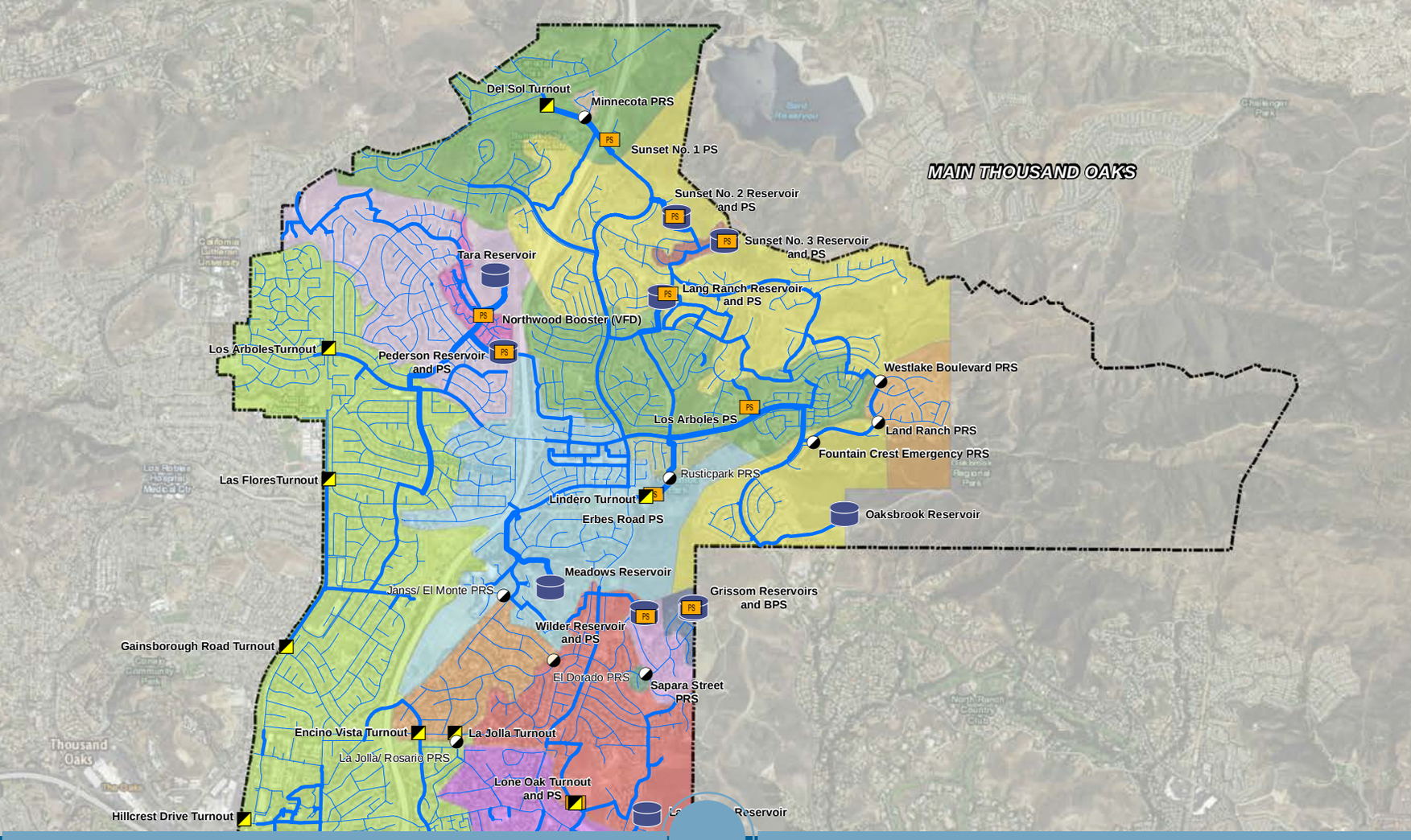

Water Master Plan

February 2018 (Second Edition)

City of Thousand Oaks

Kennedy/Jenks Consultants

Kennedy/Jenks Consultants

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Water Master Plan
FINAL REPORT

February 2018
(2nd Edition)

Prepared for

City of Thousand Oaks
2100 Thousand Oaks Boulevard
Thousand Oaks, CA 91362

K/J Project No. 1544510*00

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List of Abbreviations

AC	Asbestos Cement
ac	acre
ADD	Average Day Demand
AF	Acre-Feet
AFY	Acre-Feet per Year
AWWA	American Water Works Association
Cal Am	California American Water Company
Cal Water	California Water Service Company
Calleguas	Calleguas Municipal Water District
CFC	California Fire Code
cfs	cubic feet per second
CI	Cast Iron
CIP	Capital Improvement Plan
City	City of Thousand Oaks
CRC	Capacity Reservation Charge
CWS	Circular Welded-Steel
DBP	Disinfection Byproduct
DI	Ductile Iron
DPR	Direct Potable Reuse
DWR	California Department of Water Resources
EDU	Equivalent Dwelling Unit
EPS	Extended Period Simulation
FAR	Floor Area Ratio
FCV	Flow Control Valve
FEIR	Final Environmental Impact Report
ft msl	feet above mean sea level
ft/s	feet per second
gpd or GPD	gallons per day
gpm or GPM	gallons per minute
HGL	Hydraulic Grade Line
HPC	Heterotrophic plate count
Hydro	Hydropneumatic
ksf	thousand square feet
LF	Lineal Feet
LVMWD	Las Virgenes Municipal Water District
MDD	Maximum Day Demand
MDD+FF	Maximum Day Demand + Fire Flow
MG	million gallons
MinDD	Minimum Day Demand
MWDSC	Metropolitan Water District of Southern California
PHD	Peak Hour Demand
PHD+FF	Peak Hour Demand + Fire Flow
PRS	Pressure Reducing Station
PRV	Pressure Reducing Valve
PS	Pump Station

psi	pound per square inch
PVC	Polyvinyl Chloride
RCS	Residual Control System
RRC	Rectangular Reinforced Concrete
SCADA	Supervisory Control And Data Acquisition
SCE	Southern California Edison
SR	State Route
STL	Steel
SWP	State Water Project
TO	Turnout
TOBLSP	Thousand Oaks Boulevard Specific Plan
TOU	Time-Of-Use
UNK	Unknown
VCFD	Ventura County Fire Department
VCPWA	Ventura County Public Works Agency
VCWWD6	Ventura County Water Works District 6

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Executive Summary

The City of Thousand Oaks provides water service to approximately 17,000 service connections across 11,300 acres mostly within the City limits. This Water Master Plan Report consists of the following sections:

- **Section 1 – Introduction** describes the study area, the City's water system history and the study's objectives.

- **Section 2 – System Description** describes the existing water distribution system and its major components, including pipelines, supply turnouts, pump stations, reservoirs and pressure reducing stations.

- **Section 3 – Water Supplies and Demands** describes the City's water supply sources including imported water, groundwater, and interconnection with other agencies. The section also presents a discussion on historical water demands and supplies since 2011, demand variation and peaking, and future demands.

- **Section 4 – Water System Evaluation** presents a discussion on hydraulic model update and calibration, planning and evaluation criteria, and system evaluation results and recommendations.

- **Section 5 – Water Quality Evaluation** describes two distinct water quality evaluations performed as part of this Water Master Plan and the associated recommendations: (1) reservoir mixing and disinfection boosting pilot study, and (2) water age modeling evaluations.

- **Section 6 – Capital Improvement Plan** presents the recommended projects, their implementation priority and planning-level capital cost estimates.

The City is reliant on imported water from the Calleguas Municipal Water District for potable water supply. Potable water is delivered via 11 supply turnouts and dispersed into 19 service pressure zones via gravity, pump stations and pressure reducing stations. In addition, the City's water system includes 16 storage reservoirs, 15 pump stations, 10 pressure reducing stations and approximately 232 miles of pipelines ranging in size from 3- to 24-inches in diameter. The City is currently in the process of designing a new pump station to supply the Wilder Pressure Zone from the Freeway/ La Granada Pressure Zone (La Granada Pump Station).

Water delivery data indicates that the system's highest annual demand since 2011 was approximately 12,800 acre-feet per year (AFY) which occurred in 2013-14. Water demands have since declined by about 30 percent to approximately 8,900 AFY in 2015-16. The system's maximum day demand since 2011 was approximately 18.7 Million Gallons per Day (MGD).

The City's water service area is near buildout with only about 452 acres of developable vacant parcels available. Of this amount, approximately 417 acres is planned to be developed by 2040 with the remaining 35 acres assumed to be developed sometime beyond 2040. The development of these vacant parcels will increase the City's baseline demand. The proposed

redevelopment of the Thousand Oaks Boulevard corridor (Thousand Oaks Boulevard Specific Plan) is also expected to increase the City's baseline demand.

The projected increase in average annual demand from planned developments and redevelopments and developable vacant lands is estimated at 414 AFY or just over 3 percent of the annual demand in 2013-14.

The City's water distribution system was analyzed under normal demand, supply and operating conditions using the City's H2OMAP Water hydraulic model software. The model was updated and calibrated prior to use. Desktop evaluations were also performed to evaluate the pressure zones' supply and storage capacities. In summary, the analysis showed that the existing system for the most part has adequate hydraulic capacity to meet the projected maximum day demands under buildout conditions.

The hydraulic model was also utilized to develop operational strategies and system improvements to reduce the system's water age to the extent possible. The modeling evaluations showed that water age could be significantly reduced through a combination of operational modifications and relatively minor system improvements. The primary contributing factor for high water age in the system was identified to be the relatively high ratio of total storage to water demands. Other factors with significant impact on water age were also identified and mitigating improvements were recommended.

The reservoir mixing and disinfection boosting pilot study evaluated the effectiveness of adding mixers and/or chlorine/ammonia boosting on the water quality as means to control nitrification. The study demonstrated that the addition of PAX mixers to reservoirs provided improvements in water quality. Adding to the mixer the ability to boost chemical (chlorine and/or ammonia with a control over the dosing ratio) using the PAX RCS resulted in consistently good water quality for the two reservoirs in the study with a mixer and the PAX RCS (Willow Lane and Pederson).

A Capital Improvement Plan (CIP) consisting of the improvement projects recommended as part of this Water Master Plan was prepared. The CIP provides project IDs, names, descriptions, locations, justification, deficiency type, priority, and estimated construction and capital costs. The total capital cost for the recommended projects was estimated at about $6,500,000.

Section 1: Introduction

1.1 Study Area

The City of Thousand Oaks (City) was incorporated in 1964 in the southeastern region of the Ventura County. At the time, the City accommodated 20,000 people and spanned an area of 9,140 acres (14.28 miles). Since then, the City has grown to approximately 130,000 in population and now encompasses an area of 34,700 acres (56 square miles) as of 2015. The vicinity map of the City is shown in **Figure 1-1**.

Currently, the City is the water purveyor for approximately one third of the City. The allocation of purveyors serving the City is summarized below:

- City of Thousand Oaks: 31 percent
- California American Water Company (Cal Am): 43 percent
- California Water Service Company (Cal Water): 23 percent
- Camrosa Water District: 2 percent
- Newbury Park Academy Mutual Water Company: less than 1 percent

The potable water distributed by the City is imported water from Calleguas Municipal Water District (Calleguas), which receives its supply from the Metropolitan Water District of Southern California's (MWDSC's) Jensen Treatment Plant. The treatment plant's primary supply source is the State Water Project (SWP) water from the California Aqueduct.

The City's existing water distribution system is divided into two service areas: the Main Thousand Oaks service area and the Newbury Park service area. In total, currently the distribution system includes 11 supply turnouts from Calleguas, 15 pump stations (not including the proposed La Granada Pump Station), 16 reservoirs, and approximately 230 miles of transmission and distribution pipelines. The City purchased approximately 9,600 acre-feet (AF) of water in 2015.

The primary land use within the City's water service area is residential. The ground elevation throughout the service area ranges from about 600 to 1,500 feet above mean sea level (ft msl) with elevations generally increasing from west to east.

Two major freeways intersect the City and aid in forming a boundary for the City water service areas. Traveling north to south is California State Route 23 (SR-23) running along the center of the main Thousand Oaks service area. US Route 101 runs east to west and cuts through the southern side of the main Thousand Oaks service area and also delineates the northern boundary for the Newbury Park service area. In addition, the City serves unincorporated areas within Ventura County, including the Rolling Oaks pressure zone and several small pockets within the Newbury Park service area. All service boundaries, including the unincorporated areas, are shown in **Figure 1-2**.

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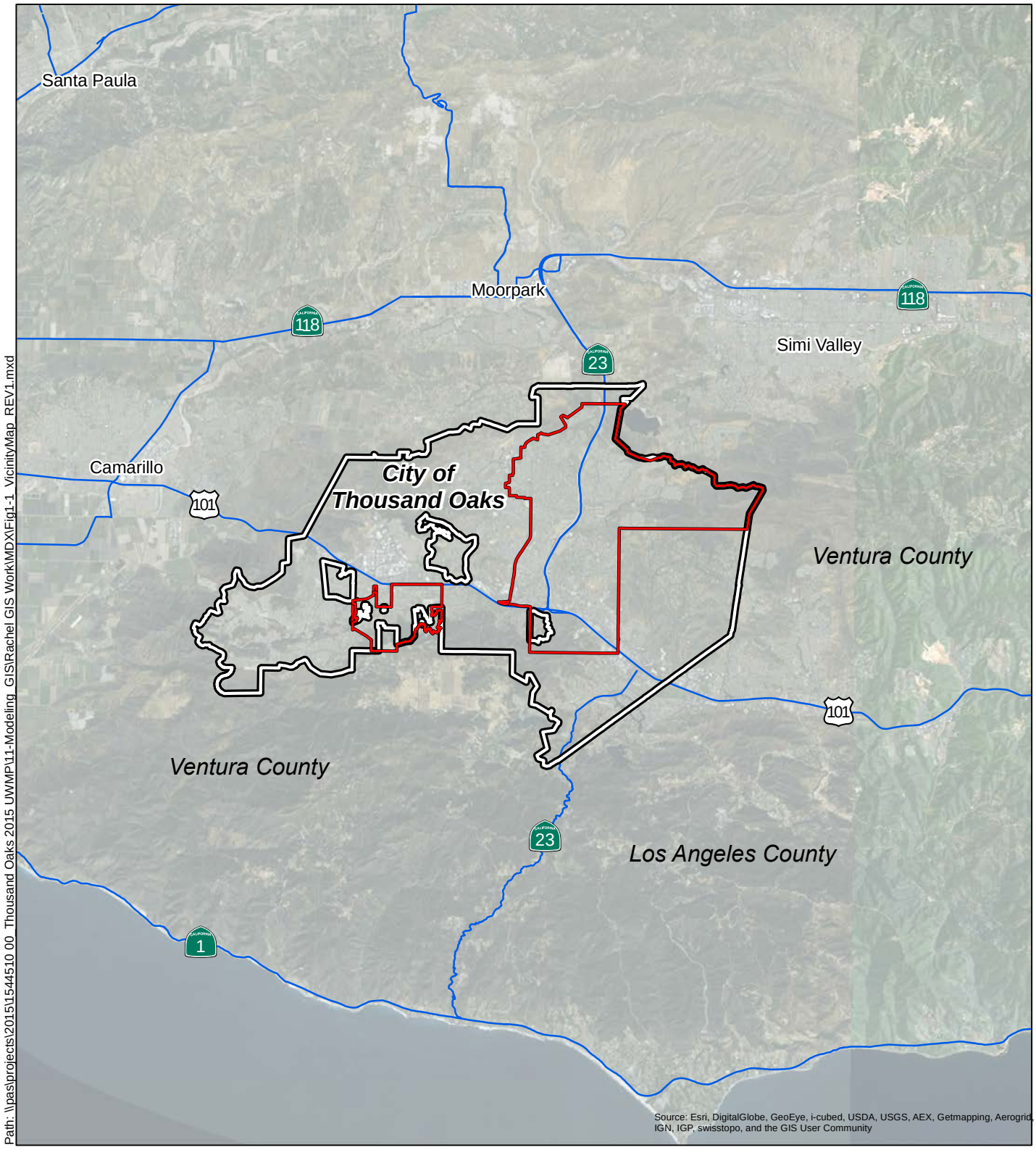

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City of Thousand Oaks Water Service Boundary

City of Thousand Oaks

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Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

City of Thousand Oaks
Vicinity Map

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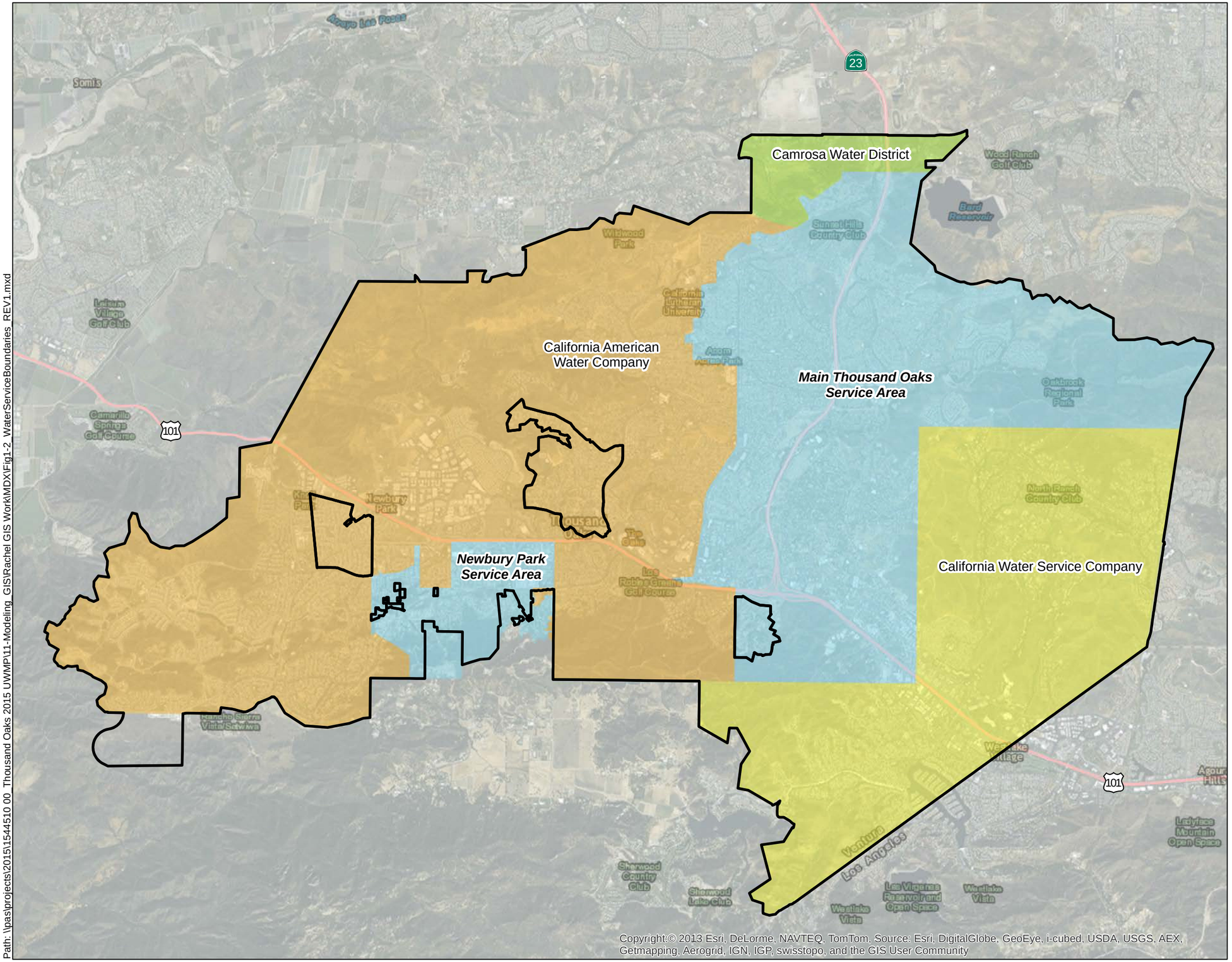
Figure 1-1



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- City of Thousand Oaks Boundary
- City of Thousand Oaks Water Service Boundary
- California American Water Company
- Camrosa Water District
- California Water Service Company

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Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

City of Thousand Oaks Water Purveyor Service Areas

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Figure 1-2

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1.2 City History

During the mid-twentieth century, the Conejo Valley was primarily served by small mutual or private water companies, often set up by land developers. However, in 1947 the Ventura County Water Works District 6 (VCWWD6) was formed under the jurisdiction of the County of Ventura. Then, in 1958 the Ventura County Board of Supervisors agreed to make the VCWWD6 autonomous with its own local Board of Directors due to customer dissatisfaction with their water service.

Over the next several years, VCWWD6 acquired several water systems including Burwood Mutual, Waverly Heights Mutual, Ventu Park Mutual, Westgate Estates Mutual, and Starlight Ranchos Mutual. Then, in 1963 the Newbury Park System (Kelley Estates/ Ventu Park) was annexed, which happened concurrently with the first backbone facilities being placed in that area of Thousand Oaks. In 1964, the City of Thousand Oaks was incorporated, and in 1966 the City Council was appointed to sit as the Board of Directors for the VCWWD6, making the VCWWD6 a subsidiary District to the City to this day. Although the appointment of the Board of Directors was due largely in part to the financial challenges VCWWD6 was facing, the City today is debt free.

However, the entirety of the City was not served by VCWWD6. During the 1950's and 1960's, the Village Water Company, formed by the Janss Corporation, served the Janss Mall and surrounding developments. VCWWD6 was in opposition to the formation of the Village Water Company, so an agreement was consequently reached that would not allow the Village Water Company to serve properties east of Moorpark Road, with the exception of the Conejo Oaks system. In 1967, the Village Water Company was sold to Cal Am, which still exists today.

The Conejo Oaks system was an area served by Cal Am, but was essentially an island surrounded by the City's service area. In order to realign the City's service area, the California Public Utilities Commission approved a Settlement Agreement in 2004 to exchange the City's Academy service area within Cal Am property for Cal Am's Conejo Oaks Service area. The annexation into the City water system was completed in January of 2008.

1.3 Project Objective

Kennedy/Jenks Consultants (Kennedy/Jenks) was contracted by the City in July of 2015 to concurrently update the City's 2010 Urban Water Management Plan (RBF, 2011) and 2005 Water Master Plan (RBF, 2005). The present report, which is an update to the latter document, will provide the City with a road map for future water supply and infrastructure improvement projects. The update to the former document is provided separately.

The primary focus of this master plan update was water quality evaluation and enhancement through various capital and/or operational improvements. As outlined in the following sub-section, the water quality evaluation included:

- Review and evaluation of water quality monitoring data to develop nitrification control recommendations (conducted by Trussell Technologies Inc. as a sub-consultant to Kennedy/Jenks)

- Hydraulic modeling analysis to develop recommendations to enhance water age within the system (conducted by Kennedy/Jenks)

1.4 Report Organization

This subsection provides a brief description of major topics discussed within each report section.

Section 1 – Introduction describes the study area, the City's water system history and the study's objectives.

Section 2 – System Description describes the existing water distribution system and its major components, including pipelines, supply turnouts, pump stations, reservoirs and pressure reducing stations.

Section 3 – Water Supplies and Demands describes the City's water supply sources including imported water, groundwater, and interconnection with other agencies. The section also presents a discussion on historical water demands and supplies since 2011, demand variation and peaking, and future demands.

Section 4 – Water System Evaluation presents a discussion on hydraulic model update and calibration, planning and evaluation criteria, and system evaluation results and recommendations.

Section 5 – Water Quality Evaluation describes two distinct water quality evaluations performed as part of this Master Plan and the associated recommendations: (1) a reservoir mixing and disinfection boosting pilot study, and (2) water age modeling evaluations. The reservoir mixing and disinfection boosting pilot study conducted from October 2015 through April 2016 is summarized along with its recommendations in this section, with a detailed Technical Memorandum in **Appendix F**.

Section 6 – Capital Improvement Plan presents the recommended projects, their implementation priority and planning-level capital cost estimates.

1.5 Reference Documents

The reports and documents reviewed and utilized in preparation of this Water Master Plan are referenced in **Appendix A**.

Section 2: System Description

This section describes the City's existing water distribution facilities including turnouts, reservoirs, pumping stations, pressure reducing stations (PRSs), and distribution system pipelines.

2.1 Billing and Pressure Zones

The City's water service area is separated into four different billing zones due to the varying range of surface elevations that require various levels of pumping. The billing zones are defined based on the number of lifts, or times the water must be pumped to reach the zones. The billing zones and their corresponding lifts are presented in **Table 2-1**.

Table 2-1: Thousand Oaks Billing Zones and Corresponding Number of Lifts

Billing Zone	Number of Lifts
1	0
2	1
3	2
4	3

The City's distribution system consists of 21 pressure zones including 11 open system and 10 closed system zones. The billing and pressure zone boundaries are shown in **Figure 2-1**.

The closed system zones include four hydropneumatic zones (Kelley Hydro, Ventu Hydro, Sunset 3 Hydro and Grissom Hydro), one zone supplied by a variable speed pump station (Northwood Booster) and five regulated zones (Conejo Oaks, Reduced Lang Ranch/ Sunset No. 2, Reduced Minnecota, Reduced Lang Ranch and Reduced Sapra).

The City's pressure zones are summarized in **Table 2-2**. The pressure zone nominal hydraulic grade lines (HGLs) range from 951 to 1611 ft msl. The pressure zone surface areas range from 8 to 1,973 acres.

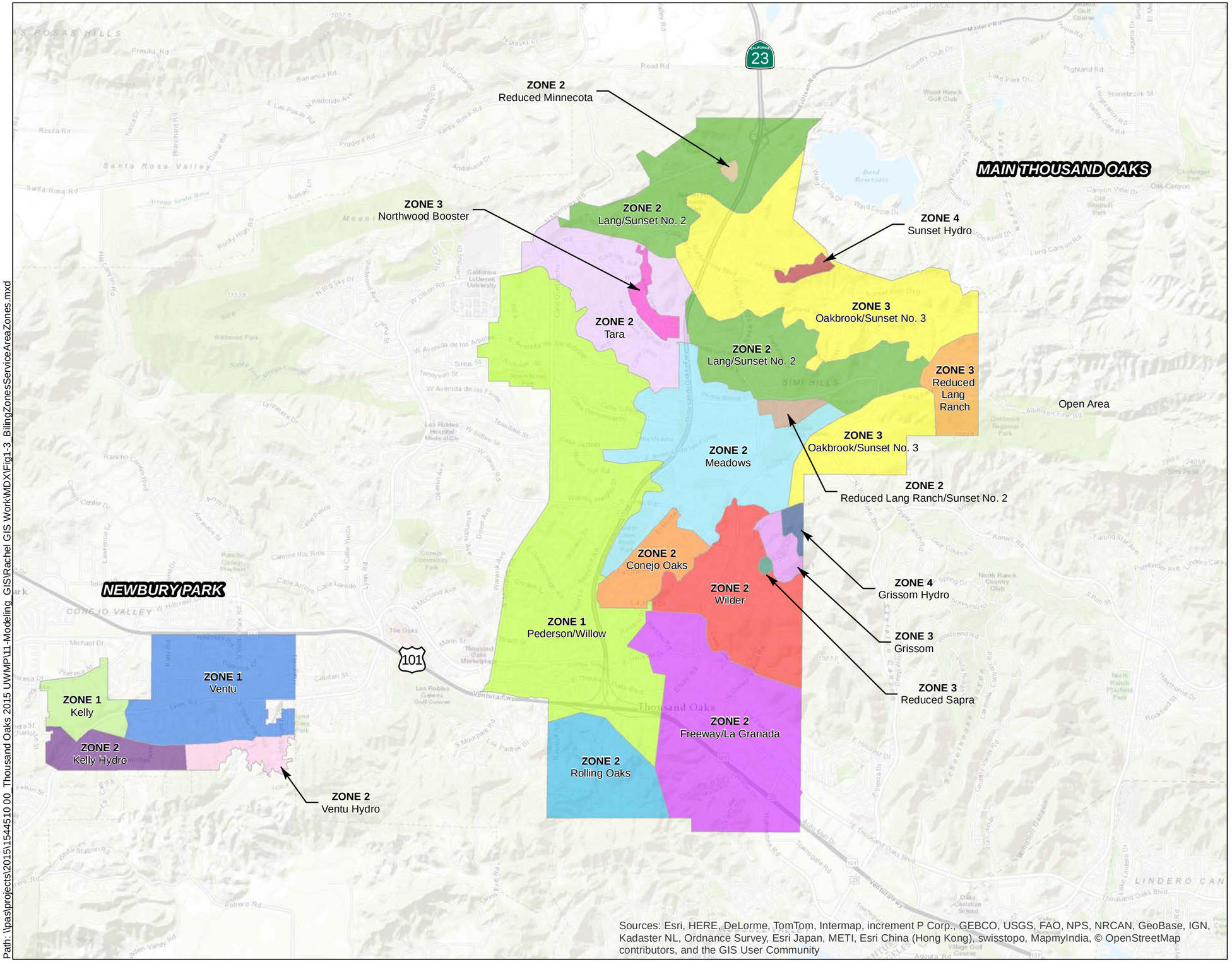
The following subsections provide a brief description of each pressure zone within the Newbury Park and Main Thousand Oaks service areas.

Table 2-2: Summary of Existing Pressure Zones

No.	Service Area	Billing Zone	Pressure Zone	Nominal HGL (feet msl)	Acreage (acres)
1	NEWBURY PARK	1	Kelley[1]	951	172
2			Ventu[1]	970	637
3		2	Kelley Hydro[2]	1,117	182
4			Ventu Hydro[2]	1,190	102
5	MAIN THOUSAND OAKS	1	Pederson/ Willow[1]	975	1,973
6		2	Conejo Oaks[3]	1,040/1,095	185
7			Freeway/ La Granada[1]	1,085	1,043
8			Lang Ranch/ Sunset No. 2[1]	1,271	1,205
9			Meadows[1]	1,092	880
10			Reduced Lang Ranch/ Sunset No. 2[3]	1,122	50
11			Reduced Minnecota[3]	1,083	11
12			Rolling Oaks[1]	1,098	399
13			Tara[1]	1,092	578
14			Wilder[1]	1,223	581
15		3	Grissom[1]	1,488	77
16			Northwood Booster[2]	1,165	62
17			Oakbrook/ Sunset No. 3[1]	1,503	1,424
18			Reduced Lang Ranch[3]	1,518	180
19			Reduced Sapra[3]	1,343	8
20		4	Grissom Hydro[2]	1,611	31
21			Sunset Hydro[2]	1,600	31

Notes:

1. Normal pressure zone (zones with dedicated gravity storage)
2. Closed pressure zone (zones with hydropenumatic or variable speed supply pump station)
3. Regulated pressure zone (zones supplied and regulated by pressure reducing stations)



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Legend

Billing Zone - Pressure Zone

- Zone 1 - Kelly
- Zone 1 - Pederson/Willow
- Zone 1 - Ventu
- Zone 2 - Conejo Oaks
- Zone 2 - Freeway/La Granada
- Zone 2 - Kelly Hydro
- Zone 2 - Lang/Sunset No. 2
- Zone 2 - Meadows
- Zone 2 - Reduced Lang/Sunset2
- Zone 2 - Reduced Minnecota
- Zone 2 - Rolling Oaks
- Zone 2 - Tara
- Zone 2 - Ventu Hydro
- Zone 2 - Wilder
- Zone 3 - Grissom
- Zone 3 - Northwood Booster
- Zone 3 - Oakbrook/Sunset No. 3
- Zone 3 - Reduced Lang Ranch
- Zone 3 - Reduced Sapra
- Zone 4 - Grissom Hydro
- Zone 4 - Sunset Hydro

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City of Thousand Oaks Water Master Plan
Thousand Oaks, California

City of Thousand Oaks
Water Service Area
Billing and Pressure Zone Boundaries

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Figure 2-1

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2.1.1 Newbury Park Service Area Pressure Zones

This subsection describes the existing pressure zones within the Newbury Park Service Area.

Kelley

The Kelley Zone is located in the western region of the Newbury Park service area and is supplied by the West Kelley Turnout. The pressure zone spans approximately 172 acres and has a nominal HGL of 951 feet. The zone's HGL is regulated by the Kelley Reservoir, where there is also a booster pump station supplying the Kelley Hydropneumatic Zone. In the event of a significant pressure loss, Kelley will be supplied from the Ventu Zone via the Lynn Road Emergency PRS.

Ventu

The Ventu Zone is located in the eastern region of the Newbury Park service area and is supplied by the Ventu Park Turnout. The pressure zone spans approximately 637 acres and has a nominal HGL of 970 feet. The zone's HGL is regulated by the Ventu Park Reservoir, where there is also a booster pump station supplying the Ventu Park Hydropneumatic Zone.

The Lynn Road Emergency PRS can be operated manually in reverse direction, allowing Ventu to be supplied from the Kelley Zone during emergencies. However, the PRS will not be able to fully refill the Ventu Park Reservoir.

Kelley Hydropneumatic

The Kelley Hydropneumatic Zone is a closed loop system located in the southwest region of the Newbury Park service area. Water stored at the Kelley Reservoir is boosted via the Kelley Hydropneumatic pump station to supply this zone. The pressure zone spans approximately 182 acres and has a nominal HGL of 1,117 feet.

Ventu Hydropneumatic

The Ventu Hydropneumatic Zone is a closed loop system located in the southeast region of the Newbury Park service area. Water stored at the Ventu Park Reservoir is boosted via the Ventu Hydropneumatic pump station to supply this zone. The pressure zone spans approximately 102 acres and has a nominal HGL of 1,190 feet.

2.1.2 Main Thousand Oaks Service Area Pressure Zones

This section describes the 17 pressure zones within the Main Thousand Oaks Service Area.

Pederson/Willow

The Pederson/Willow Zone is located in the western region of the Main Thousand Oaks service area and is supplied by the Hillcrest, Gainsborough, Las Flores, Los Arboles, and Encino Vista turnouts. The pressure zone spans approximately 1,973 acres and has a nominal HGL of 975 feet. The zone's HGL is regulated by the Pederson and Willow Lane reservoirs. From the

Pederson/ Willow Zone, water is boosted to the Rolling Oaks, Freeway/ La Granada, and the Tara pressure zones.

Conejo Oaks

This regulated pressure zone was formerly owned and operated by Cal Am. The majority of the zone is supplied and regulated by Meadows and Freeway/ La Granada pressure zones via the Janss/ El Monte and La Jolla/ Rosario PRSs, respectively. Additionally, the zone can be supplied from the La Jolla turnout during emergencies. The pressure zone spans approximately 209 acres and has a nominal HGL of 1,040 feet.

A small area along Eldorado Drive is hydraulically separated from the rest of the zone via a normally closed gate valve. This area is served from Wilder Zone via the Eldorado PRS. The nominal HGL of this isolated area is 1,096 feet.

Freeway/ La Granada

The Freeway/ La Granada Zone is located in the southeast region of the Main Thousand Oaks service area and is supplied by the Willow Lane and the Lone Oak pump stations, which are in turn supplied from the Pederson/ Willow Zone and the Lone Oak Turnout, respectively. The pressure zone spans approximately 1,043 acres and has a nominal HGL of 1,085 feet. The zone's HGL is regulated by the Freeway and La Granada reservoirs.

Meadows

The Meadows Zone is located in the central region of the Main Thousand Oaks service area and is supplied by the Erbes Road Pump Station, which receives water from the Lindero Turnout. The pressure zone spans approximately 880 acres and has a nominal HGL of 1,092 feet. The zone's HGL is regulated by the Meadows Reservoir.

Tara

The Tara Zone is located in the northwest region of the Main Thousand Oaks service area and is supplied from the Pederson/ Willow Zone via the Pederson Pump Station. The pressure zone spans approximately 578 acres and has a nominal HGL of 1,092 feet. The zone's HGL is regulated by the Tara Reservoir.

Rolling Oaks

The Rolling Oaks Zone is located in the southwest region of the Main Thousand Oaks service area and is supplied from the Pederson/ Willow Zone via the Rolling Oaks Pump Station. The pressure zone spans approximately 399 acres and has a nominal HGL of 1,098 feet. The zone's HGL is regulated by the Rolling Oaks Reservoir.

Lang Ranch/ Sunset No. 2

The Lang Ranch/ Sunset No. 2 Zone is located in the northern region of the Main Thousand Oaks service area. The pressure zone is supplied by the Erbes Road and the Sunset No.1 pump stations, which receive water from the Lindero and Del Sol Turnouts, respectively. The pressure zone spans approximately 1,205 acres and has a nominal HGL of 1,271 feet. The

zone's HGL is regulated by the Sunset No. 2 and Lang Ranch reservoirs. The Lang Ranch/ Sunset No. 2 Zone provides water to the Reduced Minnecota Zone via the Minnecota Drive PRS. During emergencies when pressures fall significantly, the zone is supplied from Oakbrook/ Sunset No. 3 Zone via the Fountain Crest PRS.

Reduced Lang Ranch/ Sunset No. 2 (Billing Zone 2)

The Reduced Lang Ranch/Sunset No. 2 Zone is a regulated pressure zone located in the central region of the Main Thousand Oaks service area. The pressure zone is supplied from the Lang Ranch/ Sunset No. 2 Zone via the Rusticpark PRS. The pressure zone spans approximately 50 acres and has a nominal HGL of 1,122 feet. If pressures fall below approximately 1,090 feet, the zone will be supplied from the Meadows pressure zone via an existing check valve located near the intersection of Sciencepark Street and Hollowpark Court.

Reduced Minnecota

The Reduced Minnecota Zone is a relatively small regulated pressure zone located in the northern region of the Main Thousand Oaks service area and is supplied via the Lang Ranch/ Sunset No. 2 Zone. The pressure zone spans approximately 11 acres and has a nominal HGL of 1,083 feet.

Wilder

The Wilder Zone is located in the southeast region of the Main Thousand Oaks service area and is supplied by the Lone Oak Pump Station, which in turn receives water from the Lone Oak Turnout. The pressure zone spans approximately 581 acres and has a nominal HGL of 1,223 feet. The zone's HGL is regulated by the Wilder Reservoir.

The City is currently planning a new pump station to supply the Wilder Zone from the Freeway/ La Granada Zone (La Granada Pump Station). The Pump Station will be located at the La Granada Reservoir site and will include two low-flow (750 gpm) and one high-flow (4,000 gpm) pumping units. The Pump Station's primary purpose is to serve as a secondary source of supply and to provide fire flow to Wilder Zone.

Northwood Booster

The Northwood Booster Zone is a small closed loop system located in the northwest region of the Main Thousand Oaks service area and surrounded by the Tara Zone. The Northwood Booster Zone is supplied by the Tara Zone via the variable frequency drive Northwood Pump Station. The pressure zone spans approximately 62 acres and has a nominal HGL of 1,165 feet.

Grissom

The Grissom Zone is located in the eastern region of the Main Thousand Oaks service area and is supplied by the Wilder Pump Station. The pressure zone spans approximately 77 acres and has a nominal HGL of 1,488 feet. The zone's HGL is regulated by the Grissom No.1 and Grissom No. 2 reservoirs. From the Grissom Zone, water is supplied to the Reduced Sapra Zone via the Sapra Street PRS.

Reduced Sapra

The Reduced Sapra Zone is the City's smallest pressure zone located in the eastern region of the Main Thousand Oaks service area. The pressure zone is supplied from the Grissom Zone via the Sapra Street PRS. The pressure zone spans approximately 8 acres and has a nominal HGL of 1,203 feet. The Sapra Street PRS was upgraded in 2007. The station now includes a 6-inch diameter main line PRV, a 3-inch diameter bypass PRV, and a 3-inch diameter pressure relief valve.

Oakbrook/ Sunset No. 3

The Oakbrook/ Sunset No. 3 Zone is located in the northeastern region of the Main Thousand Oaks service area. The pressure zone is supplied from the Lang Ranch/Sunset No. 2 Zone through Los Arboles, Lang Ranch No. 4A and Sunset No. 2 pump stations. The pressure zone spans approximately 1,424 acres and has a nominal HGL of 1,503 feet. The pressure zone's HGL is regulated by the Oakbrook and Sunset No. 3 reservoirs. The pressure zone supplies the Reduced Lang Ranch Zone via the Westlake and Lang Ranch PRSs. The Fountain Crest PRS supplies the Lang Ranch/ Sunset No.2 Zone during emergencies.

The areas served by the Oakbrook and the Sunset 3 reservoirs were temporarily separated in December 2015 via closure of multiple isolation valves in an attempt to increase Oakbrook Reservoir turnover rate. The separation is currently being tried out and may become permanent if determined to be beneficial in the long run.

Reduced Lang Ranch (Billing Zone 3)

The Reduced Lang Ranch Zone is located in the eastern edge of the Main Thousand Oaks service area and is supplied from the Oakbrook/ Sunset3 Zone via the Lang Ranch and Westlake Boulevard PRSs. The pressure zone spans approximately 180 acres and has a nominal HGL of 1,518 feet.

Grissom Hydropneumatic

The Grissom Hydropneumatic Zone is a closed loop system located along the eastern edge of the Main Thousand Oaks service area. Water stored at the Grissom No. 1 and Grissom No. 2 reservoirs is boosted via the Grissom Hydropneumatic Pump Station to supply this zone. The zone spans approximately 31 acres and has a nominal HGL of 1,611 feet.

Sunset Hydropneumatic

The Sunset Hydro Zone is a closed loop system located in the northern region of the Main Thousand Oaks service area. Water stored at the Sunset No. 3 Reservoir is boosted via the Sunset Hydropneumatic Pump Station. The pressure zone spans approximately 30 acres and has a nominal HGL of 1,600 feet.

2.2 Distribution System Facilities

The City's water distribution system currently consists of 11 turnout connections from Calleguas, 16 storage reservoirs, 15 pump stations, 10 PRSs and approximately 232 miles of active pipelines ranging in size from 3- to 24-inches in diameter.

The pipelines and facilities within the Main Thousand Oaks and the Newbury Park service areas are shown in **Figure 2-2** and **Figure 2-3**, respectively. The distribution system's hydraulic profile schematic is presented in **Figure 2-4**.

A summary description of the City's major pipelines and facilities is presented in this sub-section.

2.2.1 Turnouts

The City receives 100 percent of its potable water supply from 11 turnout connections to the Calleguas transmission system. All turnouts except La Jolla are essentially controlled by the water level of the receiving pressure zone's storage reservoir(s). La Jolla turnout is an emergency turnout serving the Conejo Oaks pressure zone. The Lone Oak, Del Sol and Lindero turnouts directly supply downstream booster pump stations. The remaining turnouts supply the system by gravity.

A summary of existing supply turnouts is presented in **Table 2-3**.

2.2.2 Reservoirs

Reservoirs provide storage for meeting peak hourly demands (equalization storage), fire suppression and other emergencies. In addition, the reservoirs are used to minimize pumping requirements during Southern California Edison (SCE) on-peak energy hours.

There are currently 16 reservoirs located within 11 of the City's 21 pressure zones. The remaining 10 pressure zones are closed loop systems (regulated or hydropneumatic) and are served by the reservoir(s) of the gravity zone(s) they are supplied from. The combined storage capacity of all 16 reservoirs is approximately 35.3 million gallons (MG).

A summary of existing storage reservoirs is presented in **Table 2-4**.

2.2.3 Pump Stations

The City currently owns and operates 15 pump stations including four hydropneumatic pump stations and one variable speed pump station. Each hydropneumatic pump station is equipped with a 1,000-gallon per minute (gpm) diesel engine-driven unit in addition to electric motor-driven pumping units.

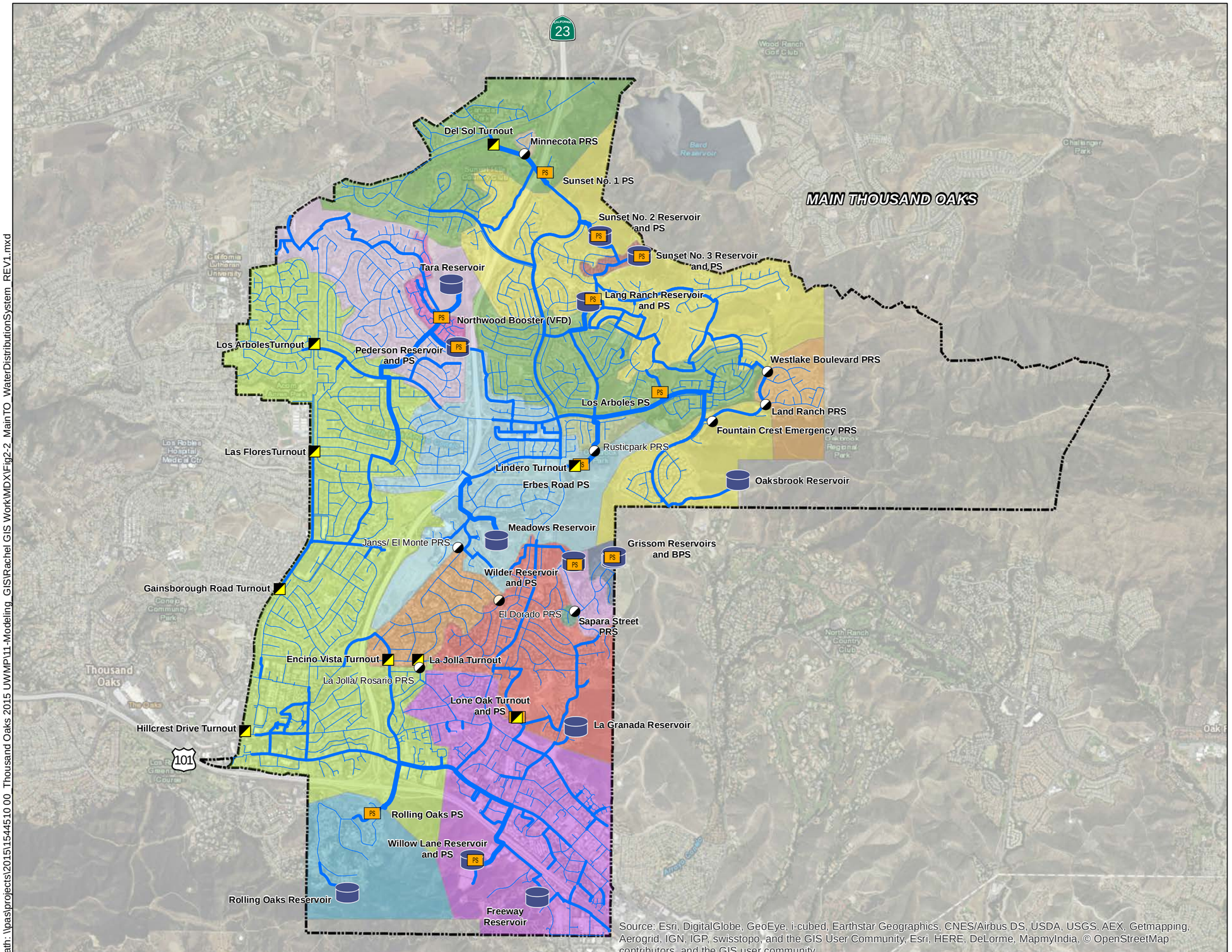
All pump stations are equipped with an emergency, uninterruptible power supply and generator connections. Additionally, all constant-speed pump stations comply with SCE's Time of Use (TOU) rate schedules. The applicable rate schedules are defined in **Appendix B**.

A summary of existing pump stations is presented in **Table 2-5**.

2.2.4 Pressure Reducing Stations

The City owns and operates a total of ten PRSs. Eight of these stations are normally flowing to supply five regulated pressure zones. The other two stations flow only during emergencies when the hydraulic grade in the downstream pressure zone falls significantly. Each PRS consists of one or more PRV set to maintain a constant downstream pressure.

A summary of existing PRSs is presented in **Table 2-6**.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Legend

- Pressure Reducing Station
- Calleguas Turnout
- Pump Station
- Storage Reservoir

Water Main

- 2-8"
- 10-14"
- 16-24"

Billing Zone - Pressure Zone

- Zone 1 - Pederson/Willow
- Zone 2 - Conejo Oaks
- Zone 2 - Freeway/La Granada
- Zone 2 - Lang/Sunset2
- Zone 2 - Meadows
- Zone 2 - Reduced Lang/Sunset2
- Zone 2 - Reduced Minnecota
- Zone 2 - Rolling Oaks
- Zone 2 - Tara
- Zone 2 - Wilder
- Zone 3 - Grissom
- Zone 3 - Northwood Booster
- Zone 3 - Oakbrook/Sunset3
- Zone 3 - Reduced Lang Ranch
- Zone 3 - Reduced Sapra
- Zone 4 - GrissomHydro
- Zone 4 - SunsetHydro
- Main Thousand Oaks Service Boundary

N

0 0.5 1
Miles

Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

MainThousand Oaks Service Area Water Distribution System

K/J 1544510.00
February 2018

Figure 2-2

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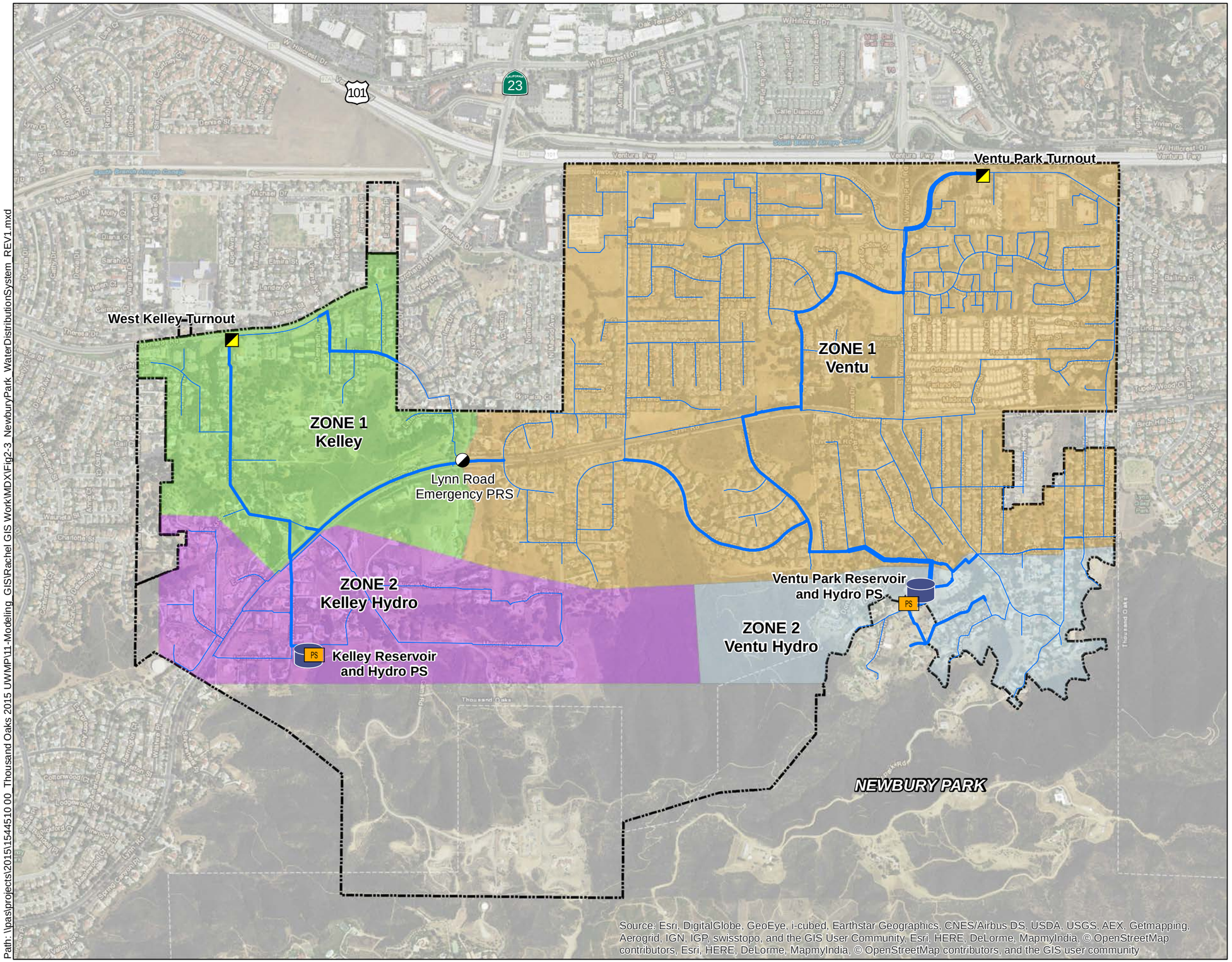


Legend

- Pressure Reducing Station
- Calleguas Turnout
- Pump Station
- Storage Reservoir

Water Main

SIZE

- 2-8"
- 10-14"
- 16-24"

Billing Zone - Pressure Zones

- Zone 1 - Kelley
- Zone 1 - Ventu
- Zone 2 - Kelley Hydro
- Zone 2 - Ventu Hydro
- Newbury Park Service Boundary

N

0 500 1,000

Feet

Kennedy/Jenks Consultants

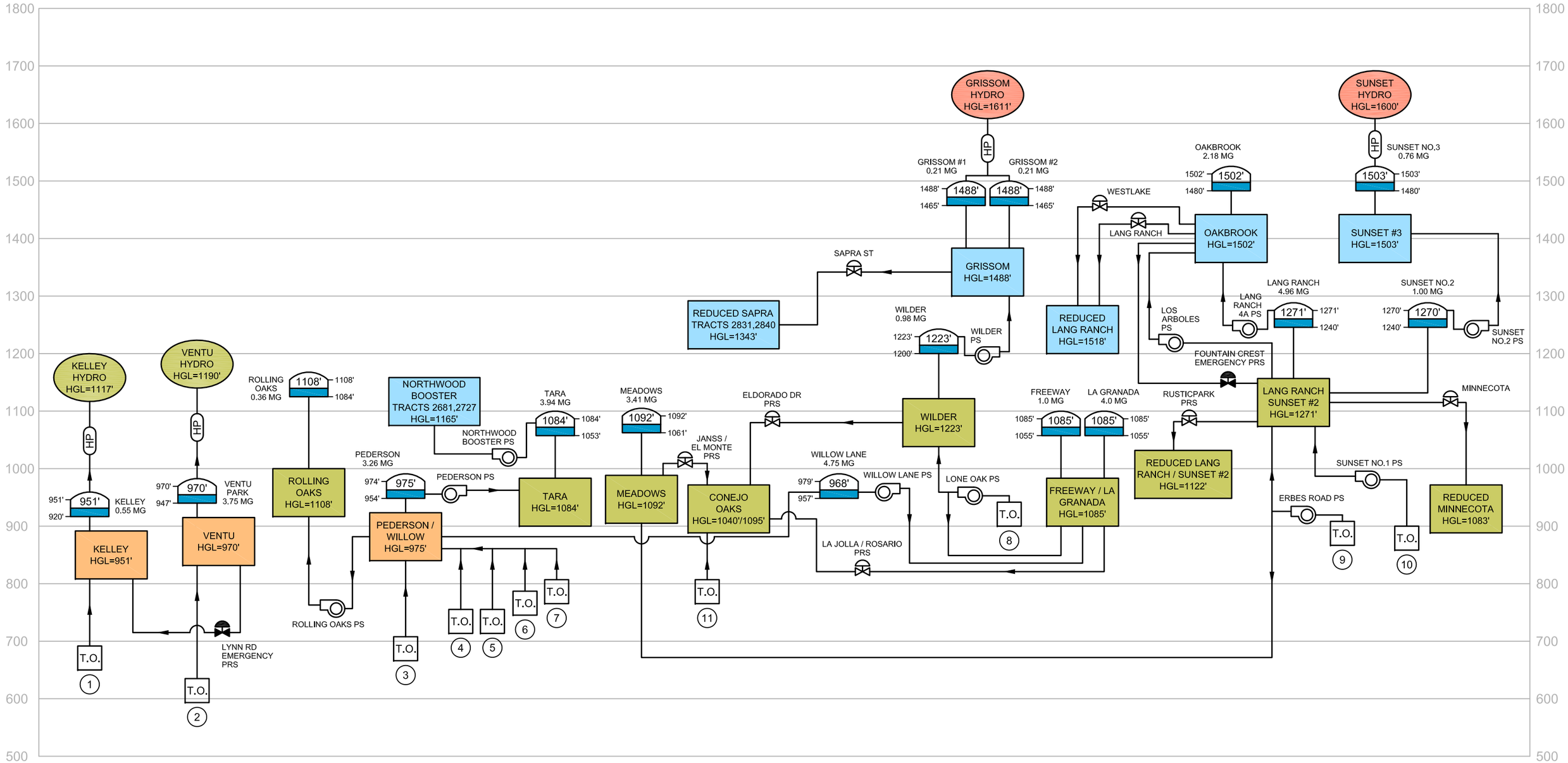
City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Newbury Park Service Area
Water Distribution System

K/J 1544510.00
February 2018

Figure 2-3

Path: \\pas\projects\2015\1544510 00_Thousand Oaks 2015 UWMP\11-Modeling_GIS\Rachel GIS Work\MDX\Fig2-3_NewburyPark_WaterDistributionSystem_REV1.mxd



PUMPING STATION (PS)

PRESSURE REDUCING STATION (PRS)

EMERGENCY CONNECTION, NORMALLY INACTIVE

HP — HYDROPNEUMATIC TANK & PUMP STATION

613' — HYDRAULIC GRADE LINE

T.O. — CALLEGUAS MUNICIPAL WATER DISTRICT TURNOUT

HGL' — HWL ELEVATION

RESERVOIR — BOTTOM ELEVATION

1. WEST KELLEY TURNOUT (ID K8-3000)
2. VENTU PARK TURNOUT (ID L10-3000)
3. HILLCREST TURNOUT (ID L14 3100)
4. GAINSBOROUGH TURNOUT (ID N14-3100)
5. LAS FLORES TURNOUT (ID Q15-3000)
6. LOS ARBOLES TURNOUT (ID R15-3011)
7. ENCINO VISTA TURNOUT (ID M15-3100)
8. LONE OAK TURNOUT (ID L17-3001)
9. LINDERO TURNOUT (ID S10-3100)
10. DEL SOL TURNOUT (ID U17-3001)
11. LA JOLLA TURNOUT (EMERGENCY)

BILLING ZONES

- ZONE 1 (NO LIFT)
- ZONE 2 (ONE LIFT)
- ZONE 3 (TWO LIFTS)
- ZONE 4 (THREE LIFTS)

Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

City of Thousand Oaks
Existing System Hydraulic Profile

1544510.00

Figure 2-4

Table 2-3: Summary of Existing Turnouts

No.	Service Area	Billing Zone	Turnout Name	Controlling Reservoir	Capacity[3] (gpm)	HGL (feet msl)	Location	Discharge Zone(s)
1	Newbury Park	1	Ventu Park	Ventu Park	2,500	1,038	1304 Newbury Road	Ventu
2			West Kelley	Kelley	2,000	984	2770 Borchard Road	Kelley
3	Main Thousand Oaks		Encino Vista	Willow Lane	2,500	1,036	819 Encino Vista	Pederson/ Willow
4			Gainsborough	Pederson	2,500	1,038	1240 N. Moorpark Road	
5			Hillcrest	Willow Lane	2,500	1,035	19 E. Hillcrest Drive	
6			Las Flores	Pederson	3,000	1,043	2194 N. Moorpark Road	
7			Los Arboles	Pederson	3,000	1,047	555 E. Avenida de Los Arboles	
8			Lone Oak[1]	-	4,000	1,035	560 Lone Oak	Freeway/ La Granada, Wilder
9		2	Del Sol Erbes[1]	-	5,000	1,048	3235 Erbes Road	Lang Ranch/ Sunset No. 2
10			Lindero[1]	-	6,000	1,047	2106 Erbes Road	Meadows, Lang Ranch/ Sunset No. 2
11			La Jolla[2]	-	1,000	1,038	1335 La Jolla Drive	Conejo Oaks

Notes:

1. Controlled by downstream pump station
2. Emergency turnout (normally inactive)
3. Capacities are taken from Calleguas' purveyor website (https://purveyor.calleguas.com/)

Table 2-4: Summary of Existing Reservoirs

No.	Service Area	Billing Zone	Reservoir Name	Diameter (feet)	Floor / HWL Elevation (feet)	Capacity (MG)	Material[1]	Zone(s) Supplied
1	Newbury Park	1	Kelley	55	920/ 951	0.55	CWS	Kelley/ Kelley Hydro
2			Ventu Park[2, 3]	-	947/ 970	3.75	RRC	Ventu/ Ventu Hydro
3	Main Thousand Oaks	1	Pederson[2]	-	954/ 974	3.26	RRC	Pederson/ Willow
4			Willow Lane	192	957/ 979	4.75	CWS	
5		2	Freeway	75	1,055/ 1,085	1.00	CWS	Freeway/ La Granada
6			La Granada	150	1,055/ 1,085	4.00	CWS	
7			Lang Ranch	165	1,240/ 1,271	4.96	CWS	Lang Ranch/ Sunset No. 2, Reduced Minnecota, Reduced Lang Ranch/ Sunset No. 2
8			Sunset No. 2	75	1,240/ 1,270	1.00	CWS	
9			Meadows[2]	-	1,061/ 1,092	3.41	RRC	Meadows, Conejo Oaks
10			Rolling Oaks	51	1,084/ 1,108	0.36	CWS	Rolling Oaks
11			Tara	147	1,053/ 1,084	3.94	CWS	Tara, Northwood Booster
12			Wilder	85	1,200/ 1,223	0.98	CWS	Wilder
13		3	Grissom No.1	39	1,465/ 1,488	0.21	CWS	Grissom, Grissom Hydro, Reduced Sapra
14			Grissom No.2	39	1,465/ 1,488	0.21	CWS	
15			Oakbrook	130	1,480/ 1,502	2.18	CWS	Oakbrook/ Sunset No. 3, Reduced Lang Ranch, Sunset Hydro
16			Sunset No. 3	75	1,480/ 1,503	0.76	CWS	

Notes:

1. CWS = Circular Welded-Steel; RRC = Rectangular Reinforced Concrete
2. Rectangular reservoir with hopper bottom. All other reservoirs are circular with flat bottom.
3. Partition wall in center creates 2 chambers

Table 2-5: Summary of Existing Pump Stations

No.	Service Area	Pump Station	No. of Pumps	Suction Pressure Zone/ Turnout	Discharge Pressure Zone	Firm/Total Capacity[3,4] (GPM)	Current SCE Rate Schedule[5]
1	Newbury Park	Kelley Road[1]	3	Kelley	Kelley Hydro	650/1,350	TOU-GS2B
2		Ventu Park[1]	3	Ventu Park	Ventu Hydro	900/1,900	TOU-PA-2-B
3	Main Thousand Oaks	Grissom[1]	2	Grissom	Grissom Hydro	500/1,500	TOU-PA-2-B
4		Sunset[1]	3	Oakbrook/Sunset No. 3	Sunset Hydro	1,200/2,200	TOU-GS1A
5		Erbes Road	3	Lindero Turnout	Lang Ranch/ Sunset No. 2	2,250/3,750	TOU-PA-3-SOP1
			1		Meadows	0/1,650	
6		Lang Ranch 4A	2	Lang Ranch/ Sunset No. 2	Oakbrook/Sunset No. 3	700/1,400	TOU-PA-2-B
7		Lone Oak	3	Lone Oak Turnout	Freeway/La Granada	1,200/1,950	TOU-PA-2-SOP1
			3		Wilder	1,400/2,000	
8		Los Arboles	2	Lang Ranch/ Sunset No. 2	Oakbrook/Sunset No. 3	600/1,200	TOU-PA-2-B
9		Pederson	3	Pederson/Willow	Tara	2,400/3,600	TOU-PA-2-SOP1
10		Rolling Oaks	2	Pederson/Willow	Rolling Oaks	200/400	TOU-GS1A
11		Sunset No. 1	3	Del Sol Turnout	Lang Ranch/Sunset No. 2	2,100/3,550	TOU-PA-3-SOP1
12		Sunset No. 2	2	Lang Ranch/ Sunset No. 2	Oakbrook/Sunset No. 3	450/900	TOU-PA-2-SOP1
13		Wilder	2	Wilder	Grissom	400/800	TOU-PA-2-B
14		Willow Lane	3	Pederson/Willow	Freeway/La Granada	1,500/2,250	TOU-PA-2-SOP1
15		Northwood Booster[2]	2	Tara	Northwood Booster	500/1,000	TOU-GS1A

Notes:

1. Hydropneumatic pump station
2. Variable speed pump station
3. Reported capacities are design operating values, as provided by the City. Due to changed system curves and/or wear and tear, pumps may not be operating at their design capacities.
4. Firm capacity is the sum of capacities of all but the largest pumping unit.
5. Rate schedules are defined in Appendix B.

