\%) Comm values/ quality of life | 9a. (50\%) Eff Resources Use | Volume of WUE \& NP direct use | 5= Mid WUE/Max Non-Potable (NP); 4= Mid WUE/Mid NP; 3= Max WUE/Mid NP; 2= Max WUE/Low NP; 1= Low WUE/No NP | Low WUE and No NP | 1 | 0.1 |
|  | 9b. (50\%) Aesthetics | Urb. canopy \& env impr. score | 5=Maintain green areas, capture SW, improve surface WQ; 1 = No environment improvement | No projects for aesthetics/ character | 1 |  |
| Pasadena Water and Power |  |  |  |  |  | 2.0 |

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| Criteria (Weight) | (Weight) Sub-Criteria | Metric | Points | Portfolio C: Maximize Local Supplies |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Data | Points | Score |
| 1. <br> Supply Reliability \& Resiliency / 19\% | 1a. (37\%) LongTerm Reliability | \% of time demand met | $\begin{aligned} & 5=100 \% ; 4=95 \%-99 \% ; 3=90 \%- \\ & 94 \% ; 2=85 \%-89 \% ; 1=<85 \% \end{aligned}$ | 92\% | 3 | 0.8 |
|  |  | Average shortage | $\begin{aligned} & 5=\text { No shortage; } 4=500 \mathrm{AFY} ; 3= \\ & 1,000 \mathrm{AFY} ; 2=1,500 \mathrm{AFY} ; 1= \end{aligned}$ | 1025 AFY | 3 |  |
|  | 1b. (26\%) LongTerm D. Resiliency | 24 months no MWD | $\begin{aligned} & 5=<10 \% \text { shortage w/ 12-mo } \\ & \text { imported water disruption; } 4=20 \% ; \\ & 3=30 \% ; 2=40 \% ; 1=>40 \% \end{aligned}$ | 0 AFY | 5 |  |
|  | 1c. (37\%) Em Resilience | Redundancy from distr. s. | 5 = Redundancy improvements (RI) made, 1 = No RI made | Distribution \& storage RI made | 5 |  |
| 2. <br> Health and Safety / 21\% | 2a. (25\%) Water Quality (WQ): Potable | GW salinity incr. to MCL | 5 = Salinity unchanged or reduced 4 = Significant salinity loading | Imported \& RW recharge | 4 | 1.1 |
|  |  | NO3 or VOC treatment | 5 = NO3 \& VOC treatment; 3 = NO3 or VOC treatm.; $1=$ No treatm. | Yes, VOC and nitrate treatment | 5 |  |
|  | 2b. (75\%) <br> Service Level / <br> Failure Risk | RR impr. cost , or \% of RR invested | 5 = Levels $1 \& 2$ rehab/ replacement $(R R)$ improvements; 3 = Level 1 RR; 1 = No RR impr | Level 1 and 2 RR improvements implemented | 5 |  |
| 3. <br> Enviro Stewardshp / 10\% | $\begin{gathered} \text { 3a. (50\%) } \\ \text { Envirom. WQ } \end{gathered}$ | SW captured | $\begin{aligned} & \text { 5:>2000 AFY; 4: 1000-2000 AFY; 3: } \\ & \text { 500-1000 AFY; 2:<500 AFY; 1: } 0 \\ & \hline \end{aligned}$ | $\begin{aligned} & \hline 5,000 \text { AFY SW } \\ & \text { captured } \\ & \hline \end{aligned}$ | 5 | 0.3 |
|  | 3b. (50\%) <br> Energy Eff / <br> Carbon <br> Footprint | Energy effic. Improv.- EEI | $\begin{aligned} & 5=\$ 350 \mathrm{~K} \text { (all EEI); 3= up to } \$ 175 \mathrm{~K} \\ & (50 \%) ; 1=\text { up to } \$ 87.5 \mathrm{~K}(25 \%) \end{aligned}$ | No EEI implemented | 1 |  |
|  |  | Carbon footprint /energy intensity | 5=Low carbon footpr./energy intensity (CF/EI); 3= High CF/EI; 1=>1 sources w/high CF/EI | Recharge/store imported \& RW | 1 |  |
| 4. <br> Cost / 11\% | 4a. (50\%) <br> Unit Cost | Unit cost in ave. year | $\begin{aligned} & 5=<\$ 1,000 / \mathrm{AF} ; 4=<\$ 1,200 / \mathrm{AF} ; \\ & 3=<\$ 1,300 / \mathrm{AF} ; 2=<\$ 1,500 / \mathrm{AF} ; \\ & 1=>\text { Tier } 1 \text { (\$1,500/AF) } \end{aligned}$ | \$900 | 5 | 0.3 |
|  | 4b. (50\%) Capital Cost | Capital cost of portfolio | $\begin{aligned} & 5=<\$ 200 \mathrm{M} ; 4=<\$ 300 \mathrm{M} ; 3=< \\ & \$ 400 \mathrm{M} ; 2=<\$ 500 \mathrm{M} ; 1=>\$ 500 \mathrm{M} \end{aligned}$ | \$522,580,000 | 1 |  |
| 5. (11\%) <br> Self- <br> Reliance | $\begin{aligned} & \text { 5a. (50\%) Local } \\ & \text { Portfolio } \end{aligned}$ | \% local supplies | $\begin{aligned} & 5=>80 \% \text { local; } 4=60-80 \% ; 3=40- \\ & 60 \% ; 2=20-40 \% ; 1=<20 \% \end{aligned}$ | 90\% | 5 | 0.6 |
|  | 5b. (50\%) Eff. <br> Basin Mngmnt | Recharge to pump ratio | $\begin{aligned} & 5=1: 3 \text { ratio or better; } 4=1: 4-1: 6 ; 3 \\ & =1: 6-1: 8 ; 2=1: 8-1: 10 ; 1=>1: 10 \end{aligned}$ | $\begin{array}{\|c\|} \hline 13,000: 21,200, \text { or } \\ 1: 1.6 \end{array}$ | 5 |  |
| 6.(4\%) Regional Collabor | n/a | Number of supply partnerships | $5=$ several; 3 = few partnerships 1 = only MWD | $\sim 6$ agencies (MWD, FMWD, SGVMWD, Desal | 5 | 0.2 |
| 7. (6\%) Complexity | n/a | Time score: permits, agrmnts, CEQA | $5=0-2$ projects to be implemented that require permits, arrangements, CEQA <br> $3=2-4$ projects; $1=4+$ projects | Complex projects: SW, recharge | 1 | 0.1 |
| 8. Flexibility (8\%) | 8a. (50\%) Op. <br> Flexibility | \# intercontns | $\begin{aligned} & 5=>2 \text { new interconnections (IC); } 3 \\ & =1 \text { new IN.; } 1=\text { No new IC } \\ & \hline \end{aligned}$ | $\begin{gathered} 2 \text { new IC (IW-4, } \\ \text { LAG-3a) } \end{gathered}$ | 5 | 0.4 |
|  | 8b. (50\%) <br> Adaptability | Score for Scalability and Phasing | 5 = Projects scaled/phased, flexible; 3 = No new projects; 1 = No scaled or phased projects | Several projects phased if needed | 5 |  |
| 9. (11\%) Comm values/ quality of life | 9a. (50\%) Eff Resources Use | Volume of WUE \& NP direct use | 5= Mid WUE/Max Non-Potable (NP); 4= Mid WUE/Mid NP; 3= Max WUE/Mid NP; 2= Max WUE/Low NP; 1= Low WUE/No NP | Low WUE and No NP | 1 | 0.3 |
|  | 9b. (50\%) Aesthetics | Urb. canopy \& env impr. score | 5=Maintain green areas, capture SW, improve surface WQ; 1 = No environment improvement | Projects to capture urban runoff | 5 |  |
|  |  |  |  |  |  | 4.0 |

Water System and Resources Plan Portfolio Evaluation Details

| Criteria (Weight) | (Weight) Sub-Criteria | Metric | Points | Portfolio D: Max. Sustainable Sources and Practices |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Data | Points | Score |
| 1. <br> Supply Reliability \& Resiliency / 19\% | 1a. (37\%) Long Term Reliability | \% of time demand met | $\begin{aligned} & 5=100 \% ; 4=95 \%-99 \% ; 3=90 \%- \\ & 94 \% ; 2=85 \%-89 \% ; 1=<85 \% \end{aligned}$ | 85\% | 2 | 0.6 |
|  |  | Average shortage | $5 \text { = No shortage; } 4=500 \text { AFY; } 3 \text { = }$ $\text { 1,000 AFY; } 2=1,500 \text { AFY; } 1 \text { = }$ | 482 AFY | 4 |  |
|  | 1b. (26\%) LongTerm D. Resiliency | 24 months no MWD | $\begin{aligned} & 5=<10 \% \text { shortage w/ 12-mo } \\ & \text { imported water disruption; } 4=20 \% ; \\ & 3=30 \% ; 2=40 \% ; 1=>40 \% \end{aligned}$ | 12,321 AFY | 2 |  |
|  | 1c. (37\%) Em Resilience | Redundancy from distr. s. | 5 = Redundancy improvements (RI) made, 1 = No RI made | Distrib. \& storage RI not made | 5 |  |
| 2. <br> Health and Safety / 21\% | 2a. (25\%) Water Quality (WQ): Potable | GW salinity incr. to MCL | 5 = Salinity unchanged or reduced 4 = Significant salinity loading | Moderate incr. from recharge | 4 | 1.1 |
|  |  | NO3 or VOC treatment | 5 = NO3 \& VOC treatment; 3 = NO3 or VOC treatm.; 1 = No treatm. | Yes, VOC and nitrate treatment | 5 |  |
|  | 2b. (75\%) <br> Service Level / Failure Risk | RR impr. cost , or \% of RR invested | 5 = Levels $1 \& 2$ rehab/ replacement $(R R)$ improvements; 3 = Level 1 RR; 1 = No RR impr | Level 1 and 2 RR improvements implemented | 5 |  |
| 3. <br> Enviro Stewardshp / 10\% | 3a. (50\%) <br> Envirom. WQ | SW captured | $\begin{aligned} & \text { 5:>2000 AFY; 4: 1000-2000 AFY; 3: } \\ & \text { 500-1000 AFY; 2:<500 AFY; 1: } 0 \end{aligned}$ | 4600 AFY SW captured | 5 | 0.5 |
|  | 3b. (50\%) <br> Energy Eff / Carbon Footprint | Energy effic. Improv.- EEI | $\begin{aligned} & 5=\$ 350 \mathrm{~K} \text { (all EEI); 3= up to } \$ 175 \mathrm{~K} \\ & (50 \%) ; 1=\text { up to } \$ 87.5 \mathrm{~K}(25 \%) \end{aligned}$ | \$350,000 energy eff improvements | 5 |  |
|  |  | Carbon footprint /energy intensity | 5=Low carbon footpr./energy intensity (CF/EI); 3= High CF/EI; 1=>1 sources w/high CF/EI | Rely on local, sustainable supplies | 5 |  |
| 4. Cost / 11\% | 4a. (50\%) <br> Unit Cost | Unit cost in ave. year | $\begin{aligned} & 5=<\$ 1,000 / \mathrm{AF} ; 4=<\$ 1,200 / \mathrm{AF} ; \\ & 3=<\$ 1,300 / \mathrm{AF} ; 2=<\$ 1,500 / \mathrm{AF} ; \\ & 1=>\text { Tier } 1(\$ 1,500 / \mathrm{AF}) \end{aligned}$ | \$1,300 | 2 | 0.2 |
|  | 4b. (50\%) Capital Cost | Capital cost of portfolio | $\begin{aligned} & 5=<\$ 200 \mathrm{M} ; 4=<\$ 300 \mathrm{M} ; 3=< \\ & \$ 400 \mathrm{M} ; 2=<\$ 500 \mathrm{M} ; 1=>\$ 500 \mathrm{M} \end{aligned}$ | \$516,130,000 | 1 |  |
| 5. (11\%) <br> Self- <br> Reliance | 5a. (50\%) Local Portfolio | \% local supplies | $\begin{aligned} & 5=>80 \% \text { local; } 4=60-80 \% ; 3=40- \\ & 60 \% ; 2=20-40 \% ; 1=<20 \% \end{aligned}$ | 62\% | 4 | 0.5 |
|  | 5b. (50\%) Eff. <br> Basin Mngmnt | Recharge to pump ratio | $\begin{aligned} & 5=1: 3 \text { ratio or better; } 4=1: 4-1: 6 ; 3 \\ & =1: 6-1: 8 ; 2=1: 8-1: 10 ; 1=>1: 10 \end{aligned}$ | $\begin{gathered} 5,800: 17,400, \text { or } \\ 1: 3 \end{gathered}$ | 5 |  |
| 6.(4\%) Regional Collabor | n/a | Number of supply partnerships | 5 = several; 3 = few partnerships 1 = only MWD | ~1 (RBMB) | 3 | 0.1 |
| 7. (6\%) Complexity | n/a | Time score: permits, agrmnts, CEQA | $5=0-2$ projects to be implemented that require permits, arrangements, CEQA <br> $3=2-4$ projects; $1=4+$ projects | Non-potable, SW, GW treatment | 1 | 0.1 |
| $\begin{aligned} & \text { 8. Flexibility } \\ & \text { (8\%) } \end{aligned}$ | 8a. (50\%) Op. <br> Flexibility | \# intercontns | $\begin{aligned} & 5=>2 \text { new interconnections (IC); } 3 \\ & =1 \text { new IN.; } 1=\text { No new IC } \end{aligned}$ | No new interconnections | 1 | 0.2 |
|  | 8b. (50\%) <br> Adaptability | Score for Scalability and Phasing | 5 = Projects scaled/phased, flexible; 3 = No new projects; 1 = No scaled or phased projects | Several projects phased if needed | 5 |  |
| 9. (11\%) Comm values/ quality of life | 9a. (50\%) Eff Resources Use | Volume of WUE \& NP direct use | 5= Mid WUE/Max Non-Potable (NP); 4= Mid WUE/Mid NP; 3= Max WUE/Mid NP; 2= Max WUE/Low NP; 1= Low WUE/No NP | Max WUE and Low NP | 3 | 0.4 |
|  | 9b. (50\%) <br> Aesthetics | Urb. canopy \& env impr. score | 5=Maintain green areas, capture SW, improve surface WQ; 1 = No environment improvement | NPW project for irrigation, \& SW capture | 5 |  |
| Pasadena Water and Power |  |  |  |  |  | 3.7 |

Water System and Resources Plan Portfolio Evaluation Details

| Criteria (Weight) | (Weight) Sub-Criteria | Metric | Points | Portfolio E: Max. Direct Use of Stormwater \& Recycled Water |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Data | Points | Score |
| 1. <br> Supply Reliability \& Resiliency / 19\% | 1a. (37\%) LongTerm Reliability | \% of time demand met | $\begin{aligned} & 5=100 \% ; 4=95 \%-99 \% ; 3=90 \%- \\ & 94 \% ; 2=85 \%-89 \% ; 1=<85 \% \end{aligned}$ | 100\% | 5 | 0.5 |
|  |  | Average shortage | 5 = No shortage; 4 = 500 AFY; 3 = 1,000 AFY; 2 = 1,500 AFY; 1 = | 0 AFY | 5 |  |
|  | 1b. (26\%) LongTerm D. <br> Resiliency | 24 months no MWD | $\begin{aligned} & 5=<10 \% \text { shortage w/ 12-mo } \\ & \text { imported water disruption; } 4=20 \% ; \\ & 3=30 \% ; 2=40 \% ; 1=>40 \% \end{aligned}$ | 10,787 AFY | 2 |  |
|  | 1c. (37\%) Em Resilience | Redundancy from distr. s. | 5 = Redundancy improvements (RI) made, 1 = No RI made | Distrib. \& storage RI not made | 1 |  |
| 2. <br> Health and Safety / 21\% | 2a. (25\%) Water Quality (WQ): Potable | GW salinity incr. to MCL | 5 = Salinity unchanged or reduced 4 = Significant salinity loading | Salinity incr. - SW recharge | 5 | 1.1 |
|  |  | NO3 or VOC treatment | 5 = NO3 \& VOC treatment; 3 = NO3 or VOC treatm.; 1 = No treatm. | Yes, VOC and nitrate treatment | 5 |  |
|  | 2b. (75\%) Service Level / Failure Risk | RR impr. cost , or \% of RR invested | 5 = Levels $1 \& 2$ rehab/ replacement $(R R)$ improvements; 3 = Level 1 RR; 1 = No RR impr | Level 1 and 2 RR improvements implemented | 5 |  |
| 3. Enviro Stewardshp / 10\% | 3a. (50\%) <br> Envirom. WQ | SW captured | $\begin{aligned} & \text { 5:>2000 AFY; 4: 1000-2000 AFY; 3: } \\ & \text { 500-1000 AFY; 2:<500 AFY; 1: } 0 \end{aligned}$ | 285 AFY SW captured | 2 | 0.2 |
|  | 3b. (50\%) <br> Energy Eff / Carbon Footprint | Energy effic. Improv.- EEI | $\begin{aligned} & 5=\$ 350 \mathrm{~K} \text { (all EEI); 3= up to } \$ 175 \mathrm{~K} \\ & (50 \%) ; 1=\text { up to } \$ 87.5 \mathrm{~K}(25 \%) \end{aligned}$ | No EEI implemented | 1 |  |
|  |  | Carbon footprint /energy intensity | 5=Low carbon footpr./energy intensity (CF/EI); 3= High CF/EI; 1=>1 sources w/high CF/EI | RW and imported projects | 1 |  |
| 4. <br> Cost / 11\% | 4a. (50\%) Unit Cost | Unit cost in ave. year | $\begin{aligned} & 5=<\$ 1,000 / \mathrm{AF} ; 4=<\$ 1,200 / \mathrm{AF} ; \\ & 3=<\$ 1,300 / \mathrm{AF} ; 2=<\$ 1,500 / \mathrm{AF} ; \\ & 1=>\text { Tier } 1(\$ 1,500 / \mathrm{AF}) \end{aligned}$ | \$1,000 | 4 | 0.3 |
|  | 4b. (50\%) Capital Cost | Capital cost of portfolio | $\begin{aligned} & 5=<\$ 200 \mathrm{M} ; 4=<\$ 300 \mathrm{M} ; 3=< \\ & \$ 400 \mathrm{M} ; 2=<\$ 500 \mathrm{M} ; 1=>\$ 500 \mathrm{M} \end{aligned}$ | \$414,240,000 | 2 |  |
| 5. (11\%) <br> Self- <br> Reliance | 5a. (50\%) Local Portfolio | \% local supplies | $\begin{aligned} & 5=>80 \% \text { local; } 4=60-80 \% ; 3=40- \\ & 60 \% ; 2=20-40 \% ; 1=<20 \% \end{aligned}$ | 84\% | 5 | 0.4 |
|  | 5b. (50\%) Eff. <br> Basin Mngmnt | Recharge to pump ratio | $\begin{aligned} & 5=1: 3 \text { ratio or better; } 4=1: 4-1: 6 ; 3 \\ & =1: 6-1: 8 ; 2=1: 8-1: 10 ; 1=>1: 10 \end{aligned}$ | $\begin{gathered} \hline 2,285: 17,770 \text {, or } \\ 1: 9 \end{gathered}$ | 2 |  |
| 6.(4\%) <br> Regional Collabor | n/a | Number of supply partnerships | $5=$ several; $3=$ few partnerships 1 = only MWD | 5 (MWD, imp. rights transfer, ext. banking, LAG, | 5 | 0.2 |
| 7. (6\%) <br> Complexity | n/a | Time score: permits, agrmnts, CEQA | $5=0-2$ projects to be implemented that require permits, arrangements, CEQA <br> $3=2-4$ projects; $1=4+$ projects | New LAG, nonpotable, | 3 | 0.2 |
| 8. Flexibility (8\%) | 8a. (50\%) Op. <br> Flexibility | \# intercontns | $\begin{aligned} & 5=>2 \text { new interconnections (IC); } 3 \\ & =1 \text { new IN.; } 1=\text { No new IC } \end{aligned}$ | 1 new IC (LAG-3a) | 3 | 0.3 |
|  | 8b. (50\%) Adaptability | Score for Scalability and Phasing | 5 = Projects scaled/phased, flexible; $3=$ No new projects; $1=$ No scaled or phased projects | Several projects phased if needed | 5 |  |
| 9. (11\%) Comm values/ quality of life | 9a. (50\%) Eff Resources Use | Volume of WUE \& NP direct use | 5= Mid WUE/Max Non-Potable (NP); 4= Mid WUE/Mid NP; 3= Max WUE/Mid NP; 2= Max WUE/Low NP; 1= Low WUE/No NP | Low WUE and Low NP | 2 | 0.4 |
|  | 9b. (50\%) <br> Aesthetics | Urb. canopy \& env impr. score | 5=Maintain green areas, capture SW, improve surface WQ; 1 = No environment improvement | NPW project for irrigation, \& SW capture | 5 |  |


