Tri-Valley Agencies

Joint Tri-Valley Potable Reuse Technical Feasibility Study

FINAL | MAY 2018

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LIVERMORE-AMADOR VALLEY
ZONE 7
WATER SUPPLY • FLOOD PROTECTION

Dublin San Ramon Services District
Water, wastewater, recycled water

CALIFORNIA WATER SERVICE

THE CITY OF PLEASANTON

Tri-Valley Agencies
Potable Reuse Feasibility Study

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Joint Tri-Valley
Potable Reuse Feasibility Study

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Abbreviations

AC	Acre
ADWF	Average Dry Weather Flow
AF	Acre-feet
AFM	Acre-Feet Per Month
AFY	Acre-foot per year
AOP	Advanced Oxidation Processes
ASR	Aquifer Storage and Recover
ATP	Adenosine Triphosphate
AWPF	Advanced Water Purification Facilities
AWTF	Advanced Water Treatment Facility
BAC	Biological Activated Carbon
BPI	Blue Plan-it®
Bq	Becquerel
Carollo	Carollo Engineers, Inc.
CalEPA	California Environmental Protection Agency
CCCSD	Central Contra Costa Sanitary District
CDPH	California Department of Public Health
CECs	Contaminants of Emerging Concern
CFR	Code of Federal Regulations
Ci	Curie
CIP	Capital Improvement Projects
CIWQS	California Integrated Water Quality System
COLs	Chain of Lakes
CRMWD	Colorado River Municipal Water District
Ct	Contact Time
CTR	California Toxic Rule
CWS	Clean Water Services

DBPs	Disinfection byproducts
DDW	California Division of Drinking Water
DEET	N,N-Diethyl-meta-toluamide
DERWA	DSRSD-EBMUD Recycled Water Authority
DPR	Direct Potable Reuse
DSRSD	Dublin San Ramon Sanitation District
DVWTP	Del Valle Water Treatment Plant
EBDA	East Bay Dischargers Authority
EBMUD	East Bay Municipal Utility District
EC	Electrical Conductivity
EPHC	Environment Protection and Health Council
ESB	Engineered Storage Buffers
ESCP	Enhanced Source Control Program
FAT	Full Advanced Treatment
FAT+	Full advanced treatment plus additional treatment
FGF	Forest Grove Facility
FRT	Failure and Response Time
ft	Feet
GAC	Granular Activated Carbon
GMF	Granular Media Filtration
GRRP	Groundwater Replenishment Reuse Projects
GWRS	Groundwater Replenishment System
HAAs	Haloacetic acids
IPR	Indirect Potable Reuse
LACSD	Los Angeles County Sanitation District
LACDPW	Los Angeles County Department of Public Works
LASAN	Los Angeles Sanitation
LAVQAR	Livermore-Amador Valley Quarry Area Reclamation
LAVWMA	Livermore-Amador Valley Water Management Agency

LF	Lineal feet
LLNL	Lawrence Livermore National Laboratory
LRCs	Log Removal Credits
LRV	Log Removal Value
LT2	Long Term 2
LWRP	Livermore Water Reclamation Plant
MCL	Maximum Contaminant level
MF	Microfiltration
MG	Million gallons
mg/L	milligrams per liter
mgd	million gallons per day
MIT	Membrane Integrity Testing
MPN	Most Probable Number
msl	Mean sea level
O&M	Operations and maintenance
NDMA	N-Nitrosodimethylamine
NF	Nanofiltration
NL	Notification Level
NHMRC	National Health and Medical Research Council
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NRMMC	National Resource Management Ministerial Council
NTU	Nephelometric Turbidity Unit
OCWD	Orange County Water District
PFOA	Perfluoro-octanoic acid
PFOS	Perfluoro-octane sulfonate
POC	Pollutants of Concern
PPWTP	Patterson Path Water Treatment Plant
Q	Flow

QMRA	Quantitative Microbial Risk Assessment
RO	Reverse Osmosis
RRT	Response Retention Times
RW	Recycled Water
RWC	Recycled Water Contribution
RWPF	Raw Water Production Facility
RWQCB	Regional Water Quality Control Board
SNL	Sandia National Laboratory
SRT	Solids Retention Time
SRVRWP	San Ramon Valley Recycled Water Program
SWA	Surface Water Augmentation
SWMORs	Surface Water Monthly Operating Reports
SWP	State Water Project
SWRCB	State Water Resources Control Board
SWTP	Surface Water Treatment Plant
SWTR	Surface Water Treatment Rule
TAT	Turnaround Time
TCEP	Tris (2-chloroethyl) phosphate
TDS	Total Dissolved Solids
TEQ	Toxic Equivalents
THMs	Trihalomethanes
TI	Terminal Island
TM	Technical Memorandum
TMF	Technical, Managerial, and Financial
TOC	Total Organic Carbon
TOrC	Trace Organic Constituents
UF	Ultrafiltration
USEPA	United States Environmental Protection Agency
UV	Ultraviolet

UV AOP	Ultraviolet advanced oxidation process
WERF	Water Environment & Reuse Foundation
WHO	World Health Organization
WRD	Water Replenishment District
WRP	Water Reclamation Plant
WRRF	WateReuse Research Foundation
WSE	Water surface elevation
WTP	Water treatment plant
WWTP	Wastewater Treatment Plant Operation
µg/L	micrograms per liter
Zone 7	Zone 7 Water Agency

EXECUTIVE SUMMARY AND NEXT STEPS

Introduction and Purpose

The Water Supply Evaluation Update (2016 WSE Update) completed by Zone 7 Water Agency (Zone 7) in February 2016 underscored the need to pursue water supply options to enhance long-term water supply reliability for the Livermore-Amador Valley (Tri-Valley). Potential future water supply options identified in the WSE Update include the California WaterFix, desalination, and potable reuse. On February 11, 2016, participants in the Tri-Valley Water Policy Roundtable—including elected representatives from the cities of Dublin, Livermore, Pleasanton, San Ramon, DSRSD, and Zone 7—agreed to proceed in a more detailed study of potable reuse, which would be a local and drought-resistant supply. In response, the Tri-Valley Water Agencies, described further below, jointly funded and oversaw the effort to complete the Joint Tri-Valley Potable Reuse Technical Feasibility Study.

The primary goals of this study are: 1) to evaluate the feasibility of a wide range of potable reuse options for the Tri-Valley based on technical, financial, and regulatory considerations and 2) assuming that potable reuse is found to be technically feasible, to recommend next steps for the agencies.

Project Participants

The study is being conducted by the Tri-Valley Water Agencies. Each agency plays a role in water treatment and distribution, and/or wastewater collection and treatment, and recycled water production and distribution. The agencies and corresponding roles are as follows:

- **California Water Service (Cal Water)** – Water retailer within the Livermore District.
- **City of Livermore** – Water retailer and provider of wastewater collection/treatment services for the residents within its service area.
- **City of Pleasanton** – Water retailer and provider of wastewater collection services within its service area.
- **Dublin San Ramon Services District (DSRSD)** – Water retailer within its service area. Provider of wastewater collection and treatment services for Dublin and southern San Ramon, and wastewater treatment for Pleasanton. DSRSD and East Bay Municipal Utility District (EBMUD) formed the San Ramon Valley Recycled Water Program (SRVRWP). The program provides tertiary-treated recycled water to DSRSD, EBMUD, and Pleasanton irrigation customers at 558 locations.
- **Zone 7 Water Agency (Zone 7)** – Wholesale water provider to the Cities of Livermore, Pleasanton, Dublin, and a portion of San Ramon[1] through the water retailer agencies listed above. Zone 7 also manages the local groundwater basin as the Groundwater Sustainability Agency for the Livermore Valley Groundwater Basin. Furthermore, Zone 7 provides flood protection in eastern Alameda County.

A map showing the service areas is shown in Figure ES.1.

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[1] Served through an out-of-service area agreement with DSRSD.

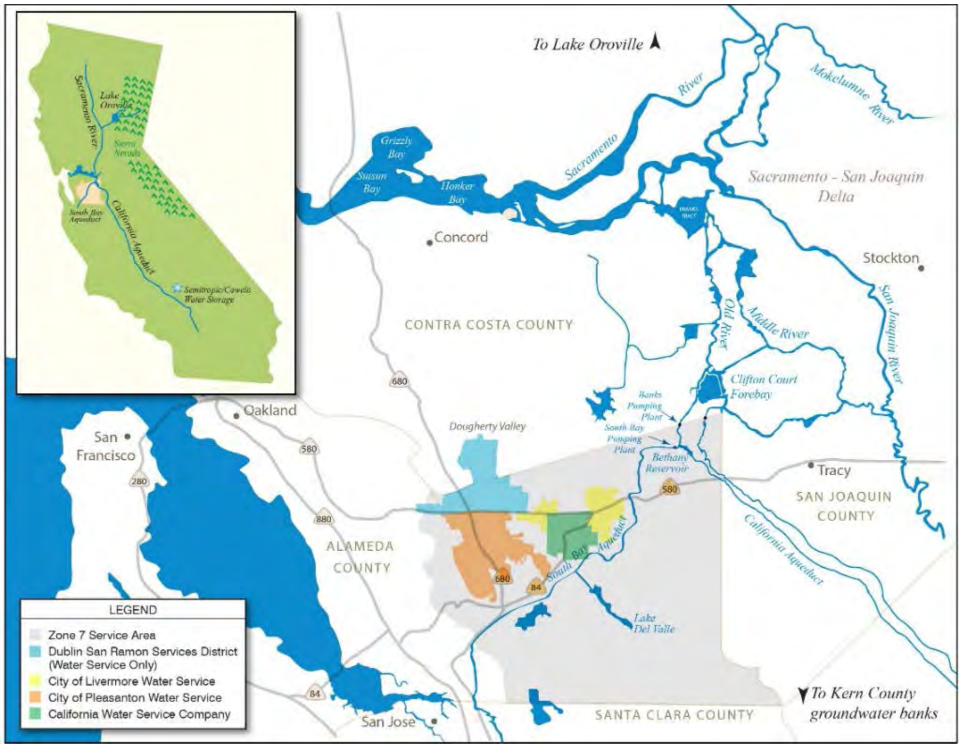


Figure ES.1 Tri-Valley Water Agencies and Service Areas

Range of Water Supply Yield

The 2016 WSE Update evaluated a number of water supply portfolios including a combination of the following potential new supplies: California WaterFix, desalination, and potable reuse. Los Vaqueros was also included as a potential new storage location. Desalination and potable reuse were assumed to have yields of 5,600 acre-feet per year (AFY) and 7,800 AFY, respectively. For the purposes of this study, an upper bookend of 10,000 AFY was assumed for potable reuse, which was also consistent with projected wastewater availability, as discussed further below. A lower bookend of 5,500 AFY was used.

Existing Facilities and Regulations

Zone 7 supplies water to the Tri-Valley using raw imported water (State Water Project), local water (Arroyo Valle), and groundwater. Raw water is treated at either the Patterson Pass Water Treatment Plant (PPWTP) or the Del Valle Water Treatment Plant (DVWTP) before distribution (locations shown in Figure ES.2). Zone 7's wells are primarily located in the western portion of the service area. Some groundwater in the Mocho Wellfield area with high total dissolved solids (TDS) is treated through a demineralization plant before distribution. Additional Zone 7 water facilities include the Chain of Lakes (COL), a series of existing or former gravel quarries that are in the process of reclamation or have been reclaimed as water storage and/or recharge lakes (Figure ES.2). Zone 7 currently owns Cope Lake and Lake I, with the rest of the ten lakes due to be transferred to Zone 7 in the future. Lake H is expected to be transferred for Zone 7's use over the next few years. Zone 7 will use the COL for a variety of water resource management activities.

Existing wastewater facilities include the DSRSD wastewater treatment plant (WWTP) and the Livermore Water Reclamation Plant (LWRP) as shown in Figure ES.2. Both DSRSD and Livermore have existing non-potable recycled water irrigation programs. Secondary effluent that is not used for producing recycled water is discharged to the San Francisco Bay through the Livermore-Amador Valley Water Management Agency (LAVWMA) and East Bay Dischargers Authority (EBDA) facilities.

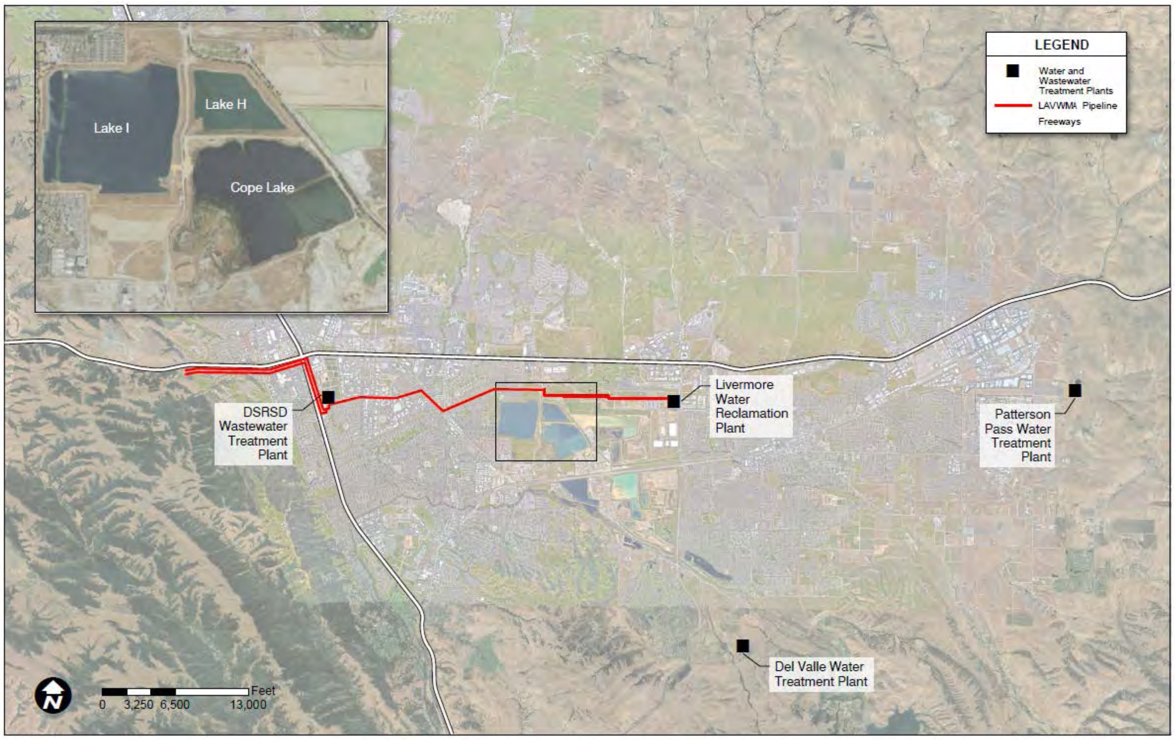


Figure ES.2 Existing Water and Wastewater Facilities

Potable Reuse Status and Regulations

Potable reuse has been utilized successfully by California agencies over 30 years as a means to extend water supplies. Other states have also successfully implemented potable reuse while being protective of public health. Project-specific permits for potable reuse have been issued in California for many years, although now regulations are clearly defined for groundwater recharge by the 2014 Groundwater Replenishment Reuse Projects (GRRPs) requirements included in Title 22 and the surface water augmentation SWA regulations were adopted following a released for public comment period in March 2018. The September 2016 draft report by the State Water Resources Control Board (SWRCB), titled "Investigation on the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse," found that it is feasible to develop uniform water recycling criteria that would incorporate a level of public health protection as good as or better than what is currently provided in California by conventional drinking water supplies (SWRCB, 2016). The state is now moving forward with developing regulations for other types of potable reuse.

The term "potable reuse" incorporates all types of reuse whereby recycled water is safely incorporated into potable water supplies. For the purposes of this study, the term "potable reuse" refers to the practice of using purified water derived from wastewater effluent to supplement water supplies. Specific terminology that will be used in this study are:

Groundwater Augmentation or Recharge: planned use of purified recycled water for replenishment of a groundwater basin or an aquifer that has been designated as a source of water supply for a public water system.

Raw Water Augmentation (RWA): planned placement of purified recycled water into a system of pipelines or aqueducts that deliver raw water to a drinking water treatment plant that provides water to a public water system.

Treatment Technology

An advanced water purification facility (AWPF) is required for any potable reuse operation. Potable reuse uses multiple barriers for reliable purification. The multiple barriers concept was designed to ensure public health and the reliability of the process. Each treatment technology has different capabilities in removing pathogens, contaminants of emerging concern, and meeting drinking water standards so combining them adds layers of safety as shown in Figure ES.3 and Table ES.1.

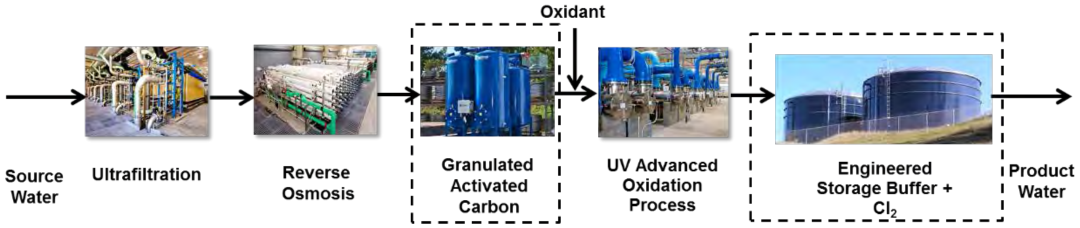


Figure ES. 3 AWPF Treatment Train (Dash lines show additional treatment assumed for RWA)

Table ES.1 Treatment Technologies Target Removal and Multiple Barrier Concept

Target	UF	RO	GAC	UV AOP	ESB + Cl_2
Protozoa	X	X		X	
Virus		X		X	X
MCLs		X	X	X	
CECs		X	X	X	

A treatment train that meets regulatory guidance for groundwater recharge has been established by Title 22, termed Full Advanced Treatment (FAT). This widely accepted and regulatory approved treatment process train for potable reuse is membrane filtration (MF/UF, micro or ultra-filtration), reverse osmosis (RO), followed by an ultraviolet light/advanced oxidation processes (UV/AOP) step. The proposed treatment train for Raw Water Augmentation involves the addition of Granular Activated Carbon (GAC) after the RO process to prevent any contaminant spikes that might pass through the RO from getting to the finished water. An engineered storage buffer (ESB) is also included at the end of the treatment train. This ESB is a series of three tanks, which provides additional monitoring time to be able to respond to any issue in the treatment train upstream. This treatment train, called FAT+, when combined with the downstream WTPs, greatly exceeds expected regulatory goals.

Alternative Development Method

Due to the numerous possibilities of potable reuse projects, with various source water, treatment locations, and end uses, a step-wise decision process was used to evaluate the potential Tri-Valley potable reuse projects, as is shown in Figure ES.4. At key stages in the selection process, workshops with representatives from all project participants were convened to facilitate key decisions. The effort was designed to develop a "book-end" of options to be considered with the end goals of improving water supply reliability, protecting water quality, and being fiscally responsible.

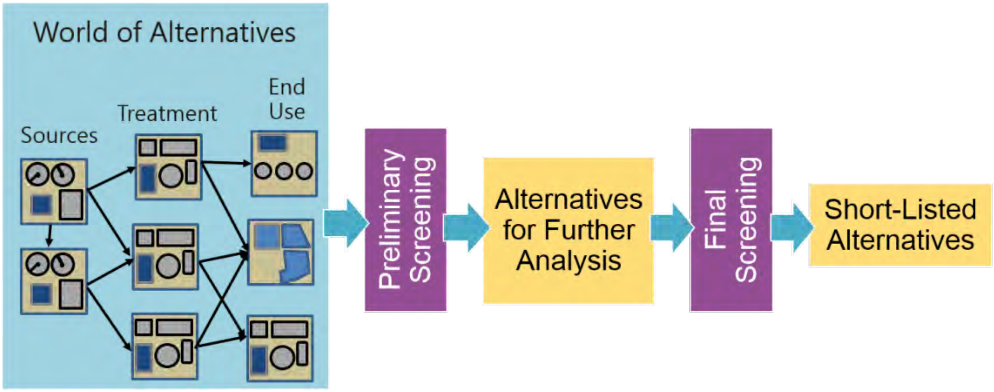


Figure ES.4 Alternative Development Process

Evaluation Criteria

The following evaluation criteria were used in the screening of project alternatives:

- Yield (measured by acre-feet per year - AFY).
- Cost (Capital and Operations & Maintenance [O&M]).
- Improved Supply Reliability.
- Improved Delivered Water Quality.
- Improved Groundwater Basin Quality.
- Clear Regulatory Pathway.
- Minimizes Neighborhood Impacts.
- Ability to Phase the Project.
- Operational Flexibility.
- Ease of Construction.

Alternatives Development

Alternatives were developed by combining source of water, treatment locations, and different end uses as discussed below.

Source Water and Potential Yield

There are two sources of water for the purified water projects, LWRP and DSRSD WWTP. These two WWTPs have existing non-potable recycled water programs. These programs limit the amount of available flow for the AWPF. The available flow for potable reuse is seasonally variable and depending on the use of the source can affect the yield of the project as shown in Figure ES.5.

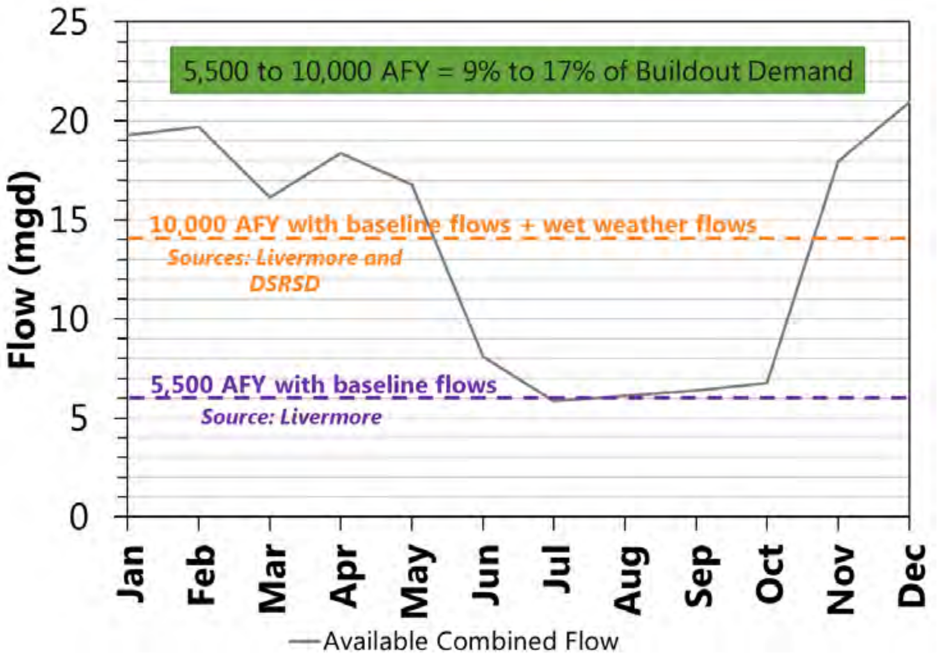


Figure ES.5 Projected Available Secondary Effluent Flows and Yields

Potential Treatment Locations and End Uses

Criteria for selecting treatment locations included available space, proximity to source water, proximity to end uses, and site accessibility. With these criteria in mind, five preliminary options were chosen for potential AWPF location as shown in Figure ES.6:

- DSRSD – in space currently used as a dedicated land disposal (DLD).
- LWRP – in the abandoned on-site facultative sludge lagoons (FSLs).
- Mocho – near Zone 7's existing Mocho Demineralization Facility.
- Chain of Lakes (COL).
- Pleasanton Corp Yard.

This study investigated three potential end uses for purified water:

- Groundwater augmentation or recharge via injection wells at two locations - one in the eastern side of the basin in Livermore and one in the western side in Pleasanton near the Mocho Demineralization facility.
- Groundwater recharge via Lake I (Chain of Lakes) surficial recharge.
- Raw water augmentation via Chain of Lakes to DVWTP (or directly to DVWTP).