Table 2-6: Summary of Existing Pressure Reducing Stations

No.	Service Area	PRS Name	No. of PRVs	PRV Sizes[2] (in)	Lead PRV HGL Set Point (ft msl)	Upstream Pressure Zone	Downstream Pressure Zone
1	Newbury Park	Lynn Road[1]	1	10	892	Ventu	Kelley
2	Main Thousand Oaks	Fountain Crest[1]	1	8	1,199	Oakbrook/ Sunset No. 3	Lang Ranch/Sunset No. 2
3		Lang Ranch	2	8/4	1,479	Oakbrook/ Sunset No. 3	Reduced Lang Ranch
4		Westlake Boulevard	2	8/4	1,518		
5		Minnecota Drive	2	4/2	1,083	Lang Ranch/ Sunset No. 2	Reduced Minnecota
6		Sapra Street	2	3/6	1,203	Grissom	Reduced Sapra
7		Rusticpark	2	3/6	1,122	Lang Ranch/ Sunset No. 2	Reduced Lang Ranch/Sunset No. 2
8		El Dorado	2	1.5/6	1,096	Wilder	Conejo Oaks
9		Janss/ El Monte	1	6	1,034	Meadows	
10		La Jolla/ Rosario	2	3/6	1,039	Freeway/ La Granada	

Notes:

1. Emergency PRS
2. For multiple-valve stations, the left number represents the lead valve size.

2.3 Distribution System Pipelines

The City's distribution system is comprised of approximately 232 miles of active pipelines ranging in size from 2- to 24-inches. The majority of pipelines are 6- and 8-inches in diameter. The distribution of total pipeline length by size is shown in **Figure 2-5**.

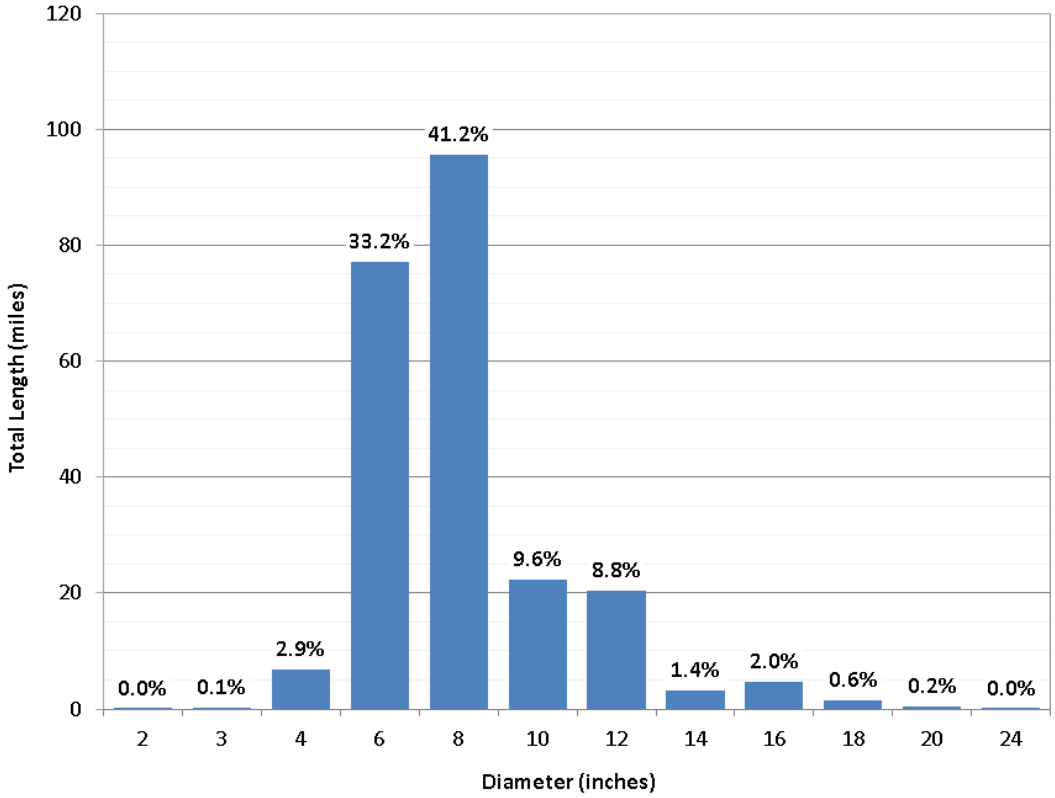


Figure 2-5: Total Pipeline Length Distribution by Size (inch diameter)

The distribution system pipelines consist of several pipe materials including Asbestos Cement Pipe (AC), Ductile Iron (DI), Polyvinyl Chloride (PVC), Cast Iron (CI), and Steel (STL). The material for approximately one percent of the pipelines is unknown (UNK). The most common material is AC with more than two thirds of all pipelines. The distribution of total pipeline length by size is shown in **Figure 2-6**.

The pipelines' age varies from 1 to 64 years with average age of nearly 40 years. The distribution of total pipeline length by age is shown in **Figure 2-7**.

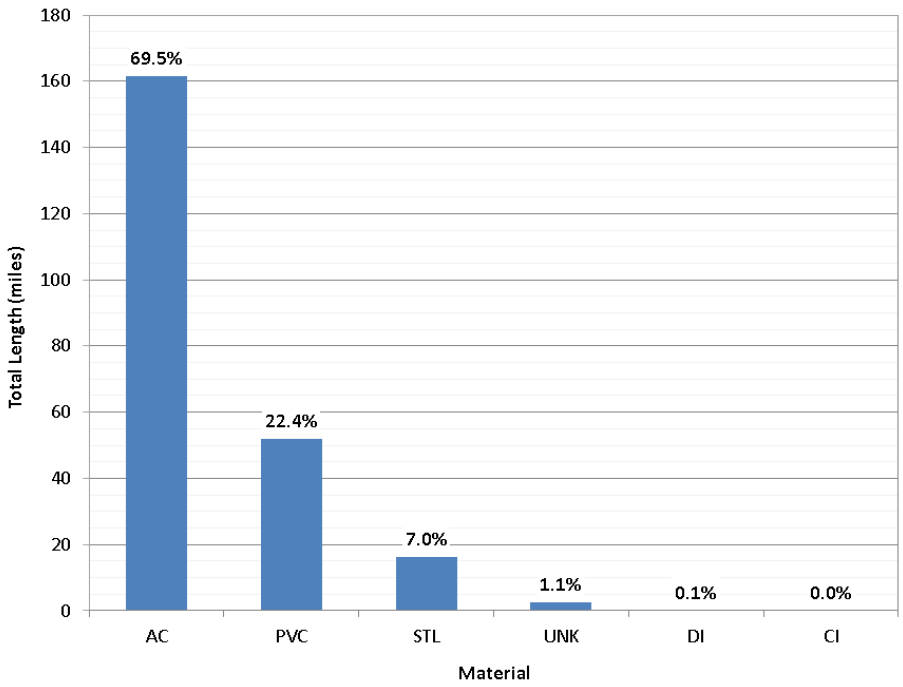


Figure 2-6: Total Pipeline Length Distribution by Material (inch diameter)

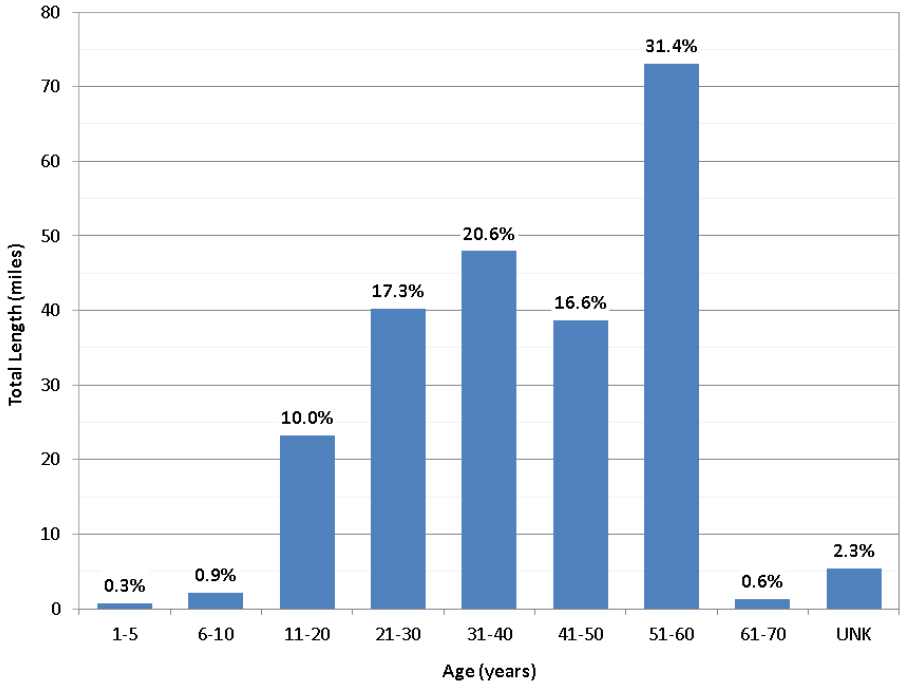


Figure 2-7: Total Pipeline Length Distribution by Age (years)

Section 3: Water Supplies and Demands

This section describes the City's existing water supply sources including imported water and groundwater. In addition, this section presents a discussion on the City's historical demands since 2011 and future demands through buildout.

3.1 Water Supplies

The City has access to two supply sources: imported water from the Calleguas Municipal Water District (Calleguas) transmission system and groundwater from the Thousand Oaks Area Groundwater Basin. These supply sources are briefly described below.

3.1.1 Imported Water

The City has relied on imported water to meet its demands for several decades. The imported water is purchased from Calleguas, who is the wholesale provider of imported water to the region. Calleguas owns and operates a transmission system to convey water to local water retail agencies spanning an area of approximately 350 square miles. Calleguas is a member agency of MWDSC and receives its potable water supply from the Jensen Treatment Plant.

The City currently has 11 turnout connections from the Calleguas system. These turnouts and their properties were described in Section 2. These turnouts are anticipated to continue to be used to purchase water from Calleguas for years to come. Historical supply deliveries from Calleguas are presented later in this section.

3.1.2 Groundwater Supply

The City owns four groundwater production wells within the California American Water Company's (Cal Am's) service area, but only two of the wells are currently active: the Hillcrest Drive and the Los Robles Golf Course wells. The produced water comes from the Thousand Oaks Area Groundwater Basin, which has an estimated total storage capacity of 130,000 AF according to the Ventura County Public Works Agency (VCPWA). However, due to poor water quality the water is used solely for irrigation purposes within the Cal Am's service area. The City is currently in the process of groundwater utilization review for potable purposes from the Los Robles Golf Course wells.

The City recently completed a study evaluating options for improving local supply reliability with a focus on local groundwater and recycled water resources (CDM, 2016). The study provided potential near-term (1-5 years), mid-term (5-10 years), and long-term (10-20 years) water supply options and concluded that approximately ten percent of water use across the City could be offset with groundwater on a long-term basis.

In the near-term, groundwater could be extracted to serve non-potable uses, such as irrigation of parks and schools, and a portion could be treated for potable distribution. In the mid-term, additional groundwater could be pumped and treated for potable distribution. In the long-term, options could include Direct Potable Reuse (DPR) and groundwater recharge of non-potable sources obtained from other municipalities.

Through the mid-term planning period, approximately 3,500 AFY of groundwater could be beneficially used. With the addition of non-potable reuse expansion and DPR, nearly 11,000 AFY in total local supplies could be developed over the long-term. For the purposes of the distribution system analysis, it is assumed that groundwater supply for potable use is zero in the future.

3.1.3 Interconnections with Other Agencies

Interconnections with neighboring water purveyors are typically constructed to share available supply and storage between neighboring agencies during emergencies. The City's water service area borders with Cal Am on the west, California Water Service Company (Cal Water) on the east and the south and Camrosa Water District on the north.

In 2009, the City conducted an interconnection feasibility evaluation study (RBF, 2009). The study identified six potential interconnection locations with Cal Am and another six locations with Cal Water. Subsequently, two interconnections with Cal Water were implemented near the intersections of Hillcrest Drive/Duesenberg Drive and Westlake Boulevard/Allyson Court.

The City is currently implementing a new interconnection with Cal-Am near the intersection of Gainsborough Road and Moorpark Road.

3.1.4 Supply Reliability

All but one of the major cities in Ventura County rely upon Calleguas to provide a reliable supplemental water supply to their customers. Calleguas' service area has come to rely on imported water to meet approximately three-fourths of its municipal and industrial water demands. However, the imported supply is subject to a variety of interruptions from earthquakes in northern California to pipeline failures due to aging infrastructure. In addition, the recent historic drought in the western United States has significantly impacted the availability and reliability of the imported water.

Calleguas has prepared an Emergency Water Supply Plan (Calleguas, 2014) which describes the existing vulnerabilities, their potential disruption of water service, and what could be accomplished to mitigate them. The plan provides a basis for the Calleguas' Board of Directors, staff, and customers to determine the most appropriate courses of action to best safeguard water supply reliability.

The plan presents more than 35 potential mitigation measures under ten different themes or categories for further consideration. Some of these measures were recently evaluated as part of Calleguas' ongoing Potable Water Master Plan Update (Kennedy/Jenks, 2016) including an emergency interconnection with Las Virgenes Municipal Water District (LVMWD), a storage reservoir within the Calleguas' Simi Valley Region and feasibility evaluation of a potential seawater desalination treatment plant and associated conveyance. These measures intend to improve the reliability of the Calleguas system during short- and long-term imported water disruptions.

During a short-term (one month) outage, Calleguas would be able to supply all of its purveyors by utilizing its Lake Bard and Las Posas Groundwater Wellfield facilities. However, this would require up to approximately 40 percent demand conservation by all purveyors.

During a long-term (six month) outage, additional supply sources such as a potential seawater desalination plant would be required to supply the purveyors. While significantly improving the reliability of Calleguas' water supply, such a project faces serious implementation hurdles related to environmental compliance and funding. With the increasing trend in imported water cost, however, seawater desalination is anticipated to become more affordable over time relative to imported water.

3.2 Water Demands

This subsection presents a discussion on historical and future water demands and deliveries. Demand variations and peaking are also discussed in this subsection.

3.2.1 Historical Demands and Supply Deliveries

Water deliveries from the Calleguas transmission system are automatically recorded and transmitted to Calleguas' SCADA system. The records are available on a minute by minute, hourly and daily basis through an interactive website managed by Calleguas (https://purveyor.calleguas.com/). Historical daily water deliveries from July 1, 2011 through June 30, 2016 were extracted from the website and aggregated to estimate total water deliveries on an annual basis.

Daily water deliveries are different from daily water usage since a portion of each day's delivery may be stored in the reservoirs and not consumed. As daily deliveries are aggregated into annual deliveries, the storage effect becomes less consequential and annual deliveries become more representative of annual system demands. Demand is defined as the sum of metered and un-metered water (water loss).

The historical annual water deliveries (system demands) since July 2011 are summarized in **Table 3-1**.

Table 3-1: Historical Water Deliveries (Demands) from Calleguas

Year[1]	Annual Water Delivery (Demand)	
	AFY	CFS
2011-12	11,600	16.0
2012-13	12,200	16.8
2013-14	12,800	17.7
2014-15	10,800	14.9
2015-16	8,900	12.3
Average	**11,300**	**15.5**

Note:

1. July 1st to June 30th

As shown, water demands consistently rose from 2011 to 2014 at an average growth rate of about 5 percent per year. Demands have since declined by about 30 percent to approximately 8,900 AFY in 2015-16 representing a negative growth rate of about 17 percent per year. The decline is largely attributed to the discretionary and mandatory water conservation efforts triggered by the ongoing drought condition. As discussed later in this section, year 2013-14 was selected to represent the City's baseline demand condition. This selection implies that once the drought is over, the decline in demands since 2013-14 will be fully recovered.

The annual water deliveries by turnout are presented in **Table 3-2**. West Kelley and Lindero turnouts have consistently been the least and the most utilized among the ten active turnouts, respectively. On a five-year average basis, these turnouts have accounted for approximately 2 and 29 percent of total annual deliveries, respectively. The La Jolla Turnout has been inactive since July 2011.

Table 3-2: Historical Annual Water Deliveries by Turnout

No.	Turnout Name	2011-12 (CFS)	2012-13 (CFS)	2013-14 (CFS)	2014-15 (CFS)	2015-16 (CFS)	5-Year Average (CFS)
1	Ventu Park	1.4	1.5	1.6	1.3	1.1	1.4
2	West Kelley	0.3	0.3	0.4	0.3	0.2	0.3
3	Encino Vista	1.6	1.5	1.7	1.9	1.6	1.7
4	Gainsborough	0.5	0.8	0.9	0.8	0.5	0.7
5	Hillcrest	0.6	0.5	0.5	0.8	0.9	0.7
6	Las Flores	1.2	1.2	1.1	0.8	0.7	1.0
7	Los Arboles	1.3	1.7	1.6	1.1	0.7	1.3
8	Lone Oak	2.8	2.8	3.0	2.2	1.6	2.5
9	Del Sol Erbes	1.5	1.9	1.9	1.5	1.1	1.6
10	Lindero	4.8	4.7	5.0	4.3	3.7	4.5
11	La Jolla[1]	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	**16.0**	**16.8**	**17.7**	**14.9**	**12.3**	**15.5**

Note:

1. Inactive

Water Usage by Pressure Zone (2015)

The distribution of demands throughout the service area was determined by the process of geocoding the service accounts using their addresses. The bi-monthly usage records for the calendar year 2015 were totaled and assigned to the geocoded accounts and from there to the parcel centroids. Parcel demands were then aggregated by their respective pressure zones. The breakdown of the City's annual water usage by pressure zone for the calendar year 2015 is presented in **Table 3-3**.

The geocoded 2015 demands were scaled globally within the hydraulic model to develop baseline and future (buildout) average and maximum day demand sets.

Water Loss (2015)

By comparing the total water deliveries in the calendar year 2015 (9,640 AFY) with the total metered usage in the same period (9,333 AFY), the total system loss was estimated at about 307 AF or 3.2 percent of the supply, which is within the acceptable range.

Table 3-3: Annual Metered Water Usage by Pressure Zone in 2015[1]

No.	Service Area	Billing Zone	Pressure Zone	Service Accounts	2015 Annual Usage	
					AFY	CFS
1	NEWBURY PARK	1	Kelley	163	99	0.14
2			Ventu	1,878	824	1.14
3		2	Kelley Hydro	86	88	0.12
4			Ventu Hydro	113	35	0.05
Subtotal – Newbury Park				**2,240**	**1,046**	**1.44**
5	MAIN THOUSAND OAKS	1	Pederson/ Willow	4,188	2,079	2.87
6		2	Conejo Oaks	297	240	0.33
7			Freeway/ La Granada	1,486	1,072	1.48
8			Lang Ranch/ Sunset No. 2	2,411	1,383	1.91
9			Meadows	1,730	773	1.07
10			Reduced Lang Ranch/ Sunset No. 2			
11			Reduced Minnecota	58	14	0.02
12			Rolling Oaks	70	88	0.12
13			Tara	1,151	574	0.79
14			Wilder	793	484	0.67
15		3	Grissom	104	65	0.09
16			Northwood Booster	273	88	0.12
17			Oakbrook/ Sunset No. 3	1,852	1,225	1.69
18			Reduced Lang Ranch	252	130	0.18
19			Reduced Sapra	16	10	0.01
20		4	Grissom Hydro	53	27	0.04
21			Sunset Hydro	66	35	0.05
Subtotal – Main Thousand Oaks				**14,800**	**8,287**	**11.44**
TOTAL				**17,040**	**9,333**	**12.88**

Note:

1. January through December

3.2.2 Demand Variation and Peaking

Water demands vary from year to year due to changes in service area population, climate and conservation practices, among other reasons. Water demands also vary over the course of a year and throughout the day due to seasonal weather and diurnal usage patterns, respectively.

Establishing maximum day and peak hourly flows is critical in system performance evaluation and future infrastructure planning. Monitoring water delivery trends is also necessary to more effectively manage turnouts' utilization and peaking.

In order to encourage water purveyors to reduce peaking, Calleguas instituted the Capacity Reservation Charge (CRC) in 2003. The annual charge was established based on purveyors' highest weekly average demands from May through September. At the time, turnout meters had to be read manually and more frequent reading was too burdensome. As a result, the charge has not been very effective in reducing Calleguas' maximum day and hourly demands.

Calleguas' Conejo Valley service area which serves the City has been particularly impacted by peak flow deliveries during high demand periods. With the implementation of the turnout automation program, Calleguas may revise its policy to assess the CRC based on maximum day and/or peak hourly flow deliveries. Peak flow optimization is also beneficial for the City in improving the water age and quality within its system.

This section documents the daily and hourly variations in water demands in the last five years and establishes the historical and recommended maximum day peaking factors and hourly diurnal patterns for existing system evaluation and future planning.

Daily Peaking

The maximum day demand (MDD) is the largest volume of water consumed by the system in a single day. Water supply, treatment, and transmission infrastructure are typically sized to handle the MDD that the system is expected to experience. Conversely, the minimum day demand (MinDD) is the smallest volume of water consumed by the system in a single day.

The City's daily water deliveries since July 2011 are graphically shown in **Figure 3-1**. As discussed, maximum day deliveries are used as proxies for maximum day demands.

To increase storage turnover and reduce water age in the system, the City typically minimizes turnouts' utilization and water deliveries during low demand periods. Therefore, the system's MinDDs and peaking factors cannot be accurately determined from daily supply deliveries.

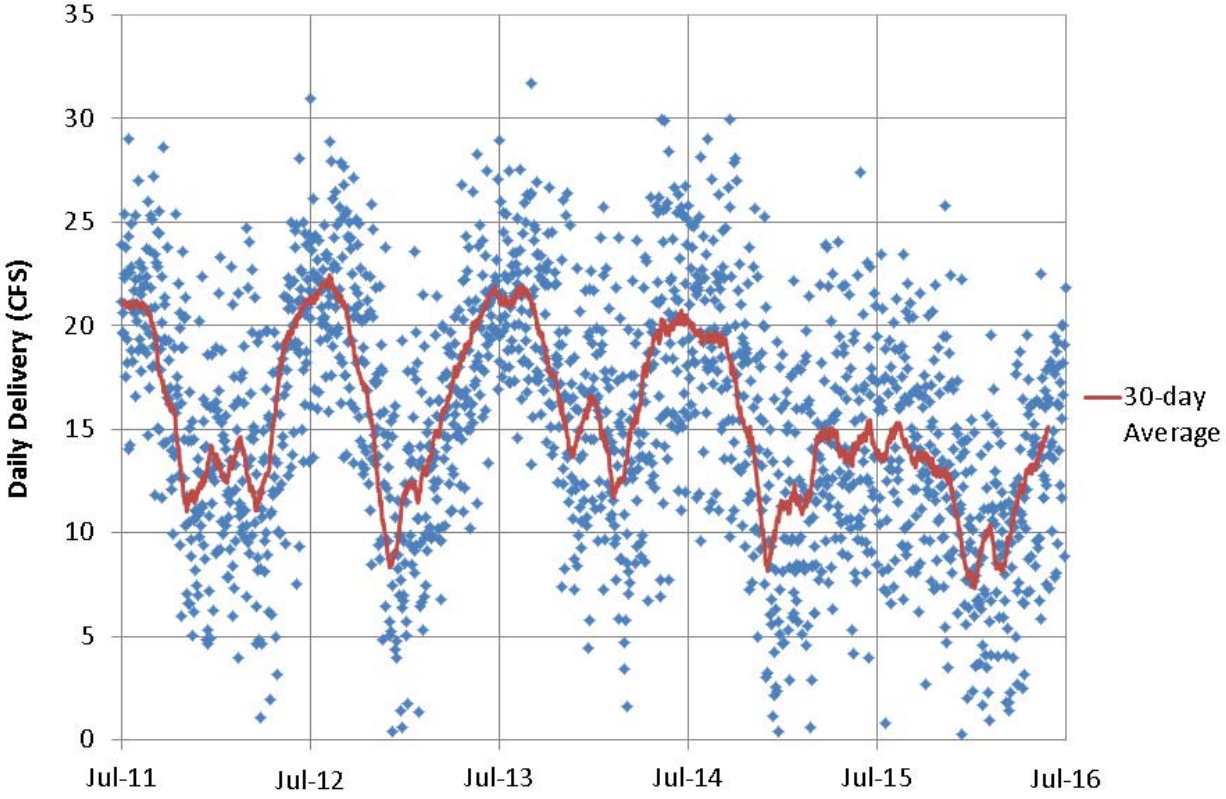


Figure 3-1: Historical Daily Water Deliveries

The MDDs of the last five years and their corresponding citywide maximum day peaking factors are presented in **Table 3-4** and shown in **Figure 3-2**.

A review of historical daily deliveries indicates that MDDs have generally followed the same trend as annual demands but to a lesser degree. While annual demands increased by about 5 percent annually from 2011-12 to 2013-14, MDDs increased by only about 1 percent annually in the same period.

Similarly, annual demands decreased by about 17 percent annually from 2013-14 to 2015-16, while MDDs decreased by only about 11 percent annually in the same period. These trends have resulted in maximum day peaking factors ranging from 1.64 to 1.89 in the last five years.

The recommended maximum day peaking factor for existing system evaluation and future system planning is 1.75. This value is recommended based upon the five-year average peaking factor of 1.76. The recommended minimum day peaking factor is 0.4 based on typical values for similar systems.

The baseline citywide MinDD and MDD are estimated at about 7 and 31 cfs, respectively. These estimates are based on year 2013-14's average annual demand of about 18 cfs and the above recommended peaking factors.

Table 3-4: Maximum Daily Deliveries (Demands) and Peaking Factors

Annual Period	Average Day Demand (CFS)	Maximum Day Demand[1] (CFS)	Maximum Day Peaking Factor (-)
2011-12	16.0	28.2	1.76
2012-13	16.8	28.0	1.67
2013-14	17.7	28.9	1.64
2014-15	14.9	28.1	1.89
2015-16	12.3	22.8	1.86
Average	**15.5**	**27.2**	**1.76**

Note:

1. 99th percentile values

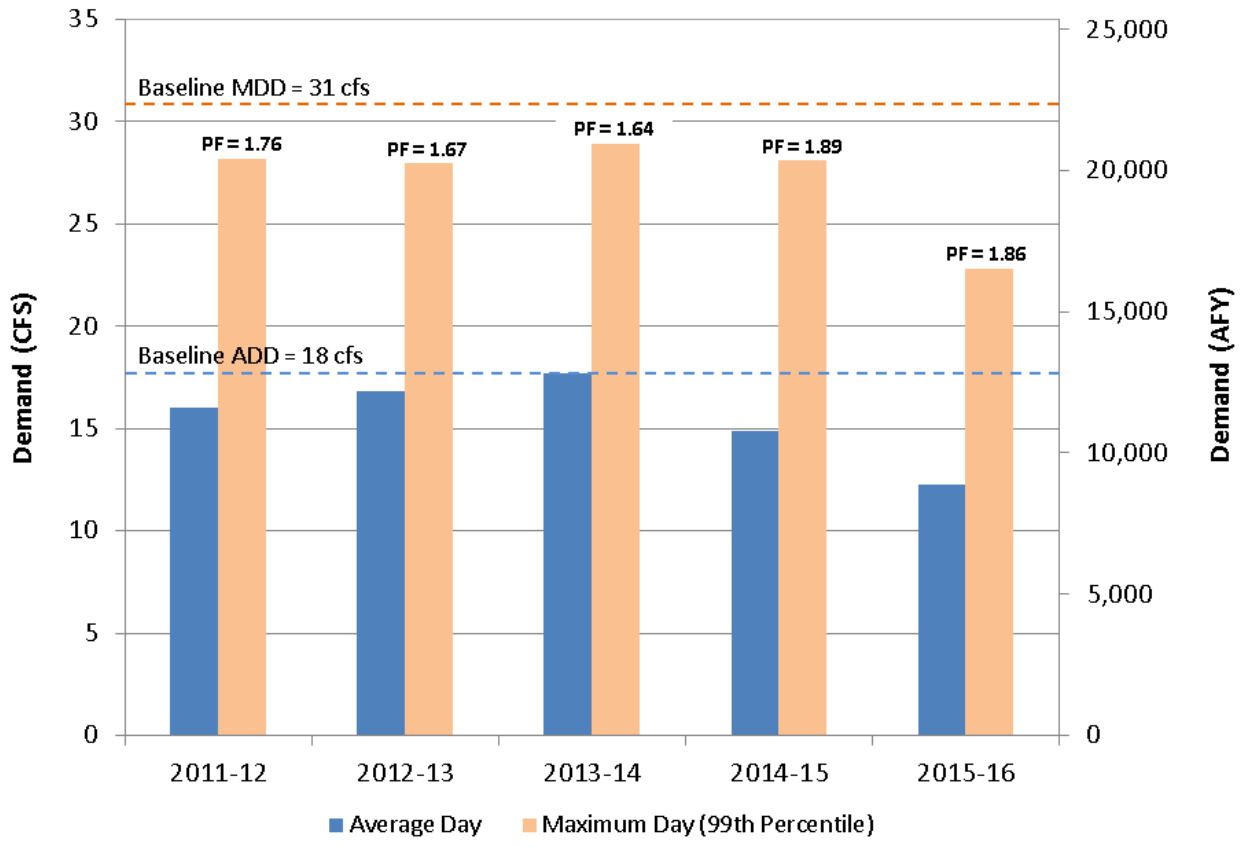


Figure 3-2: Historical and Baseline Average and Maximum Day Deliveries (Demands)

Hourly Peaking

Distribution systems must be able to meet the system's peak hourly demand (PHD); that is the largest volume of water the system is expected to deliver in a single hour. To simulate hourly demand fluctuations, individual diurnal patterns were developed for all pressure zones (or group of zones) and input into the hydraulic model.

A diurnal pattern for a given service area is a graphical representation of variation in the service area's hourly to average day demand. The amount of water stored in (or supplied by) the reservoirs was calculated and subtracted from (or added to) the total volume of water supplied by the pump stations or turnouts serving the service area. Where hourly supply information was not available through either the City's SCADA or Calleguas' turnout automation system, pressure zones were aggregated into group of zones with available boundary conditions.

The flow balance analysis showed that the system's PHD factor varies throughout the City from about 1.7 to about 3.4 with citywide average of 2.0. Individual zone patterns are presented in **Appendix C**.

The estimated citywide diurnal pattern is presented in **Figure 3-3**.

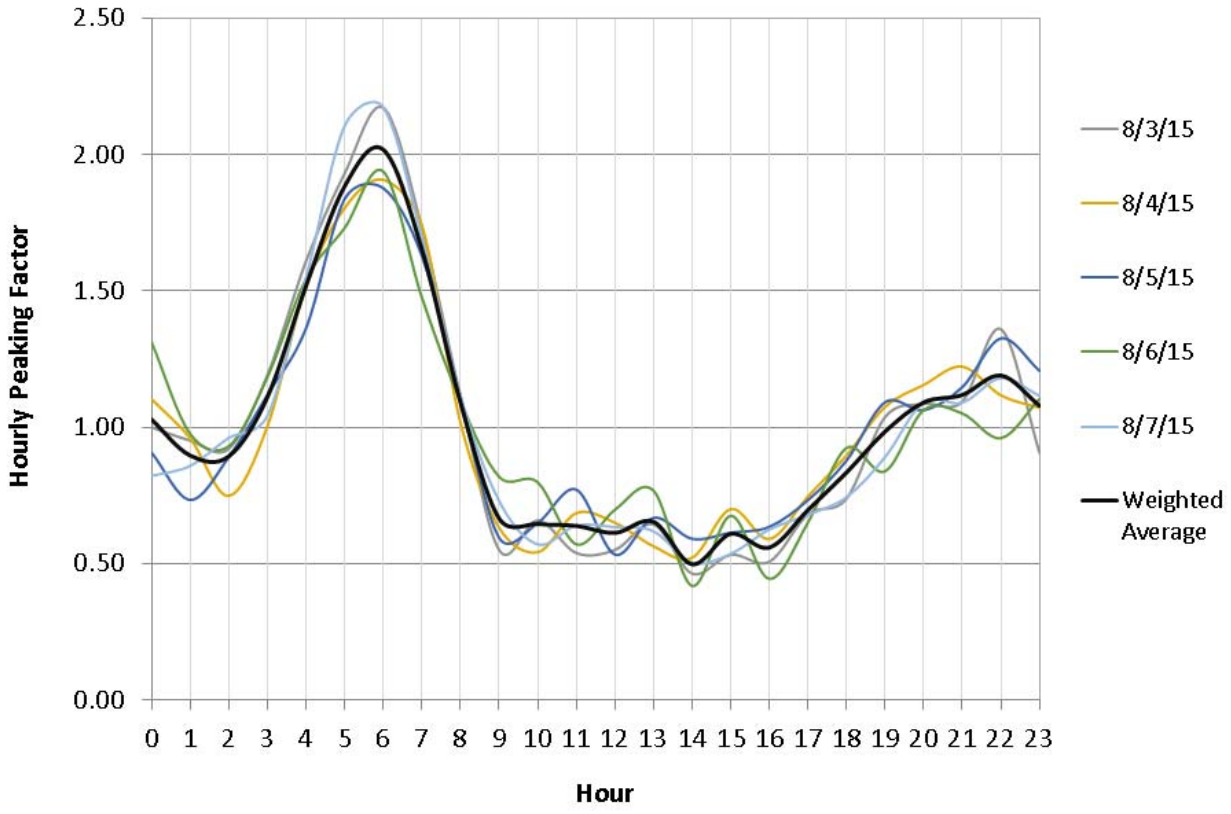


Figure 3-3: Citywide Diurnal Pattern (August 3-7, 2015)

3.2.3 Future Demands

The City's water service area is near buildout with only about 452 acres of developable vacant parcels available. Of this amount, approximately 417 acres is planned to be developed by 2040 with the remaining 35 acres assumed to be developed sometime beyond 2040. The development of these vacant parcels will increase the City's baseline demand. The proposed redevelopment of the Thousand Oaks Boulevard corridor (Thousand Oaks Boulevard Specific Plan or TOBLSP) is also expected to increase the City's baseline demand.

The City's future water demand was projected by estimating and adding the incremental future growth through buildout to the City's baseline demand. As discussed, the City's baseline demand in recent years has declined from about 12,800 AFY in 2013-14 to about 8,900 AFY in 2015-16 with the decline primarily attributed to aggressive water conservation efforts in recent years. The extent and the rate of baseline demand recovery in the coming years is uncertain. Future demands were projected assuming that by 2020, the City's baseline demand will be recovered to the 2013-14 level.

The information regarding the planned developments and other developable vacant lots including land use and equivalent dwelling units (EDUs) were provided by the City. The phasing of the planned developments through 2040 was also provided by the City. Where dwelling unit information was missing from the City's database, EDUs were estimated based on average density of other parcels with known future dwelling units and similar land use classifications.

The information provided by the City was last updated in 2012. The water demand factors were taken from the City's 2005 Water Master Plan. Independent analyses of developable vacant parcels and water demand factors were not performed as part of this master plan.

The amended TOBLSP (RRM Design Group, 2012) identifies an additional 214 commercial/ residential units along the frontage of Thousand Oaks Boulevard corridor proportionately distributed among three districts:

- Moorpark Road to Rancho Road (71 units)
- Rancho Road to Conejo School Road (72 units)
- Conejo School Road to Duesenberg Drive (71 units)

Additionally and per the TOBLSP's final environmental impact report (FEIR), adoption of the proposed Specific Plan would result in an additional 611,500 square feet of commercial space (Impact Sciences, 2011). The implementation of TOBLSP was assumed to occur between 2030 and 2035.

The TOBLSP district boundaries are shown in **Figure 3-4**. The future growth areas including TOBLSP, planned developments and developable vacant parcels are shown in **Figure 3-5**.

The breakdown of future growth areas and their projected demand increase by land use are presented in **Table 3-5**. The increase in average annual demands through buildout is estimated at about 414 AFY when compared to the baseline condition (2013-14). The TOBLSP accounts for 136 AFY (33 percent) of the projected growth. The planned developments and developable vacant parcels account for 197 AFY (48 percent) and 80 AFY (19 percent), respectively.

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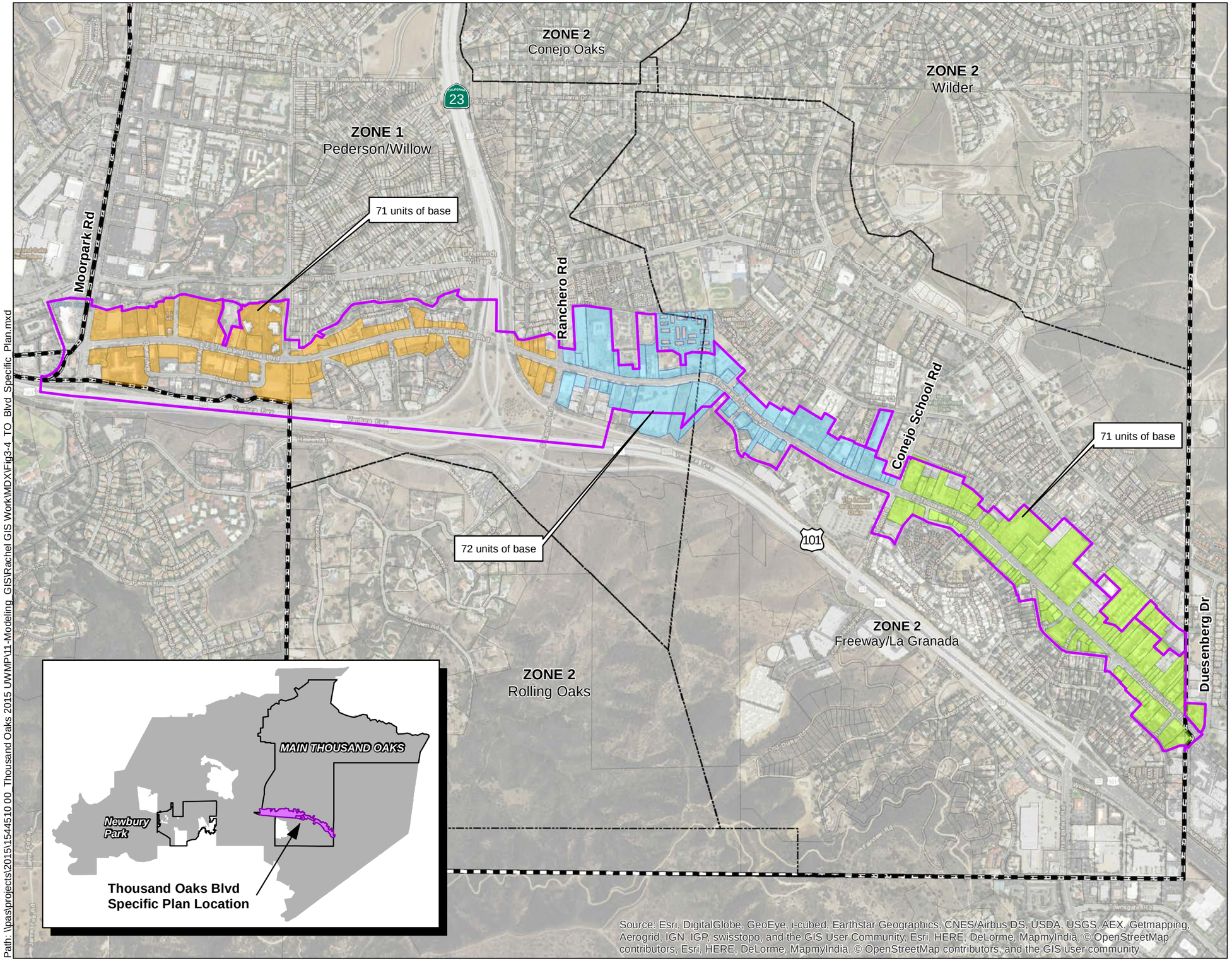

Legend

- City of Thousand Oaks Water Service
- Pressure Zones
- TOBSP Boundary *(342 gross acres)*

TOBSP Districts

- Conejo School Rd to Duesenberg
- Moorpark Rd to Rancho Rd
- Rancho Rd to Conejo School Rd

N

0 500 1,000
Feet

Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Thousand Oaks Boulevard Specific Plan Boundary

K/J 1544510.00
February 2018
Figure 3-4

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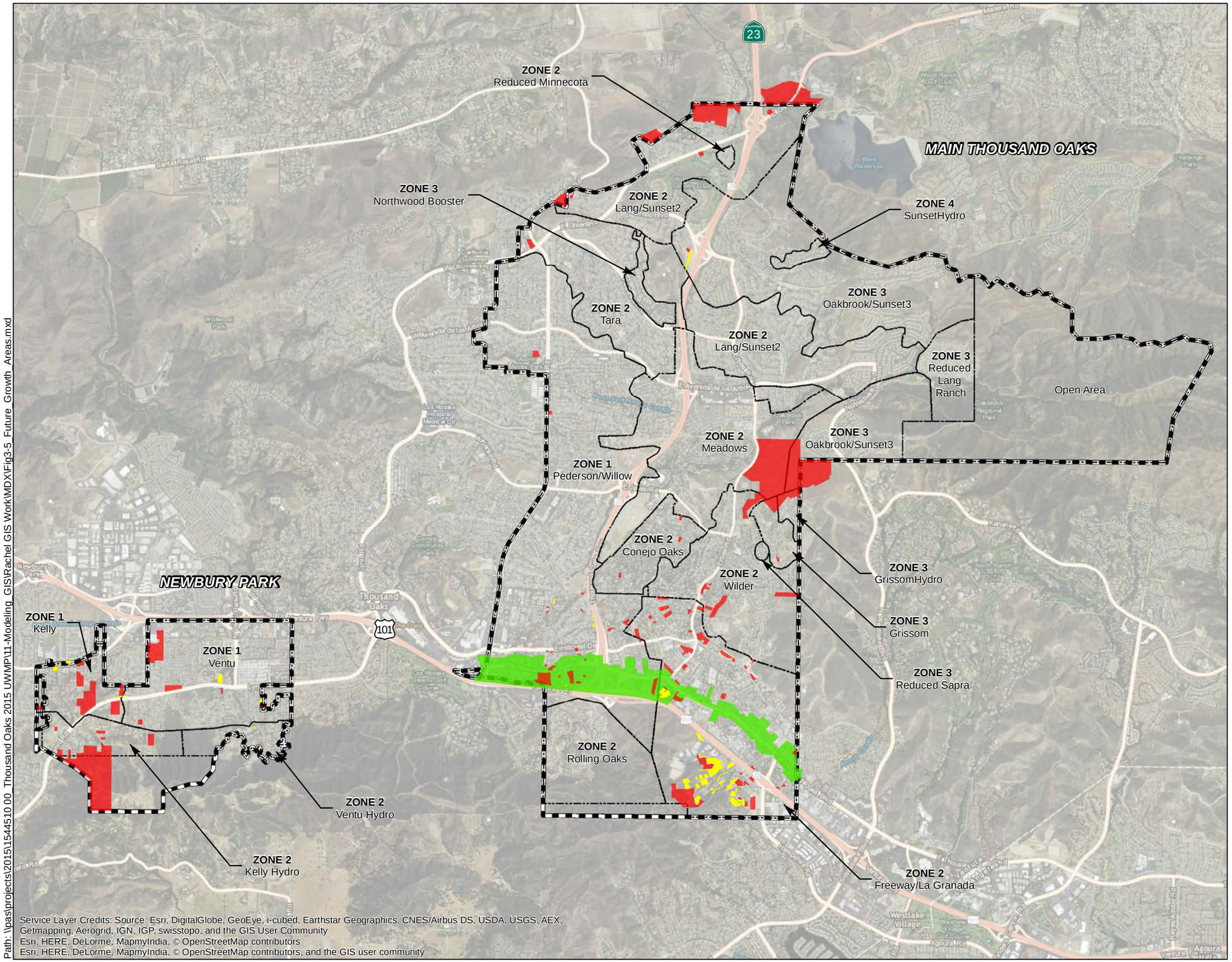

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Legend

- Developable Vacant Parcels
- Planned Development Parcels
- Thousand Oaks Blvd Specific Plan Boundary
- Pressure Zones
- City of Thousand Oaks Water Service Areas

Note:
Developable vacant and planned development parcels provided by the City of Thousand Oaks (last updated in 2012)

N

0 0.5 1
Miles

Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Parcels Contributing to Increase in Water Demands through Buildout

K/J 1544510.00
February 2018

Figure 3-5

Table 3-5: Projected Increase in Average Annual Water Demands through Buildout

Development Type	Land Use	Water Demand Factor[1]		Quantity		Projected Annual Demand Increase through Buildout	
		Value	Unit	Value	Unit	GPD	AFY
Planned Redevelopment[2]	Commercial/Residential	200	gpd/EDU	214	EDU	42,800	47
	Commercial	130	gpd/ksf	611.50	ksf	80,909	89
Planned Development	Apartments	200	gpd/EDU	45	EDU	9,000	10
	Assisted Living[3]	1.36	gpm/acre	14.53	acre	28,456	31
	Condominiums	200	gpd/EDU	49	EDU	9,800	11
	Industrial[3]	1.82	gpm/acre	5.72	acre	14,991	16
	Museum[3]	1.36	gpm/acre	1.87	acre	3,662	4
	Office[3]	3.93	gpm/acre	2.7	acre	15,450	17
	Place of Worship[3]	1.36	gpm/acre	1.28	acre	2,507	3
	Retail	200	gpd/EDU	132	EDU	26,400	29
	Single Family Residents	440	gpd/EDU	158	EDU	69,520	76
Developable Vacant Lands	Commercial/Residential[3]	3.93	gpm/acre	2.93	acre	16,596	18
	Industrial[3]	1.82	gpm/acre	1.16	acre	3,052	3
	Low Density[3]	1.27	gpm/acre	23.58	acre	43,118	47
	Medium Density[3]	3.23	gpm/acre	0.84	acre	3,924	4
	Very Low Density[3]	0.61	gpm/acre	6.55	acre	5,751	6
TOTAL						**375,936**	**414**

Notes:

1. Water demand factor for Apartments, Condominiums and Retail are based on Commercial/Residential water demand factor. Water demand factor for Assisted Living, Museum and Place of Worship are based on Institutional water demand factor. Water demand factor for Single Family Residents are based on Very Low Density Residential water demand factor.
2. Source: Thousand Oaks Boulevard Specific Plan (Adopted November 2011 – Amended May 2012)
3. Water demand factors estimated per Table 4-1 and Floor Area Ratio (FAR) of 1.0.

City's average annual demand at buildout is estimated at about 13,200 AFY. The average rate of growth in water demands from 2013-14 to 2040 is estimated at about 0.1 percent per year. The phasing and breakdown of the future demand projections by pressure zone are presented in **Table 3-6**.

The historical and projected average annual demands from 2011-12 through buildout are shown in **Figure 3-6**.The figure graphically shows the drought recovery and the development/ redevelopment components of future growth through buildout. At buildout, the development/ redevelopment component of total future water demand increase accounts for approximately 414 AFY (10 percent) with the remaining 3,900 AFY (90 percent) representing the drought recovery component.

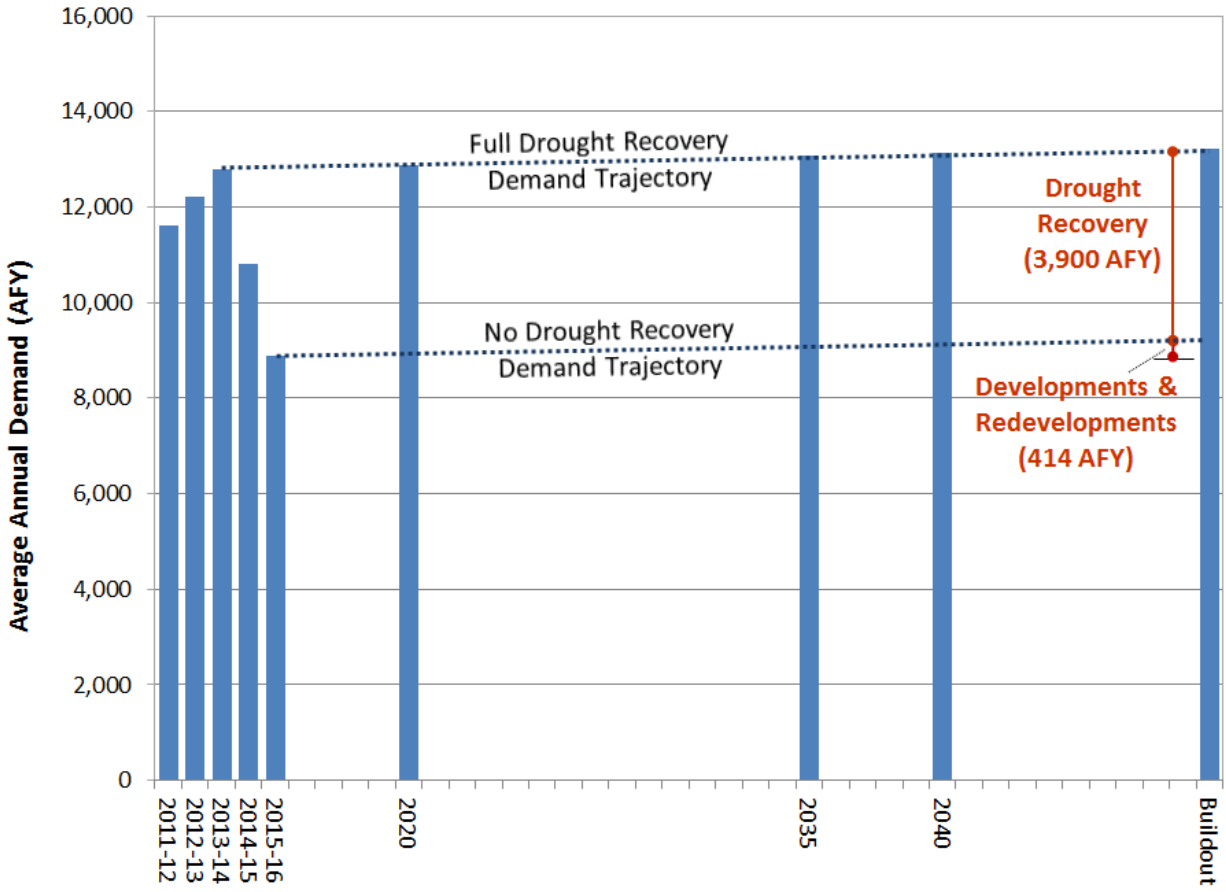

Figure 3-6: Historical and Projected Average Annual Water Demands

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Table 3-6: Future Demand Projections by Pressure Zone

No.	Service Area	Billing Zone	Pressure Zone	Baseline Demands[1]	Incremental Increase in Average Annual Demands[2, 3, 4] 2020 (AFY)	2035 (AFY)	2040 (AFY)	Buildout (AFY)	Average Annual Demand Projections 2020 (AFY)	2035 (AFY)	2040 (AFY)	Buildout (AFY)
1	NEWBURY PARK	1	Kelley	135	3	10	10	14	138	145	146	149
2			Ventu	1,131	6	38	38	42	1,137	1,169	1,169	1,173
3		2	Kelley Hydro	120	2	4	6	6	122	124	126	126
4			Ventu Hydro	49	0	0	0	1	49	49	49	49
Subtotal – Newbury Park				**1,435**	**11**	**52**	**54**	**63**	**1,446**	**1,486**	**1,489**	**1,497**
5	MAIN THOUSAND OAKS	1	Pederson/ Willow	2,851	26	87	113	118	2,877	2,938	2,964	2,969
6		2	Conejo Oaks	329	0	1	1	1	329	331	331	331
7			Freeway/ La Granada	1,470	32	107	134	197	1,503	1,577	1,604	1,667
8			Lang Ranch/ Sunset No. 2	1,897	3	6	6	6	1,900	1,903	1,903	1,903
9			Meadows	1,003	0	9	9	9	1,003	1,012	1,012	1,012
10			Reduced Lang Ranch/ Sunset No. 2	57	0	0	0	0	57	57	57	57
11			Reduced Minnecota	20	0	0	0	0	20	20	20	20
12			Rolling Oaks	120	0	0	0	0	120	120	120	120
13			Tara	788	0	0	4	4	788	788	792	792
14			Wilder	664	4	6	6	6	668	670	670	670
15		3	Grissom	89	0	0	0	0	89	89	89	89
16			Northwood Booster	120	0	0	0	0	120	120	120	120
17			Oakbrook/ Sunset No. 3	1,680	0	5	6	9	1,681	1,685	1,686	1,689
18			Reduced Lang Ranch	178	0	0	0	0	178	178	178	178
19			Reduced Sapra	14	0	0	0	0	14	14	14	14
20		4	Grissom Hydro	38	0	0	0	0	38	38	38	38
21			Sunset Hydro	49	0	0	0	0	49	49	49	49
Subtotal – Main Thousand Oaks				**11,366**	**66**	**223**	**279**	**351**	**11,432**	**11,588**	**11,646**	**11,717**
TOTAL				**12,800**	**77**	**275**	**333**	**414**	**12,877**	**13,075**	**13,133**	**13,214**

Notes:

1. Per average demand distribution in calendar year 2015 prorated to the 2013-14 demands level.
2. Includes future development/redevelopment component. Drought recovery is assumed to occur by 2020 and is reflected in Baseline Demands.
3. Information regarding future development/ redevelopment projects including parcel locations and their planned land use, and number of dwelling units and phasing through 2040 was provided by the City. The information was last updated in 2012.
4. Water demand factors used in projecting future demands were taken from the City's 2005 Water Master Plan.

Section 4: Water System Evaluation

This section describes the water system evaluation performed to identify capacity deficiencies for distribution pipelines, storage reservoirs and supply facilities and the recommended capital improvements to alleviate them. The section begins with a summary of hydraulic model update and calibration followed by a discussion on the distribution system planning, sizing and performance evaluation criteria.

4.1 Model Update and Calibration

The hydraulic model of the City's distribution system was initially created as part of the 2005 Water Master Plan (RBF, 2005) using Innovyze's H2OMap platform. The all-pipe model is capable of extended period simulation (EPS) and was last updated in 2012. As part of this Water Master Plan, the model was further updated and calibrated to reflect the latest facilities, configuration and system operation.

The following steps were taken to update the hydraulic model:

- Pipelines and facilities constructed since 2012 were identified and added to the model.
- Abandoned pipelines were identified and removed from the model.
- Pressure zone boundaries were reviewed and updated in the model where necessary.
- Surface elevations were assigned to newly added model nodes.
- Pump curves were confirmed and/or updated based on recent Southern California Edison (SCE) pump efficiency tests.
- Depth-volume curves were developed for hopper-bottom reservoirs.
- 2015 water consumption data were spatially allocated to model nodes.

Once the model was updated, it was calibrated against field data from August 3rd through August 7th, 2015. Water demands during the calibration period were calculated for individual or groups of pressure zones using pump station/turnout flows and reservoir water levels. Pump station flows and reservoir water levels were collected from the City's SCADA system. Turnout flows were collected from Calleguas' turnout automation database (available via an interactive website set up by Calleguas for its member purveyors). The spatially allocated average demands were scaled for individual (or groups of) pressure zones to reflect demands during the calibration period. Hourly diurnal patterns were also developed and assigned to demand nodes.

Level controls and facility set points were identified from the SCADA data and operational records. Simple and logic-based control statements were then developed and assigned to model facilities. The simulated pump station flows and water levels were compared to the recorded data, and the necessary adjustments or corrections were made to calibrate the model. The model calibration results are presented in **Appendix D**.

While some variations between the SCADA-recorded and model-predicted system performance parameters were observed, an overall comparison of model results with the observed field conditions showed that the model was adequately calibrated, and that the observed variations in pump station flows and reservoir water levels and trends were within the accuracy guidelines established by the American Water Works Association (AWWA) for master planning models.

4.2 Distribution System Planning, Sizing and Performance Evaluation Criteria

This subsection describes the sizing and performance evaluation criteria for the distribution system reservoirs, supply facilities and pipelines. System planning criteria such as water demand factors, peaking factors and fire flows and durations are also described. The distribution system planning, sizing and evaluation criteria are summarized in **Table 4-1**.

4.2.1 Water Demand Criteria

Future demands for planned redevelopments (Thousand Oaks Boulevard Specific Plan), planned developments and developable vacant lands are estimated based on the 2005 Water Master Plan water demand factors. Given the anticipated demand recovery in the coming years, these factors are appropriate for future planning.

As discussed in Section 3.2.2, the recommended minimum and maximum day peaking factors for existing system evaluation and future system planning are 0.5 and 1.75, respectively. The systemwide peak hourly demand (PHD) is estimated at 2.0 times the maximum day demand (MDD) or 3.5 times the average day demand (ADD).

The water demand factors, peaking factors and fire flow requirements are presented in Table 4-1. The fire flows and their durations are recommended based on typical industry values.

4.2.2 Storage Reservoir Criteria

Storage reservoirs are used to supply peak hourly demand fluctuations (operational storage), provide fire flows, and supply the service area in the event of a planned facility shutdown or emergency outage. Providing operational storage allows pumping facilities and/or associated pipelines for each pressure zone to be sized for maximum day rather than peak hour flows. Storage reservoirs should be provided separately in each pressure zone when possible, or in a higher pressure zone if necessary.

The operational storage for each reservoir should be sized to provide 50 percent of the MDD of all pressure zones supplied by the reservoir. This includes the MDD of the zone directly served by the reservoir (primary zone) and the MDD of all the zones supplied by the reservoir indirectly (linked zones without dedicated storage). For example, the operational storage for Tara Reservoir should be sized based on the MDD of both Tara and Northwood Booster pressure zones.

The fire flow storage for each reservoir should be sized based on the largest single fire flow expected to be supplied by the reservoir. For large pressure zones with multiple reservoirs such as Lang Ranch/Sunset 2, each reservoir should independently hold 100 percent of the pressure zone's fire reserve requirement.

The Ventura County Fire Department (VCFD) uses the California Fire Code (CFC) to establish minimum fire flows and flow durations for buildings based on their type and fire flow calculation area. In contrast, the fire flow requirements set forth in this Master Plan are based on general land use designations and for master planning purposes. Therefore, they may not be reflective of the actual fire flow requirements for existing buildings or development approval.

The emergency storage for each reservoir should be sized to provide 50 percent of the MDD of all the pressure zones supplied by the reservoir. This enables each pressure zone to provide 12 hours of supply during the maximum demand day in the event of a planned facility shutdown or emergency situation. For zones with multiple supply facilities, the recommended emergency storage volume is 25 percent of the MDD.

4.2.3 Supply Facility Criteria

Pressure zones with gravity storage reservoirs (open systems) are primarily supplied by constant speed pump stations. Pump stations are typically sized to meet the combined MDD of all the zones they serve with their largest unit out of service (firm capacity). The summer Time-Of-Use (TOU) restrictions, however, limit the number of hours that each station can operate during the maximum demand day.

As shown in Appendix B, the summer TOU on-peak durations are 4 and 6 hours (depending on rate schedule designation) resulting in maximum daily runtimes of 18 and 20 hours. To allow time for pump stations start/stop operation, maximum daily runtimes were limited to 17 and 19 hours. Therefore, an open system pump station should be sized to meet 126 percent (24/19) or 141 percent (24/17) of MDD with its firm capacity.

Pressure zones without gravity storage reservoirs (closed systems) are supplied by hydropneumatic pump stations, variable speed pump stations or pressure reducing stations. The hydropneumatic and variable speed pump stations should be sized to meet the PHD of the zones they serve with firm capacity. The pressure reducing stations should be sized to meet the PHD of the zones they serve with total capacity.

Additionally, all three station types should be sized to meet the peak hour demand plus fire flow (PHD+FF) of the zones they serve with total capacity. Unlike the constant speed pump stations, hydropneumatic systems and the City's sole variable speed pump station (Northwood Booster) are not constrained by TOU restrictions.

A standby pumping unit equal to the size of the largest pump within each pump station is also required. Closed system pump stations should have an on-site generator to provide backup power, while an open system pump station should have either an on-site generator or a socket which will allow connection to a portable generator. For increased reliability, it is recommended that each pressure zone is supplied by at least two supply facilities, where feasible.

4.2.4 Distribution Pipeline Criteria

Distribution system pipelines are typically sized to minimize wear on valves and fittings, protect pipeline lining, limit headloss and lower the potential for pressure surge (water hammer). Existing pipelines with flow velocities greater than 10 feet per second (ft/s) under PHD condition and greater than 15 ft/s under maximum day demand plus fire flow (MDD+FF) condition are considered deficient.

Exceeding these criteria alone does not necessarily warrant replacement, however. Pipeline replacement decisions should be made on a case-by-case basis by taking into account system pressures and pipeline characteristics such as age, material, physical condition and location.

The recommended maximum velocity for new pipelines is 7.5 ft/s under PHD condition. The recommended maximum unit headloss for new pipelines is 5 ft per 1,000 ft of pipeline under MDD condition. New distribution pipelines serving fire hydrants should be 8 inches in diameter or larger.

4.2.5 Pressure Criteria

For the existing system and under normal operating conditions, the recommended minimum hourly pressure is 40 pounds per square inch (psi). The recommended minimum pressure for new developments is 50 psi. Under emergency conditions such as fire events, the minimum required pressure is 20 psi.

The maximum allowable pressure is 150 psi for majority of the system. Several areas within the system have static pressures of up to about 200 psi. These areas are supported by pipelines with pressure class of 200 psi.

The recommended static pressure range for new developments and/or pressure zones is 60 to 135 psi (providing a headloss allowance of 10 psi and pressure surge allowance of 15 psi).

Per the California Plumbing Code, individual pressure regulators are required for service pressures exceeding 80 psi.