| Criteria (Weight) | (Weight) Sub-Criteria | Metric | Points | Portfolio F: Sustainable Groundwater, Conservation, Stormwater Capture |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Data | Points | Score |
| 1. <br> Supply Reliability \& Resiliency / 19\% | 1a. (37\%) LongTerm Reliability | \% of time demand met | $\begin{aligned} & 5=100 \% ; 4=95 \%-99 \% ; 3=90 \%- \\ & 94 \% ; 2=85 \%-89 \% ; 1=<85 \% \end{aligned}$ | 100\% | 5 | 0.9 |
|  |  | Average shortage | 5 = No shortage; 4 = 500 AFY; 3 = 1,000 AFY; 2 = 1,500 AFY; 1 = | 0 AFY | 5 |  |
|  | $\begin{gathered} \text { 1b. }(26 \%) \text { Long- } \\ \text { Term D. } \\ \text { Resiliency } \\ \hline \end{gathered}$ | 24 months no MWD | $\begin{aligned} & 5=<10 \% \text { shortage w/ 12-mo } \\ & \text { imported water disruption; } 4=20 \% ; \\ & 3=30 \% ; 2=40 \% ; 1=>40 \% \end{aligned}$ | 931 AFY | 5 |  |
|  | 1c. (37\%) Em Resilience | Redundancy from distr. s. | 5 = Redundancy improvements (RI) made, 1 = No RI made | Distrib. \& storage RI not made | 5 |  |
| 2. <br> Health and Safety / 21\% | 2a. (25\%) Water Quality (WQ): Potable | GW salinity incr. to MCL | 5 = Salinity unchanged or reduced 4 = Significant salinity loading | Imported recharge to Raymond Basin | 4 | 1.1 |
|  |  | NO3 or VOC treatment | 5 = NO3 \& VOC treatment; 3 = NO3 or VOC treatm.; $1=$ No treatm. | Yes, VOC and nitrate treatment | 5 |  |
|  | 2b. (75\%) <br> Service Level / Failure Risk | RR impr. cost , or \% of RR invested | 5 = Levels $1 \& 2$ rehab/ replacement $(R R)$ improvements; 3 = Level 1 RR; 1 = No RR impr | Levels 1 and 2 RR improvements implemented | 5 |  |
| 3. <br> Enviro Stewardshp / 10\% | $\begin{gathered} \text { 3a. (50\%) } \\ \text { Envirom. WQ } \end{gathered}$ | SW captured | 5:>2000 AFY; 4: 1000-2000 AFY; 3: $\text { 500-1000 AFY; 2:<500 AFY; 1: } 0$ | 0 AFY SW captured | 1 | 0.2 |
|  | 3b. (50\%) <br> Energy Eff / <br> Carbon <br> Footprint | Energy effic. Improv.- EEI | $\begin{aligned} & 5=\$ 350 \mathrm{~K} \text { (all EEI); 3= up to } \$ 175 \mathrm{~K} \\ & (50 \%) ; 1=\text { up to } \$ 87.5 \mathrm{~K}(25 \%) \end{aligned}$ | No EEI implemented | 1 |  |
|  |  | Carbon footprint /energy intensity | 5=Low carbon footpr./energy intensity (CF/EI); 3= High CF/EI; 1=>1 sources w/high CF/EI | Imported water projects only | 3 |  |
| 4. Cost / 11\% | 4a. (50\%) <br> Unit Cost | Unit cost in ave. year | $\begin{aligned} & 5=<\$ 1,000 / \mathrm{AF} ; 4=<\$ 1,200 / \mathrm{AF} ; \\ & 3=<\$ 1,300 / \mathrm{AF} ; 2=<\$ 1,500 / \mathrm{AF} ; \\ & 1=>\text { Tier } 1 \text { (\$1,500/AF) } \end{aligned}$ | \$1,000 | 4 | 0.3 |
|  | 4b. (50\%) Capital Cost | Capital cost of portfolio | $\begin{aligned} & 5=<\$ 200 \mathrm{M} ; 4=<\$ 300 \mathrm{M} ; 3=< \\ & \$ 400 \mathrm{M} ; 2=<\$ 500 \mathrm{M} ; 1=>\$ 500 \mathrm{M} \end{aligned}$ | \$432,680,000 | 2 |  |
| 5. (11\%) <br> Self- <br> Reliance | $\begin{aligned} & \text { 5a. (50\%) Local } \\ & \text { Portfolio } \end{aligned}$ | \% local supplies | $\begin{aligned} & 5=>80 \% \text { local; } 4=60-80 \% ; 3=40- \\ & 60 \% ; 2=20-40 \% ; 1=<20 \% \end{aligned}$ | 90\% | 5 | 0.5 |
|  | 5b. (50\%) Eff. <br> Basin Mngmnt | Recharge to pump ratio | $\begin{aligned} & 5=1: 3 \text { ratio or better; } 4=1: 4-1: 6 ; 3 \\ & =1: 6-1: 8 ; 2=1: 8-1: 10 ; 1=>1: 10 \end{aligned}$ | $\begin{gathered} 3,770: 20,100, \\ \text { or } 1: 5.3 \end{gathered}$ | 4 |  |
| 6.(4\%) Regional Collabor | n/a | Number of supply partnerships | $5=$ several; 3 = few partnerships 1 = only MWD | ~3 (MWDSC, RBMB, LAG) | 5 | 0.2 |
| 7. (6\%) Complexity | n/a | Time score: permits, agrmnts, CEQA | $5=0-2$ projects to be implemented that require permits, arrangements, CEQA <br> $3=2-4$ projects; $1=4+$ projects | 7 projects | 1 | 0.1 |
| 8. Flexibility (8\%) | 8a. (50\%) Op. <br> Flexibility | \# intercontns | $\begin{aligned} & 5=>2 \text { new interconnections (IC); } 3 \\ & =1 \text { new IN.; } 1=\text { No new IC } \\ & \hline \end{aligned}$ | 1 new IC (IW-4) | 3 | 0.3 |
|  | 8b. (50\%) <br> Adaptability | Score for Scalability and Phasing | 5 = Projects scaled/phased, flexible; 3 = No new projects; 1 = No scaled or phased projects | Several projects phased if needed | 5 |  |
| 9. (11\%) Comm values/ quality of life | 9a. (50\%) Eff Resources Use | Volume of WUE \& NP direct use | 5= Mid WUE/Max Non-Potable (NP); 4= Mid WUE/Mid NP; 3= Max WUE/Mid NP; 2= Max WUE/Low NP; 1= Low WUE/No NP | Low WUE and Max NP | 5 | 0.5 |
|  | 9b. (50\%) Aesthetics | Urb. canopy \& env impr. score | 5=Maintain green areas, capture SW, improve surface WQ; 1 = No environment improvement | NPW project will maintain green areas | 5 |  |
| Pasadena Water and Power |  |  |  |  |  | 4.1 |

## Appendix I Distribution Pipelines Evaluation Reports

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June 18, 2018

David Kimbrough, Ph.D.
Water Quality Manager
Pasadena Water \& Power
150 S. Los Robles, Suite 200
Pasadena, CA 91101
Subject: 6-inch Diameter Cast Iron Pipe Sample Evaluation Report
Dear Mr. Kimbrough:
V\&A Consulting Engineers, Inc. (V\&A) has completed an evaluation of the 6-inch diameter cast iron pipe (CIP) sample provided by Pasadena Water \& Power (PWP). V\&A performed a visual examination and thickness measurements on the pipe sample. The sample was also sent to Anamet, Inc. (Anamet) in Hayward, California for laboratory testing. The laboratory tests included visual and macroscopic examination, chemical composition, hardness testing, material toughness, microstructure examination, modulus of rupture, and secant modulus of elasticity. The information gained from the evaluation is intended to provide PWP with information regarding the remaining service life of the pipe.

PWP obtained the CIP sample from a leaking water main in Pasadena, California. Record drawings or other records were not available for review as part this evaluation; however, PWP stated that the CIP was believed to be approximately 100 years old. CIP of this vintage would likely be of the pit-cast variety. However, the apparent nominal thickness of the pipe sample, as well as the laboratory tests, indicate that the pipe is likely centrifugally cast, or "spun-cast," CIP. This will be discussed further in the report.

## Visual Examination

The pipe sample exhibited heavy corrosion on its interior and exterior surfaces, which was likely the cause of the approximately 1 -inch by 0.75 -inch perforation on the pipe, as shown in Photo 1 and Photo 2. Large corrosion tubercles were deposited on much of the interior surface. Removal of the corrosion tubercles left a rough surface with ferrous corrosion and graphitized material on the interior surface.

The exterior of the pipe had experienced graphitic corrosion, leaving the exterior with an approximately $1 / 8$-inch-thick layer of brittle graphitized material, as shown in Photo 3. Graphitization occurs in grey cast iron when the iron is selectively leached out of the material matrix, leaving behind graphite. This process leaves behind the graphite matrix in the shape of the original pipe. The preferential attack on iron results from graphite's highly noble, or corrosion resistant, position in the galvanic series. Pipe that is graphitized may look normal to the eye and still provide a shell for fluid flow. Graphitized areas of pipe wall will be brittle and can fail when moved or subject to internal or external loads. Because the graphitized material is often left behind in the original shape of the object, wall thickness measurements on graphitized CIP can often still be used to determine the original thickness of the metal.

## Thickness Measurements

Direct thickness measurements using a digital caliper and steel rule resulted in wall thicknesses of approximately 0.380 inches. This appears to be the nominal wall thickness of the pipe, which is considered thin compared to standards for pit-cast CIP ${ }^{1}$. This thickness is consistent with Class 22 for spun-cast 6-inch diameter CIP$^{2}$.

Photos 1, 2, and 4 show an approximately 3-inch-square cutout of the pipe sample at the perforation. Photo 4 shows the pipe cross section and severe loss of material due to internal and external corrosion near the perforation. Pipe wall loss was approximately 0.125 inches on both the inner and outer surface of the pipe, for a total of approximately 0.250 inches ( $66 \%$ ) wall thickness loss.

## Laboratory Testing

Table 1 summarizes the laboratory test methods and results for the pipe sample. Anamet's complete report is provided in Appendix B.

Note that Anamet's report references the American Standards Association (ASA) A21.2, as presented in the Handbook of Cast Iron Pipe (1952) in their report. However, since the pipe is spun-cast, ASA A21.6 (metal molds) or ASA A21.8 (sand molds) applies instead. The acceptance criteria presented in the table have been corrected appropriately.

[^0]2 Handbook of Cast Iron Pipe, 1952

Table 1. Description and Results of Laboratory Tests

| Test Method | Description | Result |
| :---: | :---: | :---: |
| Visual and macroscopic evaluation | Visual assessment of pipe surfaces and cross section. Macroscopic evaluation involved machining a full ring section so that the cross section of the pipe could be evaluated for inclusions, porosity, and graphitization. | - Heavy corrosion on pipe interior and exterior <br> - Cross sections indicate significant wall loss due to corrosion (graphitization) <br> - Macroscopic examination of cross section did not show inclusions, porosity, or other defects |
| Chemical analysis | Chemical analysis for silicon, sulfur, manganese, phosphorus, and total carbon to verify consistency with cast iron pipe standards. | - Chemical composition consistent with grey cast iron |
| Brinell hardness and Rockwell hardness tests | Indirect and qualitative measurement of tensile strength. | - Brinell hardness test could not be performed due to cracking of sample <br> - Rockwell hardness test showed hardness of 91 HRBW, which meets ASA A21.6 requirements |
| Charpy Impact tests | A test to measure the amount of energy absorbed by the material during fracture. Although this test is not required by ASA and AWWA standards, it will provide an indication of material toughness. | - Both notched and unnotched specimens showed impact energy values lower than $1 \mathrm{ft}-\mathrm{lb}$, which indicates that the material is highly susceptible to brittle fracture. |
| Talbot strip tests | Talbot strip test was performed on the pipe sample to evaluate the modulus of rupture and secant modulus of elasticity. | - Modulus of rupture: 30,700 psi <br> - Secant modulus of elasticity: 1,410,000 psi <br> - Does not meet ASA A21.6 or ASA A21.8 requirements ${ }^{\text {a }}$ |
| Ring test | A ring (crushing) test was performed on the pipe sample to evaluate the modulus of rupture and secant modulus of elasticity. | - Modulus of rupture: 24,079 psi <br> - Secant modulus of elasticity: not performed on pipes less than 12 inches in diameter <br> - Does not meet ASA A21.6 or ASA A21.8 requirements ${ }^{\text {b }}$ |
| Metallography | Optical microscopy to examine the microstructure of the sample. | - Microstructure consists of ferrite, pearlite, and graphite consistent with grey cast iron <br> - ASTM Form VII flake graphite at both inner and outer surface <br> - Graphite flake distribution was ASTM Type D at outer surface and Type B at inner surface, which is consistent with spun-cast pipe rather than pit-cast pipe. |

a ASA A21.6 requires: maximum Rockwell hardness of 94 HRBW
b ASA A21.6 and ASA A21.8 requires: minimum modulus of rupture of 40,000 psi and maximum secant modulus of elasticity of $10,000,000 \mathrm{psi}(12,000,000 \mathrm{psi}$ for sand-lined molds).

## Conclusions

Based on the results of the evaluation, V\&A presents the following conclusions for PWP to consider.

- The pipe sample exhibited heavy corrosion (graphitization) on its interior and exterior surfaces, which was likely the cause of the approximate 1 -inch by 0.75 -inch perforation on the pipe.
- The nominal pipe wall thickness appears to be 0.38 inches, which is consistent with 6 -inch-diameter Class 22 CIP (spun-cast). A cross section near the perforation showed approximately 0.125 -inch pipe wall loss on both the interior and exterior surfaces of the pipe (66\% pipe wall loss).
- Laboratory test results:
- Macroscopic examination of a cross section did not show inclusions, porosity, or other defects.
- Chemical composition is consistent with grey cast iron.
- Ring test and Talbot strip do not meet ASA A21.6 or ASA A21.8 requirements.
- Sharpy Impact tests indicate that the material is susceptible to brittle fracture.
- Rockwell hardness tests meet ASA A21.6 requirements.
- Microscopy indicates a microstructure consistent with grey cast iron, and, in particular, spun-cast pipe rather than pit-cast pipe.
- The pipe reach from which this sample was pulled had failed (remaining service life of 0 years). While this is a small sample size of similar pipes that may be in service, it is likely that piping installed around the same time and subjected to similar loading and exposure conditions is also nearing the end of its service life.

On behalf of our staff and myself, I would like to thank you for the opportunity to be of service to you and Pasadena Water \& Power.

Sincerely,
V\&A Consulting Engineers, Inc.


Noy Phannavong, P.E. Project Manager

## Attachment A - Evaluation Photographs



Photo 1. View of perforation in pipe sample from exterior.


Photo 2. View of perforation in pipe sample from interior.


Photo 3. Closeup of graphitized layer (approx. 1/8-inch thick) on pipe exterior.


Photo 4. Macro-etched cross section of pipe showing graphitized layers on both interior and exterior.

# METALLURGICAL EVALUATION OF A SECTION OF A GRAY CAST IRON PIPE 

Customer Authorization: Project No. 18-0066

Report To: V \& A Engineering
ATTN: Noy Phannavong
1000 Broadway, Suite 320
Oakland, CA 94607

### 1.0 INTRODUCTION

One section of a 6-in diameter gray cast iron pipe identified as Project \# 18-0066 was submitted for metallurgical evaluation.

The sample was evaluated by the following laboratory procedures:

1) Visual and Macroscopic Examination
2) Chemical Analysis
3) Hardness Test
4) Charpy Impact Tests
5) Talbot Strip Test
6) Ring Test
7) Metallography

Visual examination showed extensive corrosion products in the pipe. Cross sections showed loss of a significant portion of the pipe wall by corrosion on both the outer and inner surfaces (OD and ID, respectively). Macroetching of a cross section did not reveal any indications of inclusions or other defects. Chemical analysis of the pipe was consistent with a gray cast iron. A Rockwell B hardness (HRBW) test performed showed a hardness of 91 HRBW which converts to an equivalent Brinell hardness of 190 HBW. The average Charpy impact energy values were $0.22 \mathrm{ft} . \mathrm{lb}$ and 0.54 ft.lb, respectively for notched and unnotched 4-mm thick sub-size specimens prepared after grinding to remove corroded material. Test results are presented for Talbot strip test and a ring test. Metallographic examination showed a microstructure consisting of ferrite, pearlite and graphite consistent with a gray cast iron. Grain size was rated at ASTM No. 6. The graphite form was ASTM Type VII flake graphite at both the OD and the ID. The graphite flake distribution was ASTM D at the OD and ASTM B at the ID, consistent with a spun cast rather than a pit cast pipe.

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### 2.0 EVALUATION

### 2.1 Visual and Macroscopic Examination

Figure 1 is a photograph of the pipe section as received. The pipe was heavily corroded on the OD and a perforation is evident in the section. Figure 2(a) shows heavy corrosion deposits on the ID of the pipe. Figure 2(b) is a cross section of the pipe showing significant loss of wall due to corrosion at the OD and ID. Macroscopic examination as polished and after etching the cross section of the pipe did not show any indications of inclusions or other defects.

### 2.2 Chemical Analysis

The results of a chemical analysis performed on the pipe are in Table 1. No chemical requirements were available for the pipe. The chemical requirements per ASTM A74 - 16, Standard Specification for Cast Iron Soil Pipe and Fittings, are shown in Table 1 for information only. The chemical composition was consistent with a gray cast iron.

### 2.3 Hardness Test

A Brinell hardness (HBW) test that was requested for the pipe could not be performed as the sample cracked while attempting the test. A Rockwell B hardness (HRBW) test performed per ASTM E18 - 17 showed a hardness of 91 HRBW which converts to an equivalent Brinell hardness of 190 HBW .

### 2.4 Charpy Impact Tests

The results of Charpy impact tests performed on V-notched and unnotched specimens are in Table 2. The tests were performed for information only. Both the notched and unnotched specimens showed impact energy values lower than $1 \mathrm{ft} . \mathrm{lb}$ for 4 mm thick sub-size specimens prepared after grinding to remove corroded material.

### 2.5 Talbot Strip Test

A strip test specimen was machined from the pipe in accordance with American Standard Specifications for Cast Iron Pit Cast Pipe for Water or Other Liquids, ASA A 21.2. The results of a Talbot strip test on the specimen are in Table 3.

### 2.6 Ring Test

A ring was cut out from the pipe in accordance with American Standard Specifications for Cast Iron Pit Cast Pipe for Water or Other Liquids, ASA A 21.2. The remaining wall thickness of the ring after corrosion varied around the circumference. For the ring test, the ring test specimen was oriented such that the lowest remaining wall was 90 degrees from the point of load application to represent the worst-case loading. The results of a ring test are in Table 4. The test results may at least partly be affected by the varying remaining wall thickness around the circumference of the pipe.