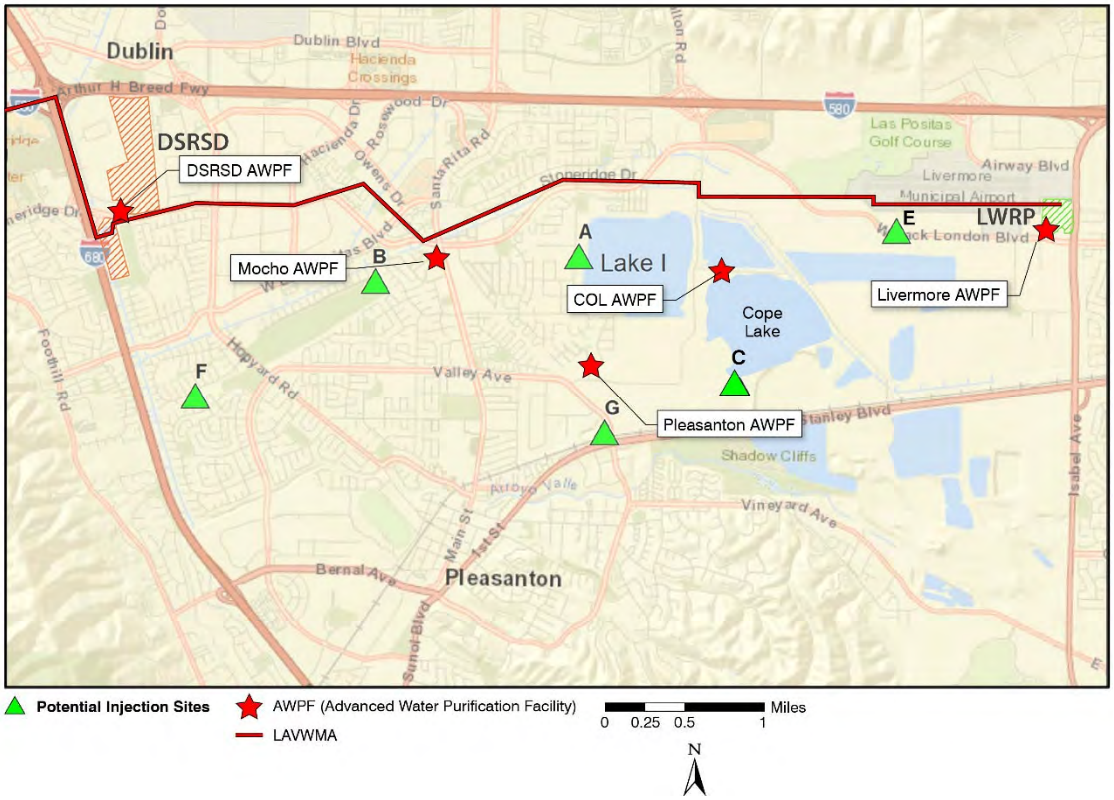


Figure ES.6 Five Potential Purification Facility Locations

The groundwater injection sites were identified based on proximity to treatment location, distance from production wells, potential to improve groundwater quality, and estimated transmissivity. These locations were evaluated using Zone 7's groundwater model to meet regulatory requirements for travel time to municipal wells.

The COL can be used in two separate ways – as a surficial recharge for the aquifer (via Lake I) or as a holding point before delivery to DVWTP (via Cope Lake and a planned COL pipeline). Since there is an existing connection between Lake I and Cope Lake, alternatives which send water to one of the lakes can, in effect, use both lakes as potential end uses. Another potential alternative is direct delivery of purified water upstream of the DVWTP, bypassing the COL.

Summary of Findings

Based on the book-end approach of considering alternatives, the major findings of this study are:

- Potable reuse for the Tri Valley is technically feasible. There were no fatal flaws identified by this technical evaluation.
- All alternatives increase water supply reliability, with the degree of benefit varying depending on yield (5,500 – 10,000 AFY) and, to a limited extent, end use (e.g., via groundwater recharge versus raw water augmentation).
- All alternatives improve drinking water quality and some improve the overall groundwater basin quality.
- There are good options available to site the AWPF facility.
- Regulatory pathways exist for all options.

- There is some variability in the overall operational flexibility and constructability depending on the option.
- Cost ranges for the book-end options:
  - Capital costs = $103 to $222 million.
  - Operations and Maintenance Costs = $6.5 to $9M/year.
  - Overall unit costs = $2,200-2,500/AF.

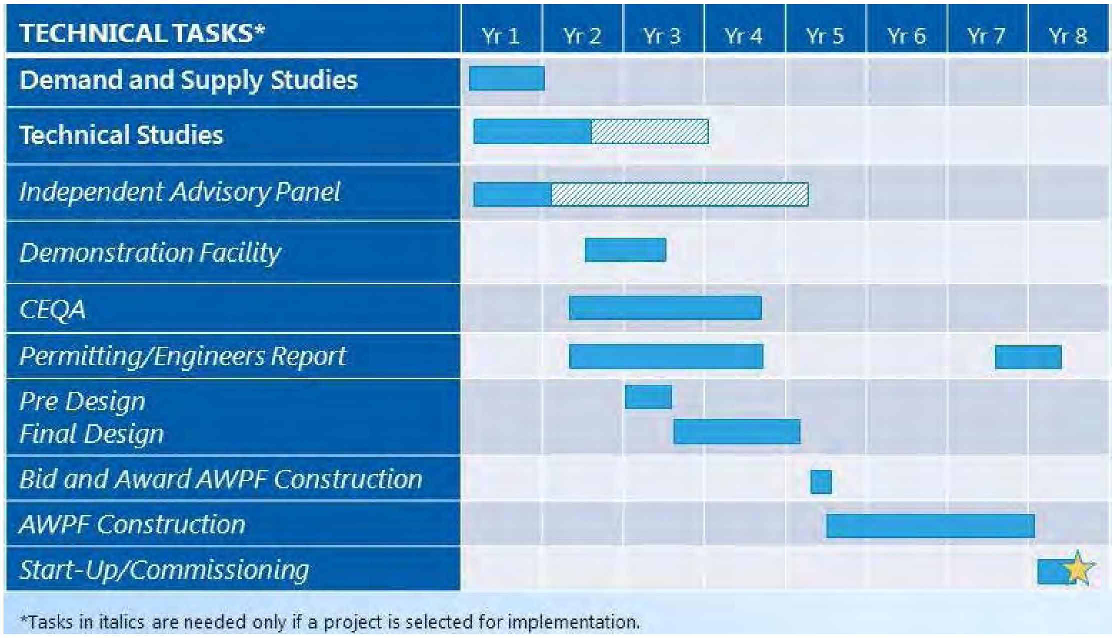
Recommendations/Next Steps

If the partnering agencies wish to continue pursuing potable reuse, there are a number of technical efforts necessary. In the near-term, to narrow the best end use option, further studies and other efforts are needed to evaluate the best candidates for siting injection wells; to characterize the potential for contaminant mobilization in the groundwater basin using models and field test; and to determine the ability of the COL to receive, store, and recharge purified water in conjunction with other potential uses of the COL.

A broader effort refining regional demand projections would also help determine the need for the various water supply options available to the Tri-Valley—including potable reuse—and the target yield for those options. To place potable reuse in the context of other water supply options, the 2016 WSE update should be updated to reflect the findings from this study as well as new data and options that have developed since 2016.

Figure ES. 7 presents one potential timeline for next step technical efforts and implementation of a potable reuse project showing a project could be online within 8 years if desired.

While this study focused on technical issues, there are also major institutional and public outreach components to potable reuse implementation that would need to be addressed. These components would support decision making and potential future efforts associated with a potable reuse project.



*Tasks in italics are needed only if a project is selected for implementation.

Figure ES.7 Potential Next Steps: Conceptual Timeline

Chapter 1

BACKGROUND AND INTRODUCTION

1.1 Project Purpose

The Water Supply Evaluation Update (2016 WSE Update) completed by Zone 7 Water Agency (Zone 7) in February 2016 underscored the need to pursue water supply options to enhance long-term water supply reliability for the Livermore-Amador Valley. Potential future water supply options identified in the WSE Update include the California WaterFix, desalination, and potable reuse. On February 11, 2016, participants in the Tri-Valley Water Policy Roundtable—including elected representatives from the cities of Dublin, Livermore, Pleasanton, San Ramon, Dublin San Ramon Services District (DSRSD), and Zone 7—agreed to proceed in a more detailed study of potable reuse, which would be a local and drought-resistant supply. In response, the Tri-Valley Water Agencies, described further below, jointly funded and oversaw the effort to complete the Joint Tri-Valley Potable Reuse Technical Feasibility Study.

The primary goals of this study are: 1) to evaluate the feasibility of a wide range of potable reuse options for the Tri-Valley based on technical, financial, and regulatory considerations and 2) assuming that potable reuse is found to be technically feasible, to recommend next steps for the agencies.

1.2 Project Participants

The study was conducted by the Tri-Valley Water Agencies. Each agency plays a role in water treatment and distribution, and/or wastewater collection and treatment, and recycled water production and distribution. The agencies and corresponding roles are as follows:

- **California Water Service (Cal Water)** – Water retailer within the Livermore District.
- **City of Livermore** – Water retailer and provider of wastewater collection/treatment services for the residents within its service area.
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[1] Served through an out-of-service area agreement with DSRSD.

A map showing the overlapping service areas is shown in Figure 1.1.

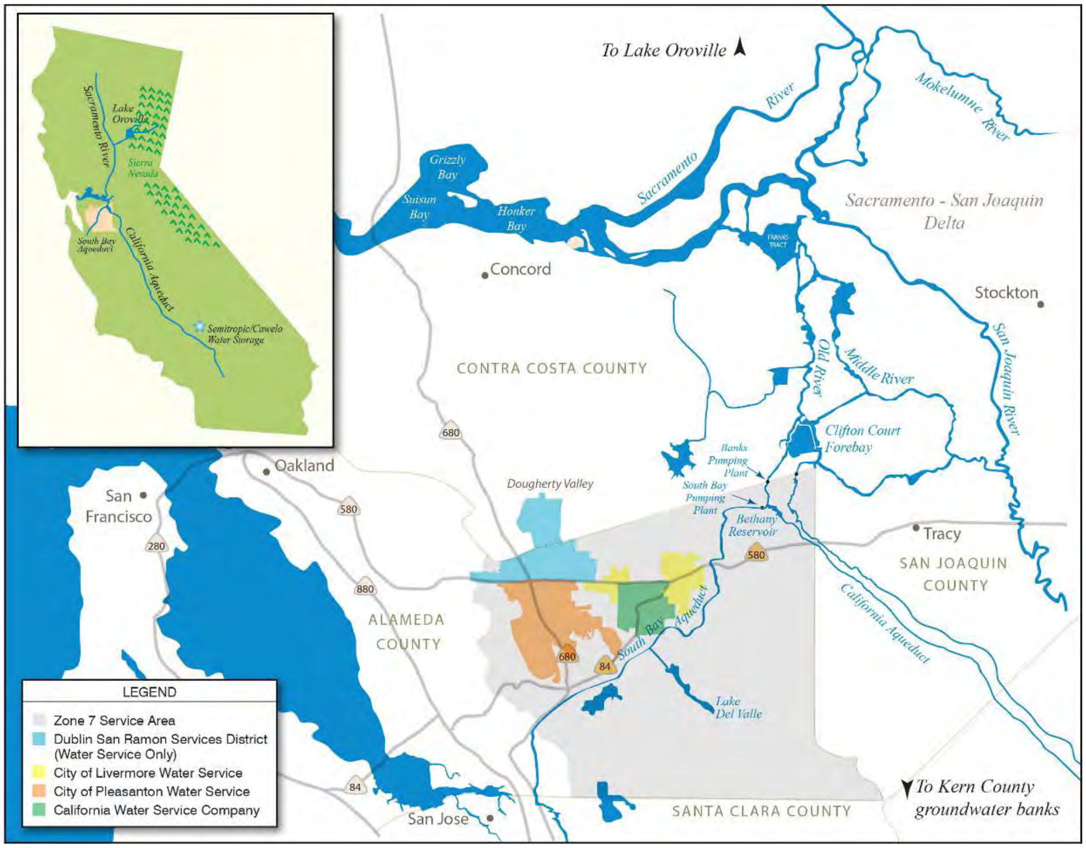

Figure 1.1 Tri-Valley Water Agencies and Service Areas

1.3 Project Location

The project is located in the Livermore-Amador Valley, also commonly referred to as the Tri-Valley, 18 miles southeast of Oakland and 33 miles from San Francisco. A vicinity map is provided in Figure 1.1.

1.4 Existing Facilities and Groundwater Basin

Figure 1.2 shows the existing water and wastewater facilities within the Tri-Valley Area, including the Zone 7 water treatment plants, the DSRSD wastewater treatment plant (WWTP), Livermore Water Reclamation Plant (LWRP), and water supply wells. Both DSRSD and Livermore have existing non-potable recycled water irrigation programs. Secondary effluent that is not used for non-potable recycled water irrigation is discharged to the San Francisco Bay through the Livermore-Amador Valley Water Management Agency (LAVWMA) and East Bay Dischargers Authority (EBDA) facilities.

Figure 1.2 also shows the boundaries of the Livermore-Amador Valley Groundwater Basin along with the major wells that draw from the basin for municipal and domestic supply.

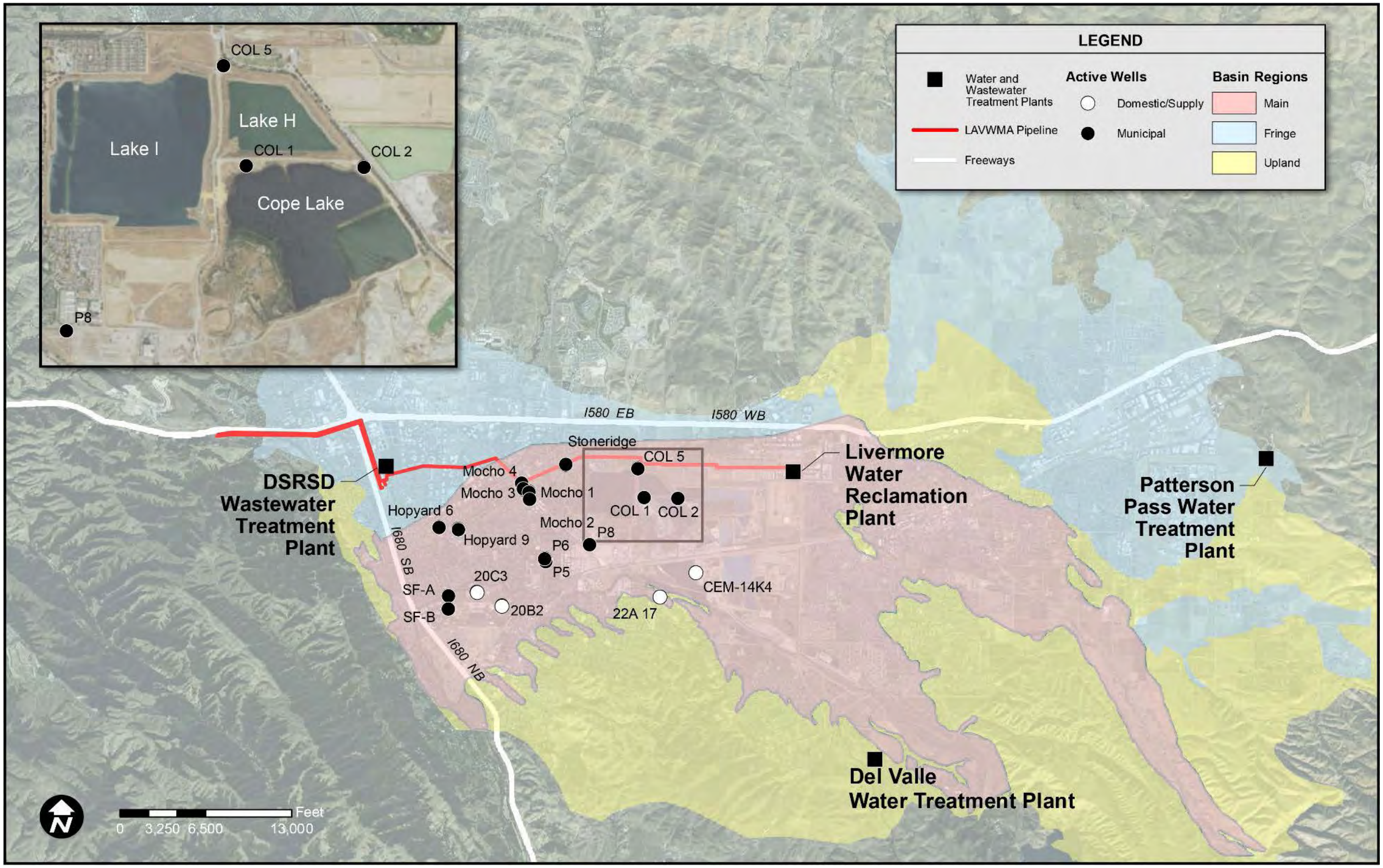

Figure 1.2 Existing Water and Wastewater Facilities

Treated wastewater from DSRSD WWTP and Livermore WRP flows to a junction box downstream of the plants and is conveyed to the LAVWMA reservoirs and export pump station adjacent to the DSRSD WWTP. The treated wastewater is pumped from the reservoirs into the LAVWMA export pipeline, over Boehmer Summit and discharged into the EBDA outfall pipeline. The EBDA pipeline conveys the effluent from LAVWMA and five other wastewater agencies (Town of Castro Valley, City of Hayward, Oro Loma Sanitary District, City of San Leandro, and Union Sanitary District) to a deep-water discharge outfall in San Francisco Bay. Under wet weather conditions and specific hydraulic conditions in the EBDA pipeline, LAVWMA can discharge to San Lorenzo Creek and Alamo Canal.

The existing water supply system for Zone 7 consists of two surface water treatment plants (WTPs) that treat State Water Project (SWP) water, local surface water (Arroyo Valle), and transfer water; and ten municipal groundwater production wells distributed over four well fields. A demineralization facility, located near the Mocho well field, uses reverse osmosis to lower total dissolved solids (TDS) in groundwater extracted from the Mocho well field prior to distribution. In addition, Zone 7 currently owns Cope Lake and Lake I, which are part of the Chain of Lakes (COL). The COL is a series of current or former gravel quarries that have been reclaimed or will be reclaimed for water management purposes. Of these ten lakes, so far Lake I and Cope Lake have been transferred over to Zone 7. Lake H will be transitioned to Zone 7 over the next few years. Zone 7 plans to use the COL for various water resource management activities such as groundwater recharge, surface water storage and conveyance, and flood management. The various Zone 7 water facilities are shown in Figure 1.3.

1.5 Risk & Reliability Tool & Project Goal

To enhance their planning studies and future projections, Zone 7 has developed a Water Supply Risk Model that assesses potential impacts to system-wide water supply reliability and water shortage risk under various water supply portfolios. The model uses Monte Carlo simulations. This model was used in the 2016 Water Supply Evaluation Update (Zone 7, 2016), and was used in this study as well. The WSE Update included analysis of Portfolio B, which included ‘purified recycled water’ or potable reuse. In this study, this portfolio is updated with the results of the more detailed analysis to evaluate the impacts on water supply reliability.

In the WSE Update, desalination and potable reuse were assumed to have yields of 5,600 acre-feet per year (AFY) and 7,800 AFY, respectively. For the purposes of this study, an upper bookend of 10,000 AFY was assumed for potable reuse, which was also consistent with projected wastewater availability, as discussed further below. A lower bookend of 5,500 AFY was used based on available year round supply.

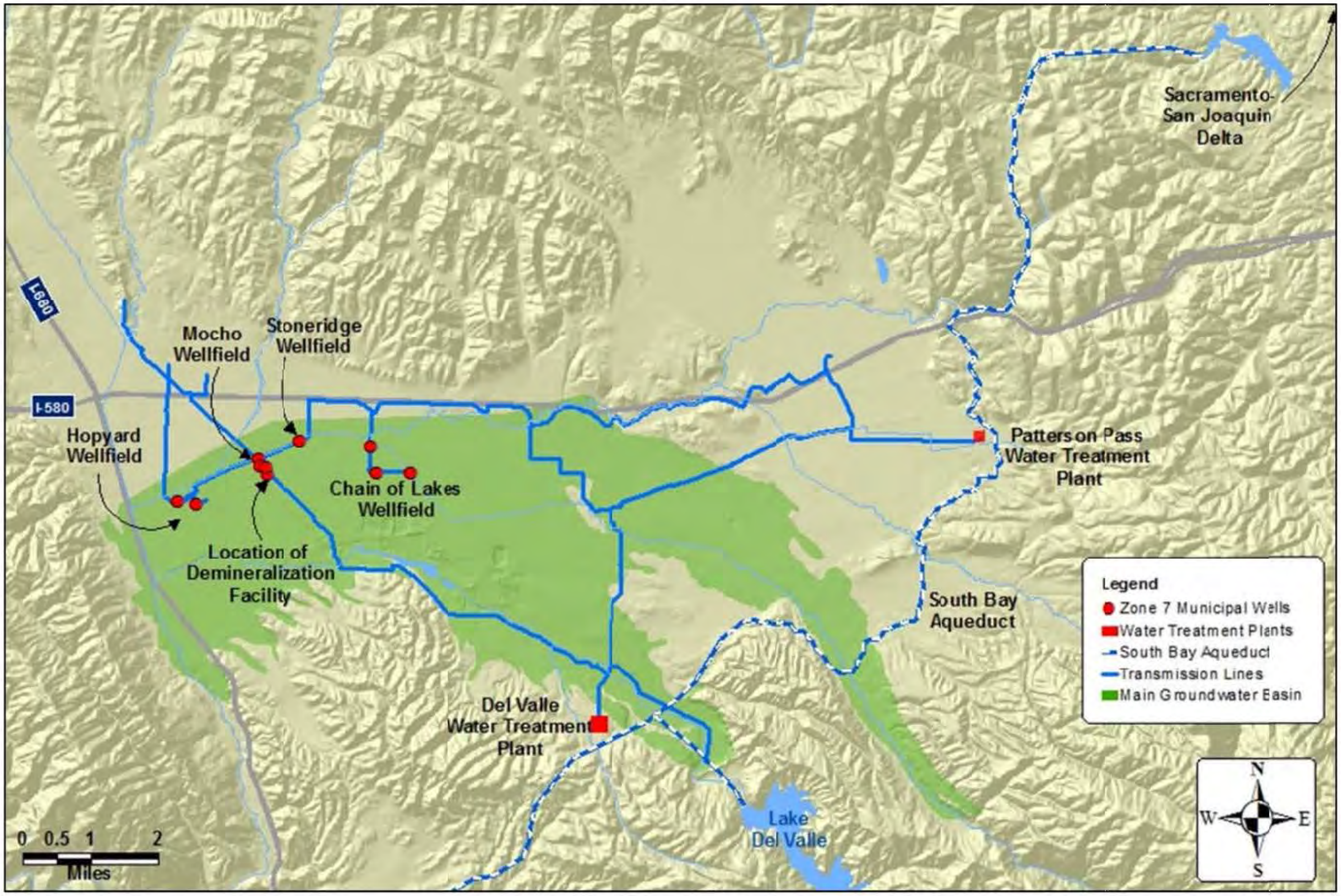

Figure 1.3 Zone 7 Water System Facilities

1.6 Alternative Development Method

Within the Tri-Valley area, there are several options for source water, treatment type, treatment location, and end use in the development of potable reuse alternatives, as will be discussed in Chapter 4. With the number of project components possible, there could be a multitude of project combinations. Selecting alternatives for detailed analysis was therefore a stepwise process, as shown in Figure 1.4. At key stages in the selection process, workshops with representatives from all project participants were convened to facilitate key decisions.