Table 4-1: Distribution System Planning, Sizing and Performance Evaluation Criteria

Water Demands		
	Water Demand Factor	**Fire Flow/Duration**
High Density Residential (15-30 EDU/acre)	180 gpd/EDU	3,000 gpm @ 3 hrs
Medium Density Residential (4.5-15 EDU/acre)	310 gpd/EDU	2,500 gpm @ 3 hrs
Low Density Residential (2-4.5 EDU/acre)	405 gpd/EDU	1,500 gpm @ 2 hrs
Very Low Density Residential (0-2 EDU/acre)	440 gpd/EDU	1,500 gpm @ 2 hrs
Residential Developable Land (0.2-1 EDU/acre)	440 gpd/EDU	1,500 gpm @ 2 hrs
Commercial/Residential (15 EDU/acre)	200 gpd/EDU	4,000 gpm @ 4 hrs
Commercial	130 gpd/1,000 sf	3,000 gpm @ 3 hrs
Industrial	60 gpd/1,000 sf	5,000 gpm @ 4 hrs
Institutional	45 gpd/1,000 sf	5,000 gpm @ 4 hrs
K-12 School	15 gpd/1,000 sf	4,000 gpm @ 4 hrs
Park and Golf Course	2,000 gpd/acre	-
Peaking Factors		
PHD	2.0 x MDD (3.5 x ADD)	
MDD	1.75 x ADD	
MinDD	0.50 x ADD	
Storage Reservoirs		
Operational Storage Volume	50% of MDD[1]	
Fire Flow Storage Volume	Largest single FF @ specified duration[2]	
Emergency Storage Volume	Single supply zones: 50% of MDD[1]	
	Multiple supply zones: 25% of MDD[1]	
Supply Facilities		
Zones with Gravity Storage (Open Systems)	MDD[3] / maximum daily runtime in hours[4] x 24 met with firm capacity	
Zones without Gravity Storage (Closed Systems)	PHD met with firm capacity for pump stations and total capacity for pressure reducing stations	
	PHD+FF met with total capacity	
Supply Reliability/Redundancy	Standby pumping unit equal to largest unit	
	On-site generator for open system pump stations; Portable generator socket for closed system stations	
	Minimum of two facilities for each zone, where feasible	
Distribution Pipelines		
Nominal Diameter	Minimum: 8 inches (New pipes with fire hydrant)	
Velocity		
PHD Condition	Maximum: 10 ft/s (Existing pipes); 7.5 ft/s (New pipes)	
MDD+FF Condition	Maximum: 15 ft/s	
Unit Headloss – MDD Condition	Maximum: 5 ft/1,000 ft (New pipes)	
Pressures		
Static Pressure (New Developments/ Pressure Zones)	Minimum: 60 psi	
	Maximum: 135 psi	
Dynamic Pressure - Normal Operation	Minimum Hourly: 40 psi (50 psi for new developments)	
	Maximum Hourly: 150 or 200 psi[5]	
Dynamic Pressure - Emergencies	Minimum Hourly: 20 psi	

Notes:

1. Total MDD of all zone(s) supplied by the storage facility directly (primary zone) or indirectly (closed system linked zones).
2. For large pressure zones with multiple storage facilities, each reservoir should separately hold the zone's required fire flow storage volume.
3. MDD of primary zone plus open and closed system linked zone(s).
4. Per summer Time-Of-Use (TOU) restrictions (Appendix B).
5. Varies by location (based on static pressure and pipeline pressure class).

4.3 Reservoir Storage Capacity Evaluation

The reservoir storage capacities were evaluated for the buildout system based on the storage criteria discussed in section 4.2.2. The City's water service area is nearly buildout with only 3 percent growth projected beyond the 2013-14 water demands.

A summary of reservoir capacity evaluation is presented in **Table 4-2**. Detailed storage calculations are presented in **Appendix E**.

The reservoirs with potential storage deficiency include: Wilder, Kelley and Grissom.

The storage deficiency at Wilder Reservoir is estimated at about 0.73 MG (76 percent). The City is currently planning a 4,000-gpm fire pump with a diesel-fueled power generator at the La Granada pump station to meet the fire flow requirement of the Wilder pressure zone. This project is expected to resolve the projected Wilder Reservoir storage deficiency.

The storage deficiency at Kelley Reservoir is estimated between 0.06 to 0.42 MG (11 to 76 percent). The actual deficiency depends on how much flow is supplied from the West Kelley turnout to the flowing hydrant. Kelley pressure zone can also receive emergency supply from the neighboring Ventu pressure zone via the Lynn Road emergency pressure reducing station. Therefore, no improvement is recommended at this point. A fire flow analysis should be performed for all hydrants within the Kelley pressure zone to ensure fire flows could be met through a combination of supplies from Kelley Reservoir, West Kelley turnout and Lynn Road emergency pressure reducing station.

The storage deficiency at Grissom Reservoirs is estimated at about 0.04 MG (10 percent). The projected deficiency is minor and within the calculation's margin of error. No improvement is recommended for the Grissom Reservoirs.

The required fire flow storage for each reservoir was calculated based on the largest fire flow within all zones supplied by the reservoir. For Billing Zone 1 pressure zones (Pederson/Willow, Kelley and Ventu), it was assumed fire flows were supplied by both turnouts and reservoirs.

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Table 4-2: Summary of Reservoir Capacity Evaluation – Buildout Demand Condition

No.	Primary Zone	Total Required Volume (MG)	Total Available Volume (MG)	Surplus/ Deficit Volume (MG)	Deficit/ Surplus Fraction (%)
1	Tara	2.37	3.94	1.56	40%
2	Meadows	2.43	3.41	0.98	29%
3	Pederson/Willow	3.61-6.01	8.02	2.01 to 4.41	25% to 55%
4	Kelley	0.61-0.97	0.55	-0.42 to -0.06	-76% to -11%
5	Ventu Park	2.50-3.10	3.75	0.65 to 1.25	17% to 33%
6	Rolling Oaks	0.36	0.36	0.00	0%
7	Freeway/La Granada	4.66	5.00	0.34	7%
8	Wilder	1.71	0.98	-0.73	-76%
9	Lang Ranch/Sunset 2	4.38	5.95	1.57	26%
10	Oakbrook	2.18	2.18	0.00	0%
11	Sunset 3	0.71	0.76	0.05	7%
12	Grissom	0.45	0.41	-0.04	-10%

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4.4 Pressure Zone Supply Capacity Evaluation

The pressure zone supply capacities were evaluated for the buildout system based on the supply criteria discussed in section 4.2.3. The evaluation summary is presented in **Table 4-3**.

The following pressure zones were identified as potentially deficient under MDD conditions: Meadows, Freeway/La Granada (when Lone Oak to La Granada pump station is off), Lang Ranch/Sunset 2, Oakbrook and Sunset 3.

A brief description of supply deficiencies and recommended improvements is provided below.

- **Meadows pressure zone** is supplied by a single pumping unit at Erbes Road pump station. While the pump capacity is sufficient to meet the zone's MDD under buildout condition, lack of a redundant pump results in a firm capacity of 0. In the event of a discharge pressure drop, the zone can be supplied via an existing pressure reducing valve (PRV) located immediately downstream of Erbes Road to Lang Ranch pumps.

  If Erbes Road pump station is out of service, the supply to Meadows will be completely cut off, however. For increased supply reliability, it is recommended to modify the Pederson pump station to utilize its excess pumping capacity to supply Meadows during emergencies.

  The proposed modifications include modification of the Pederson pump station discharge header and construction of approximately 200 ft of 12-inch diameter pipeline to connect the Pederson Pump No. 1 discharge to the existing 10-inch diameter main along Pederson Road with minor valving improvements. This is a relatively inexpensive project with significant benefits.

- **Freeway/La Granada pressure zone** is currently supplied from the Lone Oak to La Granada and the Willow Lane pump stations. These two stations together are capable of meeting the zone's MDD under buildout conditions with their largest units out of service (line item 10A in Table 4-3).

  The City is currently planning a new pump station at the La Granada Reservoir to supply the Wilder pressure zone (La Granada pump station). If the Lone Oak to Wilder pump station is off when the La Granada pump station is supplying Wilder, the Lone Oak to La Granada pump station will not be able to meet the Freeway/La Granada pressure zone's buildout MDD with its largest unit out of service (line item 10B in Table 4-3). Therefore, the La Granada and the Lone Oak to Wilder pump stations should be concurrently operated to meet the buildout MDD. As such, no capital supply improvement is needed for this zone.

- **Lang Ranch/Sunset 2** is supplied from Erbes Road to Lang Ranch and Sunset No. 1 pump stations. Under buildout MDD condition, the pressure zone has a supply deficiency of about 1,000 gpm with the largest unit at each station out of service. This deficiency could be eliminated if the Erbes Road to Lang Ranch and Sunset No. 1 pump stations could be operated without interruption during the maximum demand day (i.e., no TOU compliance). Since the deficiency of having the largest pump out of service can be resolved by overriding the TOU constraint, no capital supply improvement is recommended for this zone.

- **Oakbrook pressure zone** is supplied from Los Arboles and Lang Ranch pump stations. The zone has a firm supply deficiency of approximately 1,000 gpm. Both pump stations could benefit from a redundant pumping unit. In discussion with the City, it was determined that addition of a third unit at Los Arboles pump station was not feasible without rebuilding the entire station. The City requested that a new 750-gpm pumping unit be added to Lang Ranch pump station. Alternatively, the City could consider upsizing the existing Los Arboles pumps.

- **Sunset 3** pressure zone has a minor firm supply deficiency of about 11 gpm. No capital supply improvement is recommended for this zone.

The following pressure zones were identified as potentially deficient under buildout PHD+FF conditions:

- **Northwood Booster pressure zone** has a fire flow requirement of 1,500 gpm (Low Density Residential) and a PHD of approximately 320 gpm. The zone is supplied by two variable speed 500 gpm pumps resulting in a supply deficiency of approximately 820 gpm under PHD+FF condition.

  An existing check valve located near the intersection of Northwood Parkway and Marigold Place supplies the Northwood Booster pressure zone from Tara during emergencies when the Northwood's hydraulic grade line falls below that of the Tara pressure zone. This emergency supply is likely sufficient to make up the projected fire flow supply deficiency.

  In discussion with the City and for increased reliability, a pressure reducing station was recommended from the Lang Ranch/Sunset 2 pressure zone. The station is proposed to be located along Avenida Verano at or near the Northwood Park.

- **Reduced Minnecota pressure zone** has a fire flow requirement of 2,500 gpm (Medium Density Residential) and a PHD of approximately 70 gpm. The zone is supplied by the Minnecota pressure reducing station. The station includes a 2-inch diameter PRV and a 4-inch diameter PRV with an estimated combined capacity of about 1,000 gpm resulting in supply deficiency of approximately 1,570 gpm under PHD+FF condition. The addition of a new 8-inch diameter PRV is recommended at this station.

- **Reduced Lang Ranch/Sunset 2 pressure zone** has a fire flow requirement of 2,500 gpm (Medium Density Residential) and a PHD of approximately 200 gpm. The zone is supplied by the Rusticpark pressure reducing station. The station includes a 3-inch diameter PRV and a 6-inch diameter PRV with an estimated combined capacity of about 2,260 gpm resulting in supply deficiency of approximately 440 gpm under PHD+FF condition. An existing check valve along Scenicpark Street is expected to supply this zone from the Meadows Zone during emergencies. No supply improvement is recommended at this time.

- **Grissom Hydro pressure zone** has a fire flow requirement of 1,500 gpm (Low Density Residential) and a PHD of approximately 105 gpm. The zone is supplied by the Grissom Hydro pump station which includes two 250-gpm hydropneumatic pumps and a 1,000-gpm diesel engine fire pump resulting in a relatively minor supply deficiency of approximately 105 gpm under PHD+FF condition. No capital supply improvement is recommended for this zone.

Table 4-3: Pressure Zone Supply Capacity Evaluation – Buildout Demand Condition

No.	Primary Zone	Linked Zone(s)	Primary Zone's Supply Facility(ies)	Maximum Daily Runtime (hrs/day)	Required Capacity (gpm)		Design Capacity, Firm (gpm)	Design Capacity, Total (gpm)	Supply Surplus/ Deficit w/ Firm Capacity (gpm)	Supply Surplus/ Deficit w/ Total Capacity (gpm)	Recommended Improvement
					Value	Criteria					
1	Meadows	-	Erbes Rd to Meadows PS	19	1,289	MDD x 1.26	0	1,650	-1,289	361	Pederson PS Modification
2	Tara	Northwood Booster	Pederson PS	19	1,240	MDD x 1.26	2,400	3,600	1,160	2,360	
3	Northwood Booster	-	Northwood Booster PS	24	320	PHD	500	1,000	180	680	
					1,820	PHD+FF	500	1,000	-1,320	-820	Construct a PRS from Lang Ranch/Sunset 2
4	Pederson/Willow	Rolling Oaks, Freeway/La Granada, Conejo Oaks, Tara, Northwood	Hillcrest, Gainsborough, Las Flores, Los Arboles, Encino Vista Turnouts	24	6,544	MDD	13,500	13,500	6,956	6,956	
5	Kelly	Kelly Hydro	West Kelley Turnout	24	299	MDD	2,000	2,000	1,701	1,701	
6	Kelly Hydro	-	Kelley PS	24	361	PHD	650	1,350	289	989	
					1,861	PHD+FF	1,350	2,350	-511	489	
7	Ventu	Ventu Hydro	Ventu Park Turnout	24	1,322	MDD	2,500	2,500	1,178	1,178	
8	Ventu Hydro	-	Ventu PS	24	128	PHD	450	900	322	772	
					1,728	PHD+FF	900	1,900	-828	172	
9	Rolling Oaks	-	Rolling Oaks PS	17	174	MDD x 1.41	200	400	26	226	
10A	Freeway/La Granada (without La Granada PS)	Conejo Oaks	Lone Oak to La Granada PS, Willow Lane PS	19	2,645	MDD x 1.26	2,700	4,200	55	1,555	
10B	Freeway/La Granada (without Lone Oak to Wilder PS)	Conejo Oaks, Wilder, Grissom, Grissom Hydro, Reduced Sapra	Proposed La Granada PS, Willow Lane PS	19	3,768	MDD x 1.26	2,250	3,750	-1,518	-18	None (Operate Lone Oak to Wilder and La Granada PS concurrently)
11	Conejo Oaks	-	La Jolla & Rosario PRS (3"/6") Janss & El Monte PRS (6") El Dorado PRS (1.5"/6")	24	2,353	PHD+FF	5,985	5,985	3,632	3,632	

No.	Primary Zone	Linked Zone(s)	Primary Zone's Supply Facility(ies)	Maximum Daily Runtime (hrs/day)	Required Capacity (gpm)		Design Capacity, Firm (gpm)	Design Capacity, Total (gpm)	Supply Surplus/ Deficit w/ Firm Capacity (gpm)	Supply Surplus/ Deficit w/ Total Capacity (gpm)	Recommended Improvement
					Value	Criteria					
12	Lang Ranch/Sunset 2	Oakbrook, Sunset 3, Sunset Hydro, Reduced Lang Ranch, Reduced Lang Ranch/Sunset 2, Reduced Minnecota	Erbes Rd to Lang Ranch PS, Sunset No. 1 PS	19	5,353	MDD x 1.26	4,350	7,300	-1,003	1,947	Override TOU constraint
13	Oakbrook	Reduced Lang Ranch	Los Arboles PS, Lang Ranch 4A PS	17	2,257	MDD x 1.41	1,300	2,600	-957	343	Install a new pump at Lang Ranch PS
14	Sunset 3	Sunset Hydro	Sunset No. 2 PS	19	461	MDD x 1.26	450	900	-11	439	
15	Reduced Lang Ranch	-	Westlake Blvd PRS (4"/8") Lang Ranch PRS (4"/8")	24	1,988	PHD+FF	7,800	7,800	5,812	5,812	
16	Sunset Hydro	-	Sunset No. 3 PS	24	100	PHD	800	1,200	700	1,100	
					1,600	PHD+FF	1,200	2,200	-400	600	
17	Reduced Minnecota	-	Minnecota PRS (2"/4")	24	68	PHD	1,010	1,010	942	942	
					2,568	PHD+FF	1,010	1,010	-1,558	-1,558	Add 1 x 8" PRV
18	Reduced Lang Ranch/Sunset 2	-	Rusticpark PRS (3"/6")	24	200	PHD	2,260	2,260	2,060	2,060	
					2,700	PHD+FF	2,260	2,260	-440	-440	Check valve from Meadows (existing)
19A	Wilder (without La Granada PS)	Grissom, Grissom Hydro, Reduced Sapra	Lone Oak to Wilder PS	19	1,123	MDD x 1.26	1,300	2,000	177	877	
19B	Wilder (without Lone Oak to Wilder PS)	Grissom, Grissom Hydro, Reduced Sapra	Proposed La Granada PS	19	1,123	MDD x 1.26	750	1,500	-373	377	None (Operate Lone Oak to Wilder and La Granada PS concurrently)
20	Grissom	Grissom Hydro, Reduced Sapra	Wilder PS	17	267	MDD x 1.41	400	800	133	533	
21	Grissom Hydro	-	Grissom PS	24	105	PHD	250	500	145	395	
					1,605	PHD+FF	500	1,500	-1,105	-105	None (Deficiency is minor)
22	Reduced Sapra	-	Sapra Street PRS (3"/6")	24	1,532	PHD+FF	2,260	2,260	728	728	

4.5 Pipeline Capacity Evaluation

The distribution system pipeline capacities were evaluated for the buildout system based on system pressure and pipeline velocity and headloss criteria discussed earlier in sections 4.2.4 and 4.2.5. A summary of evaluation results is discussed in this subsection.

System Pressures

The minimum and maximum hourly pressures under buildout MDD scenario are presented in **Figure 4-1** and **Figure 4-2**, respectively.

System pressures under buildout MDD scenario are generally within the 40-150 psi range. The relatively small high pressure areas within Oakbrook, Sunset 3, Lang Ranch/Sunset 2, Reduced Lang Ranch, Wilder and Ventu pressure zones are all due to high static pressures. Pipelines in these areas are capable of sustaining pressures of up to 200 psi. Therefore, pressure zone boundary realignments to correct static pressures are not warranted.

Velocities and Headloss

An overview map of peak hourly pipeline velocities under buildout MDD scenario is presented in **Figure 4-3**. Detailed velocity maps downstream of active turnouts are presented in **Figure 4-4**.

An overview map of average hourly pipeline unit headloss under buildout MDD scenario is presented in **Figure 4-5**. Detailed unit headloss maps downstream of active turnouts are presented in **Figure 4-6**.

As shown on these figures, pipeline velocities and unit headloss are generally within the criteria range with the exception of pipelines located immediately downstream of several turnouts including Los Arboles, Las Flores, Hillcrest, Encino, Lindero and Ventu Park. Given their locations and high velocities, these pipelines have relatively high pressure surge potential. The City should consider performing a pressure surge evaluation study for these high velocity pipelines and upsizing them as necessary.

A summary of replacement pipeline candidates is presented in **Table 4-4**.

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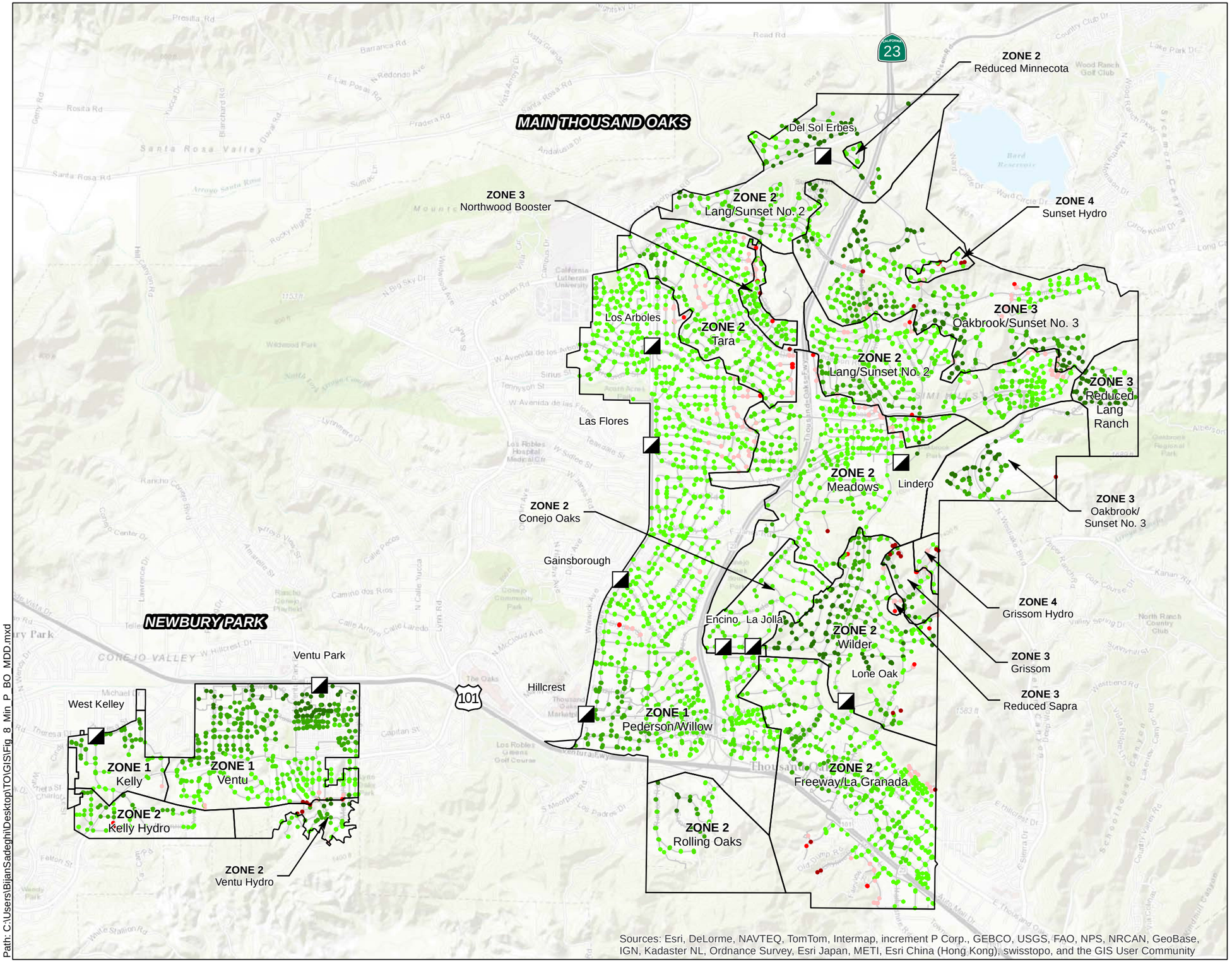

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Legend

- Turnout
- Pressure Zone

Minimum Hourly Pressure

- <30 psi
- 30.1-40 psi
- 40.1-50 psi
- 50.1-75 psi
- 75.1-100 psi
- 100.1-125 psi
- >125 psi

N

0 0.5 1

Miles

Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Minimum Hourly Pressure Overview Map
Existing System (No Improvements)
Buildout Maximum Day Demand Scenario

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February 2018

Figure 4-1

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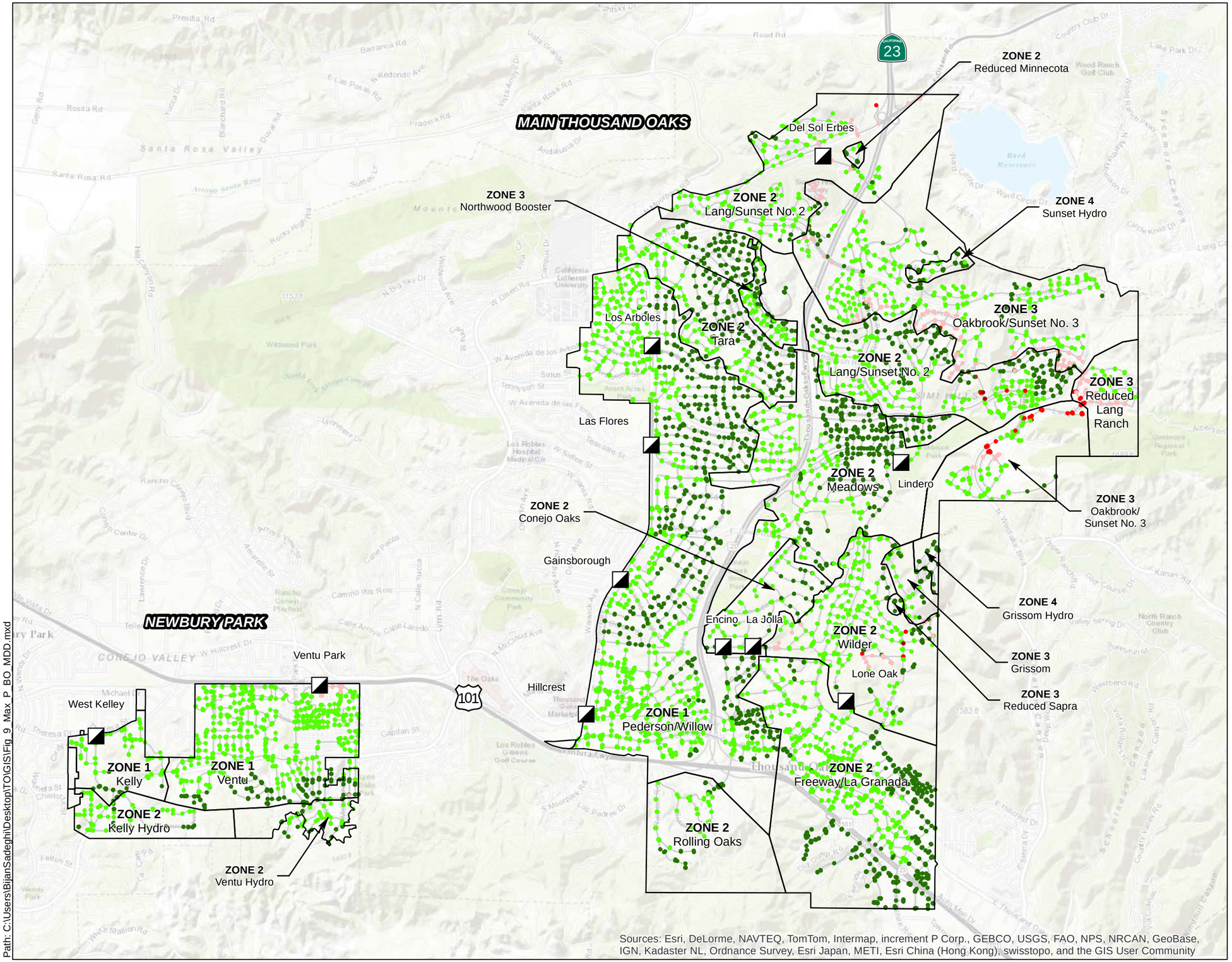

Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Legend

- Turnout
- Pressure Zone

Maximum Hourly Pressure

- < 80 psi
- 80.1-150 psi
- 150.1-175 psi
- 175.1-200 psi
- > 200 psi

N

0 0.5 1

Miles

Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Maximum Hourly Pressure Overview Map
Existing System (No Improvements)
Buildout Maximum Day Demand Scenario

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February 2018

Figure 4-2

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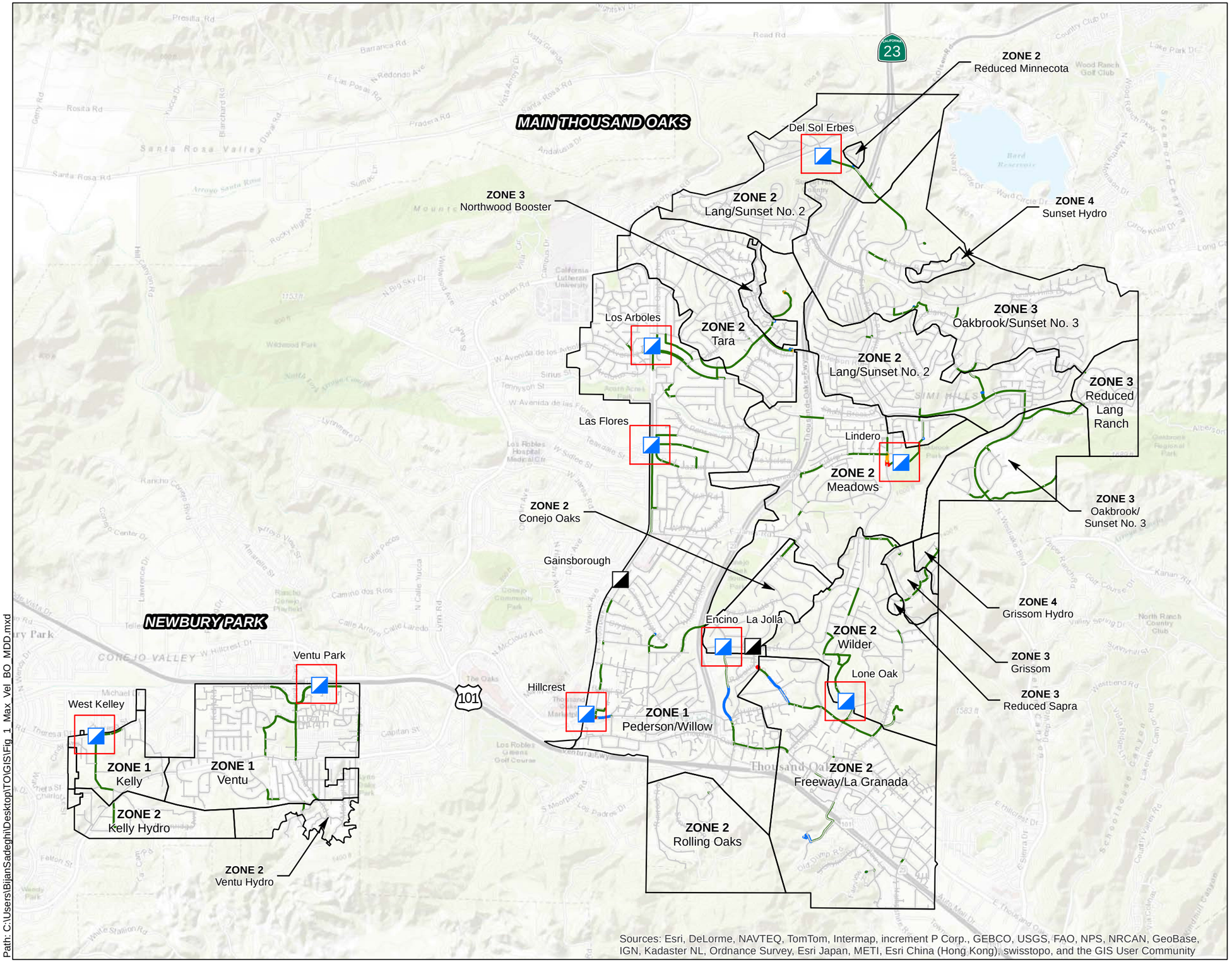

Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Legend

- Active Turnouts
- Inactive Turnouts
- Pressure Zone Boundaries

Peak Hourly Velocity

- < 2.5 ft/s
- 2.6-5.0 ft/s
- 5.1-7.5 ft/s
- 7.6-10.0 ft/s
- > 10 ft/s

Refer to Figure 4-4 for details.

N

0 0.5 1

Miles

Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Peak Hourly Pipeline Velocity
Overview Map
Existing Systrem (No Improvements)
Buildout Maximum Day Demand Scenario

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February 2018

Figure 4-3

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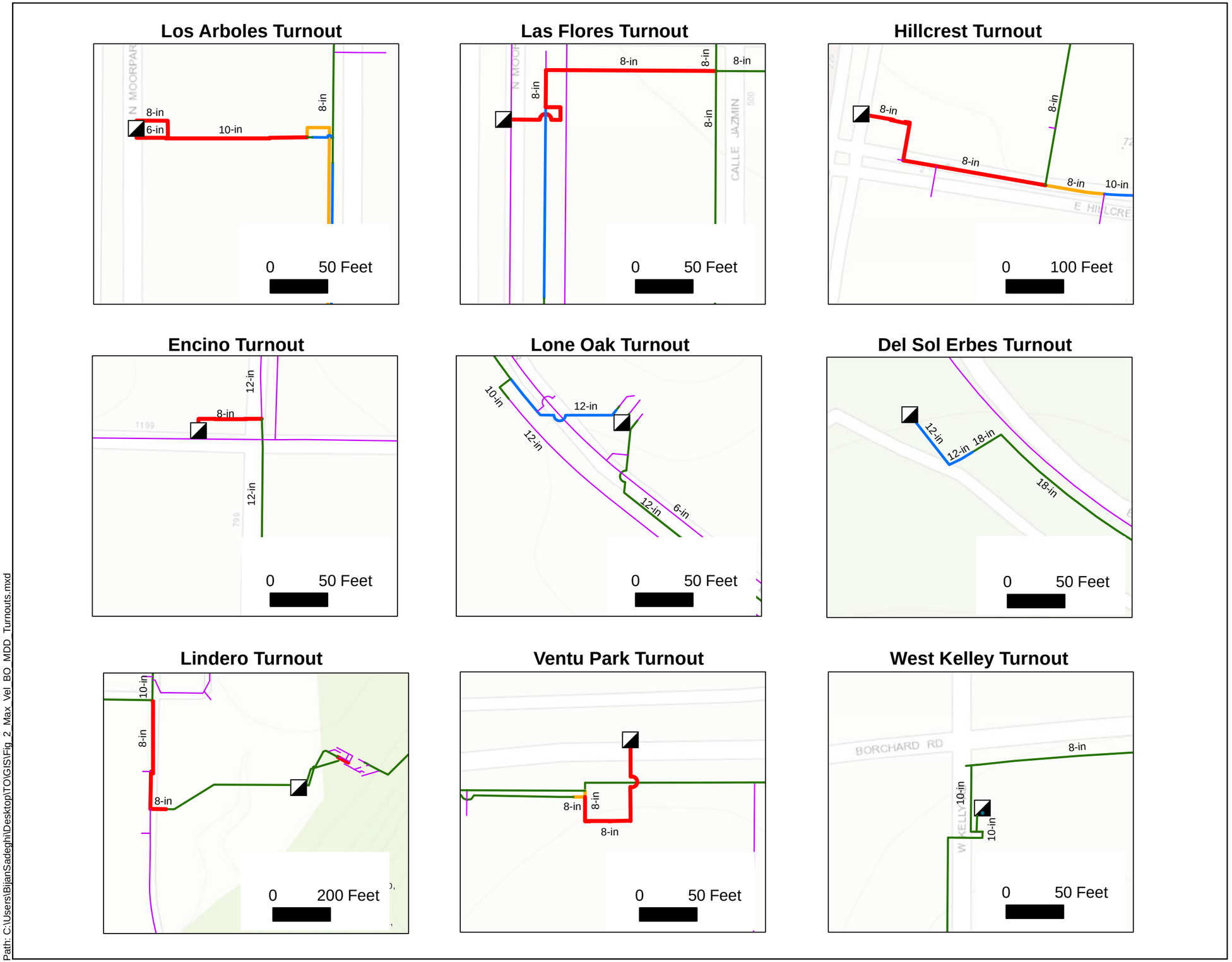

Legend

Turnouts

Peak Hourly Velocity

- < 2.5 ft/s
- 2.6-5.0 ft/s
- 5.1-7.5 ft/s
- 7.6-10 ft/s
- >10 ft/s

N

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City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Peak Hourly Pipeline Velocities
Downstream of Turnouts
Existing Systrem (No Improvements)
Buildout Maximum Day Demand Scenario

K/J 1544510.00
February 2018

Figure 4-4

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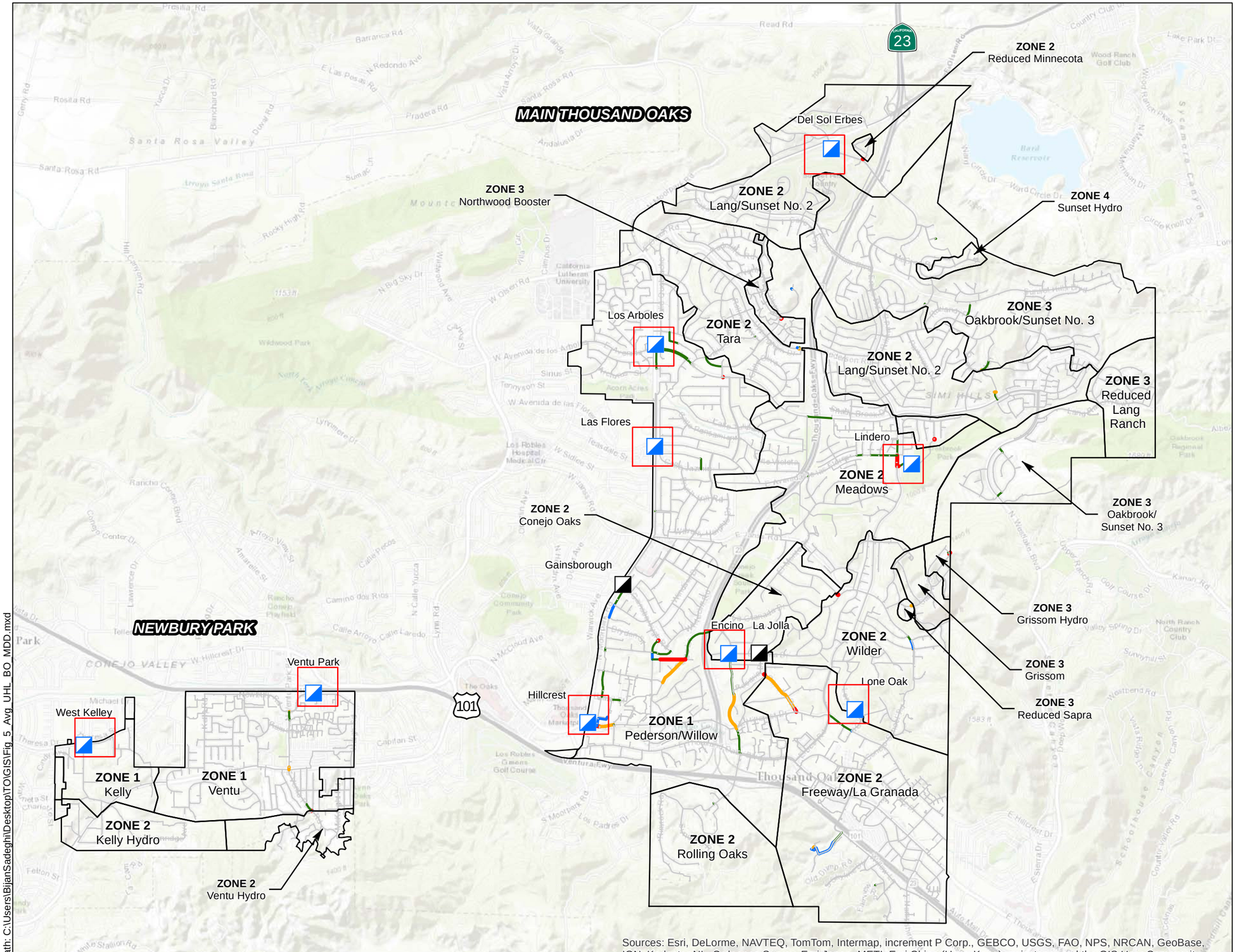

Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Legend

- Active Turnouts
- Inactive Turnouts
- Pressure Zone

Average Hourly Unit Headloss

- < 2.5 ft/1,000 ft
- 2.6-5.0 ft/1,000 ft
- 5.1-7.5 ft/1,000 ft
- 7.6-10 ft/1,000 ft
- > 10 ft/1,000 ft

Refer to Figure 4-6 for details.

N

0 0.5 1
Miles

Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Average Hourly Unit Headloss
Overview Map
Existing Systrem (No Improvements)
Buildout Maximum Day Demand Scenario

K/J 1544510.00
February 2018

Figure 4-5

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Legend

Turnouts

Average Unit Headloss

- < 2.5 ft/1,000ft
- 2.6-5.0 ft/1,000ft
- 5.1-7.5 ft/1,000ft
- 7.6-10 ft/1,000ft
- >10 ft/1,000ft

N

Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Average Hourly Unit Headloss
Downstream of Turnouts
Existing System (No Improvements)
Buildout Maximum Day Demand Scenario

K/J 1544510.00
February 2018

Figure 4-6

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Table 4-4: Summary of Deficient Pipelines and Replacement Recommendations

No.	Location	Length	Size	Age	Material	Maximum Velocity under PHD	Replacement Size	Maximum Velocity after Pipeline Upsizing
1	Between Los Arboles Turnout and Calle Quebracho	165 ft	6-in/8-in/10-in	48 yrs	Steel	12 ft/s	16-in	4.8 ft/s
2A	Between Las Flores Turnout and Calle Jazmin	85 ft	8-in	25 yrs	Asbestos Cement	16 ft/s	16-in	4.8 ft/s
2B		180 ft				10 ft/s	12-in	5.8 ft/s
3	Downstream of Hillcrest Turnout along East Hillcrest Drive	525 ft	8-in	17 yrs/ Unknown	Asbestos Cement/ Unknown	12 ft/s	16-in	4.8 ft/s
4	Between Encino Turnout and Encino Vista Drive	90 ft	8-in	Unknown	Unknown	13 ft/s	12-in	4.0 ft/s
5	Between Lindero Turnout and East Avenida De Las Flores	450 ft	8-in	48 yrs	Asbestos Cement	10 ft/s	12-in	5.1 ft/s
6	Downstream of Ventu Park	150 ft	8-in	49 yrs	Asbestos Cement	16 ft/s	16-in	4.0 ft/s
Total		**1,645 ft**						

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Section 5: Water Quality Evaluation

This section describes two distinct water quality evaluations performed as part of this Master Plan: (1) a reservoir mixing and disinfection boosting pilot study, and (2) water age modeling. The reservoir mixing and disinfection boosting pilot study conducted from October 2015 through April 2016 is summarized along with its recommendations in this section, with a detailed Technical Memorandum in **Appendix F**. The water age modeling evaluations and associated recommendations are also described in this section.

5.1 Reservoir Mixing and Disinfection Boosting Pilot Study

The City receives chloraminated drinking water from the Calleguas Municipal Water District (Calleguas) and conducts routine water quality monitoring of its reservoirs and distribution system. Historical total chlorine and nitrite data correlated with reservoir water temperatures demonstrate strong evidence of seasonal nitrification within the City's system as a whole.

Trussell Technologies, Inc. (Trussell) and Kennedy/Jenks considered several nitrification control strategies in helping the City identify an immediate strategy to mitigate the water quality degradation in the system given the scale of the nitrification issue in the City's reservoirs. Two nitrification control strategies were selected for pilot implementation and evaluation as part of this Master Plan: (1) active reservoir mixing, and (2) supplemental disinfection boosting. These strategies were selected for evaluation as the most cost effective, efficient, and likely to be successful control strategies for the City to consider. A summary of the study and its recommendation are described in the following subsections.

5.1.1 Pilot Study Summary

The study evaluated the effect of adding mixers and/or chlorine/ammonia boosting on the water quality (nitrification control) in select reservoirs. To accomplish the goals of the study, the City leased a total of five PAX mixers and two Residual Control System (RCS) units for a six month trial period. The study focused on the reservoirs where the most impact of nitrification had been observed. The mixers were installed at Willow Lane, Pederson, Rolling Oaks, La Granada and Ventu Park reservoirs. The RCS units were installed at Willow Lane and Pederson reservoirs. Along with the implementation of the mixers and supplemental boosting control systems, additional water quality monitoring was conducted by the City for the duration of the study.

The supplemental disinfection boosting study demonstrated that the addition of PAX mixers to reservoirs provided improvements in water quality. Adding to the mixer the ability to boost chemical (chlorine and/or ammonia with a control over the dosing ratio) using the PAX RCS resulted in consistently good water quality for the two reservoirs in the study with a mixer and the PAX RCS (Willow Lane and Pederson). The improved water quality in the reservoirs with the mixer and control system also benefited the downstream reservoirs, although the water quality in the downstream reservoirs was less consistent.

The reservoir mixing and disinfection boosting pilot study and the associated water quality analysis are described in more detail in the Water Quality Analysis/Enhancement of Operations Improvement Plan Technical Memorandum presented in Appendix F.

5.1.2 Pilot Study Recommendations

Based on this pilot study, the following operational improvements were recommended:

1. Procure PAX or an equivalent active mixer for each of the City's 16 reservoirs. The mixers will greatly reduce temperature stratification, which leads to water quality deterioration and the formation of nitrification biofilms.

2. Procure four PAX RCS units with two units permanently installed at Willow Lane and Pederson reservoirs. Beyond the permanent installations, two additional units should be procured and maintained as mobile supplemental boosting units to provide seasonal or as-needed treatment in various reservoirs. All reservoirs should be equipped with electrical and plumbing connections to accommodate the mobile supplemental boosting units.

3. Equip all reservoirs with a proven analyzer to provide continuous monitoring of total chlorine for a real-time gauge of residual chlorine and indicator of nitrification in reservoirs. The PAX RCS units are equipped with a Water Quality Station that provides continuous monitoring of total chlorine, pH, and oxidation-reduction potential. Integration of continuous monitoring data with the City's SCADA system will allow for real-time monitoring feedback to assess the variability of water quality and the impact of operational changes.

4. Increase reservoir monitoring for nitrification indicators (e.g., total chlorine, nitrite, water temperature) during the months of June through December, when water quality has historically been impacted. This should also be implemented when the water temperature in a reservoir exceeds 18ºC. For these conditions, monitor all reservoirs on a weekly basis, at minimum. Sampling frequency recommendations are presented in **Table 5-1**.

Table 5-1: Recommended Sampling Frequency for Nitrification Related Constituents

Constituent or Parameter	January - May	June - December	Nitrite > 0.03 and/or Total Chlorine < 0.75
Total chlorine[1]	Monthly	Weekly	3x/week
Free chlorine	Monthly	Monthly	Weekly
Nitrite	Monthly	Weekly	5x/week
Nitrate	Monthly	Monthly	2x/month
Free ammonia	Monthly	Monthly	3x/week
Total ammonia	Monthly	Monthly	Weekly
Total coliform bacteria	Monthly	Monthly	Weekly
Heterotrophic plate count (HPC)	Monthly	Monthly	Weekly
Turbidity	Monthly	Monthly	Weekly
pH	Monthly	Monthly	Weekly
Temperature	Monthly	Weekly	3x/week

Note:

1. Monthly grab samples for QA/QC if online chlorine analyzer present

5. Establish proactive water quality trigger points for initiating additional operational changes to mitigate nitrification issues. Proposed trigger points and recommended response are summarized in **Table 5-2**.

Table 5-2: Sampling Trigger Points and Recommended Response

Constituent or Parameter	Trigger	Response
Nitrite	>0.03 mg/L N	Sampling within 2 days per Table 5-1
Nitrite	>0.05 mg/L N	Run Mobile RCS
Total Chlorine	<0.75 mg/L	Sampling per Table 5-1
Total Chlorine	<0.5 mg/L	Run Mobile RCS
Total Chlorine and Nitrite	>1.0 mg/L <0.03 mg/L	Stop mobile RCS, resume seasonal monitoring
Temperature	18°C	Sampling per Table 5-1, June through December

As of October 2017, the City operates two SolarBee® mixers within Freeway and Tara reservoirs and 10 PAX mixers within Ventu Park Reservoir (one in each chamber), Willow Ln., La Granada, Wilder, Oakbrook, Lang Ranch, Pederson, Sunset #2, and Rolling Oaks.

The City has also procured an additional PAX mixer to replace the Tara Reservoir's SolarBee® mixer and plans to procure five additional PAX mixers for the remaining reservoirs.

5.2 Water Age Evaluation

Water age is defined as the time spent by a parcel of water from the moment it enters the system till when it is consumed. This includes the time spent in both pipelines and reservoirs. Excessive water age results in loss of disinfectant residual which is necessary to keep pathogens at bay and prevent nitrification. Disinfectant residual decay also results in disinfection byproduct (DBP) formation and coating buildup and biological growth in the system. Water age is used as a simple surrogate for the system's overall water quality.

The objective of the water age modeling evaluation presented in this section was to develop a set of operational strategies and system improvements to reduce water age to the extent possible. Because reservoirs make up a significant portion of the system's total storage volume, optimizing how much water they hold based on system demand and how fast they are turned over are crucial in meeting this objective.

When reservoirs are in fill cycle (typically during nighttime when demands are low), water age at most service laterals is relatively low if the source water is fresh or its water age is considerably lower than that of the stored water. When in drain cycle (typically during daytime when demands are high), supply facilities are often shut off while reservoirs meet the system's demand. Water age is relatively high during this time. Therefore, the modeling evaluation focused on reducing water age at reservoirs.

Acceptable water age depends on many system specific factors including the nature and layout of the system, pipe material, disinfectant type and residual, water temperature and the composition of source water (e.g., organic content). In the absence of a system-specific water age criteria, the hydraulic model was used to determine the effectiveness of operational adjustments and system improvements in reducing water age.

Given the system's hydraulic profile, sufficiently low age water may not be available to all pressure zones particularly to those with higher hydraulic grades where water has to travel through multiple intermediary zones before reaching the target pressure zone. The primary reason for high water age in these pressure zones is the source water that is already old. Disinfectant renewal (rechloramination) was recommended for these reservoirs.

5.2.1 Assumptions and Methodology

The water age evaluation was performed using the City's calibrated EPS model. The model treats age as a reactive constituent whose growth follows zero-order kinetics with a constant rate of 1 (i.e., each second the water becomes a second older).

The evaluation was performed based on 2015 average day demands (ADDs). The problem with high water age is greatest when temperature is warm and water demand is low. The evaluation of historical water quality data (January 2010 – March 2016) showed that total chlorine residual at reservoirs were generally lowest in the late fall when demands are typically average. Year 2015 was the lowest demand year in recent years and was selected as the basis for water age evaluations. The systemwide ADD in 2015 was approximately 8.3 million gallons per day (mgd).

Reservoirs were modeled as completely mixed reactors. Thus, the evaluation focused on system operation to increase storage utilization and turnover. Additionally, it was assumed that supply from Calleugas enters the City's distribution system with the age of zero (fresh water). Therefore, the reported water age values ignore the travel time between the point of disinfection at Jensen Water Treatment Plant and the City's supply turnouts.

The overall methodology was to start with a baseline scenario representing the existing system and simulate various operational strategies and system improvements in succession, with each strategy or improvement representing a scenario. A total of 10 scenarios were modeled and evaluated.

To quantify the effectiveness of the tested strategies and improvements, average water age at all reservoirs were documented for each successive scenario and compared to its preceding scenario. The water age modeling scenarios are presented in **Table 5-3** and further described in this subsection along with their evaluation methodologies.

The modified level controls and turnout pressure reducing valve (PRV) set points are presented in **Appendix G** for all scenarios.

Table 5-3: Water Age Evaluation Modeling Scenarios

Scenario	Preceding Scenario	Operational or System Improvements Modeled
1	None	Existing system prior to Oakbrook/Sunset 3 zone split
2	1	Existing system after Oakbrook/Sunset 3 zone split
3	2	Pump station and turnout level control/set point adjustments to optimize average daily storage volumes and increase turnover
4A	3	Planned La Granada pump station, Lone Oak to Wilder pump station off
4B		Planned La Granada pump station, Lone Oak to Wilder providing 30 percent of Wilder zone demand
4C		Planned La Granada pump station, Lone Oak to Wilder providing 50 percent of Wilder zone demand
5	4A	Average daily storage volume reduction at Freeway and La Granada reservoirs
6	5	Freeway Reservoir elimination
7	5	Flow control-based turnout operation
8	7	Recommended capacity improvements per Section 4

Scenarios 1 – Baseline System Conditions

Scenario 1 was developed based on the City's typical level controls and set points. This scenario represents baseline system conditions prior to Oakbrook/Sunset 3 zone split which was temporarily implemented in December 2015 as an attempt to increase the Oakbrook Reservoir turnover. Scenario 1 was used for water age comparison with Scenario 2 (described below).

Scenario 2 – Oakbrook/Sunset 3 Zone Split

Scenario 2 represents baseline system conditions after Oakbrook/Sunset 3 zone split. The level controls and set points for this scenario were identical to those of Scenario 1 with the exception of Lang Ranch pump station which was set to operate based on the Oakbrook Reservoir. The scenario's objective was to confirm the zone split's effectiveness in reducing water age.

Scenario 3 – Storage Reservoirs' Utilization and Turnover Improvement

Scenario 3 was developed based on Scenario 2 using adjusted level controls and set points for all turnouts and pump stations. Average reservoir water age is a function of the reservoir's average daily storage volume and its turnover rate. Both of these factors were adjusted by modifying the existing level controls for turnouts and pump stations. In addition, turnout PRV set points were modified. Prior to these modifications, the required average daily storage volumes were calculated for all reservoirs based on 2015 ADDs:

Required Average Daily Storage Volume = Fire Reserve + Emergency Storage + ½ Daily Equalization Storage

Once target volumes (levels) were estimated, the low and high level controls at turnouts and pump stations were modified iteratively to achieve the estimated average levels. Additionally and as shown in Appendix G, multiple pumping units were assigned identical level controls for simultaneous operation. This reduces the reservoirs' fill and drain cycle times thus improving their turnover rates. In practice, the lag units at the subject pump stations should come online with minimal delay in order to maximize the water quality benefits.

Scenarios 4A, 4B and 4C – La Granada Pump Station Operation

Scenarios 4A, 4B and 4C were developed based on Scenario 3 with the addition of the planned La Granada pump station. The objective was to develop an operational strategy for the pump station based on water age considerations. One of La Granada pump station's objective is to increase La Granada Reservoir turnover by pumping out the old water into the Wilder zone. Without operating the Lone Oak to Wilder pump station, this results in increased water age in Wilder and subsequently Grissom pressure zone. To develop an optimum combination of freshwater supply from the Lone Oak turnout and old water from the La Granada Reservoir, three sub-scenarios were developed evaluated:

- Scenario 4A: Wilder pressure zone supplied solely from La Granada pump station
- Scenario 4B: Wilder pressure zone supplied from both La Granada pump station (70 percent) and Lone Oak to Wilder pump station (30 percent)
- Scenario 4C: Wilder pressure zone supplied from both La Granada pump station (50 percent) and Lone Oak to Wilder pump station (50 percent)

Scenarios 5 – Reduced Storage at Freeway/La Granada

The storage capacity evaluation presented in Section 4 assumed that for pressure zones with two distant reservoirs, each reservoir held 100 percent of the zone's fire reserve requirement. This assumption was relaxed for the Freeway/La Granada pressure zone in Scenario 5.

Scenarios 5 was developed based on Scenario 4A (Lone Oak to Wilder off) assuming that the two reservoirs combined hold 100 percent of the zone's fire reserve requirement (i.e., 5,000 gpm for 4 hrs or 1.2 MG split between the two reservoirs).

Scenarios 6 – Freeway Reservoir Elimination

Scenario 6 was developed based on Scenario 5 with the Freeway Reservoir removed from service. Similar to Scenario 5, this scenario was developed to further reduce water age within the Freeway/La Granada pressure zone. In this scenario, Willow Lane pump station was operated based on the La Granada Reservoir water level.

Scenario 7 – Turnout PRV Replacements with Flow Control Valves (FCVs)

Scenario 7 was developed based on Scenario 5 with all turnouts operated in flow control mode instead of pressure regulation. The objective was to evaluate the impact of turnout operation on reservoirs turnover.

Scenario 8 – Capacity Improvements Implementation

Scenario 8 was developed based on Scenario 7 with the addition of the recommended capacity related improvements discussed in Section 4. The objective was to determine if and how the implementation of recommended capacity improvements might impact the system's water age.

5.2.2 Evaluation Results and Discussion

The average daily water age and storage volume fractions (% full) for all reservoirs and scenarios are presented in **Table 5-4** and **Table 5-5**, respectively. Evaluation results were organized into four reservoir groups:

- **Main Thousand Oaks West** includes Pederson, Tara, Willow Lane and Rolling Oaks reservoirs. These reservoirs are supplied from Los Arboles, Las Flores, Gainsborough, Hillcrest and Encino Vista turnouts.

- **Main Thousand Oaks Southeast** includes Freeway, La Granada, Wilder, Grissom 1 and Grissom 2 reservoirs. These reservoirs are primarily supplied from the Lone Oak turnout (they also receive supply from Willow Lane Reservoir).

- **Main Thousand Oaks Northeast** includes Meadows, Lang Ranch, Sunset 2, Oakbrook and Sunset 3 reservoirs. These reservoirs are supplied from Lindero and Del Sol Erbes turnouts.

- **Newbury Park** includes Kelley and Ventu Park reservoirs. These reservoirs are supplied from the West Kelley and Ventu Park turnouts.

The average water age at a given reservoir is typically influenced by other reservoirs of the same group. For example, operation of the La Granda pump station results in water age reduction at La Granada Reservoir while increasing the water age at Wilder and Grissom reservoirs. A weighted average water age was calculated for each reservoir group in each scenario. The calculation gave a higher weight to reservoirs storing larger volumes of water. In addition and for each modeling scenario, a systemwide weighted average water age was calculated for all 16 reservoirs.

The average water age at each demand node in the model was also calculated for all scenarios. The results are graphically shown in **Figures 5-1** through **Figure 5-10** one for each modeled scenario (presented at the end of this section). As discussed earlier, water age within the

distribution system may significantly vary throughout the day with relatively low age water available to customers during the reservoirs' fill cycles and relatively high water age during the drain cycles.

Table 5-4: Water Age Evaluation Results, Average Water Age at Reservoirs (days)

	Reservoir	Capacity (MG)	Scenario 1	Scenario 2	Scenario 3	Scenario 4A	Scenario 4B	Scenario 4C	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Main Thousand Oaks West	Pederson Reservoir	3.26	4.3	3.8	3.2	3.2	2.9	3.0	3.0	3.0	2.7	2.7
	Willow Lane Reservoir	4.75	7.0	6.6	3.8	3.3	3.6	3.6	2.3	2.4	2.5	2.4
	Tara Reservoir	3.94	7.5	8.2	6.4	6.7	6.7	6.3	6.5	6.4	6.6	6.3
	Rolling Oaks Reservoir	0.36	11.1	11.1	7.5	6.4	6.7	6.1	6.0	5.8	5.9	5.9
	Weighted Average	**-**	**6.4**	**6.4**	**4.3**	**4.1**	**4.1**	**4.1**	**3.6**	**3.7**	**3.6**	**3.5**
Main Thousand Oaks Southeast	Freeway Reservoir	1.00	26.8	26.8	7.8	6.8	7.2	7.6	4.1	NA	4.2	4.1
	La Granada	4.00	26.4	26.4	4.8	3.3	3.9	4.2	3.3	3.2	3.2	3.2
	Wilder Reservoir	0.98	3.0	3.0	2.9	6.0	5.4	4.6	5.9	5.9	5.9	5.9
	Grissom Reservoir No. 2	0.21	5.7	5.9	5.4	8.9	7.9	6.8	9.0	9.0	9.0	8.8
	Grissom Reservoir No. 1	0.21	5.7	6.0	5.4	9.0	8.0	6.9	9.0	9.1	9.1	8.9
	Weighted Average	**-**	**20.9**	**20.9**	**5.0**	**4.7**	**4.9**	**5.0**	**4.5**	**4.4**	**4.5**	**4.4**
Main Thousand Oaks Northeast	Meadows Reservoir	3.41	5.3	5.5	3.8	3.8	3.8	3.8	3.7	3.9	3.9	3.9
	Lang Ranch Reservoir	4.96	10.8	4.9	4.2	4.4	4.4	4.5	4.4	4.3	4.5	3.3
	Sunset Reservoir No. 2	1.00	5.8	4.0	3.1	3.1	2.9	3.0	3.1	3.0	3.0	3.0
	Oakbrook Reservoir	2.18	13.6	5.5	3.7	3.9	3.8	3.8	3.7	3.7	3.8	5.5
	Sunset Reservoir No. 3	0.76	5.5	6.4	3.7	4.1	3.8	3.8	3.9	3.7	3.8	3.5
	Weighted Average	**-**	**9.1**	**5.2**	**3.9**	**4.0**	**4.0**	**4.0**	**4.0**	**3.9**	**4.0**	**3.9**
Newbury Park	Kelley Reservoir	0.55	12.5	12.7	6.1	6.2	6.1	6.1	6.1	6.1	4.5	4.5
	Ventu Park Reservoir	3.75	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	3.7	3.7
	Weighted Average	**-**	**5.6**	**5.6**	**4.7**	**4.7**	**4.7**	**4.7**	**4.7**	**4.7**	**3.8**	**3.8**
Systemwide Weighted Average		**-**	**9.7**	**8.3**	**4.4**	**4.3**	**4.3**	**4.3**	**4.0**	**4.0**	**3.9**	**3.8**

Table 5-5: Water Age Evaluation Results, Average Daily Storage Fractions (% of Reservoir Capacities)

	Reservoir	Capacity (MG)	Minimum Required Ratio	Scenario 1	Scenario 2	Scenario 3	Scenario 4A	Scenario 4B	Scenario 4C	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Main Thousand Oaks West	Pederson Reservoir	3.26	12%	75%	72%	63%	65%	64%	68%	67%	62%	69%	65%
	Willow Lane Reservoir	4.75	12%	56%	61%	62%	63%	61%	62%	55%	52%	56%	57%
	Tara Reservoir	3.94	36%	63%	62%	37%	36%	37%	37%	37%	37%	37%	37%
	Rolling Oaks Reservoir	0.36	66%	64%	64%	59%	59%	59%	58%	59%	59%	58%	59%
	Subtotal	**12.31**	**32%**	**63%**	**64%**	**54%**	**55%**	**54%**	**55%**	**52%**	**50%**	**53%**	**53%**
Main Thousand Oaks Southeast	Freeway Reservoir	1.00	59%	53%	53%	59%	62%	60%	61%	45%	0%	46%	46%
	La Granada	4.00	59%	55%	55%	57%	56%	57%	57%	37%	43%	37%	38%
	Wilder Reservoir	0.98	21%	64%	64%	62%	56%	57%	57%	55%	55%	55%	55%
	Grissom Reservoir No. 2	0.21	65%	64%	65%	65%	65%	64%	64%	64%	64%	64%	64%
	Grissom Reservoir No. 1	0.21	65%	64%	65%	65%	65%	64%	64%	64%	64%	64%	64%
	Subtotal	**6.40**	**54%**	**56%**	**56%**	**59%**	**57%**	**58%**	**58%**	**43%**	**40%**	**43%**	**43%**
Main Thousand Oaks Northeast	Meadows Reservoir	3.41	41%	61%	61%	43%	43%	43%	43%	43%	43%	43%	43%
	Lang Ranch Reservoir	4.96	44%	63%	63%	44%	44%	44%	44%	44%	44%	44%	43%
	Sunset Reservoir No. 2	1.00	44%	67%	69%	46%	46%	46%	46%	46%	46%	46%	47%
	Oakbrook Reservoir	2.18	43%	63%	64%	51%	51%	51%	51%	51%	51%	51%	52%
	Sunset Reservoir No. 3	0.76	45%	66%	68%	47%	47%	47%	47%	47%	47%	47%	47%
	Subtotal	**12.31**	**43%**	**63%**	**64%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**	**45%**
Newbury Park	Kelley Reservoir	0.55	55%	61%	61%	62%	62%	62%	62%	62%	62%	54%	54%
	Ventu Park Reservoir	3.75	31%	60%	60%	60%	60%	60%	60%	60%	60%	45%	45%
	Weighted Average	**4.30**	**34%**	**60%**	**60%**	**60%**	**60%**	**60%**	**60%**	**60%**	**60%**	**47%**	**47%**
Total		**35.32**	**40%**	**62%**	**62%**	**53%**	**53%**	**52%**	**53%**	**49%**	**48%**	**48%**	**48%**

Scenarios 1 – Baseline System Conditions

As shown in Table 5-4, the baseline average reservoir water age values are relatively high in Scenario 1. The top five reservoirs with highest water age included Freeway Reservoir (26.8 days), La Granada (26.4 days), Oakbrook (13.6 days), Rolling Oaks (11.1 days) and Lang Ranch (10.8 days). The weighted average water age at all 16 reservoirs was estimated at 9.7 days.