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### 2.7 Metallography

A longitudinal section of the pipe was metallographically prepared and examined by optical microscopy. Examination showed that the graphite form was Type VII flake graphite per ASTM A247 - 16a at both the OD and the ID (Figure 3). The graphite flake distribution was D per ASTM 247 - 16a at the OD and B at the ID, consistent with a spun-cast rather than a pit-cast pipe. The typical microstructure (Figure 4) consisted of ferrite, pearlite and graphite consistent with a gray cast iron. Grain size was rated at No. 6 per ASTM E112-13.

### 3.0 CONCLUSIONS ${ }^{1}$

The following conclusions are based upon the submitted samples and the evidence gathered:

1) Visual examination showed extensive corrosion products in the pipe. Cross sections showed loss of a significant portion of the pipe wall by corrosion on both the outer and inner surfaces.
2) Macroetching of a cross section did not reveal any indications of inclusions or other defects.
3) Chemical analysis of the pipe was consistent with a gray cast iron.
4) The Rockwell B hardness for the pipe was 91 HRBW which converts to an equivalent Brinell hardness of 190 HBW.
5) The Charpy impact energy values were 0.22 and $0.54 \mathrm{ft} . \mathrm{lb}$, respectively for notched and unnotched $4-\mathrm{mm}$ thick sub-size specimens prepared after removing corroded material.
6) A Talbot strip test showed a maximum load of 54 lb , secant modulus of elasticity of $1,410,000$ psi and an indicated modulus of rupture of $30,700 \mathrm{psi}$.
7) A ring test showed a secant modulus of elasticity of $92,600 \mathrm{psi}$ and an indicated modulus of rupture of $24,079 \mathrm{psi}$. The test results may at least partly be affected by the varying remaining wall thickness around the circumference of the pipe after corrosion.
8) The microstructure of the pipe consisted of ferrite, pearlite and graphite consistent with a gray cast iron. Grain size was rated at ASTM No. 6. The graphite form was ASTM Form VII flake graphite at both the OD and the ID. The graphite flake distribution was ASTM Type D at the OD and Type B at the ID, consistent with a spun cast rather than a pit cast pipe.
[^1]Anamet, inc HAYWARD, CALIFORNIA

## Prepared by:


M. Dilip Bhandarkar

Senior Materials Engineer

Reviewed by:


Sam McFadden, Ph.D.
Associate Director of Engineering

Table 1
Results of Quantitative Chemical Analysis of the Pipe (wt \%)

| Element | Pipe 18-0066 | Requirements, ASTM A74-16 |
| :---: | :---: | :---: |
| Aluminum (Al) | $<0.005$ | 0.50 max |
| Arsenic (As) | 0.08 | Info |
| Carbon ${ }^{1}$ (C) | 3.69 | Info |
| Chromium (Cr) | 0.02 | 0.50 max |
| Copper ( Cu ) | 0.04 | Info |
| Magnesium (Mg) | $<0.005$ | Info |
| Manganese (Mn) | 0.52 | Info |
| Molybdenum (Mo) | $<0.005$ | Info |
| Nickel (Ni) | $\leq 0.01$ | Info |
| Phosphorus (P) | 0.72 | 0.38 max |
| Silicon $^{2} \quad(\mathrm{Si})$ | 1.63 | Info |
| Sulfur ${ }^{1}$ (S) | 0.052 | 0.15 max |
| Titanium (Ti) | 0.06 | 0.10 max |
| Vanadium (V) | 0.05 | Info |
| Carbon Equivalent (C.E.) ${ }^{3}$ | 4.47 | 4.10 min |

${ }^{1}$ Carbon (C) and Sulfur (S) determined by LECO combustion
${ }^{2}$ Silicon by wet chemical analysis
All other elements determined by spark optical emission spectroscopy (OES)
3 Carbon Equivalent $=\% \mathrm{C}+\% \mathrm{Si} / 3+\% \mathrm{P} / 3$

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Table 2
Charpy V-Notch Impact Test Results for L-T specimens from the pipe (ASTM A327-11)
Test Temperature: Ambient
Specimen Thickness: 4 mm

| Specimen <br> ID | Energy Absorbed <br> (ft-lb) | Average Energy <br> Absorbed (ft-lb) |
| :---: | :---: | :---: |
| V-Notched | 0.20 |  |
|  | 0.27 | 0.22 |
|  | 0.20 |  |
|  | 0.54 | 0.54 |
|  | 0.54 |  |

Table 3
Talbot Strip Test Results

| Dimensions of Specimen (in.): | Pipe 18-0066 |
| :--- | :---: |
| Width (in.) | 0.664 |
| Thickness (in.) | 0.163 |
| Support Span (in.) | 10 |
| Loading Span (in.) | 3.333 |
| Maximum Bending Load (lb) | 54 |
| Secant Modulus of Elasticity (psi) | $1,410,000$ |
| Indicated Modulus of Rupture (psi) | 30,700 |

Table 4
Ring Test Results

|  | Pipe 18-0066 |
| :--- | :---: |
| Diameter of Specimen (in.) | 6.92 |
| Average Wall Thickness (in.) | 0.180 |
| Secant Modulus of Elasticity (psi) | 92,600 |
| Indicated Modulus of Rupture (psi) | 24,079 |

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Figure 1 Photograph of the pipe section as received. A perforation is visible. The white outlined box at the top left indicates the area from which a specimen for Talbot strip test was taken. A ring test sample was taken from the white outlined box near the right end.

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(a) Photograph showing corrosion deposits on the inside surface of the pipe section

(b) Cross section of the pipe showing a remaining wall thickness less than half of the overall wall thickness in some areas

Figure 2 Photographs of the pipe section showing corrosion and loss of wall thickness.
(a) Optical micrograph (100X) showing ASTM Type VII, Distribution D graphite near the OD of the pipe.

(b) Optical micrograph (100X) showing ASTM Type VII, Distribution B graphite near the ID of the pipe.

Figure 3 Optical micrographs showing graphite type and form in the pipe. As polished

(a) 100 X


Figure 4 Optical micrographs showing the typical microstructure of the pipe. The microstructure consisted of graphite (dark) in a matrix containing ferrite (lighter phase) and pearlite (gray). Etchant: 2\% Nital

November 27, 2018

| Ms. Natalie Ouwersloot | Lab. No.: 3K46 |
| :--- | ---: |
| CITY OF PASADENA | P. O. No.: 1191294-00 |
| Water \& Power Field Operations | Page 1 of 12 |
| 245 West Mountain St. | Pasadena 2020 Water System Resources Plan |
| Pasadena, CA 91103 | Appendix I |
| SUBJECT: Evaluation of 6" Cast Iron Pipe Section. | Evaluation Report \#2 |
|  |  |
| Pages 18-29 |  |

Dear Ms. Ouwersloot;
At your request, TEI has performed an evaluation of the above referenced pipe section.

## SCOPE

The scope of testing per our proposal dated September 18, 2018 was as follows:

| Test | Detail of Test |
| :---: | :---: |
| Corrosion \& Graphitization | Cross section the pipe and measure depth of corrosion <br> and grahitization |
| Charpy Impact | Impact test on three (3) specimens removed from pipe |
| Chemical Analysis | Chemical analysis to determine pipe's composition |
| Macroetch | Macro examination of cross section |
| Metallography | Microscopic examination of cross section the <br> microstructure of cast iron |
| Hardness | Rockwell hardness of the pipe |
| Ring Test* | Modulus of rupture of the pipe |
| Strip Test | Modulus of elasticity of pipe material |

*Not performed due to the axial crack extending the entire length of the section.

## PROCEDURES \& RESULTS

## 1. Visual \& Macrotech Examination

The pipe section was visually examined in our laboratory. Photos 1 and 2 are views of the exterior and interior of the pipe, respectively. Note the wide crack along the entire length of the pipe (Photo 1). There is also evidence of large scale pitting on the outside of the pipe along the crack (Photo 1). On the interior, the pipe large scale build-up of deposits (Photo 2). Note the gradual thinning of the wall towards the crack location in Photo 2. Following the cleaning of deposits no significant pitting is evident on the interior of the pipe (Photo 3).

Two cross sections were prepared for macro examination of the pipe from areas that appeared to have the most damage. Photos 4 and 5 are overall views of the cross sections. Pitting and graphitization on the outside, and graphitization on the inside of the pipe is evident in both images. The location of the damaged area is highlighted with circles in both photographs. There is no evidence of macro-cracks on the cross sections.

## 2. Corrosion and Graphitization

The cross sections referred to in section 1 of this report were examined at higher magnification for the extent of corrosion/pitting and graphitization. Photos 6 through 8 are close-up views indicating the extent of the damage on both sides of the pipe. Graphitization (dark areas) is evident on the exterior and interior of the sections. Photo 9 is a macro view of a typical area severely affected by corrosion with measurements of the graphitization and metal loss. Based on these measurements, only $10 \%$ of the total original thickness ( $0.5^{\prime \prime}$ ) of the pipe has remained intact.

## 3. Metallography

The cross section depicted in Photo 9 was viewed at higher magnification to determine the microstructure of the cast iron. Photo 10 is an optical micrograph of the un-etched material at transition between the graphitizaed and intact material. The microstructure of the cast iron in the intact area following etching is depicted in Photo 11. The microstructure is typical of gray cast iron. It consists of graphite flakes in a matrix of pearlite and phosphide eutectic. These constituents are highlighted with arrows..

## 4. Chemical Analysis

A specimens of the pipe was removed and analyzed for verification of the material. The results are presented in Table 1. Based on the analysis, the pipe's material composition is consistent with typical compositions of gray cast irons, albeit with a slightly higher than typical carbon content.

## 5. Hardness Tests

The hardness of the pipe section was determined on the cross section using a Wilson Rockwell Hardness Tester. The average hardness of the pipe was found to be 86 HRB. This value is consistent with gray cast iron. The hardness data is presented in Table 2.

## 6. Charpy Impact Test

Charpy Impact tests were performed on three specimens removed from the pipe section in the longitudinal direction. The specimens were taken from an area that appeared least affected by corrosion. The results are presented in Table 3. The average absorbed energy of the pipe material was found to be less than $1 \mathrm{ft}-\mathrm{lbs}$ at $84^{\circ} \mathrm{F}$.

## CITY OF PASADENA

## 7. Talbot Strip Test

A $12^{\prime \prime}$ long and $1 / 2^{\prime \prime}$ wide strip of the pipe was removed in the axial direction and tested in flexure to determine its modulus of rupture and modulus of elasticity. The test was performed per section 8-A1 of AWWA C108-62 test procedure. The results are presented in the table below.

| Width, <br> inches | Thickness, <br> inches | Maximum Force, <br> lbf | Displacement @ maximum <br> force, inches | Modulus of <br> Rupture, psi | Secant Modulus <br> of Elasticity, psi |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 0.584 | 0.537 | 404 | 0.127 | 23,998 | $7,495,086$ |

If you have any questions regarding this report, please contact the undersigned at (510) 8353142 Ext. 199.

Respectfully Submitted;
TESTING ENGWNEERS, INC. -

Hossein Arbabi, Ph.D., P.E.
Senior Materials Engineer


Photo 1
Overall view of the pipe section.


Photo 2
Partial view of the pipe section's interior showing heavy deposit accumulation on the inside.


Photo 3
View of the interior of the pipe before and after removal of deposits.


Photo 4
Overall view of a polished cross section. Affected areas are circled.


Photo 5
Overall view of a polished cross section. Affected areas are circled.


Photo 6
Close-up view of typical damage.


Photo 7
Another close-up view of typical damage.


Photo 8
Additional close-up view of typical damage.


Photo 9
Macroscopic view of a cross section showing the degree of metal loss.


Un-etched micrograph at transition from the graphitized to the intact material. 100X Magnification.


Photo 11
Microstrcture of the gray cast iron pipe. 400X Magnification.

| Laboratory No.: 3K46 | TABLE 1 | Report Date: $11 / 27 / 18$ | Page 10 of 12 |
| :--- | :---: | :--- | :--- |

Client No.: CIT600
P.O. No.: 1191294-00

Project: City of Pasadena - Water \& Power Field Operations
Material: Cast Iron Pipe

| ELEMENT | PERCENT |
| :---: | :---: |
| Carbon (C) | 4.42 |
| Manganese (Mn) | 0.40 |
| Silicon (Si) | 2.21 |
| Phosphorus (P) | 0.940 |
| Sulfur (S) | 0.100 |
| Chromium (Cr) | 0.04 |
| Nickel (Ni) | 0.01 |
| Molybdenum (Mo) | 0.01 |
| Copper (Cu) | 0.02 |
| Titanium (Ti) | 0.07 |
| Magnesium (Mg) | 0.01 |
| Aluminum (Al) | 0.02 |
| Vanadium (V) | 0.08 |
| Cobalt (Co) | 0.01 |
| Iron (Fe) | Balance |

Remarks:
SOP 20.121
Chemical Analysis performed by ICPas per Element SOP 17.00, Revison 20.
Carbon and Sulfer performed by Combustion as per Element SOP 7.00, Revision 18.
Results Reported To: Ciyt of Pasadena

| Laboratory No.: 3K46 | TABLE 2 | Report Date: $11 / 27 / 18$ | Page 11 of 12 |
| :--- | :---: | :--- | :--- |
|  | HARDNESS TESTS | Test Date: $11 / 21 / 18$ |  |

Client No.: CIT600
P.O. No.: 1191294-00

Project: City of Pasadena - Water \& Power Field Opetations
Material: Cast Iron Pipe

| Mark No. | N/A |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Specimen No. | N/A |  |  |  |  |  |
| Hardness: | 87.0 |  |  |  |  |  |

Remarks:
Results Reported To: Ciyt of Pasadena

| Laboratory No.: 3 K46 | TABLE 3 | Report Date: 11/27/18 <br> Test Date: 11/19/18 | Page 12 of 12 |
| :--- | :--- | :--- | :--- |
| Client No.: CIT600 | P.O. No.: 1191294-00 |  |  |
| Project: City of Pasadena - Water \& Power Field Operations | Material: Cast Iron Pipe |  |  |


| Sample ID | Tested at $84^{\circ} \mathrm{F}$ |  |  |
| :---: | :---: | :---: | :---: |
| $3 \mathrm{~K} 46-1$ | $10 \mathrm{~mm} \times 10 \mathrm{~mm}$ | Absorbed Energy, Ft.Lbs. | Orientation to Base Metal |
| $3 \mathrm{~K} 46-2$ | $10 \mathrm{~mm} \times 10 \mathrm{~mm}$ | 1 | Longitudinal |
| $3 \mathrm{~K} 46-3$ | $10 \mathrm{~mm} \times 10 \mathrm{~mm}$ |  | Longitudinal |
|  |  |  |  |

Remarks: Machined and tested in accordance with ASTM E23
Results Reported To: Ciyt of Pasadena

| Date: | March 19th, 2020 |
| :---: | :---: |
| Client: | City of Pasadena, CA |
| Echologics Project \# | 42219175 |
| Report Classification: | Draft |

## Pasadena 2020 Water System Resources Plan

 Appendix I Evaluation Report \#3This page left intentionally blank

## Executive Summary

The City of Pasadena (the City) engaged Echologics to complete a pilot project to gain valuable, evidence based pipe condition assessment information on critical components of the City's potable water network. Echologics successfully tested 2.2 miles of various diameter cast iron and riveted steel water mains for the City.
The primary objectives of this pilot condition assessment project were as follows:

- Determine the remaining structural condition of the water mains tested
- Determine the remaining service lives of the water mains tested
- Along with condition assessment measurements, simultaneously investigate the system for the existence of any potential leaks
- Evaluate the logistics and feasibility of using ePulse ${ }^{\circledR}$ non-invasive testing within the City’s potable water transmission and distribution network
- Understand the suitability of ePulse ${ }^{\circledR}$ and EchoLife ${ }^{\circledR}$ results in the City’s asset management desktop model


## Project Observations and Results

Echologics tested 24 pipe segments to determine the average remaining structural wall thickness (measured thickness). These measured thicknesses were compared to the nominal wall thicknesses to estimate the structural wall loss. Each pipe segment was also assigned a rating category as per the table below. The Echolife ${ }^{\circledR}$ analysis was also performed on all cast iron segments to estimate the remaining service life under current operating and site conditions. Echolife ${ }^{\circledR}$ analysis combines the ePulse ${ }^{\circledR}$ results along with measured operating conditions such as soil loading, traffic loading, operating pressure and maximum estimated surge pressure.

| Change in Pipe Wall Thickness | Description | Color Code |
| :---: | :---: | :---: |
| Less than 10\% | Good | Green |
| $10 \%$ to $30 \%$ | Moderate | Yellow |
| Greater than 30\% | Poor | Red |
| No Results (NR) | NR | Grey |

The following table and chart summarizes the results from the 24 pipe segments that were tested

| General <br> Information | Segments Tested | 24 |
| :--- | :---: | :---: |
|  | Length Tested (ft) | $11,715 \mathrm{ft}$ (2.2 miles) |
| Structural <br> Condition: <br> Qualitative <br> Category | Moderate Segments (\#/\%) | $8(31 \%)$ |
|  | Poor Segments (\#/\%) | $15(66 \%)$ |
|  | No Results Segments (\#/\%) | None |
| Performance <br> Analysis: <br> Remaining <br> Service Life <br> (RSL) | RSL Exceeded | 13 |
|  | RSL Less than 10 yrs. | 1 |
|  | RSL between 10-50 yrs. | 5 |



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## 1. PROJECT BACKGROUND

The need for comprehensive condition assessment of our buried and aging water infrastructure is ever increasing. Most water utilities across North America are struggling with budget and efficient management renewal plans of their buried water assets that are approaching the end of their service life. One of the primary concerns to water utility asset managers is prioritizing the limited renewal budgets (to the assets that require it the most). This is where an effective condition assessment program can help. According to the Water Research Foundation ${ }^{1}$, the objectives of an effective condition assessment program should include:

- Reduce the number and cost of failures, by identifying high-risk assets and enabling cost-effective, targeted, proactive remedies;
- Extend the lives of assets, by distinguishing those that are merely old from those that are truly impaired; and
- Generally reduce uncertainties, enabling confident answers to questions from the public and others.

Echologics understands that these objectives hold true for the City of Pasadena and their asset management program. Most cities and utilities currently use an asset management desktop model to prioritize water main renewal efforts. Typically the primary focus of these types of models is water main failure/break history coupled with additional parameters such as hydraulic capacity, criticality and surrounding parallel asset infrastructure renewal efforts (i.e. - storm/sanitary sewer or road renewal projects) to set the renewal priority.

However, it is understood that every desktop assessment model is missing a critical parameter, namely: "actual evidence based condition of the subject water mains". By adding the current water main structural condition to the desktop assessment, it would provide a high level of confidence to the any utility that the prioritization of water mains scheduled for future renewals represents the best value for the currently available capital dollars.

As such, the City of Pasadena (the City) contracted Echologics, LLC (Echologics) in to complete a pilot program to gain valuable evidence based condition assessment information on select segments of their cast iron and riveted steel water mains. This pilot testing project is expected to assist the City in both calibrating their own asset management desktop model and identifying the current condition of their tested buried pipes.

The primary objectives of the pilot program were as follows:

- Determine the remaining structural condition of the water mains tested
- Determine the remaining service lives of the water mains tested
- Along with condition assessment measurements, simultaneously investigate the system for the existence of any potential leaks
- Determine the logistics and feasibility of using ePulse ${ }^{\circledR}$ non-invasive testing within the City's potable water transmission and distribution network
- Understand the suitability of ePulse ${ }^{\circledR}$ and EchoLife ${ }^{\circledR}$ results in the City’s asset management desktop model

[^2]To achieve these objectives, Echologics utilized its patented ePulse ${ }^{\circledR}$ technology to determine the current condition of the pipes tested. In addition to condition assessment, leak detection was performed simultaneously with this survey. Echologics also performed EchoLife ${ }^{\circledR}$ calculations to estimate the remaining service life for the mains tested. This report provides detailed information on how these objectives have been met.

The project included 11,715 feet or 2.2 miles of cast iron and steel water mains spread throughout the city as illustrated below in Figure 1: System Overview and Site Locations


Figure 1: System Overview and Site Locations

The project scope included water mains spread across ten sites, selected by the City based on different criteria such as age, criticality and related civil works in the proximity. Table 1 details the information regarding each site, in the order of on-site testing. Field tests began on February 11 ${ }^{\text {th }}, 2020$ and required four days to complete with a team of two Echologics Technicians.