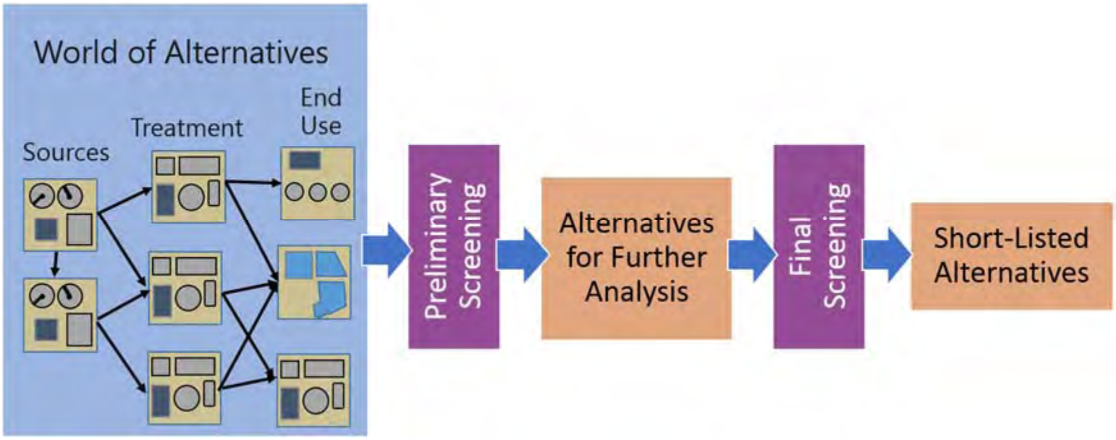

Figure 1.4 Alternative Selection Process

1.7 Evaluation Criteria

A preliminary set of evaluation criteria was developed to narrow the initial list of alternatives down for further investigation. These criteria are as follows:

- Yield (measured by acre-feet per year - AFY).
- Cost (Capital and Operations and Maintenance [O&M]).
- Improved Supply Reliability.
- Improved Delivered Water Quality.
- Improved Groundwater Basin Quality.
- Clear Regulatory Pathway.
- Minimizes Neighborhood Impacts.
- Ability to Phase the Project.
- Operational Flexibility.
- Ease of Construction.

As decided by the project management team, the main criteria for the initial screening were cost and yield. After the initial screening of alternatives, additional criteria were used in the more detailed analysis.

Ultimately, six options were chosen for the detailed analysis to serve as bookends.

1.8 Report Organization

This report is divided into 8 chapters, listed below:

1. Background and Introduction
2. Potable Reuse Regulations
3. Treatment Technology Assessment
4. Water Availability, Balance, and Quality
5. Preliminary Alternatives Evaluation
6. Hydrogeologic Feasibility
7. Short-Listed Options Detailed Analysis
8. Recommended Next Steps
9. Summary

1.9 References

Zone 7 Water Agency (2016) Water Supply Evaluation Update - Water Supply Alternatives for the Livermore-Amador Valley. URL: http://www.zone7water.com/images/pdf_docs/water_supply/wse-update_2-16.2.pdf

Chapter 2

POTABLE REUSE REGULATIONS

This chapter is intended to address the following goals:

- To document the successful application of potable reuse in California and in other states.
- To define the finished water quality goals for potable reuse. These goals will be protective of public health, surface water quality, and groundwater quality, regardless of the application/use.
- To define existing and anticipated future regulations for different types of potable reuse projects.

2.1 Summary of Findings

Potable reuse has been utilized by agencies as a means to extend water supplies for over 30 years in California. Other states have also successfully implemented potable reuse while being protective of public health. Project-specific permits for potable reuse have been issued in California for many years, although now regulations are clearly defined for groundwater recharge by the 2014 Groundwater Replenishment Reuse Projects (GRRPs) included in Title 22. Regulations are currently being developed for other types of potable reuse including the recently adopted reservoir augmentation regulations (adopted March 6, 2018) and a framework for other types of potable reuse is being considered. The December 2016 report, titled "Investigation on the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse," found that it is feasible to develop uniform water recycling criteria that would incorporate a level of public health protection as good as or better than what is currently provided in California by conventional drinking water supplies (SWRCB, 2016). In implementing potable reuse, protection of public health requires adequate treatment to remove pathogens and chemicals, a system of multiple barriers for reliability and redundancy, systematic monitoring to ensure compliance, proper operation and maintenance, careful source control, and qualified operator training.

2.2 Definitions

Terminology related to potable water reuse has evolved from the initial classification of *indirect* and *direct* potable water reuse defined in the report *Framework for Direct Potable Reuse* (WateReuse, 2015) to more specific definitions established by California Assembly Bill 574, which was passed in October 2017. This bill finds that by June 2018 the State Board should establish a framework for the regulation of potable reuse projects to encourage the development of potable reuse to mitigate the impact of long-term drought and climate change. The term "potable reuse" incorporates all types of water reuse that are safely incorporated into potable water supplies.. For the purposes of this study, the term "potable reuse" refers to the practice of using purified water derived from wastewater effluent to supplement water supplies.

The definitions below were compiled from the *Framework for Direct Potable Reuse* and the California Assembly Bill 574 to reflect the recent changes in the terminology and for the specific terminology that will be used **in this report**:

Disinfected Tertiary Recycled Water: Water that has been filtered and subsequently disinfected to "Title 22" standards for unrestricted non-potable reuse applications.

Purified Water: Water that has been treated at a wastewater treatment plant and a full advanced treatment plant (or advanced water purification facility), and has been verified through monitoring to be suitable for augmenting drinking water supplies.

Indirect Potable Reuse (IPR): The addition of recycled and/or purified water to augment groundwater or surface waters. Groundwater and surface waters are considered environmental buffers for providing public health protection benefits, such as contaminant attenuation dilution, and time to detect and respond to failures before final treatment and distribution. Indirect potable reuse can used with advanced treated water, but can also be accomplished with tertiary effluent when applied by spreading (i.e., groundwater recharge) to take advantage of soil aquifer treatment (SAT).

IPR for Groundwater Recharge: Planned used of purified recycled water for replenishment of a groundwater basin or an aquifer that has been designated as a source of water supply for a public water system.

Reservoir Water Augmentation (SWA): Planned placement of purified recycled water into a raw surface water reservoir used as a source of domestic drinking water supply for a public water or into a constructed system conveying water to such a reservoir.

Direct Potable Reuse (DPR): Planned introduction of purified recycle water either directly into a public water system, or into a raw water supply immediately upstream of a water treatment plant. DPR includes (i) raw water augmentation and (ii) treated drinking water augmentation. Additional treatment, monitoring, and/or an engineered buffer(s) would be used in place of an environmental buffer to provide equivalent protection of public health and response time in the event that the purified water does not meet specifications.

Raw Water Augmentation: Planned placement of purified recycled water into a system of pipelines or aqueducts that deliver raw water to a drinking water treatment plant that provides water to a public water system.

Treated Drinking Water Augmentation: Planned placement of purified recycled water intothe water distribution system of a public water system.

2.3 History of Successful Potable Reuse

Potable reuse projects have been successfully implemented in California and nationally using a broad range of treatment and monitoring technology to be protective of public health. Currently permitted potable reuse projects in California are shown in Table 2.1.

In addition to these operational projects, the map shown in Figure 2.1 below also includes the planned potable reuse projects in California as of February 2016. Seven long-standing examples potable reuse projects in the United States are also briefly reviewed in the following section.

Table 2.1 Operational Potable Reuse Projects in California

Agency	Project Name	Facility Start-up	Potable Reuse Type	Current Treatment	Capacity (mgd)
Los Angeles County Sanitation Districts (LACSD), Water Replenishment District (WRD), Los Angeles County Department of Public Works (LACDPW)	Montebello Forebay Groundwater Recharge Project	1962	Spreading	Tertiary (biological, GMF, disinfection)	50
Orange County Water District	Groundwater Replenishment System	1978	Spreading Injection	Purification (biological, MF, RO, UV/H_2O_2)	100
West Basin Municipal Water District	West Coast Basin Seawater Intrusion Barrier	1992	Injection	Purification (biological, MF, RO, UV/H_2O_2)	17.5
Inland Empire Utilities Agency	Chino Basin	2005	Spreading	Tertiary (biological, GMF, disinfection)	19
Water Replenishment District	Alamitos Barrier	2005	Injection	Purification (biological, MF, RO, UV/H_2O_2)	10
Los Angeles Bureau of Sanitation	Dominguez Gap Seawater Intrusion Barrier	2006	Injection	Purification (biological, MF, RO, disinfection)	10
Cambria Community Services District	Sustainable Water Facility at the San Simeon Well Field and Percolation Pond System	2016	Injection	Purification (biological, MF, RO, disinfection)	0.5
				TOTAL	207

Notes:
(1) GMF – granular media filtration.
(2) MF – microfiltration.
(3) RO – reverse osmosis.
(4) UV – ultraviolet disinfection.

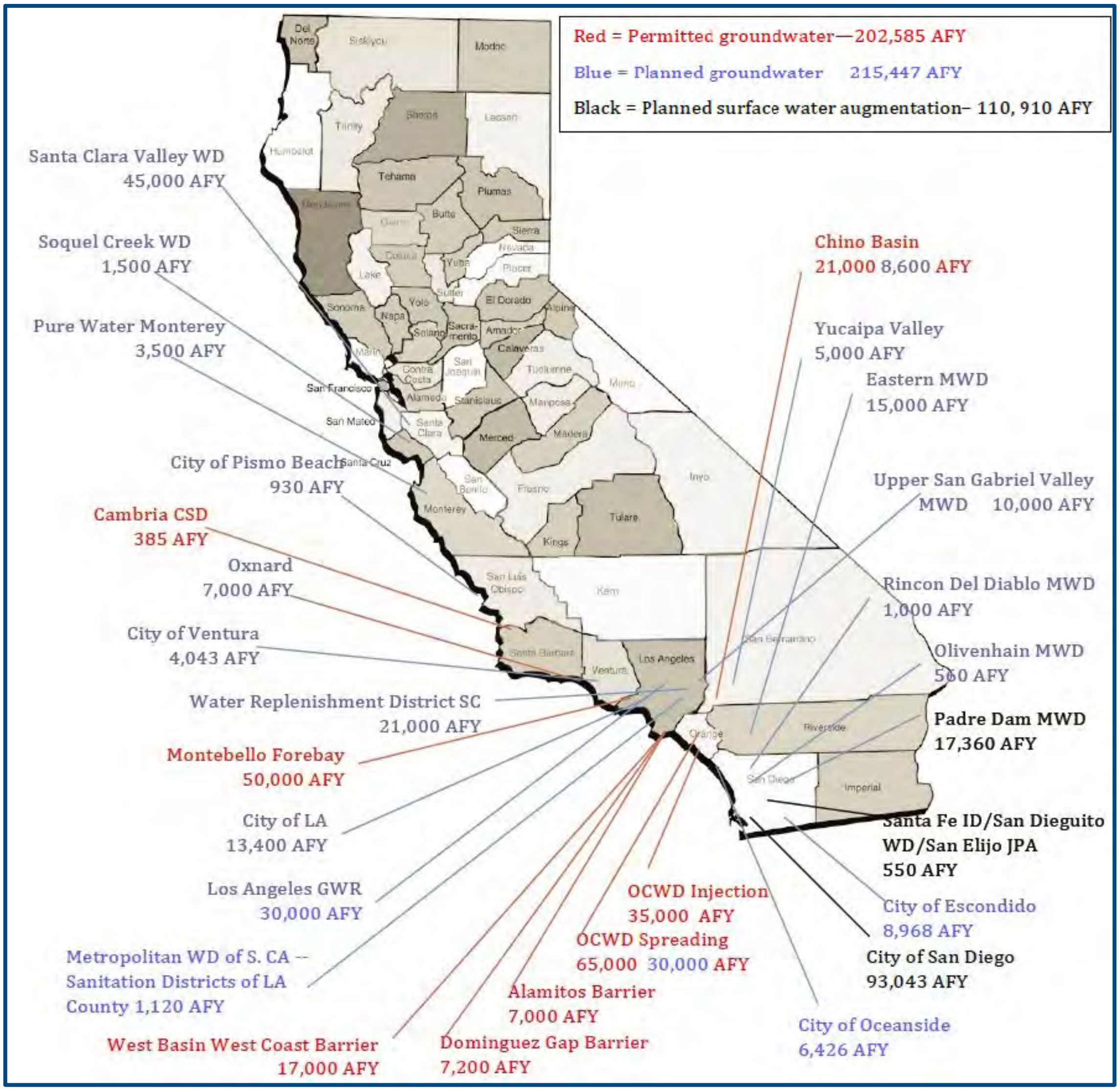

Figure 2.1 Existing and Planned Potable Reuse Projects in California (WateReuse California, February 2016)

2.3.1 Orange County Water District California (OCWD)

The Orange County Water District's Groundwater Replenishment System (GWRS) is the world's largest potable water reuse project, with a daily production of 100 million gallons of purified water, which is injected into the local groundwater basin. Since starting up in the late 1970s, this project has injected more than 188 billion gallons of purified water into the groundwater basin, later to be extracted for potable water use. Currently, OCWD is exploring the feasibility of expanding the GWRS to a total production to 130 mgd. A photo of the OCWD's reverse osmosis (RO) membranes is shown below in Figure 2.2.

Figure 2.2 OCWD RO Membranes Used to Purify Reclaimed Water for Potable Reuse

2.3.2 Terminal Island Advanced Water Purification Facility

The Los Angeles Sanitation (LASAN) Terminal Island Advanced Water Purification Facilities (TI AWPF) provides highly purified water to recharge the Dominguez Gap Barrier (Figure 2.3). Currently the facility is undergoing an expansion that will increase the plant's capacity from 6 to 12 mgd and will add UV/AOP (UV + sodium hypochlorite) for disinfection. The project's expansion will allow TI AWPF to continue supplying water to the Dominguez Gap Barrier, and to supply reclaimed water to Harbor Area industrial users and replenish the evaporation losses at Lake Machado.

Figure 2.3 City of Los Angeles Terminal Island AWPF

2.3.3 Water Replenishment District/Los Angeles County Sanitation Districts California

The Water Replenishment District (WRD) and the Los Angeles County Sanitation Districts (LACSD) are partners in the recharge of tertiary recycled water (secondary treated effluent that is then filtered and disinfected) into the local groundwater basin. Over the last 30+ years, more than 472,500 million gallons of reclaimed water have been placed into spreading basins and percolated down into the aquifer, later to be extracted for potable water use. A photo of the Rio Hondo spreading grounds is shown below in Figure 2.4.

Figure 2.4 Rio Hondo Spreading Grounds

2.3.4 VenturaWaterPure

The goal of the City of Ventura and Ventura Water's VenturaWaterPure demonstration facility was to document the high quality of purified reclaimed water through extensive water quality testing, and to understand the impact of blending this purified water with the conventional finished potable water. Additionally, this demonstration facility provided an educational opportunity for the community (Figure 2.5).

The VenturaWaterPure demonstration facility was designed to have multiple barriers for both pathogens and trace pollutants in excess of the treatment required for groundwater augmentation in anticipation of potential additional barriers needed for treated drinking water augmentation, and for direct potable water reuse. The ~20 gallon per minute (28,800 gallons per day) process train took filtered secondary effluent from the Ventura Water Reclamation Facility and treated it through pasteurization, UF, RO, and a UV light advanced oxidation process.

Moving forward, a granular activated carbon (GAC) process may be added after RO for an additional barrier to trace pollutants, and an engineered storage buffer may be added to the treatment train after the UV AOP to allow for appropriate system monitoring and water quality assurance.

Figure 2.5 Pure Water Demonstration Facility

2.3.5 Gwinnett County Georgia

Gwinnett County Georgia is responsible for the advanced treatment of wastewater prior to discharge into Lake Lanier (Figure 2.6, below). The latest treatment process modifications to the F. Wayne Hill Water Resources Center were completed in 2005, allowing the advanced treatment of secondary effluent at up to 150 million gallons per day using microfiltration (MF), pre-ozone, biofiltration, and post-ozone. Water from Lake Lanier is then treated at a conventional water treatment plant and distributed to customers throughout Gwinnett County.

Figure 2.6 Lake Lanier Georgia

2.3.6 Colorado River Municipal Water District Texas

The Colorado River Municipal Water District (CRMWD) is a regional water agency in Texas, serving the cities of Big Spring, Odessa, Snyder, and others, with a current combined population of about 500,000. Extreme drought in Texas led the CRMWD to construct the Raw Water Production Facility (RWPF) in Big Spring, Texas (Figure 2.7). The RWPF started operating in May 2013, with a steady production capacity of 2 mgd. The RWPF uses the same advanced treatment processes as OCWD's GRWS: MF, RO, and UV advanced oxidation. After purification, the water from the RWPF is fed into a raw water supply line which blends with other raw water (up to 50 percent) and is then subjected to treatment at a standard water treatment plant (media filtration and chlorine disinfection). The City of Big Spring's surface water treatment plant (SWTP) is the first downstream user to withdraw from the pipeline. The cities of Snyder, Odessa, Stanton, and Midland also operate SWTPs that take water downstream of that pipeline.

Figure 2.7 Colorado River Municipal Water District's Raw Water Production Facility in Big Spring, TX

A two-year third-party evaluation of the water quality produced at this facility was recently completed. Water quality was tested across the treatment train at four major sample events, with test parameters including enteric virus, Giardia, Cryptosporidium, bacterial indicators, a large suite of CECs (pharmaceuticals, personal care products, consumer chemicals, flame-retardants, steroid hormones, perfluorinated alkyl substances, conventional and emerging disinfection byproducts) and many other constituents. The study concluded that the product water met public health standards and was fit to drink without the additional treatment that occurs at the downstream conventional water treatment plants, and is generally of a better quality than the conventional water supply from Moss Creek Lake; which has served the CRMWD's customers for many decades (Figure 2.8).

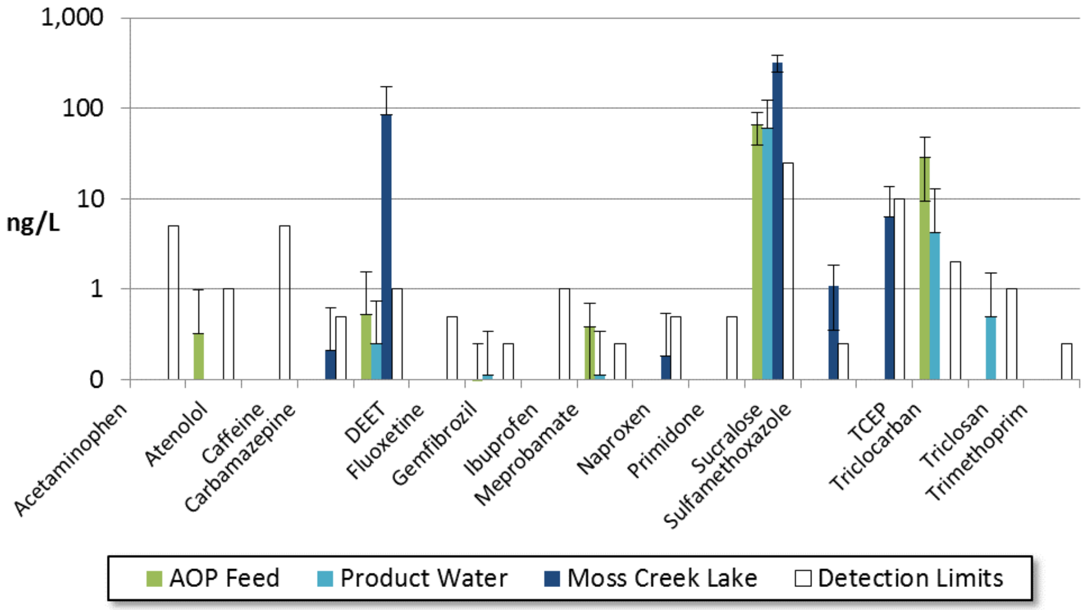

Figure 2.8 Big Spring Finished Water (AOP Feed and Product Water) and Existing Source (Moss Creek Lake) Concentrations of CECs

2.3.7 DPR High Purity Water Project Demonstration Facility, Oregon

Clean Water Services (CWS) is a water resources management utility in Washington County, Oregon. CWS has Oregon's largest water reuse program and is exploring further options to address water needs within the Tualatin River Watershed. As part of their water reuse program, CWS funded, designed and constructed a High Purity Water Project DPR Demonstration Facility to purify municipal disinfected secondary effluent to various levels which would be sufficient for use in a variety of purposes, including semiconductor processing, agriculture and food crops, product manufacturing, and human consumption (Figure 2.9). The end goal was not to immediately produce a purified water for potable use, but to elevate the discussion of water in Oregon and to allow for a future potable reuse project.

Included in the overall process design were the following advanced water treatment technologies, which, when combined, provided robust pathogen and pollutant treatment:

- Ultrafiltration.
- Reverse osmosis.
- Ultraviolet light advanced oxidation processes.
- Granular activated carbon.

These processes were used in series to purify disinfected secondary effluent from CWS's Forest Grove Facility (FGF). The testing demonstrated that the FGF effluent, when treated with UF, RO, and UV/AOP, provides a very high quality water absent of trace pollutants and/or pathogens. As a result, the purified water was deemed suitable for potable use, public consumption was confirmed, and a single use DPR permit was obtained from the Oregon Department of Environmental Quality.

Figure 2.9 Clean Water Services (Pure Water Brew) Project Demonstrated the Safety of Potable Water Reuse Using Innovative and Understandable Methods – Beer!

2.4 Chemical Pollutant and Pathogen Goals

California Division of Drinking Water (DDW, formerly the California Department of Public Health or CDPH) has been approving potable reuse projects for many years now, although regulations for groundwater recharge were only finalized in 2014. In the consideration and permitting of potable reuse, the two critical factors for protection of public health are pathogens and chemical pollutants. Many of the standards used for potable reuse are based on drinking water regulations and goals.

2.4.1 Chemical Pollutants

A large number of chemicals known to be detrimental to human health above certain concentrations are regulated through maximum contaminant levels (MCLs). The DDW has also established health-based advisory levels, called notification levels (NLs). Drinking water must be treated to meet these standards regardless of the source. Any effluent that is proposed for supply augmentation should, therefore, be tested for the full suite of these constituents. Treatment processes at the wastewater treatment, advanced treatment, and/or drinking water treatment stage can be adapted to remove these constituents.

For example, in almost all cases, inorganic nitrogen species (nitrate, nitrite) will be of particular concern. From a drinking water perspective, these are regulated with primary standards (10 mg/L as nitrogen for nitrate and nitrite combined, and 1 mg/L as nitrogen for nitrite) due the acute toxicity concerns associated with methemoglobinemia, known for causing "blue baby syndrome." These health-based standards can often be exceeded in treated wastewater effluents.

A second example is salinity, which has both primary and secondary drinking water standards. Due to the human contribution of salinity during municipal use, it is often necessary to remove salt in order to maintain water quality with acceptable aesthetic characteristics (based on secondary standards). In some cases, it is required in order to meet primary standards. Salt removal is commonly achieved with nanofiltration (NF) or reverse osmosis (RO), though at a relatively high cost.

Most other exceedances of primary or secondary standards will vary based on the nature of the contributions to the collection system, but, generally, treated effluent of strictly municipal origin does not contain many, if any, additional chemicals at concentrations above primary standards (Trussell *et al*., 2013). The initial treated effluent water quality assessment, ongoing source control measures, and periodic sampling requirements will serve to maintain and confirm compliance with regulatory limits on an ongoing basis.

Industrial contributions to the effluent are of significant concern with respect to metals and regulated organic constituents in particular. Concerns about contamination with industrial chemicals led the longest-operating DPR project on the globe, in Windhoek, Namibia, to segregate industrial wastewater from municipal sewage and only use the municipal stream for DPR. As part of this study, historical data for secondary effluent will provide some indication of upstream industrial source control issues.

2.4.2 Disinfection Byproducts

The formation of disinfection byproducts (DBPs) deserves special attention. Conventional DBPs, such as trihalomethanes (THMs), haloacetic acids (HAAs), bromate, and chlorate, are already regulated by the Stage 1 and Stage 2 Disinfectant and Disinfection Byproduct Rules (USEPA, 1998 and 2006a). n-Nitrosodimethylamine (NDMA) and other nitrosamines have been considered for regulation by the USEPA for over a decade (they are on the Unregulated Contaminant Monitoring Rule 2 list and the Candidate Contaminant List 3), and NDMA has a California Notification Level of 10 nanograms per liter (ng/L), which is considered the minimum treatment benchmark by the California utilities currently implementing potable reuse.