While historically the above mentioned reservoirs have shown evidence of year-round or seasonal nitrification, it is acknowledged that the actual water age during low and average demand conditions may not be as high as the above estimates. As water demands change throughout the year, the City alters its typical level controls and set points, which may not have been reflected in this scenario. Scenario 1 was only used as a baseline scenario for comparison with Scenario 2 in order to quantify the impact of Oakbrook/ Sunset 3 zone split.

Scenario 2 – Oakbrook/Sunset 3 Zone Split

Comparison of Scenarios 1 and 2 shows that Oakbrook/Sunset 3 zone split resulted in considerable water age reduction in the Main Thousand Oaks Northeast reservoir group. The zone split increased the water age at Sunset 3 Reservoir by approximately 15 percent, but significantly reduced it at Lang Ranch and Oakbrook reservoirs (by approximately 54 percent and 60 percent, respectively). The weighted average water age for the Main Thousand Oaks Northeast reservoir group (Meadows, Lang Ranch, Sunset 2, Oakbrook and Sunset 3) was reduced by approximately 43 percent from 9.1 to 5.2 days.

Comparison of Figure 5-1 and Figure 5-2 indicates that the zone split resulted in average water age reduction within a portion of the Oakbrook pressure zone along North Westlake Boulevard (between the reservoir and Lang Ranch Parkway). This area which accounts for approximately 16 percent of the total water demand within the Oakbrook and Sunset 3 pressure zones, is under the direct influence of the Oakbrook Reservoir. The average water age within this area was reduced from about 7 days to about 4 days. The average water age within the remainder of Oakbrook and Sunset 3 pressure zones was increased from about 2 days to about 5 days.

This is anticipated because the old water previously trapped in Oakbrook Reservoir is now distributed throughout a larger area. The zone split not only results in a more uniform distribution of water age within the Oakbrook and Sunset 3 zones, it also results in a more balanced water age between Lang Ranch/Sunset 2 and Oakbrook/Sunset 3 pressure zones.

Scenario 3 – Storage Reservoirs' Utilization and Turnover Improvement

This scenario resulted in considerable water age reduction across the system. The systemwide weighted average water age at all reservoirs was reduced from about 8.3 days in Scenario 2 to about 4.4 days in Scenario 3. The largest water age reduction occurred in Freeway and La Granada reservoirs. The average water age at Freeway Reservoir was reduced from about 26.8 days to about 7.8 days (71 percent reduction). The average water age at La Granada Reservoir was reduced from about 26.4 days to about 4.8 days (82 percent reduction).

As shown in Appendix G, this was in part accomplished by lowering the high level control at Willow Lane and Lone Oak to La Granada pump stations. Additionally, the Willow Lane pump

station was operated based on La Granada Reservoir allowing the concurrent operation of the lead pumping units at both stations (by assigning identical level controls).

The average water age at Willow Lane Reservoir was also reduced from about 6.6 days to about 3.8 days (42 percent reduction) by reducing the PRV set points at Encino Vista and Hillcrest turnouts which in turn contributed in water age reduction at Freeway and La Granada reservoirs.

As shown in Figure 5-3 and similar to Scenario 2, distribution of old water previously trapped in these reservoirs resulted in average water age increase within a large portion of the zone (previously under the influence of Willow Lane and Lone Oak to La Granada pump stations).

The water age at the Kelley Reservoir was also reduced considerably from about 12.7 days to about 6.1 days (52 percent reduction) in this scenario. This was accomplished by reducing the PRV set point at the West Kelley turnout from 127 to 115 psi. This adjustment resulted in increased reservoir turnover by limiting peaking from the turnout.

The combined average stored volume in all reservoirs was reduced from about 21.9 MG (62% of combined capacities) to about 18.7 MG (53% of combined capacities) in this scenario. This reduction contributed to lower water age across the system.

Scenarios 4A, 4B and 4C – La Granada Pump Station Operation

All three scenarios resulted in water age reduction at Freeway and La Granada reservoirs and water age increase in Wilder and Grissom reservoirs. The largest change in water age occurred in Scenario 4A where Lone Oak to Wilder pump station was off. Average water age at Freeway and La Granada reservoirs in this scenario were reduced from 7.8 to 6.8 days and from 4.8 to 3.3 days, respectively. Average water age at Wilder and Grissom reservoirs were increased from 2.9 to 6.0 days and from 5.4 to 9.0 days, respectively. The weighted average water age for the Main Thousand Oaks Southeast reservoir group was reduced moderately from 5.0 to 4.7 days.

Operating the Lone Oak to Wilder pump station alongside La Granada pump station (Scenarios 4B and 4C) resulted in similar trend albeit to a lesser degree with insignificant change in weighted average water age for the reservoir group. Scenario 4A was selected as the basis for Scenario 5. However, Scenarios 4B and 4C resulted in a more uniform water age distribution within the zones supplied by the Main Thousand Oaks Southeast reservoir group (Freeway/La Granada, Wilder and Grissom).

Scenario 5 – Reduced Storage at Freeway/La Granada

Splitting the fire flow reserve between Freeway and La Granada reservoirs resulted in approximately 40 percent reduction in average water age at Freeway Reservoir (from 6.8 to 4.1 days). The average water age at La Granada Reservoir remained unchanged at about 3.3 days compared to Scenario 4A.

Additionally, maintaining a lower storage within Freeway/La Granada pressure zone allowed less storage to be maintained within the Willow Lane Reservoir which resulted in approximately 30 percent average water age reduction at this reservoir (from 3.3 to 2.3 days).

Scenario 5 was used as the basis for Scenario 6. However, a fire flow analysis should be conducted to confirm that the City's fire suppression ability was not hindered in this zone.

Scenario 6 – Freeway Reservoir Elimination

Removing Freeway Reservoir from service resulted in lower average water age within the southwestern part of the pressure zone. This area is under the direct influence of Freeway Reservoir and has a poor water age. Abandoning the reservoir did not significantly reduce the La Granada Reservoir's water age.

The reservoir's removal from service is potentially beneficial from the water quality stand point. However, it is not recommended at this time. Similar to Scenario 5, a fire flow analysis should be conducted to determine its potential impact on fire suppression capability within the southwestern part of the zone.

Scenario 7 – Turnout PRV Replacements with FCVs

Seven of the City's 11 turnouts with Calleguas operate with downstream PRVs. This enables the City to peak off of the Calleguas system up to the turnout capacities but it also results in poor turnover within the receiving pressure zone reservoirs (Pederson, Willow Lane, Kelley and Ventu Park).

Modeling evaluation of Scenario 7 showed that under average demand conditions, Kelley and Ventu Park reservoirs benefited from flow control-based turnout operation more than the Pederson and Willow Lane reservoirs. The average water age for Kelley Reservoir was reduced from 6.1 to 4.5 days (26 percent reduction) and the average water age for Ventu Park Reservoir was reduced from 4.5 to 3.7 days (18 percent reduction). The average water age at Kelley Hydro and Ventu Hydro pressure zones were also considerably reduced.

Due to higher peaking, the flow control-based turnout operation benefits the system even more as demands increase from average day to maximum day.

Scenario 8 – Capacity Improvements Implementation

The implementation of pipeline improvements developed in Section 4 did not significantly impact the system's water age. However, running three pumps at Lang Ranch pump station and one pump at Las Arboles pump station reduced the average water age at Lang Ranch Reservoir from 4.5 to 3.3 days (27 percent reduction) and increased the average water age at Oakbrook Reservoir from 3.8 to 5.5 days (45 percent increase). Given the higher storage volume at Lang Ranch Reservoir compared to Oakbrook Reservoir, the weighted average water age for the Main Thousand Oaks Northeast Reservoir group was not significantly changed.

The operation of Pederson pump 1 to supply Meadows pressure zone was not modeled in this scenario. This operation is reserved for emergencies when Erbes Road to Meadows pumping unit is out of service. However, this operation is expected to reduce the water age at Tara Reservoir and increase the water age at Meadows Reservoir.

5.2.3 Conclusions and Recommendations

The modeling evaluations showed that water age could be significantly reduced through a combination of operational modifications and relatively minor system improvements. The primary contributing factor for high water age in the system is the relatively high ratio of total storage in pipelines and reservoirs to water demands. Therefore, reservoir storage volumes should be actively managed by adjusting level controls throughout the year. Optimizing level controls can also considerably improve reservoirs turnover.

Another key contributing factor in poor water age is turnout operation with downstream PRVs. Peaking off of turnouts reduces turnover in the downstream storage tanks. Operating turnouts with FCVs forces the reservoirs to drain at higher flows resulting in increased turnover rates.

Pipeline looping did not appear to improve system water age in general. Several attempts at looping particularly in pressure zones with limited looping such as Rolling Oaks resulted in slight increase in water age. This could be attributed to larger storage volume associated with the addition of new pipelines for looping. In general, looping is recommended for system bottlenecks where velocities are high. Under 2015 ADDs, however, more than 95 percent of pipelines had average velocities of less than 1 ft/s.

A summary of the water age related recommendations is presented below:

1. Continue operating the Oakbrook and Sunset 3 as separate pressure zones.

2. Coordinate with Calleguas to replace the turnout PRVs with FCVs.

3. Using the storage criteria and methodology presented in Table 4-1, calculate the required average daily storage volume at each reservoir and adjust the low and high level controls at all pumps and turnouts seasonally to achieve the required average volumes.

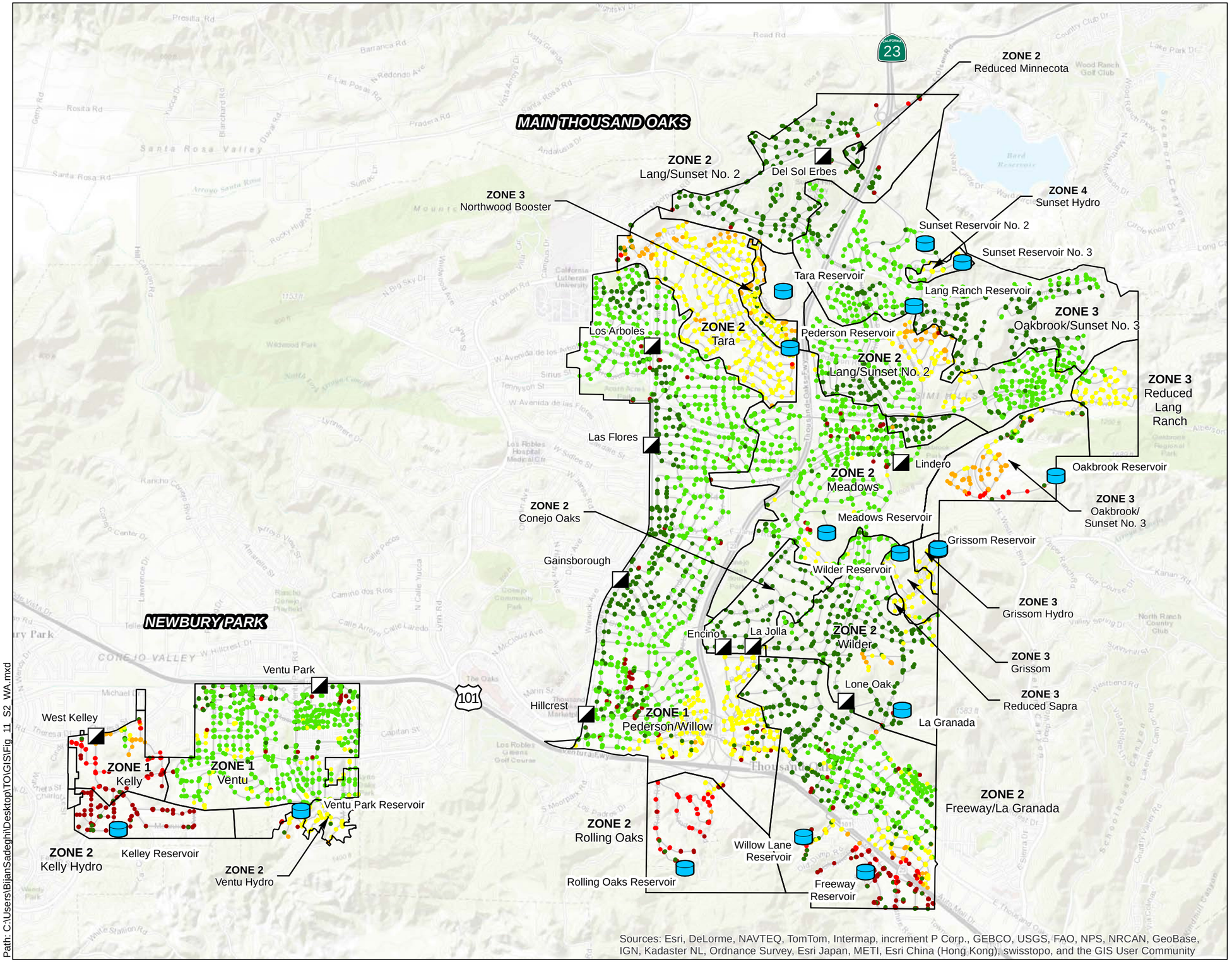
4. For zones with multiple pump stations, operate the lead pumping units simultaneously. Similarly, adjust the level controls to operate the lag units simultaneously.

5. During low demand periods, operate the Willow Lane pump station based on La Granada Reservoir water level.

6. For pressure zones with multiple reservoirs, perform a fire flow analysis study to determine how much fire reserve storage should be maintained at each reservoir. Specifically, a fire flow analysis should be performed for Freeway/La Granada pressure zone to determine whether the Freeway Reservoir could be permanently removed from service.

7. The installation of RCS units at Pederson and Willow Lane reservoirs is expected to improve water quality at these other reservoirs with high water age including Tara, Rolling Oaks, Wilder and Oakbrook. The mobile RCS units should be utilized at these reservoirs on an as-needed basis and based on real-time water quality data.

8. Developing a limited water main flushing program for dead-end pipelines and areas with poor water age is recommended.



Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Legend

- Storage Tank
- Turnout
- Pressure Zone

Average Hourly Water Age

- < 2 days
- 2.1-4.0 days
- 4.1-6.0 days
- 6.1-8.0 days
- 8.1-10.0 days
- > 10 days

N

0 0.5 1

Miles

Kennedy/Jenks Consultants

City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Average Hourly Water Age
Scenario 1 - Baseline
(Before Oakbrook/Sunset 3 Zone Split)
2015 Average Day Demands

K/J 1544510.00
February 2018

Figure 5-1

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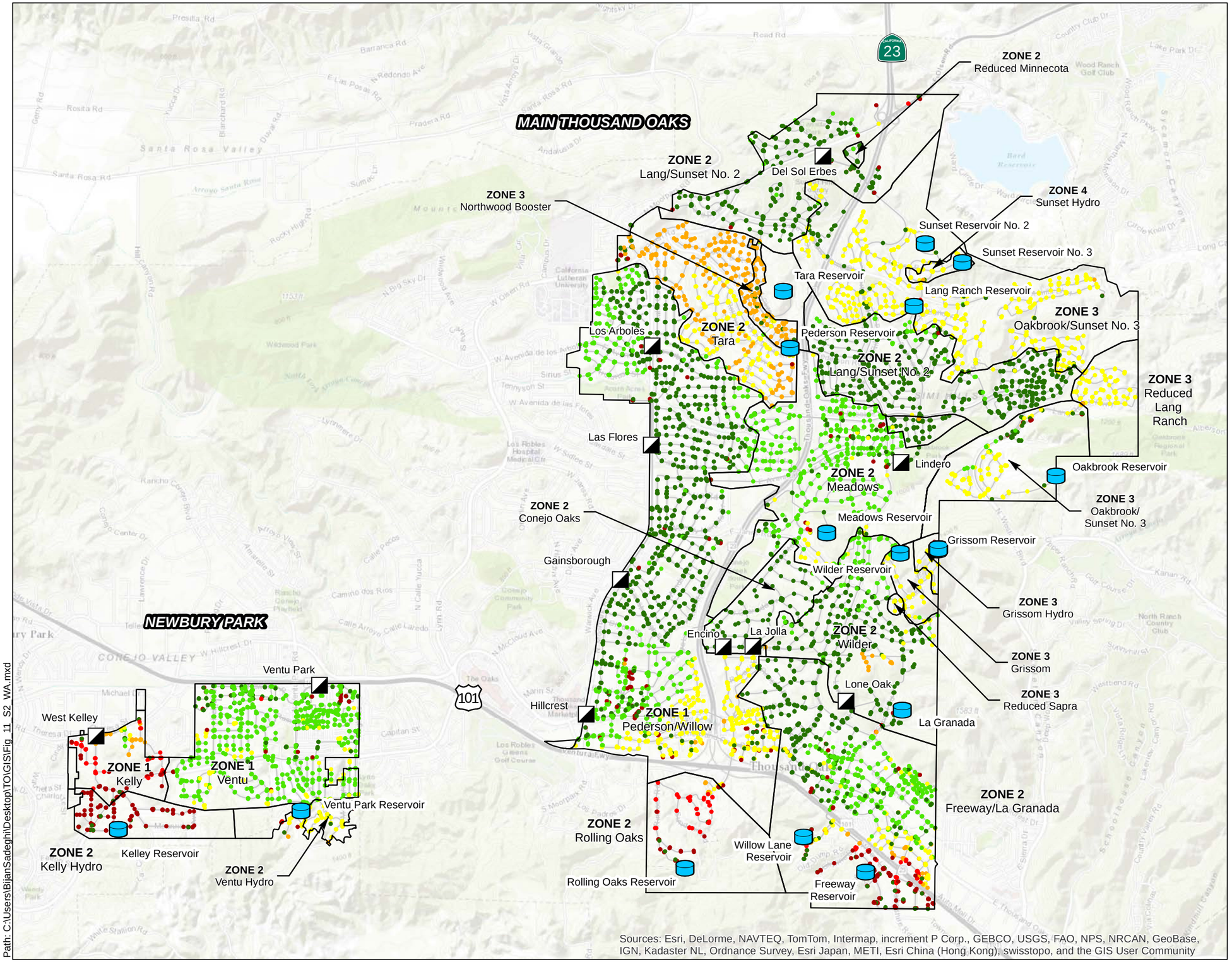

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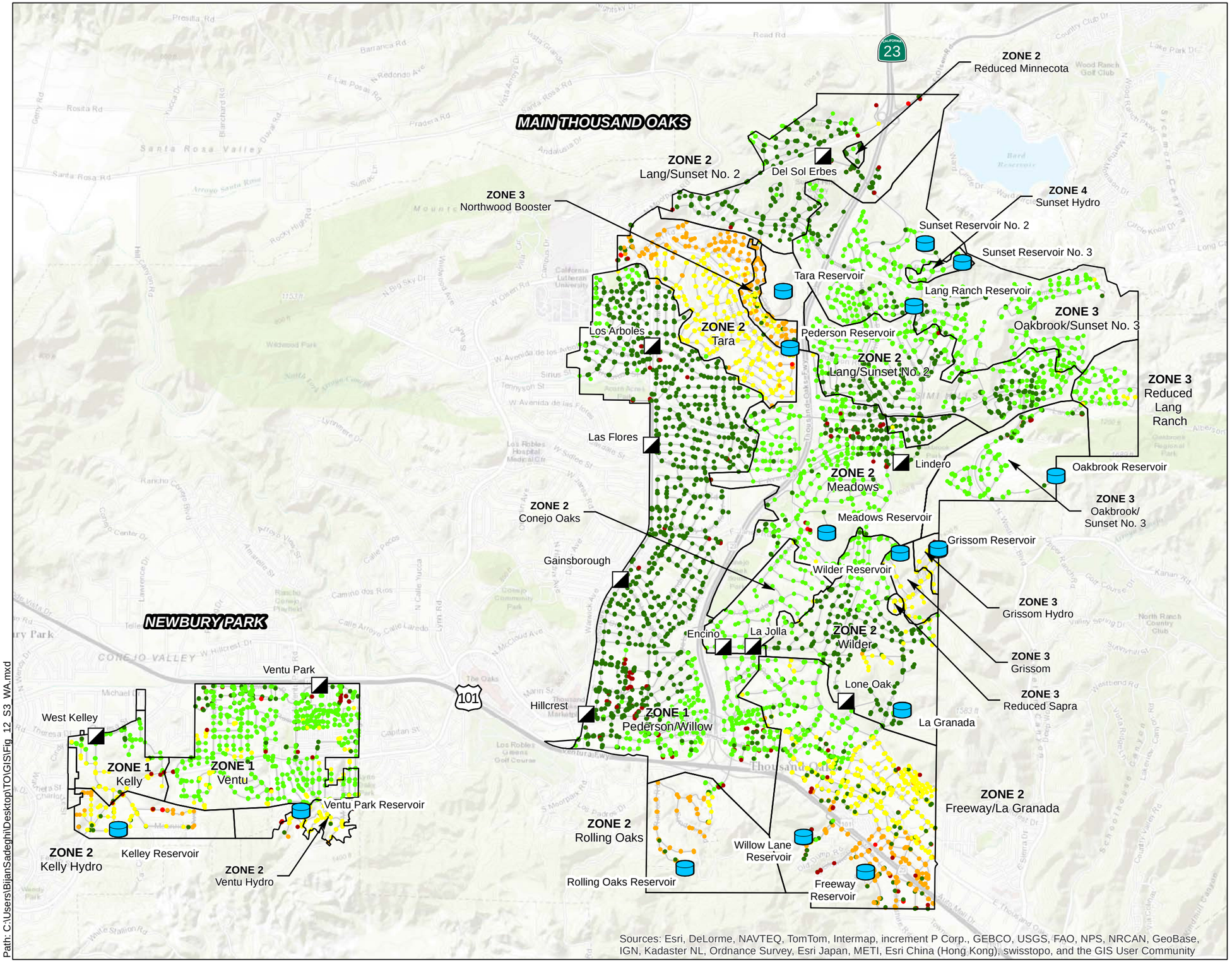
Thousand Oaks, California

Average Hourly Water Age
Scenario 2 - Baseline
(After Oakbrook/Sunset 3 Zone Split)
2015 Average Day Demands

K/J 1544510.00
February 2018

Figure 5-2



Legend

- Storage Tank
- Turnout
- Pressure Zone

Average Hourly Water Age

- < 2 days
- 2.1-4.0 days
- 4.1-6.0 days
- 6.1-8.0 days
- 8.1-10.0 days
- > 10 days

N

0 0.5 1

Miles

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Thousand Oaks, California

Average Hourly Water Age - Scenario 3 (Scenario 2 + Optimized Controls/Settings) 2015 Average Day Demands

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February 2018

Figure 5-3

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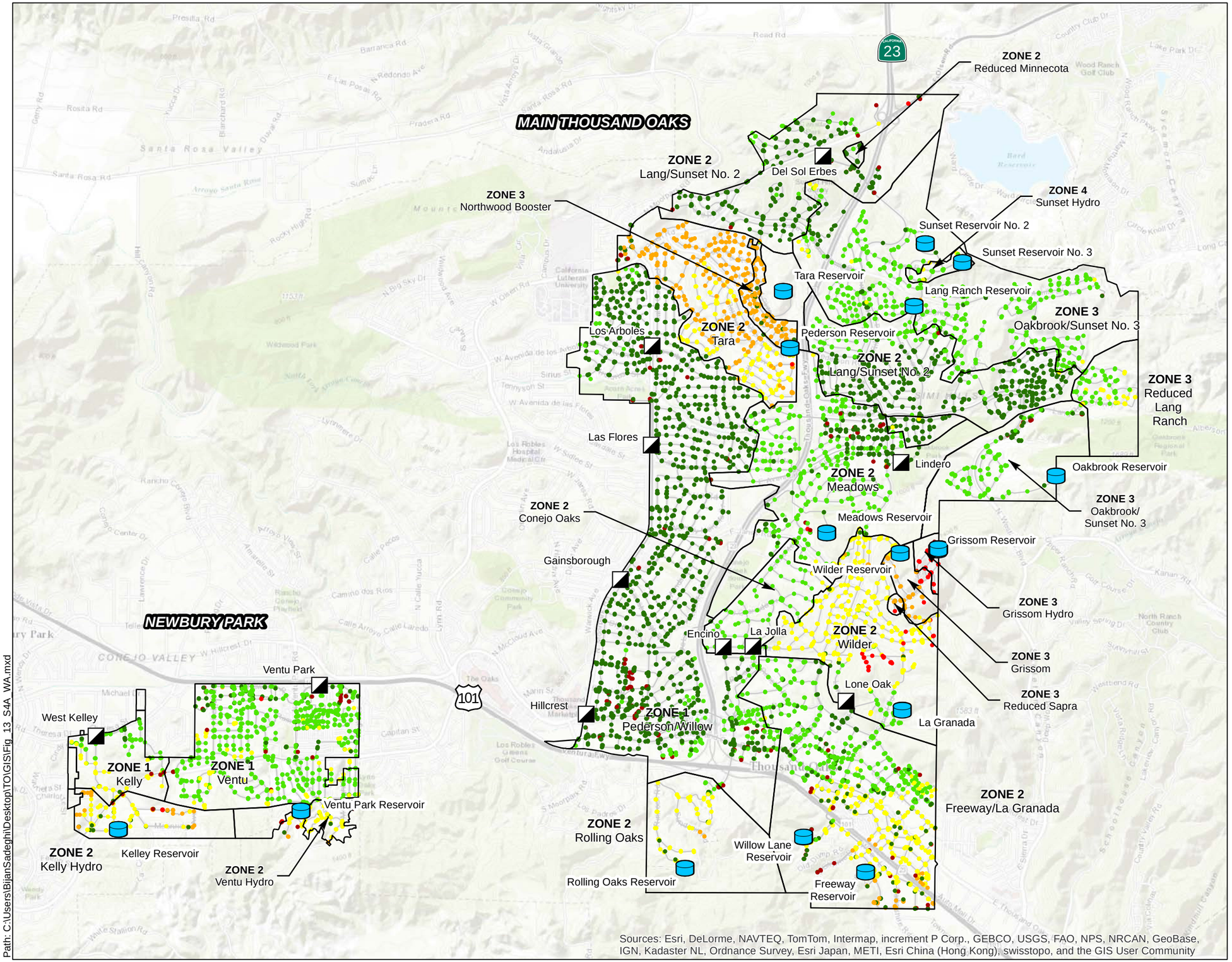

Legend

- Storage Tank
- Turnout
- Pressure Zone

Average Hourly Water Age

- < 2 days
- 2.1-4.0 days
- 4.1-6.0 days
- 6.1-8.0 days
- 8.1-10.0 days
- > 10 days

N

0 0.5 1

Miles

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City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Average Hourly Water Age - Scenario 4A (Scenario 3 + La Granda PS + Lone Oaks to Wilder PS Off) 2015 Average Day Demands

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February 2018

Figure 5-4

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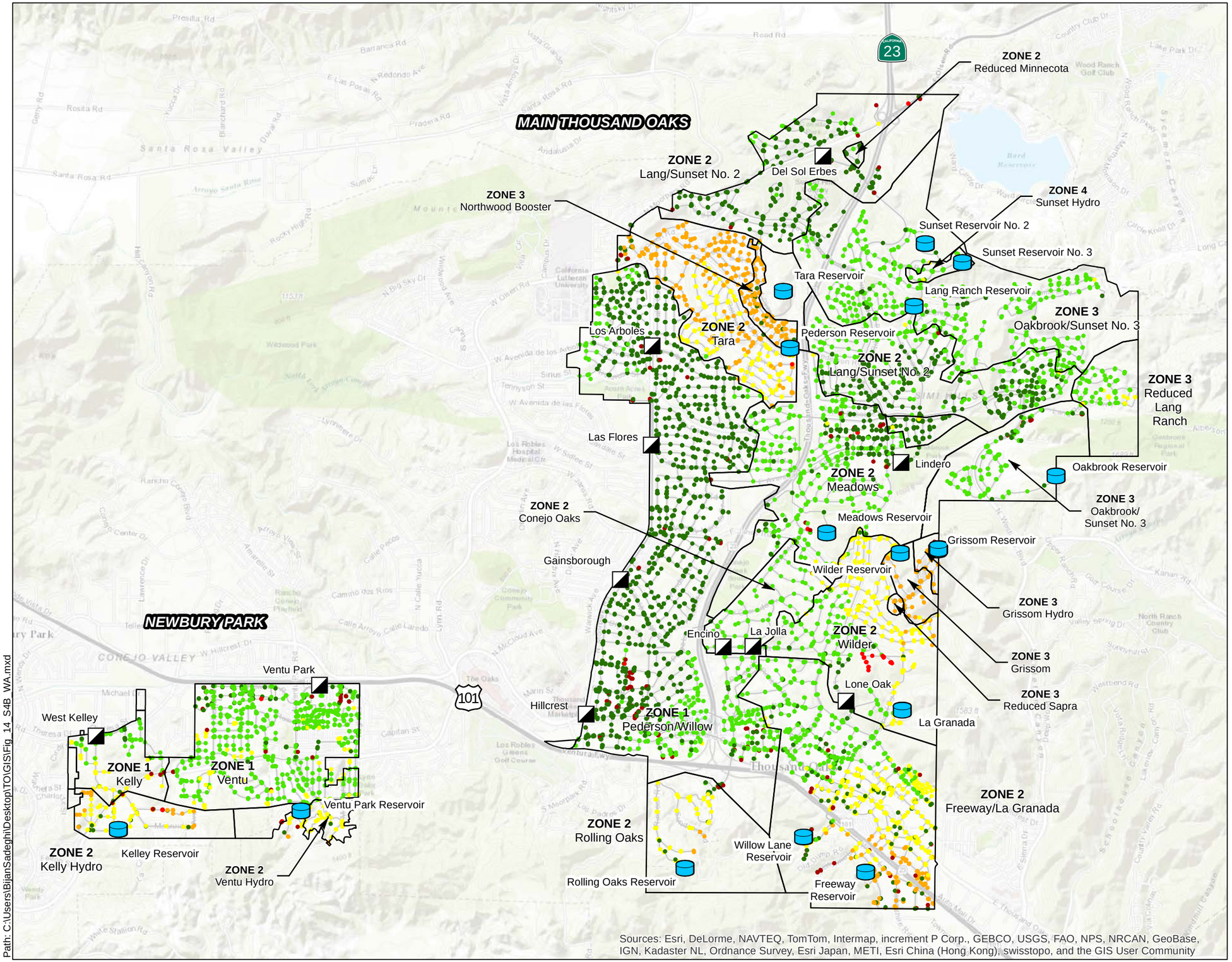

Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Legend

- Storage Tank
- Turnout
- Pressure Zone

Average Hourly Water Age

- < 2 days
- 2.1-4.0 days
- 4.1-6.0 days
- 6.1-8.0 days
- 8.1-10.0 days
- > 10 days

N

0 0.5 1

Miles

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Thousand Oaks, California

Average Hourly Water Age - Scenario 4B (Scenario 3 + La Granda PS @ 50% + Lone Oaks to Wilder PS @ 50%) 2015 Average Day Demands

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February 2018

Figure 5-5

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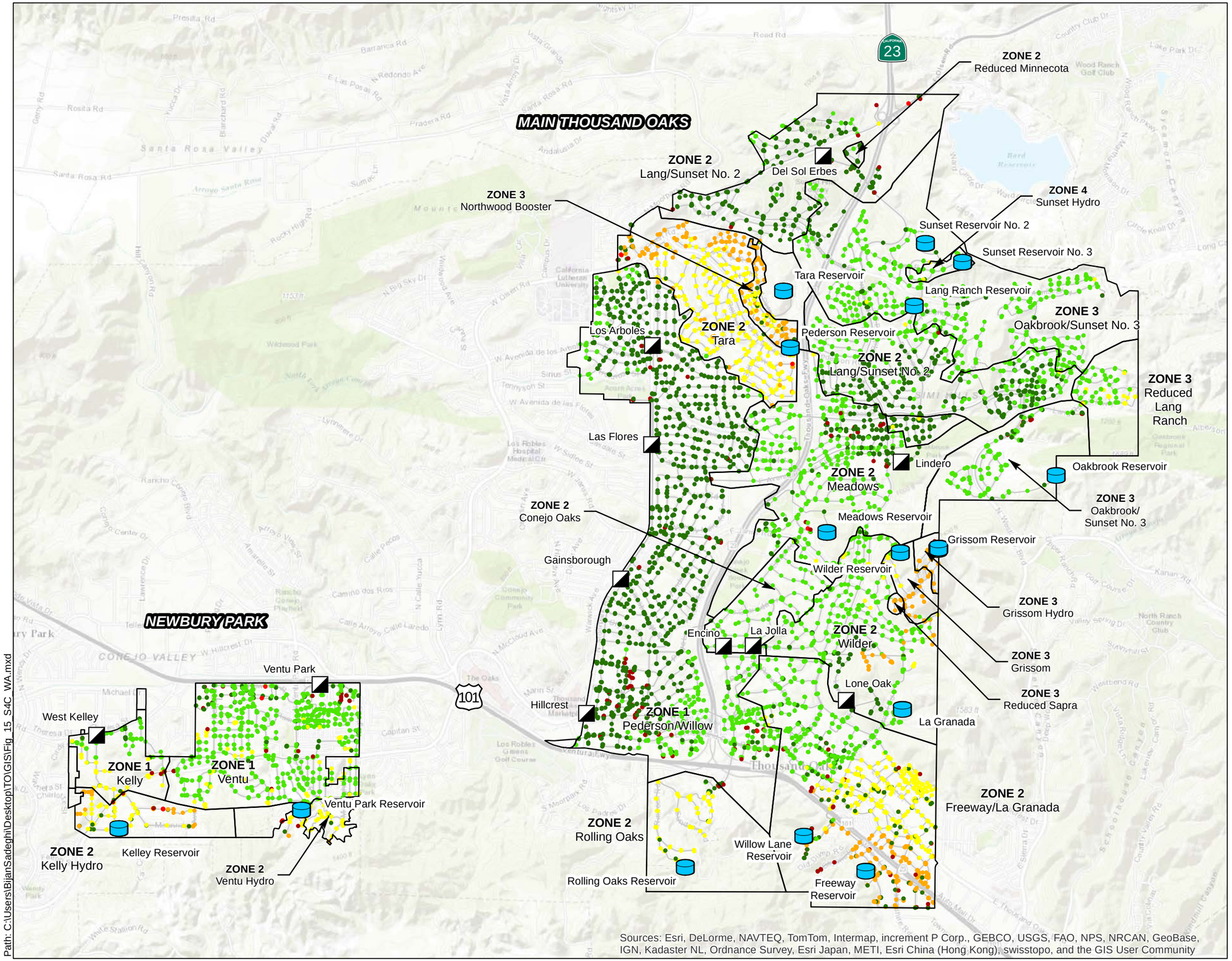

Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Legend

- Storage Tank
- Turnout
- Pressure Zone

Average Hourly Water Age

- < 2 days
- 2.1-4.0 days
- 4.1-6.0 days
- 6.1-8.0 days
- 8.1-10.0 days
- > 10 days

N

0 0.5 1

Miles

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City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Average Hourly Water Age - Scenario 4C (Scenario 3 + La Granda PS @ 30% + Lone Oaks to Wilder PS @ 70%) 2015 Average Day Demands

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February 2018

Figure 5-6

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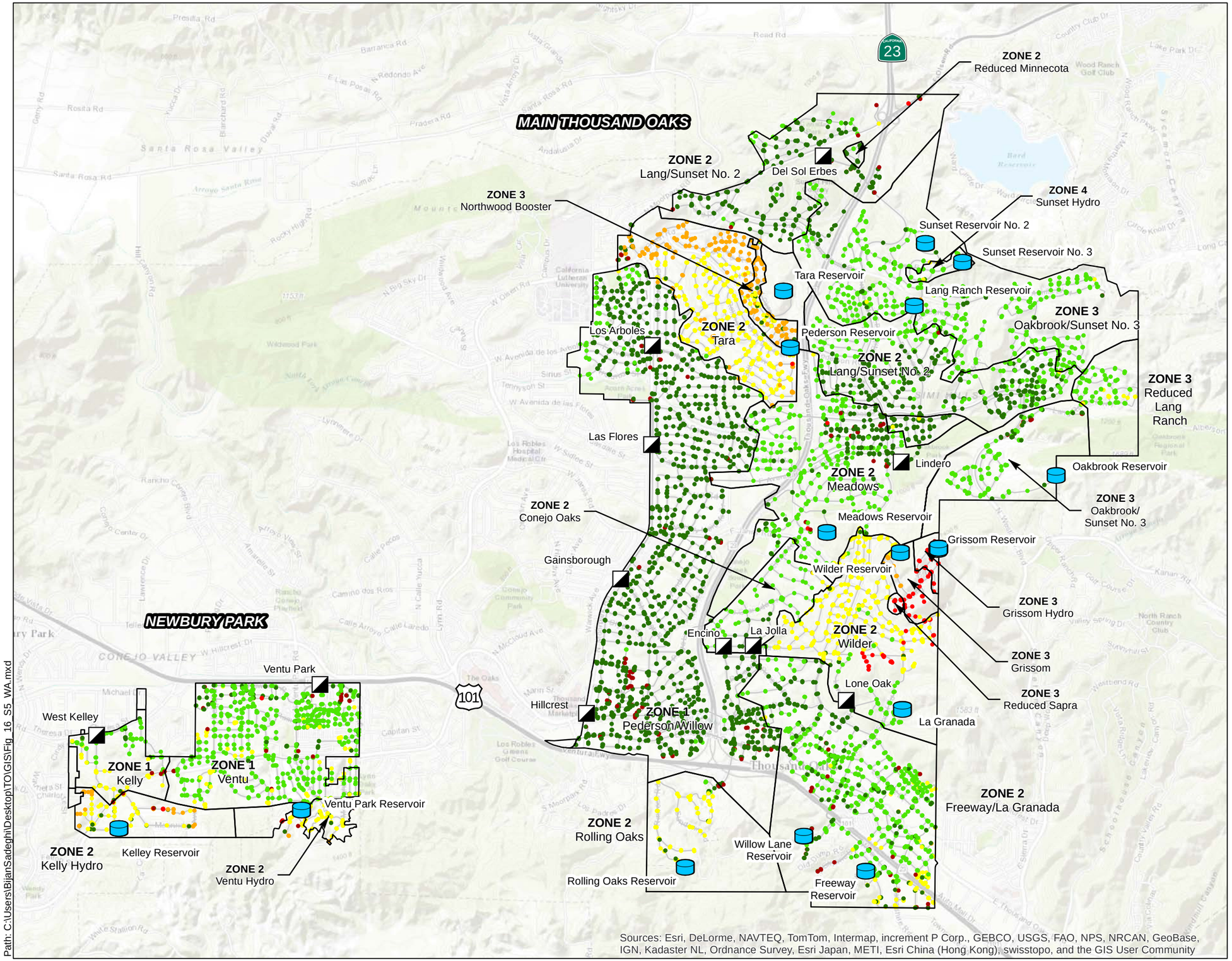

Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

Legend

- Storage Tank
- Turnout
- Pressure Zone

Average Hourly Water Age

- < 2 days
- 2.1-4.0 days
- 4.1-6.0 days
- 6.1-8.0 days
- 8.1-10.0 days
- > 10 days

N

0 0.5 1

Miles

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City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Average Hourly Water Age - Scenario 5 (Scenario 4A + Reduced Storage at Freeway/ La Granada)

2015 Average Day Demands

K/J 1544510.00
February 2018

Figure 5-7

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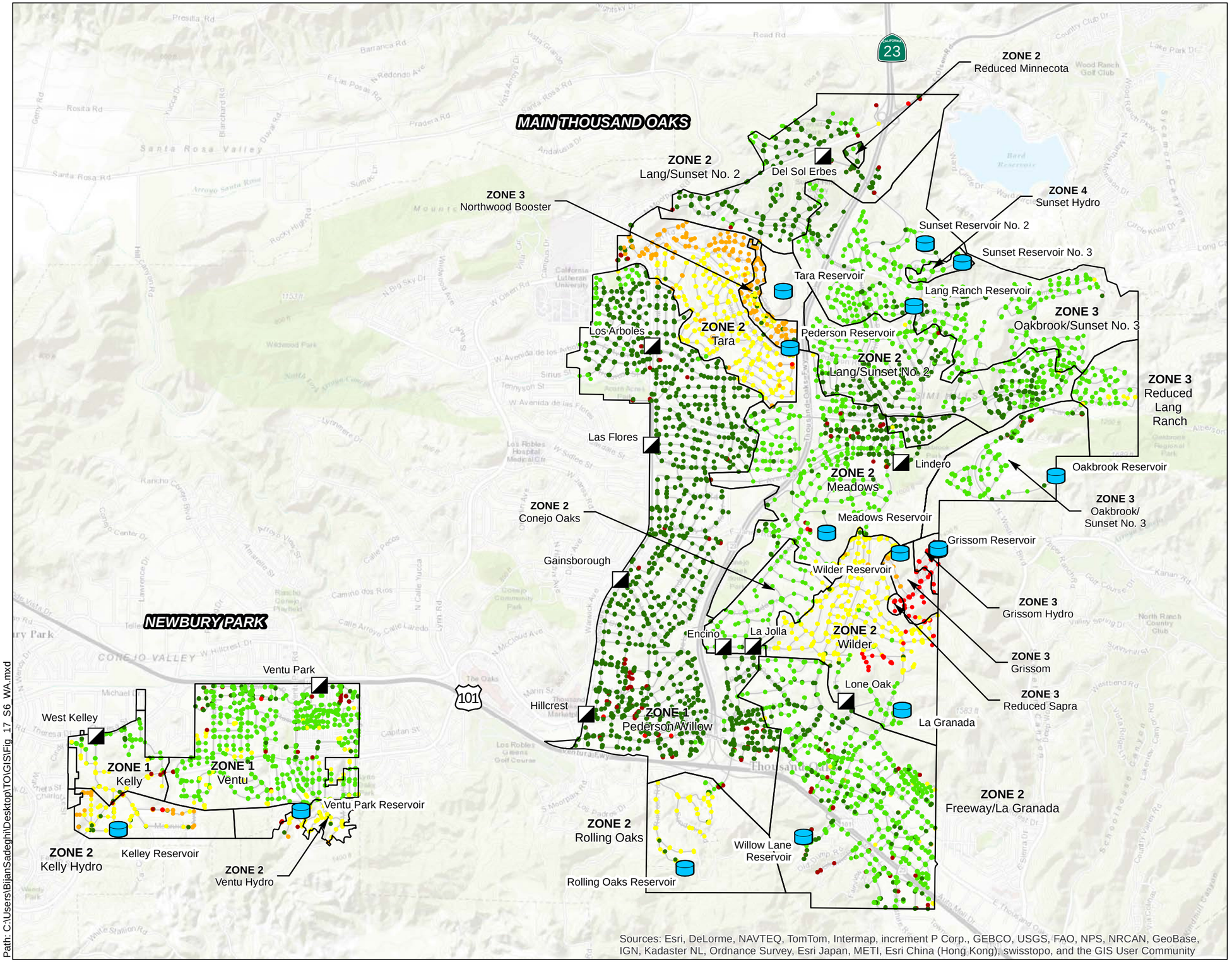

Legend

- Storage Tank
- Turnout
- Pressure Zone

Average Hourly Water Age

- < 2 days
- 2.1-4.0 days
- 4.1-6.0 days
- 6.1-8.0 days
- 8.1-10.0 days
- > 10 days

N

0 0.5 1

Miles

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City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Average Hourly Water Age - Scenario 6
(Scenario 5 + Freeway Reservoir Elimination)
2015 Average Day Demands

K/J 1544510.00
February 2018

Figure 5-8

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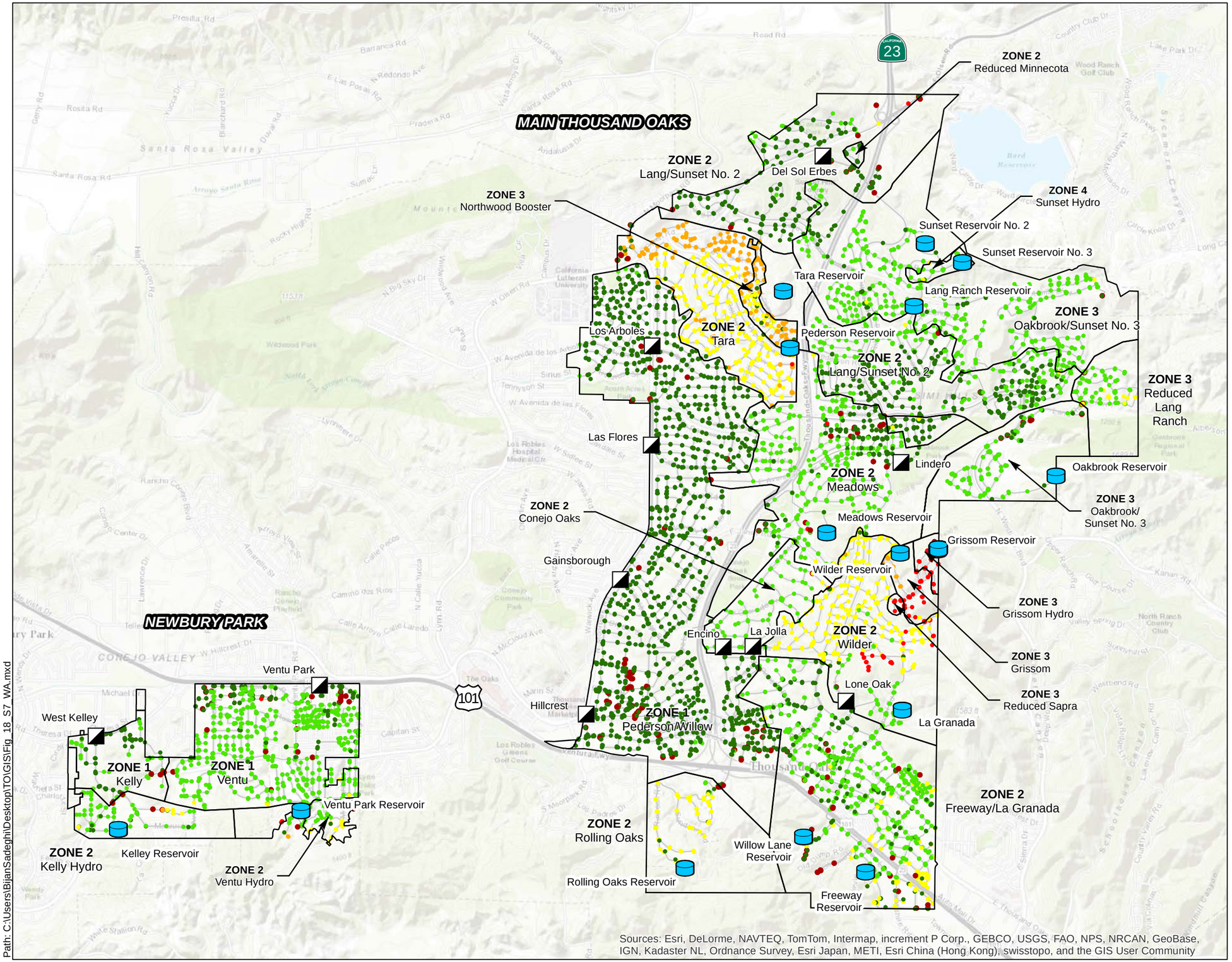

Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

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Legend

- Storage Tank
- Turnout
- Pressure Zone

Average Hourly Water Age

- < 2 days
- 2.1-4.0 days
- 4.1-6.0 days
- 6.1-8.0 days
- 8.1-10.0 days
- > 10 days

N

0 0.5 1

Miles

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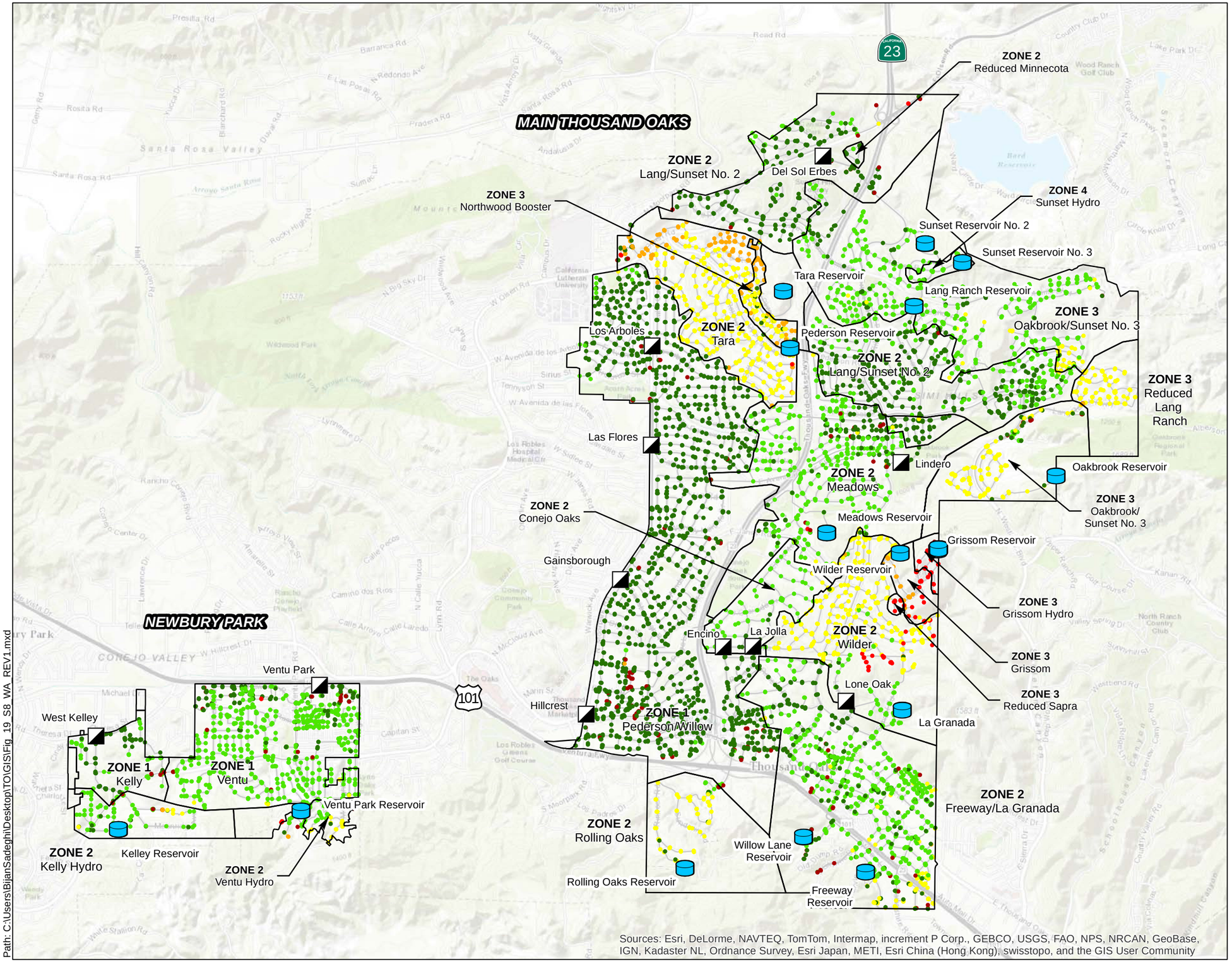
City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Average Hourly Water Age - Scenario 7 (Scenario 5 + Flow Control instead of Pressure Regulation at Turnouts) 2015 Average Day Demands

K/J 1544510.00
February 2018

Figure 5-9



Legend

- Storage Tank
- Turnout
- Pressure Zone

Average Hourly Water Age

- < 2 days
- 2.1-4.0 days
- 4.1-6.0 days
- 6.1-8.0 days
- 8.1-10.0 days
- > 10 days

N

0 0.5 1
Miles

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City of Thousand Oaks Water Master Plan
Thousand Oaks, California

Average Hourly Water Age - Scenario 8 (Scenario 7 + Pipeline Improvements + Lang Ranch PS Upgrade) 2015 Average Day Demands

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February 2018

Figure 5-10

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Section 6: Capital Improvement Plan

This section presents the recommended Capital Improvement Plan (CIP) for the City of Thousand Oaks (City's) water distribution system based on the evaluations performed and findings of this Master Plan. The recommended CIP is organized into three priority groups as later discussed in this section. Planning-level capital cost estimates and the basis for cost estimating are also described. Prior to design and construction of the recommended projects, the City should consider conducting a preliminary engineering evaluation to assess the projects feasibility and develop more detailed cost estimates.

6.1 Cost Estimating Assumptions

The planning-level cost estimates presented in this section are consistent with the Association for Advancement of Cost Engineering International's (AACE International's) Class 5 cost estimating classification. Class 5 estimates are typically developed based on limited available information using unit cost or cost/capacity curve methodologies and have an accuracy range of -20 to -50 percent on the low side and +30 to +100 percent on the high side.

The unit costs used in estimating the construction costs of the recommended projects are presented in **Table 6-1**. These assumptions are developed based on the analysis of recent construction bid tabs for similar capital projects by other water agencies in California, from Kennedy/Jenks' experience working on similar water master planning projects and from industry manufacturers. All estimates have been adjusted based on the Engineering News Record Construction Cost Index of 10,530 (20-city average, December 2016).

Table 6-1: Construction Cost Estimating Assumptions

Cost Item Description	Unit Construction Cost	
Pipelines		
8-inch	$180	per LF
10-inch	$210	per LF
12-inch	$235	per LF
16-inch	$290	per LF
Regulating Valve/Station		
8-inch/10-inch Flow or Pressure Regulating Valve	$30,000	ea.
8-inch Flow or Pressure Regulating Station	$80,000	ea.
Reservoir		
Mixer	$40,000	ea.
Analyzer and SCADA Integration	$12,000	ea.
Supplemental Disinfectant Boosting Unit (RCS)[1]	$120,000	ea.
Pump		
Pump Unit (<100 HP)	$1,000	per HP

Note:

1. Includes reservoir plumbing and electrical upgrades

The capital cost estimates are developed based on construction cost estimates and application of a 25-percent contingency markup and an additional 25-percent implementation markup to account for planning and design (10 percent), construction management (10 percent), and administration and legal (5 percent).

A summary of the recommended markups is presented in **Table 6-2**. As shown, the combined construction contingency and implementation markup is 56 percent of the estimated baseline construction costs.

Table 6-2: Recommended Construction Contingency and Implementation Markups

Description	Markup
Planning and Design	10 percent
Construction Management	10 percent
Administrative and Legal	5 percent
Total Implementation Markup	**25 percent**
Construction Contingency	**25 percent**
Combined Markup	**(1.25 x 1.25 -1) or 56 percent**

The cost estimates presented in this Master Plan are intended to provide guidance for project evaluation and budgeting. The final project costs will depend on actual labor and material costs, competitive market condition, actual site conditions, final project scope, implementation schedule and other variables. Therefore, the final project costs may vary from the estimates presented in this section.

6.2 Capital Improvement Plan Summary

The recommended water distribution system CIP is presented in **Table 6-3**. For each recommended project, the CIP provides a project ID, name, description, location, justification, deficiency type, priority, and estimated construction and capital costs.

The proposed projects are organized into three priority groups: high, medium and low. The water quality related improvements are designated as High Priority. The supply facility improvement projects are designated as Medium Priority. Finally, the pipeline improvement projects are designated as Low Priority.

The total capital cost for water quality improvement projects (High Priority) is estimated at about $1.8M (provided by the City). The total capital cost for supply facility improvement projects (Medium Priority) is estimated at about $4.0M. The total capital cost for supply pipeline improvement projects (Low Priority) is estimated at about $0.7M. The combined capital cost of all projects is estimated at about $6.5M.

While the recommended projects in this Master Plan are not inherently tied to any particular timeframe, they are organized in a 5-year CIP per the City's request. A summary of the 5-year CIP is presented in **Table 6-4**.

Table 6-3: Recommended Water Distribution System Capital Improvement Plan

ID	Project Name	Project Description	Project Location	Project Justification	Deficiency Type	Priority	Estimated Total Project Cost
WQ1	Turnouts Downstream Regulating Valve Upgrade	Replacement of existing pressure reducing valves with flow control valves (total of 7)	Los Arboles, Las Flores, Gainsborough, Hillcrest, Encino Vista, Ventu Park and West Kelley turnouts	To improve water quality by increasing reservoirs turnover	Water Quality (ADD/MDD)	High	$400,000
WQ2	Reservoir Circulation Improvements	Install a mixer (PAX or equivalent) at all 16 reservoirs	All reservoirs	To improve water quality by increasing water circulation within all reservoirs	Water Quality (ADD/MDD)	High	$200,000
WQ3	Reservoir Supplemental Disinfectant Boosting Improvements	Installation of 2 permanent disinfectant boosting units & 2 additional mobile units with trailers & perform plumbing/electrical upgrades at all other reservoirs to accommodate a mobile unit	Permanent units to be installed at Pederson and Willow Lane reservoirs, Rotate mobile units among other reservoirs as necessary	To improve water quality by renewing disinfectant residual at select reservoirs	Water Quality (ADD/MDD)	High	$400,000
WQ4	Reservoir Water Quality Monitoring and SCADA Improvements	14 x water quality analyzer + SCADA integration	All reservoirs except Pederson and Willow Lane reservoirs	To provide real-time measurement for total chlorine, nitrite and temperature	Water Quality (ADD/MDD)	High	$800,000
Subtotal – High Priority Projects							**$1,800,000**
FF1	La Granada Pump Station and Pipeline[1]	- Construction of a new pump station with two low-flow (750 gpm) and one high-flow (4,000 gpm) units and a diesel-fueled power generator - Construction of 70 ft of 8-inch diameter, 2,800 ft of 10-inch diameter and 850 ft of 18-inch diameter pipeline	Pump station will be located at the La Granada Reservoir Site. Pipeline are along Mountain Crest Circle and La Granada Drive (See **Appendix H**)	To serve as a secondary source of supply and to provide fire flow to Wilder Zone	Supply Capacity (PHD+FF)		$3,600,000
PS1	Pederson to Meadows Supply Improvements	Modification of Pederson pump station discharge header, construction of 200 ft of 12" pipe	From Pederson Pump Station discharge header to the existing 10" main along Pederson Road east of Uppingham Drive	To provide backup supply to Meadows pressure zone	Supply Capacity (MDD/PHD)	Medium	$95,000
PS2	Lang Ranch Pump Station Upgrade	Installation of 1 x 75-HP pump (750 gpm @ 250 ft) at Lang Ranch pump station	Lang Ranch Pump Station (Sunset Hills Boulevard and Peak Place)	To reduce Oakbrook pressure zone supply deficiency	Supply Capacity (MDD/PHD)	Medium	$115,000
FF2	Northwood Booster Emergency Pressure Reducing Station	Construction of 1 x pressure regulating station (4"/8" PRVs)	Along Avenida Verano at or near the Northwood Park	To provide emergency (fire flow) supply to Northwood Booster pressure zone from Lang Ranch/Sunset 2 pressure zone	Supply Capacity (PHD+FF)	Medium	$125,000
FF3	Minnecota Pressure Reducing Station Upgrade	Installation of 1 x 8" PRV at Minnecota PRS	Minnecota Pressure Reducing Station (Erbes Road and Minnecota Drive)	To increase fire flow supply to Minnecota pressure zone	Supply Capacity (PHD+FF)	Medium	$45,000
Subtotal – Medium Priority Projects							**$3,980,000**
PL1	Los Arboles Turnout Pipeline Upgrade	Replacement of 165 ft of 6"/8"/10" pipe with 16" pipe	Between Los Arboles Turnout and Calle Quebracho	To reduce pipeline velocity and pressure surge potential downstream Los Arboles turnout	Pipeline Capacity (PHD)	Low	$75,000
PL2	Las Flores Turnout Pipeline Upgrade	Replacement of 85 ft of 8" pipe with 16" pipe, and 180 ft of 8" pipe with 12" pipe	Between Las Flores Turnout and Calle Jazmin	To reduce pipeline velocity and pressure surge potential downstream Las Flores turnout	Pipeline Capacity (PHD)	Low	$100,000

ID	Project Name	Project Description	Project Location	Project Justification	Deficiency Type	Priority	Estimated Total Project Cost
PL3	Lindero Turnout Pipeline Upgrade	Replacement of 450 ft of 8" pipe with 12" pipe	Downstream of Hillcrest Turnout along East Hillcrest Drive	To reduce pipeline velocity and pressure surge potential downstream Lindero turnout	Pipeline Capacity (PHD)	Low	$165,000
PL4	Hillcrest Turnout Pipeline Upgrade	Replacement of 525 ft of 8" pipe with 16" pipe	Downstream of Hillcrest Turnout along East Hillcrest Drive	To reduce pipeline velocity and pressure surge potential downstream Hillcrest turnout	Pipeline Capacity (PHD)	Low	$235,000
PL5	Encino Vista Turnout Pipeline Upgrade	Replacement of 90 ft of 8" pipe with 12" pipe	Between Encino Turnout and Encino Vista Drive	To reduce pipeline velocity and pressure surge potential downstream Encino Vista turnout	Pipeline Capacity (PHD)	Low	$30,000
PL6	Ventu Park Turnout Pipeline Upgrade	Replacement of 150 ft of 8" pipe with 16" pipe	Downstream of Ventu Park	To reduce pipeline velocity and pressure surge potential downstream Ventu Park turnout	Pipeline Capacity (PHD)	Low	$70,000
Subtotal – Low Priority Projects							**$675,000**
Total							**$6,455,000**

1- Recommended as a result of an independent study.

Table 6-4: Recommended Five-Year Capital Improvement Plan

Project ID	Project Name	FY 2017/18	FY 2018/19	FY 2019/20	FY 2020/21	FY 2021/22	Total
WQ1	Turnouts Downstream Regulating Valve Upgrade	$50,000	$350,000	$0	$0	$0	$400,000
WQ2	Reservoir Circulation Improvements	$200,000	$0	$0	$0	$0	$200,000
WQ3	Reservoir Supplemental Disinfectant Boosting Improvements	$200,000	$200,000	$0	$0	$0	$400,000
WQ4	Reservoir Water Quality Monitoring and SCADA Improvements (Analyzers)	$400,000	$400,000	$0	$0	$0	$800,000
FF1	La Granada Pump Station and Pipeline	$3,600,000	$0	$0	$0	$0	$3,600,000
PS1	Pederson to Meadows Supply Improvements	$0	$0	$95,000	$0	$0	$95,000
PS2	Lang Ranch Pump Station Upgrade	$0	$0	$115,000	$0	$0	$115,000
FF2	Northwood Booster Emergency Pressure Reducing Station	$0	$125,000	$0	$0	$0	$125,000
FF3	Minnecota Pressure Reducing Station Upgrade	$0	$0	$45,000	$0	$0	$45,000
PL1	Los Arboles Turnout Pipeline Upgrade	$0	$0	$75,000	$0	$0	$75,000
PL2	Las Flores Turnout Pipeline Upgrade	$0	$0	$0	$100,000	$0	$100,000
PL3	Lindero Turnout Pipeline Upgrade	$0	$0	$0	$165,000	$0	$165,000
PL4	Hillcrest Turnout Pipeline Upgrade	$0	$0	$0	$0	$235,000	$235,000
PL5	Encino Vista Turnout Pipeline Upgrade	$0	$0	$0	$30,000	$0	$30,000
PL6	Ventu Park Turnout Pipeline Upgrade	$0	$0	$0	$70,000	$0	$70,000
	Project Totals	**$4,450,000**	**$1,075,000**	**$330,000**	**$365,000**	**$235,000**	**$6,455,000**

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Appendix A: References

1. California Department of Water Resources (DWR), 2003. *California's Groundwater-Hydrologic Region South Coast-Thousand Oaks Area Groundwater Basin, Bulletin 118*.