Table 1 - Sites Surveyed

| Site | Pipe Material | Year of Installation | Selection Criteria ${ }^{1}$ | System Pressure (psi) |
| :---: | :---: | :---: | :---: | :---: |
| Avenue 64 | Spun Cast Iron | 1965 | Two main breaks, but pipe is newer | 130 |
| San Remo Road | Pit Cast Iron | 1924 | Age and main break | 90 |
| Bellefontaine Street | Pit Cast Iron | 1913 | Age, but appears to be in good condition, may be on PW paving list | 70 |
| San Gabriel Boulevard | Pit Cast Iron | 1923 | Extension of section being designed from Walnut St to Colorado Blvd | 99 |
| Mentor Avenue | Pit Cast Iron | 1930 | WSRP Critical Main | 60 |
| Pasadena Avenue | Spun Cast Iron | 1955 | To decide whether to replace one or two mains in section | 58 |
| Glenarm St | Pit Cast Iron | 1923 | Age and is on the PW paving list, but did not score high on inventory spreadsheet | 70 |
| Walnut Street | Pit Cast Iron | 1915 | Age, but appears to be in good condition | 78 |
| Colorado Boulevard | Pit Cast Iron | 1930 | WSRP Critical Main | 60 |
| Raymond Avenue | Riveted Steel | 1913 | Age, but appears to be in good condition | 41 |
| 1. Provided by the City |  |  |  |  |

ePulse ${ }^{\circledR}$ condition assessment combines acoustic data acquired in the field with information about a pipe's construction to calculate its current wall thickness. The pipe's material, internal diameter, and modulus of elasticity are critical variables in this calculation. The percentage of wall thickness loss is calculated by comparing the measured (current) thickness to the design (nominal) thickness of the pipe. The City provided the installation dates, pipe material, internal lining and system pressure information to Echologics. Based on this information, Echologics assumed reasonable pressure class or thickness class according to AWWA standards.
The majority of the scope (except on Raymond Avenue) consisted of cast iron pipes. In Echologics' experience, cast iron pipes manufactured before the 1940s were generally manufactured with pit cast method which had a higher pipe wall thickness and lower material strength. In contrast, cast iron pipes manufactured after the 1940s were generally manufactured with spun cast or centrifugally cast method resulting in higher material strength and lower pipe wall thickness. Therefore, Echologics assumed pipe wall and material strength according to their install dates. However, Echologics understands every utility is different in their selection of water pipes and encourages the City to explore more information regarding the pipe manufacturing methods of the pipes tested. If more accurate information is found Echologics can update the results included in this report for the final version. Further details on the pipe properties are available in Appendix A: Detailed Results.

Table 2 - Pipe Properties

| Pipe Material | Pressure <br> Class | Internal <br> Diameter | Nominal <br> Thickness | Lining <br> Thickness | Equivalent <br> Thickness | Standard |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | inch | inch | inch | inch |  |
| Pit Cast Iron | Class D $^{1}$ | 6 | 0.55 | No Lining | 0.55 | AWWA 1908 |
| Pit Cast Iron | Class D $^{1}$ | 8 | 0.60 | No Lining | 0.60 | AWWA 1908 |
| Pit Cast Iron | Class D $^{1}$ | 10 | 0.68 | 0.1875 | 0.73 | AWWA 1908 |
| Pit Cast Iron | Class D $^{1}$ | 14 | 0.82 | 0.1875 | 0.87 | AWWA 1908 |
| Pit Cast Iron | Class D $^{1}$ | 24 | 1.16 | 0.1875 | 1.21 | AWWA 1908 |
| Spun Cast Iron | PC 150 | 8 | 0.41 | No Lining | 0.41 | AWWA 1952 |
| Spun Cast Iron | PC 150 | 12 | 0.48 | No Lining | 0.48 | AWWA 1952 |
| Riveted Steel | Schedule 40 | 16 | 0.50 | 0.1875 | 0.53 | AWWA 1941 |

1. Class $D$ is rated for 173 psi of pressure
2. The equivalent thickness includes the nominal thickness of the pipe plus an equivalent thickness of the lining as it contributes to the structural thickness of the pipe
3. Closest available AWWA standard

## 2. RESULTS

### 2.1 LEAK DETECTION

Echologics defines a leak as a point along a pipe that is likely losing water to the surrounding soil and environment. For a leak to be classified as discovered, a field technician must acquire three pieces of evidence that confirms the existence and location of it. These include, positive correlation, acoustic noise, and physical evidence of moisture in the surrounding area (if available). Similarly, Echologics defines a Point of Interest (POI) as evidence of some form of noise or energy on the pipe while there is not enough evidence to classify a point of interest as a leak. The leak detection survey did not find any leaks during the time of the assessment.

### 2.2 EPULSE ${ }^{\circledR}$ CONDITION ASSESSMENT

ePulse ${ }^{\circledR}$ measures the average wall thickness of the main. The technology combines acoustic data measured in the field with information about a pipe's manufacturing to calculate its current wall thickness. The pipe's material, internal diameter, and modulus of elasticity are all critical variables in this calculation. The results of the average wall thickness measurement Echologics reports is independent of the nominal wall thickness. The percentage of wall thickness loss is calculated by comparing the measured thickness to the assumed design/nominal thickness. The results are also presented as a qualitative category indicating the expected condition of the main. Table 3 shows these qualitative condition categories. Results will be marked "NR" to indicate when no result was attainable on a pipe segment.

Table 3 - Qualitative Categories and Colour Coding

| Change in Hoop <br> Thickness | Description | Color Code |  |
| :---: | :---: | :---: | :---: |
| Less than $10 \%$ | Good | Green |  |
| $10 \%$ to $30 \%$ | Moderate | Yellow |  |
| More than $50 \%$ | Poor | Red |  |
|  |  |  |  |

Figure 2 shows the color coded map of all the segments tested. Table 4 lists the details and ePulse® results of all segments tested


Figure 2: Results Overview Color Coded Map

Table 4 - ePulse® Pipe Condition Assessment Results

| Echologics Segment ID | Street Name | Segment Length | Pipe Material | Internal Diameter | Nominal Thickness | Lining Thickness | Equivalent Thickness | Measured Thickness | \% Change from Nominal |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | (feet) |  | (inch) | (inch) | (inch) | (inch) | (inch) |  |
| 91751A001 | Avenue 64 | 597 | Spun Cast Iron | 12 | 0.52 | No Lining | 0.48 | 0.37 | -23 |
| 91751A002 | Avenue 64 | 375 | Spun Cast Iron | 12 | 0.52 | No Lining | 0.48 | 0.40 | -17 |
| 91751A003 | San Remo Rd | 1149 | Pit Cast Iron | 6 | 0.55 | No Lining | 0.55 | 0.30 | -45 |
| 91751A004 | Bellefontaine St | 450 | Pit Cast Iron | 10 | 0.68 | 0.1875 | 0.73 | 0.51 | -30 |
| 91751A005 | Bellefontaine St | 544 | Pit Cast Iron | 10 | 0.68 | 0.1875 | 0.73 | 0.52 | -29 |
| 91751A006 | Bellefontaine St | 301 | Pit Cast Iron | 10 | 0.68 | 0.1875 | 0.73 | 0.36 | -51 |
| 91751A008 ${ }^{1}$ | San Gabriel Ave | 400 | Pit Cast Iron | 8 | 0.60 | No Lining | 0.60 | 0.33 | -45 |
| 91751A009 | Mentor Ave | 639 | Pit Cast Iron | 8 | 0.60 | No Lining | 0.60 | 0.32 | -47 |
| 91751A010 | Mentor Ave | 599 | Pit Cast Iron | 8 | 0.60 | No Lining | 0.60 | 0.32 | -47 |
| 91751A011 | San Gabriel Ave | 377 | Pit Cast Iron | 8 | 0.60 | No Lining | 0.60 | 0.33 | -45 |
| 91751 A 012 | San Gabriel Ave | 614 | Pit Cast Iron | 8 | 0.60 | No Lining | 0.60 | 0.33 | -45 |
| 91751A013 | Pasadena Ave | 509 | Spun Cast Iron | 8 | 0.41 | No Lining | 0.41 | 0.32 | -22 |
| 91751A0151 | Pasadena Ave | 344 | Spun Cast Iron | 8 | 0.41 | No Lining | 0.41 | 0.24 | -41 |
| 91751A016 | Pasadena Ave | 640 | Spun Cast Iron | 8 | 0.41 | No Lining | 0.41 | 0.28 | -32 |
| 91751A017 | Glenarm St | 356 | Pit Cast Iron | 8 | 0.60 | No Lining | 0.60 | 0.29 | -52 |
| 91751A018 | Glenarm St | 510 | Pit Cast Iron | 8 | 0.60 | No Lining | 0.60 | 0.32 | -47 |
| 91751A019 | Glenarm St | 433 | Pit Cast Iron | 8 | 0.82 | No Lining | 0.60 | 0.29 | -52 |
| 91751A020 | Walnut St | 370 | Pit Cast Iron | 14 | 0.82 | 0.1875 | 0.87 | 0.42 | -52 |
| 91751A021 | Walnut St | 516 | Pit Cast Iron | 14 | 0.82 | 0.1875 | 0.87 | 0.61 | -30 |
| 91751A022 | Colorado Blvd | 297 | Pit Cast Iron | 24 | 1.16 | 0.1875 | 1.21 | 1.17 | -3 |
| 91751A023 | Colorado Blvd | 286 | Pit Cast Iron | 24 | 1.16 | 0.1875 | 1.21 | 1.06 | -12 |
| 91751A024 | Colorado Blvd | 438 | Pit Cast Iron | 24 | 1.16 | 0.1875 | 1.21 | 0.98 | -19 |
| 91751A025 | Raymond Ave | 497 | Steel | 16 | 0.50 | 0.1875 | 0.53 | 0.19 | -64 |
| 91751A026 | Raymond Ave | 502 | Steel | 16 | 0.50 | 0.1875 | 0.53 | 0.18 | -66 |

Table 4 shows that the majority of the segments ( 15 segments) tested showed significant levels of degradation with greater than $30 \%$ wall loss. There were also 8 segments that appeared to be in moderate condition with wall thickness loss between $10 \%$ and $30 \%$. Only one segment appeared to be in good condition. These observation indicate that the pipes tested had undergone "significant uniform corrosion and/or numerous areas of localized pitting corrosion" (see Appendix B for details). Considering the age of all of the mains tested these advanced levels of degradation is generally expected. According to the City records, some of the mains were internally cement mortar lined. Therefore, for these mains the corrosions may have been concentrated on the external surface and could be a result of aggressive soil condition.

In the sections below the results for each site/street will be described further.

### 2.2.1 Avenue 64

There were two pipe segments tested on Avenue 64 between Nithsdale Road and Cheviotdale Drive. This 12 inch spun cast iron pipe is relatively newer (installed 1965) but was selected for testing by the City due to two recent main breaks. Both segments tested appeared to be in moderate condition. However, EchoLife ${ }^{\circledR}$ calculation revealed that segment 91751A001 has between 1 and 9 years of remaining service life whereas segment 91751A002 has remaining service life between 20 and 29 years (see Table 5)

Echologics observed that this main is situated on a portion of Avenue 64 that experiences high traffic and is major thoroughfare connecting the City to greater Los Angeles area. It was also noted that this main is operating under quite high pressure of 130 psi. Even for a relatively newer pipes like this, high system pressure coupled with pressure transient sometimes can cause premature main breaks.

### 2.2.2 San Remo Road

There was one pipe segment tested on San Remo Road between San Rafael Avenue and Laguna Road. The City selected this 6 inch pit cast iron main for testing due to its age and main break history. The results indicate that this segment appeared to be poor condition and has exceeded its remaining service life (see Table 5).

### 2.2.3 Bellefontine Street

There were three pipe segments tested on Bellefontaine Street between St Johns Avenue and Fair Oaks Avenue. According to City records this main appeared to be in good condition. The primary reason for selection of this 10 inch pit cast iron main for testing was age (installed in 1913). Bellefontaine Street is also included in the upcoming street paving list and the City wanted to evaluate its condition prior to that.

Segment 91751A006 appeared to be in poor condition and had exceeded the remaining service life. The other two segments appeared to be in moderate condition with remaining service life between 20 years and 29 years (see Table 5).

### 2.2.4 San Gabriel Avenue

There were three pipe segments tested on San Gabriel Boulevard between Colorado Boulevard and Millicent Way. According to City records this portion of the main is to be an extension of the main being currently designed between Walnut Street and Colorado Boulevard. The City wanted to evaluate the condition of this 8 inch pit cast iron main that could supplement decision making of the new main design.
All three segments on San Gabriel Avenue appeared to be in poor condition and have exceeded their remaining service lives (see Table 5).

### 2.2.5 Mentor Avenue

There were two pipe segments tested on Mentor Avenue between Green Street and Del Mar Boulevard. The city selected this 8 inch pit cast iron main for testing as it is marked as a critical main and the City wanted to gather more information about its current condition. Echologics observed that this main is situated on a portion of Mentor Avenue that is in the downtown core of the City with businesses and high occupancy buildings nearby.
Both segments on Mentor Avenue appeared to be in poor condition and have exceeded their remaining service lives (see Table 5).

### 2.2.6 Pasadena Avenue

There were three pipe segments tested on Pasadena Avenue between California Boulevard to Bellefontaine Street. The city selected this 8 inch spun cast iron main for testing to determine whether to replace one or two sections of this main. Echologics observed this main is situated on a portion of Pasadena Avenue that experiences very high traffic and services a hospital nearby.

Two segments on Pasadena Avenue appeared to be in poor condition and exceeded their remaining service lives. The other segment appeared to be in moderate condition with remaining service life between 10 and 19 years (see Table 5).

### 2.2.7 Glenarm Street

There were three pipe segments tested on Glenarm Street between Pasadena Avenue and Fair Oaks Avenue. While this main did not score high on criticality inventory spreadsheet the city selected this 8 inch pit cast iron main for testing due to its age and because it is on the street paving list.

All three segments appeared to be in poor condition and have exceeded their remaining service lives (see Table 5).

### 2.2.8 Walnut Street

There were two pipe segments tested on Walnut Street between Corson Street and Fair Oaks Avenue. According to the City records this 14 inch pit cast iron main appeared to be in good condition and the primary reason for its selection in the testing was its age (installed 1915). Echologics observed this main is situated on a portion of Walnut Street that experiences very high traffic with high occupancy buildings nearby.

One of the segments appeared to be in poor condition and exceeded its remaining service life. The other segment appeared to be in moderate condition with between 20 and 29 years of service life remaining (see Table 5).

### 2.2.9 Colorado Boulevard

There were three pipe segments tested on Colorado Boulevard between Chester Avenue and Hill Avenue. The City selected this 24 inch pit cast iron main as it is listed as critical main in their records. Echologics observed this main is situated on a portion of Colorado Boulevard that experiences very high traffic and one the major thoroughfares in the city.

Although installed in the 1930, this main appears to be in relatively better condition than other mains of similar age. Two segments appeared to be in moderate condition and one segment appeared to be in good condition. All three segments had remaining service life of more than 50 years (see Table 5).

### 2.2.10 Raymond Avenue

There were two pipe segments tested on Raymond Avenue between Montana Street and Tremont Street. The primary reason the City selected this 16 in riveted steel main was its age (installed 1913).

Both segments appeared to be in poor condition on Raymond Avenue. The system pressure listed for this main is quite low at 41 psi. Echologics also observed that the acoustic signature and sound propagation velocity or wave velocity on this main was quite low. Echologics suggests that the pipe material information should be verified to ensure that the assumptions made regarding the main are correct. The Echolife ${ }^{\circledR}$ remaining service life calculation is not available on steel pipes.

### 2.3 ECHOLIFE® ${ }^{\text {REMAINING SERVICE LIFE RESULTS }}$

Table shows the remaining service life ( RSL ) of pipe segments tested. Table 6 lists the assumptions made in the remaining service life analysis. Echologics estimated the remaining service life based on ePulse ${ }^{\circledR}$ measured wall thickness measurements, which is an average measurement over the entire length of a test segment. It is important to note that higher levels of degradation may exist, concentrated over smaller lengths of pipe within a given test segment; this is especially true in metallic mains since they are prone to isolated areas of corrosion.

### 2.3.1 ECHOLIFE®RESULTS

The results of the EchoLife ${ }^{\circledR}$ analysis are shown in Table 5 below.
Table 5: EchoLife ${ }^{\circledR}$ Results
$\left.\begin{array}{|c|c|c|l|c|c|c|c|c|c|}\hline \text { Segment } & \text { Street } & \begin{array}{c}\text { Segment } \\ \text { Length }\end{array} & \text { Pipe Material } & \begin{array}{c}\text { Internal } \\ \text { Diameter }\end{array} & \begin{array}{c}\text { Nominal } \\ \text { Thickness }\end{array} & \begin{array}{c}\text { Equivalent } \\ \text { Thickness }\end{array} & \begin{array}{c}\text { Measured } \\ \text { Thickness }\end{array} & \begin{array}{c}\text { Remaining } \\ \text { Change } \\ \text { from } \\ \text { Nominal }\end{array} \\ \text { (RSL) }\end{array}\right\}$

Note: EchoLife ${ }^{\circledR}$ results are capped at 50 years.

### 2.3.2 CAST IRON ECHOLIFE® ASSUMPTIONS

In addition to the pipe specification assumptions mentioned above, the EchoLife ${ }^{\circledR}$ calculations for cast iron also incorporate a number of additional variables. External load is calculated using the Marston equation plus $\mathrm{H}-20$ traffic load with a safety factor of 1.1. To account for water pressure, the system pressure plus a surge pressure of 50 psi with no safety factor is used for the analysis. We assigned a criticality rating typical of a residential street based on the target suggested by AWWA Research foundation to be used in the rating criteria, 0.16 breaks $/ \mathrm{miles} / \mathrm{yr}$. These criticalities were selected based on the location, size of the pipe and relative effect a failure would have on the neighbourhood. A detailed table of assumptions can be found below in Table 6.