2.4.3 Unregulated Constituents

Besides the chemical (and radiological) constituents explicitly regulated through MCLs, a wealth of research has been conducted on the concentrations of unregulated trace organic constituents (TOrCs) in wastewater, their attenuation through conventional WWTPs, and their further breakdown during advanced treatment (Baronti *et al.*, 2000; Lovins *et al*., 2002; Schäfer *et al*., 2005; Sedlak *et al*., 2006; Steinle-Darling *et al*., 2010; Linden *et al*., 2012; Salveson *et al*., 2010; Salveson *et al*., 2012; Snyder *et al*., 2012; and many others). These constituents include pharmaceuticals, personal care products, consumer chemicals, coatings (perfluorinated compounds), flame retardants, and others, some of which have endocrine disrupting, carcinogenic, and/or other potentially harmful properties at sufficiently high concentrations. Due to these potential effects, combining with media interest, this group of constituents has been the cause of more public concern than the pathogens discussed below. However, the vast majority of TOrCs are present in wastewater effluent at concentrations that are not of concern for human health, if present at all. Table 2.2 (original Table 1.14 and 1.15 from Trussell *et al.*, 2013) includes a cross-section of TOrCs detection in secondary wastewater effluent as well as through an advanced treatment train. For comparative purposes, the Maximum Recommended Value is also shown in Table 2.3.

Table 2.2 Effluent Concentration of Indicator Trace Organic Compounds in Treated Secondary Effluent and in the Purified Water from Advanced Treatment per California IPR Regulations Compared to Maximum Recommended Value

Target Compound	Use of Target Compound	Secondary Wastewater Treatment(1) (ng/L)	MF-RO-UV/H_2O_2(2) (ng/L)	Maximum Recommended Value(3) (ng/L)
Atenolol	Pharmaceutical, beta blocker	710	<25	70,000
Atrazine	Herbicide	28	<10	1,000
Bisphenol A	Plastics additive	<50	<50	200,000
Carbamazepine	Pharmaceutical, anti-convulsant	140	<10	1,000
DEET	Insect repellant	54	<25	2,500,000
Diclofenac	Pharmaceutical, nonsteroidal anti-inflammatory drug	62	<25	1,800
Gemfibrozil	Pharmaceutical, lipid regulating agent	31	<10	45,000
Ibuprofen	Pharmaceutical, pain reliever	<25	<25	400,000
Meprobamate	Pharmaceutical, anti-anxiety medication	41	<10	260,000
Musk Ketone	Fragrance additive	<100	<100	350,000
Naproxen	Pharmaceutical, pain reliever	<25	<25	220,000
Phenytoin	Pharmaceutical, anti-convulsant	110	<10	6,800
Primidone	Pharmaceutical, anti-convulsant	67	<10	10,000
Sulfamethoxazole	Pharmaceutical, antibiotic	570	<25	35,000
Triclosan	Biocide	26	<25	350
Trimethoprim	Pharmaceutical, antibiotic	280	<10	70,000
Tris(2-chloroethyl)phosphate (TCEP)	Fire retardant	540	<200	1,000

Notes:

(1) Data reported by Trussell *et al*. (2013; see Table 1.14).

(2) Data reported by Trussell *et al*. (2013; see Table 1.15).

(3) As reported by Trussell *et al*. (2013).

An independent advisory panel recommended regulatory criteria for potable reuse, as part of WateReuse Research Foundation project 11-02 (NWRI, 2013). The information in Table 2.3, proposed regulatory criteria for chemicals, is adapted from Trussell *et al*. (2013). Any treatment train proposed for potable reuse for the Tri-Valley would be designed to meet or exceed these recommended regulatory criteria.

Table 2.3 Recommended Regulatory Criteria for Maximum Concentration Levels of Chemicals in Finished Water from Potable Reuse Treatment Trains (reproduced from Trussell et al., 2013 Table 2.8)

Chemical Group	Criterion	Rationale	Sources Used for Criteria
Disinfection byproducts that should be measured to evaluate treatment trains:			
Trihalomethanes (THMs)	80 ug/L	Prominent chlorination byproducts.	MCL
Halogenated acetic acids (HAA5)	60 ug/L	Polar group of chlorination byproducts.	MCL
N-nitrosodimethylamine (NDMA)	10 ng/L	Byproduct of chloramination.	DDW notification level.
Bromate	10 ug/L	Byproduct of ozonation.	MCL / WHO guideline.
Chlorate	800 ug/L	Reflective of hypochlorite use.	DDW notification level.
Non-regulated chemicals of interest from a public health stand point (if present in wastewater source):			
Perfluoro-octanoic acid (PFOA)	0.4 ug/L	Known to occur, frequency unknown.	Provisional short-term U.S. EPA Health Advisory.
Perfluoro-octane sulfonate (PFOS)	0.2 ug/L	Known to occur, frequency unknown.	Provisional short-term U.S. EPA Health Advisory.
Perchlorate	15 ug/L 6 ug/L	Of interest, same analysis as chlorate and bromate.	U.S. EPA Health Advisory California MCL.
1,4-dioxane	1 ug/L	Occurs at low frequency in wastewater, but likely to penetrate RO membranes.	DDW notification level.
Ethinyl Estradiol	None, close to detection limit if established.	Steroid hormone, should evaluate presence in source water.	Bull *et al.* (2011).

Table 2.3 Recommended Regulatory Criteria for Maximum Concentration Levels of Chemicals in Finished Water from Potable Reuse Treatment Trains (reproduced from Trussell et al., 2013 Table 2.8) (Continued)

Chemical Group	Criterion	Rationale	Sources Used for Criteria
17-ß-estradiol	None, close to detection limit if established.	Steroid hormone, should evaluate presence in source water.	Bull *et al.* (2011).
Pharmaceuticals of potential health concern that should be useful to evaluate the effectiveness of organic chemical removal by treatment trains.			
Cotinine/Primidone/ Dilantin	1/10/2 ug/L	Surrogate for low molecular weight, partially charged cyclics.	Bruce *et al.* (2010); Bull *et al.* (2011).
Meprobamate/Atenolol	200/4 ug/L	Occur frequently at the ng/L level.	Bull *et al.* (2011).
Carbamazepine	10 ug/L	Unique structure.	Bruce *et al.* (2010).
Estrone	320 ng/L	Surrogate for steroids.	Based on an increased risk of stroke in women taking the lowest dose of conjugated estrogens.
Other chemicals of potential health concern that should be useful to evaluate the effectiveness of organic chemical removal by treatment trains:			
Sucralose	150 mg/L	Surrogate for water soluble, uncharged chemicals of moderate molecular weight.	CFR Title 12, revised 4/1/12.
TCEP	5 ug/L	Chemical of interest.	Minnesota Department of Health (2011) guidance value.
N,N-diethyl-meta-toluamide (DEET)	200 ug/L	Chemical of interest.	Minnesota Department of Health (2011) guidance value.
Triclosan	2,100 ug/L	Chemical of interest.	Risk-based action level (NRC, 2012).

2.5 Pathogens

In contrast to most chemical constituents, pathogens represent an acute risk, as a single event in which concentrations leaving a treatment plant are above an illness-causing threshold can cause a public health crisis with a significant fraction of the population falling ill. Accordingly, substantial effort in purification is focused on the reduction of pathogens to below regulated levels.

2.5.1 Wastewater Pathogen Concentrations

DDW has been approving protozoa and virus reduction credits for the primary and secondary treatment processes as part of recent IPR projects (WRD, 2013). That work relied upon risk analysis data presented in Olivieri *et al*. (2007), which was developed based upon data collected by Rose *et al*. (2004).

Rose *et al*. 2004 collected and analyzed samples of raw wastewater and secondary effluent from six different full-scale WWTPs for bacteria, enterovirus, *Cryptosporidium*, and *Giardia*. Variability of up to three orders of magnitude is shown in the data for both raw wastewater and secondary effluent at some of the individual facilities, which must be accounted for in a public health analysis of potable reuse.

The statistics shown in Table 2.4 describe the distribution of the pathogen concentrations in secondary effluents from Rose *et al*. (2004). The 95th percentile data was assumed as the secondary effluent pathogen concentrations requiring further treatment.

Table 2.4 Summary Statistics for Secondary Effluent Pathogen Concentrations(1)

Statistic	*Giardia* (cysts/L)	*Cryptosporidium* (oocyts/L)	Enteric Virus (MPN/L)
Number of Samples	33	33	30
Minimum	$1.00 \times 10^{+1}$	$1.00 \times 10^{+1}$	5.00×10^{-1}
Mean	$1.28 \times 10^{+3}$	$2.27 \times 10^{+2}$	$4.01 \times 10^{+1}$
95th Percentile	$8.81 \times 10^{+3}$	$7.43 \times 10^{+2}$	$2.17 \times 10^{+2}$
Maximum	$1.40 \times 10^{+4}$	$3.33 \times 10^{+3}$	$2.70 \times 10^{+2}$

Notes:

(1) As provided by Olivieri *et al.* (2007) and Rose *et al.* (2004).

2.5.2 Pathogen Removal Goals

While different states have taken different approaches to permitting potable reuse projects, the fundamental potable water end goals are generally accepted. These goals are based on reducing annual risk of *infection* below 1 in 10,000 with each examined pathogen group (Regli *et al.*, 1991), which was also applied to the control of *Cryptosporidium* oocysts as part of USEPA Long Term 2 (LT2) (USEPA, 2006b). This method represents one additional level of conservatism in comparison to the approach taken in the EPA Surface Water Treatment Rule (SWTR), which determined *Giardia* goal concentrations on the basis of a 1 in 10,000 annual risk of *illness* (USEPA, 1989). Where *infection* represents the moment when a pathogen first enters the body, whether or not it causes symptoms, *illness* is defined by when symptoms first appear. Not all infections lead to illnesses, but all illnesses result from infections. Drinking water pathogen goal concentrations are shown in Table 2.5.

Table 2.5 Drinking Water Pathogen Goal Concentrations

Pathogen	Drinking Water Goal	Reference
Giardia	$< 6.8 \times 10^{-6}$ oocysts/L	Regli *et al.* (1991)
Cryptosporidium	$< 3.0 \times 10^{-5}$ oocysts/L	Haas *et al.* (1999)
Enteric virus	$< 2.2 \times 10^{-7}$ MPN/L	Regli *et al.* (1991)

Notes:

(1) Drinking water goals are identified for national potable reuse research and as implied by California regulations and cited by Trussell *et al.* (2013). These are consistent with values used in Texas based on personal communications with staff at the Texas Commission on Environmental Quality (TCEQ).

(2) The *Cryptosporidium* goal as inferred from the treatment requirements under the (LT2) Rule for Bin 3, which is the most conservative defined-boundary bin (only a lower boundary is defined for Bin 4). Bin 3 has an upper limit of 3 oocysts/L and requires 5-log treatment. The original quantitative microbial risk assessment defining this limit based on a 1 in 10,000 annual risk of *infection* was performed by Haas *et al.* (1999).

(3) MPN/L = most probable number per liter. The 10^{-4} risk level concentrations of a number of enteric viruses is provided by Regli *et al.* (1991). The most conservative value listed in Table 2 of this reference is for rotavirus (at 2.22×10^{-7} MPN/L).

2.5.3 Pathogen Removal Analysis

With a clear understanding of secondary effluent pathogen loads, the amount of reduction of pathogens to meet water quality goals can be readily determined as shown in Table 2.6.

Table 2.6 Pathogen Removal Analysis

Concentrations	*Giardia*	*Cryptosporidium*	Enteric Virus
95th Percentile estimated Concentrations in Secondary Effluent (#/L)(1)	$8.81 \times 10^{+3}$	$7.43 \times 10^{+2}$	$2.17 \times 10^{+2}$
Goal Concentration (#/L)	$< 6.8 \times 10^{-6}$	$< 3.0 \times 10^{-5}$	$< 2.2 \times 10^{-7}$
Overall Pathogen Removal Needed by Advanced Treatment/Purification	**9.1-log**	**7.4-log**	**9.0-log**

Notes:

(1) 95th percentile value presented by Olivieri *et al.* (2007) and Rose *et al.* (2004).

Texas regulators take a tact similar to Table 2.7. The Texas Commission on Environmental Quality (TCEQ) has defined treatment goals based on a case-by-case evaluation of the specific treated effluent proposed as the source water for advanced treatment for potable reuse. The pathogen sampling requirements are in general analogous to those required for *Cryptosporidium* under LT2, but extend to sampling for *Giardia* and enteric virus as well. This process has been applied to three approved potable reuse projects and has resulted in slightly different Log Removal Value (LRV) requirements (Table 2.8).

National expert panels and California regulators approach the pathogen log reduction targets for potable reuse in a different fashion, looking first at the concentrations of pathogens in raw wastewater and then determining the log reduction requirements to attain the 1 in 10,000 risk of infection level concentrations for pathogens (CDPH, 2014; Trussell *et al.*, 2013). The log removal value (LRV) set by California in Title 22 and the values targeted in a study by Trussell *et al.*, 2013 from raw wastewater to potable water consumption are shown in Table 2.8. In both cases, the approach uses the most conservative values available in the datasets described above and applies a generous safety factor of ≥100-fold to provide a safeguard against "outbreak conditions" (Trussell *et al.*, 2013).

Table 2.7 Summary of Log Removal Value Requirements (LRV) for Approved Potable Reuse Projects in Texas

Project	*Giardia* LRV	*Cryptosporidium* LRV	Enteric Virus LRV
Raw Water Production Facility at Big Spring(1)	6.0	5.5	8.0
Wichita Falls Emergency DPR Project(2)	7.0	5.5	9.0
City of Brownwood DPR Project(3)	6.0	5.5	8.0

Notes:
(1) Operating since May 2013
(2) Started operation June 2014, no longer in operation
(3) Approved for construction but not yet built

Table 2.8 Summary of Log Removal Value Requirements for California

Parameter	Log Removal Value	
	California Title 22	Trussell *et al.*, 2013
Virus	12	12
Giardia	10	10
Cryptosporidium	10	10
Total Coliform	NS	9

Notes:
(1) NS - none specified

For this project, we recommend setting the pathogen reduction targets for purification processes based upon conservative secondary effluent values from Rose *et al*. (2004), resulting in 9-log *Giardia*, 7.4-log *Cryptosporidium*, and 9-log virus.

2.5.4 Groundwater and Surface Water Protection

Groundwater and surface water quality protection is one of the main concerns when developing a potable reuse project. As an example, addition of purified water for recharge can result in arsenic mobilization due to changes in the native geochemistry of the groundwater basin where arsenic occurs naturally. The OCWD has done extensive research at the groundwater replenishment system (GWRS) and has developed a successful formula using lime as post-treatment of the purified water to avoid metal mobilization (Fakhreddine, 2015). The lime dosing specifications developed for OCWD are shown in Table 2.9. The OCWD information provides a basis for RO permeate stabilization and cost analysis. A detailed analysis to determine the appropriate groundwater stabilization strategy should be developed for the project implementation.

Table 2.9 Lime Dosing Specifications

Product	Ultra-pure hydrate (95+% CaOH)
Supplier	Lhoist, N.A.
Dose	26 mg/L
Target pH	8 – 8.5
Target Alkalinity	40 – 45 mg/L

2.6 Potable Reuse Regulations in California

Regulations are in place for potable reuse for groundwater recharge (CDPH, 2014). In March 2018, SWA regulations were adopted following a public comment period on the draft regulations. However, they are unlikely to change significantly with respect to LRVs. The State has released the report to Legislature on the feasibility of establishing regulations for DPR. The recently enrolled AB 574 has established a deadline of December 31, 2023, for the creation of regulations governing DPR through raw water augmentation. No deadline has been set for regulations regarding treated drinking water augmentation.

2.6.1 California Water Code (CWC)

The CWC stipulates that each Regional Water Quality Control Board (RWQCB) formulate and adopt Water Quality Control Plans (Basin Plans) for all areas governed by the boards. These plans must contain water quality objectives for surface water and groundwater within the regions that provide reasonable protection of the beneficial uses of the waters. During the process of formulating such plans the RWQCBs must consult with and consider recommendations of affected state and local agencies. Such plans shall be periodically reviewed and may be revised (section 13240). In accordance with CWC Section 13260, all persons discharging waste within the region must file with the appropriate boards and provide information pertaining to their discharge. Within the region, it is not permitted for a person to construct, maintain, or use any waste well that interferes with a source for domestic water supply without proper permitting or exceptions (CWC Section 13540).

2.6.2 Regulations for Groundwater Recharge/Groundwater Augmentation

The Division of Drinking Water (DDW) has developed extensive guidelines regarding Groundwater Replenishment Reuse Projects (GRRPs) included in Title 22. The DDW revised Title 22 regulations on June 2014. There are two types of GRRPs regulated, surface and subsurface application. General requirements for groundwater recharge are listed in Table 1.10.

Table 2.10 Groundwater Recharge Criteria for Potable Reuse

Parameter	Criteria
Pathogen Microorganism Control	
Enteric Virus	12-log Reduction
Giardia Cyst	10-log Reduction
Cryptosporidium oocysts	10-log Reduction
Total Organic Carbon (TOC)	Maximum 0.25 mg/L in 95% of samples within first 20 weeks Maximum 0.5 mg/L in 20-week running average
1,4-dioxane	0.5-log Reduction
Total Nitrogen	10 mg/L

Notes:
(1) Log reductions are from the point of raw wastewater to the point of finished water for public consumption.

2.6.2.1 Surface Spreading Application

For surface spreading applications the process relies on treatment through percolation and dilution once the percolated water is in the groundwater basin. Regulations establish that spreading projects for subsurface applications can use up to 20 percent of tertiary recycled water and 80 percent of other acceptable dilution water. Per regulations, "acceptable dilution water" is water that meets drinking water standards. This percentage of recycled water (named the recycled water contribution [RWC]) can be increased as operations proceed, with approval from DDW. It is even possible to have an RWC of 100 percent if there is sufficient travel time in the groundwater basin before the nearest drinking water well (approximately 6 months). This retention time target is based on tracer tests or conservative hydraulic modeling. Based upon discussions with DDW, secondary effluent treated with microfiltration (MF) and reverse osmosis (RO) can be an acceptable supply for dilution water. Our experience suggests that RO permeate will meet all potable water regulations with the possible exception of NDMA. Further discussion about the use of treatment technologies to meet different regulatory criteria is detailed in a subsequent TM.

2.6.2.2 Groundwater Injection Application

Subsurface application or injection of purified water directly into the groundwater basin would require full advanced treatment that includes RO and advanced oxidation processes (AOP). Additionally, a minimum of two months of subsurface travel time is required before extraction for potable use. These two months provide "Response Retention Time" (RRT) which is time to monitor water quality and respond to water quality concerns. Direct injection projects have less room for innovation due to the close connectivity between the injected water and the extraction wells. Cost savings have been realized by using alternative UV AOP systems, including the City of Los Angeles' new UV AOP that used NaOCl instead of H_2O_2 in the advanced oxidation process (12 mgd) and the Ventura Water demonstration of UV AOP using an electrode technology and thus not using any type of dosed chemical oxidant.

2.6.3 Reservoir Water Augmentation

In March 2018, the SWA regulations were adopted following a public comment period on the draft regulations. The City of San Diego completed their DDW Regional Water Quality Control Board (RWQCB) Engineering Report in early 2017, which serves as both a template for SWA across the State and for this project.

Water Code section 13561 defines Direct Potable Reuse (DPR) as "the planned introduction of recycled water either directly into a public water system, as defined in Health and Safety Code section 116275, or into a raw water supply immediately upstream of a water treatment plant." This definition provides a potential 'gap' between SWA and DPR, as certain projects may use a reservoir that is too small to qualify for the SWA regulations. According to the Expert Panel, this 'gap' was defined as projects with reservoirs that had hydraulic retention times of less than 4 months but greater than or equal to 2 months. This 'gap' is incorporated into the SWA regulations via an alternatives clause.

This section summarizes the key requirements stipulated in the SWA regulations (released in 2018). These include pathogen and chemical control at the advanced water purification facility (AWPF) and retention time and dilution requirements in the reservoir.

SWA projects use an environmental buffer (e.g., reservoir) between treatment and distribution like in GRRPs (Figure 2.10). The major difference is that the retention time in the reservoir is shorter than GRRP retention times in aquifers.

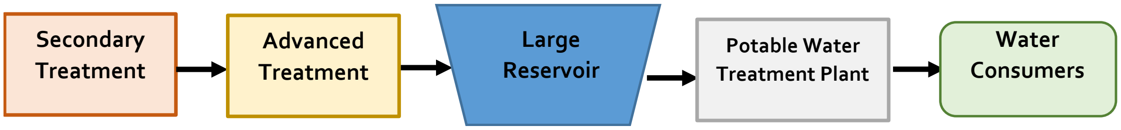

Figure 2.10 SWA Project Schematic Process Flow Diagram

The key requirements for SWA are summarized below.

- **Dilution Requirement -** the dilution requirements stipulate that *any 24-hour input of recycled water* to the reservoir must be mixed such that water withdrawn for use as drinking water will never contain more than 1 percent of this input. This is meant to provide a buffer against off-specification water that enters the reservoir; pathogen concentrations will be reduced by 2 logs, either through 100:1 dilution or 10:1 dilution with 1-log treatment. Log removal requirements and pathogenic microorganism control are discussed below.
- **Hydrodynamic modeling** - required in order to demonstrate compliance with this requirement. The modeling will verify the ability of the reservoir to meet this requirement under all conditions, as well as completion of a tracer study with added tracer prior to the end of the first six months of operation. The achievable dilution of a 24-hour input can be estimated using a simplifying assumption of complete mixing in the reservoir. Under this assumption, dilution is related to the theoretical retention time (τ) and the duration of the input (Δt):

  $$\text{dilution factor} = \tau/\Delta t$$
- **Retention Time** - The SWA regulations continue to incorporate the concept of retention time, albeit taking into account the differences in hydrodynamics between an aquifer and a reservoir. The final regulations currently available stipulate that a reservoir used for SWA must have a minimum theoretical retention time (τ) of 180 days, to be measured on a monthly basis as follows:

  $$\tau = (V_{total}/Q_{out}) \geq 180 \text{ days}$$

  where V_{total} is the volume in the reservoir at the end of the month and Q_{out} is the total outflow from the reservoir during that month. The project may apply for an alternative minimum less than 120 days, however, a 1-log reduction of pathogen is required. The alternative minimum cannot be less than 60 days.
- **Pathogenic Microorganism Control** - The treatment requirements in the draft SWA regulations look very similar to those for a GRRP, particularly with regard to pathogenic microorganism control. If at least a 100:1 dilution is achieved in the reservoir, then the log removals for enteric virus, *Cryptosporidium*, and *Giardia* are the same as in the GRRP regulations. If less than 100:1 but at least 10:1 is dilution achieved in the reservoir, then an additional 1-log of pathogen treatment is required by an additional process. If there is less than 10:1 dilution available in the reservoir, then the project will likely be considered immediately upstream of a drinking water treatment plant and will be defined as direct potable reuse (DPR). Table 2.11 illustrates the required removal criteria for enteric virus, *Cryptosporidium*, and *Giardia*.

Table 2.11 SWA Pathogenic Microorganism Control - Draft Regulations

Dilution	Enteric Virus Removal	*Cryptosporidium* Removal	*Giardia* Removal
San Diego Pure Water(1)	14-log	12-log	12-log
Dilution ≥ 100:1	8-log	7-log	8-log
100:1 ≥ Dilution ≥ 10:1	9-log	8-log	9-log
Dilution < 10:1	Not classified as surface water augmentation		

Notes:
(1) San Diego has an expected retention time of only sixty days, which is why DDW requires such high pathogen log removal credits.

- GRRPs have the benefit of receiving log removal credit from the retention time underground, whereas SWA projects do not. Instead, SWA projects allow treatment credits from the conventional drinking water treatment plant downstream of the reservoir. The original surface water treatment rule, promulgated by EPA (EPA 1989), required the water treatment plant to provide treatment to remove 4-log virus and 3-log *Giardia*. This rule has since been updated to include 2-log *Cryptosporidium* removal as well. SWA projects can combine the treatment credit achieved prior to the reservoir and at the conventional drinking water treatment plant to achieve the required pathogen reductions.
- A primary goal in the design of the treatment train will be to design an overall system that has enough credit to achieve the required log removals in the SWA regulations.
- **Regulated Contaminant Limits** - As with the GRRP regulations, the recycled water must meet all current regulatory limits. The inclusion of an RO system will ordinarily keep the product water quality well below any current regulatory limits; however, it is possible that the San Diego Regional Water Quality Control Board (SDRWQCB) may require strict nutrient limits for environmental reasons, lowering the total nitrogen discharged to as low as 1 mg/L.