2. Calleguas Municipal Water District, 2014. *Emergency Water Supply Plan*.

3. CDM Smith, 2016. *Thousand Oaks Groundwater and Reclaimed Water Study*.

4. HDR, 2013. *Citywide Reservoir Seismic Evaluation/Structural Retrofit City of Thousand Oaks (MI 2094)*

5. Impact Sciences, Inc, 2011. *Thousand Oaks Boulevard Specific Plan Final Environmental Impact Report.*

6. Kennedy/Jenks Consultants, 2016. *Potable Water Master Plan Update (Draft Report Sections)*

7. RBF Consulting, 2005. *City of Thousand Oaks Water Master Plan*.

8. RBF Consulting, 2009. *CI-1165 Water Master Plan Emergency Interconnections Technical Memorandum.*

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10. Red Oak Consulting and RBF Consulting, 2004. *City of Thousand Oaks Water System Operations Manual.*

11. RRM Design Group, 2012. *Amended Thousand Oaks Boulevard Specific Plan.*

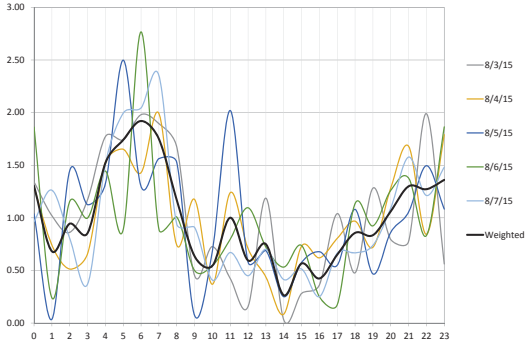
12. AWWA, 2012. *Manual of Water Supply Practices M32, Computer Modeling of Water Distribution Systems, Third Edition.*

Appendix B: SCE Rate Schedule Definitions

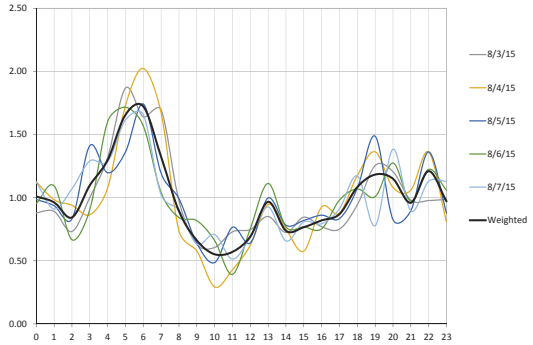
Current Rate Schedule	Pump Station(s)	Rate Class	Eligible Maximum Monthly Load	Summer TOU				Winter TOU			
				On Peak	Mid Peak	Off Peak	Super-Off Peak	On Peak	Mid Peak	Off Peak	Super-Off Peak
TOU-GS1A	Northwood, Rolling Oaks, Sunset No. 3	Commercial and Industrial	0-20 kW	Noon to 6:00 p.m. summer weekdays except holidays	8:00 a.m. to noon and 6:00 p.m. to 11:00 p.m. summer weekdays except holidays	All other hours	NA	NA	8:00 a.m. to 9:00 p.m. winter weekdays except holidays	All other hours	NA
TOU-GS2B	Kelley	Commercial and Industrial	20-200 kW								
TOU-PA-2-B	Wilder, Lang Ranch 4A, Los Arboles, Ventu Park, Grissom	Agriculture and Pumping	0-200 kW								
TOU-PA-2-SOP1	Willow Lane, Sunset No. 2, Pederson, Lone Oak	Agriculture and Pumping	0-200 kW	1:00 p.m. to 5:00 p.m. summer weekdays except holidays	NA	All other hours - all year everyday	Midnight to 6:00 a.m. all year everyday	NA	NA	All other hours - all year every day	Midnight to 6:00 a.m. all year everyday
TOU-PA-3-SOP1	Sunset No. 1, Erbes Road	Agriculture and Pumping	200-500 kW								

Appendix C: Diurnal Demand Patterns (August 3-7, 2015)

Tara, Meadows, Northwood Diurnal Pattern (Hourly)
August 3-7, 2015



Pederson/Willow Zone Diurnal Pattern (Hourly)
August 3-7, 2015



Kelly/Kelly Hydro Diurnal Pattern (Hourly)
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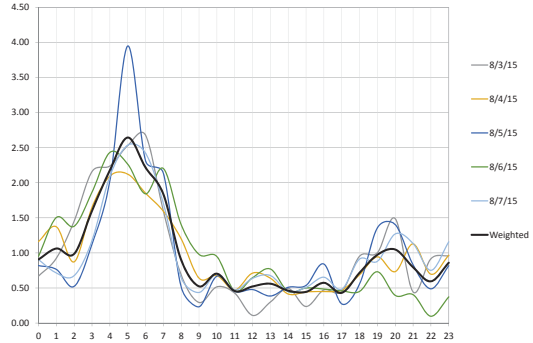

Ventu/Ventu Hydro Diurnal Pattern (Hourly)
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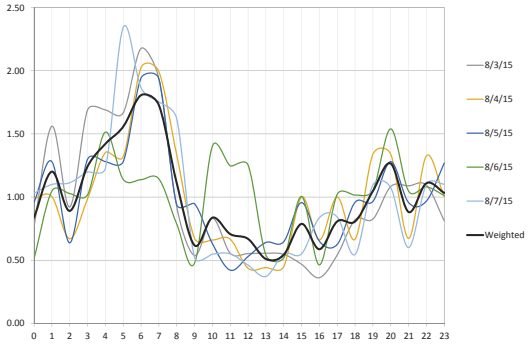

Rolling Oaks Diurnal Pattern (Hourly)
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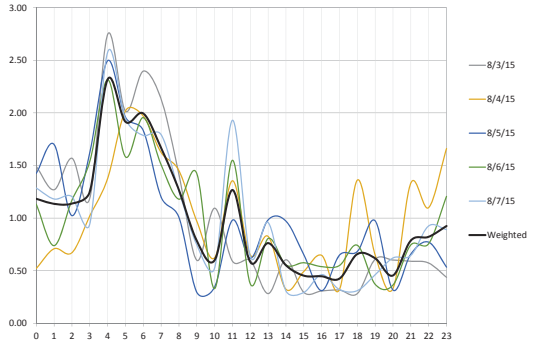
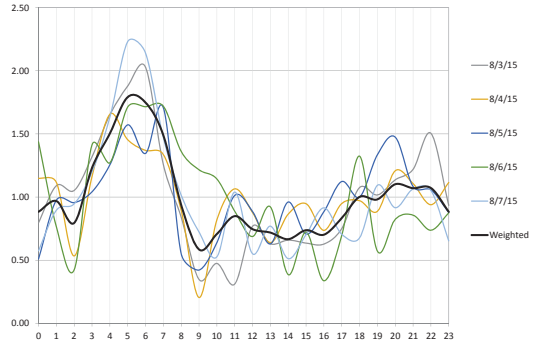
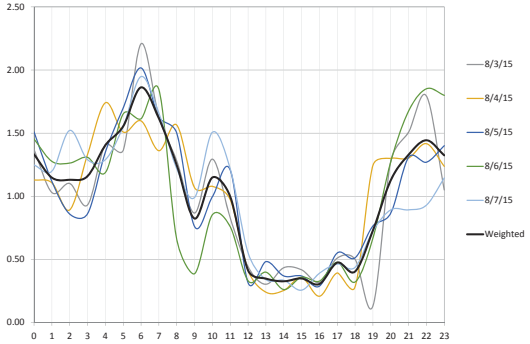


Freeway/La Granada, Wilder Diurnal Pattern (Hourly)
August 3-7, 2015



Lang Ranch/Sunset 2 (LR/S2), Reduced LR/S2, Reduced Minecota
Diurnal Pattern (Hourly), August 3 -7, 2015



Oakbrook/Sunset 3, Reduced Lang Ranch, Sunset Hydro
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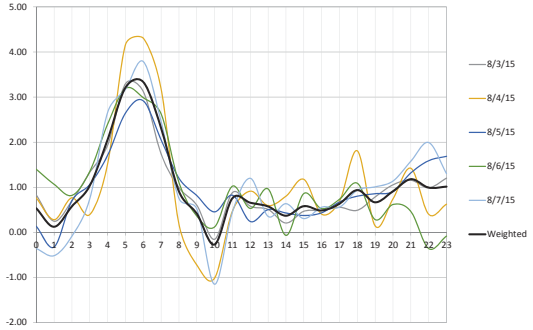
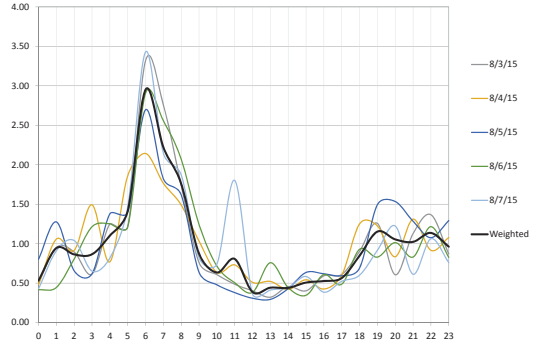
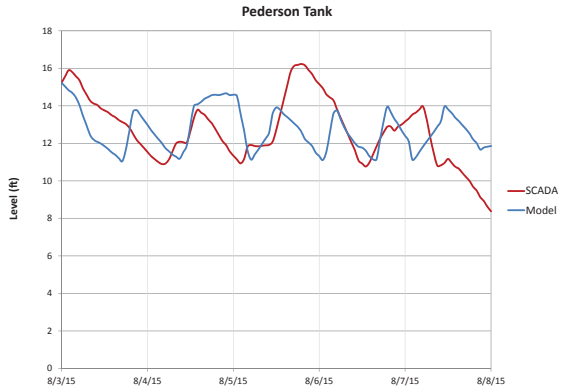


Grissom, Gissom Hydro, Reduced Sapra Diurnal Pattern (Hourly)
August 3-7, 2015



Appendix D: Model Calibration Results

STORAGE TANKS



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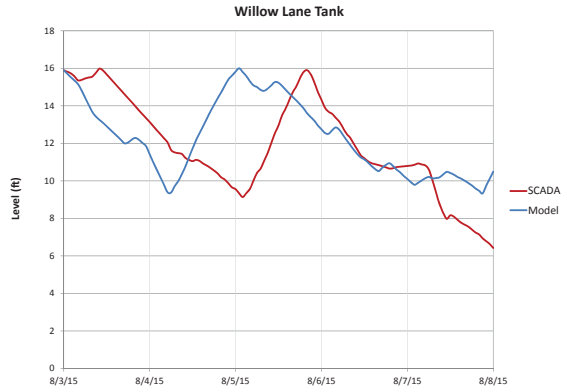

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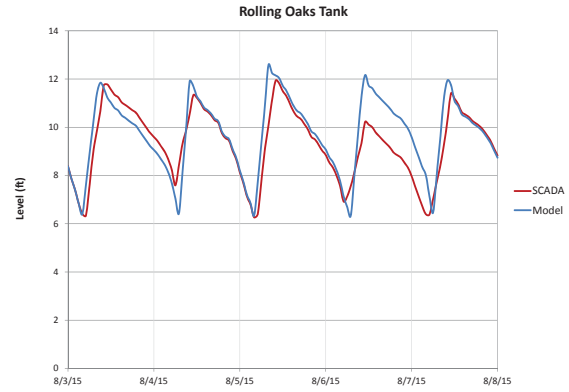

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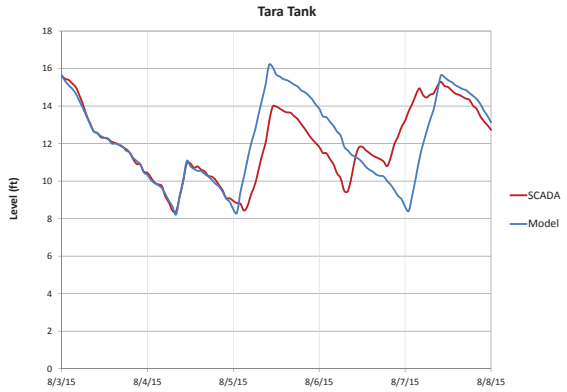

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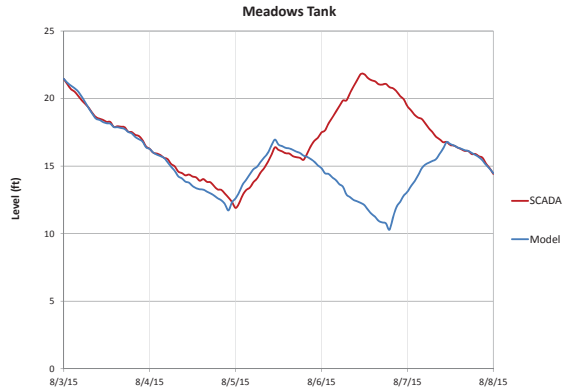

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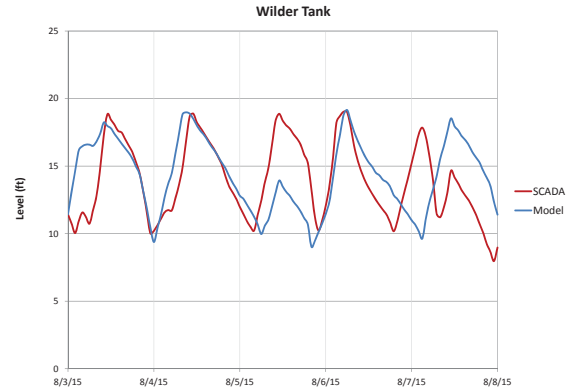

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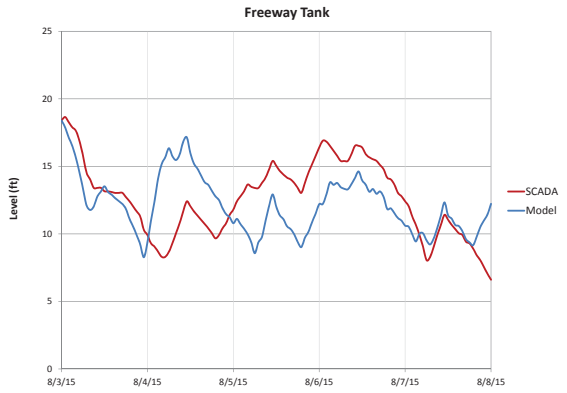

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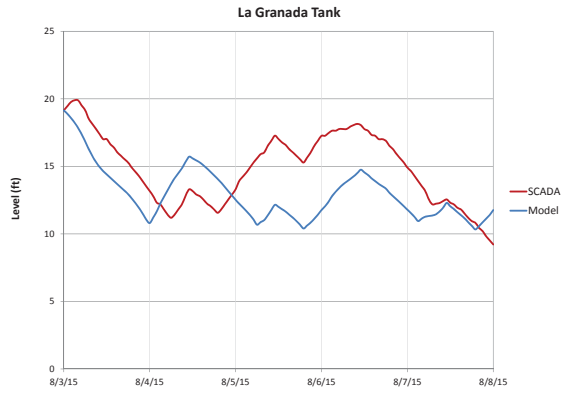

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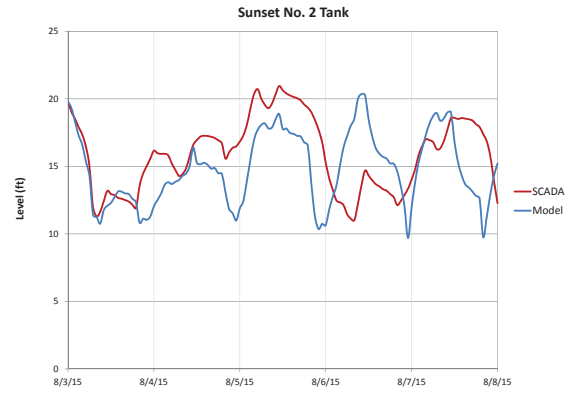

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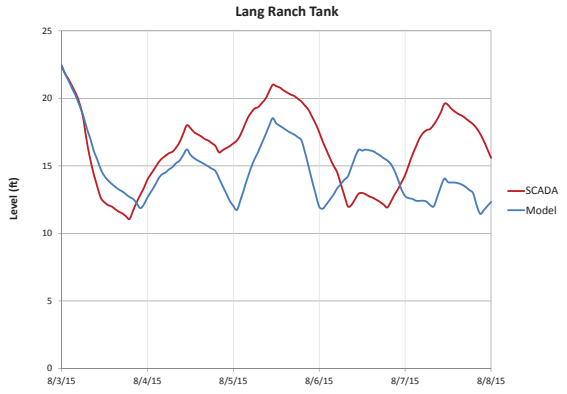

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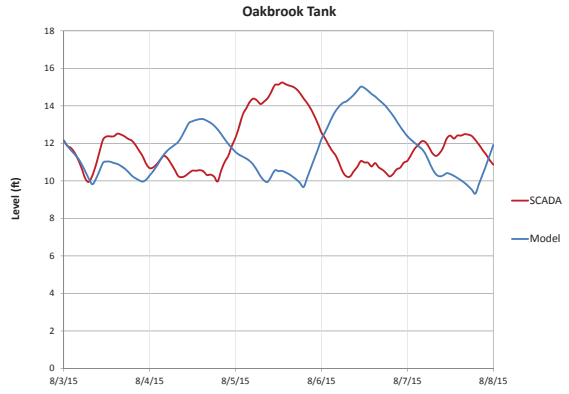

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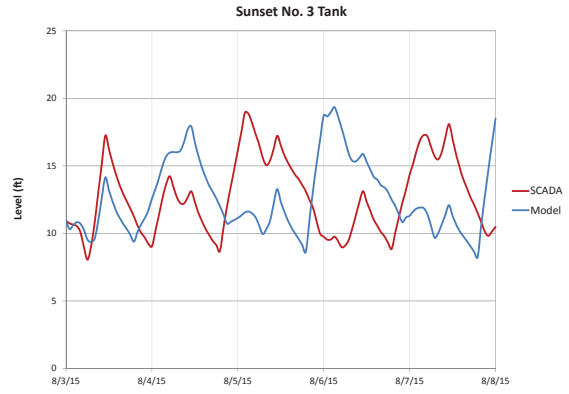

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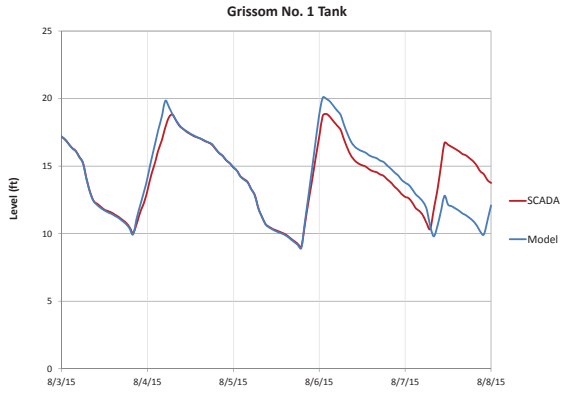

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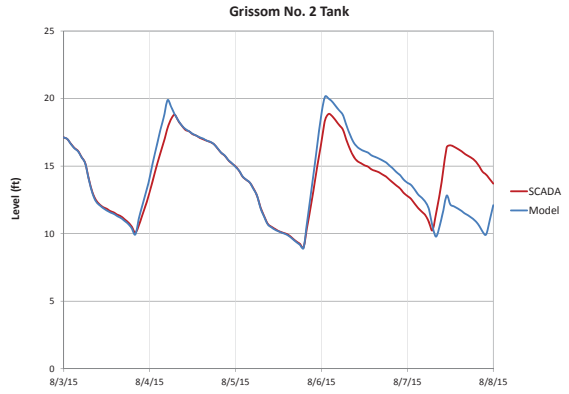

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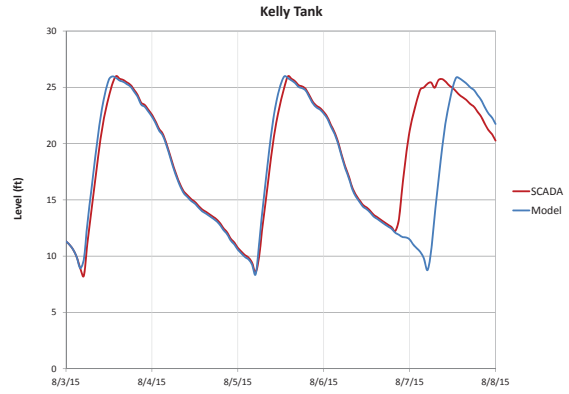

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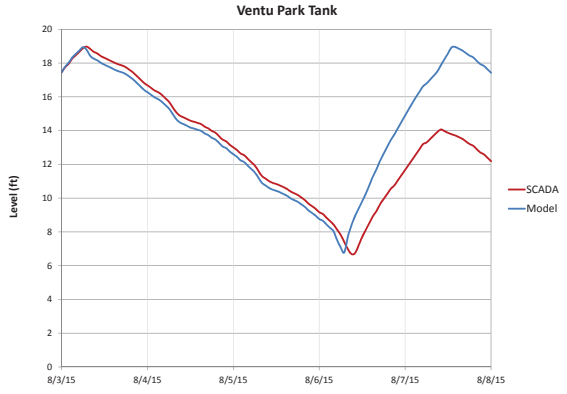

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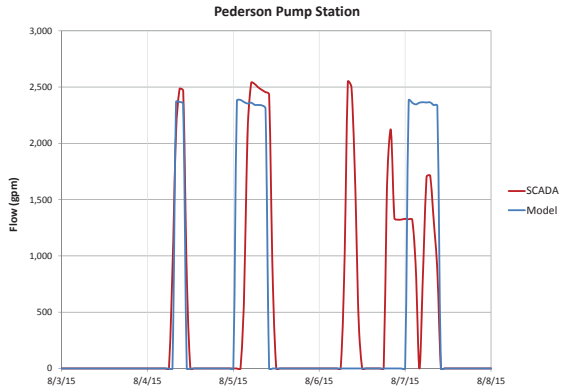
PUMP STATIONS



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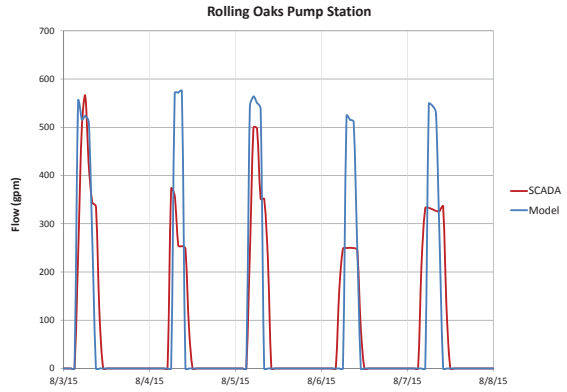

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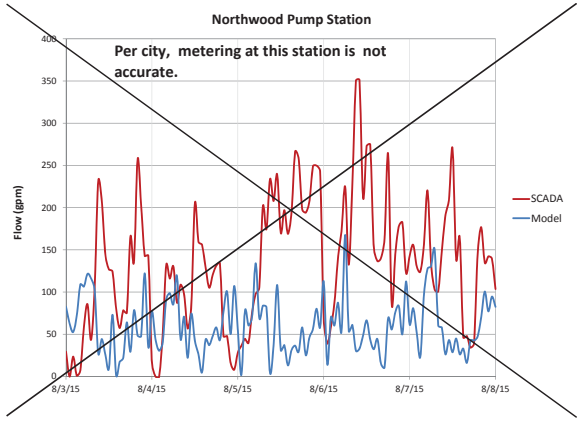

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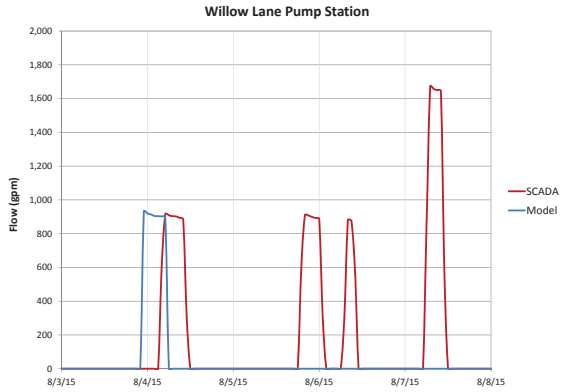

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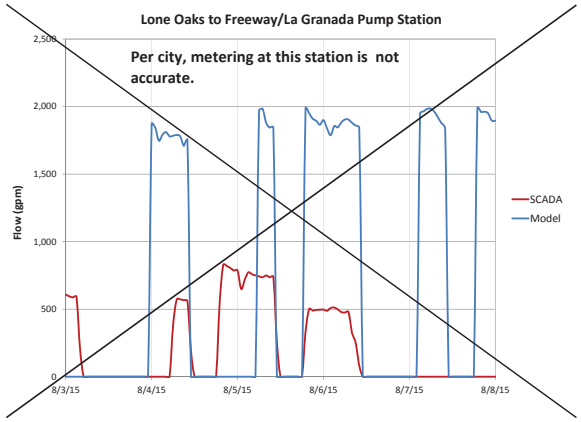

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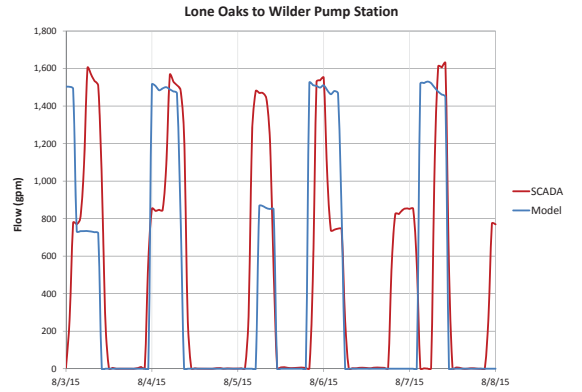

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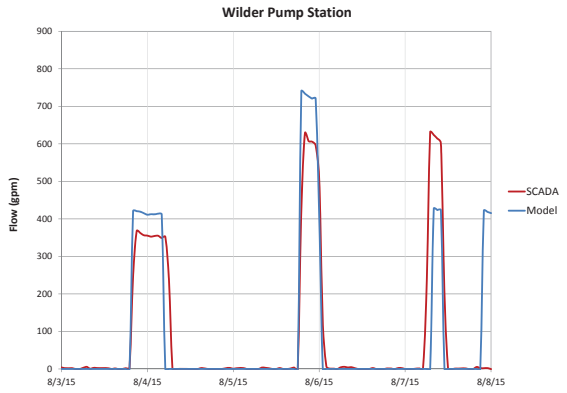

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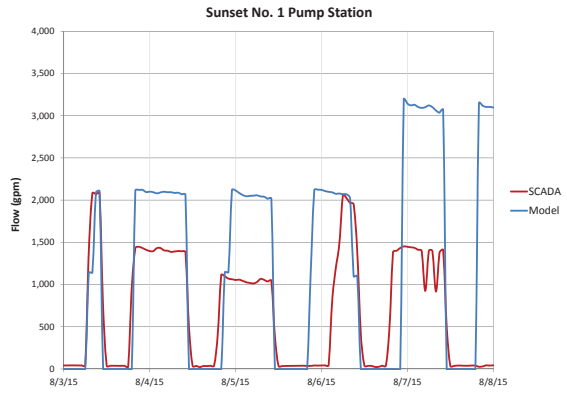

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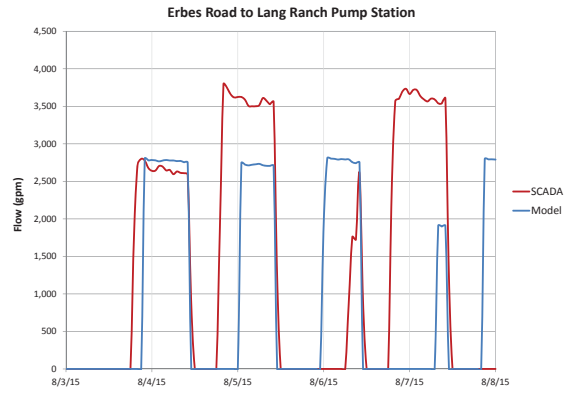

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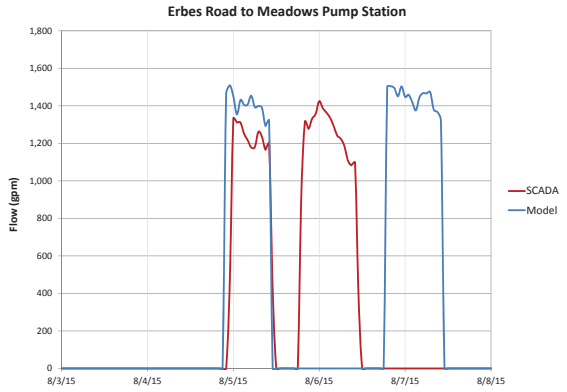

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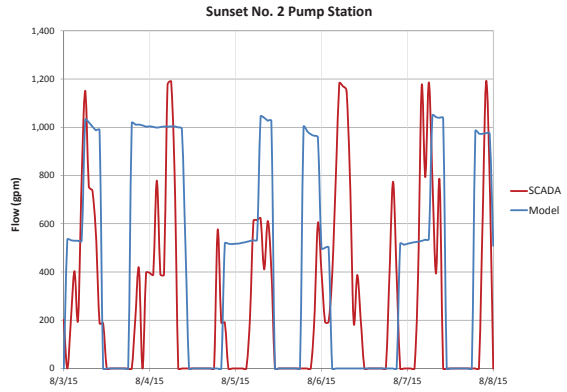

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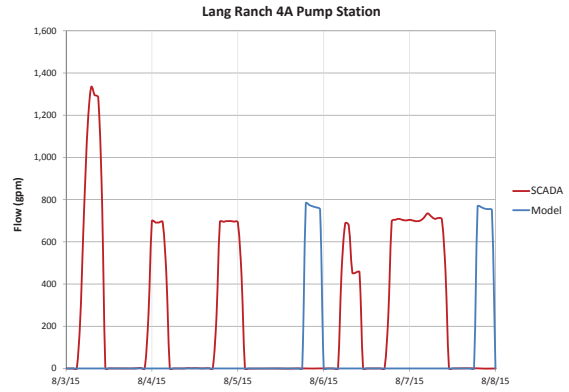

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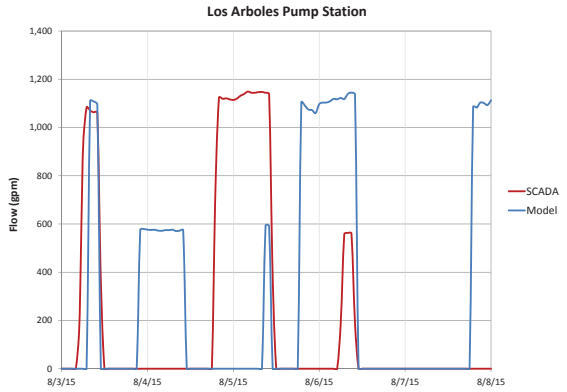

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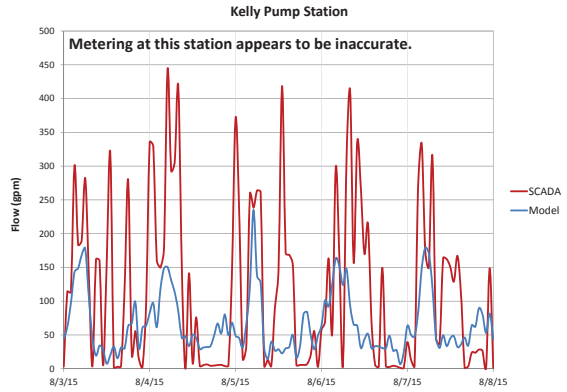

City of Thousand Oaks Water Master Plan Update

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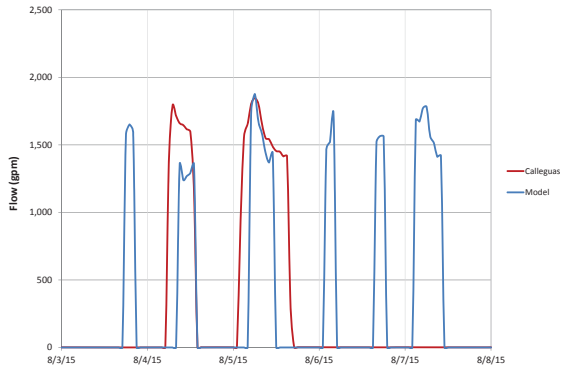
TURNOUTS

Los Arboles Turnout



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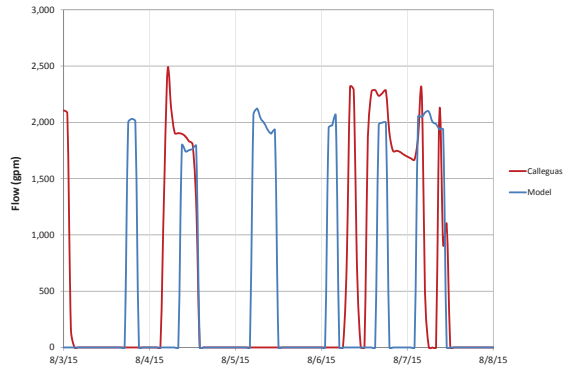
Las Flores Turnout



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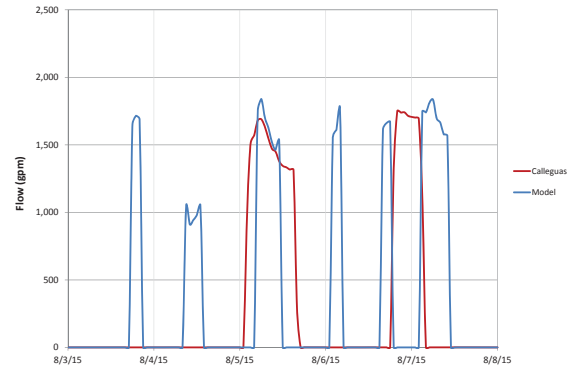
Kennedy/Jenks Consultants

Gainsborough Turnout



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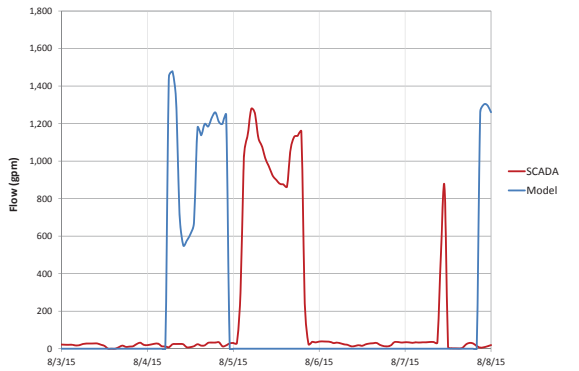
Hillcrest Turnout



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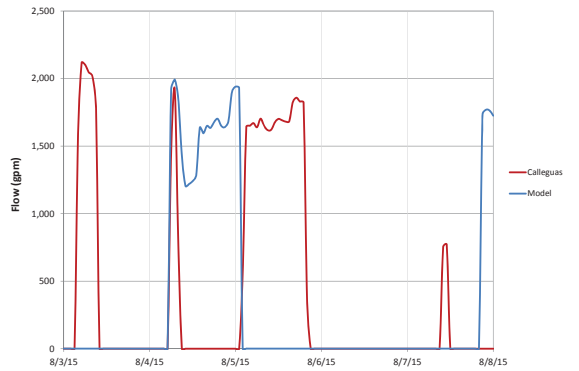

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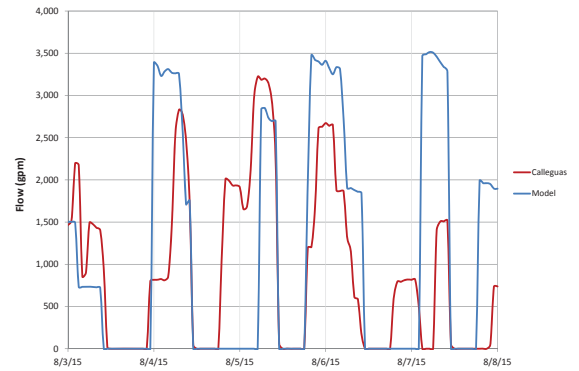
Lone Oaks Turnout



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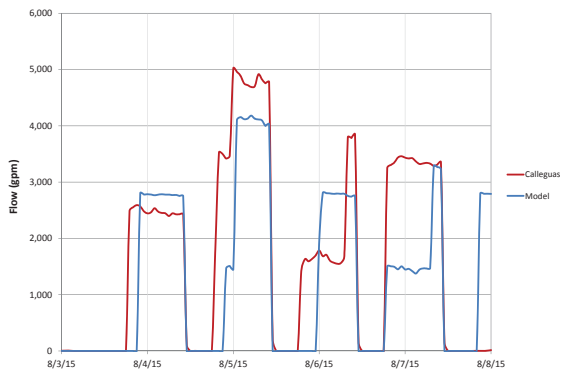
Lindero Turnout



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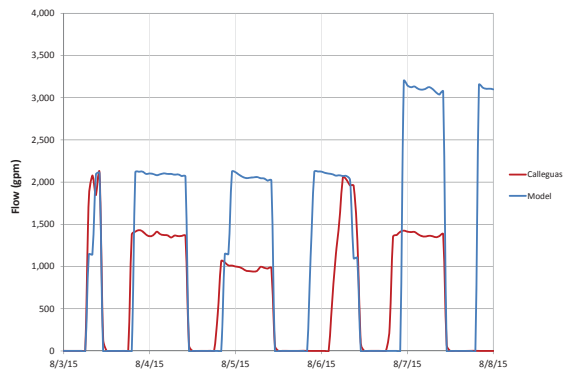
Del Sol Turnout



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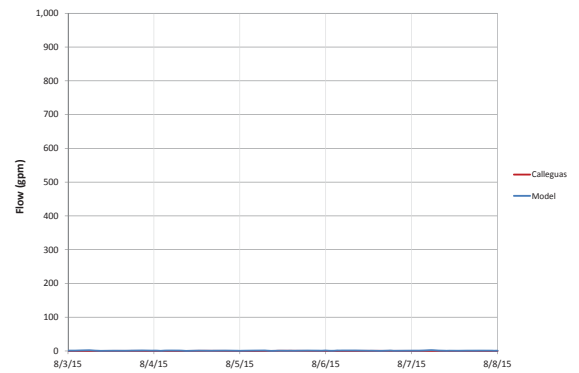
La Jolla Turnout



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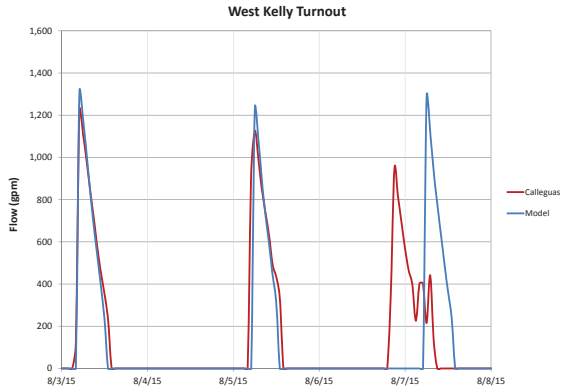

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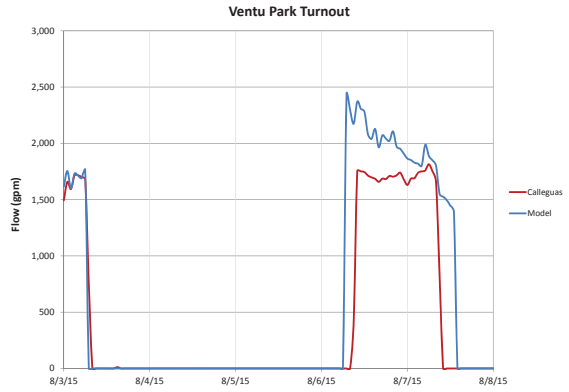

City of Thousand Oaks Water Master Plan Update

Kennedy/Jenks Consultants

Appendix E: Buildout Storage Requirements

Table E-1: Operational and Emergency Storage Requirements – Buildout

No.	Primary Zone	Closed System Linked Zone(s)	Primary Zone MDD (mgd)	Linked Zone(s) MDD (mgd)	Total MDD (mgd)	Required Operational Volume (MG)	Emergency Volume: Total MDD (%)	Required Emergency Volume (MG)
1	Tara	Northwood Booster	1.23	0.18	1.41	0.71	50%	0.71
2	Meadows	-	1.47	0.00	1.47	0.73	50%	0.73
3	Pederson/Willow	-	4.82	0.00	4.82	2.41	25%	1.20
4	Kelley	Kelley Hydro	0.22	0.21	0.43	0.22	50%	0.22
5	Ventu	Ventu Hydro	1.83	0.07	1.90	0.95	50%	0.95
6	Rolling Oaks	-	0.18	0.00	0.18	0.09	50%	0.09
7	Freeway/La Granada	Conejo Oaks	2.52	0.49	3.01	1.51	25%	0.75
8	Wilder	-	1.01	0.00	1.01	0.50	25%	0.25
9	Lang Ranch/Sunset 2	Reduced Minnecota, Reduced Lang Ranch/ Sunset 2	3.12	0.15	3.27	1.64	25%	0.82
10	Oakbrook	Reduced Lang Ranch	2.02	0.28	2.30	1.15	25%	0.58
11	Sunset 3	Sunset Hydro	0.47	0.06	0.53	0.26	50%	0.26
12	Grissom	Grissom Hydro, Reduced Sapra	0.19	0.08	0.27	0.14	50%	0.14

Table E-2: Fire Flow Storage Requirements – Buildout Demand Condition

No.	Primary Zone	Governing Land Use	Required Fire Flow and Duration	Available Flow from Calleguas (gpm)	Required Fire Flow Volume for Single Fire (MG)	Fire Reserve Multiple	Total Required Fire Flow Volume (MG)
1	Tara	K-12 School	4,000 gpm x 4 hrs	-	0.96	1	0.96
2	Meadows	K-12 School	4,000 gpm x 4 hrs	-	0.96	1	0.96
3	Pederson/Willow	Institutional	5,000 gpm x 4 hrs	0-5,000	0-1.2	2	0-2.4
4	Kelley	Commercial	3,000 gpm x 3 hrs	0-2,000	0.18-0.54	1	0.18-0.54
5	Ventu Park	Institutional	5,000 gpm x 4 hrs	0-2,500	0.60-1.2	1	0.6-1.2
6	Rolling Oaks	Very Low Density	1,500 gpm x 2 hrs	-	0.18	1	0.18
7	Freeway/La Granada	Industrial/ Institutional	5,000 gpm x 4 hrs	-	1.2	2	2.4
8	Wilder	K-12 School	4,000 gpm x 4 hrs	-	0.96	1	0.96
9	Lang Ranch/Sunset 2	K-12 School	4,000 gpm x 4 hrs	-	0.96	2	1.92
10	Oakbrook	Medium Density	2,500 gpm x 3 hrs	-	0.45	1	0.45
11	Sunset 3	Low Density	1,500 gpm x 2 hrs	-	0.18	1	0.18
12	Grissom	Low Density	1,500 gpm x 2 hrs	-	0.18	1	0.18

Table E-3: Reservoir Capacity Evaluation – Buildout Demand Condition

No.	Primary Zone	Required Operational Volume (MG)	Required Fire Flow Volume (MG)	Required Emergency Volume (MG)	Total Required Volume (MG)	Total Available Volume (MG)	Surplus/ Deficit Volume (MG)	Deficit/ Surplus Fraction (%)	Min. Water Level to Maintain Em+FF (ft)
1	Tara	0.71	0.96	0.71	2.37	3.94	1.56	40%	13
2	Meadows	0.73	0.96	0.73	2.43	3.41	0.98	29%	18
3	Pederson/ Willow	2.41	0.00-2.40	1.20	3.61-6.01	8.02	2.01--4.41	25%-55%	Minimum Practical
4	Kelley	0.22	0.18-0.54	0.22	0.61-0.97	0.55	**-0.42 to -0.06**	**-76% to -11%**	22
5	Ventu Park	0.95	0.60-1.20	0.95	2.50-3.10	3.75	0.65-1.25	17%-33%	11.5
6	Rolling Oaks	0.09	0.18	0.09	0.36	0.36	0.00	0%	17.5
7	Freeway/La Granada	1.51	2.40	0.75	4.66	5.00	0.34	7%	19
8	Wilder	0.50	096	0.25	1.71	0.98	**-0.73**	**-76%**	10
9	Lang Ranch/ Sunset 2	1.64	1.92	0.82	4.38	5.95	1.57	26%	14
10	Oakbrook	1.15	0.45	0.58	2.18	2.18	0.00	0%	10
11	Sunset 3	0.26	0.18	0.26	0.71	0.76	0.05	7%	13.5
12	Grissom	0.14	0.18	0.14	0.45	0.41	**-0.04**	**-10%**	17.5

Appendix F: Pump Station and Turnout Level Controls and Set Points for Water Age Modeling Scenarios

WATER MASTER PLAN

Appendix F: Water Quality Analysis/Enhancement of Operations Improvement Plan

Prepared for the City of Thousand Oaks

Draft Submitted: April 4, 2016
Toaks Comments: May 11, 2016
Final Date: January 26, 2017

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Reviewer: David Ferguson, Ph.D., P.E. (Kennedy Jenks)

Subject: Water Quality Analysis/Enhancement of Operations Improvement Plan

EXECUTIVE SUMMARY

The City of Thousand Oaks (City) receives chloraminated drinking water from the Calleguas Municipal Water District (CMWD). The City maintains and operates 16 reservoirs and a distribution system that includes 19 pressure zones, all supplied by way of 11 turnouts from CMWD. The City conducts routine water quality monitoring of its reservoirs and distribution system.

Historical total chlorine and nitrite data correlated with reservoir water temperatures demonstrate strong evidence of seasonal nitrification within the City's system as a whole. Trussell Tech and Kennedy/Jenks considered several nitrification control strategies (Section 3.3) in helping the City identify an immediate strategy to mitigate the water quality degradation in the system given the scale of the nitrification issue in the City's reservoirs as the Water Master Plan project commenced in August 2015. Two nitrification control strategies were selected for implementation and evaluation in this project: (1) active reservoir mixing, and (2) supplemental disinfection boosting. These strategies were selected for evaluation as the most cost-effective, efficient, and likely to be successful control strategies for the City to consider.

The study looked at the effect on control of nitrification of adding mixers and/or chlorine/ammonia boosting on the water quality in select reservoirs. To accomplish the goals of the study, the City leased a total of 5 PAX mixers and 2 Residual Control System (RCS) units for a 6 month trial period. Two of the five PAX mixers were deployed in the reservoirs with the RCS units. The study focused on the reservoirs where the most impact of nitrification had been observed. The final implementation of the equipment included the following:

- **Mixer + Control System #1 (RCS): Willow Reservoir**
  - Freeway Reservoir (no change, but fed by Willow Reservoir)
- **Mixer + Control System #2 (RCS): Pederson Reservoir**
  - Tara Reservoir (no change, but fed by Pederson Reservoir)
- **Mixer only (PAX**):
  - Rolling Oaks Reservoir (fed by Willow Reservoir)
  - La Granada Reservoir
  - Ventu Park Reservoir, inactive partition
- No change, no influence (control system for comparison):
  - Kelley Reservoir
  - Ventu Park Reservoir, active partition (mixer in inactive partition)

Along with the implementation of the mixers and supplemental boosting control systems, additional water quality monitoring by the Environmental Programs staff was recommended. The supplemental disinfection boosting study demonstrated that the addition of PAX mixers to reservoirs provided improvements to the water quality. Adding to the presence of the mixer the ability to boost chemical (chlorine and/or ammonia with a control over the dosing ratio) using the PAX RCS units resulted in consistently good water quality for the two reservoirs in the study with a mixer and the PAX RCS. The improved water quality in the reservoirs with the mixer and control system provided a benefit to downstream reservoirs, as well, although the water quality in the downstream reservoirs was less consistent.

Enhancement of Operations Improvement Plan

Improvements in Equipment to Reduce Nitrification Events and Increase the Ability to Respond Quickly

1. Procure PAX or equivalent active mixer for each of the City's reservoirs.
   a. Procure permanent PAX RCS installations for Willow and Pederson Reservoirs.
   b. The City has purchased the two mobile PAX RCS units used during the 6 month trial period. Equip all remaining reservoirs (14 total) with electrical and plumbing connections to accommodate these mobile supplemental boosting units.
2. Equip all of the City's reservoirs with a proven total chlorine analyzer.
   a. Procure Hach CLT10 sc or equivalent to provide continuous monitoring of total chlorine for a real-time gauge of residual chlorine and indicator of nitrification in reservoirs.

b. The PAX RCS units continuously monitor total chlorine, pH, and ORP, thus Willow and Pederson Reservoirs will not need an additional analyzer.
c. Integration of continuous total chlorine monitoring data with the City's SCADA system will allow for real-time monitoring feedback to assess the variability of water quality and the impact of operational changes including reservoir fill levels, turnout operation, demand in system, time of day, temperature, and upstream/downstream system conditions (residual chlorine, mixing, water quality in distribution system).

Recommendations for Operations

With the assumption that the new equipment recommended for implementation has been installed, the following are recommendations for operations.

1. Increase reservoir monitoring for nitrification indicators (e.g., total chlorine, nitrite, water temperature) during the months of June through December, when water quality has historically been impacted. This should also be implemented when the water temperature in a reservoir exceeds 18ºC. For these conditions, monitor all reservoirs on a weekly basis, at minimum. Recommended sampling frequency for the most critical parameters is shown in Table ES-1 (see Table 4 for additional sampling recommendations).

Table ES-1. Recommended Sampling Frequency of Key Constituents/Parameters Related to Nitrification Issues

Constituent	Sampling Frequency		
	January - May	June - December	Nitrite > 0.03 and/or Total Chlorine < 0.75
Total chlorine[1]	Monthly	Weekly	3x/week
Nitrite	Monthly	Weekly	5x/week
Water Temperature	Monthly	Weekly	3x/week

[1]Grab samples for QA/QC monthly if online chlorine analyzer present

2. Establish proactive water quality trigger points for initiating additional operational changes to mitigate nitrification issues. Proposed trigger points and recommended response are summarized in Table ES-2. In the case where trigger conditions call for running a mobile RCS unit in more than two reservoirs simultaneously, the response should be prioritized based on reservoir groupings defined in Water Master Plan Update Section 5.2.2. The mobile RCS units should be deployed first at reservoirs meeting the trigger points that feed additional impacted reservoirs.

Table ES-2. Trigger points and recommended response

Constituent or Parameter	Trigger	Response
Nitrite	>0.03 mg/L N	Sampling per Table ES-1 Sampling within 2 days
Nitrite	>0.05 mg/L N	Run Mobile RCS
Total Chlorine	<0.75 mg/L	Sampling per Table ES-1
Total Chlorine	<0.5 mg/L	Run Mobile RCS
Total Chlorine and Nitrite	>1.0 mg/L <0.03 mg/L	Stop mobile RCS, resume seasonal monitoring
Water Temperature	> 18°C	Sampling per Table ES-1, June-December

1 - WATER QUALITY MONITORING PROGRAM

Introduction

The City of Thousand Oaks (City) receives chloraminated drinking water from the Calleguas Municipal Water District (CMWD) and provides storage and delivery to meet the water demands of approximately 16,700 customers. The City maintains and operates 16 reservoirs and a distribution system that includes 19 pressure zones, all supplied by way of 11 turnouts from CMWD. For compliance with the California State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW) drinking water regulations and to provide an indication of conditions within the water storage and distribution system, the City conducts routine water quality monitoring of its reservoirs and distribution system. At a minimum, the Environmental Programs staff samples each reservoir on a monthly basis, measuring total and free chlorine, nitrite, nitrate, free and total ammonia, total coliform bacteria, heterotrophic plate count (HPC), turbidity, and pH. During the summer and late fall months, when the water temperature in the reservoirs increases, the Environmental Programs staff conducts more frequent monitoring and measurement of total chlorine and nitrite for reservoirs with historical water quality issues. Table 1 lists the City‘s reservoirs, along with a summary of historical water quality issues and any mixers, analyzers, or control systems that have been implemented through this project or by the City outside this project.

Table 1. Summary of the City water reservoirs, including historical water quality issues and any mixers, analyzers, or control systems.

Reservoir	Storage Capacity (MG)	Inlet/Outlet Piping (Dual/Individual)	Historical Water Quality Issues	Mixers, Analyzers, & Control Systems	
				City Actions (pre-October 2015)	Current Project (since October 2015)
Freeway	1.00	10" Dual	Consistent nitrification	Solar Bee 500PWc v18	No change
Grissom (2)	0.21 each	8" Dual	Seasonal nitrification	None	None
Kelley	0.55	12" Dual	Seasonal nitrification	None	None
La Granada	4.00	14" Dual	Seasonal nitrification	None	PAX 500 mixer
Lang Ranch	4.90	18" Dual	Seasonal nitrification	None	None
Meadows	3.40	16" Dual	Some seasonal nitrification	None	None
Oakbrook	2.20	14" Dual	Consistent nitrification	None	None
Pederson	3.00	18" Dual	Seasonal nitrification	None	PAX 500 mixer PAX RCS
Rolling Oaks	0.35	10" Dual	Consistent nitrification	Solar Bee 500PWc v18 (removed 2014)	PAX 400 mixer ATI chlorine analyzer
Sunset No. 2	1.00	12" Dual	Some seasonal nitrification	None	None
Sunset No. 3	0.76	10" Dual	Some seasonal nitrification	None	None
Tara	4.00	16" Dual	Seasonal nitrification	Solar Bee 1250PW v18	No change
Ventu Park	4.00	Two 16" Dual	Seasonal nitrification	None	PAX 500 mixer*
Wilder	0.98	16" Dual	Seasonal nitrification	None	None
Willow Lane	5.00	16" Dual, 12" Outlet	Seasonal nitrification	Solar Bee 1250PW v18	PAX 600 mixer PAX RCS

* Mixer at Ventu Park Reservoir was installed in the inactive partition

As depicted in Table 1, the historical water quality issues observed in the reservoirs have largely occurred on a seasonal basis. This technical memorandum will include (1) Assessment of Historical Data; (2) Nitrification Background, Detection, and Control; (3) Disinfection Boosting Program; (4) Enhancement of Operations Improvement Plan; (5) Conclusions and Recommendations; and (6) Attachments.

2 - ASSESSMENT OF HISTORICAL DATA

To better characterize the seasonal issues and identify historical trends, a water quality assessment was completed, incorporating water quality data collected from all of the City's reservoirs between January 2010 and March 2016. Of particular interest were the seasonal patterns of total chlorine and nitrite concentrations, and the correlation of these parameters with water temperatures.

Water from CMWD is chloraminated and delivered through 11 turnouts (including one emergency turnout) with a total chlorine residual of 2.0 to 2.5 mg/L as Cl_2. A probability plot of the total chlorine concentrations measured from the reservoirs between January 2010 and September 2015 is presented in Figure 1.

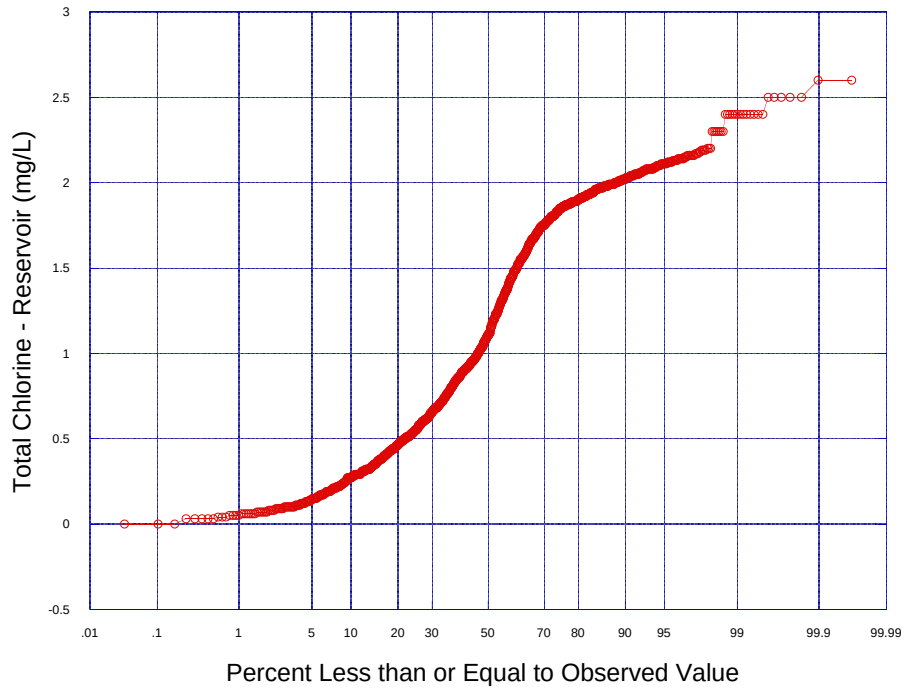


Figure 1. Probability plot of total chlorine concentration based on monitoring data from all reservoirs measured between January 2010 and September 2015.

From Figure 1, it is evident that the total chlorine residual deteriorates after being supplied through the CMWD turnouts, as the median for Jan. 2010 through Sep. 2015 was near 1 mg/L as Cl_2. This means that approximately half of the reservoir measurements were at or below 1 mg/L as Cl_2, representing more than a 50% drop in total chlorine residual from the original CMWD supply.

Along with total chlorine residual, nitrite is commonly used to indicate chloramine decay and the occurrence of water quality issues in a drinking water system. Nitrite is an intermediate species in the nitrification process as ammonia present in chloramines degrades initially to form nitrite followed by subsequent reactions to form nitrate. Therefore, rising levels of nitrite in the reservoirs are an indicator that chloramine decay is occurring that may lead to nitrification problems. To appreciate the seasonal impact of the total chlorine decay and the occurrence of nitrite in the system, measurements of these parameters from all reservoir samples collected between January 2010 and March 2016 were depicted on a calendar basis (January-December) in Figures 2 and 3. Water temperature is provided in both figures using red dots and the secondary y-axis, to provide the seasonal context.

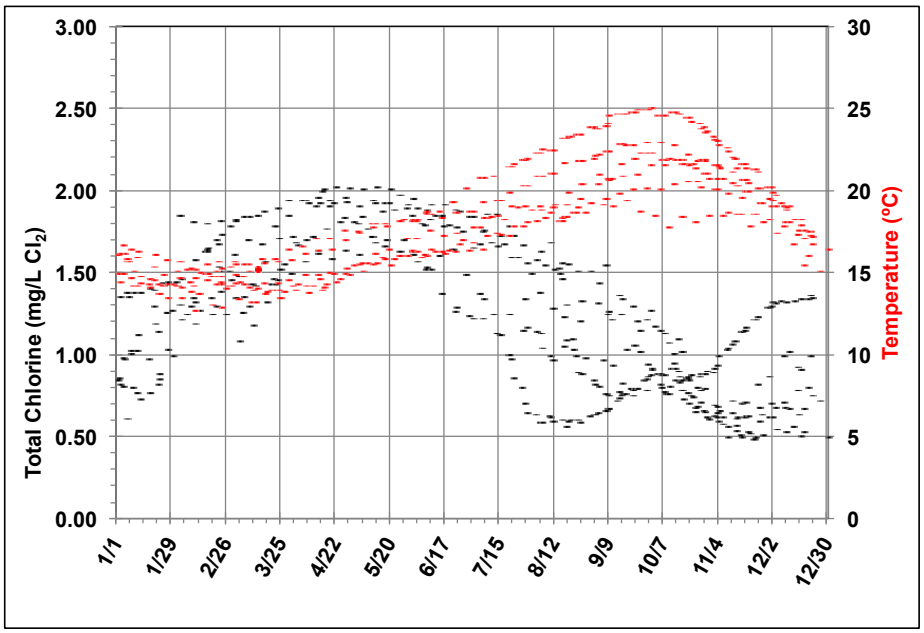


Figure 2. Historical data (January 2010 – March 2016) for total chlorine (black dots, primary y-axis) and temperature (red dots, secondary y-axis) with monthly running average values from all reservoirs presented on a calendar basis (January – December).

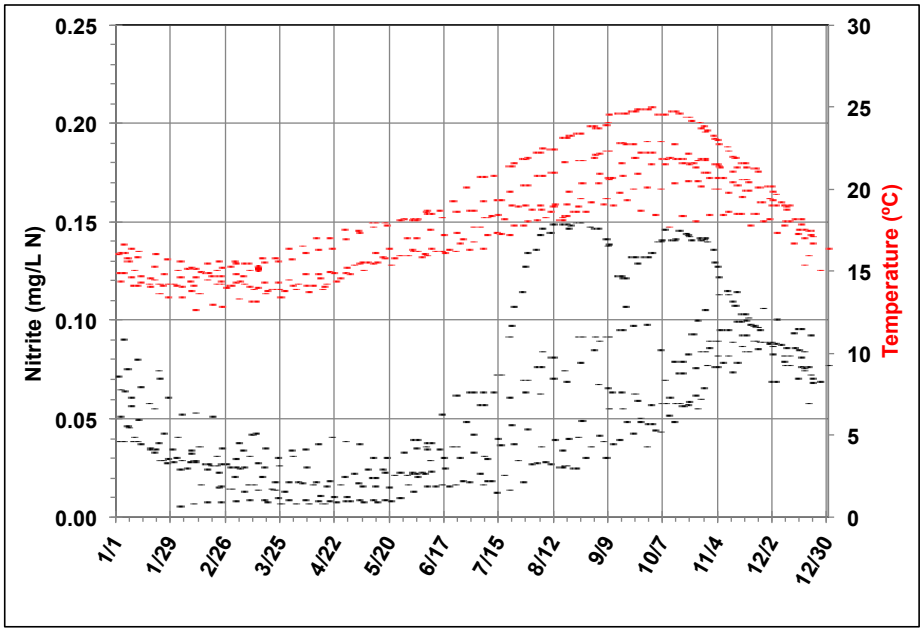


Figure 3. Historical data (January 2010 – March 2016) for nitrite (black dots, primary y-axis) and temperature (red dots, secondary y-axis) with monthly running average values from all reservoirs presented on a calendar basis (January – December).

The historical trends in Figure 2 depict a period of peak total chlorine concentrations from March through June, followed by a general decrease in concentration from July through February. The nitrite values in Figure 3 are characterized by an opposite response pattern from the total chlorine. In general, nitrite concentrations increase from July through February, mirroring the water temperature trend, with a 1 to 2 month delay in response time. Running averages calculated on a monthly basis are used to minimize the noise in the data. The noise is caused by samples being collected as the reservoir is filled with fresh water from the turnout near the time that CMWD water is fed into the reservoir, as opposed to samples that are representative of the water quality in the reservoir.

These general historical water quality patterns are further examined by way of plots depicting the trends in temperature, total chlorine, and nitrite values measured from year to year (2010 to 2016), in Figures 4, 5, and 6, respectively.