Table 6 - EchoLife ${ }^{\circledR}$ Cast Iron Assumptions

| Pipe Information | Estimate or Assumption | Source |
| :---: | :---: | :---: |
| Soil Density | $120 \mathrm{lbs} / \mathrm{ft}{ }^{3}$ | Buried Pipe Design Third Edition. A. P. Moser \& Steven Folkman. Table 2.1-Approximate Values of Soil Unit Weight, Page 15 |
| Bedding Type | Class B: Compacted Granular Bedding. <br> Load Factor $=1.5$ | Buried Pipe Design Third Edition. A. P. Moser \& Steven Folkman. Table 3.2-Bedding Factors, Page 80 |
| Pipe Depth | N/A | Measured on site at fittings. |
| Surge Pressure | 50 psi | Echologics standard surge pressure. |
| Safety Factor on Pressure | 1 | Echologics standard safety factor. |
| Safety Factor on External load | 1.1 | Echologics standard external load factor. |
| Rupture modulus of Cl | 31,000 psi | Buried Pipe Design Third Edition. A. P. Moser \& Steven Folkman. |
| Tensile strength of Cl | 11,000 psi | Buried Pipe Design Third Edition. A. P. Moser \& Steven Folkman. |

## 3. CONCLUSIONS AND RECOMMENDATIONS

### 3.1 CONCLUSIONS

Echologics has successfully completed a pilot condition assessment project for the City of Pasadena on pipe wall condition and leak detection of 2.2 miles of cast iron and steel water mains in Pasadena, California. The main conclusions that can be drawn from this project are as follows:
A. The ePulse ${ }^{\circledR}$ testing was able to isolate 15 segments ( 7,731 feet) of degraded pipe with more than $30 \%$ wall thickness loss. This is valuable evidence based pipe condition data that will assist the City's replacement planning efforts and has demonstrated the usefulness of ePulse ${ }^{\circledR}$ method.
B. EchoLife ${ }^{\circledR}$ analysis identified 13 segments of pipes that had exceeded their remaining service life along with two segments with less than 10 years of remaining service life
C. ePulse ${ }^{\circledR}$ testing can be easily implemented within the City without the need for excavations or substantial support from Pasadena water operators. The field-testing was completed without any interruption to service or disruptions to Pasadena customers.
D. In addition to obtaining valuable structural condition assessment data, ePulse ${ }^{\circledR}$ also demonstrated that it could simultaneously survey the water mains for existing leaks.
E. The pipes tested showed significant levels of degradation that is expected of buried water mains of similar age

### 3.2 RECOMMENDATIONS AND NEXT STEPS

Based on the results of the condition assessment and leak detection measurements for this project, Echologics offers the following overall program recommendations and next steps:
A. In order to avoid sudden main breaks and to extend the service lives of segments in poor condition, the operating pressure and the transient pressure needs to be monitored and controlled
B. The City may want to implement a permanent monitoring system to monitor the mains that are critical in nature but cannot be readily replaced or accessed for repair
C. As several mains that had internal lining also appeared in poor condition, the City may want to collect soil samples and test for aggressiveness in bedding soil.
D. Echologics has only tested a very small percentage of the City's water network. As only a small sample of cast iron mains were tested, the City may wish to consider establishing an annual program to test a larger sample with a wider variety of material and age. This could extend the service life of pipes in good condition and allow better prioritization of their pipe replacement program for pipes identified in poor condition. Utilizing "evidence based" condition assessment data is a proactive approach to asset management.
E. The City might consider exhuming and examining samples from water mains that are scheduled for replacement as part of the capital replacement budget. If the City moves forward with this exercise in future, Echologics recommends taking samples from segments identified to be in very poor condition to verify the extent of degradation. Exhumed samples can be used to verify assumptions of the design wall thickness and Young's modulus.
F. Echologics has worked through pipe sample testing with utilities around the world and would be happy to guide Pasadena through this process if required.

It is important to note that structural pipe condition is one of many factors in evaluating a pipes suitability for service, but should not be the only consideration used in replacement and deferral decisions. Other important factors that should be considered may include pipe-loading conditions, hydraulic capacity of the pipe, road repair/renewal schedules, consequence of pipe failure, customer complaints, rate of decay etc. With this is mind, we further recommend the following actions for the three condition categories based on the categories in Table 3

## Good Condition Pipe - DEFER / LOW PRIORITY

The condition assessment results suggest the mains in this category are in good structural condition and do not need attention in the near future unless they are under higher than normal loading conditions. The results suggest that pipes in this category have a remaining wall thickness within $10 \%$ of the nominal wall thickness. We suggest that the City continue with their standard maintenance programs for these mains. Common industry practice is follow-up condition assessment testing in approximately 10 years depending on consequence of failure to allow measurement of the rate of change of condition with time. If these mains require rehabilitation for other reasons such as low pressure or poor water quality complaints, then cleaning and lining may be an option to consider. The use and benefits of cathodic protection to slow or even stop the "aging" process of external corrosion may also be of interest.

When interpreting ePulse ${ }^{\circledR}$ results, asset owners should understand the following:

1. Leaks can still occur on water mains with good pipe wall condition for reasons other than pipe wall degradation, such as pressure transients, leaks at joints, leaks on service connections, winter weather (freeze/thaw), poor installation, etc.
2. If a leak is detected on these segments, a repair should be sufficient for remediation, because the majority of the remaining pipe wall is in good structural condition.
3. The need for future assessment of these pipes should take into account consequence of failure. Depending on the consequence of failure, it may be beneficial to equip these pipelines with a continuously monitoring leak detection system. For example, a non-redundant main servicing a hospital may benefit from immediate detection of leaks as soon as they develop.

## Moderate Condition Pipe - MONITOR / MEDIUM PRIORITY

The results suggest that the pipes in this category are in moderate condition (medium priority) and should be monitored depending on pipe loading conditions. It is important to note pipes in this category may show a reduced capacity to withstand loading conditions, especially on pipes that are approaching $30 \%$ loss in wall thickness.

Depending on the criticality of the main, we recommend monitoring these pipes. The following are some of possible monitoring methods:

1. For mains without an internal lining, cleaning and lining can often extend the life of moderate condition mains as well as adding cathodic protection.
2. Regularly scheduled, traditional leak detection surveys. These are a relatively inexpensive option capable of finding many leaks within a system. However, this method can be fairly labour intensive and may not prevent catastrophic failures on high consequence pipelines.
3. A permanent leak monitoring system that is capable of finding most leaks on a pipeline including small leaks before they turn into catastrophic failures.
4. A follow-up condition assessment survey to measure the rate of decay and update the condition of the mains. A common practice is to reassess these mains in 5 years depending on consequence of failure. An analysis of the results can be used to determine the decay rates for these mains. The current decay rate may have an impact on the remaining service life of the mains. Measuring this can allow for improved asset management.

## Poor Condition Pipe - ADDRESS / HIGH PRIORITY

The results indicate that pipes in this category are in poor condition and likely in need of immediate attention. Depending on pipe loading condition, these pipes are at higher risk of experiencing leaks and catastrophic failures and should be addressed as soon as possible. As noted above other important factors should also be considered when preparing a remediation or replacement plan.

In most cases, pipe segments that fall within this category have reached or are close to the end of their useful life. Actions such as structural lining, slip-lining, and/or full replacement should be investigated as a likely immediate requirement.
Such actions as continuous leak monitoring, cathodic protection and/or cleaning and lining will most likely not offer tremendous value or extend the life of the water main in a cost-effective manner.

Each water network will have its own dominant degradation mechanism, as well as unique local considerations. We recommend that Pasadena use the results presented in this report in combination with other data and information available from additional services. This additional asset information may include:

- Soil Corrosivity. This comparison will help determine if external corrosion due to aggressive soil is a significant degradation mechanism for these mains. For example, if corrosive soils are discovered and the main is in poor condition, the degradation is likely related to soil conditions.
- Water Aggressiveness. This comparison will reveal whether or not the water is a mechanism for uniform degradation. For example, aggressive water would suggest that some of the degradation is caused from the inside; this can be assumed to cause similar degradation rates for similar types of main.
- Break History. Collating condition assessment results and break history help identify sections of main that are at increased risk of failure. These factors are not necessarily related, as it is possible for pipes to have high break rates for reasons other than pipe wall degradation.
- Consequence of Failure. Combining condition assessment results with consequence of failure analysis is used to generate a risk assessment.

Comparing our results with some of the aforementioned datasets will allow for Pasadena to direct their rehabilitation efforts in a cost-effective manner by creating a global rehabilitation picture which takes multiple sources of degradation into consideration.

## 4. DISCLAIMER

This report is intended to be used as a guide only. All forms of non-destructive testing involve an inherent level of uncertainty. Such testing is dependent on input parameters, and outputs can be significantly affected by variation from assumed parameters. This report includes certain suggestions and recommendations made by us which are based on, among others, (i) the findings included in the report, (ii) its experience and (iii) an understanding of the client's particular requirements. We acknowledge that the client may use this report to consider potential opportunities for pipeline replacement/rehabilitation; however, we disclaim any liability that may arise in connection with decisions based on these suggestions or recommendations or their implementation.

## APPENDIX A DETAILED RESULTS

This section provides a detailed presentation of the project scope, as well as the data collected and results obtained during the project.

## A. 1 SITE DETAILS

An overview map of the site is shown in Figure A.1-1 : System Overview below with the pipes to be tested highlighted in blue.


Figure A.1-1 : System Overview

## A. 2 LEAK DETECTION RESULT DETAILS

No leaks were detected at the time of the condition assessment.

## A. 3 PIPE PROPERTY DETAILS

The pipe properties used in this project are presented in Table A.3-1, which were obtained from Echologics and approved by Pasadena. Echologics was instructed to assume all segments are cast iron since there were not records available of ductile iron pipe installation.

Table A.3-1: Pipe Properties

| Site | Pipe Material | Year of <br> Installation | Selection Criteria | System <br> Pressure (psi) |  |
| :--- | :---: | :---: | :---: | :---: | :---: |
| Avenue 64 | Spun Cast Iron | 1965 | Two main breaks, but pipe is newer | 130 |  |
| San Remo Road | Pit Cast Iron | 1924 | Age and main break | 90 |  |
| Bellefontaine Street | Pit Cast Iron | 1913 | Age, but appears to be in good condition, may <br> be on PW paving list | 70 |  |
| San Gabriel <br> Boulevard | Pit Cast Iron | 1923 | Extension of section being designed from <br> Walnut St to Colorado Blvd | 99 |  |
| Mentor Avenue | Pit Cast Iron | 1930 | WSRP Critical Main | 60 |  |
| Pasadena Avenue | Spun Cast Iron | 1955 | To decide whether to replace one or two <br> mains in section | 58 |  |
| Glenarm St | Pit Cast Iron | 1923 | Age and is on the PW paving list, but did not <br> score high on inventory spreadsheet | 70 |  |
| Walnut Street | Pit Cast Iron | 1915 | Age, but appears to be in good condition | 78 |  |
| Colorado Boulevard | Pit Cast Iron | 1930 | WSRP Critical Main | 60 |  |
| Raymond Avenue | Riveted Steel | 1913 | Age, but appears to be in good condition | 41 |  |
|  |  |  |  |  |  |

Table A.4-1 below presents the full results of the ePulse ${ }^{\circledR}$ and EchoLife ${ }^{\circledR}$ testing. Detailed results follow for all sites and segments.

| Segment | Street Name | Segment Length | Fitting 1 | Fitting 2 | Depth | Pressure | Internal Diameter | Nominal Thickness | Remaining Thickness | \% Change from Nominal | Remaining Life |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | (feet) |  |  | (feet) | (psi) | (inch) | (inch) | (inch) |  | (Years) |
| 91751A001 | Avenue 64 | 597 | GV017-70 | GV018-75 | 3 | 130 | 12 | 0.52 | 0.37 | -23 | 1 to 9 |
| 91751A002 | Avenue 64 | 375 | GV018-34 | GV018-75 | 3 | 130 | 12 | 0.52 | 0.40 | -17 | 20 to 29 |
| 91751A003 | San Remo Rd | 1149 | GV119-14 | GV120-13 | 3 | 90 | 6 | 0.55 | 0.30 | -45 | Exceeded RSL |
| 91751A004 | Bellefontaine St | 450 | WSV419-96 | SOV319-20 | 3 | 70 | 10 | 0.73 | 0.51 | -30 | 20 to 29 |
| 91751A005 | Bellefontaine St | 544 | WSV419-96 | WSV419-172 | 3 | 70 | 10 | 0.73 | 0.52 | -29 | 20 to 29 |
| 91751A006 | Bellefontaine St | 301 | GV419-34 | WSV419-172 | 3 | 70 | 10 | 0.73 | 0.36 | -51 | Exceeded RSL |
| 91751A008 ${ }^{1}$ | San Gabriel Ave | 400 | GV1117-103 | SOV1117-33 | 3 | 99 | 8 | 0.60 | 0.33 | -45 | Exceeded RSL |
| 91751A009 | Mentor Ave | 639 | GV617-53 | 617-4 | 3 | 60 | 8 | 0.60 | 0.32 | -47 | Exceeded RSL |
| 91751A010 | Mentor Ave | 599 | SOV618-5 | 617-4 | 3 | 60 | 8 | 0.60 | 0.32 | -47 | Exceeded RSL |
| 91751A011 | San Gabriel Ave | 377 | GV1117-10 | WSV1117-77 | 3 | 99 | 8 | 0.60 | 0.33 | -45 | Exceeded RSL |
| 91751A012 | San Gabriel Ave | 614 | GV1117-102 | GV1117-28 | 3 | 99 | 8 | 0.60 | 0.33 | -45 | Exceeded RSL |
| 91751A013 | Pasadena Ave | 509 | GV319-42 | WSV319-51 | 3 | 58 | 8 | 0.41 | 0.32 | -22 | 10 to 19 |
| 91751A015 ${ }^{1}$ | Pasadena Ave | 344 | 319-10 | WSV319-51 | 3 | 58 | 8 | 0.41 | 0.24 | -41 | Exceeded RSL |
| 91751A016 | Pasadena Ave | 640 | 319-10 | GV319-39 | 3 | 58 | 8 | 0.41 | 0.28 | -32 | Exceeded RSL |
| 91751 A017 | Glenarm St | 356 | GV320-15 | GV420-6 | 3 | 70 | 8 | 0.6 | 0.29 | -52 | Exceeded RSL |
| 91751A018 | Glenarm Ave | 510 | SOV420-13 | GV420-6 | 3 | 70 | 8 | 0.60 | 0.32 | -47 | Exceeded RSL |
| 91751A019 | Glenarm Ave | 433 | SOV420-13 | GV420-50 | 3 | 70 | 8 | 0.87 | 0.50 | -52 | Exceeded RSL |
| 91751A020 | Walnut St | 370 | WSV416-162 | GV416-91 | 3 | 78 | 14 | 0.87 | 0.42 | -52 | Exceeded RSL |
| 91751A021 | Walnut St | 516 | WSV416-162 | GV416-10 | 3 | 78 | 14 | 0.87 | 0.61 | -30 | 20 to 29 |


| Segment | Street Name | Segment Length | Fitting 1 | Fitting 2 | Depth | Pressure | Internal Diameter | Nominal Thickness | Remaining Thickness | \% Change from Nominal | Remaining Life |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | (feet) |  |  | (feet) | (psi) | (inch) | (inch) | (inch) |  | (Years) |
| 91751 A022 | Colorado Blvd | 297 | GV717-45 | WSV717-68 | 3 | 60 | 24 | 1.21 | 1.17 | -3 | 50+ |
| 91751A023 | Colorado Blvd | 286 | GV717-43 | WSV717-68 | 3 | 60 | 24 | 1.21 | 1.06 | -12 | 50+ |
| 91751A024 | Colorado Blvd | 438 | GV717-43 | GV717-8 | 3 | 60 | 24 | 1.21 | 0.74 | -19 | 50+ |
| 91751A025 | Raymond Ave | 497 | SOV411-9 | SOV411-17 | 3 | 41 | 16 | 0.53 | 0.19 | -64 | N/A ${ }^{2}$ |
| 91751 A026 | Raymond Ave | 502 | GV411-41 | SOV411-17 | 3 | 41 | 16 | 0.53 | 0.18 | -66 | N/A ${ }^{2}$ |

Figure A.4-1 below displays the results of the ePulse® results in an overview map and Figures A.4-2 through Figures A.4-6 shows the results for individual site/sites


Figure A.4-1: Results Overview Map


Figure A.4-2: Color Coded ePulse® Results for Avenue 64 and San Remo Rd


Figure A.4-3: Color Coded ePulse® Results for Bellefontaine St and Pasadena Rd


Figure A.4-4: Color Coded ePulse® Results for Mentor Ave


Figure A.4-5: Color Coded ePulse® Results for Walnut St


Figure A.4-6: Color Coded ePulse® Results for Raymond Ave

## APPENDIX B INTERPRETATION OF RESULTS

## B. 1 ECHOWAVE® LEAK DETECTION

When we discover a noise on a main, it can be classified as a leak or a point of interest (POI). If further investigation reveals negative results, it is classified as no leak discovered. Within all our reports, if no mention is made of leaks on a given section, it may be assumed that the result of the test is no leak discovered.

## No Leak Discovered

When a negative correlation is matched with poor coherence, it is concluded that no leak was detected. In effect, there is no indication of a noise source of any sort, and therefore that there is no other evidence of leakage. Where possible, leak simulations are performed to confirm the absence of leaks and to ensure equipment functionality.

## Point of Interest (POI)

A Point of Interest (POI) designation indicates that some, but not all, of the criteria for a positive leak detection result are met. This could mean that a strong correlation is observed but coherence is poor, or that there is no confirmation of leak noise through other test methods such as ground sounding or secondary correlation tests. This does not indicate a conclusive leak, however it is recommended that the City perform a secondary investigation. This will confirm the presence and location of the leak, as there is evidence of some form of noise inside the pipe.

## Leak

Three pieces of conclusive evidence must be acquired for a Point of Interest to be upgraded to a Leak. This includes but is not limited to the following methods of detection:

- Leak correlation
- Ground sounding
- Acoustic sounding of fittings
- Visual observation of moving water
- Confirmation of chlorine residuals in stagnant water

Several criteria must be met for audio recordings in order to provide a positive leak detection result. This includes but is not limited to:

- A clean distinctive correlation peak
- An observable coherence level
- Similar frequency spectra in each channel
- A minimum amount of clipping in the time signal

In some instances, more than one correlation test can be used as evidence to conclusively identify a leak. For instance, a field specialist can perform multiple correlation tests with sensors mounted to different pipe fittings.

## B. 2 EPULSE ${ }^{\circledR}$ CONDITION ASSESSMENT

ePulse ${ }^{\circledR}$ condition assessment measures the mean minimum hoop thickness (for asbestos cement or metallic mains) or mean hoop stiffness (for reinforced concrete). Where the original nominal thickness (or stiffness) is available, results are also presented as a percentage loss, and as a category indicating a qualitative description of the expected condition of the main.

## Qualitative Condition Description Categories

The color-coding and descriptions in Table B.2-1: Color Coding and Hoop Thickness Loss Qualitative Descriptions are used for the results presented in all ePulse ${ }^{\circledR}$ condition assessment reports.

Table B.2-1: Color Coding and Hoop Thickness Loss Qualitative Descriptions

| Change in <br> Hoop <br> Thickness | Description | Color Code | Description <br>  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |

These descriptions are based on our experience and with validation of results through the exhumation of pipe samples tested. Following the table, more detail is provided as to the expected condition of different types of main in each condition category, along with examples of validation of the ePulse ${ }^{\circledR}$ method on each type of main.

## Distribution of Degradation within Segments

Each ePulse ${ }^{\circledR}$ result represents an average condition within a segment between two sensor attachment points. Pipe conditions may vary within a segment. The condition at any one point within the segment may not reflect the average conditions within that segment.
The ePulse ${ }^{\circledR}$ method tests the mean minimum hoop thickness of the pipe, which is not the same as the average thickness of the pipe. ePulse ${ }^{\circledR}$ measures a pipe's hoop stiffness: its resistance to axi-symmetric expansion under the tiny pressure variations caused by sound waves. Material properties are then used to calculate the hoop thickness which would provide exactly this stiffness. This is referred to as the mean minimum hoop thickness.

To obtain this same value mechanically, you would need to: divide a pipe into hoops; measure the thinnest section of structural material around the circumference of each hoop (i.e. graphite, tuberculation product, or asbestos cement with the calcium leached out would not be counted); and then average these.

For example, any of the following descriptions will hold true for a pipe with a loss of $25 \%$ :

1. Circumferentially uniform loss of $25 \%$ along the entire segment.
2. Circumferentially uniform loss of $50 \%$ along half of the segment, but $0 \%$ loss along the other half of the segment.
3. Loss of $25 \%$ at the crown of the pipe along the entire segment, but $0 \%$ loss along any other point in the circumference along the entire segment.

These descriptions hold true for asbestos cement, metallic and reinforced concrete mains.

## Condition Interpretation in Asbestos Cement Mains

As asbestos cement pipes age and degrade, they will not lose physical thickness, but will lose structural (or effective) thickness as the calcium leaches out of the asbestos cement matrix. This portion of the asbestos cement will become soft, and will no longer bear a structural load, and therefore does not contribute to the structural thickness. The ePulse ${ }^{\circledR}$ method measures the remaining structural hoop thickness (also known as the effective hoop thickness), as illustrated in Figure B.2-1, rather than the actual physical hoop thickness (which will generally remain at the nominal hoop thickness).


Figure B.2-1: Structural Hoop Thickness in Asbestos Cement Pipe

## Condition Interpretation in Metallic Mains

Corrosion can occur in metallic pipes either in a localized area or in a generalized manner along the main. Examples of various levels of corrosion are presented in Figure B.2-5 below.