2.6.4 Direct Potable Reuse

DPR projects are differentiated from IPR based on the absence of an environmental buffer. The SWRCB defines DPR as the planned introduction of recycled water either directly into a public water distribution system, or into a raw water supply immediately upstream of a water treatment plant. No uniform regulations have been established within the State of California or nationally for DPR. However, two important documents have now been completed, the Framework for Direct Potable Water Reuse and the Investigation on the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse. The Framework for Direct Potable Water Reuse provides an overview of DPR, identifies key issues that need to be addressed in the development of regulations, and provides step-by-step recommendations on how to safely implement DPR (Tchobanoglous, *et al.*, 2015). The two DPR facilities currently operated worldwide (one in Windhoek, Namibia and the other in Big Spring, Texas) have site-specific permits and treatment requirements set forth by regional regulatory agencies. A summary of the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse is presented in section 6.4.1.1.

2.6.4.1 State of California Efforts

Senate Bill (SB) 918 directed the SWRCB to investigate the feasibility of developing uniform water recycling criteria for direct potable reuse, convene an Expert Panel to study the technical and scientific issues, and provide a final report to the California State Legislature by December 31, 2016. SB 322 further required that the SWRCB convene an Advisory Group comprised of utility stakeholders to advise the SWRCB and its Expert Panel on the development of the feasibility report. SB 322 also amended the scope of the Expert Panel to include identification of research gaps that should be filled to support the development of uniform water recycling criteria for DPR.

The SWRCB DDW released their draft report on the feasibility of DPR in California on September 8, 2016. The draft report is titled "*Investigation on the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse*," and was issued pursuant to requirements set forth in SB 918.

Summary of SWRCB Report

In general, the SWRCB found that regulations for DPR projects are attainable and that a common framework across the various types of DPR will help avoid discontinuities in the risk assessment and management approach. The SWRCB clearly indicated that further quantification of reliability is necessary in order to develop criteria for DPR. The SWRCB states that the process for developing criteria for DPR can be initiated with a parallel analysis of the knowledge gaps.

The SWRCB outlines recommendations that must be addressed in order to successfully adopt uniform water recycling criteria for DPR that are protective of public health. The recommendations, which are documented in Chapter 4 and further described in Table 1 of the report (SWRCB, 2016), are summarized as follows:

1. The SWRCB recommends that the development of uniform water recycling criteria for DPR be initiated concurrently with the six Expert Panel research recommendations such that the findings from these parallel efforts can be used to inform the development of the criteria.
2. Convene a “blue ribbon” panel to review scientific literature and report on the current state of scientific knowledge regarding the potential health risks of emerging contaminants in recycled water that present serious harm to health.
3. Consider the use of probabilistic quantitative microbial risk assessment (QMRA) as part of criteria development to provide better assessment of the performance of DPR treatment trains, provide an opportunity to identify additional effective DPR treatment trains, and result in DPR criteria that ensure the protectiveness of DPR.
4. Work with the Regional Water Quality Control Boards to include monitoring requirements for pathogens (i.e., Giardia cysts, Cryptosporidium oocysts, and several human viruses) in raw wastewater feeding potable reuse systems to improve characterization methods and improved precision of concentrations to provide more information on concentrations and their variability.
5. The SWRCB will work with other agencies (DDW, local health departments, and wastewater agencies) to investigate the feasibility of collecting pathogen concentration data in raw wastewater associated with community outbreaks of disease.
6. Conduct short term research to identify treatment options for final treatment processes that can provide attenuation with respect to potential chemical peaks, particularly for chemicals

that have the potential to persist through advanced water treatment. Simple concepts could include the use of GAC to capture organic spikes.

7. Develop more comprehensive analytical methods to identify low molecular weight unknown contaminants. This includes non-targeted analysis as a screening tool and bioanalytical tools.
8. Convene technical workgroups to address the knowledge gaps regarding resiliency to assist in developing uniform water recycling criteria for DPR.
9. SWRCB will continue to work with Water Environment & Reuse Foundation (WE&RF) on its DPR Research initiative. SWRCB will serve as an advisor to prioritize projects and serve in its Project Advisory Committees.
10. The SWRCB will partner with other relevant agencies within California Environmental Protection Agency (CalEPA), to assess the technical capability in areas relevant to DPR.

The SWRCB also adopted the Expert Panel and Advisory Group recommendations for non-treatment barriers. The recommendations include:

1. Training and certification of operators for potable reuse treatment facilities.
2. Optimizing wastewater treatment plant performance to prepare for DPR.
3. Enhancing source control programs designed to prevent or minimize discharges of toxic chemicals to sewer systems that feed into DPR treatment plants.
4. Ensuring that agencies implementing DPR projects have adequate technical, managerial, and financial capacity to ensure the success and safety of the project.

The SWRCB recommendations were derived in large part from the Expert Panel report. The Expert Panel report is available in the State Water Resources Control Board website and includes the following specific findings:

The Expert Panel found that it "is technically feasible to develop uniform water recycling criteria for DPR in California, and that those criteria could incorporate a level of public health protection as good as or better than what is currently provided by conventional drinking water supplies and IPR."

The Expert Panel indicated that increasing the reliability of mechanical systems and treatment plant performance will address the absence of an environmental buffer and the level of protection that it provides in IPR projects. The Expert Panel identified several reliability features that should be incorporated into DPR projects to provide an equivalent level of health protection as IPR:

"1) providing multiple, independent barriers, 2) ensuring the independent barriers represent a diverse set of processes, 3) using parallel independent treatment trains, 4) providing diversion of inadequately-treated water, 5) providing a final treatment step to attenuate any remaining short-term chemical peaks, 6) incorporating frequent monitoring of surrogate parameters at each step to ensure treatment processes are performing properly, and 7) developing and implementing rigorous response protocols, such as a formal Hazard Analysis Critical Control Point (HACCP) system."

The Expert Panel provided six research recommendations to ensure that DPR is protective of public health and promote understanding and acceptability of DPR. However, the Expert Panel stated that the research could be undertaken either before and/or concurrently with the development of the uniform water recycling criteria. The six research recommendations are summarized below (SWRCB, 2016):

- Improve source control and final water quality monitoring, and perform a literature review to identify new compounds that may pose health risks (especially to fetuses and children) from short-term exposures.
- Evaluate the performance and reliability of DPR treatment trains by implementing a probabilistic method (QMRA) to confirm the necessary removal values for viruses, Cryptosporidium and Giardia based on a literature review and new pathogen data collected.
- Develop better empirical data on concentrations and variability by monitoring of pathogens in raw wastewater.
- Investigate the feasibility of collecting raw wastewater pathogen concentration data associated with community outbreaks of disease, and implement where possible.
- Identify suitable options for final treatment processes that can provide some "averaging" with respect to potential chemical peaks, particularly for chemicals that have the potential to persist through advanced water treatment.
- Develop more comprehensive analytical methods to identify unknown contaminants (e.g., low molecular weight compounds) that may not be removed by advanced treatment and are not presently detectable by current regulatory monitoring approaches.

These findings and recommendations generally follow the state of the industry in terms of best practices and critical considerations for DPR. A few specific points warrant further discussion, particularly in terms of how they can impact DPR projects in California, which are either currently being considered or that could be developed in the future.

Key Findings

The SWRCB makes several statements in the report that could have implications to the path forward for DPR projects in California:

- **Timing.** The SWRCB plans to further address knowledge gaps related to reliability prior to finalizing uniform water recycling criteria for DPR. This indicates that any planned DPR projects may need to be brought before the Board for site-specific approval in the absence of a statewide framework.
- **Framework for Criteria.** The report indicates that each type of DPR project (i.e., a project delivering advanced treated recycled water directly to a surface water treatment plant or surface water reservoir with minimal retention time, or a project delivering finished water to a public water system's distribution system) will have its own unique set of criteria that are possibly captured within a common framework to avoid discontinuities in the risk assessment. The goal of any type of project is to provide identical water quality and minimal risk.
- **Raw Water Pathogen Monitoring, Including During Outbreaks and Recommendation to Consider Incorporating QMRA.** The SWRCB approach on establishing pathogen log inactivation / removal requirements will directly impact treatment requirements and costs. The language in the report suggests that rather than setting uniform values as with the groundwater replenishment requirements (Table 2.2), the log inactivation / removal requirements could be based on site-specific raw water

pathogen concentrations, or a more robust set of raw water pathogen concentrations for California that encompasses outbreak data. Those site-specific or worst case raw water pathogen data would be used to calculate the required log removal / inactivation requirements to achieve a target finished water quality, potentially derived from QMRA. Depending on the database of raw water pathogen data, this approach could result in similar or more stringent requirements for log inactivation / removal than those established for IPR using injection into the groundwater aquifer as an environmental buffer.

- **Monitoring and Control of Ongoing Projects.** The Expert Panel suggests that a new formal process be established by the SWRCB to administer periodic review of treatment performance data of permitted potable reuse projects. This proposed process is not unlike the process for ongoing monitoring and review of surface water treatment plant operation through surface water monthly operating reports (SWMORs), annual reports (e.g., consumer confidence reports), and California DDW inspections. The SWRCB also indicates a plan to review the state of the science on chemicals of emerging concern every five years. Either of these activities could have implications on permitted operation of a DPR facility, but with the benefit of providing a mechanism for continued review of whether a specific DPR facility, or DPR in general, is providing the best feasible level of protection of public health.
- **Start-up and Commissioning.** The Expert Panel cautioned that the introduction of DPR water into a public water system be staged to demonstrate reliability before contribution is increased. This language, if adopted by the SWRCB in DPR criteria, has potential implications on the approach for starting up new DPR facilities.
- **Approach to Fill Knowledge Gaps and Incorporate New Research Findings.** The SWRCB recognizes the need to consider recently completed and ongoing research through its plan to convene a blue ribbon panel and technical workgroups focused on further developing quantitative metrics and criteria that address the concept of reliability. Outcomes of ongoing research and those panel discussions will influence the criteria for DPR and should be carefully tracked by any ongoing planned DPR project to make sure that the facility design reflects any updated requirements that could be incorporated in the uniform water recycling criteria for DPR based on emerging science.
- **DPR Projects without Reverse Osmosis (RO) Treatment.** The Expert Panel recommended that the SWRCB consider proposals for DPR projects that do not employ RO. While RO provides a robust barrier for protozoa, viruses, nitrate, nitrite, TDS, and multiple metals and chemical microconstituents, it produces a concentrate stream of up to 20 percent or more of the raw water production rate that requires disposal with environmental implications. To facilitate consideration of non-RO treatment trains, the uniform water recycling criteria will need to be written in a manner that allows for these alternatives. The SWRCB highlights that "...there should be some specific reliability criteria for alternatives." The SWRCB's approach to establishing criteria for alternatives to RO will have significant ramification for the design and cost of DPR projects that do not include that unit process, and the feasibility of such an implementation.
- **Provision of a Final Treatment Step to "Average" Out Any Chemical Peaks.** The Expert Panel recommendation for research to identify suitable options for final treatment processes that can provide some "averaging" with respect to chemical peaks,

and any resulting incorporation of that language in the criteria, will have important implications to the design, cost, and operation of DPR projects.

- **Consideration and Incorporation of Non-Treatment Barriers.** The Expert Panel and the SWRCB recommend incorporation of non-treatment barriers, including optimization of wastewater treatment plant operation (WWTP), source control, technical, managerial, and financial capacity (TMF), and operator training and certification. The SWRCB approach to incorporating these non-treatment barriers in any uniform water recycling criteria for DPR could have implications to:
    - WWTP capital improvement projects (CIP) and operational costs.
    - Pre-treatment program requirements for monitoring, management, and local limits.
    - Industrial discharge options and costs.
    - Water utility investment in technical, managerial, and financial capacity.
    - Staffing and training costs for operation of a new DPR facility.
    - Generally, these non-treatment factors reflect best practices for DPR and are recommended within the potable reuse industry. However, their potential adoption within State criteria for DPR projects highlights the importance of planning in advance to ensure that they are addressed as part of a comprehensive DPR project requiring State of California approval.
- **Research on Low Molecular Weight Organics.** One of the SWRCB recommendations is that research be conducted to develop more comprehensive methods to identify low molecular weight unknown compounds for DPR, including non-targeted analysis as a screening tool. How the SWRCB proceeds with this may impact monitoring requirements at a minimum for DPR projects, but could also affect treatment requirements and incorporation of processes that address low molecular weight compounds. Low molecular weight compounds are perhaps the most challenging to remove through established treatment processes (e.g., membrane filtration, membrane desalination, advanced oxidation, granular activated carbon adsorption, biologically active filtration, and chemical disinfection). Requirements to mitigate these compounds could include source control strategies as one of the more effective approaches to reduce concentrations in DPR projects.

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Chapter 3

TREATMENT TECHNOLOGY ASSESSMENT

This chapter details the level of treatment that will be obtained through key processes, how those processes should be monitored, and the total level of treatment that results in both regulatory approval and public health protection as defined by the California Division of Drinking Water, DDW (formally known as the California Department of Public Health, CDPH). As detailed in Chapter 2, the primary acute risk for potable reuse is pathogens; therefore, this chapter focuses on pathogen removal through advanced processes.

3.1 Summary of Findings

Treatment process performance for potable reuse applications have been documented in both demonstration and full-scale applications through years of research and performance monitoring. Combining treatment processes into a series of multiple barriers provides effective pathogen and chemical pollutant reduction. While the pathogen and chemical pollutant removal goals are the same for all types of potable reuse, the actual combination of treatment processes can vary, depending on the end use.

Due to the need to protect water quality (both surface and ground water) we are evaluating treatment process trains that include reverse osmosis for reduction of salts as well as their excellent removal of pollutants and pathogens. The widely accepted and regulatory approved treatment process train for potable reuse is membrane filtration (MF/UF, micro or ultra-filtration), reverse osmosis (RO), followed by an ultraviolet light/advanced oxidation processes (UV/AOP) step. There are several types of oxidants that have proven successful, including hydrogen peroxide and sodium hypochlorite. Additional processes including granular activated carbon (GAC), soil aquifer treatment (SAT), and engineered storage buffers (ESB) may be desired for their removal capabilities in the overall treatment train. Final selection of treatment trains will be made when alternatives for end-use are determined.

3.2 Treatment Process Performance

The performance of each type of treatment process is measured by log reduction of pathogens and removal of chemical compounds (e.g. 1 log = 90 percent removal, 2 log = 99 percent removal, etc.). Because a system of multiple barriers is added up to meet the total log reduction criteria established by regulations, it is important to understand the log reductions that occur across each process, starting with primary and secondary treatment. For each process, we have summarized research findings and generally accepted removal values. The potable reuse goals to meet existing, draft, and prospective regulatory criteria are defined in Table 3.1.

Table 3.1 Potable Reuse Pathogen Reduction Goals/Requirements

Applicable Potable Reuse Form	Virus	*Giardia*	*Crypto*
Surface Water/Reservoir Augmentation (standard: Dilution $\geq$ 100:1)(1)	8	7	8
Surface Water/Reservoir Augmentation (reduced dilution: 100:1 $\geq$ Dilution $\geq$ 10:1) (1)	9	8	9
Groundwater Augmentation(2)	12	10	10
Raw Water Augmentation(3)	14	12	12

Notes:

(1) Surface Water/Reservoir Augmentation requires a minimum residence time of 180 days in the reservoir be calculated theoretically (volume in surface water reservoir divided by total outflow). A lower residence time may incur a proportional increase in required log removal credits.

(2) Groundwater augmentation requires a minimum of two months (60 days) of travel time in the ground before reaching a potable water extraction well.

(3) It is expected that the State will increase several Log Removal Credits (LRCs) for Raw Water Augmentation projects. This increase does not imply an increase in health protection but an increase in risk minimization due to process failure. There is no environmental buffer between the AWPF and the drinking water treatment plant.

3.2.1 Primary and Secondary Treatment

Primary treatment and secondary treatment are the basic physical and biological treatment processes required for wastewater treatment and discharge. However, these processes are also an important first step in the removal of both pathogens and chemical pollutants from a wastewater source. United States Environmental Protection Agency (USEPA) has investigated the removal of pathogens and Table 2-3 of the Design Manual for Municipal Wastewater Disinfection (1986) lists primary treatment as providing 10 to 35 percent removal of bacteria and less than 10 percent removal of viruses. Protozoa removal through primary treatment is not listed. The same table (2-3) includes bacteria and virus removal percentages for secondary treatment, showing 90 to 99 percent removal of bacteria and 76 to 99 percent removal of viruses.

Francy *et al.* (2012) indicates that secondary treatment is capable of 99 percent to 99.98 percent removal of bacteria and 88 percent to 99.9995 percent removal of various virus and coliphage. The single data set with any data below 90 percent removal, which was for adenovirus, showed removal ranging from 88 percent to 99.93 percent with a median removal of 99.8 percent.

Recent DDW approval of pathogen removal credits for combined primary and secondary treatment was obtained by the Water Replenishment District (WRD, 2013). That document relied upon risk analysis data presented in Olivieri *et al.* (2007), which was developed based upon Rose *et al.* (2004). Within Rose *et al.* (2004), the research team defined the range of bacteria, enterovirus, *Cryptosporidium*, and *Giardia* removal through 6 different full scale wastewater treatment plants. The raw data from that work is reported in Olivieri *et al.* (2007). For WRD (2013), the pathogen removal credits for their secondary process were based upon the data from 2 of the 6 tested secondary process configurations. Specifically, two of the secondary process trains (Facilities C and D, with solids retention time (SRT) of 1.6-2.7 days and 3-5 days, respectively) had SRT values less than the secondary process feeding the WRD advanced treatment system (>9 days), and thus are presumed to be conservative estimates of performance. Per CDPH request, WRD (2013) used the lower 10th percentile values calculated for each pathogen, resulting in 2.06-log reduction of enterovirus, 1.42-log reduction of

Cryptosporidium, and 2.42-log reduction of *Giardia*. Note that our analysis of the same data set found one data translation error, but the overall impact on the log reduction credits is minimal. Interpretations of the data set (Rose *et al.* 2004) suggest that longer SRT values result in increased pathogen removal. While this may be the case, the raw data from Rose *et al.* (2004) does not show this clearly (Table 3.2). For example, Facility F from that research with the longer SRT has lower protozoa reduction than most of the other facilities, but also shows the best virus removal compared to the other facilities. The lowest virus removal occurs at Facility A, which has an SRT of 6 to 8 days. This data set is limited and making projections based upon SRT is speculative. Thus, we recommend using the lower 10th percentile of the entire data set, which results in 1.9-log reduction of virus, 1.2-log reduction of *Cryptosporidium*, and 0.8-log reduction of *Giardia*.

Table 3.2 Pathogen Reduction Values Through Primary and Secondary Treatment (from Rose et al., 2004)

Lower 10th Percentile Values		Log Reduction		
SRT	**Facility**	**Enterovirus**	***Giardia***	***Crypto***
1.6 - 2.7	C	1.8	2.6	1.25
3-5	D	2.05	1.35	1.4
3.5-6	B	1.95	2.45	1.6
6-8	A	1.65	0.8	0.7
8.7-13.3	E	1.75	2.6	1.9
8-16	F	2.6	0.9	0.25
1.6-16	**ALL**	**1.85**	**0.8**	**1.2**
50th Percentile Values		**Log Reduction**		
SRT	**Facility**	**Enterovirus**	***Giardia***	***Crypto***
1.6-2.7	C	2.05	3.05	1.65
3-5	D	2.5	1.9	2.6
3.5-6	B	2.25	2.6	1.9
6-8	A	2.1	1.6	1.1
8.7-13.3	E	2.2	2.8	2.1
8-16	F	2.75	1.1	0.95
1.6-16	**ALL**	**2.3**	**2.6**	**1.6**

Overall Performance: The primary and secondary treatment should account for 1.9-log reduction of virus, 1.2-log reduction of *Cryptosporidium*, and 0.8-log reduction of *Giardia*. Primary and secondary treatment is also an important step in removing a significant portion of the chemical pollutants found in raw wastewater.

3.2.2 Membrane Filtration - Microfiltration (MF)/Ultrafiltration (UF)

MF and UF are both types of physical filtration processes. Membranes used for MF applications have a pore size that ranges from 0.1 to 10 µm, while UF membrane pore size are smaller in the range of 0.001 to 0.1 µm. MF is a robust technology that has proven to be effective in removing *Giardia* and *Cryptosporidium* cysts, algae, and some bacterial species. However, MF is not an effective barrier to viruses. On the other hand, UF has proven to be effective in removing viruses.

Recent work with Clean Water Services (CWS) (Oregon), as part of DPR demonstration testing, indicates that a well-functioning UF membrane (0.01 µm nominal pore size in this case) can attain 4.7-log reduction of seeded virus (CWS, 2014) without chemical use (such as alum or polymer) ahead of the membrane. Equivalent or greater reduction of protozoa can be assumed based upon this data because protozoa are much greater in size, and is directly supported by NSF (2012). Furthermore, MF or UF membrane integrity testing (MIT) confirms system performance and demonstrates how MIT data can be used to track and ensure continued membrane performance (CWS, 2014). The UF system at the Ventura Water Pure Demonstration Facility reliably provided at least 4-log protozoa removal and 1-log virus removal.

Overall Performance: Both MF and UF membranes can be relied upon for 4+ log reduction of protozoa. System performance monitoring (to provide regulators' confidence in the removal credit) is accomplished through the use of precise and accurate filtrate turbidity monitoring coupled with daily pressure hold tests (MIT). Innovative methods to track MF or UF performance include the use of bench-scale particle counting and the use of adenosine triphosphate (ATP) to daily verify bacteria removal. MF/UF processes have not been shown to remove a significant amount of chemical pollutants.

3.2.3 Reverse Osmosis (RO)

The RO process in a potable reuse treatment train provides for removal of salt (measured as electrical conductivity (EC)), organics (measured as total organic carbon (TOC)), and pathogens. RO removes ~95 percent of incoming salt. Depending on the feed water quality, RO product water can have a total dissolved solids (TDS) concentration as low as 50 mg/L. Along with salt and TOC removal, RO removes trace level pollutants such as hormones, pharmaceuticals, and personal care products.

Studies have found virus removal by RO to be from 3 to >6-log (Reardon *et al.*, 2005, NRMMC/EPHC/NHMRC 2008, CWS 2014). Equal or greater removal is expected for protozoa based upon size differences (protozoa being much larger than virus). RO process performance for pathogen rejection is not governed by the ability of an intact membrane to reject pathogens; it is governed by the ability to monitor process integrity (Reardon *et al.*, 2005 and Schäfer *et al.*, 2005). The monitoring tools currently used, electrical conductivity (EC) meters and total organic carbon (TOC) meters, can measure 99 percent or less removal of both parameters through the RO process. Recently, the DDW granted 1.5-log reduction credit for all pathogens for RO (WRD, 2013), based upon a requirement to continuously monitor TOC reduction across RO. The Orange County Water District (OCWD) currently attains 2-log pathogen credit through their online TOC meters.

Alternative technologies, such as online fluorescent dye monitoring, have been shown to have higher accuracy in assessing membrane efficiency (Kitis *et al.*, 2003, Henderson *et al.*, 2009, Pype *et al.*, 2013). The Trasar fluorescent dye is stable over a range of temperature and is not impacted by pH in the range of 4 to 10. At 600 g/mole, this compound is larger than the openings in the RO membrane, but smaller than the size of any target pathogen, making the Trasar compound a potentially valuable tool for RO system performance monitoring.

The Trasar technology's efficiency to detect any flaw in a RO membrane was tested by Carollo, with the assistance of Nalco, as part of the Ventura Water Pure demonstration testing. The test included monitoring the removal of seeded virus MS2, EC, and Trasar for different RO operational conditions, including "normal" operation, a cut O-ring condition, and two chlorine oxidized RO membranes. The performance was tracked across both the first stage of RO and for the entire RO. Results from this research demonstrate the ability to conservatively monitor 3 to >4-log removal of virus using Trasar, compared to ~1.5-log removal of other monitoring surrogates.

The RO at the Ventura Water Pure demonstration facility reliably provided at least 1.5-log removal of both protozoa and virus based upon standard monitoring processes (e.g., EC). Results from Trasar testing at the Ventura Water Pure facility documented 4+ log removal of virus (and thus also 4+ log removal of protozoa) under normal operating conditions.