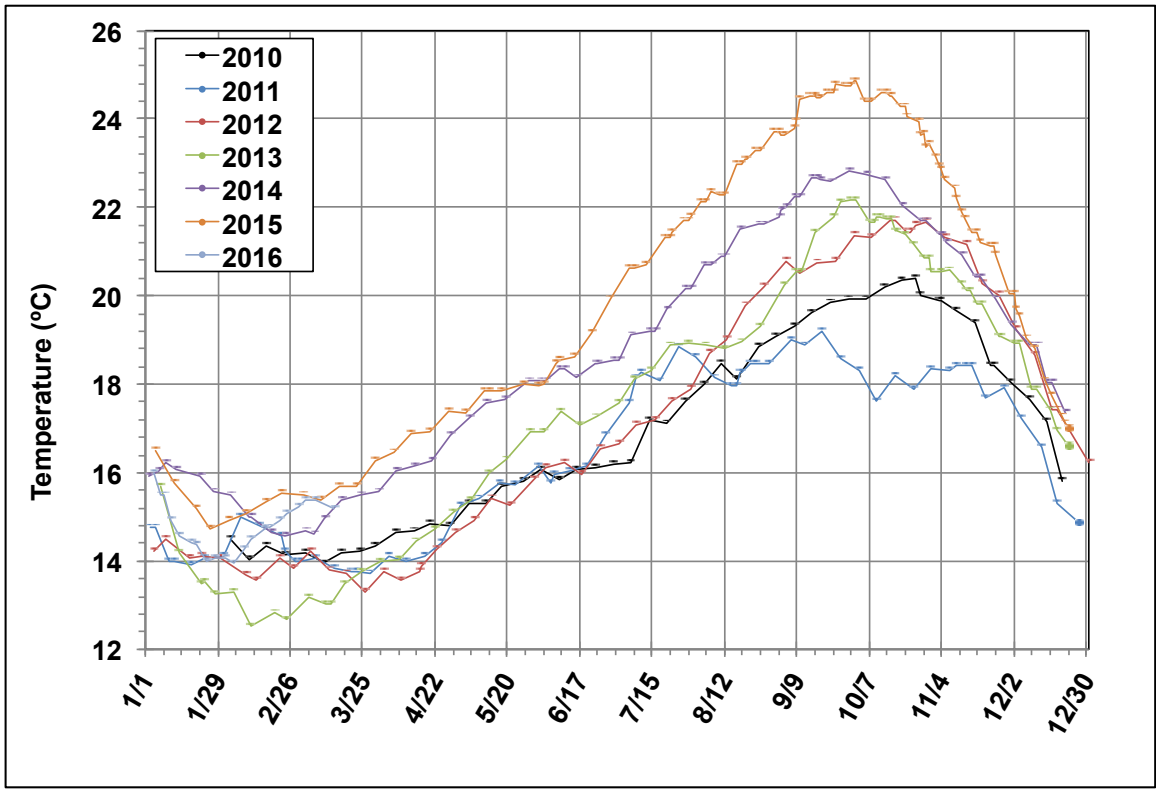


Figure 4. Monthly running average values for water temperature from all reservoirs presented for 2010 through 2016, on a calendar basis (January – December).

***Note y-axis scale has been minimized to include the range of temperatures from 12-26ºC**

While the seasonal pattern of water temperature variation remained consistent from 2010 to 2016 (Figure 4), the magnitude generally increased on an annual basis from 2013 through 2015.

Likewise, the seasonal pattern of variation in total chlorine concentrations remained relatively consistent from 2010 to 2016 (Figure 5). The timing of the decrease in total chlorine concentrations occurred progressively earlier from May 2013 through mid-August 2015, but this trend changed at that point. The monthly running average total chlorine values for 2015 recovered to the historical average from mid-August through October, likely in response to operational changes by the City. During this time period, the City lowered reservoir fill set points to promote faster turnover and reduce water age within the distribution system. Despite the continuing trend through November 2015 of water temperatures that exceeded the monthly running average values from previous years (Figure 4), the trend for total chlorine concentration depicted in Figure 5 was reversed and concentrations increased steadily through the month of November. This improvement in water quality was likely in response to continued practice of the previously-described operational changes, as well as the introduction of new mixers and a control system at Willow Reservoir. These changes will be discussed further in Section 4.

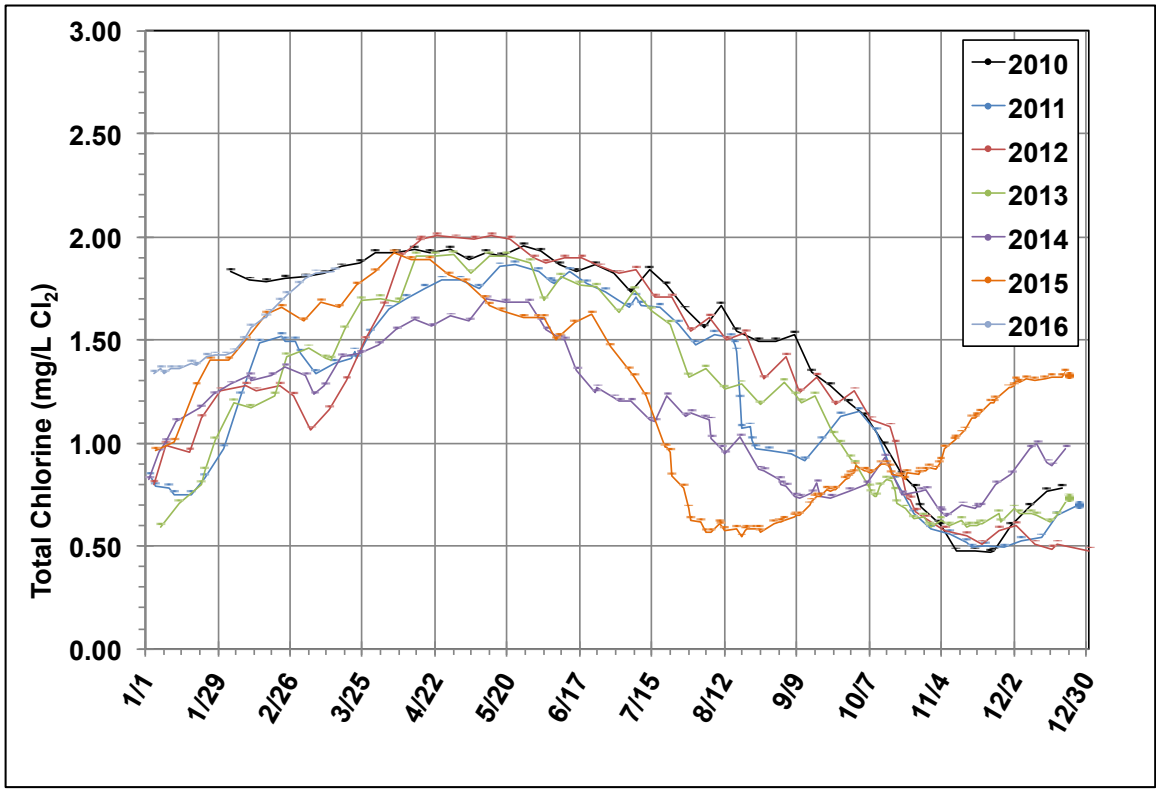


Figure 5. Monthly running average values for total chlorine from all reservoirs presented for 2010 through 2016, on a calendar basis (January – December).

The year-to-year seasonal pattern of nitrite values mirrored that of the temperature profiles depicted in Figure 4, with the exception of 2015. Similar to the trend in total chlorine for the same time period (Figure 5), the nitrite seasonal change occurred earlier and with greater magnitude in 2015. Beginning in July 2015, Figure 6 depicts a strong spike in nitrite monthly running average values. The nitrite values plateaued through August 2015, and decreased for a brief period in early September, likely in response to the aforementioned operational changes by the City. Another relative increase can be observed in late September 2015, followed by a steady decrease in nitrite concentrations to historical average values by the end of December 2015 and into the beginning of 2016.

Additional historical data is presented in Section 6 Attachment 2 for select reservoirs included in an evaluation of operational changes aimed at enhancing water quality within the system. This evaluation is discussed further in Section 4.

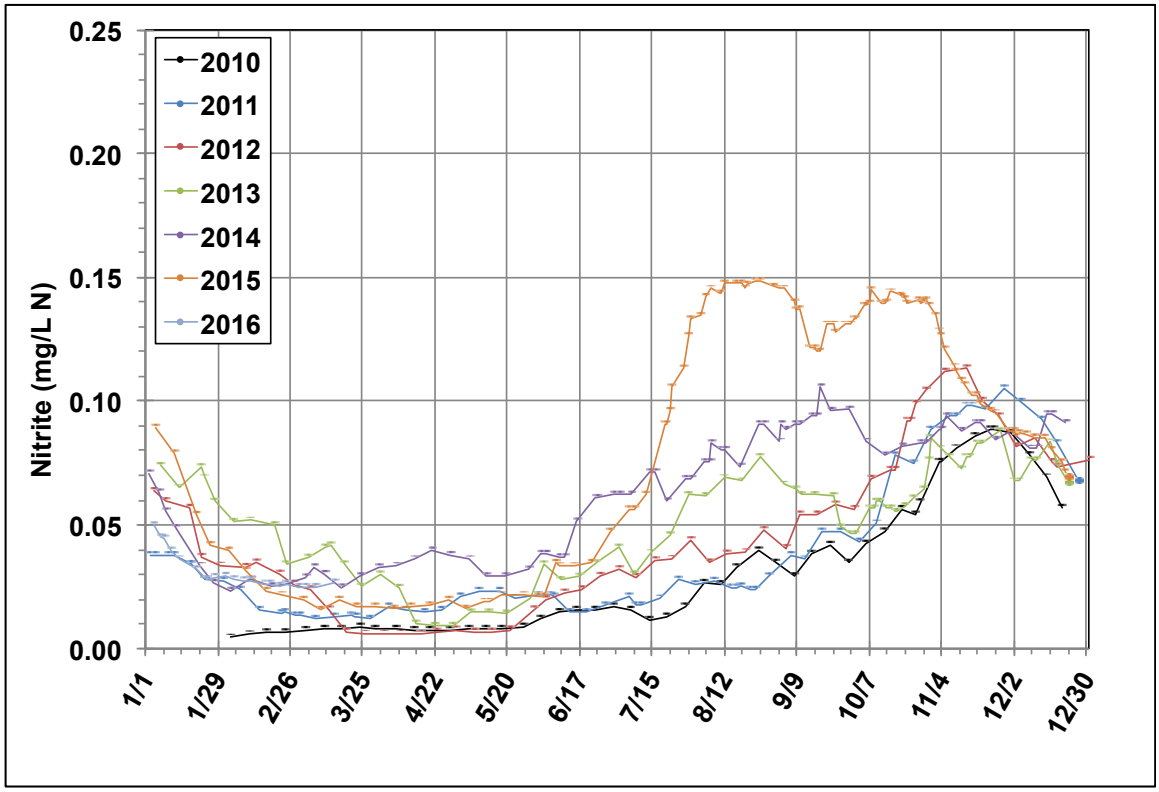


Figure 6. Monthly running average values for nitrite from all reservoirs presented for 2010 through 2016, on a calendar basis (January – December).

3 - NITRIFICATION BACKGROUND, DETECTION, AND CONTROL

Background

The City receives drinking water from CMWD that is disinfected with chloramine, formed from the reaction of aqueous chlorine with ammonia. The theoretical chloramination breakpoint curve is represented in Figure 7. Monochloramine (NH_2Cl) is the target stable chloramine species and is formed through the combination of chlorine and ammonia using a chlorine-to-nitrogen mass ratio of up to 5:1. When the chlorine-to-nitrogen ratio exceeds 5:1, up to approximately 7.6:1, the chloramine residual (as measured through total chlorine concentrations) begins to decay. The chloramine breakpoint occurs with a chlorine-to-nitrogen ratio of approximately 7.6:1, above which only free chlorine is present.

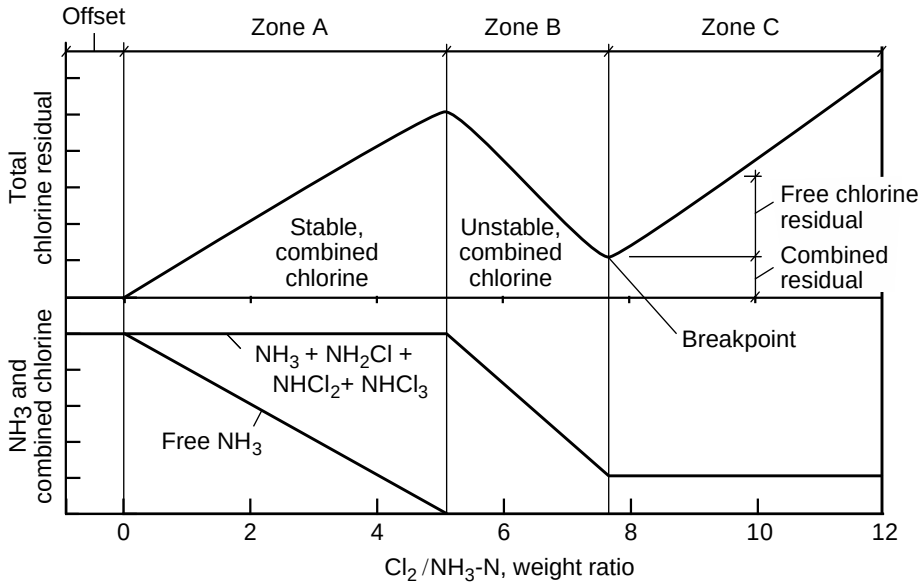


Figure 7. Chloramine breakpoint curve (adapted from Crittenden, J.C., R.R. Trussell, D.W. Hand, K.J. Howe, and G. Tchobanoglous (2012) Water Treatment: Principles and Design, 3rd ed., John Wiley & Sons, Hoboken, NJ.).

Nitrification results from microbiological oxidation of ammonia into nitrite and/or nitrate. As chloramines degrade within the storage and distribution system, the concentration of free ammonia can increase. This excess ammonia is a food source for ammonia oxidizing bacteria (AOB), which convert ammonia into nitrite. Once nitrite is present in the drinking water system, a feedback loop can be created; nitrite can accelerate chloramine decomposition and release additional free ammonia, which fuels AOB growth and leads to increased oxidation of free ammonia into nitrite. Once established, AOB biofilms can proliferate within the drinking water system, and reversing the water quality impacts can be a challenge.

High water temperatures in excess of 15°C promote the nitrification process, and the impacts can be severe when water temperatures exceed 20°C. Figures 2

and 3 correlate the City's historical reservoir water temperatures with total chlorine and nitrite concentrations, respectively. From these plots, it is clear that water temperatures of 16-25ºC dominate in the City's reservoirs from July through December, and there is a corresponding drop in total chlorine concentrations and increase in nitrite concentrations over the same time period.

Reservoirs with high water temperatures and poor circulation are also prone to stratification, where warm water stagnates on top of colder water. This is particularly prevalent in above-ground steel tanks with the structure exposed to direct sunlight, which is the case for most of the City's reservoirs. Once established, stratification contributes to nitrification.

Finally, water age is an important factor in nitrification. High water age results in loss of disinfectant residual. Maintaining disinfectant residual is important for controlling pathogens and preventing nitrification. Areas with excess storage capacity and low reservoir turnover are locations where nitrification can take hold. A water age modeling evaluation was completed as part of the Water Master Plan Update (Section 5.2) and recommendations for improving water age within the City's system are provided in Section 5.2.3.

Evidence of nitrification

A number of water quality indicators can be used to characterize the nitrification process in a drinking water system. Typically, water purveyors use routine measurement of low-level nitrite, in combination with total chlorine, throughout the system to identify early signs of nitrification issues. As shown in Section 2, total chlorine and nitrite demonstrated strong evidence of seasonal nitrification within the City's system as a whole. Individual plots of total chlorine and nitrite for reservoirs identified as being especially prone to water quality degradation are presented in Section 6 Attachment 2.

Nitrification control strategies

Nitrification can be controlled or mitigated through the implementation of a number of operational strategies. Potentially viable strategies for the City include:

- Improving reservoir mixing with the addition of active mixers
- Supplemental boosting of small, controlled doses of free chlorine to trim excess free ammonia
- Maintaining chloramines with a 5:1 chlorine to ammonia ratio
- Increased reservoir turnover through level control tied to turnout operation, pump station settings, and separate inlet and outlet piping.
- Boosting chlorine and ammonia to achieve elevated chloramine residual levels of 2.2 to 2.5 mg/L (CMWD distributes water with a target of 2.5 mg/L)
- Distribution system flushing of dead-end mains, or elimination of dead-ends through looped piping networked where feasible and practical.

4 - DISINFECTION BOOSTING PROGRAM

Following a review of the historical water quality data (Section 2) and nitrification indicators, Trussell Tech and Kennedy/Jenks considered nitrification control strategies identified in Section 3.3. The City was looking for an immediate strategy to mitigate the water quality degradation in the system given the scale of the nitrification issue in the City's reservoirs as the Water Master Plan project commenced in August 2015.

The nitrification control strategies selected for implementation and evaluation in this project were:

- active reservoir mixing and
- supplemental disinfection boosting

These strategies were selected for evaluation as the most cost-effective, efficient, and likely to be successful control strategies for the City to consider. It was also recognized that these strategies could readily be implemented on a trial basis as a part of the project. At the same time, the project team worked with the City to design and implement a study aimed at assessing the impact of these control strategies.

Supplemental disinfection boosting options

The best strategy for mitigation of chloramine decay involves disinfection boosting to prevent the nitrification events before they occur. This is often achieved through the addition of *small dosages of free chlorine*. The concept is that as temperatures increase and monochloramine begins to decay, free ammonia is released. By adding free chlorine in a controlled, well-mixed environment, any free ammonia present in the water will be re-combined into monochloramine.

Unfortunately, about 1/3 of the ammonia in chloramines is oxidized and 2/3 is recovered as free ammonia due to reaction with natural organic matter (NOM) that produces ammonia during chloramine decay. This means about 1/3 of the free ammonia is lost as the chloramine decay occurs. For this reason, a chloramine residual equal to the initial concentration cannot be achieved when boosting free chlorine alone. When boosting free chlorine alone, it is also difficult to achieve the level of control to hit the target chlorine-to-ammonia ratio. An elevated chlorine-to-ammonia ratio may result in breakpoint chlorination that converts the chloramine residual to free chlorine.

Alternatively, supplemental boosting can involve *large dosages of free chlorine* to "breakpoint chlorinate" any remaining monochloramine in the reservoirs and provide a free chlorine residual for a defined period of time. This time period

could vary from weeks to months. Free chlorine is effective at eliminating nitrification, but it may not destroy biofilm that may be present on the surface of the reservoirs and tanks. This can lead to additional nitrification events downstream of breakpoint chlorination.

To efficiently implement supplemental disinfection boosting for the City on a trial basis, the project team pursued strategies for the continuous control of chlorine and ammonia levels. Technologies from two different vendor systems were considered: (1) the Residual Control System (RCS) with mixer by PAX Water Technologies (PAX), and (2) the MONOCLOR Chloramine Management System with Tank Shark mixer by Process Solutions, Inc. (PSI). Both of these vendors offered packaged systems with the ability to boost chemical (chlorine and ammonia) in combination with an active mixer from a portable, containerized platform. Additionally, both systems have been implemented on at least a trial basis, in California. The PAX system controls consist of an automated PLC that incorporates continuous online measurements of total chlorine, pH, and oxidation-reduction potential (ORP), whereas the PSI system controls were limited to continuous online measurement of total chlorine. Table 2 provides a comparison of the two supplemental disinfection boosting systems.

Table 2. Comparison of PAX RCS to PSI MONOCLOR

Component	PAX RCS	PSI Monochlor
Cost	$75,000 (w/trailer)	Over $200,000
Boosting Capability	Chlorine and Ammonia	Chlorine and Ammonia
Chemical	None included[1]	On-site generation Cl_2
Control	Automated PLC w/total chlorine, pH, & ORP	Automated PLC tied to total chlorine analyzer
Energy requirement	200 W	1,200 W

[1]If City desires, on-site chlorine generation systems at 40 lb/d are available for under $100,000.

On the project team's recommendation, the City initially pursued the procurement of one system from each of these vendors. The intention was to directly compare the two boosting systems (e.g., water quality response, ease of operation, cost, etc.), while simultaneously addressing the immediate water quality problems. Each system would be assigned to a reservoir with historical and on-going nitrification issues that also feeds a down-stream reservoir. Because of hurdles encountered in the contract process, the PSI system was eliminated and two portable PAX RCS units with trailers were acquired on a 6-month trial basis, along with 5 PAX mixers.

Disinfection Boosting study

The disinfection boosting study looked at the effect on control of nitrification of adding mixers and/or chlorine/ammonia boosting on the water quality in select

reservoirs. To accomplish the goals of the study, the City procured a total of 5 PAX mixers and 2 RCS units for a 6 month trial period. Two of the five mixers were dedicated to the reservoirs with the RCS units. The study focused on the reservoirs where the most impact of nitrification had been observed. The final implementation of the equipment included the following:

- Mixer + Control System #1 (mobile RCS+Mixer):
  - Willow Reservoir
  - Freeway Reservoir (no change, but fed by Willow Reservoir)
- Mixer + Control System #2 (mobile RCS+Mixer):
  - Pederson Reservoir
  - Tara Reservoir (no change, but fed by Pederson Reservoir)
- Mixer only (PAX):
  - Rolling Oaks Reservoir (fed by Willow Reservoir)
  - La Granada Reservoir
  - Ventu Park Reservoir, inactive partition
- No change, no influence (control system for comparison):
  - Kelley Reservoir
  - Ventu Park Reservoir, active partition (mixer added to inactive partition)

Along with the implementation of the mixers and supplemental boosting control systems, additional water quality monitoring by the Environmental Programs staff was recommended to assess the impact of the changes. The project team recommended more frequent monitoring for nitrification-related parameters from each of the reservoirs included in the study. The water quality parameters included total and free chlorine, total and free ammonia, nitrite, pH, and temperature. In addition, the Environmental Programs staff was asked to track the elevation of the water level in the reservoir at the time of sampling. Table 3 summarizes the monitoring locations and frequencies.

The reservoirs with the RCS units (Willow and Pederson) were sampled on a daily basis for two weeks following the installation of the control system, and then all reservoirs included in the study (Table 2) were sampled two times per week from late October 2015 through February 2016. Water quality measurements included total and free chlorine, nitrite, pH, and temperature, with the addition of free ammonia at Willow and Pederson Reservoirs (sites with RCS units). To complement the efforts of the Environmental Programs staff, Trussell Technologies completed 4 monitoring visits on October 28, 2015 (following startup of the RCS and mixer at Willow Reservoir), November 3, 2015, December 3, 2015 (following startup of the RCS and mixer at Pederson Reservoir), and December 10, 2015.

Table 3. Water quality monitoring to complement supplemental disinfection boosting study for total and free chlorine, nitrite, pH, and temperature (free ammonia was monitored for reservoirs with PAX RCS)

Reservoir	Nitrification Control Measure	Frequency
Willow	PAX RCS and mixer	Daily for 2 weeks, then 3 times per week
Pederson	PAX RCS and mixer	Daily 2 weeks, then 3 times per week
Rolling Oaks	PAX mixer	Daily for 2 weeks, then 3 times per week
Ventu Park	PAX mixer (inactive partition only)	Daily for 2 weeks, then 3 times per week
La Granada	PAX mixer	Daily for 2 weeks, then 3 times per week
Tara	none	3 times per week
Freeway	none	3 times per week
Kelley	none	3 times per week

Figure 8 shows a summary of operational changes in the boosting study.

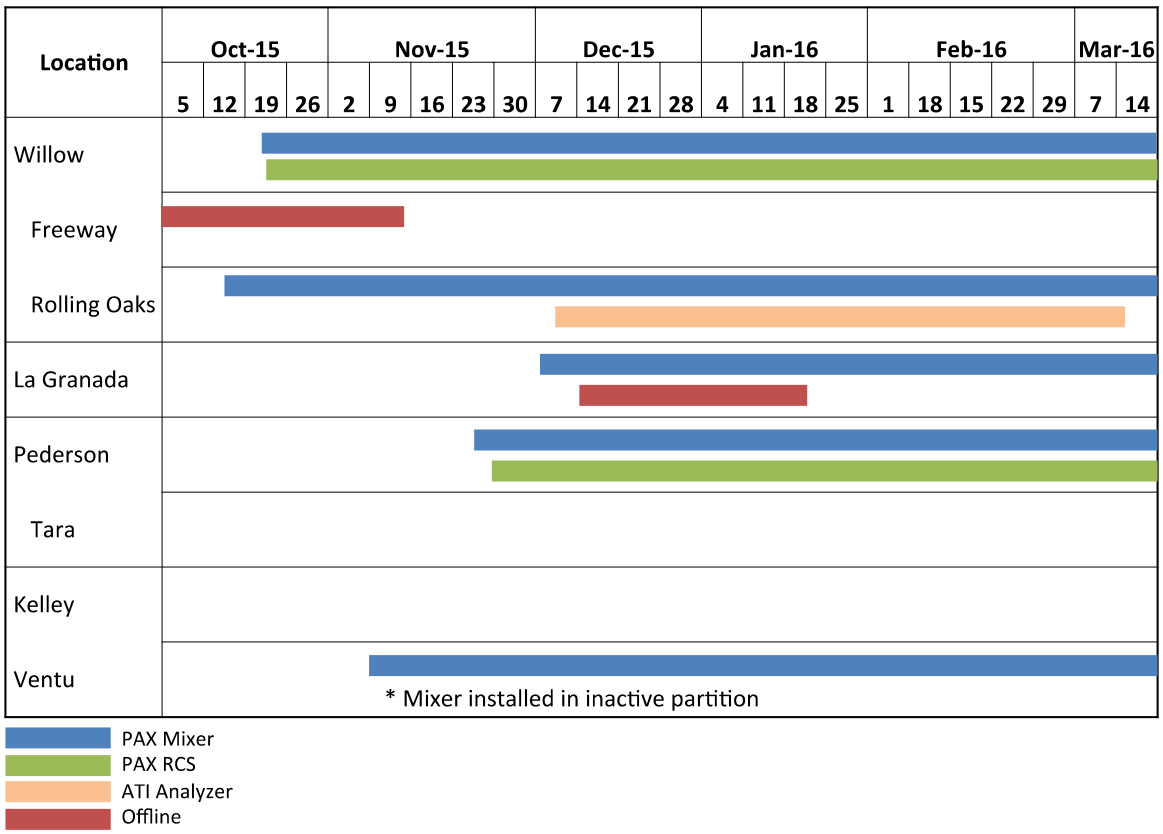


Figure 8. Summary of operational changes for reservoirs in boosting study

The reservoirs listed in Figure 8 are grouped based on operational changes and/or influence. For example, Freeway and Rolling Oaks Reservoirs receive some water supplied from Willow Reservoir. Likewise, Tara Reservoir is

downstream of, and receives all of its supply from, Pederson Reservoir. La Granada largely receives water from an adjacent turnout. Finally, Kelley and Ventu Park are located in the Newbury Park branch of the City's system.

Disinfection boosting study results

It is important to consider the timing of the study (October-March) in relation to the historical seasonal nitrification patterns observed in the City's reservoirs (Figures 2 and 3). In general, the City's reservoirs experienced peak nitrification impacts (as measured through decreasing total chlorine concentration and increasing nitrite concentrations) in November, followed by a gradual, but steady recovery (increasing total chlorine concentrations and decreasing nitrite concentrations) into April. Historically, water temperatures decreased starting in October, related to seasonal influences, so there was a slight delay of 1-2 months before the nitrification issues diminished. The mixers and control systems related to the current study were installed starting in late October 2015, with the final installations occurring in early December. The impacts of the new chlorine and ammonia boosting equipment and mixers evaluated during the study are demonstrated through the comparisons presented below.

4.1.1 Reservoir with mixer and control system

While the monitoring program associated with the boosting study was initiated in late October 2015, along with the installation of a mixer and control system at Willow Reservoir, the mixer and control system for Pederson Reservoir were not installed and fully operational until the beginning of December 2015. Consequently, data collected before and after mid-December 2015 allows for a better comparison of the water quality before and after the implemented changes at Pederson Reservoir. Figures 9 and 10 present the total chlorine and nitrite monitoring data from the complete boosting study period.

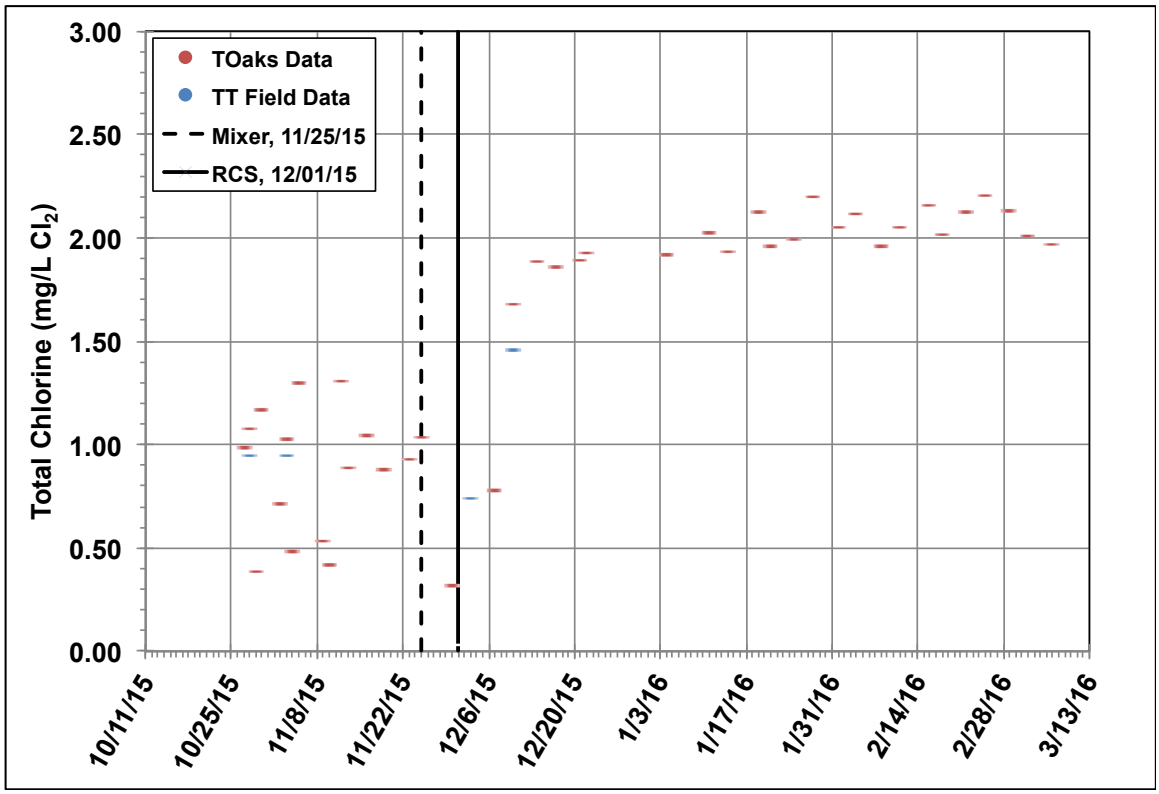


Figure 9. Total chlorine results from grab samples at Pederson Reservoir

TT = Trussell Technologies, Inc.

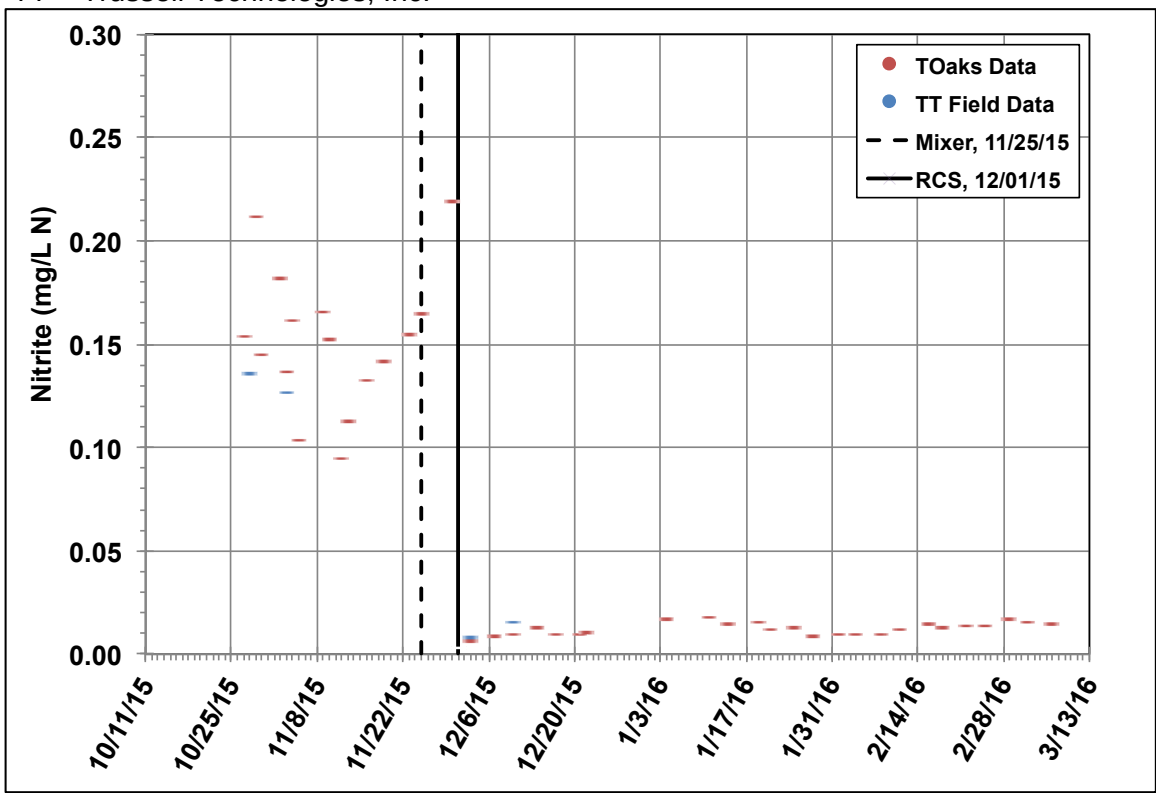


Figure 10. Nitrite results from grab samples at Pederson Reservoir

A marked, stepwise change in both total chlorine (increase) and nitrite (decrease) measurements can be observed following the installation of the RCS mixer and control system at Pederson Reservoir (Figures 9 and 10). The change is almost immediate, demonstrating the effectiveness of the PAX Residual Control System with Mixer.

4.1.2 Online Analyzers

Online analyzers are a key part of the strategy to control nitrification with the PAX RCS. A benefit of the PAX RCS was the ability to continuously monitor water quality through online measurement of total chlorine, oxidation-reduction potential (ORP), and pH provided by the system's Water Quality Station (WQS). The WQS provides continuous measurement of total chlorine through the use of an amperometric sensor with no reagents. During the boosting study the City also conducted a trial of the Q46 total chlorine analyzer from Analytical Technology, Inc. (ATI) analyzer in the Rolling Oaks Reservoir. The ATI analyzer also provided continuous measurement of total chlorine through the use of an amperometric sensor with no reagents, however unlike the flow-through cell included in the WQS, the ATI unit sensor was mounted directly on the inside wall of the reservoir (steel tank). Continuous measurements of total chlorine at Willow Reservoir, Pederson Reservoir, and Rolling Oaks Reservoir are compared with grab measurements in Figures 11, 12, and 13, respectively.

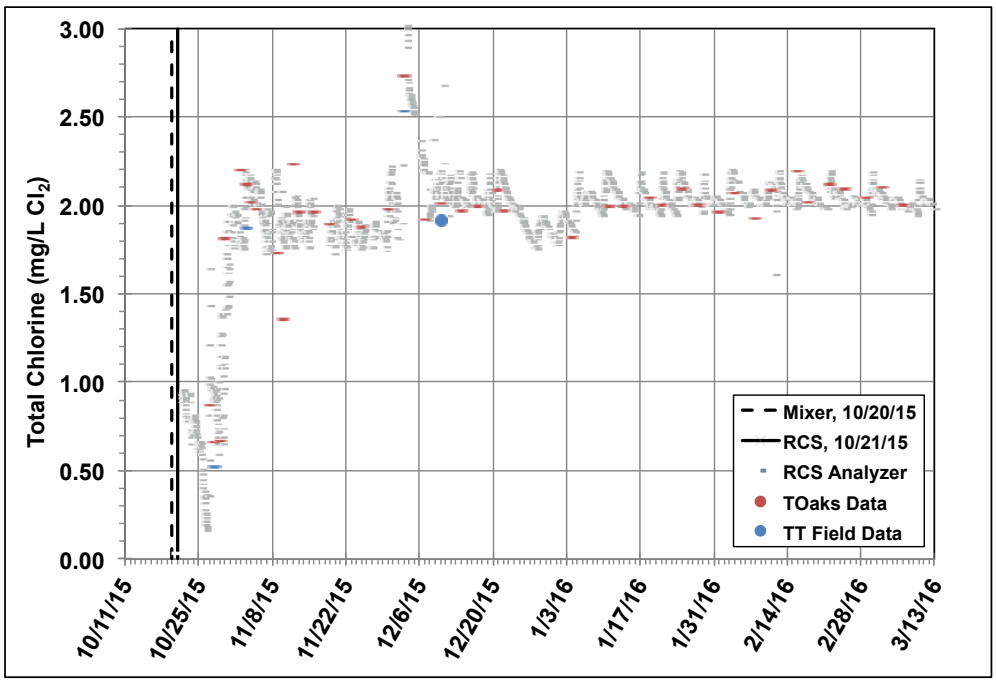


Figure 11. Continuous monitoring data from PAX RCS total chlorine analyzer correlated with total chlorine measurements from grab samples at Willow Reservoir.

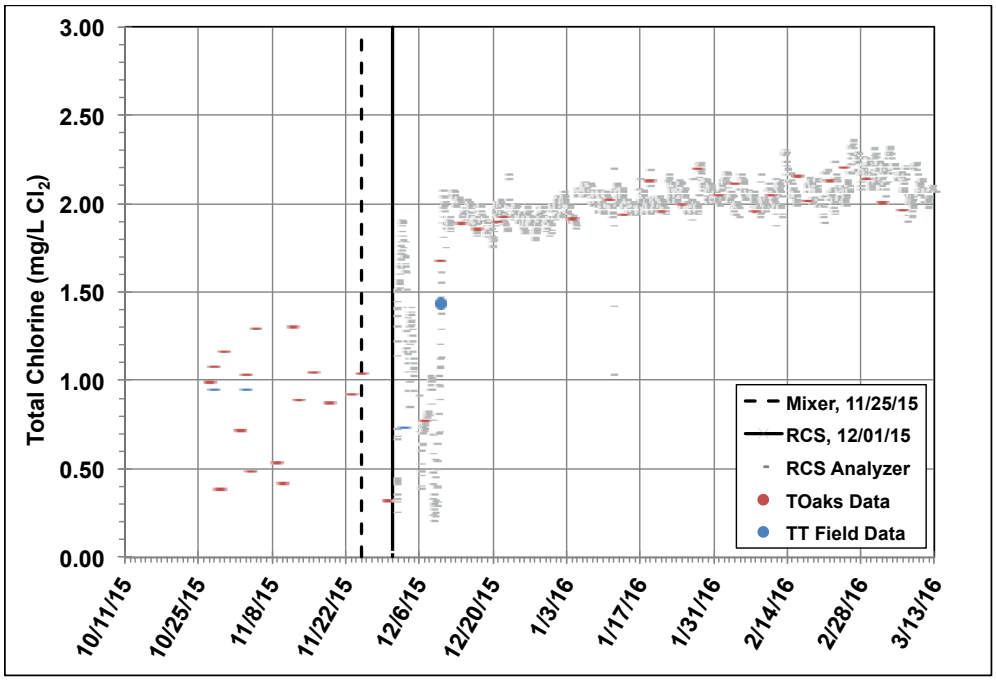


Figure 12. Continuous monitoring data from PAX RCS total chlorine analyzer correlated with total chlorine measurements from grab samples at Pederson Reservoir.

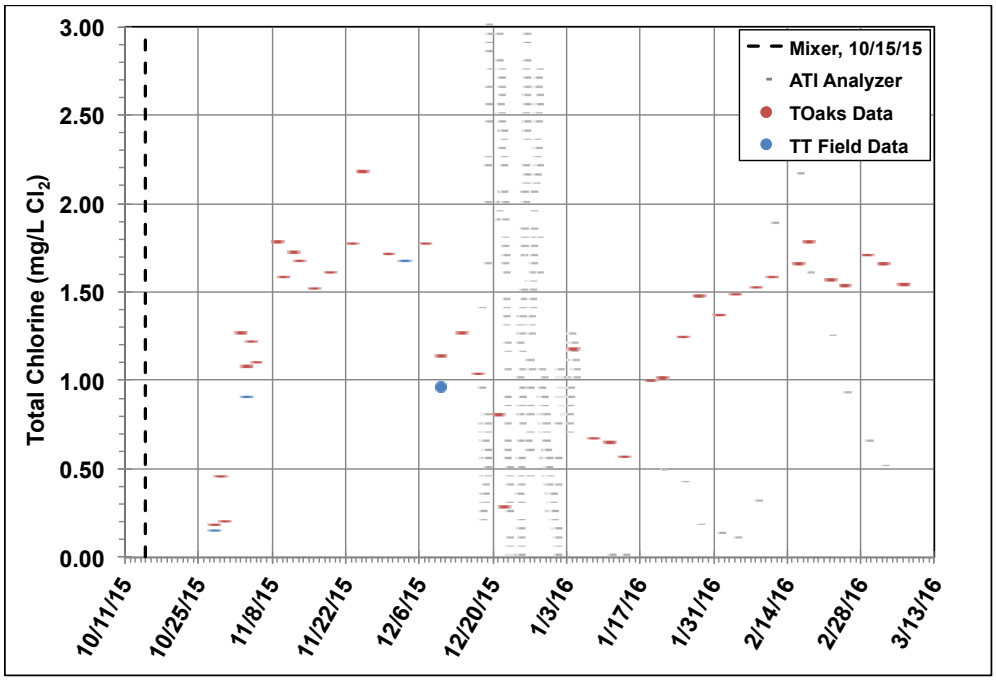


Figure 13. Continuous and discrete monitoring data from ATI chlorine analyzer correlated with total chlorine measurements from grab samples at Rolling Oaks Reservoir. Note that the continuous data collected after 1/4/16 was found to be corrupt and the analyzer was removed in early March 2016.

Performance of the total chlorine analyzers associated with the PAX RCS installations was shown to be consistent and well-correlated with the grab samples (Figures 11 and 12). The ATI analyzer performance was very inconsistent, not well-correlated with grab samples, and the data was found to be corrupted when the analyzer was removed in early March 2016.

4.1.3 Reservoirs downstream of a control system without a mixer

The boosting study included additional monitoring for two reservoirs located downstream of reservoirs with a mixer and control system, but where no operational changes were implemented. Freeway Reservoir was offline prior to the study, due to poor water quality associated with nitrification. This reservoir was sprayed with concentrated chlorine prior to being brought back online, but still experienced a period of inconsistent and poor water quality through mid-December 2015. By January 2016, water quality samples from Freeway Reservoir had consistent total chlorine values above 1.5 mg/L Cl_2 and nitrite values below 0.02 mg/L N (Section 6, Attachment 1, Figures 4-5).

Tara Reservoir, fed exclusively with water received from Pederson Reservoir, also benefitted from the upstream operational changes (Section 6, Attachment 1, Figures 12-13). Following the installation of the mixer and control system at Pederson Reservoir, a stepwise improvement was observed in both total chlorine and nitrite. The improvement in water quality at Tara Reservoir was not as evident or consistent as the upstream impacts observed at Pederson Reservoir (Section 6, Attachment 1, Figures 9-11).

4.1.4 Reservoirs with a mixer

PAX mixers were installed at Rolling Oaks and La Granada Reservoirs. Prior to the boosting study, Rolling Oaks Reservoir, the smallest of the reservoirs included in the study, had poor water quality related to nitrification through much of the year (Section 6, Attachment 2, Figures 5 and 6). Once the mixer was installed, the water quality from Rolling Oaks Reservoir improved, but there was still some fluctuation over time.

A mixer was installed at La Granada Reservoir on December 9, 2015, but shortly after this, the reservoir was taken offline for a period of approximately one month and boosted with free chlorine. Prior to the mixer installation, nitrite measurements from La Granada were particularly high (Section 6, Attachment 1, Figure 15), but once the reservoir was brought back online the nitrite was consistently low.

4.1.5 Reservoirs with no implemented changes

Kelley and Ventu Park Reservoirs can be considered control cases for the boosting study. These locations were monitored closely throughout the study period, but no operational changes were made. A PAX mixer was installed on the inactive partition of the Ventu Park Reservoir, but this did not impact the measured water quality from the active partition. Some seasonal nitrification has

been historically observed at both of these locations, with recovery associated with decreasing water temperatures in the late fall and winter seasons. Results from the study period (Section 6, Attachment 1 Figures 16-19 and Attachment 2 Figures 13-16) were generally consistent with this historical pattern of seasonal change related to decreasing water temperature, with gradual changes in the water quality over time. Ventu Park Reservoir samples tended to have more variable total chlorine results, due to the impact of reservoir filling from the turnout (sample tap is located on the reservoir inlet line).

Results from all monitoring associated with the boosting study are presented in Section 6, Attachments 1 and 2.

5 - ENHANCEMENT OF OPERATIONS IMPROVEMENT PLAN

The enhancement of operations improvement plan has two components: (1) improvements in equipment and (2) recommendations for operations.

Improvements in Equipment to Reduce Nitrification Events and Increase the Ability to Respond Quickly

The supplemental disinfection boosting study demonstrated that the addition of PAX mixers to reservoirs provided improvements to the water quality. Adding to the mixer the ability to boost chemical (chlorine and/or ammonia with a control over the dosing ratio) using the PAX RCS resulted in consistently good water quality for the two reservoirs in the study with a mixer and the PAX RCS. The improved water quality in the reservoirs with the mixer and control system provided a benefit to downstream reservoirs, as well, although the water quality in the downstream reservoirs was less consistent.

Based on the results from the study, the following operational improvements are recommended in terms of equipment:

1. Procure 11 additional PAX active mixers or equivalent in addition to the five already purchased for each of the City's reservoirs. The mixers will greatly reduce temperature stratification, which leads to water quality deterioration and the formation of nitrification biofilms.
2. Procure two additional PAX RCS units beyond the two RCS units already purchased. Permanent installations should be maintained at Willow Reservoir and Pederson Reservoir. Beyond the permanent installations, two additional units should be procured and maintained as portable, mobile supplemental boosting unit with trailers to provide seasonal or as-needed treatment in various reservoirs.
3. Equip all remaining reservoirs besides Willow Reservoir and Pederson Reservoir (14 total) that do not have permanent RCS units with electrical and plumbing connections to accommodate these mobile supplemental boosting units.

4. Equip all reservoirs with a proven* analyzer to provide continuous monitoring of total chlorine for a real-time gauge of residual chlorine and serve as an indicator of nitrification in reservoirs. The PAX RCS units are equipped with a WQS that provides continuous monitoring of total chlorine, pH, and ORP. Total chlorine analyzers should be procured for the fourteen reservoirs (all except Willow Reservoir and Pederson Reservoir) that are not equiped with permanent PAX RCS units. Integration of continuous monitoring data with the City's SCADA system will allow for real-time monitoring feedback to assess the variability of water quality and the impact of operational changes including:
   - Reservoir fill levels
   - Turnout operation
   - Demand in system
   - Time of day
   - Temperature
   - Upstream/downstream system conditions (residual chlorine, mixing, water quality in distribution system)

   *Hach CLT10 sc Total Chlorine Analyzer with sc200 controller, or equivalent, that provides continuous measurement, amperometric analysis with no reagents or waste stream, and SCADA integration capability.

Recommendations for Operations

With the assumption that the new equipment recommended for implementation has been installed, the following are recommendations for operations.

1. Increase reservoir monitoring for nitrification indicators (e.g., total chlorine, nitrite, water temperature) during the months of June through December, when water quality has historically been impacted. This should also be implemented when the water temperature in a reservoir exceeds 18ºC. For these conditions, monitor all reservoirs on a weekly basis, at minimum. Recommended sampling frequency is shown in Table 4.
2. Establish proactive water quality trigger points for initiating additional operational changes to mitigate nitrification issues. Proposed trigger points and recommended response are summarized in Table 5.

Table 4. Recommended Sampling Frequency of Constituents/Parameters Related to Nitrification Issues

Constituent	Sampling Frequency		
	January - May	June - December	Nitrite > 0.03 and/or Total Chlorine < 0.75
Total chlorine[1]	Monthly	Weekly	3x/week
Free chlorine	Monthly	Monthly	Weekly
Nitrite	Monthly	Weekly	5x/week
Nitrate	Monthly	Monthly	2x/mo.
Free ammonia	Monthly	Monthly	3x/week
Total ammonia	Monthly	Monthly	Weekly
Total coliform bacteria	Monthly	Monthly	Weekly
Heterotrophic plate count (HPC)	Monthly	Monthly	Weekly
Turbidity	Monthly	Monthly	Weekly
pH	Monthly	Monthly	Weekly
Temperature	Monthly	Weekly	3x/week

[1]Grab samples for QA/QC monthly if online chlorine analyzer present

Table 5. Trigger points and recommended response

Constituent or Parameter	Trigger	Response
Nitrite	>0.03 mg/L N	Sampling per Table 4 Sampling within 2 days
Nitrite	>0.05 mg/L N	Run Mobile RCS (if reservoir has connection)
Total Chlorine	<0.75 mg/L	Sampling per Table 4
Total Chlorine	<0.5 mg/L	Run Mobile RCS (if reservoir has connection)
Total Chlorine and Nitrite	>1.0 mg/L <0.03 mg/L	Stop mobile RCS, resume seasonal monitoring
Temperature	> 18°C	Sampling per Table 4, June-December

6 - ATTACHMENTS: MONITORING RESULTS

The preceeding subsections provide monitoring results associated with the boosting study. Attachment 1 presents only the water quality results from the study period (late October 2015 through early March 2016); whereas, these results are compared with historical water quality results (January 2010 through September 2015, represented using black circles) and presented on an annual basis (January through December) in Attachment 2. Water quality results from monitoring by the City during the study period are represented using red circles and those from Trussell Technologies are represented using blue circles (solid circles in Attachment 1 and open circles in Attachment 2).

Attachment 1 – Boosting Study Results

Routine grab sampling and continuous monitoring (select locations only) were implemented by the City of Thousand Oaks, with some supplemental sampling by Trussell Tech, as part of the boosting study from late October 2015 through early March 2016. Plots in Attachment 1 present total chlorine and nitrite data for individual reservoirs. Implementation of reservoir changes (e.g., mixer installation or PAX RCS unit startup) are indicated with vertical lines, where applicable. The results are organized per the study groupings (Section 4).

Mixer + RCS System #1:

Willow Reservoir

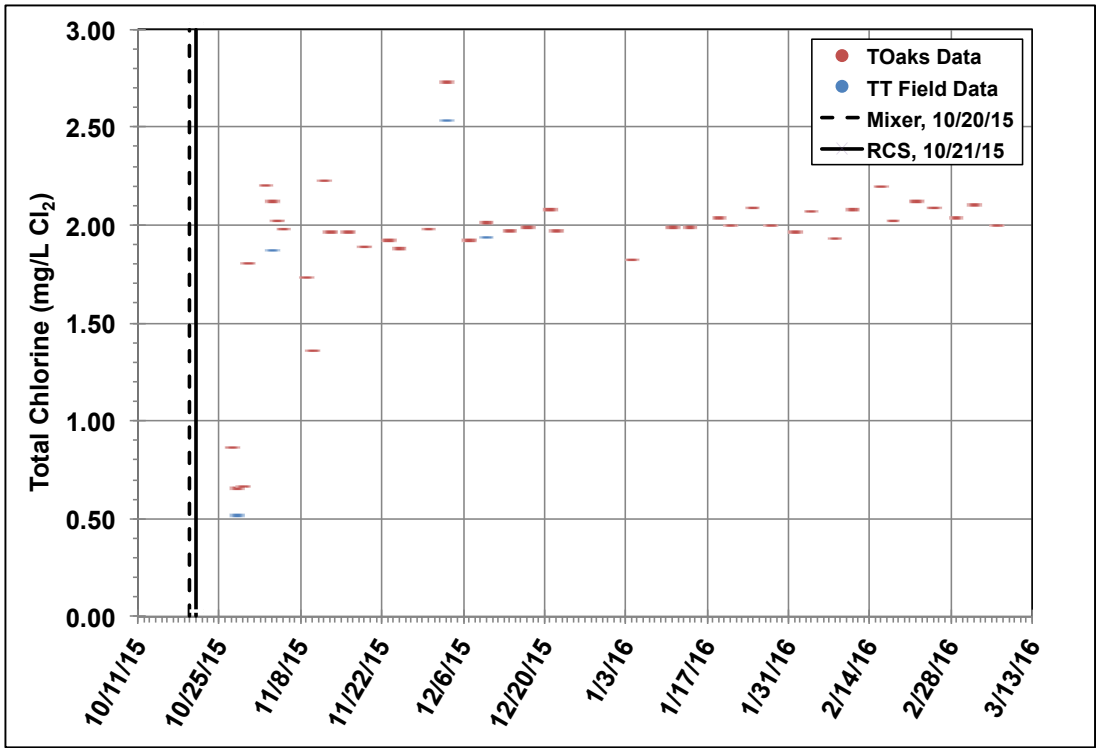


Figure A1-1. Total chlorine grab sample data for Willow from October 2015 onward

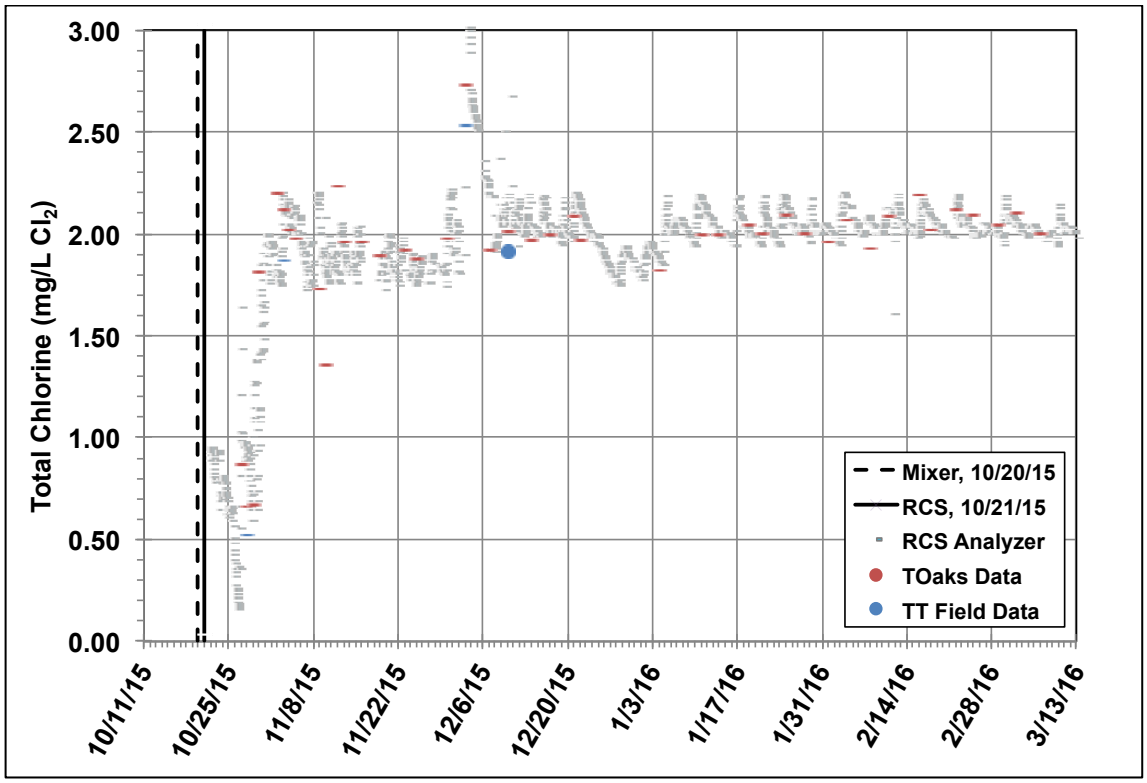


Figure A1-2. Comparison of grab samples and online analyzer for Willow

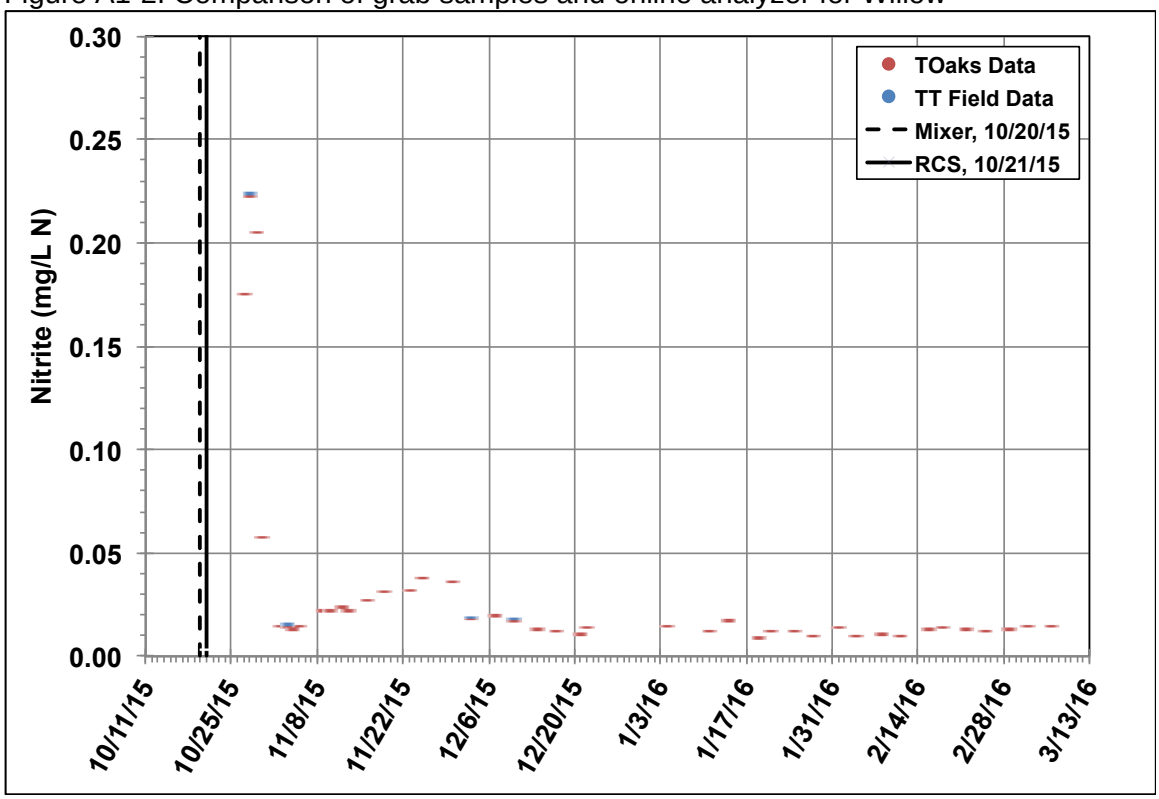


Figure A1-3. Nitrite grab sample data for Willow from October 2015 onward

Freeway Reservoir

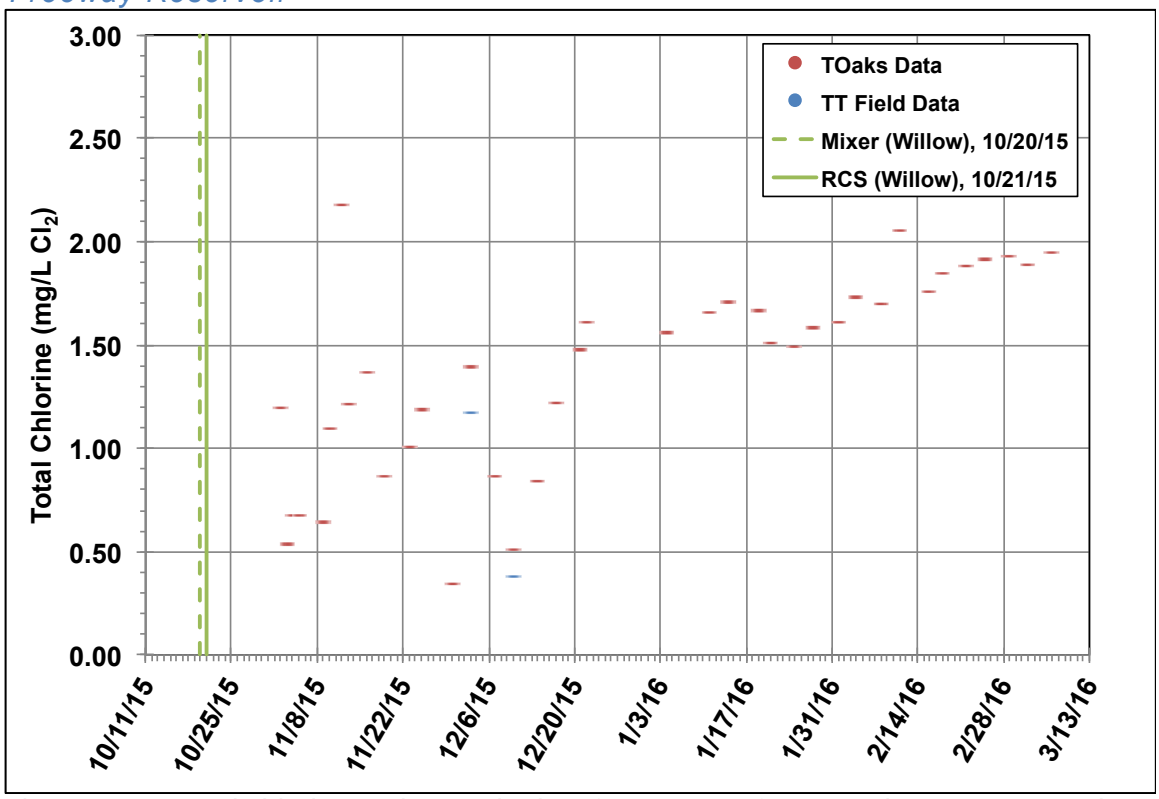


Figure A1-4. Total chlorine grab sample data for Freeway from October 2015 onward