Most of the degradation is often caused by a combination of internal corrosion, soil aggressiveness and coating defects on the surface of the main. If no coating was present upon installation, then the degradation would be due to soil aggressiveness alone.

For cement mortar lined pipes, areas with higher losses may indicate the lining has been degraded to the point that the water column is now in contact with the metal, locally accelerating the degradation rate. This may also suggest that the soil loading conditions were such that the pipe experienced an over-deflection during its lifetime, causing damage to the interior lining.

When considering the water aggressiveness as a mechanism for corrosion, it can be assumed that the degradation is relatively uniform across the length of the main. If pipes are unlined (bare), internal degradation may be attributed to a combination of localized pitting, and the formation of tuberculation that can also be accompanied by the formation graphitic corrosion (leaching of iron from the metal matrix).

Localized corrosion is most likely due to isolated mechanisms such as direct current corrosion, or localized aggressive soil conditions. For cement lined pipes, areas with higher losses may indicate the lining has been degraded to the point that the water column is now in contact with the metal, locally accelerating the degradation rate.


6" Cl pipe with $4.2 \%$ measured loss


6" Cl pipe with $10 \%$ measured loss


6" CI pipe with $47 \%$ measured loss


18 " Cl pipe with $18.5 \%$ measured loss

Figure B.2-2: Examples of Different Levels of Corrosion in Metallic Pipe

## Validation

As of the February 2016, a total of 104 ePulse ${ }^{\circledR}$ validation results have been provided to us by our clients or third parties. Some clients have requested confidentiality, however we are able to present the result in aggregate.


Figure B.2-3: ePulse $^{\circledR}$ Validations On All Materials


Figure B.2-4: ePulse ${ }^{\circledR}$ Validations On All Iron Pipes (left) and Asbestos Cement Pipes (right)
Two factors are worth attention in the charts.
The $\mathrm{R}^{2}$ value is known as the coefficient of determination. This provides a measure of how well validation results are predicted by ePulse ${ }^{\circledR}$ results. It is the proportion of total variation of outcomes in validation results explained by the ePulse ${ }^{\circledR}$ results. An $R^{2}$ of 1 indicates that the data match perfectly, while an $\mathrm{R}^{2}$ of O indicates that the ePulse ${ }^{\circledR}$ results cannot be used to predict the validated results at all. For non-destructive testing methods, an $\mathrm{R}^{2}$ value above 0.5 represents strong predictive power.

The correlation coefficient $R$ is the square root of the $R^{2}$ value. For example, an $R^{2}$ value of 0.5 means the same thing as a correlation of 0.71 .

The equation $(y=\alpha+\beta x)$ indicates how well calibrated the ePulse ${ }^{\circledR}$ measurements are, on average. Values of $\alpha$ close to zero, and of $\beta$ close to 1, indicate good calibration. For non-destructive testing methods, a $\beta$ greater than 0.5 and an $\alpha$ less than $25 \%$ of the average value represent good calibration.

Note that the variation between the ePulse ${ }^{\circledR}$ results and validation measurements is not the same thing as the error in the ePulse ${ }^{\circledR}$ results. It is actually the combination of the error in the ePulse ${ }^{\circledR}$ results and the random variation in point samples versus the true average.

Comparing ePulse ${ }^{\circledR}$ results to the results of validations will over-estimate the actual error in the ePulse ${ }^{\circledR}$ results. The reason for this is that the ePulse ${ }^{\circledR}$ results are averages over segments of about 100 m ( 300 ") in length, whereas the validation results indicate the thickness at a one point or a small sub-segment. Each validation measurement will have a random error versus the true average over that segment. The difference between an ePulse ${ }^{\circledR}$ measurement and a validation measurement can be understood as:
ePulse ${ }^{\circledR}$ - Validated $=\left(e P u l s e^{\circledR}-\right.$ True_Average $)+($ True_Average - Validated $)$
Even if the ePulse ${ }^{\circledR}$ results perfectly match the true average (ePulse ${ }^{\circledR}$ - True_Average $=0$ ), we would still expect to see a difference between validation results and ePulse ${ }^{\circledR}$ :
ePulse ${ }^{\circledR}$ - Validated $=($ True_Average - Validated $)$
Actual pipe conditions will vary randomly along the sample, so the difference between the true average and validation results should be a normal distribution centered around zero. If ePulse ${ }^{\circledR}$ is effectively measuring the true average, we should see the same pattern in the difference between the ePulse ${ }^{\circledR}$ and Validated results. The actual distribution is shown in Figure B.2-5, and appears to match the expected pattern.


Figure B.2-5: Variance between ePulse ${ }^{\circledR}$ results and validation results
There are a small number of outliers, which likely represent errors in those ePulse ${ }^{\circledR}$ measurements. The remainder of the data match the expected normal distribution.

## B. 3 LIMITATIONS

The accuracy of the final results presented in this report can be impacted by a certain factor. The following are some of the factors that affect the accuracy of results.

## B.3.1 MODULUS OF ELASTICITY

The modulus of elasticity of the pipe material is one of the factors in the calculation of the mean minimum hoop thickness. While we have significant experience estimating the modulus of elasticity based on the material, age, and region of manufacture, we can improve the accuracy of the results by testing the actual modulus of elasticity of an exhumed sample of the pipe. If interested, please contact us for more information.

## B.3.2 PIPE SPECIFICATIONS

Original pipe specifications were not available for all pipes surveyed. Although Echologics made reasonable assumptions for pipe type and nominal thickness thickness, the results can be improved if accurate pipe specifications can be provided. If original specifications cannot be located, the City may wish to exhume a pipe coupon to verify diameter, material and thickness assumptions.

## B.3.3 STATISTICAL VARIATION

The values generated by ePulse ${ }^{\circledR}$ testing are averaged for a segment of pipe which ranges in length from 297 feet to 1149 feet. This averaging allows for the possibility of having small lengths within the segment which are severely degraded. This degradation will not be shown in the final result. Therefore it is important to note that the value presented describes the general condition of the pipe and may not show future potential point failures.

## B. 4 SENSITIVITY ANALYSES AND CONSIDERATIONS

Several variables may affect accurate analysis:

- Inaccurate distance measurements
- Variance in manufacturing tolerances
- Variance in the modulus of elasticity of the material
- Unknown pipe repairs
- Inadequate correlation signals.

We are constantly committed to reducing error during every step of the testing process.

## Distance Measurement

An accurate distance measurement is crucial for an accurate assessment. In general, a 1\% error in distance measurement can result to more than a $2 \%$ error in final percentage of thickness lost. For this reason, our preference is to use potholes or in-line valves, as these provide the most accurate distance measure, since it is a point-to-point measurement. As the number of bends and/or elevation changes between the sensor connection points increases, so does the potential error in the distance measurement.

## Pipe Manufacturing Tolerances

Small differences in nominal specifications will occur between pipes due to differences in manufacturers and tolerances. These differences commonly range from between $5 \%$ and $10 \%$ depending on the manufacturer and the material. Furthermore, a contractor may have installed a pipe that exceeds the minimum specifications. Under these circumstances the measurements may show a pipe with a hoop thickness that is greater than expected. This is particularly true of older pipes as their tolerances were not adhered to as strictly.

The material properties used for calculations are selected using conservative estimates. This provides for a worst-case scenario analysis.

## Repair Clamps on Previous Leaks

Acoustic waves are primarily water borne. As such, a small number of repair clamps will have an insignificant effect on the test results, since the acoustic wave will bypass the clamps.

## Modulus of Elasticity

A change in elastic modulus of $10 \%$ will cause a change in the calculated thickness by approximately $10 \%$. The elastic modulus is known for common materials used in the manufacturing of pressure pipe, but this value can vary among manufacturers. It is dependent on the manufacturing process and the quality of the material. The material properties used for calculations are selected using conservative estimates. This provides for a worst-case scenario analysis.

## Unaccounted for Replacement of Pipe Sections During Repairs

Acoustic waves propagate differently depending upon the pipe material. This effect remains true for unaccounted for short pipe replacements with different materials, and can result in significant error. For example, a new 6 meter long ( $\sim 20$ feet) ductile iron repair in a 100 meter long ( $\sim 328$ feet) cast iron pipe section of average condition, will produce a small error of $+3.5 \%$ in measured hoop thickness. However, the same repair made with PVC pipe would produce an error of $-41 \%$ in measured hoop thickness.

Preferably, pipe sections selected for testing should be free of repaired sections. However, if this condition does not exist, the impact of the repaired pipe section can be accounted for, provided accurate information is available for the age, location, length, material type, and class of the repair pipe section.

## Inadequate Correlation Signals

Inadequate correlation signals can sometimes occur in the field. The following are some of the conditions that may cause an inadequate correlation:

1. The presence of plastic repairs in metallic pipes which can cause poor propagation of sound.
2. Loose or worn components in fittings used for the measurements, such as valve or hydrant stems.
3. Large air pockets in the pipe which heavily attenuate acoustic signals.
4. Heavily tuberculated pipe, particularly old cast iron or unlined ductile iron pipes, which can attenuate the acoustic signals to such an extent that a correlation is of very low quality.

## APPENDIX C DETAILED METHODOLOGY

## C. 3 LEAK DETECTION

The methodology employed is known as the cross-correlation method. A correlator listens passively for noise created by a leak. If one is detected, it uses the time delay between sensors to determine the position of the leak. The following procedure was used to conduct the leak detection survey:

1. For each location surveyed, the distance between the sensors was measured.
2. Sensors were mounted either directly on the pipe or were connected to the water column with hydrophones.
3. A correlation measurement was performed without introducing noise (known as a background recording), and the signal was saved to the computer so that further analysis could be performed off-site. A preliminary analysis is performed onsite to determine if any leaks are present.

## C. 2 EPULSE ${ }^{\circledR}$ MEAN MINIMUM HOOP THICKNESS TESTING

A section of pipe is the length bracketed by two contact points on the main. An out-of-bracket noise source is located outside of that segment. A known noise source may be used to determine the acoustic wave velocity in a segment of pipe. Knowing the distance between the sensors, the acoustic wave velocity (v) will be given by $v=d / t$, where $d$ is the length of pipe between the sensors, and $t$ is the time taken for the acoustic signal to propagate between the two sensors.

The following procedure is followed to conduct an ePulse ${ }^{\circledR}$ data collection survey:
4. A leak detection survey is performed on the length of pipe to check for the presence of existing leaks. (Described in previous section)
5. A noise source is created "out-of-bracket". A variety of different noise sources can be used including an existing leak noise, blow-off noise, pump noise, impulse noise, running a fire hydrant, tapping on a fire hydrant, or directly on the pipe.
6. A new correlation measurement is performed and stored as a wave file for further analysis and confirmation off-site. Data is analysed further to obtain an optimum correlation, ensuring an accurate velocity measurement.

## Wave Velocity Equation

The general form of the acoustic pipe integrity testing equation is shown below.
Equation C.2-1: Wave Velocity - Thickness Model

$$
v=v_{o} \times \sqrt{\frac{1}{\left[1+\left(\frac{D_{i}}{t_{r}}\right) \times\left(\frac{K_{l}}{E}\right)\right]}}
$$

$v$ : measured velocity
vo: propagation velocity in an infinite body of water
$D_{i}$ : pipe internal diameter
$K_{1}$ : bulk modulus of the liquid
$E$ : elastic modulus of the pipe material
$t_{r}$ : residual thickness of the pipe

## Bulk Modulus of Water Calibration

Different water sources often produce a different bulk modulus of water. The bulk modulus essentially represents the water's inherent resistance to compression, and is impacted by factors like water temperature, dissolved salts and entrained air. Our field specialists calibrate the bulk modulus at each water company's water source. This requires performing a single test on a stretch of pipe with a known pipe condition. In practice, this generally means performing an additional test on a new section of pipe that has been installed within the past few years.

## C. 3 ECHOLIFE® ${ }^{\text {D }}$ DTAILED METHODOLOGY

## C.3.1 CAST IRON DETAILED ECHOLIFE® METHODOLOGY

The EchoLife ${ }^{\circledR}$ method uses ePulse ${ }^{\circledR}$ condition assessment results and a proprietary statistical model to calculate the segment's probability of failure. For each segment, we estimate the critical failure thickness, the maximum pit depth, and the probability of failure.
We define a "failure" as the state at which the mean minimum hoop thickness reaches or falls under the calculated critical thickness. The critical thickness is the hoop thickness at which the pipe is expected to fail. The probability of failure is the likelihood of the critical thickness occurring on the segment in question. In most AWWA and Water Research Foundation publications, "break" is defined as any breech of the pipe barrel, and includes "leaks", "ruptures", and "blow-outs". It also includes leaks at joints. It excludes failures on service laterals. The model calculates the probability of failure based on our definition of "failure". The EchoLife ${ }^{\circledR}$ model is calibrated to convert from an Echologics-defined "failure" to utility defined "breaks" using break rate data obtained from a Utah State University Study ${ }^{1}$.

The general approach is as follows:
7. Review Utility Records,
8. Calculate Critical Thickness,
9. Establish Criticality,
10. Determine Likelinood of Failure

## Review Utility Records:

We shall review available water utility records and drawings to establish operating and surge pressures, soil loading, pipe age, original pipe thickness, historical failures, and any records or samples from failed pipe segments. Where records are unavailable, we and the City shall agree on assumptions that shall be used in the calculation. In some cases, pressure transient monitors may be installed to establish operating and surge pressures. Some data for the analysis will be determined in the field such as measured hoop thickness and depth of cover for soil loading calculations.

## Calculate Critical Thickness

The critical thickness is the hoop thickness at which the pipe is expected to fail catastrophically under the specified surge load. For cast iron mains, we average the critical thickness calculated using the Schlick failure criterion (Equation C.3-1: Schlick Failure Criterion (Combined Loading)) and the hoop stress failure criterion (Equation C.3-2: Hoop Stress2).

$$
\left(\frac{P}{P_{c}}\right)+\left(\frac{W}{W_{c}}\right)^{2}>1
$$

## Equation C.3-1: Schlick Failure Criterion (Combined Loading)

Where $P$ is the design pressure which is 50 psi (to account for pressure surges) $+P_{\text {operating (or value measured using pressure }}$ transient monitors), $\mathrm{P}_{\mathrm{c}}$ is the critical failure pressure in the absence of external loading, W is the external load, and $\mathrm{W}_{\mathrm{c}}$ is the critical failure load in the absence of internal pressure. No additional safety factors have been used in this failure criterion.

$$
\sigma_{h}=\frac{P_{c} \cdot D_{i}}{2 \cdot t_{c}}
$$

## Equation C.3-2: Hoop Stress

Where $\sigma_{h}$ is the maximum hoop stress which is equal to material tensile strength, $P_{c}$ is the critical failure pressure which is equal to two times the operating pressure to account for pressure surges, $D_{i}$ is the internal diameter, and $\mathrm{t}_{\mathrm{c}}$ is the critical failure thickness when the pipe is expected to experience a catastrophic failure. No safety factors have been used in this failure criterion.

## Establishing Criticality:

In discussion with the City, we shall establish the criticality (maximum acceptable likelihood of failure) of each main. The EchoLife ${ }^{\circledR}$ (Remaining Service Life) model uses a statistical approach to determine the annual probability of pipe line failure. The remaining service life model is a comprehensive tool to assist clients in critical asset management decisions.
AWWA calculated the average tolerance to break rate for distribution cast iron pipes to be 0.244 breaks/mile/year (Folkman, Rice, \& Sorenson, 2012); however, the failure rate decreases as pipe diameter increases as it can be seen in the study conducted by Kettler (Kettler \& Goulter, 1985). This average can be used for the acceptable failure rate. The acceptable failure rate is normalized to each individual segment to account for variation in segment length. Table C.3-1: Criticality Ranking of Pipeline can be used to select the acceptable failure rate.

Table C.3-1: Criticality Ranking of Pipeline

| Acceptable Break Rate <br> (Breaks / Mile / Year) | Annual Probability of Failure / Mile | Description |
| :---: | :---: | :---: |
| Less than 0.001 | $0.1 \%$ | No tolerance for corrosion related <br> failures. E.g. the sole water supply <br> main to a nuclear power plant. |
| 0.03 | $3 \%$ | Little tolerance to pipe failure. E.g. a <br> main running in front of a hospital. |
| 0.08 | $8 \%$ | Low level of tolerance to pipe failure. <br> E.g. a break will cause service outage <br> to a large number of people. |
| 0.16 | $20-30 \%$ | Moderate level of tolerance to pipe <br> failure. E.g. a break will cause <br> moderate traffic disruptions. |
| $0.20-0.30$ | $80 \%$ | Target level of tolerance to pipe failure <br> according to AWWA Research <br> Foundation. E.g. a residential main <br> that can be easily bypassed. |
| 0.80 |  | High level of tolerance to pipe failure. <br> E.g. a redundant line in an <br> undeveloped environment. |

As the length of main being considered decreases, the acceptable tolerance to failure also decreases. For example, if the client's allowable annual probability of failure is $10 \%$ on a 1 kilometers ( 0.62 miles) main, this would then equate to a tolerance to failure of $1 \%$ on a 100 meters ( 328 feet) main.

## Determine Likelihood of Failure and Remaining Service Life

For cast iron mains, the next stage of the analysis is to calculate the likelihood of failure.
The ePulse ${ }^{\circledR}$ measured mean minimum hoop thickness is assumed to be equal to the difference between the design thickness and the average maximum pit depth along the segment. This component of the model incorporates this average maximum pit depth and other proprietary information developed by us into a Gumbel distribution to estimate the probability of a break occurring on a segment at the year of testing. The results are presented in break rate format (breaks/mile/year) for ease of comparison to the City's break rate tolerance.
The EchoLife ${ }^{\circledR}$ model was developed using pitting distribution data obtained from cast iron pipe.
The Gumbel distribution is used in applications that require extreme value probabilities such as floods, earthquakes, and other such events. This is commonly used in the pipeline industries by Advanced Engineering Solutions Limited (United Kingdom), PCA now PCA-Echologics (Australia) to predict maximum pit depths.

Corrosion Rate is assumed to be equal to the difference between the ePulse ${ }^{\circledR}$ measured thickness and the original thickness divided by the age. Using the ePulse ${ }^{\circledR}$ results, criticality, failure state, and design information, we will calculate the time for each main to reach the maximum acceptable likelihood of failure (this is the remaining service life).

## EchoLife ${ }^{\circledR}$ Assumptions

EchoLife ${ }^{\circledR}$ remaining service life estimates the number of years left in a pipes service life. The results are presented as a number of years until the critical failure thickness is reached. The number of years is capped at 50 years due to the accuracy of predicting future degradation rates.
EchoLife ${ }^{\circledR}$ calculations incorporate internal pressure and external loading conditions.
Error! Reference source not found. below lists the assumptions made in the remaining service life analysis.

Table C.3-2: Cast Iron EchoLife ${ }^{\circledR}$ Assumptions

| Pipe Information | Estimate or Assumption | Source |
| :---: | :---: | :---: |
| Soil Density | $120 \mathrm{lbs} / \mathrm{ft}^{3}$ | Buried Pipe Design Third Edition. A. P. Moser \& Steven Folkman. Table 2.1Approximate Values of Soil Unit |
| Bedding Type | Class B: Compacted Granular Bedding. Load Factor $=1.5$ | Buried Pipe Design Third Edition. A. P. Moser \& Steven Folkman. Table 3.2Bedding Factors, Page 80 |
| Pipe Depth | 3 ft | Field Measurement |
| Surge Pressure | 50 psi | Assumed |
| Safety Factor on Pressure | 1 | Buried Pipe Design Third Edition. A. P. Moser \& Steven Folkman. Table 6.15Thickness for Internal Pressure, Page |
| Safety Factor on External load | 1.1 | Buried Pipe Design Third Edition. A. P. Moser \& Steven Folkman. Page 199 |
| Rupture modulus of Cl | 31,000 psi | Buried Pipe Design Third Edition. A. P. Moser \& Steven Folkman. |
| Tensile strength of Cl | 11,000 psi | Buried Pipe Design Third Edition. A. P. Moser \& Steven Folkman. |
| Break Rate Threshold | 0.16/brks/mile/yr | Assuming a moderate tolerance for main breaks |

The EchoLife ${ }^{\circledR}$ analysis involves an inherent level of uncertainties and is dependent on input parameters and output can be significantly affected by variation from assumed parameters; therefore, EchoLife ${ }^{\circledR}$ should be used as a guide only.