Overall Performance: RO provides a robust removal for all pathogens. OCWD currently attains 2-log pathogen credit trough online TOC meters. RO also provides for substantial removal of trace pollutants.

3.2.4 UV Advance Oxidation Processes (AOP)

In the event of pathogens passing through RO, the UV system provides for a high level of disinfection. A dose of 235 mJ/cm2 will result in 6+ log reductions of all target pathogens (USEPA 2006; Hijnen et al., 2006, Rochelle et al., 2005), including Cryptosporidium, Giardia, and adenovirus. Potable water reuse UV AOP systems will commonly operate at UV doses greater than 900 mJ/cm2; thus, higher reductions are theoretically possible, but DDW allows only a maximum of 6-log reduction credits per any one treatment technology (CDPH, 2014).

Adding an oxidant before the high dose UV results in the generation of hydroxyl radicals thought the UV process. This turns the treatment into an AOP, providing destruction of a range of pollutants that may pass through RO. Either hydrogen peroxide (H_2O_2) or sodium hypochlorite (NaOCl) can be used as an oxidant for this application. H_2O_2 is a more common oxidant than NaOCl for UV AOP applications. NaOCl presents benefits such as increased disinfection due to the presence of free chlorine, lower chemical cost, and operator familiarity. An additional benefit of the UV/NaOCl AOP is a more efficient generation of hydroxyl radicals at a low pH (<6), and RO permeate is typically in this pH range. Both the NaOCl and H_2O_2 UV advanced oxidation processes are controlled by oxidant dose and UV dose (UV intensity, UV Transmittance, or Power). However, the UV/NaOCl process is also controlled by the influent pH to the UV reactor and is sensitive to ammonia residual through the RO process which has a high NaOCl demand, thereby requiring a higher oxidant dose. pH and free chlorine concentration should be closely monitored to ensure the UV AOP design dose is met.

DDW requires the UV AOP to provide at least 0.5-log reduction of 1,4-dioxane, a conservative surrogate for destruction of trace pollutants (CDPH, 2014). Additionally, NDMA, with a DDW notification level (NL) of 10 ng/L, can pass through RO at low concentrations (typically 20 to 100 ng/L), requiring destruction by UV photolysis (Sharpless and Linden, 2003). Therefore, it is common to set the UV dose at 900 mJ/cm2 or higher. This high UV dose photolyzes NDMA as well as many other smaller chemicals that may have passed through the RO train. NDMA is particularly photolabile.

Overall Performance: UV AOP (either with H_2O_2 or NaOCl) reliably provides at least 6-log disinfection of both protozoa and virus. Higher reductions are theoretically possible, but the DDW allows only a maximum of 6-log reduction credits per any one treatment technology (CDPH, 2014).The same system will reduce NDMA to <10 ng/L and destroy at least 0.5-log of 1,4-dioxane, thus also reducing other trace level pollutants. Online dose monitoring systems, using real time inputs of UV, UV intensity, flow, and oxidant dosing, is recommended for continuous confidence in UV AOP performance.

3.2.5 Granular Activated Carbon (GAC)

Granular activated carbon (GAC) and biological granular activated carbon (BAC) are able to remove a wide range of substances in solution (natural organic compounds, taste and odor compounds, and synthetic organic chemicals) via both physical (adsorption) and chemical (absorption) processes. GAC is activated carbon with a diameter greater than 0.1 mm, and a porous interior, greatly increasing the surface area for chemical removal. GAC filters can provide biological treatment of chemicals and organic matter in addition to physical removal when they are not exposed to disinfectants, and a biofilm layer is allowed to grow on the media (Crittenden, *et al*. 2012).

The State Water Resources Control Board recommended in the report to the legislature "*Investigating the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse*" that short term research be conducted to identify suitable treatment options for final treatment processes that can provide some attenuation with respect to potential chemical peaks (in particular, for chemicals that have the potential to persist through advanced water treatment)...". GAC and BAC are both options for a final barrier in an advanced treatment train, to act as a "polishing" step to remove any potential chemical peaks persisting through the processes. A polishing step can further reduce concentrations of any unlikely chemicals persisting in the water, rather than simply averaging. Public health benefits from incorporation of a final treatment step in the treatment train for attenuation of chemical peaks should be balanced with an assessment of environmental impacts (e.g., carbon generation, regeneration/disposal, and transport).

The Prairie Waters Project in Aurora, Colorado is a potable reuse augmentation project developed to alleviate the drought effects in the area. The treatment capacity is 50 million gallons per day (mgd). The project recovers the return flows discharged to the South Platte River downstream of Denver. The multi-barrier purification approach starts with riverbank filtration followed by artificial aquifer recharge with a retention time of 30 days. Once the water is recovered, the water is chemically softened before undergoing advanced oxidation (UV/H_2O_2), granular filters, and GAC as a polishing step to remove any trace organics that were not destroyed by the previous processes.

Overall Performance: GAC will readily adsorb organic compounds and provides a good option for a final barrier in a potable reuse train. However, GAC effectiveness is observed to be lower for low-molecular weight polar organic compounds.

3.2.6 Soil Aquifer Treatment (SAT)

Soil Aquifer Treatment (SAT) is a simple and effective process that has become an economical treatment alternative for water reuse applications. In SAT, water is recharged to an underlying aquifer through the unsaturated vadose zone. Physical, chemical, or biological treatment may be achieved when water infiltrates or percolates trough vadose zone.

The City of Fresno with Carollo, working with the WateReuse Research Foundation, completed leading edge research on the pathogen removal ability of spreading basins, showing 4 to 5-log reduction of virus through filtration in the upper levels of the percolation process. As protozoa are much larger than virus, equal or greater protozoa removal is also anticipated. The State of California credits the SAT process with substantial pathogen removal, but note that such pathogen removal is based upon 6+ months of travel time in the subsurface, not based upon removal in the upper levels of percolation through SAT. This new work tells another story, the robust value of filtration which would supplement pathogen die-off.

Overall Performance: The City of Fresno study showed 4 to 5-log reduction of pathogens through filtration as part of SAT. It should be noted that this work has been repeated at two locations (Fresno, Dinuba), but further soil column work is recommended until a more robust data set is completed. For this study, we are assuming a 3-log reduction of all pathogens through an SAT process. Field studies have shown that SAT process is capable of efficiently removing organic matter and estrogen (Fox, 2006).

3.2.7 Engineered Storage Buffer

For projects with short "Response Retention Time" (RRT), minimum time required for analytical procedures to be completed so that the quality and health effects can be determined, on the order of days to weeks or less, the use of an Engineered Storage Buffer (ESB) is recommended. Minimizing the environmental buffer leads to the loss of several benefits, including dilution, and, perhaps most importantly, time to detect and respond to a treatment failure. Recent potable reuse reports suggest that these are limitations that can be overcome. These studies include the WateReuse Research Foundation's 2011 report entitled "Direct Potable Reuse: A Path Forward" (Tchobanoglous *et al.*, 2011), the National Research Council's 2012 report entitled "Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater" (NRC, 2012), the Australian Academy of Technological Sciences and Engineering’s 2013 report entitled “Drinking Water through Recycling: The benefits and costs of supplying direct to the distribution system” (ATSE 2013), and the WateReuse Research Foundation (WRRF) Project 11-10, Application of Risk Reduction Principles to Direct Potable Reuse (Salveson *et al.*, 2014). They suggest that a higher level of treatment at the Advanced Water Treatment Facility (AWTF) can compensate for the lack of treatment and dilution provided by the groundwater aquifer or surface water reservoir.

Tng *et al.* (2015) collected a cumulative 64 years' worth of operating data from seven operating advanced treatment facilities around the world to calibrate a model that simulated failure events for potable reuse. One of the significant findings of the modeling effort by Tng *et al.* (2015) is that *"the best approach to improving a plant’s resilience is not by having multiple redundancies, but rather, via implementing more efficient maintenance protocols with an adequate amount of treated water storage."* This second point dovetails with the findings from WRRF 12-06 (Salveson *et al.*, 2016), which defines a framework for engineered storage buffer sizing as a function of monitoring system characteristics and robustness as opposed to redundant treatment, essentially providing a roadmap for the approach recommended by Tng *et al.* (2015).

The ESB could hold the finished water for a duration sufficient to fully monitor the performance of each key process and respond any potential performance issue (Figure 3.1.). This hold time is the "Failure and Response Time," or FRT (Salveson *et al.*, 2016). The FRT can be minimized by not taking credit for processes that require long sampling and analysis time frames. Advanced processes such as pasteurization, RO, and UV AOP all can be rapidly monitored and maintain FRT values of ~30 minutes or less. The implication with this FRT is that the operators of the AWPF will have sufficient time to divert water or shut down the plant. A 30-minute FRT does not give enough time to necessarily address a water quality concern, but instead to identify it and prevent water from leaving the plant.

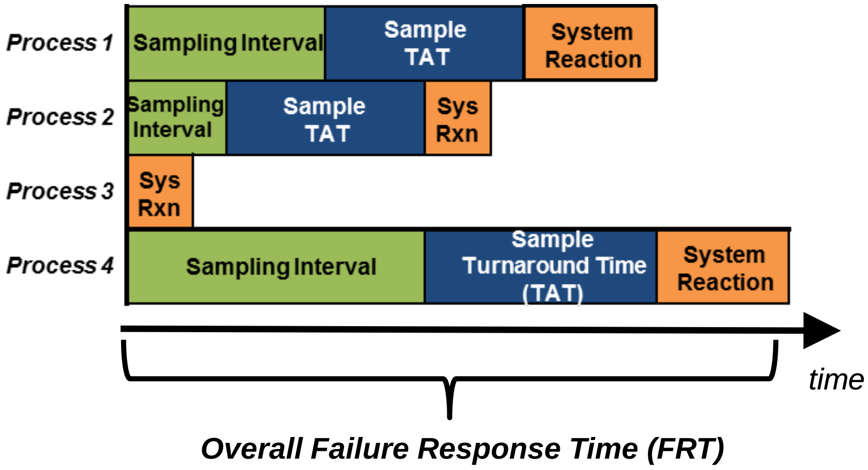

Figure 3.1 Treatment Train Failure Response Time (Salveson et al., 2016)

ESB also provides disinfection due to the maintenance of a free chlorine residual. Free chlorine contact time (Ct) values required for *Giardia* and virus inactivation are defined by the 1990 Surface Water Treatment Rule (SWTR) Guidance Manual (USEPA 1991). The Ct tables in that reference are flexible. 4-log virus credit can be obtained at a Ct of 12 mg-min/L, though higher Cts would be required for *Giardia* credit. USEPA (1991) was only designed to meet a maximum 4-log virus kill, though higher virus kill has been demonstrated. For a minimum FRT of 30 minutes and a minimum residual of 1 mg/L, the Ct of 30 mg-min/L will result in the 4+ log reduction of virus and 0.5-log reduction of *Giardia*, but no reduction of *Cryptosporidium*.

Overall Performance: The ESB would provide for 30 minutes of failure and response time, allowing the proposed online monitoring systems time to measure water quality and time for response and diversion procedures to be properly implemented in the event of a water quality or monitoring system failure. Additional, the ESB would provide for 4-log reduction of virus and a 0.5-log reduction of *Giardia*. ESB does not provide any removal of chemical pollutants.

3.2.8 Surface Water Treatment Plant (SWTP) - Filtration and Ozonation

Treatment processes at a conventional SWTP (sedimentation, coagulation, filtration, and disinfection) provide another set multiple barriers. For projects where purified water will be introduced upstream of the existing SWTPs, the treatment processes at the WTP provide another set of multiple barriers in meeting pathogen and pollutant removal goals. Most of the WTPs have replaced the chlorine-treatment process with a combination of ozonation (O_3), ultrafiltration, and UV. This process provides faster treatment time, requires a smaller footprint, and allows enhanced performance. Sections 3.2.2 and 3.2.4 describe the UF and UV processes.

Zone 7 has two SWTPs, Del Valle Water Treatment Plant (DVWTP) and Patterson Path Water Treatment Plant (PPWTP). It also uses a demineralization facility (Mocho Demin) to treat brackish groundwater. However, the Mocho Demin is not included as part of any potable reuse treatment train. Zone 7 is planning to add O_3 at both SWTPs. The agency expects to make the addition to the DVWTP by 2019, and possibly PPWTP by 2020.

O_3 is widely used for drinking water treatment because of its disinfection and oxidation qualities. It is usually added as a pre-oxidation step before filtration to remove organic, inorganic matter, and micro-pollutants. It is also used for odor and taste control. O_3 is generated on-site due to the very short half-life of the molecule.

Overall Performance: A typical SWTP must meet a 4-log virus, 3-log *Giardia*, and 2.5-log *Cryptosporidium* requirement. Log removal credit for *Giardia* cysts and viruses by ozone (O_3) disinfection is based on contact time (Ct) per USEPA Ct tables (USEPA, 1991). According to the Long Term 2 Enhanced Surface Water Treatment Rule - Toolbox Guidance Manual, a log credit of 0.25 to 3.0-log for *Cryptosporidium* inactivation can be granted to systems with the addition of ozone, depending on the ozone dose applied. This value is determined by the Ct values. Ct values are established to provide a conservative characterization of the dose of ozone necessary to achieve a specified inactivation of *Cryptosporidium* (USEPA, 2010). O_3 can remove some trace organics like pesticides.

3.3 Overall Treatment Process Performance

The anticipated total performance of a proposed treatment train will depend upon the coupled treatment processes, which depends upon the planned type of potable reuse. The final selection of treatment trains paired with end use (types of potable reuse) will be made in later TMs that focus on alternative development and evaluation/comparison. Example potable reuse projects are listed below, including summary tables (Tables 3.3 through 3.6) of treatment performance for each listed option. For this analysis, the following considerations have been taken (i) SWTPs include sedimentation, coagulation, filtration, and disinfection, and (ii) two types of Groundwater Replenishment Reuse Projects (GRRPs) are surface spreading (SAT) and groundwater injection. Surface water spreading allows the stabilized purified water to infiltrate and percolate through the soil into the aquifer. This process is known as soil aquifer treatment(SAT). Surface spreading projects rely heavily upon treatment through the percolation process and dilution once the percolated water is in the groundwater basin. Groundwater injection of stabilized purified water directly into the groundwater basin would require full advanced treatment that includes RO and advanced oxidation processes (AOP). Additionally, a minimum of two months of subsurface travel time is required before extraction for potable use. General requirements for groundwater recharge are described in Chapter 2.

1a. Groundwater Recharge by Surface Spreading: DDW will allow for 20 percent tertiary recycled water and 80 percent approved "dilution" water. The dilution water can be reclaimed water that has gone through sufficient treatment to meet all regulatory standards; use of MF and RO should be sufficient. Thus, the process train, by regulation, could include 20 percent tertiary recycled water (filtered and disinfected) with 80 percent MF/RO product water. Spreading projects require 6+ months of subsurface travel time to extraction wells. Given the proximity to extraction wells and the connectivity of Lake I to the shallow aquifer, which could be a potential spreading location, Option 1b, below, may be required.

Table 3.3 Treatment Option 1a. Groundwater Recharge by Surface Water Spreading (6+ months Travel Time)

Parameter	Primary/ Secondary Treatment	Tertiary Filtration and Disinfection	SAT	Subsurface Travel	Total Credits	Removal Goal
Viruses (log)	1.9	5	3	6	12+	12
Giardia (log)	0.8	0	3	*	10+	10
Crypto (log)	1.2	0	3	*	10+	10
NDMA			X			<10 ng/L
Turbidity		X				<0.2 NTU
Total Organic Carbon			X			<0.5 mg/L
Drinking Water MCLs			X			Varies

Notes:
(1) Extra log removal credits are granted by subsurface travel time. Assumes 6 months of travel time

1b. Groundwater Recharge by Surface Spreading with Short Travel Time: Option 1a must be modified in the event of a travel time of less than 6 months. The treatment train would require MF (or UF), RO, and UV AOP following a strict regulatory interpretation. However, the SAT process still provides value and the goal would be to utilize that value and reduce the purification costs through the use of low dose UV instead of UV AOP.

Table 3.4 Treatment Option 1b. Groundwater Recharge by Surface Water Spreading with Short RRT (<6 months)

Parameter	Primary/ Secondary Treatment	MF	RO	UV/ NaOCl	SAT	Subsurface Travel	Total Credits	Removal Goal
Viruses (log)	1.9	0	3	6	3	0	13.9	12
Giardia (log)	0.8	4	3	6	3	0	16.8	10
Crypto (log)	1.2	4	3	6	3	0	16.8	10
NDMA				X	X			<10 ng/L
Turbidity			X					<0.2 NTU
Total Organic Carbon		X			X			<0.5 mg/L
Drinking Water MCLs			X		X			Varies

2. Reservoir (Surface) Water Augmentation: Cope Lake could be used for Reservoir Augmentation, recognizing that the travel time is likely less than 6 months and anticipated DDW requirements for V/Q and blending may not be met. The resulting treatment and monitoring system would be MF (or UF), RO, and UV AOP, followed by the use of an ESB, and using advanced monitoring of the RO process with Trasar. Using the more conservative log removal credits from the Pure Water San Diego project, this treatment may be appropriate for Raw Water Augmentation as well, with the water sent directly to DV WTP or PPWTP

Table 3.5 Treatment Option 2 - Reservoir Water Augmentation or Raw Water Augmentation

Parameter	Primary/ Secondary Treatment	MF	RO	UV / NaOCl	ESB+ $Cl_2$$^{(1)}$	WTP	Total Credits	San Diego Pure Water Goal
Virus (log)	1.9	0	3	6	4	4	18.9	14
Giardia cysts (log)	0.8	4	3	6	0.5	3	17.3	12
Cryptos oocysts (log)	1.2	4	3	6	0	3	17.2	12
1,4-dioxane				X		X		0.5-log by AOP
NDMA			X	X				<10 ng/L
Turbidity		X				X		<0.2 NTU
Total Organic Carbon			X			X		<0.5 mg/L
Drinking Water MCLs			X	X		X		Varies

Notes:

(1) Assumes a CT (chlorine dose - contact time relationship) of 3.0.

3. Groundwater Injection: Groundwater injection, either in a conventional mode or with Aquifer Storage and Recover (ASR), would require MF (or UF), RO, and UV AOP. Use of advanced monitoring with Trasar allows the project greater flexibility in the minimum time the purified water must be stored underground.

Table 3.6 Treatment Option 3 - Groundwater Injection

Parameter	Primary/ Secondary Treatment	MF	RO	UV/NaOCl	Subsurface Travel	Total Credits	Removal Goal
Viruses (log)	1.9	0	3	6	2	12.9	12
Giardia (log)	0.8	4	3	6	0	13.8	10
Crypto (log)	1.2	4	3	6	0	13.8	10
1,4-dioxane				X			0.5-log by AOP
NDMA			X	X			<10 ng/L
Turbidity		X					<0.2 NTU
Total Organic Carbon			X				<0.5 mg/L
Drinking Water MCLs			X				Varies

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Chapter 4

WATER AVAILABILITY, BALANCE, AND QUALITY

This chapter presents a summary of the analysis on water availability and source water quality. Results of the following specific analyses are presented in this chapter:

- Water availability of sources both within and outside of Tri-Valley.
- Treatment process and source water evaluation.
- Water balance analysis and yields/losses.

Potential treatment, storage, conveyance, and end use options were identified to develop the components of the water balance and to assess yields and losses. As noted in the sections that follow, more detailed analysis is conducted on the options as part of the alternatives analysis and the refined results is presented in Chapter 5.

4.1 Summary of Findings

There are a number of key findings and conclusions from information presented in this chapter that impact the next step in the analysis of developing and evaluating alternatives. The flows presented in this study are based on master plan projections for buildout flows - 2020 for Livermore and 2035 for Dublin San Ramon Services District (DSRSD).

The water supply related findings and conclusions include:

- Projected summer available flows from the LWRP and DSRSD WWTP are 6.1 million gallons per day (mgd) and 0 mgd, respectively.
- Projected combined summer available flow from LWRP and DSRSD WWTP is 6.1 mgd.
- Projected maximum month flows from the LWRP and DSRSD WWTP are 8.7 mgd and 12.3 mgd, respectively.
- Projected combined maximum month available flow from LWRP and DSRSD WWTP is 20.9 mgd.
- While the EBDA pipeline provides a potential source of effluent, the cost of conveying the water to the Tri-Valley will likely exceed $60 M to reliably obtain 6 mgd of water to avoid developing a very complex system of batch processing and operation.

The water storage related findings and conclusions include:

- The available volume of storage at LWRP is not sufficient to provide an appreciable increase in year round flows to a purification process. Storage at this site is not further considered.
- The potential storage options at DSRSD present more of a potential flow benefit, although these storage options require replacement of DSRSD’s existing biosolids management facilities Approximately 170 MG (605 AF) of storage is required to increase the purification flow by 1.1 mgd.
- Storage of the combined flow from DSRSD and Livermore, at DSRSD, has the potential to appreciably increase year round flow to a purification process. This storage option will

be further considered in the alternatives analysis only for alternatives with treatment at DSRSD or nearby.

The treatment, water quality, and end use related findings and conclusions include:

- FAT is assumed for all potential sites for injection wells and ASR wells, with the exception of the site adjacent to Lake I, where FAT, GAC, and engineered storage are assumed to be required.
- FAT, GAC, and engineered storage are assumed for all other end uses including Lake I recharge and surface water augmentation.
- Wastewater or concentrate treatment for ammonia removal is assumed not to be required to meet current discharge permit limitations; however this should be confirmed if a project was to move forward.
- Concentrate treatment to reduce fouling and scaling potential may be required.

While pollutants in the secondary effluent do not appear to present issues for a purification process, an Enhanced Source Control Program (ESCP) will be used as a first barrier for protecting public health. Even though an ESCP is not a specific regulatory requirement, it is expected that this will become part of the State's requirements to permit potable reuse projects. Background

4.2 Background

Figure 4.1 shows the existing facilities, including the Zone 7 water treatment plants, the DSRSD WWTP and the LWRP. Both DSRSD and Livermore have existing non-potable recycled water irrigation programs. Secondary effluent that is not used for non-potable recycled water irrigation is discharged to San Francisco Bay through the LAVWMA and EBDA facilities.

Treated wastewater from DSRSD WWTP and LWRP flows to a junction box downstream of the plants and is conveyed to the LAVWMA reservoirs and export pump station located north of the DSRSD WWTP. The effluent is then pumped from LAVWMA reservoirs into the LAVWMA export pipeline, sent over Boehmer Summit and discharged into the EBDA outfall pipeline. The EBDA pipeline conveys the effluent from LAVWMA and five other wastewater agencies (Town of Castro Valley, City of Hayward, Oro Loma Sanitary District, City of San Leandro, and Union Sanitary District) to a deep-water discharge outfall in San Francisco Bay. Under wet weather conditions and specific hydraulic conditions in the EBDA pipeline, LAVWMA can discharge to San Lorenzo Creek and Alamo Canal.

This project explores opportunities to treat the secondary effluent that is currently discharged to San Francisco Bay as potable reuse for water supply. The amount of available water for potable reuse depends upon the supply patterns, other existing uses (e.g. non-potable recycled water programs), and the projected recovery of the treatment train. The treatment trains were discussed in Chapter 3. Figure 4.2 presents a schematic of the components of the potable reuse alternatives, and additional detail is provided in Table 4.1, including identification of locations for treatment as agreed upon through discussions with staff from the Tri-Valley Water Agencies. This chapter will focus on available water supply and projected yield. A further analysis of project alternatives based on end uses and treatment location is presented in Chapter 5.