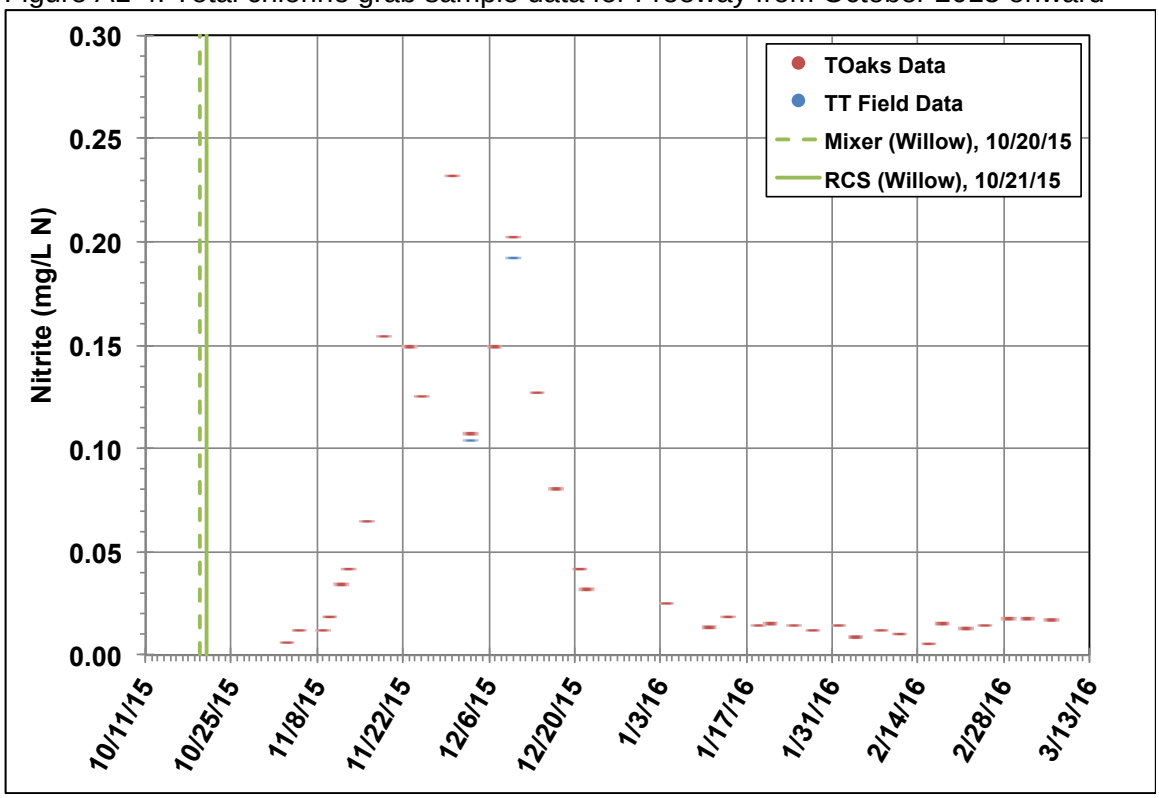


Figure A1-5. Nitrite grab sample data for Freeway from October 2015 onward

Rolling Oaks Reservoir

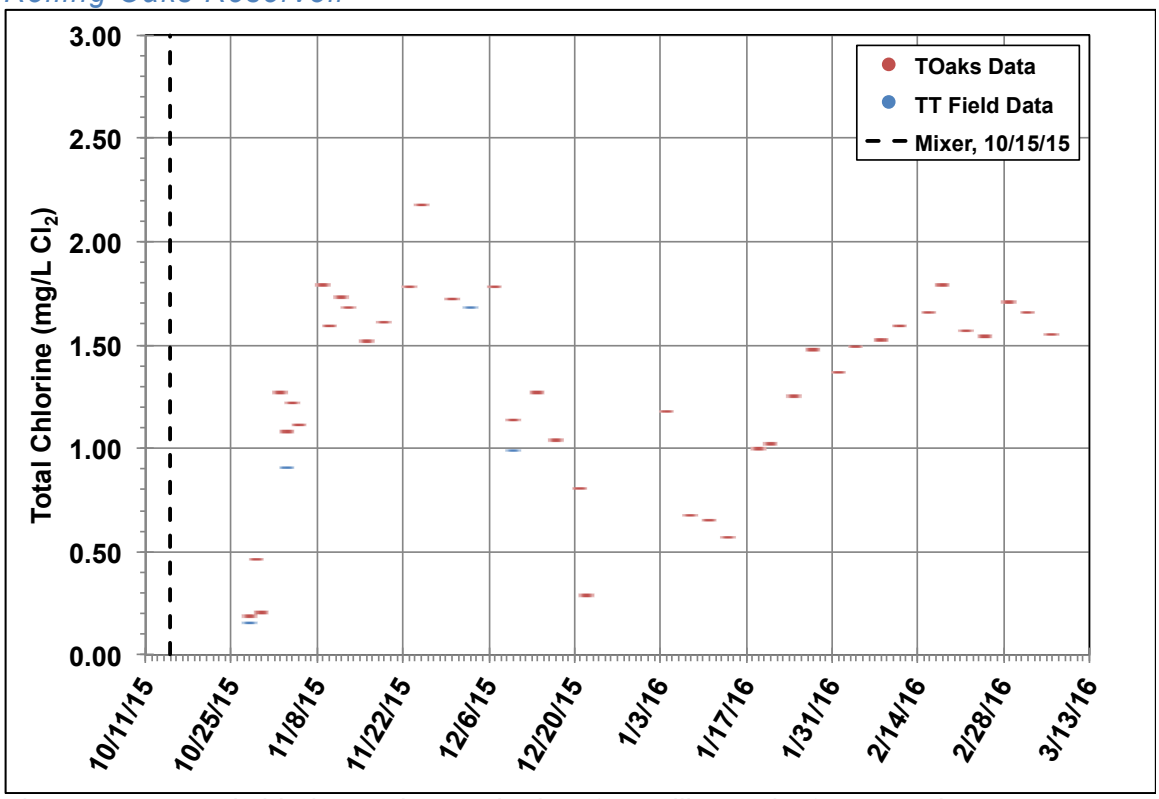


Figure A1-6. Total chlorine grab sample data for Rolling Oaks from October 2015 onward

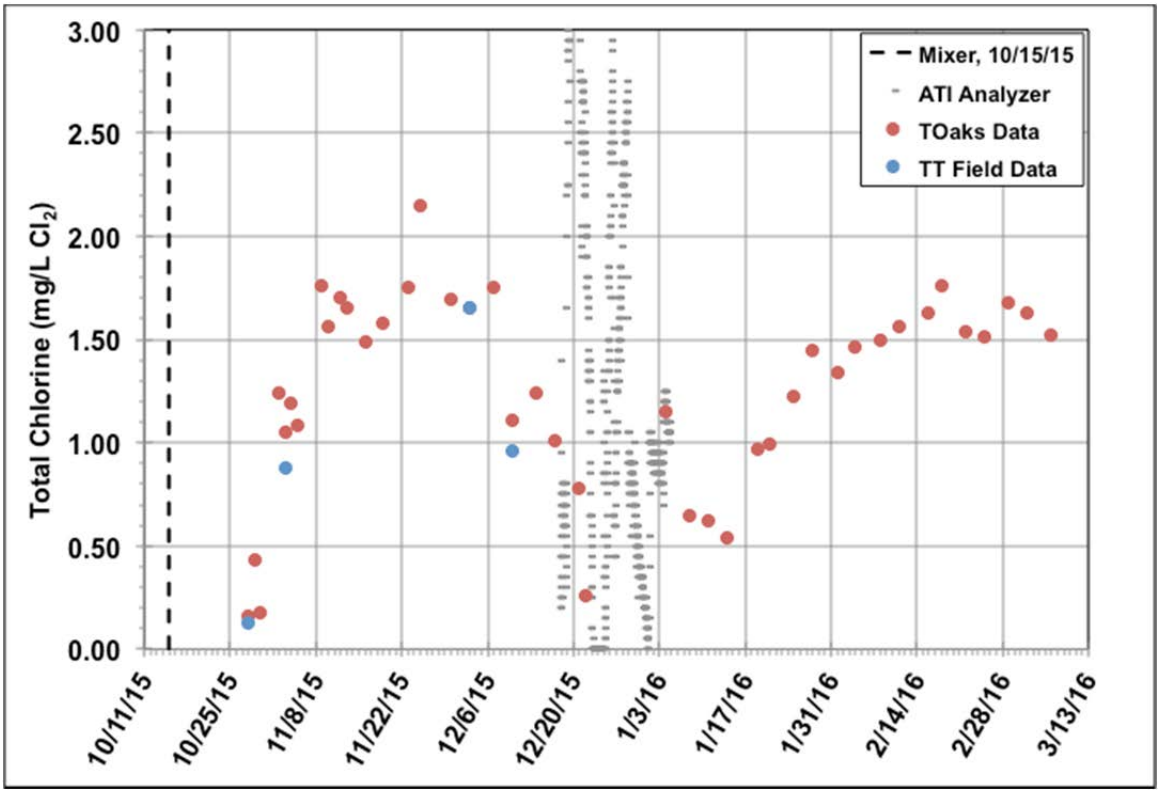


Figure A1-7. Comparison of grab samples and online analyzer for Rolling Oaks

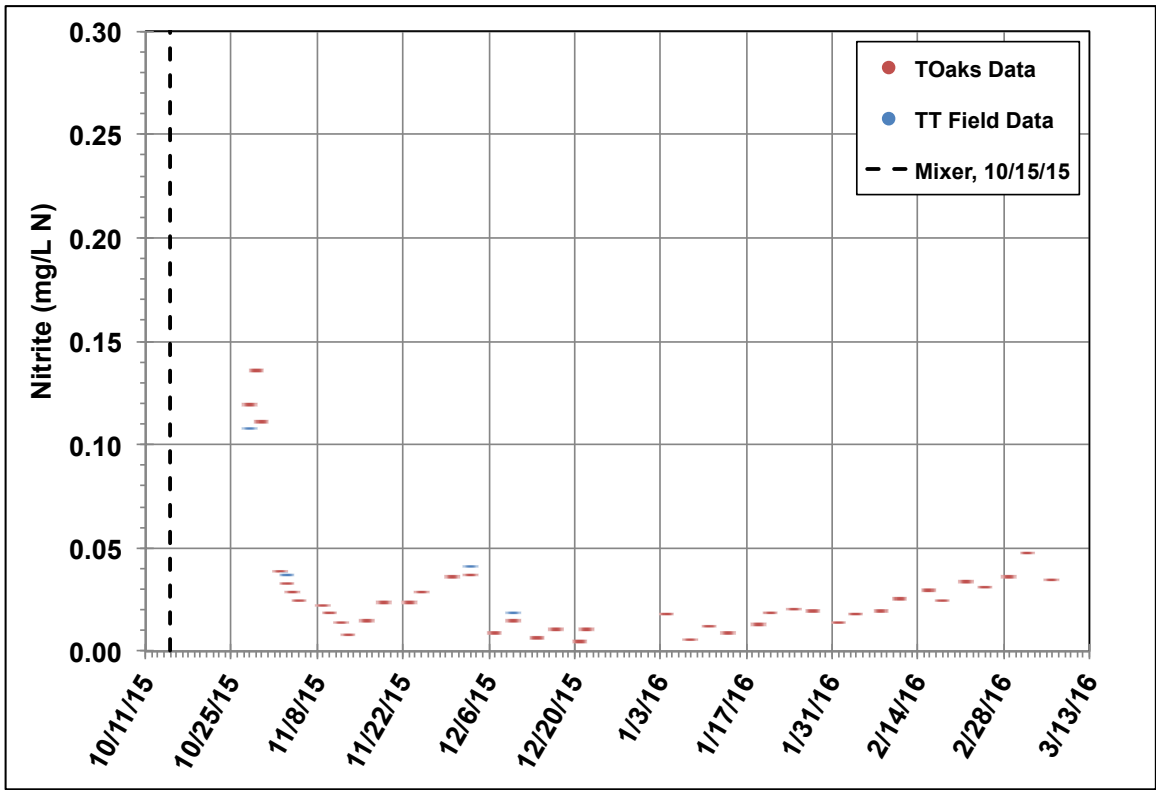


Figure A1-8. Nitrite grab sample data for Rolling Oaks from October 2015 onward

Mixer + RCS System #2:

Pederson Reservoir

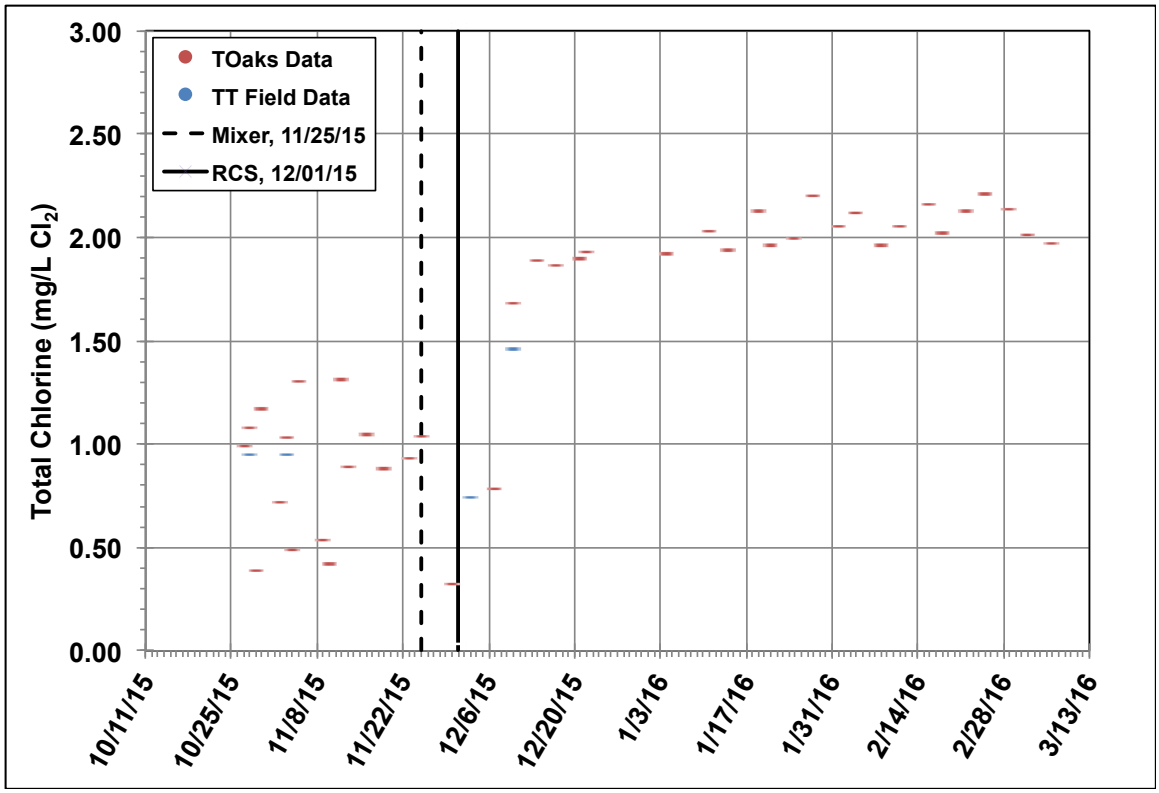


Figure A1-9. Total chlorine grab sample data for Pederson from October 2015 onward

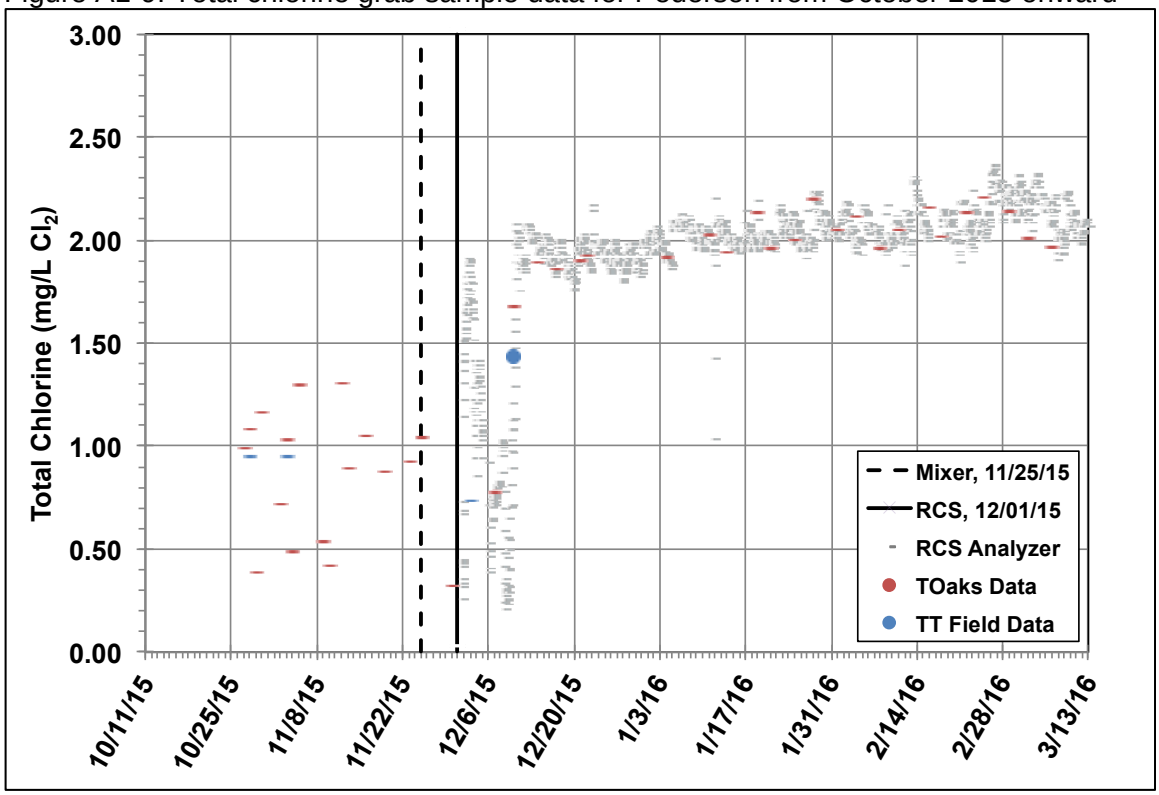


Figure A1-10. Comparison of grab samples and online analyzer at Pederson

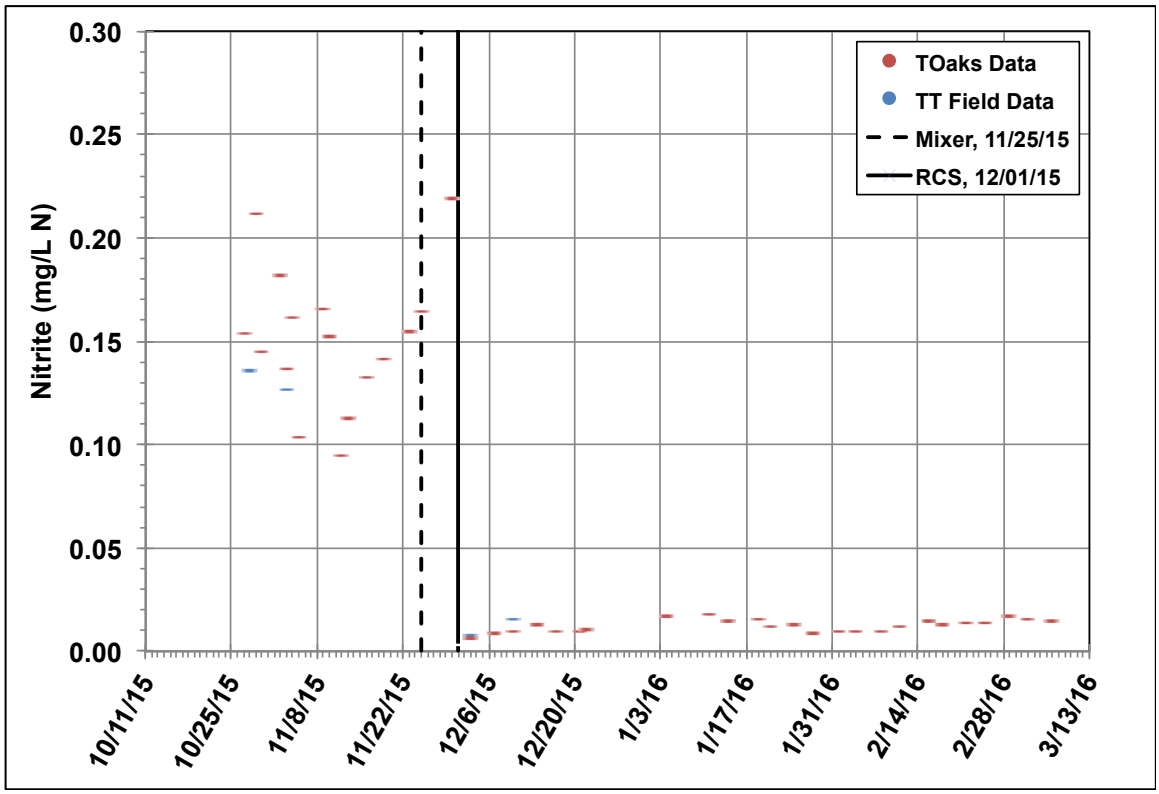


Figure A1-11. Nitrite grab sample data for Pederson from October 2015 onward

Tara Reservoir

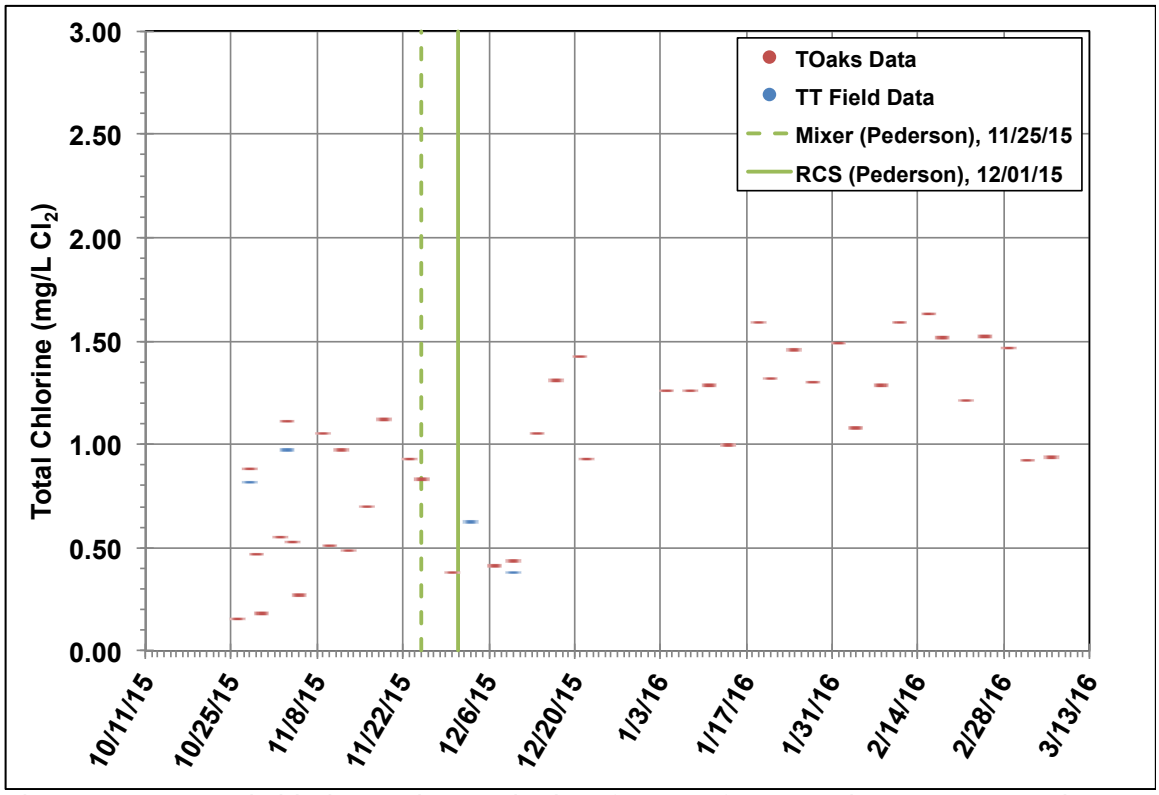


Figure A1-12. Total chlorine grab sample data for Tara from October 2015 onward

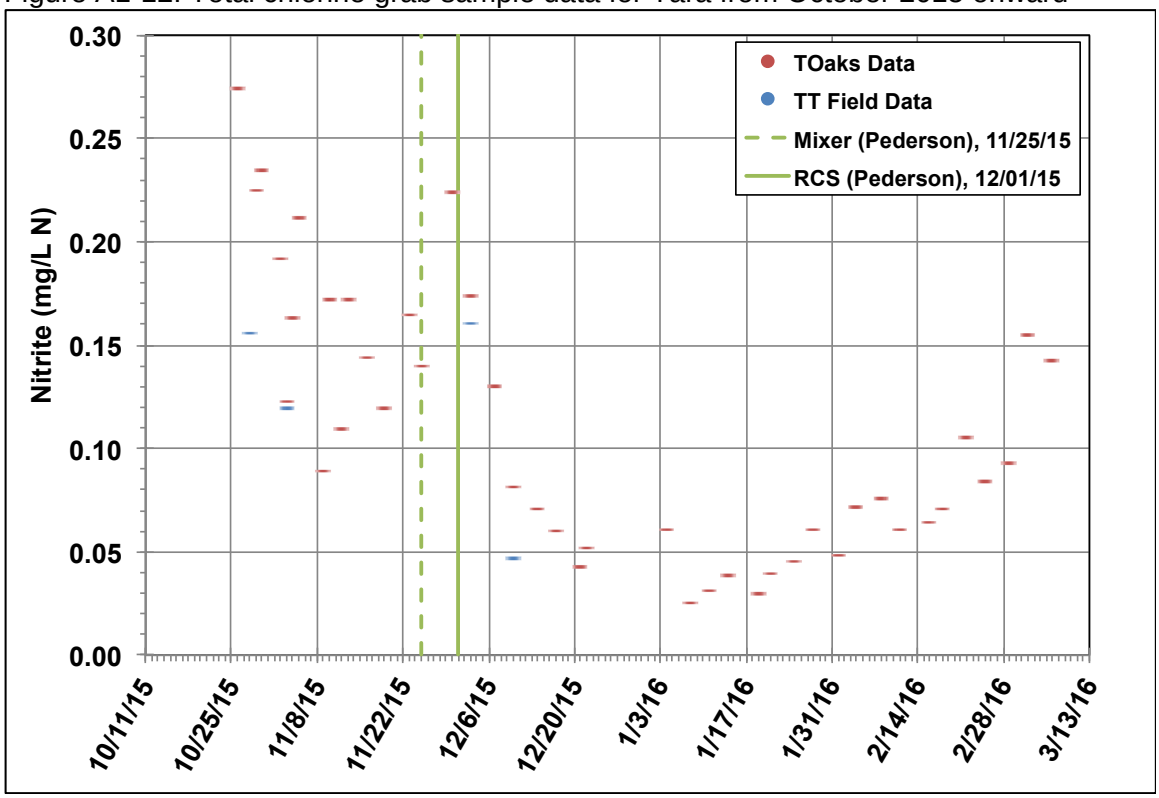


Figure A1-13. Nitrite grab sample data for Tara from October 2015 onward

Mixers Only:

La Granada Reservoir

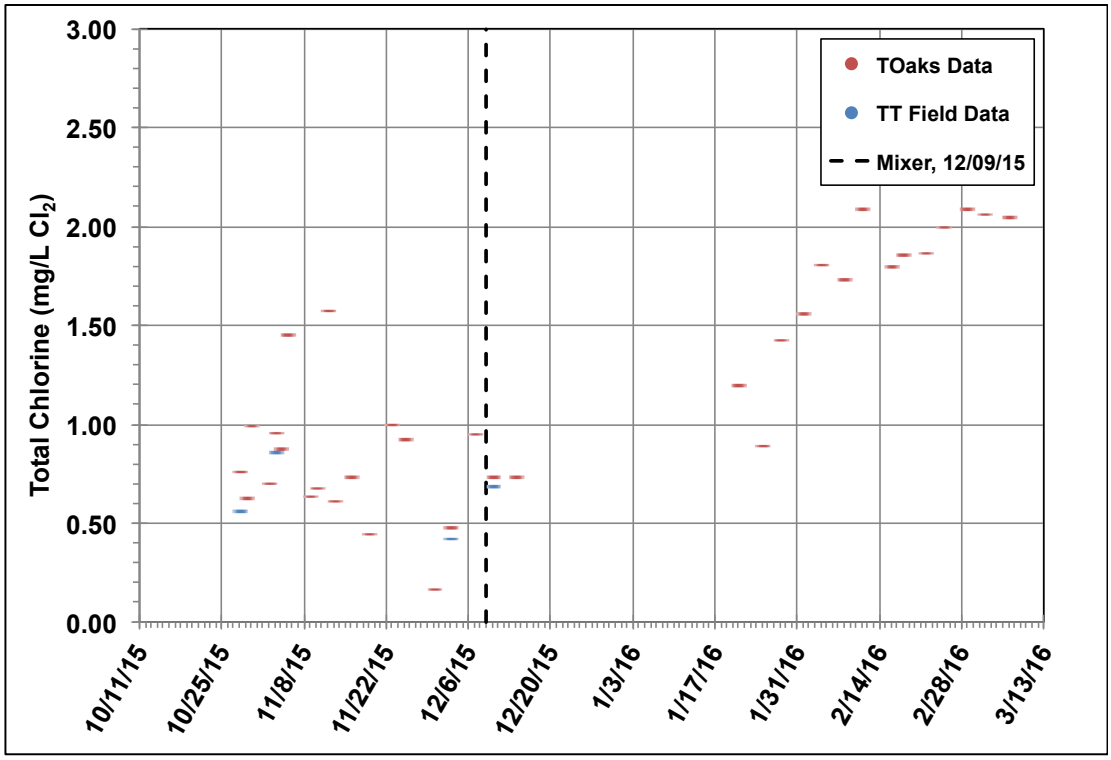


Figure A1-14. Total chlorine grab sample data for La Granada from October 2015 onward (Note: La Granada was offline from approximately 12/17/15-1/20/16)

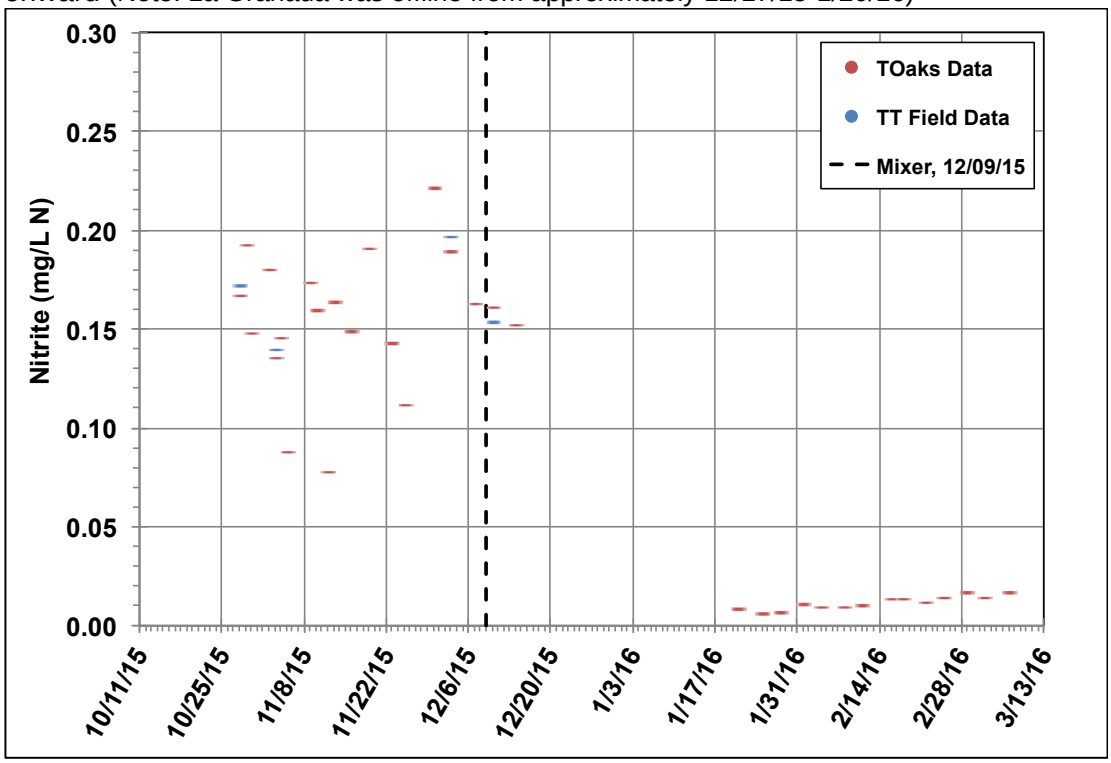


Figure A1-15. Nitrite grab sample data for La Granada from October 2015 onward (Note: La Granada was offline from approximately 12/17/15-1/20/16)

No Changes:

Kelley Reservoir

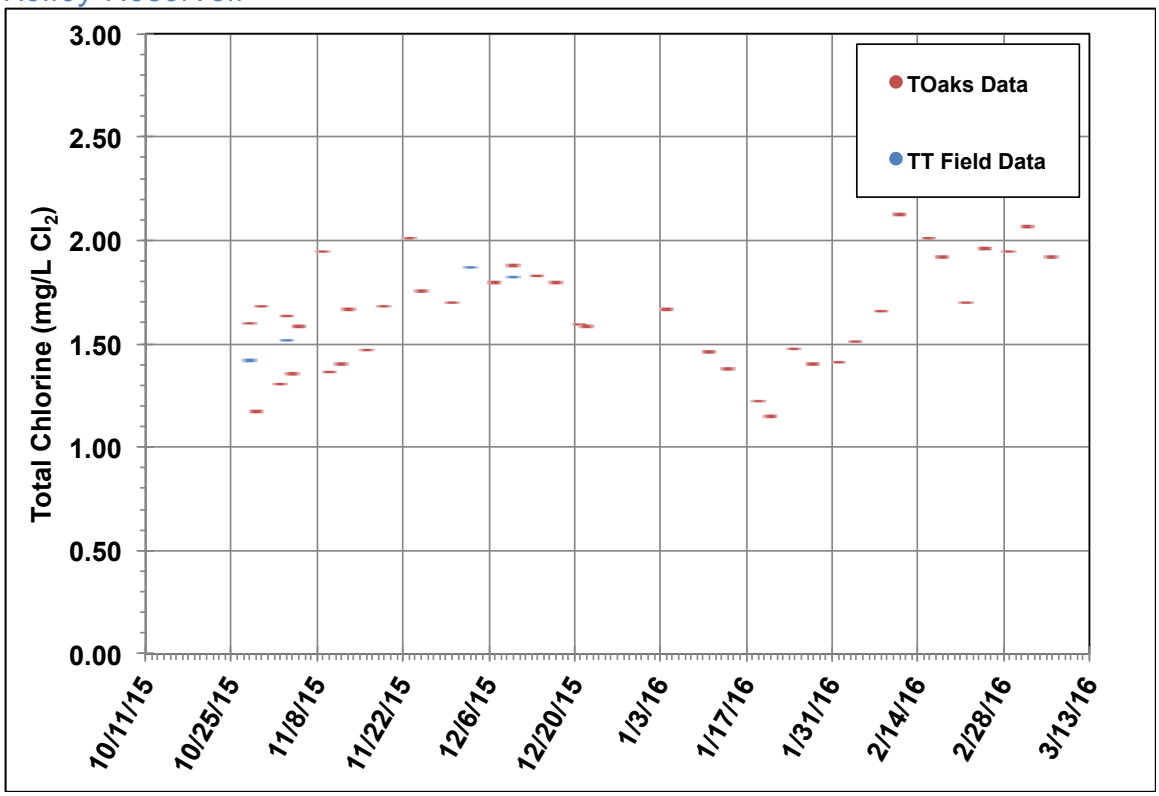


Figure A1-16. Total chlorine grab sample data for Kelley from October 2015 onward

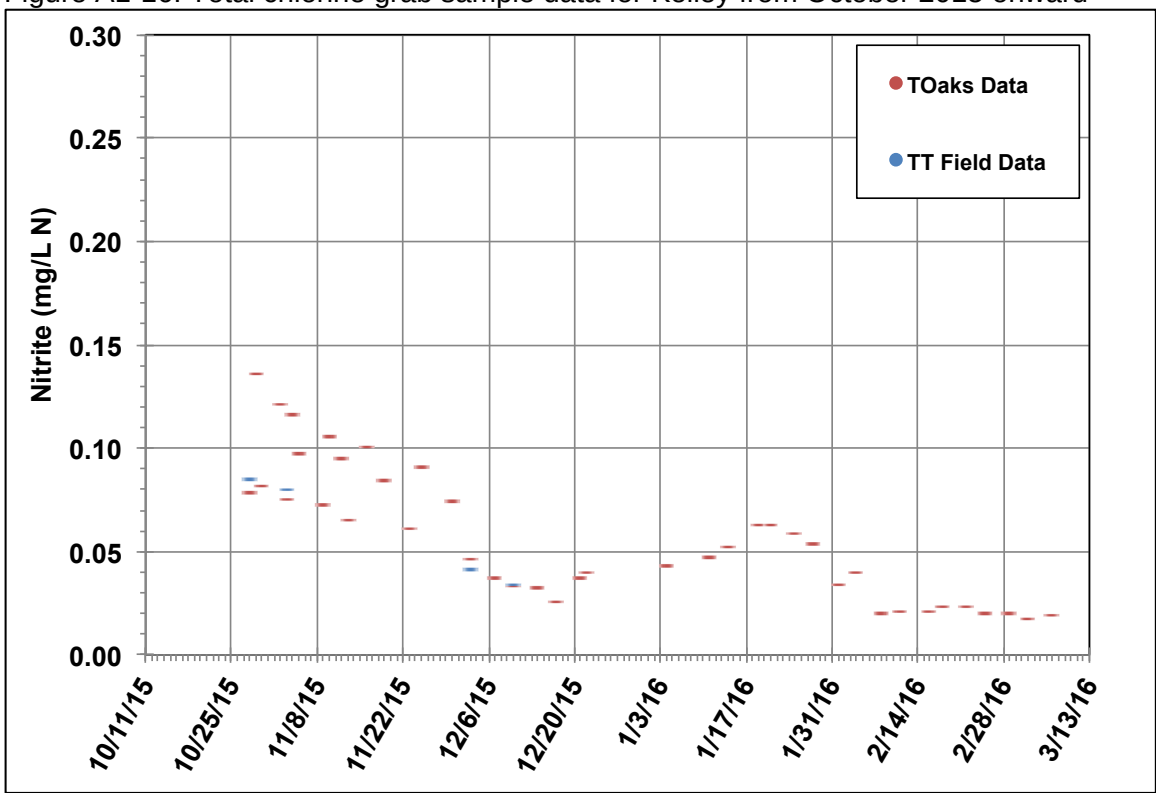


Figure A1-17. Nitrite grab sample data for Kelley from October 2015 onward

*Ventu Park Reservoir**

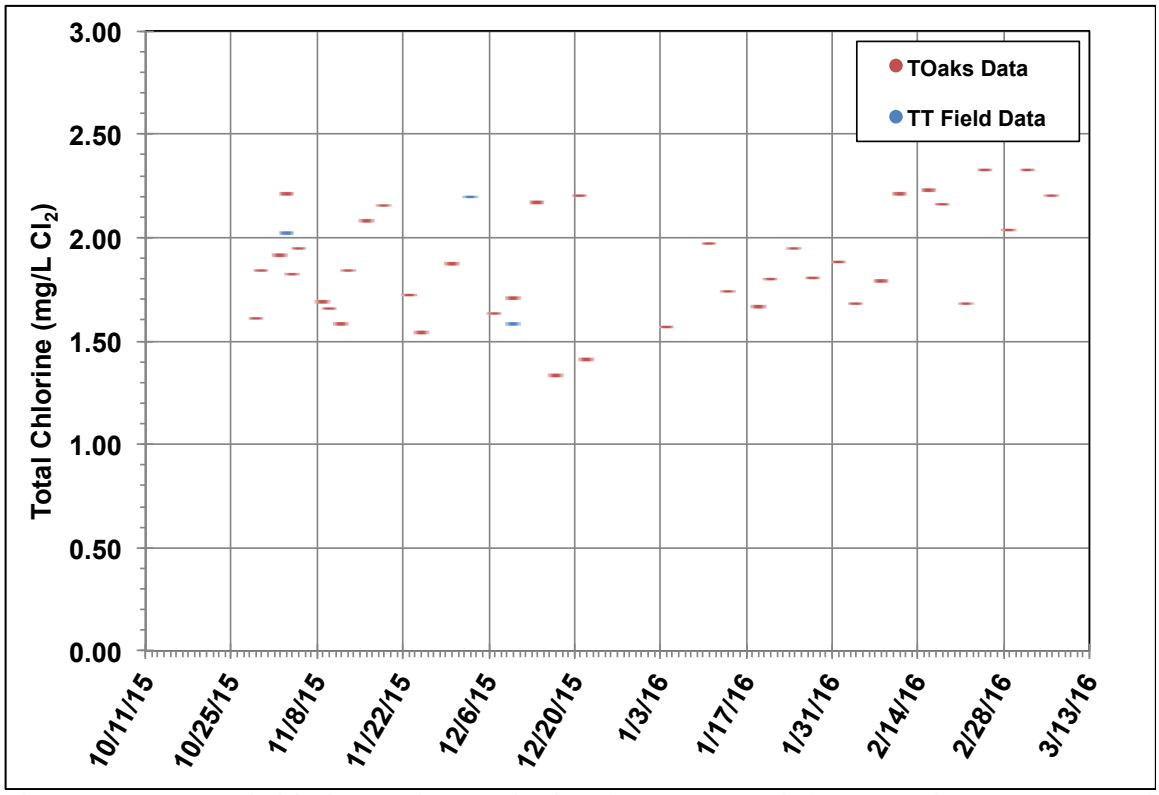


Figure A1-18. Total chlorine grab sample data for Ventu Park from October 2015 onward

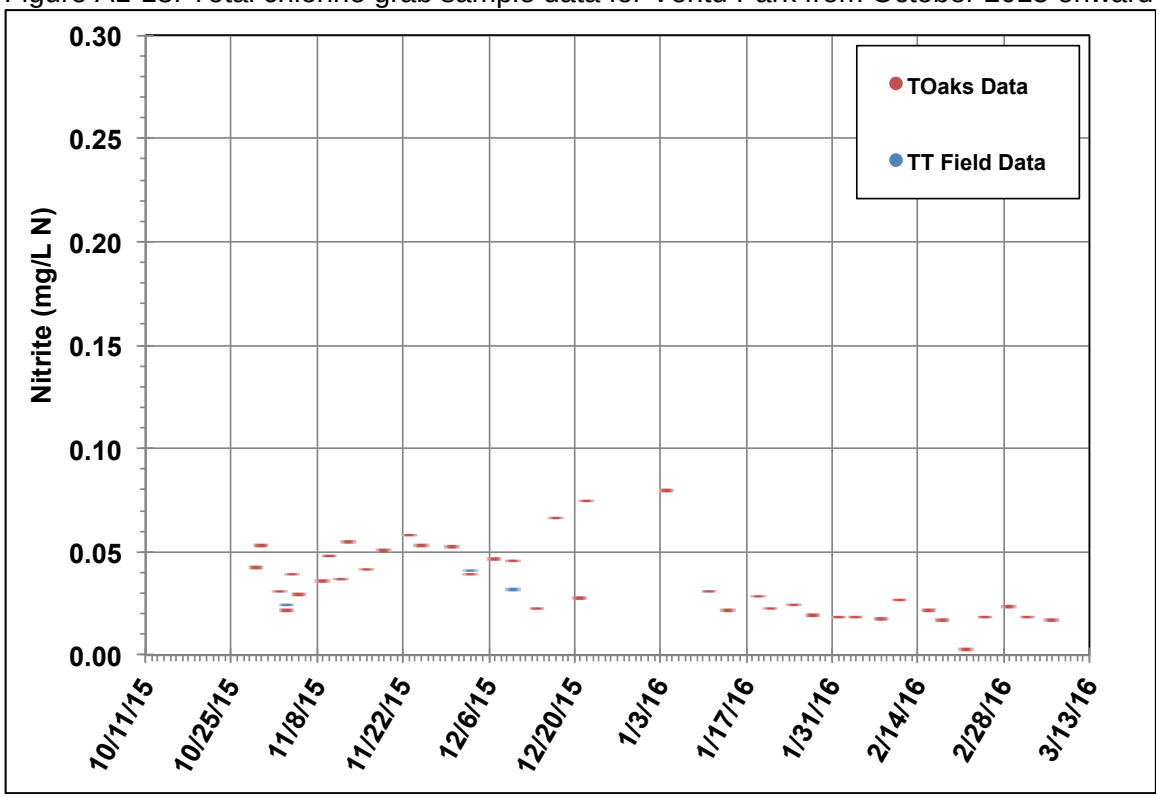


Figure A1-19. Nitrite grab sample data for Ventu Park from October 2015 onward
* Mixer was added to the inactive partition of Ventu Park on November 9, 2015

Attachment 2 – Historical Monitoring Results

Plots in this section present the grab sample data for total chlorine and nitrite from January 2010 to March 2016. The data is presented on an annual basis to show the seasonal variability in the constituents and the change after the addition of mixers and RCS units. The plots categorize the data into historical data and more recent data, where the historical data extends from January 2010 to September 2015. The recent data – October 2015 onward – was from both Thousand Oaks grab samples and Trussell Tech grab samples.

Mixer + RCS System #1:

Willow Reservoir

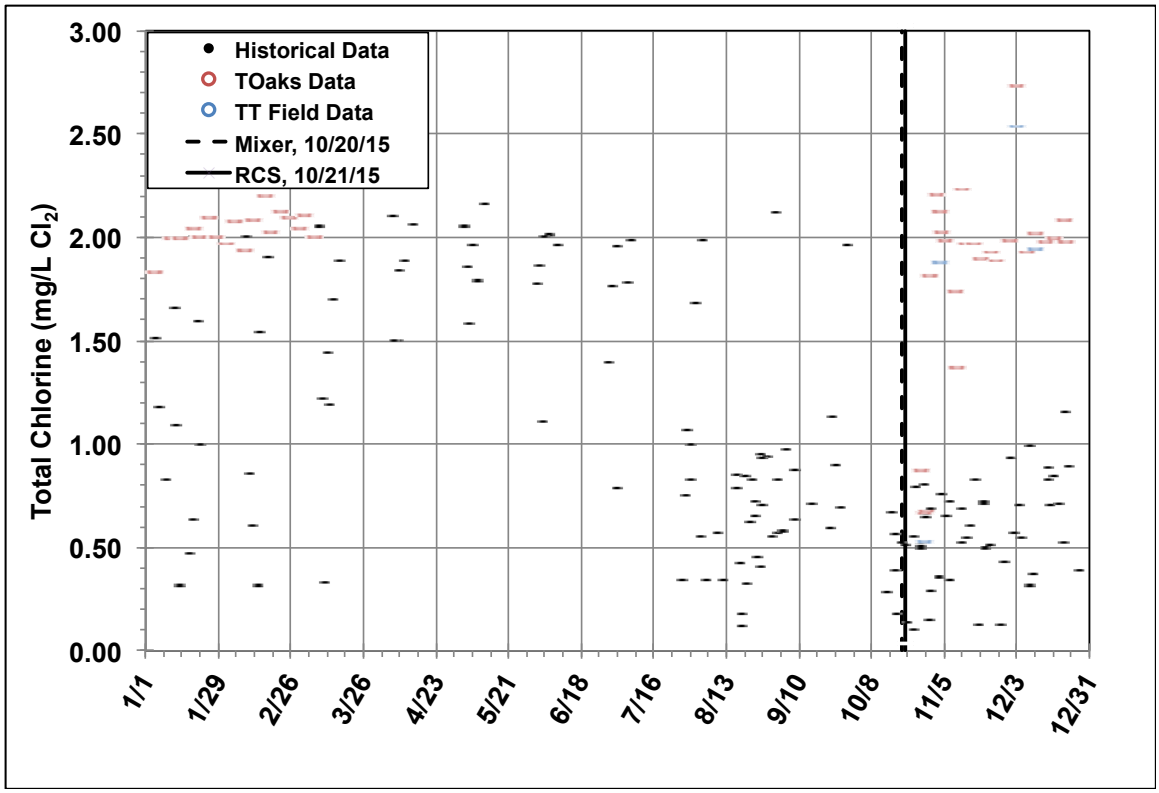


Figure A2-1. Total chlorine grab sample data for Willow Reservoir

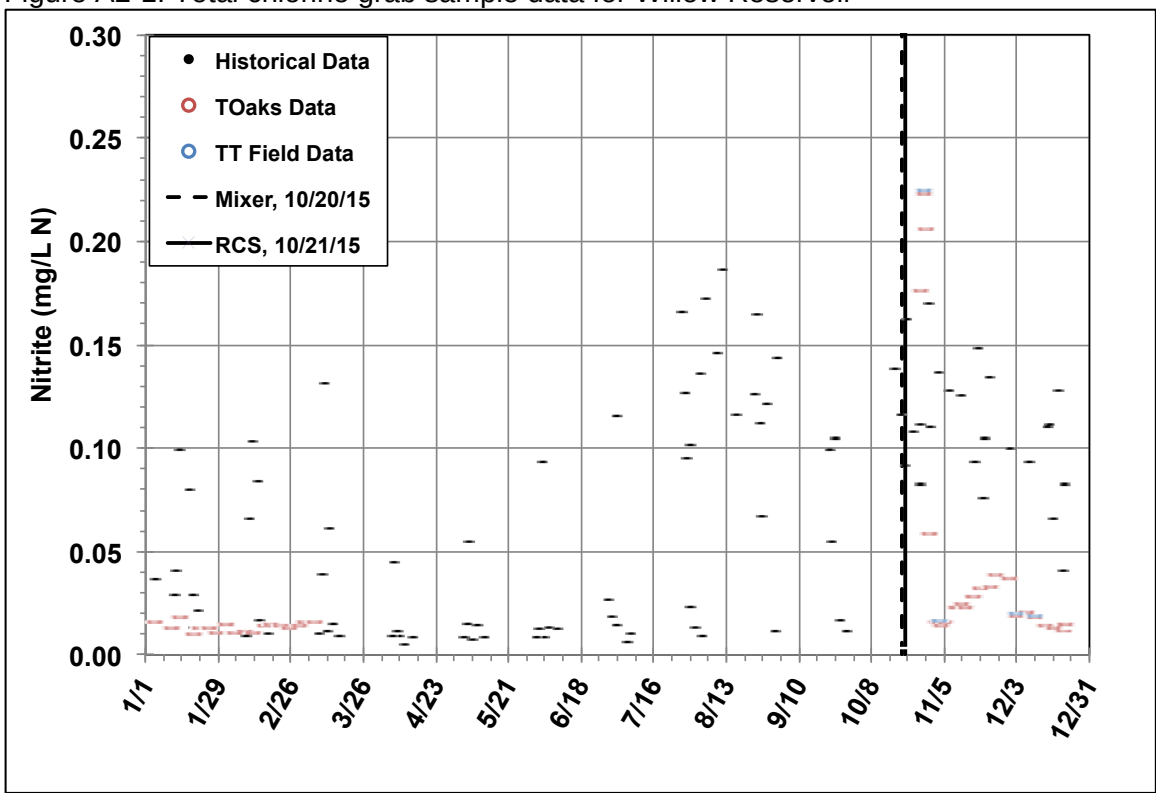


Figure A2-2. Nitrite grab sample data for Willow Reservoir

Freeway Reservoir

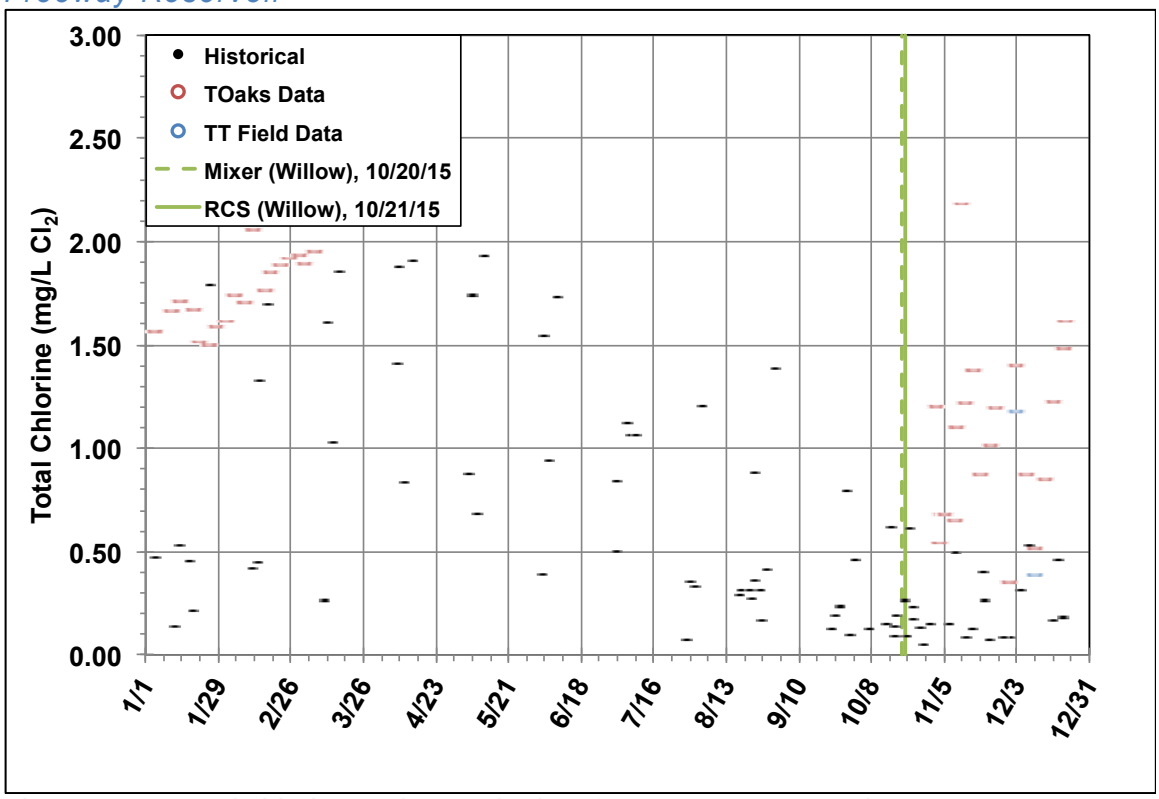


Figure A2-3. Total chlorine grab sample data for Freeway Reservoir

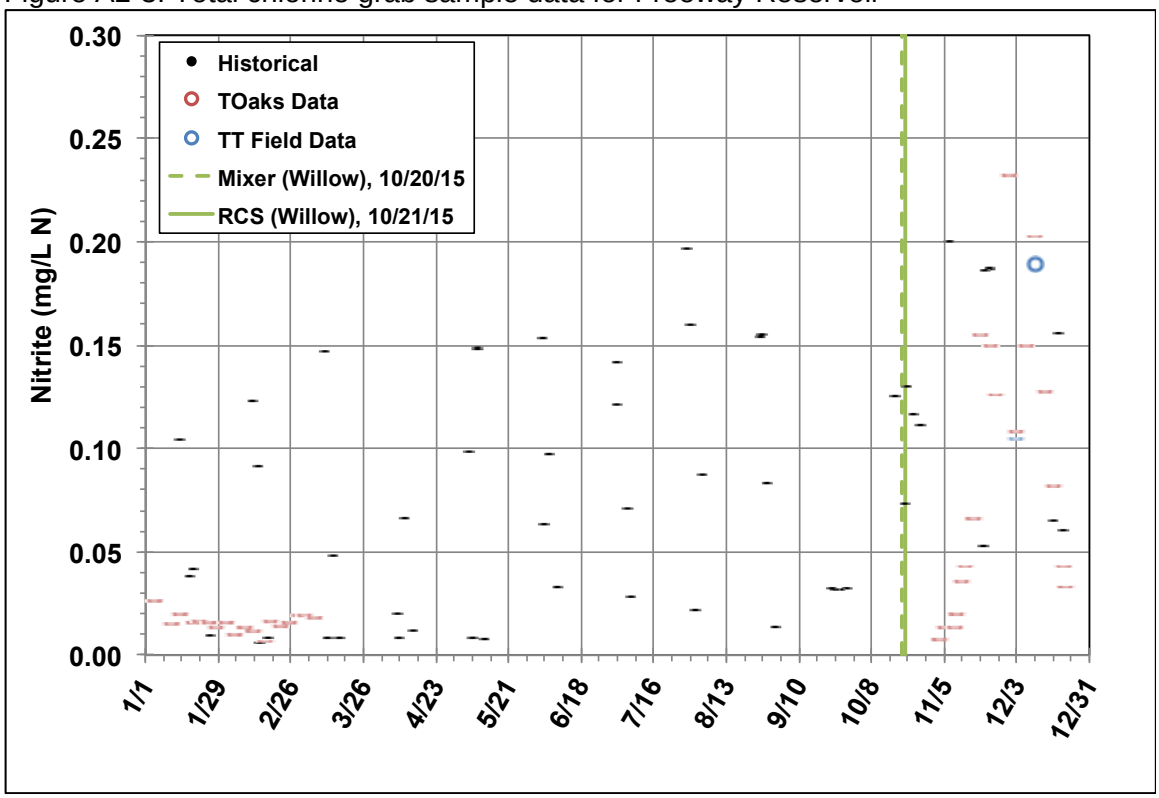


Figure A2-4. Nitrite grab sample data for Freeway Reservoir

Rolling Oaks Reservoir

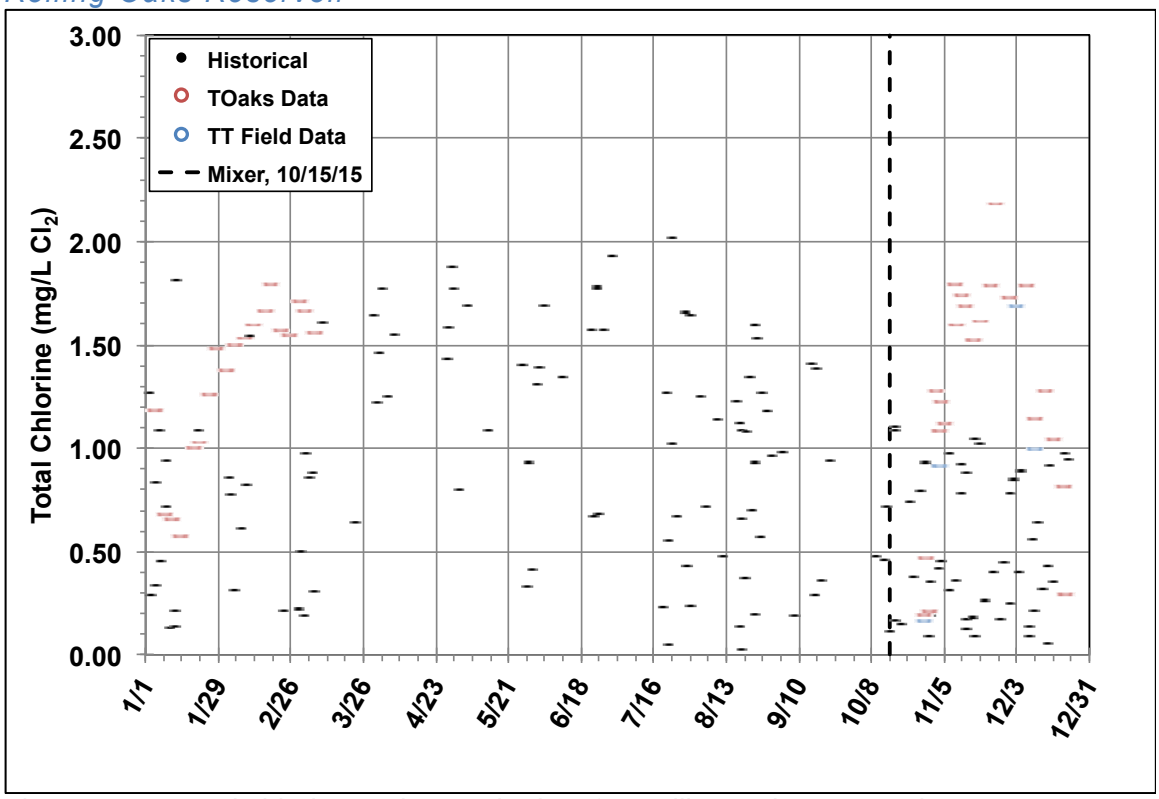


Figure A2-5. Total chlorine grab sample data for Rolling Oaks Reservoir

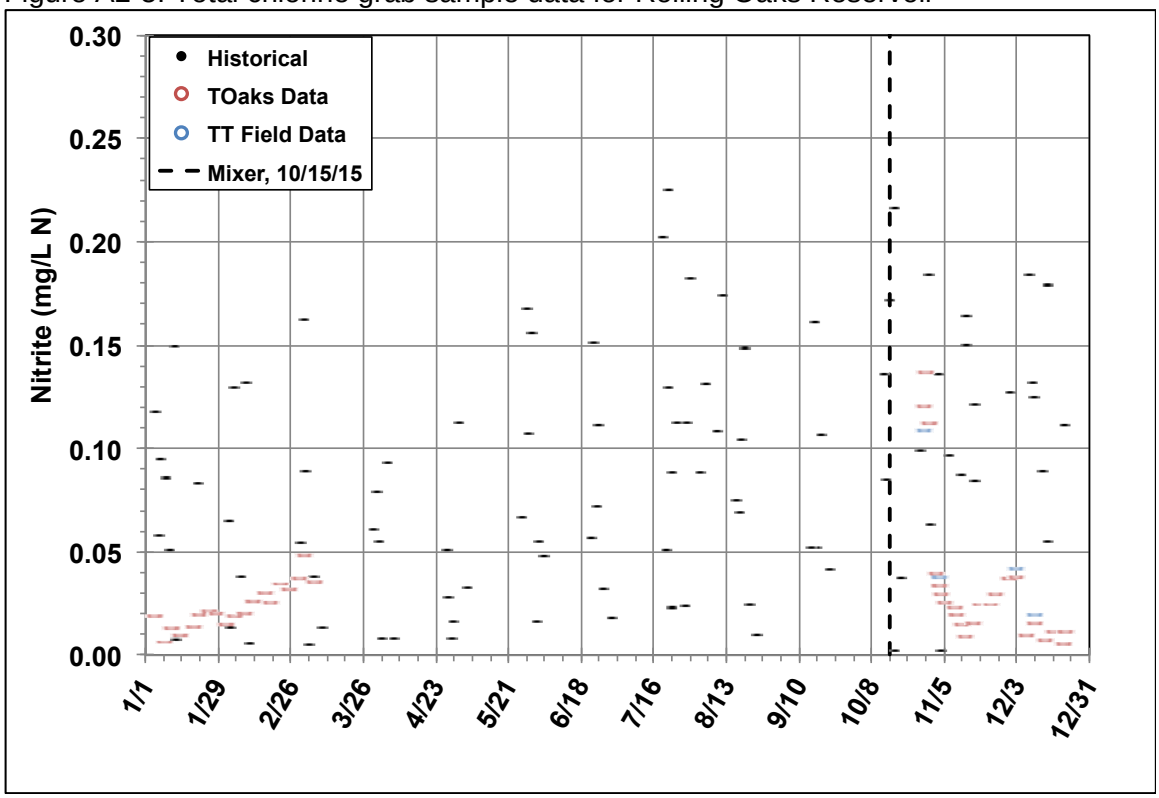


Figure A2-6. Nitrite grab sample data for Rolling Oaks Reservoir

Mixer + RCS System #2:

Pederson Reservoir

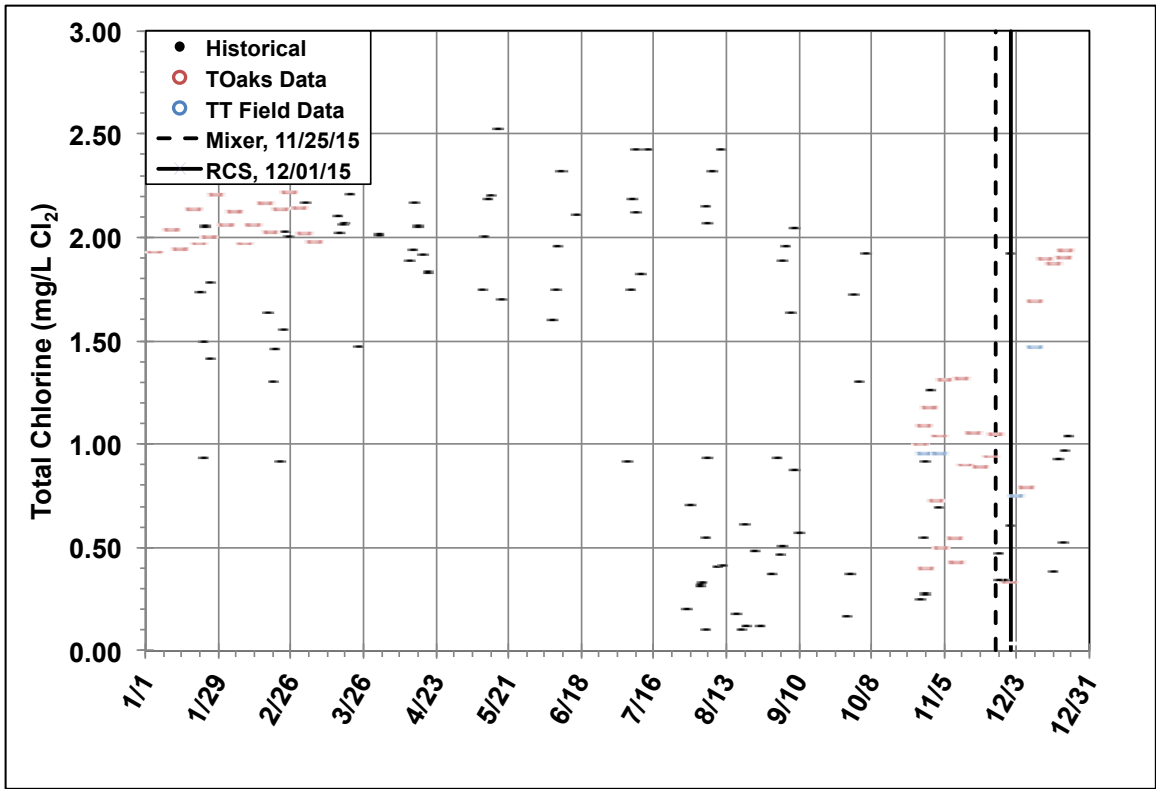


Figure A2-7. Total chlorine grab sample data for Pederson Reservoir

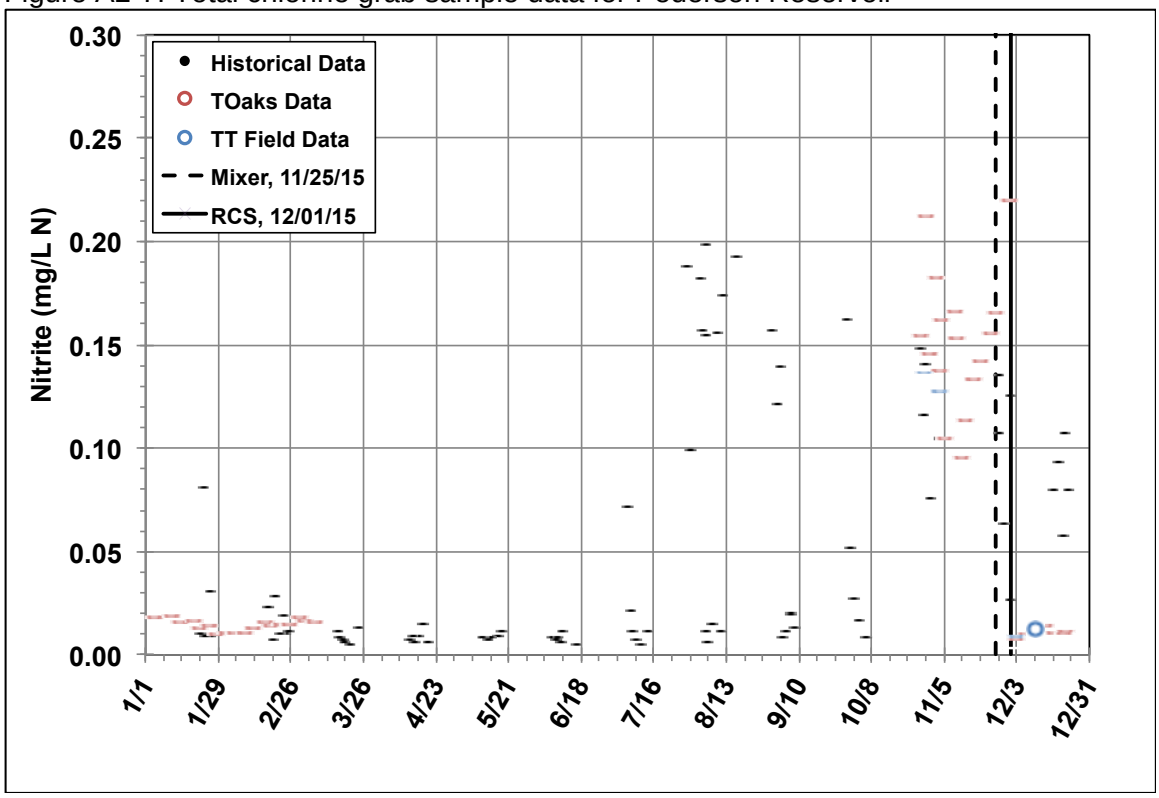


Figure A2-8. Nitrite grab sample data for Pederson Reservoir

Tara Reservoir

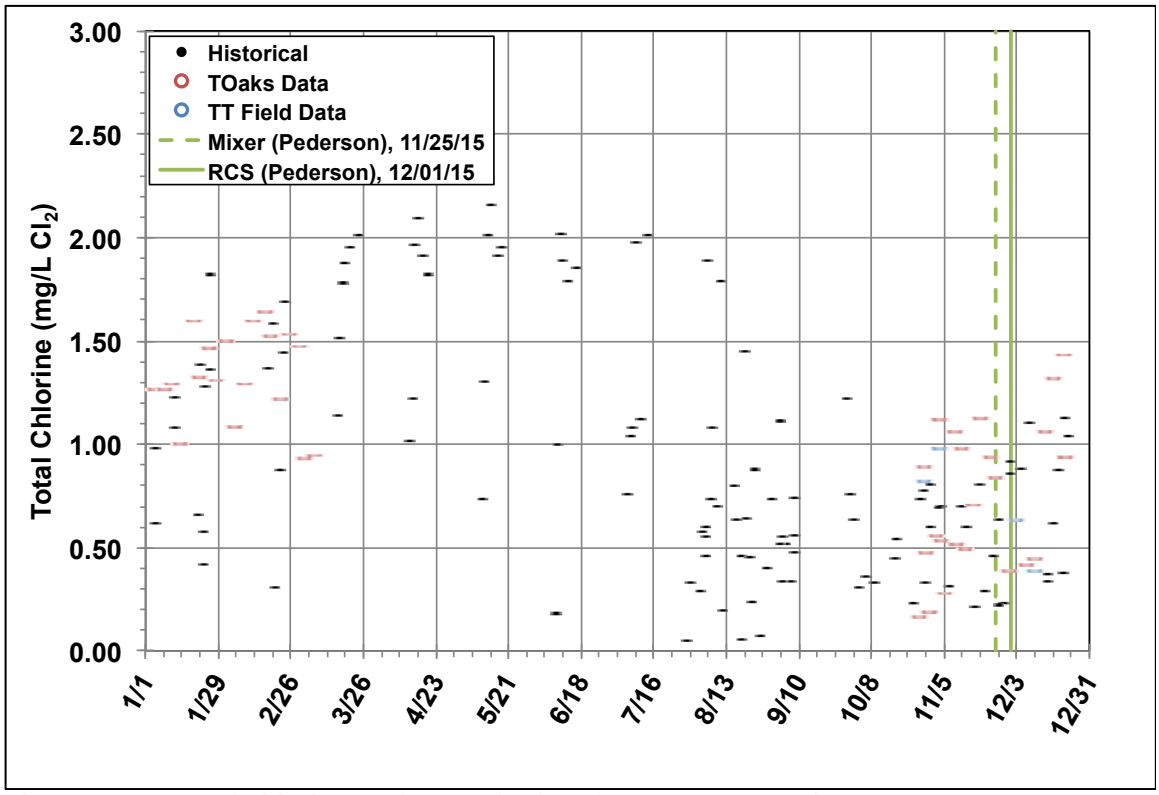


Figure A2-9. Total chlorine grab sample data for Tara Reservoir

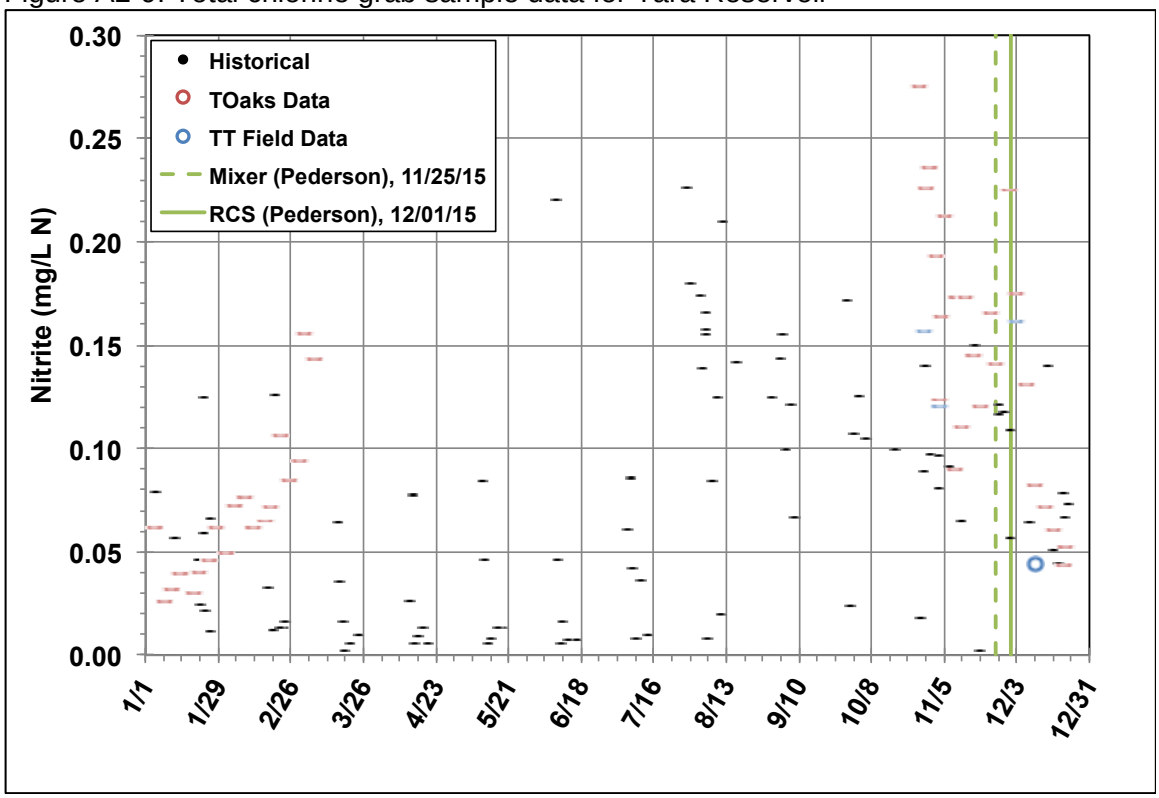


Figure A2-10. Nitrite grab sample data for Tara Reservoir

Mixers Only:

La Granada Reservoir

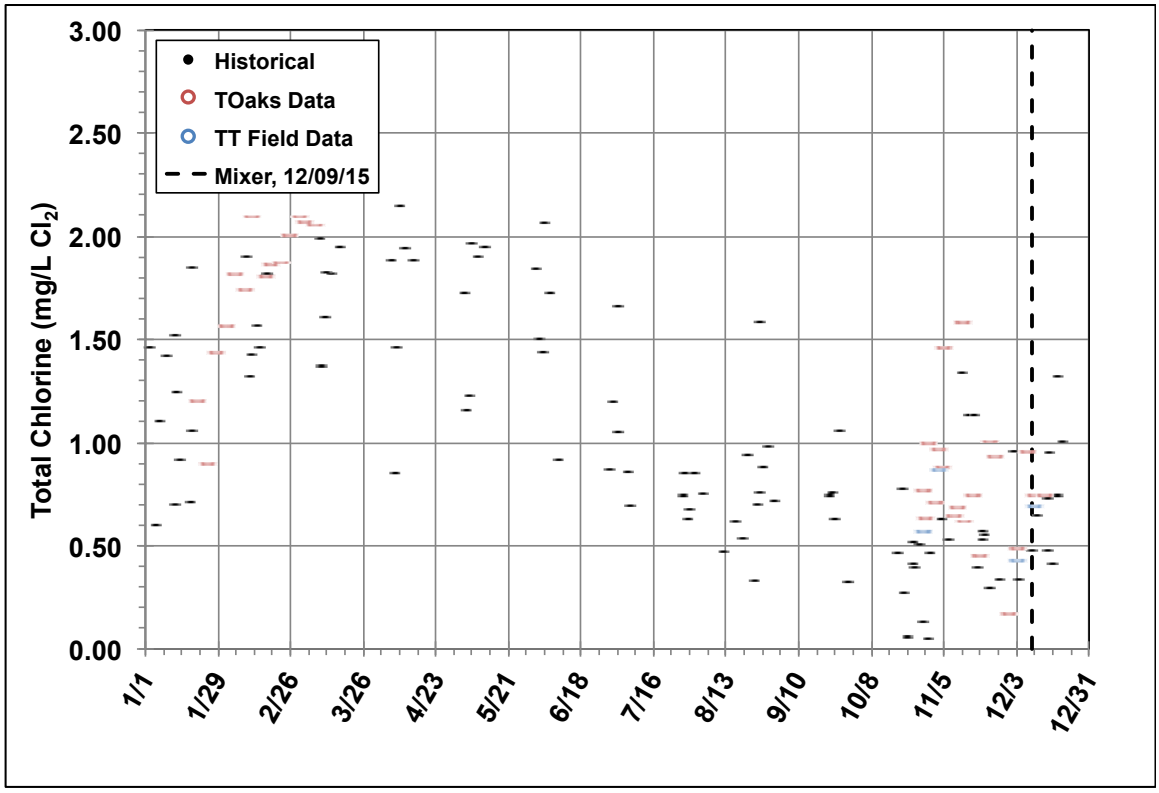


Figure A2-11. Total chlorine grab sample data for La Granada Reservoir

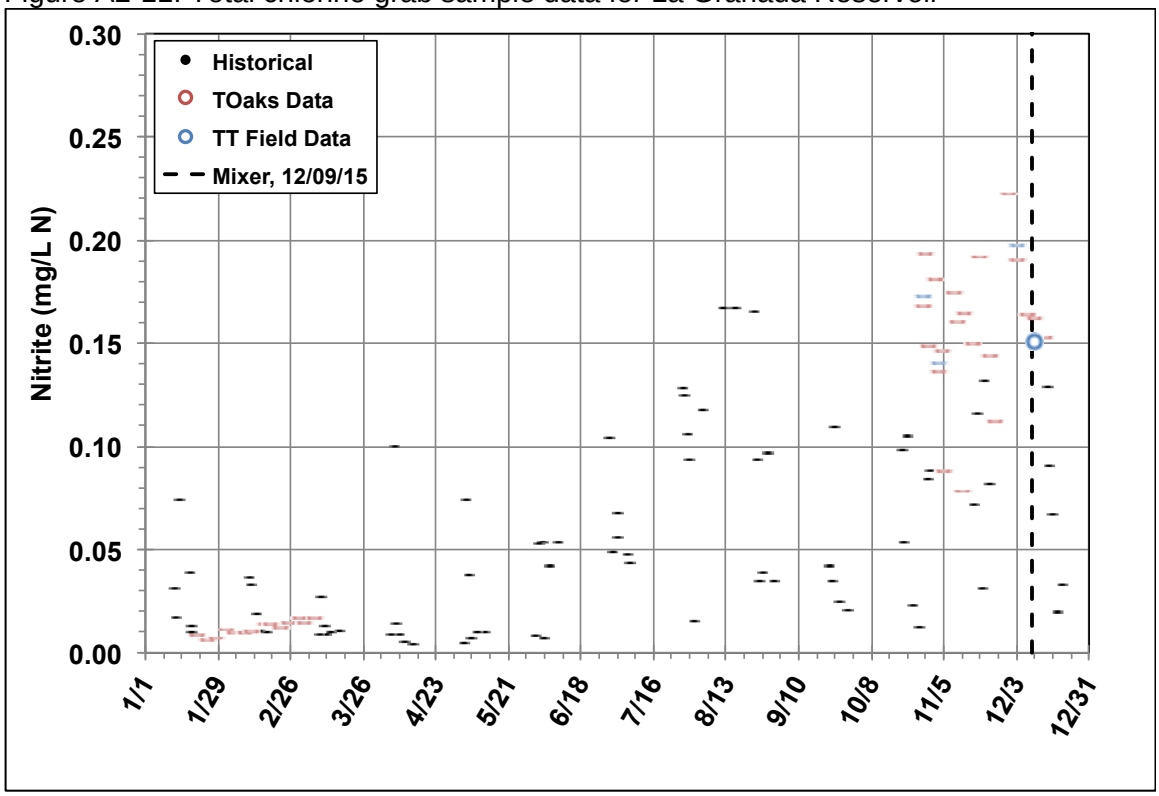


Figure A2-12. Nitrite grab sample data for La Granada Reservoir

No Changes:

Kelley Reservoir

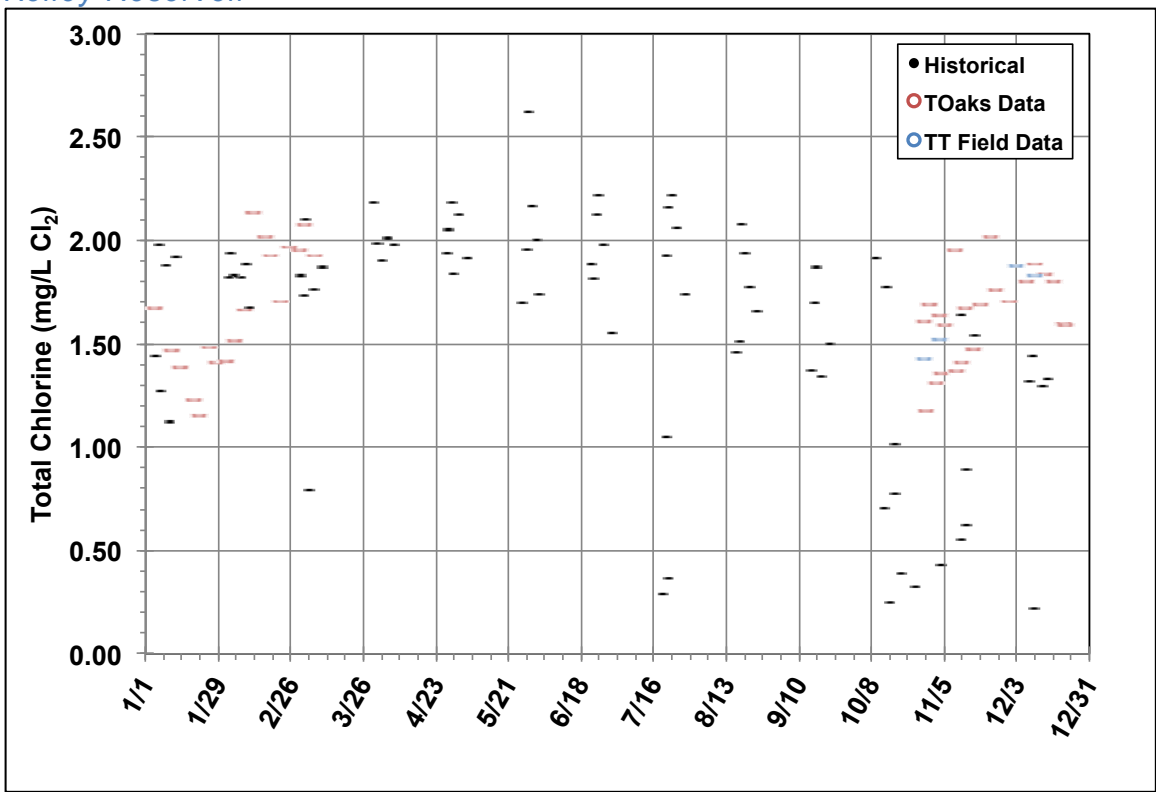


Figure A2-13. Total chlorine grab sample data for Kelley Reservoir

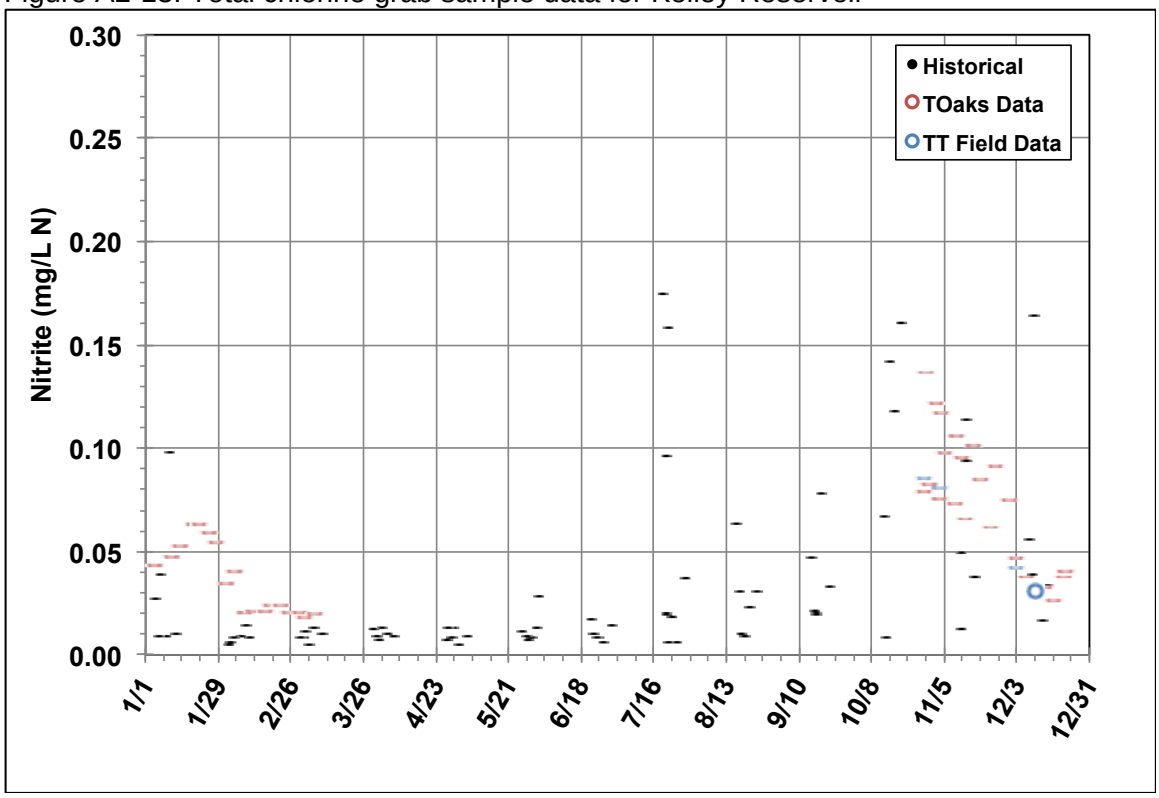


Figure A2-14. Nitrite grab sample data for Kelley Reservoir

*Ventu Park Reservoir**

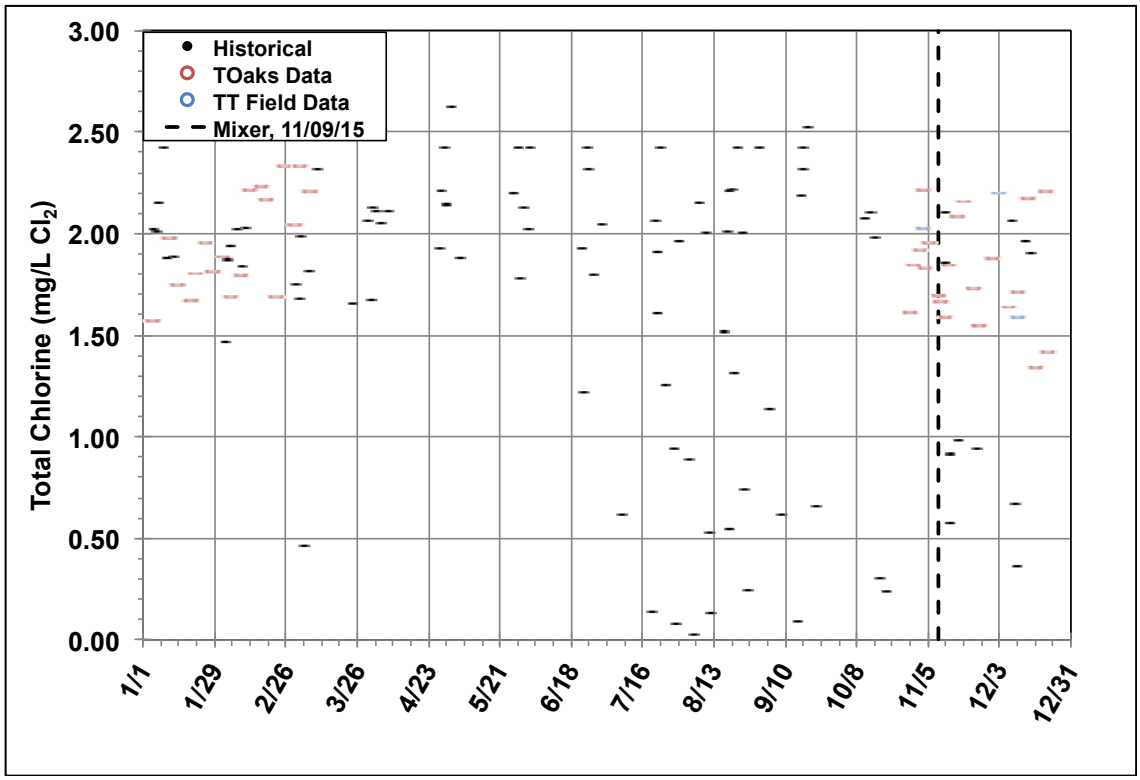


Figure A2-15. Total chlorine grab sample data for Ventu Park Reservoir

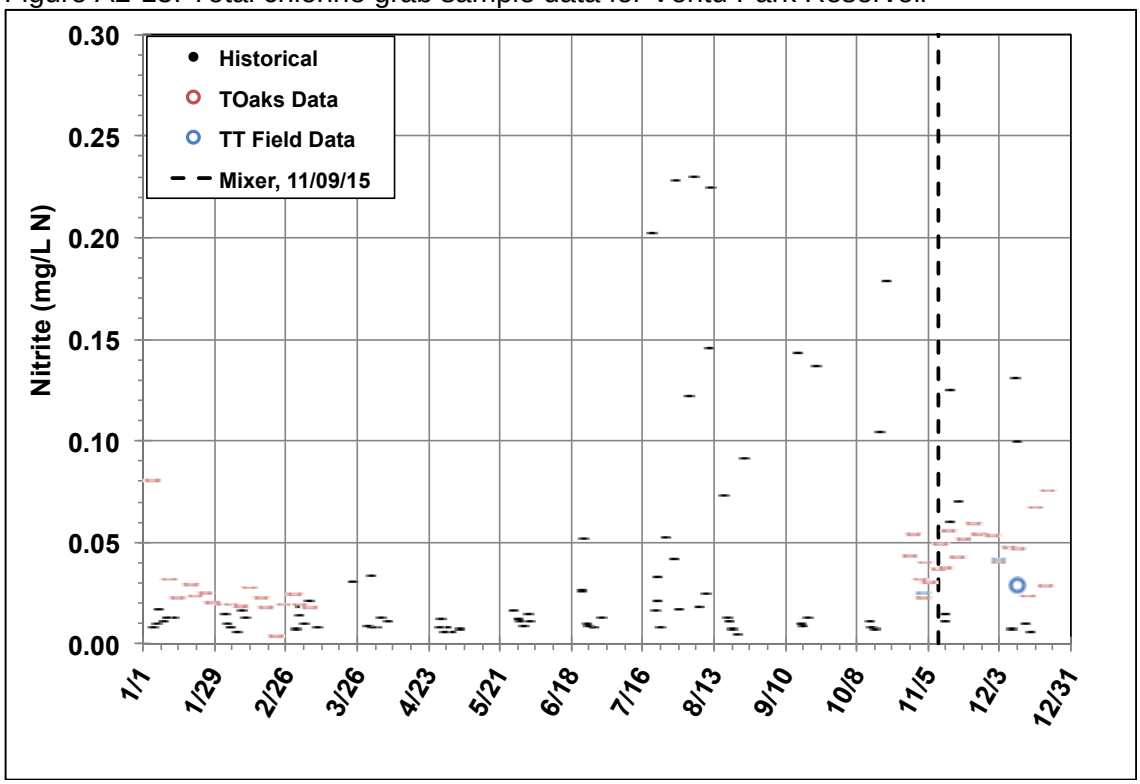


Figure A2-16. Nitrite grab sample data for Ventu Park Reservoir

* Mixer was added to the inactive partition of Ventu Park Reservoir on November 9, 2015

Appendix G: Pump Station and Turnout Level Controls and Set Points for Water Age Modeling Scenarios

Scenario 1 Pump Station Level Controls

No.	Pumping Unit	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Erbes Rd Pump 1	12	25	Meadows Reservoir
2	Erbes Rd Pump 2	14	26	Lang Ranch Reservoir
3	Erbes Rd Pump 3	13.9	25.9	Lang Ranch Reservoir
4	Erbes Rd Pump 4	12	24	Lang Ranch Reservoir
5	Los Arboles Pump 1	10	18	Oakbrook Reservoir
6	Los Arboles Pump 2	9.9	17.9	Oakbrook Reservoir
7	Lone Oak to Wilder Pump 1	10	19	Wilder Reservoir
8	Lone Oak to Wilder Pump 2	9.9	18	Wilder Reservoir
9	Lone Oak to Wilder Pump 3	8	16	Wilder Reservoir
10	Lone Oak to La Grana Pump 1	12	26	La Granada
11	Lone Oak to La Grana Pump 2	11.9	25.9	La Granada
12	Lone Oak to La Grana Pump 3	11.5	25	La Granada
13	Lang Ranch Pump 1	10	19	Sunset Reservoir No. 3
14	Lang Ranch Pump 2	9.5	18	Sunset Reservoir No. 3
15	Pederson Pump 1	12	26	Tara Reservoir
16	Pederson Pump 2	11.5	25	Tara Reservoir
17	Pederson Pump 3	10	22	Tara Reservoir
18	Rolling Oaks Pump 1	10	19	Rolling Oaks Reservoir
19	Rolling Oaks Pump 2	9.5	17.5	Rolling Oaks Reservoir
20	Sunset 2 Pump 1	12	19	Sunset Reservoir No. 3
21	Sunset 2 Pump 2	11.5	18	Sunset Reservoir No. 3
22	Sunset 1 Pump 1	14	26	Sunset Reservoir No. 2
23	Sunset 1 Pump 2	13.5	24	Sunset Reservoir No. 2
24	Sunset 1 Pump 3	12	20	Sunset Reservoir No. 2
25	Wilder Pump 1	10	19	Grissom Reservoir No. 1
26	Wilder Pump 1	10	19	Grissom Reservoir No. 2
27	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 1
28	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 2
29	Willow Lane Pump 1	12	26	Freeway Reservoir
30	Willow Lane Pump 2	11.9	25.9	Freeway Reservoir
31	Willow Lane Pump 3	10	24	Freeway Reservoir

Scenario 1 Turnout PRV Level Controls and Set Points

No.	Turnout PRV	Set Point (psi)	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Hillcrest	129	8	18.5	Willow Lane Reservoir
2	Encino Vista	88	8	19	Willow Lane Reservoir
3	Los Arboles	87	10.8	18	Pederson Reservoir
4	Las Flores	97	10.7	18	Pederson Reservoir
5	Gainsborough	99	10.5	18	Pederson Reservoir
6	Ventu Park	161	8	19	Ventu Park Reservoir
7	West Kelley	127	12	26	Kelley Reservoir

Scenario 2 Pump Station Level Controls

No.	Pumping Unit	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Erbes Rd Pump 1	12	25	Meadows Reservoir
2	Erbes Rd Pump 2	14	26	Lang Ranch Reservoir
3	Erbes Rd Pump 3	13.9	25.9	Lang Ranch Reservoir
4	Erbes Rd Pump 4	12	24	Lang Ranch Reservoir
5	Los Arboles Pump 1	10	18	Oakbrook Reservoir
6	Los Arboles Pump 2	9.9	17.9	Oakbrook Reservoir
7	Lone Oak to Wilder Pump 1	10	19	Wilder Reservoir
8	Lone Oak to Wilder Pump 2	9.9	18	Wilder Reservoir
9	Lone Oak to Wilder Pump 3	8	16	Wilder Reservoir
10	Lone Oak to La Grana Pump 1	12	26	La Granada
11	Lone Oak to La Grana Pump 2	11.9	25.9	La Granada
12	Lone Oak to La Grana Pump 3	11.5	25	La Granada
13	Lang Ranch Pump 1	10	18	Oakbrook Reservoir
14	Lang Ranch Pump 2	8	16	Oakbrook Reservoir
15	Pederson Pump 1	12	26	Tara Reservoir
16	Pederson Pump 2	11.5	25	Tara Reservoir
17	Pederson Pump 3	10	22	Tara Reservoir
18	Rolling Oaks Pump 1	10	19	Rolling Oaks Reservoir
19	Rolling Oaks Pump 2	9.5	17.5	Rolling Oaks Reservoir
20	Sunset 2 Pump 1	12	19	Sunset Reservoir No. 3
21	Sunset 2 Pump 2	11	18.5	Sunset Reservoir No. 3
22	Sunset 1 Pump 1	14	26	Sunset Reservoir No. 2
23	Sunset 1 Pump 2	13.5	24	Sunset Reservoir No. 2
24	Sunset 1 Pump 3	12	20	Sunset Reservoir No. 2
25	Wilder Pump 1	10	19	Grissom Reservoir No. 1
26	Wilder Pump 1	10	19	Grissom Reservoir No. 2
27	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 1
28	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 2
29	Willow Lane Pump 1	12	26	Freeway Reservoir
30	Willow Lane Pump 2	11.9	25.9	Freeway Reservoir
31	Willow Lane Pump 3	10	24	Freeway Reservoir

Scenario 2 Turnout PRV Level Controls and Set Points

No.	Turnout PRV	Set Point (psi)	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Hillcrest	129	8	18.5	Willow Lane Reservoir
2	Encino Vista	88	8	19	Willow Lane Reservoir
3	Los Arboles	87	10.8	18	Pederson Reservoir
4	Las Flores	97	10.7	18	Pederson Reservoir
5	Gainsborough	99	10.5	18	Pederson Reservoir
6	Ventu Park	161	8	19	Ventu Park Reservoir
7	West Kelley	127	12	26	Kelley Reservoir

Highlighted rows are changed from the preceding scenario.

Scenario 3 Pump Station Level Controls

No.	Pumping Unit	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Erbes Rd Pump 1	10	15.5	Meadows Reservoir
2	Erbes Rd Pump 2	12.5	15.5	Lang Ranch Reservoir
3	Erbes Rd Pump 3	12	15	Lang Ranch Reservoir
4	Erbes Rd Pump 4	10.5	13.5	Lang Ranch Reservoir
5	Los Arboles Pump 1	8	14	Oakbrook Reservoir
6	Los Arboles Pump 2	7.9	13.9	Oakbrook Reservoir
7	Lone Oak to Wilder Pump 1	9	19	Wilder Reservoir
8	Lone Oak to Wilder Pump 2	8.9	18.9	Wilder Reservoir
9	Lone Oak to Wilder Pump 3	7.5	17.5	Wilder Reservoir
10	Lone Oak to La Grana Pump 1	12	22	La Granada
11	Lone Oak to La Grana Pump 2	11	21	La Granada
12	Lone Oak to La Grana Pump 3	12	22	La Granada
13	Lang Ranch Pump 1	8	14	Oakbrook Reservoir
14	Lang Ranch Pump 2	7	13	Oakbrook Reservoir
15	Pederson Pump 1	8	14.5	Tara Reservoir
16	Pederson Pump 2	8	14.5	Tara Reservoir
17	Pederson Pump 3	7	13.5	Tara Reservoir
18	Rolling Oaks Pump 1	8	19	Rolling Oaks Reservoir
19	Rolling Oaks Pump 2	7	18	Rolling Oaks Reservoir
20	Sunset 2 Pump 1	8.5	12.5	Sunset Reservoir No. 3
21	Sunset 2 Pump 2	8	12	Sunset Reservoir No. 3
22	Sunset 1 Pump 1	12	15	Sunset Reservoir No. 2
23	Sunset 1 Pump 2	11.5	14.5	Sunset Reservoir No. 2
24	Sunset 1 Pump 3	10	13	Sunset Reservoir No. 2
25	Wilder Pump 1	10	19	Grissom Reservoir No. 2
26	Wilder Pump 1	10	19	Grissom Reservoir No. 1
27	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 1
28	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 2
29	Willow Lane Pump 1	12	22	La Granada
30	Willow Lane Pump 2	11	21	La Granada
31	Willow Lane Pump 3	10	20	La Granada

Scenario 3 Turnout PRV Level Controls and Set Points

No.	Turnout PRV	Set Point (psi)	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Hillcrest	126	8	18.5	Willow Lane Reservoir
2	Encino Vista	74	8	19	Willow Lane Reservoir
3	Los Arboles	87	8.8	16	Pederson Reservoir
4	Las Flores	97	8.7	16	Pederson Reservoir
5	Gainsborough	99	8.5	16	Pederson Reservoir
6	Ventu Park	158	8	19	Ventu Park Reservoir
7	West Kelley	115	12	26	Kelley Reservoir

Highlighted rows are changed from the preceding scenario.

Scenario 4A Pump Station Level Controls

No.	Pumping Unit	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Erbes Rd Pump 1	10	15.5	Meadows Reservoir
2	Erbes Rd Pump 2	12.5	15.5	Lang Ranch Reservoir
3	Erbes Rd Pump 3	12	15	Lang Ranch Reservoir
4	Erbes Rd Pump 4	10.5	13.5	Lang Ranch Reservoir
5	Los Arboles Pump 1	8	14	Oakbrook Reservoir
6	Los Arboles Pump 2	7.9	13.9	Oakbrook Reservoir
7	Lone Oak to Wilder Pump 1	Inactive	Inactive	-
8	Lone Oak to Wilder Pump 2	Inactive	Inactive	-
9	Lone Oak to Wilder Pump 3	Inactive	Inactive	-
10	Lone Oak to La Grana Pump 1	12	22	La Granada
11	Lone Oak to La Grana Pump 2	11	21	La Granada
12	Lone Oak to La Grana Pump 3	12	22	La Granada
13	Lang Ranch Pump 1	8	14	Oakbrook Reservoir
14	Lang Ranch Pump 2	7	13	Oakbrook Reservoir
15	Pederson Pump 1	8	14.5	Tara Reservoir
16	Pederson Pump 2	8	14.5	Tara Reservoir
17	Pederson Pump 3	7	13.5	Tara Reservoir
18	Rolling Oaks Pump 1	8	19	Rolling Oaks Reservoir
19	Rolling Oaks Pump 2	7	18	Rolling Oaks Reservoir
20	Sunset 2 Pump 1	8.5	12.5	Sunset Reservoir No. 3
21	Sunset 2 Pump 2	8	12	Sunset Reservoir No. 3
22	Sunset 1 Pump 1	12	15	Sunset Reservoir No. 2
23	Sunset 1 Pump 2	11.5	14.5	Sunset Reservoir No. 2
24	Sunset 1 Pump 3	10	13	Sunset Reservoir No. 2
25	Wilder Pump 1	10	19	Grissom Reservoir No. 1
26	Wilder Pump 1	10	19	Grissom Reservoir No. 2
27	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 2
28	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 1
29	Willow Lane Pump 1	12	22	La Granada
30	Willow Lane Pump 2	10	21	La Granada
31	Willow Lane Pump 3	9	20	La Granada
32	La Granada Pump 1	9	16	Wilder Reservoir
33	La Granada Pump 2	8.5	15.5	Wilder Reservoir

Scenario 4A Turnout PRV Level Controls and Set Points

No.	Turnout PRV	Set Point (psi)	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Hillcrest	126	8	18.5	Willow Lane Reservoir
2	Encino Vista	74	8	19	Willow Lane Reservoir
3	Los Arboles	87	8.8	16	Pederson Reservoir
4	Las Flores	97	8.7	16	Pederson Reservoir
5	Gainsborough	99	8.5	16	Pederson Reservoir
6	Ventu Park	158	8	19	Ventu Park Reservoir
7	West Kelley	115	12	26	Kelley Reservoir

Highlighted rows are changed from the preceding scenario.

Scenario 4B Pump Station Level Controls

No.	Pumping Unit	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Erbes Rd Pump 1	10	15.5	Meadows Reservoir
2	Erbes Rd Pump 2	12.5	15.5	Lang Ranch Reservoir
3	Erbes Rd Pump 3	12	15	Lang Ranch Reservoir
4	Erbes Rd Pump 4	10.5	13.5	Lang Ranch Reservoir
5	Los Arboles Pump 1	8	14	Oakbrook Reservoir
6	Los Arboles Pump 2	7.9	13.9	Oakbrook Reservoir
7	Lone Oak to Wilder Pump 1	9.2	16	Wilder Reservoir
8	Lone Oak to Wilder Pump 2	8.7	15.5	Wilder Reservoir
9	Lone Oak to Wilder Pump 3	8.2	15	Wilder Reservoir
10	Lone Oak to La Grana Pump 1	12	22	La Granada
11	Lone Oak to La Grana Pump 2	11	21	La Granada
12	Lone Oak to La Grana Pump 3	12	22	La Granada
13	Lang Ranch Pump 1	8	14	Oakbrook Reservoir
14	Lang Ranch Pump 2	7	13	Oakbrook Reservoir
15	Pederson Pump 1	8	14.5	Tara Reservoir
16	Pederson Pump 2	8	14.5	Tara Reservoir
17	Pederson Pump 3	7	13.5	Tara Reservoir
18	Rolling Oaks Pump 1	8	19	Rolling Oaks Reservoir
19	Rolling Oaks Pump 2	7	18	Rolling Oaks Reservoir
20	Sunset 2 Pump 1	8.5	12.5	Sunset Reservoir No. 3
21	Sunset 2 Pump 2	8	12	Sunset Reservoir No. 3
22	Sunset 1 Pump 1	12	15	Sunset Reservoir No. 2
23	Sunset 1 Pump 2	11.5	14.5	Sunset Reservoir No. 2
24	Sunset 1 Pump 3	10	13	Sunset Reservoir No. 2
25	Wilder Pump 1	10	19	Grissom Reservoir No. 1
26	Wilder Pump 1	10	19	Grissom Reservoir No. 2
27	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 2
28	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 1
29	Willow Lane Pump 1	12	22	La Granada
30	Willow Lane Pump 2	10	20	La Granada
31	Willow Lane Pump 3	10	20	La Granada
32	La Granada Pump 1	9	16	Wilder Reservoir
33	La Granada Pump 2	8.5	15.5	Wilder Reservoir

Scenario 4B Turnout PRV Level Controls and Set Points

No.	Turnout PRV	Set Point (psi)	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Hillcrest	126	8	18.5	Willow Lane Reservoir
2	Encino Vista	75	8	19	Willow Lane Reservoir
3	Los Arboles	87	8.8	16	Pederson Reservoir
4	Las Flores	97	8.7	16	Pederson Reservoir
5	Gainsborough	99	8.5	16	Pederson Reservoir
6	Ventu Park	158	8	19	Ventu Park Reservoir
7	West Kelley	115	12	26	Kelley Reservoir

Highlighted rows are changed from the preceding scenario.

Scenario 4C Pump Station Level Controls

No.	Pumping Unit	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Erbes Rd Pump 1	10	15.5	Meadows Reservoir
2	Erbes Rd Pump 2	12.5	15.5	Lang Ranch Reservoir
3	Erbes Rd Pump 3	12	15	Lang Ranch Reservoir
4	Erbes Rd Pump 4	10.5	13.5	Lang Ranch Reservoir
5	Los Arboles Pump 1	8	14	Oakbrook Reservoir
6	Los Arboles Pump 2	7.9	13.9	Oakbrook Reservoir
7	Lone Oak to Wilder Pump 1	9	16	Wilder Reservoir
8	Lone Oak to Wilder Pump 2	8.5	15.5	Wilder Reservoir
9	Lone Oak to Wilder Pump 3	8	15	Wilder Reservoir
10	Lone Oak to La Grana Pump 1	12	22	La Granada
11	Lone Oak to La Grana Pump 2	11	21	La Granada
12	Lone Oak to La Grana Pump 3	12	22	La Granada
13	Lang Ranch Pump 1	8	14	Oakbrook Reservoir
14	Lang Ranch Pump 2	7	13	Oakbrook Reservoir
15	Pederson Pump 1	8	14.5	Tara Reservoir
16	Pederson Pump 2	8	14.5	Tara Reservoir
17	Pederson Pump 3	7	13.5	Tara Reservoir
18	Rolling Oaks Pump 1	8	19	Rolling Oaks Reservoir
19	Rolling Oaks Pump 2	7	18	Rolling Oaks Reservoir
20	Sunset 2 Pump 1	8.5	12.5	Sunset Reservoir No. 3
21	Sunset 2 Pump 2	8	12	Sunset Reservoir No. 3
22	Sunset 1 Pump 1	12	15	Sunset Reservoir No. 2
23	Sunset 1 Pump 2	11.5	14.5	Sunset Reservoir No. 2
24	Sunset 1 Pump 3	10	13	Sunset Reservoir No. 2
25	Wilder Pump 1	10	19	Grissom Reservoir No. 1
26	Wilder Pump 1	10	19	Grissom Reservoir No. 2
27	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 2
28	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 1
29	Willow Lane Pump 1	12	22	La Granada
30	Willow Lane Pump 2	10	20	La Granada
31	Willow Lane Pump 3	9	19	La Granada
32	La Granada Pump 1	9	16	Wilder Reservoir
33	La Granada Pump 2	8.5	15.5	Wilder Reservoir

Scenario 4C Turnout PRV Level Controls and Set Points

No.	Turnout PRV	Set Point (psi)	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Hillcrest	126	8	18.5	Willow Lane Reservoir
2	Encino Vista	75	8	19	Willow Lane Reservoir
3	Los Arboles	87	8.8	16	Pederson Reservoir
4	Las Flores	97	8.7	16	Pederson Reservoir
5	Gainsborough	99	8.5	16	Pederson Reservoir
6	Ventu Park	158	8	19	Ventu Park Reservoir
7	West Kelley	115	12	26	Kelley Reservoir

Highlighted rows are changed from the preceding scenario.

Scenario 5 Pump Station Level Controls

No.	Pumping Unit	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Erbes Rd Pump 1	10	15.5	Meadows Reservoir
2	Erbes Rd Pump 2	12.5	15.5	Lang Ranch Reservoir
3	Erbes Rd Pump 3	12	15	Lang Ranch Reservoir
4	Erbes Rd Pump 4	10.5	13.5	Lang Ranch Reservoir
5	Los Arboles Pump 1	8	14	Oakbrook Reservoir
6	Los Arboles Pump 2	7.9	13.9	Oakbrook Reservoir
7	Lone Oak to Wilder Pump 1	Inactive	Inactive	-
8	Lone Oak to Wilder Pump 2	Inactive	Inactive	-
9	Lone Oak to Wilder Pump 3	Inactive	Inactive	-
10	Lone Oak to La Grana Pump 1	10	12	La Granada
11	Lone Oak to La Grana Pump 2	10	12	La Granada
12	Lone Oak to La Grana Pump 3	9	11	La Granada
13	Lang Ranch Pump 1	8	14	Oakbrook Reservoir
14	Lang Ranch Pump 2	7	13	Oakbrook Reservoir
15	Pederson Pump 1	8	14.5	Tara Reservoir
16	Pederson Pump 2	8	14.5	Tara Reservoir
17	Pederson Pump 3	7	13.5	Tara Reservoir
18	Rolling Oaks Pump 1	8	19	Rolling Oaks Reservoir
19	Rolling Oaks Pump 2	7	18	Rolling Oaks Reservoir
20	Sunset 2 Pump 1	8.5	12.5	Sunset Reservoir No. 3
21	Sunset 2 Pump 2	8	12	Sunset Reservoir No. 3
22	Sunset 1 Pump 1	12	15	Sunset Reservoir No. 2
23	Sunset 1 Pump 2	11.5	14.5	Sunset Reservoir No. 2
24	Sunset 1 Pump 3	10	13	Sunset Reservoir No. 2
25	Wilder Pump 1	10	19	Grissom Reservoir No. 1
26	Wilder Pump 1	10	19	Grissom Reservoir No. 2
27	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 2
28	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 1
29	Willow Lane Pump 1	10	12	La Granada
30	Willow Lane Pump 2	10	12	La Granada
31	Willow Lane Pump 3	9	11	La Granada
32	La Granada Pump 1	9	16	Wilder Reservoir
33	La Granada Pump 2	8	15	Wilder Reservoir

Scenario 5 Turnout PRV Level Controls and Set Points

No.	Turnout PRV	Set Point (psi)	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Hillcrest	126	8	15.5	Willow Lane Reservoir
2	Encino Vista	74	8	16	Willow Lane Reservoir
3	Los Arboles	87	8.8	16	Pederson Reservoir
4	Las Flores	97	8.7	16	Pederson Reservoir
5	Gainsborough	99	8.5	16	Pederson Reservoir
6	Ventu Park	158	8	19	Ventu Park Reservoir
7	West Kelley	115	12	26	Kelley Reservoir

Highlighted rows are changed from the preceding scenario.

Scenario 6 Pump Station Level Controls

No.	Pumping Unit	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Erbes Rd Pump 1	10	15.5	Meadows Reservoir
2	Erbes Rd Pump 2	12.5	15.5	Lang Ranch Reservoir
3	Erbes Rd Pump 3	12	15	Lang Ranch Reservoir
4	Erbes Rd Pump 4	10.5	13.5	Lang Ranch Reservoir
5	Los Arboles Pump 1	8	14	Oakbrook Reservoir
6	Los Arboles Pump 2	7.9	13.9	Oakbrook Reservoir
7	Lone Oak to Wilder Pump 1	Inactive	Inactive	-
8	Lone Oak to Wilder Pump 2	Inactive	Inactive	-
9	Lone Oak to Wilder Pump 3	Inactive	Inactive	-
10	Lone Oak to La Grana Pump 1	10	16	La Granada
11	Lone Oak to La Grana Pump 2	9	15	La Granada
12	Lone Oak to La Grana Pump 3	10	16	La Granada
13	Lang Ranch Pump 1	8	14	Oakbrook Reservoir
14	Lang Ranch Pump 2	7	13	Oakbrook Reservoir
15	Pederson Pump 1	8	14.5	Tara Reservoir
16	Pederson Pump 2	8	14.5	Tara Reservoir
17	Pederson Pump 3	7	13.5	Tara Reservoir
18	Rolling Oaks Pump 1	8	19	Rolling Oaks Reservoir
19	Rolling Oaks Pump 2	7	18	Rolling Oaks Reservoir
20	Sunset 2 Pump 1	8.5	12.5	Sunset Reservoir No. 3
21	Sunset 2 Pump 2	8	12	Sunset Reservoir No. 3
22	Sunset 1 Pump 1	12	15	Sunset Reservoir No. 2
23	Sunset 1 Pump 2	11.5	14.5	Sunset Reservoir No. 2
24	Sunset 1 Pump 3	10	13	Sunset Reservoir No. 2
25	Wilder Pump 1	10	19	Grissom Reservoir No. 1
26	Wilder Pump 1	10	19	Grissom Reservoir No. 2
27	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 2
28	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 1
29	Willow Lane Pump 1	10	16	La Granada
30	Willow Lane Pump 2	10	16	La Granada
31	Willow Lane Pump 3	9	15	La Granada
32	La Granada Pump 1	9	16	Wilder Reservoir
33	La Granada Pump 2	8	15	Wilder Reservoir

Scenario 6 Turnout PRV Level Controls and Set Points

No.	Turnout PRV	Set Point (psi)	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Hillcrest	126	8	15	Willow Lane Reservoir
2	Encino Vista	73	8	15	Willow Lane Reservoir
3	Los Arboles	87	8.8	16	Pederson Reservoir
4	Las Flores	97	8.7	16	Pederson Reservoir
5	Gainsborough	99	8.5	16	Pederson Reservoir
6	Ventu Park	158	8	19	Ventu Park Reservoir
7	West Kelley	115	12	26	Kelley Reservoir

Highlighted rows are changed from the preceding scenario.

Scenario 7 Pump Station Level Controls

No.	Pumping Unit	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Erbes Rd Pump 1	10	15.5	Meadows Reservoir
2	Erbes Rd Pump 2	12.5	15.5	Lang Ranch Reservoir
3	Erbes Rd Pump 3	12	15	Lang Ranch Reservoir
4	Erbes Rd Pump 4	10.5	13.5	Lang Ranch Reservoir
5	Los Arboles Pump 1	8	14	Oakbrook Reservoir
6	Los Arboles Pump 2	7.9	13.9	Oakbrook Reservoir
7	Lone Oak to Wilder Pump 1	Inactive	Inactive	-
8	Lone Oak to Wilder Pump 2	Inactive	Inactive	-
9	Lone Oak to Wilder Pump 3	Inactive	Inactive	-
10	Lone Oak to La Grana Pump 1	10	12	La Granada
11	Lone Oak to La Grana Pump 2	10	12	La Granada
12	Lone Oak to La Grana Pump 3	9	11	La Granada
13	Lang Ranch Pump 1	8	14	Oakbrook Reservoir
14	Lang Ranch Pump 2	7	13	Oakbrook Reservoir
15	Pederson Pump 1	8	14.5	Tara Reservoir
16	Pederson Pump 2	8	14.5	Tara Reservoir
17	Pederson Pump 3	7	13.5	Tara Reservoir
18	Rolling Oaks Pump 1	8	19	Rolling Oaks Reservoir
19	Rolling Oaks Pump 2	7	18	Rolling Oaks Reservoir
20	Sunset 2 Pump 1	8.5	12.5	Sunset Reservoir No. 3
21	Sunset 2 Pump 2	8	12	Sunset Reservoir No. 3
22	Sunset 1 Pump 1	12	15	Sunset Reservoir No. 2
23	Sunset 1 Pump 2	11.5	14.5	Sunset Reservoir No. 2
24	Sunset 1 Pump 3	10	13	Sunset Reservoir No. 2
25	Wilder Pump 1	10	19	Grissom Reservoir No. 1
26	Wilder Pump 1	10	19	Grissom Reservoir No. 2
27	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 2
28	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 1
29	Willow Lane Pump 1	10	12	La Granada
30	Willow Lane Pump 2	10	12	La Granada
31	Willow Lane Pump 3	9	11	La Granada
32	La Granada Pump 1	9	16	Wilder Reservoir
33	La Granada Pump 2	8	15	Wilder Reservoir

Scenario 7 Turnout Flow Control Valve (FCV) Level Controls and Set Points

No.	Turnout FCV	Set Point (gpm)	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Hillcrest	1900	8	15.5	Willow Lane Reservoir
2	Encino Vista	2500	8	16	Willow Lane Reservoir
3	Los Arboles	1200	8.8	16	Pederson Reservoir
4	Las Flores	1200	8.7	16	Pederson Reservoir
5	Gainsborough	2500	8.5	16	Pederson Reservoir
6	Ventu Park	2500	7	13	Ventu Park Reservoir
7	West Kelley	200	8	26	Kelley Reservoir

Highlighted rows are changed from the preceding scenario.

Scenario 8 Pump Station Level Controls

No.	Pumping Unit	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Erbes Rd Pump 1	10	15.5	Meadows Reservoir
2	Erbes Rd Pump 2	12.5	15.5	Lang Ranch Reservoir
3	Erbes Rd Pump 3	12	15	Lang Ranch Reservoir
4	Erbes Rd Pump 4	10.5	13.5	Lang Ranch Reservoir
5	Los Arboles Pump 1	8	14	Oakbrook Reservoir
6	Los Arboles Pump 2	Inactive	Inactive	-
7	Lone Oak to Wilder Pump 1	Inactive	Inactive	-
8	Lone Oak to Wilder Pump 2	Inactive	Inactive	-
9	Lone Oak to Wilder Pump 3	Inactive	Inactive	-
10	Lone Oak to La Grana Pump 1	10	12	La Granada
11	Lone Oak to La Grana Pump 2	10	12	La Granada
12	Lone Oak to La Grana Pump 3	9	11	La Granada
13	Lang Ranch Pump 1	8	14	Oakbrook Reservoir
14	Lang Ranch Pump 2	8	14	Oakbrook Reservoir
15	Lang Ranch Pump 3	8	14	Oakbrook Reservoir
16	Pederson Pump 1	8	14.5	Tara Reservoir
17	Pederson Pump 2	8	14.5	Tara Reservoir
18	Pederson Pump 3	7	13.5	Tara Reservoir
19	Rolling Oaks Pump 1	8	19	Rolling Oaks Reservoir
20	Rolling Oaks Pump 2	7	18	Rolling Oaks Reservoir
21	Sunset 2 Pump 1	8.5	12.5	Sunset Reservoir No. 3
22	Sunset 2 Pump 2	8	12	Sunset Reservoir No. 3
23	Sunset 1 Pump 1	12	15	Sunset Reservoir No. 2
24	Sunset 1 Pump 2	11.5	14.5	Sunset Reservoir No. 2
25	Sunset 1 Pump 3	10	13	Sunset Reservoir No. 2
26	Wilder Pump 1	10	19	Grissom Reservoir No. 2
27	Wilder Pump 1	10	19	Grissom Reservoir No. 1
28	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 2
29	Wilder Pump 2	9.5	18.5	Grissom Reservoir No. 1
30	Willow Lane Pump 1	10	12	La Granada
31	Willow Lane Pump 2	10	12	La Granada
32	Willow Lane Pump 3	9	11	La Granada
33	La Granada Pump 1	9	16	Wilder Reservoir
34	La Granada Pump 2	8	15	Wilder Reservoir

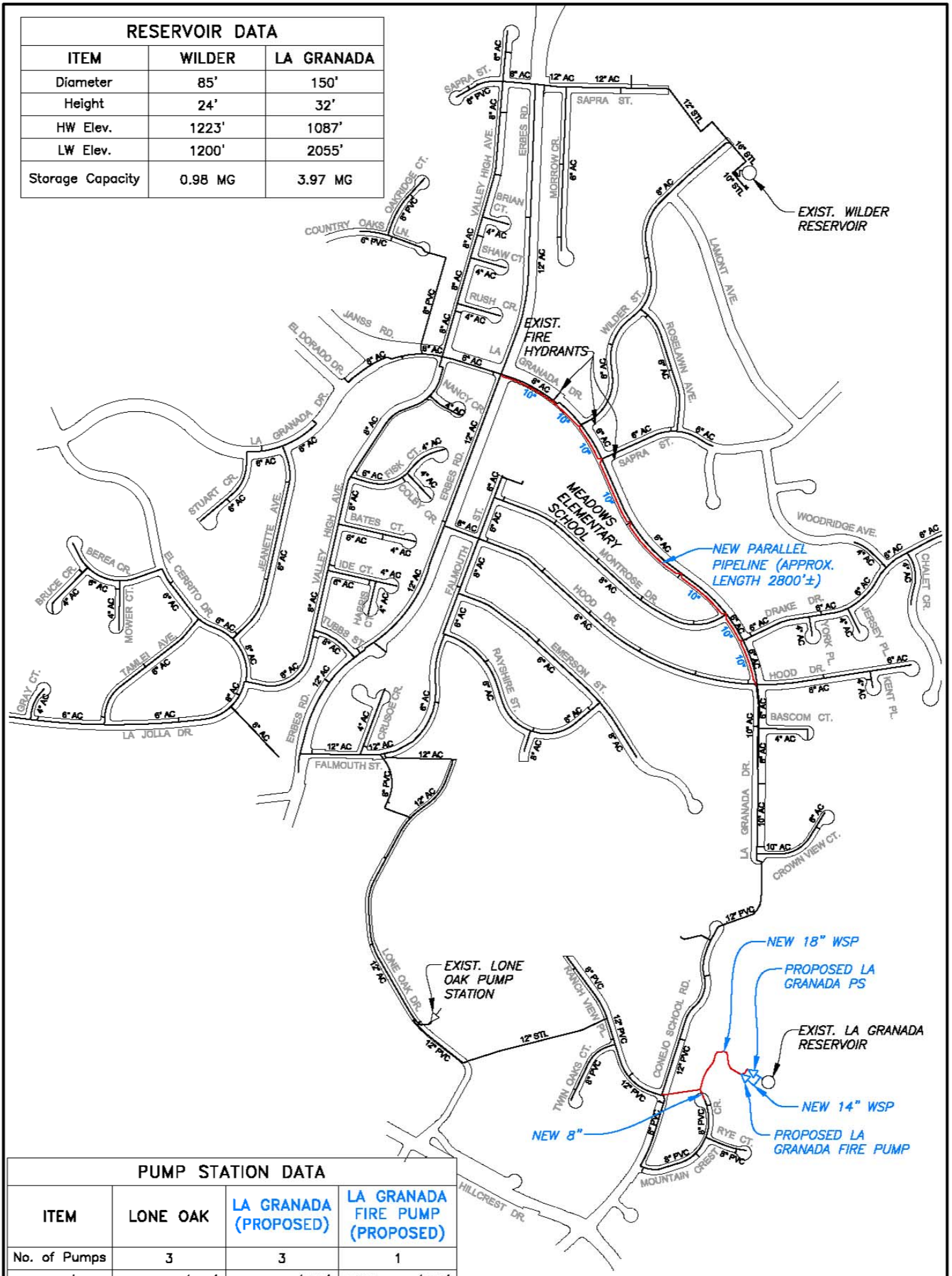
Scenario 8 Turnout Flow Control Valve (FCV) Level Controls and Set Points

No.	Turnout FCV	Set Point (gpm)	Low Level Control (ft)	High Level Control (ft)	Controlling Reservoir
1	Hillcrest	1900	8	15.5	Willow Lane Reservoir
2	Encino Vista	2500	8	16	Willow Lane Reservoir
3	Los Arboles	1200	8.8	16	Pederson Reservoir
4	Las Flores	1200	8.7	16	Pederson Reservoir
5	Gainsborough	2500	8.5	16	Pederson Reservoir
6	Ventu Park	2500	7	13	Ventu Park Reservoir
7	West Kelley	200	8	26	Kelley Reservoir

Highlighted rows are changed from the preceding scenario.

Appendix H: Proposed La Granada Project Site Map

RESERVOIR DATA		
ITEM	WILDER	LA GRANADA
Diameter	85'	150'
Height	24'	32'
HW Elev.	1223'	1087'
LW Elev.	1200'	2055'
Storage Capacity	0.98 MG	3.97 MG



PUMP STATION DATA			
ITEM	LONE OAK	LA GRANADA (PROPOSED)	LA GRANADA FIRE PUMP (PROPOSED)
No. of Pumps	3	3	1
P1 Flow/Head	700 gpm/220'	750 gpm/200'	4000 gpm/230'
P2 Flow/Head	600 gpm/220'	750 gpm/200'	
P3 Flow/Head	700 gpm/220'	750 gpm/200'	

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