## APPENDIX D ABBREVIATIONS

Cl

CL Concrete lined: Indicates whether or not a specific pipe type has some form of concrete lining. This abbreviation will typically follow a pipe type abbreviation Ex: DICL for ductile iron concrete lined.

GIS

IB

OOB

PCl

POI

PVC

SCl

St
Cast Iron: Pipe wall construction consisting of cast iron. This includes pipes classified as pit cast iron or spun cast iron as well.

Geographic Information System: A system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data.

In-Bracket. Please refer to the technical glossary.

Out-of-Bracket. Please refer to the technical glossary.

Pit Cast Iron: Pipe wall construction consisting of pit cast iron.

Point of Interest. Please refer to the technical glossary.

Poly Vinyl Chloride: Pipe wall construction consisting of poly vinyl chloride.

Spun Cast Iron: Pipe wall construction consisting of spun cast iron.

Steel: Pipe wall construction consisting of steel.

## APPENDIX E GLOSSARY OF TECHNICAL TERMS

Acoustic Wave Also known as: wave speed, wave velocity, velocity. The speed at which a coupled-mode pressure Speed wave travels along a pipe.

Blue/White Station A piece of equipment where a sensor is connected to transmit the data to a central location. Typically stations are colour coded blue or white.

| Coherence | Measure of similar vibration frequency between two channels (Blue and White stations or a <br> node pair). |
| :--- | :--- |
| Correlation | The process of comparing two acoustic signals for similarity in the time domain. Echologics <br> technologies use correlation to judge the time delay between two signals. This allows for <br> determination of the location of leaks along a pipeline. |
| In-Bracket | A noise source that is within the span of pipe between two Stations or Nodes. |

Leak Discovered A point along a pipe that is likely loosing water to the surrounding soil and environment. For a leak to be classified as discovered, a field technician must acquire at least three pieces of unique evidence that suggest existence and location.

No Leak
Discovered
No evidence of leakage was discovered or a POI was under investigate and it was determined that it was not a leak.

Node A piece of equipment where a sensor is connected to transmit the data to a central location. Typically nodes are paired with other nodes as part of a large array installed on a pipeline or in an area.

Out-of-Bracket A noise source that is outside the span of pipe between two Stations or Nodes.

Point of Interest Evidence of some form of noise or energy on the pipe. There is not enough evidence to classify a point of interest as a leak.

Segment A section of pipe surveyed in one measurement. The length of the segment is the distance between
two sensors.

Sensor A device used to measure physical or chemical properties of a system. In the context of this report this term will be typically used as a reference to a vibration sensor.

Site
A neighbourhood or area within which a segment of pipe exists.

## Appendix J <br> Responses to the <br> Environmental Advisory Commission Comments

Pasadena Water and Power Responses To<br>The Environmental Advisory Commission Memorandum<br>Dated November 20, 2020<br>Regarding Draft Water System and Resources Plan

The EAC memorandum, dated 11/20/2020 expressed the following concerns regarding the Public Draft Water System and Resources Plan ("WSRP"):

1. The draft report does not present engineering analyses required for the replenishment of the Raymond groundwater basin or how it is achieved. The WSRP does not evaluate potential impacts of climate change or a decrease in water supplied by MWD and how these events will further deplete the basin.

## Answer:

The Raymond Basin Management Board ("RBMB") and the State of California are the regulatory authorities overseeing the basin. RBMB represents and manages the groundwater basin for 16 water rights holders to pump from the Raymond Basin. Watermaster Service reports have reported the decline of the basin water levels and numerous technical studies have been completed. RBMB has changed policies and adjusted factors within its control as determined by the RBMB to manage the basin. The basin has been listed by the State in 2019 as low priority due to the management controls implemented by RBMB. Moreover, based on reports submitted to the State conclusion is that hydrographs are stable. Pasadena Water and Power ("PWP") has been working with the RBMB to implement management of groundwater levels.

Depending on where in the basin it is placed and how fast it might be lost to the lower Main San Gabriel Basin ("Main Basin"), groundwater levels can be increased by three means: the first is by adding more water to the basin, the second is by reducing the groundwater pumping, and the third is to reduce hydraulic differential of the lower basin to slow the rate of loss. Increasing water levels by pumping less groundwater and buying more imported water from the Metropolitan Water District of Southern California ("MWD") is expensive. The cost to increase the water levels by 50 feet is over $\$ 100$ million.

## Adding More Water to the Basin

The available water replenishment sources in the area are stormwater from rain precipitation and imported water from MWD. Imported water from MWD contains disinfectants and high mineral content which are not desirable for injection and
expensive for infiltration as evaporation and in-basin losses compound the inefficiency and carry heavy carbon footprint further exasperating water supply issues in California.

The WSRP report recommends for implementation three large scale projects that would help replenish the groundwater:

- Pasadena Groundwater Storage Program proposed to recharge imported MWD water in the Basin via infiltration.
- Arroyo Seco Canyon Project proposed to recharge approximately 1,000 AFY of stormwater in the Basin via infiltration and reducing pumping.
- Arroyo Seco Pump Back Project proposed to recharge approximately 1,000 AFY of stormwater captured from behind Devil's Gate Dam that otherwise would be released by LA County Flood Control District and discharged to the Pacific Ocean.

In 2019, RBMB approved PWP's in-lieu program and purchased 1,000 AFY of imported water for basin replenishment.

In addition, Pasadena led effort to work with the Main Basin agencies and the Main Basin Watermaster to reduce the loss of water from the Raymond Basin to the Main Basin. As the Main Basin is at a lower elevation than the Raymond Basin, the Raymond Basin is experiencing increased losses. It was estimated that an additional 6,000 to 10,000 AF of groundwater may be lost every year from Raymond Basin to the Main Basin through the Raymond Fault. Increasing water levels in the Main Basin appears to be a sound policy.

Pasadena supported the Main Basin agencies efforts to obtain additional water and MWD's Carson recycled water program to bring recharge water to the Main Basin. Continued coordination of the Pasadena and Upper San Gabriel Valley Municipal Water District may result in other mutually beneficial projects.

Coordination with neighboring agencies was not highly valued by the community members of the WSRP Stakeholder group and is an example of professional judgement departing from popular opinion for the benefit of the groundwater basin and the community.

## Reducing Groundwater Pumping

Raymond Basin has an estimated volume of 820,000 AF. Of the 16 pumpers in the Basin, Pasadena is the largest water rights holder representing 42\% of the total rights in the Monk Hill sub-area (4,464 AFY) and Pasadena sub-area (8,343 AFY) of the Basin.

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In January 2008 RBMB adopted a resolution to put in place voluntary pumping reductions of $30 \%$ implemented over 5 years in the Pasadena subarea only. On July 1, 2009 the implementation began and by January 2014 the reduction was in full effect.

However, the reduced pumping did not increase the water levels. The drought, the increased losses to the Main Basin and the tail of previously established pumping rights have diminished RBMB efforts to stabilize the basin and initiate new management initiatives. In 2019 RBMB commissioned a study to evaluate the effectiveness of the voluntary reduction currently in place and consider additional measures to assist in groundwater recovery. Also in 2019, RBMB purchased 1,000 AF of water to augment the basin. Recent data indicates the current water levels in the basin are holding relatively steady in the short time with these efforts.
2. WSRP goal of $10 \%$ conservation is not supported by thorough evaluation. More aggressive conservation goal is recommended.

## Answer:

The WSRP provides focus for long-term water use reduction building on the success achieved meeting the mandated goal of 20\% conservation by 2020 under Senate Bill ("SB") X7-7 and the temporary measures imposed during the drought.

The WSRP anticipates new State requirements established under Assembly Bill 1668 and SB 606 and sets the objective to exceed those as an integrated demand management program providing flexibility to annual water supply and leveling peak demands, which not only save water but provide a financial advantage to rate payers. The City intends to roll off peak demand with an agile integrated supply portfolio.

The City Council members are the policy setters and community leaders that will ultimately determine an appropriate level for water use reduction and balance the appetite to support more costly imported water solutions. The new State regulations and the WSRP's 10\% conservation goal establish the water demand to be reduced by $18 \%$ from year 2020 to year 2030. This goal will require innovative approaches which employ a combination of programs and policies focused on optimizing water use for landscapes through enhanced soil health and soil moisture retention, application of water based on plant water needs (water budget), enhanced irrigation efficiencies, and a rate structure tailored to meet the needs of the community.

The greatest impact for water use reduction identified is the single family residence customer using an average of 412 gallons per day per household from 2017 to 2020. Meeting the $18 \%$ reduction goal, household use would decrease to 338 gallons daily. Included in this is a $13 \%$ reduction in indoor water use sought by the State. This reduction represents reduced water use to the minimum required for health and

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safety as established by State regulations. With approximately 28,000 households, the $18 \%$ reduction yields 2,300 AF of water.

Conservation gains do not correlate directly with reduced groundwater pumping.
3. Evaluation of the best use of water with elevated nitrate - cost benefit analysis is not clearly presented to justify the use of the water for irrigation as best and most cost effective use.

## Answer:

The WSRP was based on planning level analysis of the costs and benefits of each program/project based on nine criteria and modeling. The nine criteria include cost effectiveness, degree of reliability, local control, energy efficiency, level of service, water quality protection, among others. The portfolio with the highest score was selected for implementation. The programs and projects in the selected portfolio will undergo thorough analysis and feasibility studies, including a cost benefit component, prior to implementation. However, nitrate removal for drinking water is extraordinarily expensive and only recently being considered by others in the region. Using local high nitrate groundwater for irrigation is orders of magnitude better environmental policy than using imported water, moreover, plants provide an effective mechanism to remove nitrate from the environment. This approach has been effectively used in many communities, including the City of Alhambra, for decades.

## 4. Evaluation of Arroyo Seco stream and the water needed to sustain fish and natural resources should be conducted.

## Answer:

Several studies to consider the Arroyo Seco stream for fish and related habitat have been conducted. In 2018, prior to the initiation of the Arroyo Seco Canyon Project's ("ASCP") Environmental Impact Report, PWP retained the services of Psomas to study the impacts to riparian habitat as a result of the reduced flow in the Arroyo Seco from the project. The final report from the year-long study concluded that for representative average, dry and wet years "downstream reduced flows associated with ASCP diversions are not expected to result in any measurable effects on downstream riparian habitat."

In addition, PWP intends to remove the current fish barrier and upgrade the diversion and intake structure including features for the protection of future fish. PWP plans for additional features when connectivity from headwaters to the ocean is restored, contingent in part on LA County Flood Control District's retrofitting Devil's Gate Dam

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to allow for fish passage and the removal of Brown Mountain Dam.
Water is a vital natural resource and the ratepayers of Pasadena have made substantial investment to protect and develop this resource. Forgoing a local resource, preferring to exporting detrimental environmental impacts associated with imported water is not a sustainable practice or sound policy. Protections for fish and other resources are embedded in the permitting and regulatory practices to be addresses with any project.
5. Evaluation of stormwater capture - PWP should work closely with the Department Public Works to incorporate a stormwater capture program into the WSRP.

Answer:
PWP has been working with the Department of Public Works to utilize available funding including Proposition W moneys for projects that would increase stormwater capture in Pasadena. However, stormwater from streets and parking lots is not suitable for infiltration in the groundwater without treatment in one form or another which have ongoing maintenance obligations for Public Works or the property owners.

## ENVIRONMENTAL ADVISORY COMMISSION MEMORANDUM

To: Pasadena Water and Power
From: Environmental Advisory Commission

Date: November 20, 2020
Subject: Draft Water System Resources Plan
The Environmental Advisory Commission (EAC) received a presentation from Pasadena Water and Power (PWP) on October 27, 2020 regarding the Draft Water System Resources Plan (WSRP). EAC ad hoc members also reviewed additional information to better understand water conditions including a 2018 report entitled Raymond Basin Assessment prepared by Zanjero. The EAC recommends that final plan address the comments below.

Respectfully submitted,


Daniel Rossman, Chair
The Environmental Advisory Commission

Attachment 1: EAC Comments on the Draft WSRP

Attachment 2: Declining Groundwater Levels in Pasadena

## Attachment 1: EAC Comments on the Draft WSRP

Pasadena is in a water crisis evidenced by decades of declining groundwater levels in the Raymond Basin. The figure provided in Attachment 2 illustrates the historic water level measurements from a basin well. The water level has dropped approximately 300 feet as a result of the withdrawal of more water from the basin than is replenished. In a report entitled Raymond Basin Assessment (December 17, 2018), Zanjero concluded:

> The Raymond Basin is not managed in a sustainable manner as evidence by the decrease in basin groundwater levels over the last 118 years, and is under threat of spreading contamination. PWP and RBMB must change its course and take action to prevent permanent failure of the basin.

However, the Draft Water System Resources Plan (WSRP) does not present analyses required for basin replenishment or how it can be achieved. The WSRP does not evaluate potential impacts of climate change or a decrease in water supplied by Metropolitan Water District (MWD) and how these events could further deplete the basin. Furthermore, the selected WSRP Portfolio F, Maximize Value of Groundwater/Non-Potable Supplies with moderate water conservation is likely not appropriate for maintaining sustainable water supply. Consequently, prior to presenting the WSRP to the Municipal Services Committee (MSC), the Environmental Advisory Commission (EAC) recommends conducting engineering analyses to ensure a wholistic approach to managing Pasadena's water supply and replenishing the basin to provide a more resilient and flexible water plan. The recommended analyses are described below.

## 1. Engineering analysis of the groundwater basin

Slide 4 of PWP's WSRP PowerPoint presented to the EAC indicates that the primary goal is to "develop and manage sustainable water supplies" and the stated objectives are: to improve the health of the Raymond Basin, efficiently use available supplies, adapt to a changing climate, and enhance local supplies and support regional water supply programs.

However, there is a lack of information on how basin replenishment will be achieved and there is no determination of the volume of water needed to raise the level of groundwater in the basin. Basin replenishment is critical to protect water quality, prevent land subsidence, withstand drought and potential reduction of supply from MWD, and provide a reliable water supply in an emergency.

## 2. Thorough analysis of water conservation

An estimated sixty percent of water is used for residential irrigation. Calculations should be conducted for reducing household irrigation by $10 \%, 20 \%, 30 \%, 40 \%$, and $50 \%$, and the volume of saved water for each percentage of water reduction and the corresponding impact to the Raymond Basin groundwater level.

The stated goal of $10 \%$ outdoor conservation with $18 \%$ by 2030 is not supported by a thorough evaluation as to what this may accomplish and may be underachieving what is required to meet a sustainable water system.

PWP's WaterSmart indicates that the average household uses 343 gallons per day (GPD) with three occupants. Thus, the average water use is 114 GPD per person. Using a population of 70,500 that live in single-family households (Pasadena's population of 141,000 with $50 \%$ living in multifamily dwellings), yields $8,037,000$ GPD, which equals approximately 2.9 billion gallons per year. Implementing a 30
percent conservation measure, would result in saving 870,000,000 gallons (2,670 acre-feet) per year, excluding apartment dwellers.

EAC believes more aggressive conservation measures should be evaluated to combat continued basin depletion and to support long term water resilience. Conservation methods and water savings should be presented and implemented to reduce demand for imported water and to reduce basin water withdrawal.

## 3. Evaluation of the best use of water with elevated nitrate

The WSRP recommends using water with elevated nitrate levels for irrigation of municipal property. However, a cost benefit analysis is not clearly presented to justify that this is the best and most costeffective use of the water.

## 4. Evaluation of the Arroyo Seco stream

An evaluation of the Arroyo Seco natural stream and the quantity of water needed to sustain the native fish and natural resources should be conducted. Alternatives that provide environmental benefits to the stream and spread the water to percolate into the Raymond Basin beneath Pasadena should be fully evaluated and presented.

## 5. Evaluation of stormwater capture

Stormwater capture is an opportunity to provide water to the Pasadena's system that would otherwise flow through the city. The state, county, and CalTrans provide funds for such projects (e.g., Proposition 1 and Measure W). PWP should work closely with the Department of Public Works to incorporate a stormwater capture program into the WSRP for long term resilience.

## Declining Groundwater Levels

Historic Pasadena Area Groundwater Levels


Source: RMBM, Draft Opportunities to Enhance Groundwater Levels in Pasadena Subarea.

# Appendix K Responses to the Raymond Basin Management Board Comments 

# Pasadena Water and Power Responses To <br> the Raymond Basin Management Board Comments <br> <br> Dated April 27, 2021 <br> <br> Dated April 27, 2021 <br> Regarding Public Draft Water System and Resources Plan 

The Raymond Basin Management Board's ("RBMB") letter, dated April 27, 2021 expressed the following concerns regarding the Public Draft Water System and Resources Plan ("WSRP").

1. A serious concern is the exclusion of the RBMB (court-appointed manager of the Raymond Basin Judgment) from the entire WSRP process, even though Pasadena sits as a voting member of the RBMB and its Pumping and Storage Committee.

## Response:

The 2020 WSRP is a planning document that updates both the 2002 Water System Master Plan ("WSMP") and the 2011 Water Integrated Resources Plan ("WIRP").It was not PWP's intention to exclude the RBMB from the process, rather to get community input on priorities for the updated document. The document does not present any new projects requiring RBMB's technical input and any implementation of projects will be coordinated with the RBMB.
2. It is inappropriate for Pasadena's WSRP to criticize the RBMB's management of the basin, while being represented as a voting member of the RBMB and Committees.

## Response:

In preparation for the WSRP, PWP hired a consultant to independently look at the water system and water resources needs and provide recommendations on what programs PWP would need to implement in the next 25 years. The goal of the WSRP report was not to criticize, but to plan for adequate supply and facility upgrades, for the betterment of PWP and the Raymond Basin. PWP envisions working with RBMB to implement specific projects identified to replenish the basin.
3. This WSRP suggested concepts and programs to increase Pasadena's rights to pump groundwater. Any concepts or programs relating to increased pumping must be consistent with the Raymond Basin Judgment and approved by the RBMB.

Response: Yes, PWP agrees.
4. The WSRP in some areas is based on flawed logic, when it supports restoration of the Basin groundwater levels, and at the same time, prioritizes Pasadena's LongTerm Storage (LTS) as the "key underpinning Pasadena's water supply resiliency".

The RBMB staff considers the water in LTS accounts to be "paper water", while Basin groundwater levels are declining. Pumping LTS water has been documented to exacerbate declining water levels.

## Response:

Thank you for the comment. During the past several years PWP has not pumped out of LTS, but has contributed to it thereby not causing further decline to groundwater levels in this manner.
5. Page 1 - The WSRP emphasizes greater dependency on local water and groundwater basin sustainability. This is the role and responsibility of the RBMB. This WSRP should have been coordinated for review by the RBMB.

## Response:

The improvement of the groundwater basin water levels should be the goal of all RBMB pumpers and the RBMB. Implementation of programs aimed to replenish the basin as identified in the WSRP will be coordinated with RBMB and other pumpers in the basin. Just as with the 2002 Water System Master Plan and the 2011 Water Integrated Resources Plan, PWP did not seek RBMB's input for the planning of specific programs as no new projects were presented.
6. Page 1 - The Stakeholder Advisory Group (SAG) did not include the RBMB. Typically agency planning involves outside entities, and some mechanism included in the process for technical review by those agencies, such as the RBMB.

## Response:

SAG was not created as a technical committee. The purpose of SAG was to obtain community input from a diverse group of individuals representing Pasadena's residential, commercial, and large water customers to determine the priority of nine ranking criteria, such as reliability, cost, community values, adaptability, etc.
7. Page 3 - The WSRP indicates that Pasadena's water use likely to decline from 28,500 AFY to 23,500 AFY by 2030, the Preferred Portfolio is $50 \%$ GW, assuming reduced demand, and groundwater is declining and must be revived. The assumption of significant water conservation is not a given and will artificially influence water resources planning. The RBMB has presented several concepts to revive groundwater levels in both the Pasadena and Monk Hill Subareas. However

RBMB concepts require producer participation, producer consensus, and funding.