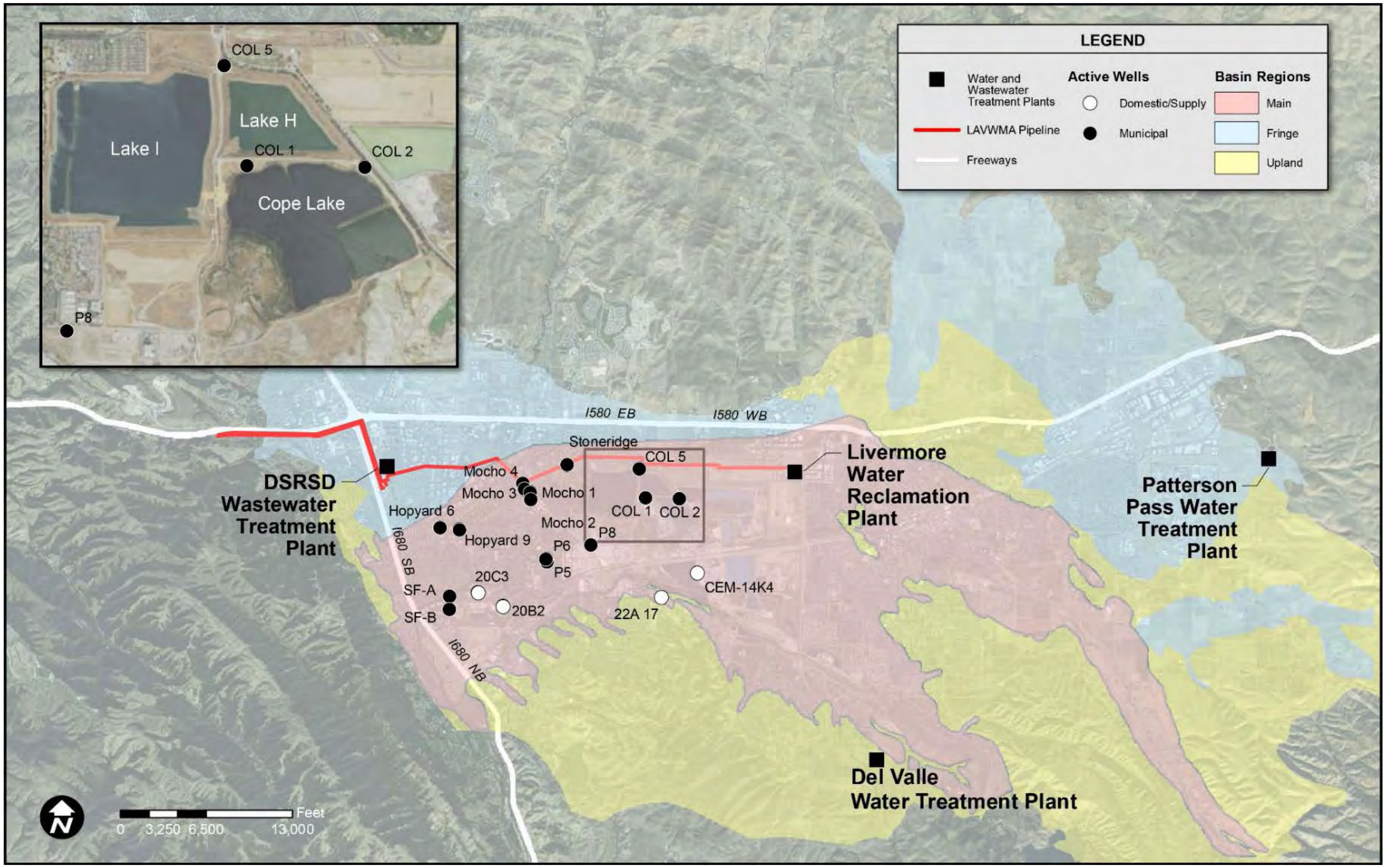

Figure 4.1 Existing Facilities

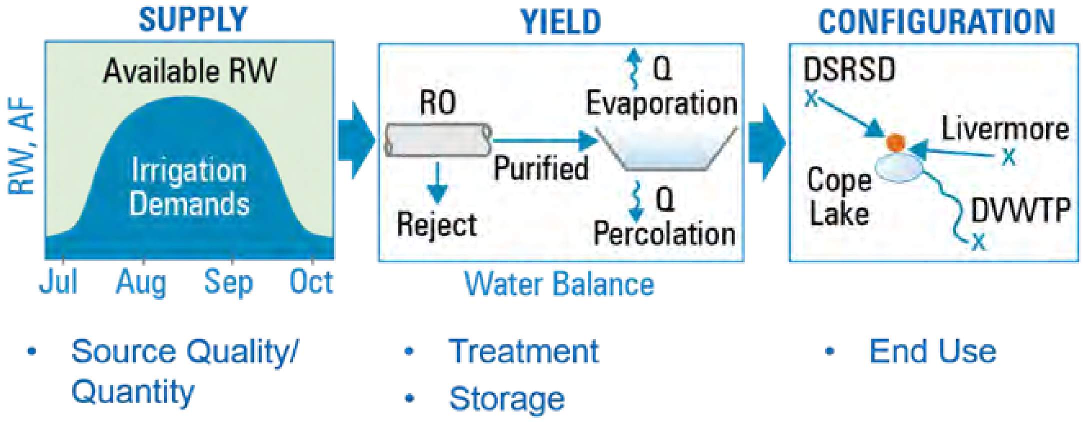

Figure 4.2 Schematic Diagram of Potable Reuse Alternatives

4.3 Water Availability

Both in-valley and out-of-valley sources of water were considered for this evaluation of flows available for potable reuse.

4.3.1 Within Tri Valley Sources

The in-valley analysis was performed for current conditions using historical data from the WWTPs from 2011 to 2015. However, during that period, California experienced a severe drought. While conservation measures have increased from the pre-drought usage there is expected to be some rebounding in per-capita water usage (and corresponding wastewater production) in non-drought conditions. Future flows were identified through review of the agencies' wastewater and recycled water master plans and used to develop the flow projections for 2035. The projections include compensation for the "bounceback" from the drought. For this study, the available water for potable reuse is defined as the secondary effluent flow from DSRSD WWTP and LWRP that is not being used to supply recycled water for non-potable uses.

Both agencies have existing and planned non-potable recycled water programs to serve irrigation customers within their service areas. Given the significant capital investment incurred, and the community support for the non-potable recycled water programs, it is highly unlikely that the agencies will discontinue these programs in the near future and divert wastewater to potable reuse instead. However, it is noted that if severe drought and water scarcity conditions persist in the future, non-potable uses may eventually be significantly reduced or eliminated (e.g. no landscape watering). Until such time that outdoor irrigation is banned, it is appropriate that recycled water be used, where feasible, to reduce demands on the potable water system for non-potable uses. This concept is termed "fit for purpose" and considers examining the best and highest use for each type of water. Clearly potable water should not be used for non-potable uses if an alternative exists.

Table 4.1 Components of Potable Reuse Alternatives

Component	Description
Potable Reuse Source Water	
Livermore Effluent	The available secondary effluent from the LWRP
DSRSD Effluent	The available secondary effluent from the DSRSD WWTP
Combined Effluent	The combined total available from the DSRSD WWTP and LWRP
Outside Tri-Valley Effluent	Any source of secondary effluent that is not generated in the Tri-Valley Area
Purification Process/Location	
LWRP	Purification treatment of available LWRP secondary effluent, located at the LWRP
DSRSD WWTP	Purification treatment of available DSRSD WWTP secondary effluent, located at the DSRSD WWTP
Regional Plant at DSRSD	Purification treatment of the combined secondary effluent, located at the DSRSD WWTP
Regional Plant at Chain of Lakes	Purification treatment of the combined secondary effluent, located at a new site in the Chain of Lakes area
Regional Plant Near Zone 7 Demineralization Facility	Purification treatment of the combined secondary effluent, located at a new site near the Zone 7 Demineralization Facility
Pleasanton AWPF to COLs/DVWTP(1)	Purification treatment of the combined secondary effluent, located at the Pleasanton Corp Yard
End Uses	
Groundwater Augmentation: Groundwater Recharge with injection wells (various locations)	Groundwater recharge of purified water through injection wells, and extraction at a downgradient location.
Groundwater Augmentation: Aquifer Storage and Recovery (ASR) wells (various locations)	Groundwater recharge of purified water through a well, followed by temporary underground storage, and extraction via the same well.
Surface Water Augmentation: Surface spreading (Lake I)	Groundwater recharge of purified water through surface spreading, and percolation into the underlying groundwater aquifer.
Raw Water Augmentation: Augmenting surface water to PPWTP or DVWTP	Augmentation of surface water supplies with purified water, followed by additional treatment at the PPWTP or DVWTP

Note:
(1) This alternative was added after Workshop #4 to provide an alternate regional location.

For the purposes of illustration, we have included a discussion in this chapter regarding the potential future flows available for potable reuse if non-potable recycled water programs were eliminated at some point in the future. However, for developing alternatives for potable reuse we will use only the flows available beyond what is planned for non-potable reuse. The flow discharged to the shared LAVWMA outfall to the San Francisco Bay is used as the available water for potable reuse. The projected 2035 combined LAVWMA discharge from DSRSD and Livermore is used as a maximum flow to size the different advanced water treatment facilities alternatives. It should be noted, that even though the values considered in this study are conservative, there is a level of uncertainty in terms of how the actual flows will vary in the future due to changes in climatic conditions, growth, and/or water use patterns.

4.3.1.1 DSRSD

DSRSD has made significant investments in non-potable recycled water over the last two decades. DSRSD's wastewater effluent is recycled at the recycled water treatment facilities, collocated at its regional wastewater treatment plant. DSRSD partnered with the East Bay Municipal Utility District (EBMUD) to form the DSRSD-EBMUD Recycled Water Authority (DERWA), a joint powers authority. DERWA acts as a recycled water wholesaler, which treats and distributes tertiary treated recycled water to DSRSD, EBMUD and the City of Pleasanton primarily for landscape irrigation. DERWA's most recent project is an $18 million recycled water treatment facilities expansion project that increases capacity to over 16 mgd to provide for projected increased demands by DSRSD, EBMUD and the City of Pleasanton. Upon completion in 2018, the facilities will essentially use all of the secondary effluent available from DSRSD during the summer irrigation season.

Historical data from October 2011 to April 2015 on DSRSD's wastewater influent flows and recycled water demands and projections for 2035 were provided by West Yost Associates developed as part of DSRSD's Wastewater Treatment and Biosolids Facilities Master Plan (West Yost Associates, 2016). Flow projection data for 2035, for the influent and recycled water demand flow rates, were only available for the months of October to April.

Figure 4.3 shows the historical data for flows discharged to LAVWMA from DSRSD that could be made available for potable reuse. The flow fluctuates seasonally with lower available flows for potable reuse during the summer months when demand for recycled water is higher. The average available flow during the summer (June, July, and August) is 3.8 mgd.

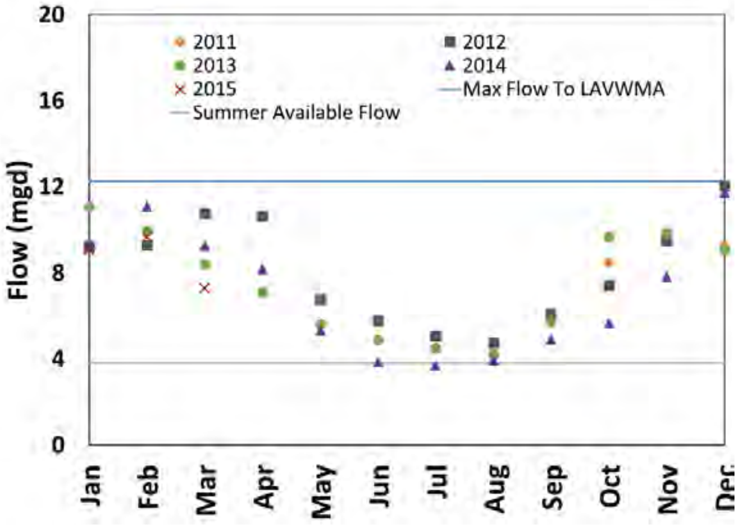

Figure 4.3 DSRSD's Historical Water Available for Potable Reuse

Figure 4.4 shows the 2035 flow projections for the available water compared to the historical data from 2012 to 2014. In 2035, based on the current plans to expand DSRSD, EBMUD, and the City of Pleasanton's non-potable system, the recycled water demand during the summer months would exceed the available wastewater influent flow. DSRSD is working on alternatives and seeking partnerships with adjacent agencies for alternatives to supplement their influent flows to meet recycled water demands. In conclusion, there is essentially no flow available from DSRSD for potable reuse during the summer months when there is the highest demand for non-potable recycled water. Potential outside source options to supplement flows are discussed in Section 4.3.2. The maximum available water flow from DSRSD during winter months is 12.3 mgd.

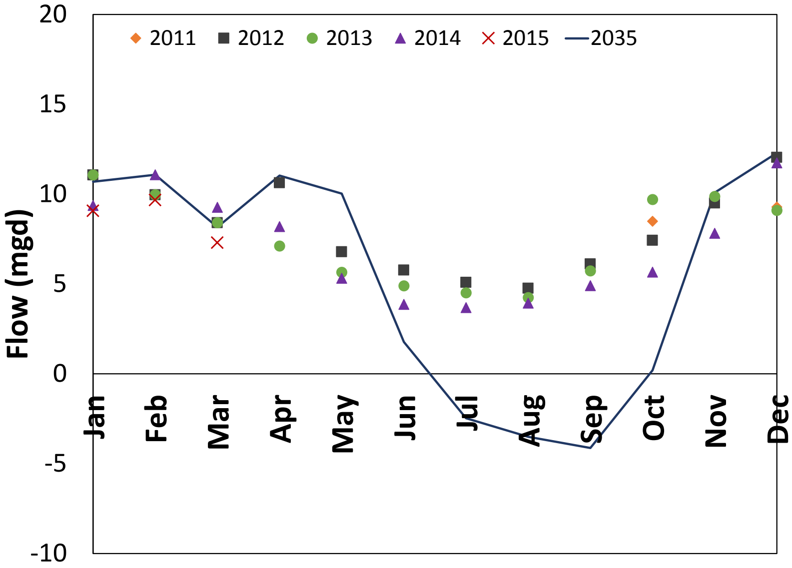

Figure 4.4 DSRSD 2035 Net Flow Projection After Recycled Water Production

4.3.1.2 Livermore

Like DSRSD, the City of Livermore has invested in a non-potable recycled water system, however, the existing and planned non-potable recycled water commitments are not expected to exceed the supply of secondary effluent throughout the year. Figure 4.5 shows historical data from 2011 to 2015 for flows discharged to LAVWMA that shows a seasonal variation with lower flows available during the peak irrigation months (summer). The maximum flow available during the winter is 6.4 mgd and the average summer flow is 3.1 mgd.

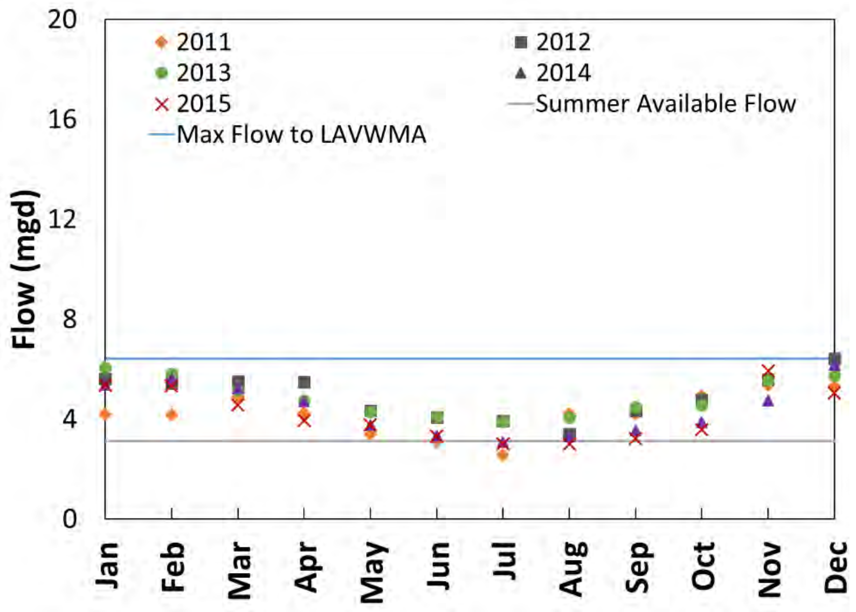

Figure 4.5 Livermore's Historical Available Flow Data

Livermore's flow projections were based on the Livermore Water Reclamation Plant 2012 Master Plan Update (Tetratech, 2013). The buildout Average Dry Weather Flow (ADWF) of 9.66 mgd was used to develop the flow projection for this study. Currently, Livermore is working on updating their master plan; however, the document was not ready for release at the time of this writing. It is expected that future flows could vary depending on the development of an extension of the Bay Area Rapid Transit (BART) to the area. This potential increase in flow would offset the decreases seen in recent years by conservation efforts during the drought. In the absence of an updated master plan, Livermore agreed to use the 2012 Master Plan's buildout value for this study. Figure 4.6 shows flow data for 2013 to 2015 along with the water available flow projection at buildout. The projection maximum flow is 8.7 mgd and the average summer flow is 6.1 mgd.

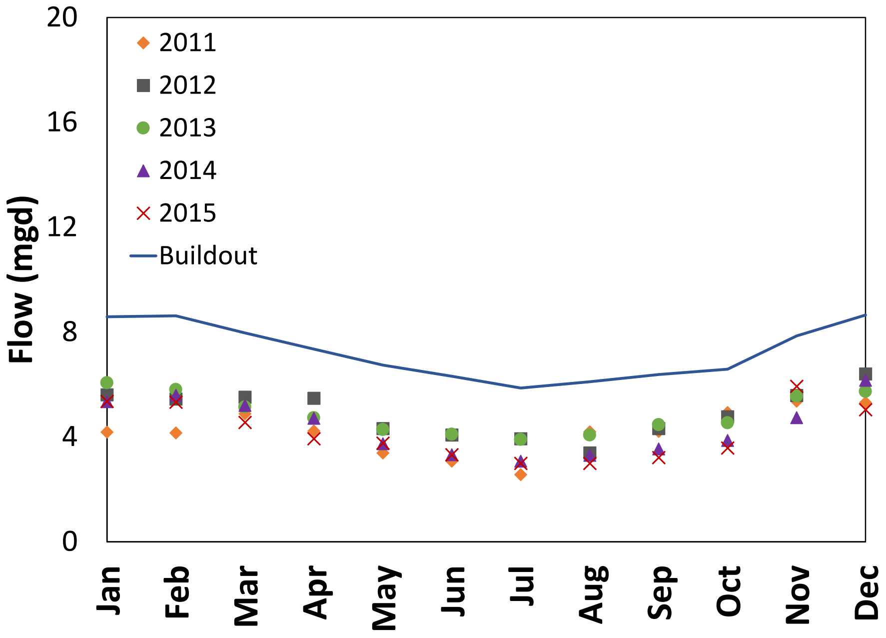

Figure 4.6 Livermore's Net Flow Projection After Recycled Water Production

4.3.1.3 Combined Flows Available

There are different approaches that could be used for considering the available supply for potable reuse. Three scenarios were analyzed for the combined flows available as summarized in Table 4.2. Based on input from the Tri-Valley agencies, it was decided that only future flows should be considered. Table 4.2 shows the available supply for: 1) after removing planned recycled water demands, 2) existing recycled water demands, and 3) eliminating recycled water altogether.

Table 4.2 Summary of Projected Summer Flows

Scenario	Projected Summer Influent Flow (mgd)			Average Summer RW Demand Flow (mgd)			Available Summer Flow for Potable Reuse (mgd)
	DSRSD	Livermore	Combined	Combined	DSRSD	Livermore	
1. Planned RW Use	12.7	9.4	22.1	19.3(1) (more than available	16.0	3.3	6.1(2) (Livermore only)
2. Existing RW Use	12.7	9.4	22.1	8.1(3)	5.5	2.6	14.2
3. No RW Use	12.7	9.4	22.1	None			22.1

Notes:

(1) Projected non-potable reuse demands (DSRSD/Livermore).

(2) Represents only Livermore's secondary effluent flow during the summer months. DSRSD's flow is fully diverted to recycled water use. Deficit DSRSD recycled water demands assumed to be supplied by other supplemental flow.

(3) Existing demands (DSRSD/Livermore).

Scenario 1 assumes the projected combined flows (DSRSD and Livermore) for the projected influent and the recycled water demand. Figure 4.7 shows the annual variation for the projected combined influent and recycled water with an annual average influent flow of 22.7 mgd and a summer influent combined flow of 22.1 mgd. The combined recycled water demand during peak irrigation months is projected at 19.3 mgd, primarily made up by DSRSD's demand of 16 mgd and a smaller demand from Livermore of 3.3 mgd. The maximum available flow during the months with lower recycled water demand (winter months) is 20.9 mgd. The average available flow for potable reuse during summer months is 6.1 mgd. This available water represents only Livermore's flow since DSRSD's flow is fully diverted to recycled water use during the summer months. Water sources outside the Tri-Valley area are discussed in Section 4.3.2.

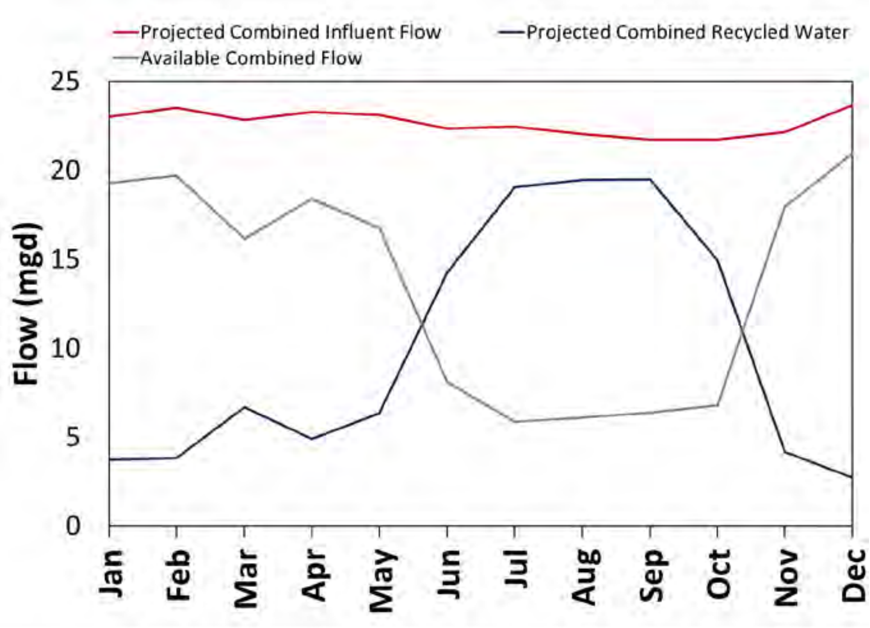

Figure 4.7 Combined Projected 2035 Available Flows for Potable Reuse with Planned RW Expansions

Scenario 2 considers the projected combined flow with the existing combined recycled water demand. In this scenario, further expansion of the non-potable recycled water system is suspended at current level. The average existing summer recycled water demand is 8.1 mgd which leaves the average summer water available for potable reuse at 14.2 mgd. This value includes both DSRSD and Livermore's flow since neither of the agencies' existing recycled water demand exceeded the influent flow. This scenario was discussed and eliminated from further discussion since there has already been a significant investment made to expand the DERWA recycled water services to Pleasanton using secondary effluent at DSRSD's wastewater treatment plant as source water. Therefore, the historical recycled water demands are not a realistic representation of future demands.

Finally, scenario 3 examines the option of the eliminating the recycled water programs for DERWA and Livermore. This would provide the maximum available flow equivalent to their combined summer influent of 22.1 mgd. However, the Tri-Valley agencies indicated a commitment to continuing to serve non-potable demands with recycled water in the foreseeable future to both offset potable uses and to provide a "fit for purpose" water supply. Therefore, this scenario is presented for informational purposes only and will not be used in developing alternatives.

4.3.2 Outside Tri-Valley Sources

Given the limitations of the wastewater available for potable reuse in the summer, the potential for treated wastewater from outside the Tri-Valley to serve as a source of water supply for potable reuse was considered.

Due to the projected deficit of available water for their non-potable recycled water program, DSRSD previously identified a number of options for augmenting flows. The following options have been considered:

- Wastewater from the Dougherty Valley area - This wastewater flow is currently exported to the Central Contra Costa Sanitary District (CCCSD) via the San Ramon Pump Station. The five-year average (2011-2015) flow recorded at the pump station was 2.75 mgd. However, this flow has been fluctuating with an average of 2.57 mgd in 2015.
- Treated effluent from the East Bay Dischargers Authority (EBDA) Pipeline - The disinfected, secondary effluent in this pipeline is from several Bay Area facilities and is currently discharged to San Francisco Bay. Use of this effluent would require conveyance from the EBDA pipeline over the Boehmer Summit and into the Tri-Valley. Alternatives for conveying 6 mgd and 25 mgd from the EBDA pipeline have been previously considered.