## Response:

The estimated demand reductions in the WSRP are based on California law, specifically the requirements of SB 606 and AB 1668, and include an additional 10\% outdoor conservation. While the additional 10\% conservation is optional, meeting the State's conservation laws are mandatory for water suppliers. PWP agrees that participation, consensus, and funding are needed for programs that replenish the basin.
8. Page 4 - The WSRP indicates Pasadena is planning for "banking" wet-year discounted imported water. RBMB believes there is no basis for the assumption of "discounted" imported water on an ongoing basis. Plans for storing imported water must assume at a minimum, some purchases at full-service rates.

## Response:

PWP agrees that wet year discounts may be sporadic, but it is important to take advantage of those opportunities as they become available.
9. Page 5 - The WSRP suggests "retooling of policies" to manage the basin. RBMB has not been advised of "new concepts" during the regular meetings with Pasadena.

## Response:

Now that WSRP is finalized, PWP intends to share with RBMB any new concepts developed and implement them as mutually agreed upon.
10. Page 1-1 - The WSRP describes Pasadena's surface diversion rights, which are not unlimited. RBMB suggests more detail be included on "limits" to surface diversions based on water rights.

## Response:

The limits of Pasadena's surface water diversion rights for Eaton Wash are 8.9 cubic feet per second ("cfs") and for Arroyo Seco and Millard Canyon streams are 25 cfs. Discussions about the spreading credits are included in the WSRP specifically on pages 2-14, 4-2 through 4-4, and page 5-10 (December 2020 Report).
11. Page $1-1$ - The WSRP describes the $30 \%$ reduction of pumping rights. RBMB suggests adding context and history to the water rights adjustment - Decreed rights were raised too high in 1955 and not reevaluated since then as suggested in 1955.

## Response:

Duly noted. Thank you. This statement was included in the 2020 Urban Water Management Plan.
12. Pages 1-3 and 1-4 - The WSRP indicates defined Goals and Objectives were developed in partnership with SAG. The RBMB should have been included, at a minimum, from a technical perspective, in these discussions in addition to SAG. The omission of the RBMB is significant, and challenges the application of this WSRP.

## Response:

As stated previously, the goals and objectives of the WSRP were community driven, not technically oriented.
13. Page 2-1 - The WSRP indicates Pasadena purchased portions of Arroyo Seco and Eaton Wash watersheds. More detail is needed, including a description of additional associated surface water rights. New recharge facilities will require Board approval and adoption of measurement and reporting procedures.

## Response:

The referenced purchases are historical, not new. We agree that any new recharge facilities will require approval, adoption, and reporting procedures.
14. Page 2-12 - The WSRP indicates approximately 6,000 to 10,000 AFY are estimated to leak from the eastern portion (primarily Santa Anita Subarea) of this basin to the Main San Gabriel Basin (MSGB), and that pumping to historically low groundwater levels in MSGB increases leakage. These statements are not supported with current information and data. No technical information is provided. The statement on leakage should be significantly "qualified" and the statement regarding groundwater levels in MSGB increasing leakage be removed.

## Response:

The statements that (1) higher groundwater levels in the Raymond basin relative to MSGB will cause more groundwater to flow across the fault and (2) the range of the estimated leakage across Raymond Fault are from Geoscience Support Services, Inc. "Raymond Basin Ground Water Flow Model Predictive Simulations" report, dated December 10, 2004, section 5.4 Outflow across Raymond Fault. Yes, PWP agrees that more technical studies need to be completed to better understand the interaction between the Raymond Basin and the MSGB. The statement regarding groundwater levels in MSGB increasing leakage was removed from the final report.
15. Page 2-13 - The WSRP indicates Pasadena will be implementing projects in

Raymond Basin to reduce loss of groundwater to MSGB, revising policy on basin sustainability, and developing basin protection policies/guidelines for basin adoption. These are the roles and responsibilities of the RBMB. Pasadena is on the RBMB and all committees. Pasadena has not introduced any concepts to the RBMB.

## Response:

Yes, PWP agrees and is looking forward to working with RBMB to implement specific projects that help the basin be more sustainable.
16. Page 2-14 - The WSRP indicates "... on July 1, 2009, the RBMB implemented a resolution that voluntary reduced pumping from the Pasadena subarea for a term of five years." This statement is incorrect. In order to meet the goal of 30\% reduction, water production reductions were implemented incrementally at a rate of 1,070 AFY for over a five year period. The $30 \%$ reduction plan is still in place and there is no term limit of five years. The WSRP needs to include more details on why the $30 \%$ reduction plan was implemented. The RBMB determined the re- determination of the Safe Yield in 1955 and the adoption of the Long-Term Storage (LTS) Policy by the RBMB in 1993 played a major role in lower overall groundwater levels that the Pasadena subarea was experiencing.

Response: Yes, PWP agrees. Thank you for the clarification.
17. Pages 2-16, and 4-3 - The WSRP states PWP's current LTS is 13,400 AF in Monk Hill and 20,600 AF in Pasadena subareas and LTS is the key underpinning Pasadena's water supply resiliency. The RBMB suggests this discussion be clarified to include termination of long-term storage when accounts are exhausted (no new storage), and current declining water levels while water is "stored" in LTS accounts. RBMB determined the LTS Policy adopted in 1993 was one factor in lower overall groundwater levels the Pasadena subarea was experiencing.

## Response: Duly noted. Thank you.

18. Page $2-17$ - The WSRP states "...governing practices confound groundwater pumping capacity in the area." The RBMB is unaware of the "practices" referred to in the WSRP. The RBMB was not included in the SAG and has not been advised of these Pasadena concerns at any RBMB or Committee meetings where Pasadena is a voting member. Pasadena suggesting the RBMB has "failed" to address sustainability of the basin in the WSRP, is totally inappropriate while Pasadena sits on the Board and Committee and has never expressed these concerns or provided alternative suggestions.

## Response:

PWP values the efforts made by RBMB over the years to support the groundwater basin. This statement has been removed from the final report.
19. Page 2-17 - The WSRP includes "Historic Pasadena Area Groundwater Levels" and indicates source is from RBMB Draft Opportunities to Enhance Groundwater Levels in Pasadena Subarea. RBMB does not recognize this graph. Please indicate where the graph was obtained and which well(s) the water levels represent and provide a location map of why this is a good representation of the Pasadena Subarea.

Response: PWP's consultant developed the graph based on data from RBMB.
20. Page 4-1 - RBMB would like the opportunity to review the data from the Pasadena simulation model including inputs and outputs data.

## Response:

PWP does not have the model developed by PWP's consultant which was used for the WSRP assessment.
21. Page 4-2 - In the WSRP discussion on Groundwater Supply, there are several assumptions made for "modeling". Any party to the RBMB can certainly make internal management assumptions and model different scenarios; however, the provisions of the RBMB Judgment must be followed and water rights be respected. The WSRP also appears to not recognize the inconsistency of reliance on LTS (declining WLs) and the stated goal of restoring basin water levels and basin sustainability.

Response: Thank you for the comment.
22. Page $4-5$ - Figure $4-1$ stops in 2009 , why is the most recent drought not included?

## Response:

Figure 4-1 illustrates that diversions fluctuate over time depending on rainfall and increased flows. The 2009 Station Fire in the Angeles National Forest and the subsequent storms damaged PWP's diversion facilities in the Arroyo Seco, rendering more recent data inaccurate. Historical spreading and available flows provide enough data to present the correct message.
23. Page 5-8 - The WSRP describes a potential Raymond Basin imported water storage project. The RBMB has always supported review and consideration of new groundwater storage projects that will benefit the Basin. Similar to efforts to "revive" water levels throughout the Basin, in order for RBMB to implement new groundwater storage projects, we need producer participation, producer consensus and funding sources. In the Monk Hill Subarea, there has been no progress in pushing forward defined projects and storage agreements with MWD, even though Pasadena is a

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MWD member agency, the majority water rights holder and owner of the spreading facilities in that subarea.

Response: Yes, those projects require participation, consensus, and funding.
24. Page 5-10 - The WSRP discusses various options to enhance Pasadena's groundwater pumping rights through improved conservation of local water supplies. The RBMB fully supports increased conservation of local water supplies to benefit the Basin. RBMB also advises that all storage credits must comply with the RBMB Judgment. In addition, all beneficial uses of surface water (groundwater storage, potable and non-potable use) must comply with the RBMB Judgment. This includes centralized capture of stormwater, Low Impact Development Programs, MS-4 programs and compliance with Enhanced Watershed Management Plans.

Response: Yes, PWP agrees. Thank you for the comment.

| City of Alhambra | April 27, 2021 |
| :---: | :---: |
| City of Arcadia |  |
| California-American Water Company | City of Pasadena |
|  | Water and Power Department |
| East Pasadena Water Company | 150 South Los Robles Avenue, Suite 200 |
|  | Pasadena, California 91101 |
| H.E. Huntington Library and Art Gallery | Re: Public Draft - Water System and Resources Plan |
| Kinneloa Irrigation District | Raymond Basin Management Board staff was recently made aware of the City of Pasadena's |
| La Canada Irrigation District | Public Draft Water System and Resources Plan (WSRP), dated May 2020 (Woodard \& Curran), and asked by representatives of the Arroyo Seco Foundation to respond to specific references in the plan to Basin resources and overall management. |
| Las Flores Water Company |  |
|  | The Raymond Basin Management Board (RBMB) staff performed an initial review of the City of |
| Lincoln Avenue Water Company | Pasadena's WSRP. The RBMB provides general comments here, and more specific comments below. |
| Pasadena Cemetery Association | The WSRP is a very extensive and detailed plan to guide Pasadena's future water supply. The |
|  | RBMB applauds and supports Pasadena's efforts to maintain and improve Pasadena's future water |
| City of Pasadena | supplies. |
| Rubio Canon Land and Water Association | The RBMB would like to express serious concerns with multiple parts and provisions of this |
| San Gabriel County Water District | "exclusion" of the RBMB (court-appointed manager of the Raymond Basin Judgment) from the entire WSRP process, even though Pasadena sits as a voting member of the RBMB and its |
| City of Sierra Madre | Pumping and Storage Committee ( $\mathrm{P} \& ~ \mathrm{~S}$ Committee). This oversight manifests itself in multiple areas of misstatements and incomplete presentation of the efforts and work by the RBMB and |
| Sunny Slope Water Company | staff. |
|  |  |
| Valley Water Company | It is inappropriate for Pasadena's WSRP to criticize the RBMB's management of the Basin, under the Judgement, while being represented as a voting member of the RBMB and Committees. There is no record of Pasadena's criticisms or suggested alternative solutions at the RBMB. On the contrary, the RBMB staff has made multiple attempts and efforts to identify, characterize basin issues, and present alternative solutions to water supply concerns on all three Basin subareas. Pasadena has participated, and at times, supported, and opposed, RBMB-presented alternative solutions. At no time has Pasadena presented a reasonable and viable Basin management alternative that was not fully presented and vetted by the RBMB and staff. |

Throughout this WSRP, there are suggested concepts and programs to "increase" Pasadena's "rights" to pump groundwater. It must be clear, any concepts or programs relating to increased pumping must be consistent with the Raymond Basin Judgment and approved by the RBMB.

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The RBMB staff has consistently emphasized that significant water in LTS accounts, and declining groundwater levels, are inconsistent. The RBMB staff considers the water in LTS accounts to be "paper water", while Basin groundwater levels are declining. Pumping LTS water has been documented to exacerbate declining water levels.

RBMB Staff has performed an initial review of the WSRP with the following comments noted below:

Page 1 - The Pasadena WSRP emphasizes, "greater dependency on local water" and "groundwater basin sustainability". This is the role and responsibility of the RBMB. This WSRP should have been coordinated for review by the RBMB, by the City of Pasadena as an internal "draft", before public release.

Page 1 - The Pasadena WSRP Stakeholder Advisory Group (SAG) did not include the RBMB. Typically when agency planning involves outside entities, there is some mechanism included in the process for technical review and discussion by those agencies, such as the RBMB.

Page 3 - The WSRP indicates Pasadena's water use "likely" to decline from 28,500 AFY to 23,500 AFY by 2030. This assumption of significant water conservation is not a given and will artificially influence water resources planning.

Page 3 - The WSRP indicates groundwater is declining and must be "revived". The RBMB has presented several concepts and programs to "revive" groundwater levels in both the Pasadena and Monk Hill Subareas. However, short of going back to the Court to amend the water rights allocations, all of RBMB concepts require at least three components: Producer Participation, Producer Consensus, and funding sources as needed. This approach has met with some success in the Santa Anita and Pasadena Subareas.

Page 3 - The WSRP indicates Pasadena's Preferred Portfolio is $50 \%$ GW, assuming "reduced" demand. This assumption of significant water conservation is not a given and will artificially influence water resources planning.

Page 4 - The WSRP indicates Pasadena is Planning for "banking" wet-year discounted imported water. RBMB believes there is no basis demonstrated for this assumption of "discounted" imported water on an ongoing basis. Plans for storing imported water must assume at a minimum, some purchases at full-service rates.

Page 5 - The WSRP suggests "retooling of policies" to manage and balance Raymond Basin. RBMB has not been advised of these "new concepts", despite regular Pumping \& Storage Committee and Monk Hill Task Force meetings with Pasadena present.

Page 1-1 - The WSRP describes Pasadena's surface diversion rights. It is important to note that these rights are not unlimited. RBMB suggests more detail be included on "limits" to surface diversions based on water rights.

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Page 1-1 - The WSRP describes the $30 \%$ reduction of pumping rights. RBMB suggests adding context and history to the water rights adjustment- Decreed rights were raised too high in 1955 and not reevaluated from time to time as suggested in 1955.

Page 1-3 - The WSRP indicates defined Goals and Objectives were developed in partnership with SAG. The RBMB should have been included, at a minimum, from a technical perspective, in these Basin specific discussions in addition to SAG.

Page 1-4 - The WSRP indicated SAG was selected as a diverse group. The omission of the RBMB from the plan development is significant, and severely challenges the application of this WSRP.

Page 2-1 - The WSRP indicates Pasadena purchased portions of Arroyo Seco and Eaton Wash watersheds. More detail is needed, including a description of additional associated surface water rights. New recharge facilities will require Board approval and adoption of measurement and reporting procedures.

Page 2-12 - The WSRP indicates approximately 6,000 to 10,000 AFY are estimated to leak from the eastern portion (primarily Santa Anita Subarea) of this basin to the Main San Gabriel Basin (MSGB), and that pumping to historically low groundwater levels in MSGB increases leakage. These statements are not supported with current information and data. No technical information is provided. The statement on leakage should be significantly "qualified" and the statement regarding groundwater levels in MSGB increasing leakage be removed.

Page 2-13 - The WSRP indicates Pasadena will be (1) implementing specific projects in RB to reduce loss (leakage) of groundwater to MSGB, (2) revise policy on Basin sustainability, (3) develop Basin protection policies and guidelines for Basin wide adoption. RBMB advises these are the roles and responsibilities of the RBMB. Pasadena is on the RBMB and all committees. Pasadena has not introduced any of these concepts in any form to the RBMB. Had RBMB input been included in the WSRP draft, some of these concepts could have already been vetted.

Page 2-14 - The WSRP indicates "... on July 1, 2009, the RBMB implemented a resolution that voluntary reduced pumping from the Pasadena subarea for a term of five years." This statement is incorrect. In order to meet the goal of $30 \%$ reduction, water production reductions were implemented incrementally at a rate of $1,070 \mathrm{AFY}$ for over a five year period. The $30 \%$ reduction plan is still in place and there is no term limit of five years. The WSRP needs to include more details on why the $30 \%$ reduction plan was implemented. The RBMB determined the redetermination of the Safe Yield in 1955 and the adoption of the Long-Term Storage (LTS) Policy by the RBMB in 1993 played a major role in lower overall groundwater levels that the Pasadena subarea was experiencing.

Page 2-16, 4-3 - The WSRP indicates Pasadena's current "long-term storage" is 13,400 AF in Monk Hill and 20,600 AF in Pasadena subareas. The WSRP indicates, "Long-term storage is the key underpinning Pasadena's water supply resiliency". The RBMB suggests this discussion be clarified to include (1) termination of long-term storage when accounts are exhausted (no new storage), and (2) current declining water levels while water is "stored" in LTS accounts. RBMB

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determined the LTS Policy adopted in 1993 was one factor in lower overall groundwater levels the Pasadena subarea was experiencing.

Page 2-17 - The WSRP states, "...governing practices confound groundwater pumping capacity in the area." The RBMB is unaware of the "practices" referred to in the WSRP. The RBMB was not included in the SAG and has not been advised of these Pasadena concerns at any RBMB meetings or Committee meetings, where Pasadena is a voting member. Pasadena suggesting the RBMB has "failed" to address sustainability of the basin in the WSRP, is totally inappropriate while Pasadena sits on the Board and Committee and has never expressed these concerns or provided alternative suggestions.

Page 2-17 - The WSRP includes "Historic Pasadena Area Groundwater Levels" and indicates source is from RBMB Draft Opportunities to Enhance Groundwater Levels in Pasadena Subarea. RBMB does not recognize this graph. Please indicate where the graph was obtained and which well(s) the water levels represent and provide a location map of why this is a good representation of the Pasadena Subarea.

Page 4-1 - RBMB would like the opportunity to review the data from the Pasadena simulation model including inputs and outputs data.

Page 4-2 - In the WSRP discussion on Groundwater Supply, there are several assumptions made for "modeling". Any Party to the RBMB can certainly make internal management assumptions and model different scenarios; however, it should be stated and understood, in the WSRP, that the provisions of the RBMB Judgment must be followed and water rights be respected. The WSRP also appears to not recognize the inconsistency of reliance on LTS (declining WLs) and the stated goal of restoring basin water levels and basin sustainability.

Page 4-5 - Figure 4-1 stops in 2009, why is the most recent drought not included?
Page 5-8 - The WSRP describes a potential Raymond Basin imported water storage project. The RBMB has always supported review and consideration of new groundwater storage projects that will benefit the Basin. Similar to efforts to "revive" water levels throughout the Basin, in order for RBMB to implement new groundwater storage projects, we need producer participation, producer consensus and funding sources. In the Monk Hill Subarea, there has been no progress in pushing forward defined projects and storage agreements with MWD, even though Pasadena is a MWD member agency, the majority water rights holder and owner of the spreading facilities in that subarea.

Page 5-10 - The WSRP discusses various options to enhance Pasadena's groundwater pumping rights through improved conservation of local water supplies. The RBMB fully supports increased conservation of local water supplies to benefit the Basin. RBMB also advises that all storage credits must comply with the RBMB Judgment. In addition, all beneficial uses of surface water (groundwater storage, potable and non-potable use) must comply with the RBMB Judgment. This includes centralized capture of stormwater, Low Impact Development Programs, MS-4 programs and compliance with Enhanced Watershed Management Plans.

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Please don't hesitate to contact me with any questions you have regarding these comments. I can be reached by telephone at 626-815-1300 or by email at tony@watermaster.org.

Sincerely,


Anthony C. Zampiello
Executive Officer
Raymond Basin Management Board


[^0]:    ${ }^{1}$ Handbook of Cast Iron Pipe, 1927

[^1]:    ${ }^{1}$ The conclusions in this report are based upon the available information and evidence provided by the client and gathered by Anamet, within the scope of work authorized by the client, and they are hereby presented by Anamet to a reasonable degree of engineering and scientific certainty. Anamet reserves the right to amend or supplement its conclusions or opinions presented in this report should additional data or information become available, or further work be approved by the client.

[^2]:    ${ }^{1}$ Ellison, D., Bell, G., Reiber, S., Spencer, D., \& al., e. (2014). Answers to Challenging Infrastructure Management Questions. Water Research Foundation and EPA, Infrastructure. Washington, D.C.: Water Research Foundation. Retrieved from http://www.waterrf.org/PublicReportLibrary/4367.pdf