To increase the available wastewater supply to meet projected irrigation demands, DSRSD is exploring the possibility of receiving 2.5 mgd of wastewater from the Dougherty Valley area during the summer months and has approached CCCSD. If an agreement is reached, this outside supply would be dedicated to meeting non-potable recycled water irrigation demands. The wastewater from Dougherty Valley will therefore not be available as a supply for potable reuse.

DSRSD, EBMUD and the City of Pleasanton examined supplemental supply options for DERWA (DSRSD, EBMUD and the City of Pleasanton, 2016). Among the options explored is to use the wastewater in the EBDA pipeline as a potential source of water for potable reuse. Two different options were considered previously: 1) use existing infrastructure and add pump stations to reverse flow back into the valley; and 2) add new pipeline and pump stations to allow flow both directions. Both options were developed for importing 6 mgd and importing 25 mgd. Option 1 to use existing infrastructure may be feasible but would be operationally complex requiring storage of brine and alternating use of the pipeline between secondary effluent into the valley and RO concentrate discharges out of the valley. Option 2 of adding a new parallel line the entire length of LAVWMA outfall is costly and may have permitting and siting issues.

Preliminary analysis of these options suggests that it may be technically feasible, but that the cost of conveyance may be significant, as shown in Table 4.3. Costs shown do not include the cost of storage needed to batch process the water for brine disposal and conveyance of secondary source water. Operational complexity and perception issues of importing wastewater into the valley are also important considerations. After discussion with the Tri-Valley agencies, it was determined that there was not a sufficient water need in the Tri-Valley area to further consider importing 25 mgd. The agencies also agreed that the operational complexity of batch processing was not appealing.

Table 4.3 Advantages and Disadvantages of using Secondary Effluent from the EBDA Pipeline

	Advantages	Disadvantages
Technical Considerations	Can offset lack of available summer flows or greatly increase capacity of potable reuse project May be able to maximize use of existing infrastructure	Construction of either 61,000 feet new pipeline (parallel to existing) or 6 new pump stations to reverse flow. Siting, right of ways and permitting for pump stations and/or new pipeline may be complex.
Operational Considerations	Higher year-round flows available will allow operation of purification facilities at a steady rate (best operational scenario for membranes)	Batch storage/discharge of RO concentrate and batch import of water for purification facilities creates operational complexity
Cost Considerations (DSRSD, EBMUD and the City of Pleasanton, 2016).)	6 mgd in existing pipe = $27 M 25 mgd in existing pipe = $60 M	6 mgd in new pipe = $60 M 25 mgd in new pipe = $106 M Includes one 25 mgd pump station, and 61,000 linear feet of 36" diameter force main. Estimated costs do not include easement or property acquisition.

Due to the expense and complication of importing EBDA's effluent into the Tri-Valley, it is not recommended to include these flows into the current alternatives analysis. The Tri-Valley agencies have also recognized that for a potable reuse project to succeed, there needs to be a potable water need and incremental successes. An initial smaller project using only Tri-Valley generated flows has a greater potential to fit within the supply portfolio needs and be a first phase for implementing potable reuse.

However, the Tri-Valley agencies may wish to consider this option in the future when reviewing alternatives for additional water sources.

4.4 Effluent Storage Options

The secondary effluent available for potable reuse varies on a monthly basis, with the lowest flows available in the summer months and the highest flows available in the winter months. The variation in flow presents some operational challenge for reverse osmosis (RO) process, which is assumed to be included in all purification process treatment trains. The preferred operational approach for a RO membrane process is to provide a relatively constant feed flow with maximum variation of +/- 10%. A relatively constant flow keeps the membranes wet and provides for relatively uniform use of the individual membrane units. For this study, approaches for maintaining a constant RO feed flow and alternative options for protecting the RO membranes are considered:

- Assume that the capacity of the purification processes is equivalent to the minimum summer flow.
- Assume that the capacity of the purification processes is equivalent to a flow greater than the minimum summer flow, and operate the purification processes at capacity on a seasonal basis. This assumption requires that some portion of the RO system would not

be used on a seasonal basis, and it would be preserved over this period to maintain the integrity of the RO membranes. Alternatively, flow to the RO membranes would be cycled between membrane units during low flow periods, keeping the membranes wetted.

- Assume that the capacity of the purification processes is equivalent to a flow greater than the minimum summer flow, and utilize storage of water when it is available in the winter months to supplement the available flow in the summer months.

4.4.1 Secondary Effluent Storage

Each of the treatment facilities has onsite storage for the purpose of equalization and wet weather flow management. However, based on input from the operations and management staff, the use of these existing storage basins was confirmed to be an important piece in operating the facilities that will still be required in the future. Therefore, the existing basins are not available for seasonal equalization of the secondary supply before a purification process. Storage of the secondary effluent supply for potable reuse would require new storage facilities. Given that secondary effluent needs to be contained for public health reasons, only options for onsite storage at a WWTP were considered for secondary effluent storage. Given the limited available space onsite, the following options were identified:

- DSRSD WWTP - Conversion of sludge lagoons and/or dedicated land disposal area.
- LWRP - Conversion of sludge lagoons and/or use of additional unused space.

Conversion of the DSRSD solids areas presents a number of issues and implications. Most relevant are the significant costs that would be required for DSRSD to convert to mechanical dewatering and disposal offsite. There also may be legacy issues associated with siting a reservoir on facilities that were used for sludge disposal. These issues are incorporated in cost estimates for storage that are developed in Chapter 5.

A monthly water balance was conducted using data from October 2011 through March 2015, to quantify the constant flow of the purification process that could be achieved for various storage volume assumptions. The mass balance accounts for precipitation and evaporation, but assumes that the storage basins would be lined and therefore seepage is assumed to be negligible. This analysis was conducted for storage of LWRP secondary effluent at the LWRP, storage of DSRSD secondary effluent at the DSRSD WWTP and storage of secondary effluent from both facilities at the DSRSD WWTP.

Table 4.4 presents a summary of the storage basin assumptions and estimated constant purification process flow that could be achieved through constructing new or re-purposing storage facilities. The projected average monthly flows available for potable reuse and average net evaporation values were used for this analysis. Analysis of historical flow data showed significant variation due to varying hydrologic conditions. Therefore, the estimated amount of storage needed to achieve a constant purification process flow differs between scenarios. Results in Table 4.4 are estimated using average hydrologic conditions. Thus, under dry conditions, such as the one experienced in 2014, the storage volumes will not likely yield the purification process flows. The results suggest that purification process flow would not appreciably change with the addition of storage basins at the LWRP. The potential storage options at DSRSD present more of a potential flow benefit. Approximately 170 MG (605 AF) of storage is required to increase the purification flow by 1.1 mgd.

More detailed mass balance analysis combined with cost estimates for new/repurposing storage basins was conducted as part of future modeling tasks and alternatives analysis in Chapter 5.

4.4.2 Tertiary Storage

Storage of disinfected, tertiary treated water does not have the advantage of secondary effluent storage to equalize out tertiary facility sizing, but still may have some benefit in reducing RO sizing. There are limited locations for storage offsite from a WWTP that would not require a major rezoning or siting in an already developed area. Cope Lake is one of the few available options for the following reasons:

- Unlike some of the other existing and future lakes in the Chain of Lakes, the ownership and operation of Cope Lake has already been transferred to Zone 7.
- Due to the buildup of silt, there is limited recharge from Cope Lake to underlying groundwater.

While there are some distinct advantages of using Cope Lake for tertiary storage, this alternative was eliminated for the following reasons:

- Cope Lake is in very close proximity to some of Zone 7's municipal supply wells (Chain of Lakes wells), which would potentially present issues with requirements for setbacks between recycled water impoundments and potable supply wells, and potential issues with unplanned recharge of underlying groundwater.
- Planned uses of Cope Lake include flood management, which will require use of Cope Lake storage capacity in combination with Lake H and I (Zone 7, 2014).
- Even though, the Preliminary Lake Use Evaluation for the Chain of Lakes scored the use of Cope Lake for recycled water storage positively, this may conflict with the primary use of flood management.
- The Vulcan mining operations holds a permit to dewater groundwater and discharge it to Cope Lake, where a portion of the water is then routed to Lake I for groundwater recharge. Given the proximity to downstream wells and the connectivity of Lake I to the shallow aquifer, it is unlikely that Title 22 requirements for groundwater recharge with tertiary effluent co-mingled with the groundwater could be met for Lake I.
- Zone 7 plans to build a multi-use pipeline between the DVWTP/South Bay Aqueduct and Cope Lake. One of the potential uses for this pipeline is to convey surface water from the Cope Lake area to DVWTP for use as a supply during emergencies (e.g., outage on the South bay Aqueduct) and droughts. Water in Cope Lake therefore has to remain suitable for use as a raw water supply. Under Title 22, there has never been a tertiary effluent permitted for direct use at a WTP, even if it is co-mingled with dewatered groundwater. It is unlikely that the State would approve this type of project.

Table 4.4 Storage Evaluation Results

Facility	Storage Location	Secondary Effluent Source	Storage Facility Characteristics			Without Storage	With Storage
			Area (Acres)	Depth (ft)	Volume (AF)	Constant Purification Flow (mgd)	Constant Purification Flow (mgd)
Livermore	Converted Sludge Lagoons	Livermore Effluent	2.9	10[1]	29	6.1	6.1
	Additional Unused Space		7.1	10[2]	71		6.2
	Combined		10	10	100		6.3
DSRSD	Converted Sludge Lagoons	DSRSD Effluent	27	11[1]	286	0	0.5
	Converted Dedicated Land Disposal (DLD)		55	11[2]	605		1.1
	Combined		82	11	891		1.6
DSRSD	Converted Sludge Lagoons	Combined DSRSD + Livermore Effluent	27	11[1]	286	6.1	6.6
	Converted DLDs		55	11[2]	605		7.3
	Combined		82	11	891		7.9

Notes:

(1) Calculated from estimated volume and area.

(2) Assumed value.

4.5 Treatment Process and Source Water Evaluation

4.5.1 Discharge Requirements

Conveyance of secondary effluent from the DSRSD WWTP and the LWRP, via the LAVWMA and EBDA facilities, is regulated by the following permits:

- DSRSD WWTP NPDES permit.
- LWRP NPDES permit.
- LAVWMA NPDES permit.
- EBDA NPDES permit.

The permit limits and compliance locations for the above listed facilities have been aligned, with recognition that several facilities are involved in the overall conveyance and discharge of secondary effluent to San Francisco Bay. Table 4.5 presents a summary of the current permit requirements related to discharge to San Francisco Bay. The most stringent limit is presented for each parameter in Table 4.5.

In addition, as the LAVWMA discharge permit allows discharge to San Lorenzo Creek and Alamo Canal under certain conditions (intermittent peak wet weather flows only when EBDA capacity is exceeded), Table 4.6 presents a summary of the LAVWMA discharge permit limits.

4.5.1.1 Evaluation of Discharge Compliance

Under future potable reuse scenarios, a portion of the secondary effluent that is currently discharged to SF Bay would be diverted to purification treatment processes, and through the reverse osmosis process a concentrate waste stream would be generated. It is assumed that the RO concentrate would be discharged to SF Bay, via LAVWMA and EBDA facilities.

A high-level analysis was conducted to assess compliance with ammonia limits (due to toxicity concerns) under a future potable reuse scenario. More detailed investigation of compliance with all parameters was conducted as part of modeling analysis of potable reuse alternatives. The following data sources and assumptions were used to assess compliance with ammonia discharge limits:

- As a conservative scenario, it was assumed that all available secondary effluent from the DSRSD WWTP and LWRP would be diverted to purification treatment. This scenario generates the maximum volume of RO concentrate.
- Monthly discharge flows and ammonia concentrations for LWRP secondary effluent, DSRSD WWTP secondary effluent, and the EBDA discharge were compiled for 2014 from data provided by agencies and/or the California Integrated Water Quality System Project (CIWQS) database.
- As a conservative estimate, a high ammonia removal rate of 99% through the RO process was assumed. Anticipated ammonia removal rates from RO are closer to 80%. The higher removal efficiency value leads to a higher concentrating factor for the ammonia in the concentrate.
- It was assumed that the RO concentrate flow would be 20% of the flow diverted to purification processes, which uses an appropriate RO capture efficiency of 80%.

Table 4.5 Permit Limits Related to Discharge to SF Bay

Parameter	Units	Frequency	LWRP Compliance Location	DSRSD WWTP Compliance Location	Limit	Permit Reference
CBOD	mg/L	Monthly	Discharge to LAVWMA	Discharge to LAVWMA	25	Livermore R2-2017-0018
TSS	mg/L	Monthly			30	
pH	s.u.	Instantaneous		Discharge to LAVWMA(3)	6-9	DSRSD R2-2017-0017
Oil and Grease	mg/L	Monthly	EBDA Discharge to SF Bay	EBDA Discharge to SF Bay	10	Livermore R2-2017-0018 DSRSD R2-2017-0017 R2-2017-0016
Chlorine residual	mg/L	Instantaneous			0.0	
Fecal Coliform	MPN/100 mL	5-sample geometric mean			500	
Fecal Coliform	MPN/100 mL	11-sample 90th percentile			1100	
Enterococci	MPN/100 mL	Monthly geometric mean			242	
Copper, Total Recoverable	µg/L	Average Monthly			53	
Cyanide, Total	µg/L	Average Monthly			21	
Dioxin TEQ	µg/L	Average Monthly			1.4E-8	
Total Ammonia	mg/L as N	Average Monthly			93	
Whole Effluent Acute Toxicity(1)		An eleven (11)-sample median value			Not less than 90 percent survival	
Whole Effluent Acute Toxicity(1)		An eleven (11)-sample 90th percentile value			Not less than 70 percent survival.	
Whole Effluent Chronic Toxicity(1)		Based on indicator organisms and toxicity tests			No chronic toxicity	

Notes:

(1) Additional information on acute and chronic toxicity limitations are provided in the Livermore, DSRSD, and EBDA discharge permits (Livermore R2-2012-0006, DSRSD R2-2012-0005, and EBDA R2-2012-0004).

(2) Upstream of Zone 7 brine addition.

(3) Downstream of Zone 7 brine addition.

Table 4.6 LAVWMA Discharge Permit Limits

Parameter	Units	Frequency	LAVWMA Compliance Location	Limit	Permit Reference
CBOD	mg/L	Weekly	San Lorenzo Creek or Alamo Canal	40	LAVWMA R2-2016-0015
TSS	mg/L	Weekly		45	
pH	s.u.	Instantaneous		6.5-8.5	
Oil and Grease	mg/L	Daily		20	
Lead, Total	µg/L	Monthly		5.5	
Lead, Total	µg/L	Weekly		11	
Chlorine residual	mg/L	Instantaneous		0.0	
Fecal Coliform	MPN/100 mL	Maximum Daily		400	

The ammonia concentration in the EBDA discharge was calculated using mass balance relationships. Results suggested that the ammonia concentration in the EBDA discharge would increase by approximately 7 mg/L as N, with the highest concentration estimated at approximately 40 mg/L as N. This value is well below the average monthly permit limit of 93 mg/L as N. Based on this analysis, compliance with ammonia discharge limits is anticipated even under the scenario where all secondary effluent is diverted to purification processes. Potential reduction in wastewater discharges may influence this analysis, thus requiring a re-evaluation in the future.

In addition to potential water quality impacts of diverting secondary effluent to potable reuse, the potential hydraulic impacts to the LAVWMA facility were investigated. It is anticipated that there would not be any adverse hydraulic impacts on LAVWMA facilities, and that the reduction in effluent flows could be accommodated with operational adjustment (personal communication with Levi Fuller (DSRSD, 2016).

4.5.2 Concentrate Treatment Needs

As discussed in the previous section, the purification processes will generate RO concentrate that will be discharged to SF Bay via LAVWMA and EBDA facilities. Additional treatment of the brine was considered for the following two reasons:

- Potential for the concentrate to impact attainment of discharge permit limits, and
- Potential impacts to LAVWMA conveyance and discharge facilities.

As discussed in Section 4.5.2, discharge of RO concentrate via the EBDA common outfall is not expected to present issues with attainment of ammonia discharge limits. Therefore, treatment to remove ammonia, either from the concentrate or the secondary effluent wastewater that feeds the purification processes, is not expected to be needed to meet current discharge requirements and no issues are projected with continued attainment of all discharge limits. While more detailed analysis of attainment of all discharge permit limits was included in future modeling analysis, concentrate treatment for the purpose of meeting discharge limits is not anticipated at this time. However, as nutrient limits are under discussion for future permits, removal of nutrients from either the concentrate or the secondary effluent may be required in the future. Exact nutrient standards and timelines for implementation are not known yet.

Discharge of RO concentrate has the potential to impact the existing DSRSD, Livermore and LAVWMA infrastructure. In the summer months, it is possible that all of the available secondary effluent would be diverted to purification facilities. Under this scenario, 100% of the discharge in the DSRSD WWTP effluent pipeline, the LWRP effluent pipeline, and the LAVWMA facilities will be RO concentrate. LAVWMA infrastructure includes concrete lined storage basins, pump stations, and an export pipeline with segments made from different materials including, concrete lined welded steel and HDPE. It is anticipated that additional treatment of the RO concentrate will be needed to reduce scaling and corrosion potential of the RO concentrate. More detailed investigation of concentrate treatment will be needed to be evaluated further if a project were selected to be implemented.

4.5.3 Water Quality/Source Control

In considering implementation of a potable reuse project, the source water quality is of upmost importance to protect public health. Recent regulatory discussions in CA regarding potable reuse have focused in on the need for enhanced source control programs.

Both DSRSD and Livermore have existing pretreatment (source control) programs, per regulatory requirements. Pretreatment programs are designed to protect the wastewater collection and treatment system from substances that could potentially interfere with operation of the system, pass through the treatment process, compromise work safety, or harm the public health or environment.

For both treatment facilities the current end uses of the secondary effluent include discharge to SF Bay, and source water to tertiary treatment and disinfection facilities for the purposes of landscape irrigation. Implementation of a potable reuse project would introduce the new end use of potable water supply. The end use of potable water supply triggers regulatory requirements for enhanced levels of source control.

4.5.3.1 Regulatory Requirements

The regulatory requirements for wastewater source control are defined in California's 2014 Groundwater Recharge Regulations (Title 22). The regulations require that the project owner implement and maintain a program that includes, at a minimum:

- An assessment of the fate of DDW-specified and Regional Board-specified chemicals and contaminants through the wastewater and recycled municipal wastewater treatment systems,
- Chemical and contaminant source investigations and monitoring that focuses on DDW-specified and Regional Board-specified chemicals and contaminants.
- An outreach program to industrial, commercial, and residential communities within the portions of the sewage collection agency's service area that flows into the water reclamation plant subsequently supplying the groundwater recharge project, for the purpose of managing and minimizing the discharge of chemicals and contaminants at the source, and

- A current inventory of chemicals and contaminants identified pursuant to this section, including new chemicals and contaminants resulting from new sources or changes to existing sources, that may be discharged into the wastewater collection system.

To meet the wastewater source control requirements in the groundwater recharge regulations, an ESCP will need to be developed. Some of the key differences between the existing source control program and an ESCP include more monitoring parameters (drinking water MCLs, parameters with notification levels, and unregulated contaminants), increased monitoring frequency, and increased monitoring locations.

4.5.3.2 DSRSD – Existing Source Control Program and Water Quality

DSRSD's ongoing pollution prevention program generally consists of tracking industrial users within the DSRSD WWTP service area, industrial user site inspections, monitoring and reporting, source control program implementation, and outreach/education.

DSRSD's pollution prevention program focuses on pollution minimization and control of pollutants of concern (POCs) and other pollutants. A POC is defined as a substance that exceeds the applicable water quality objectives from the California Toxic Rule (CTR), NPDES permit limits, or the water quality criteria established in the Regional Water Quality Control Board (RWQCB) Basin Plan.

Monitoring for the pretreatment program includes monthly data for the treatment plant influent and effluent. While the data were not collected with the intent of comparison to drinking water standards, this comparison is relevant for understanding the quality of the secondary effluent as source water to purification treatment. Table 4.7 presents a comparison of secondary effluent concentrations and drinking water standards.

The limited comparison of secondary effluent concentrations to drinking water standards suggests that the secondary effluent is of relatively good water quality, with exceedance of standards for only alpha-BHC and NDMA. However, it is important to recognize that this is a limited comparison and that an enhanced source control program would require monitoring of all regulated drinking water contaminants, contaminants with notification levels, and unregulated contaminants.

4.5.3.3 Livermore - Existing Source Control Program and Water Quality

Livermore has an ongoing Pollution Prevention Program that generally consists of tracking industrial users within the LWRP service area, industrial user site inspections, monitoring and reporting, source control program implementation, and outreach/education.

Similar to DSRSD's pollution prevention program, the Livermore pollution prevention program focuses on pollution minimization and control of POCs and other pollutants. Monitoring data from the pretreatment program includes treatment plant influent and effluent on a monthly basis. Similar to the analysis in the previous section, Table 4.8 presents the secondary effluent data as compared to drinking water standards.

Table 4.7 Comparison of DSRSD Secondary Effluent to Drinking Water Standards

Parameter	Units	DSRSD Secondary Effluent Concentration	Drinking Water Standard
Metals [1]			
Arsenic	µg/L	<0.8	100
Cadmium	µg/L	<0.2	5
Chromium	µg/L	<0.6	50
Copper	µg/L	8.2	1300
Lead	µg/L	<0.1	15
Mercury	µg/L	0.0028	2
Nickel	µg/L	2.4	100
Selenium	µg/L	<0.5	50
Silver	µg/L	<0.4	-
Zinc	µg/L	20.9	-
Organics [2]			
alpha-BHC	µg/L	**0.49**	0.2
Bis (2-ethylhexyl) phthalate	µg/L	0.29	-
Bromoform	µg/L	0.4	80 [3]
Chloroform	µg/L	0.65-0.8	80 [3]
NDMA	µg/L	**0.48**	0.01 [4]
Phenol	µg/L	0.75-1.1	-
Pyrene	µg/L	0.0014	--

Notes:

(1) For the metals, the average of monthly samples from 2015 is presented.

(2) For the organics, any data point within 2015 with a value greater than the method detection limits is reported. Where a range is presented, there was more than one sample with a value greater than the method detection limits.

(3) Standard is for total trihalomethanes which is the sum of chloroform, chlorodibromethane, dichlorbromomethane, and bromoform.

(4) Notification Level.

Table 4.8 Comparison of Livermore Secondary Effluent to Drinking Water Standards

Parameter(2)	Units	Livermore Secondary Effluent Concentration	Drinking Water Standard
Metals(1)			
Arsenic	µg/L	0.581	100
Cadmium	µg/L	0.097	5
Chromium	µg/L	0.6	50
Copper	µg/L	6.18	1300
Lead	µg/L	0.154	15
Mercury	µg/L	0.004	2
Nickel	µg/L	3.723	100
Silver	µg/L	0.69	-
Zinc	µg/L	17.63	-

Notes:

(1) For the metals, the average of monthly samples from 2011-2015 is presented.

(2) In addition to the metals presented above, Livermore's monitoring program includes tritium, plutonium, methyl ethyl ketone, 1,1,2-trichloroethane, 1,1,2,2,-tetrachloroethane, toluene, ethyl benzene, benzene, tetrachloroethene, trichlorethane, phenols, chloroform, methylene chloride, acetone, and Freon. The 2015 annual report indicates that concentrations of these pollutants in the influent were below levels of concern or below method detection limits.

The LWRP service area includes Lawrence Livermore National Laboratory (LLNL) and Sandia National Laboratory (SNL). Combined flow from these laboratories represented approximately 4.2% of the influent flow in 2015 but can vary year to year based on hydrologic conditions. One pollutant of concern is tritium, which has been used at LLNL since the 1950s. LLNL has developed environmental monitoring programs to monitor radioactive material releases. Annual environmental reports document LLNL's compliance with environmental standards and requirements, describe environmental protection and remediation programs, and present the results of environmental monitoring (LLNL, 2015).

LLNL determines the total radioactivity contributed by tritium, gross alpha emitters, and gross beta emitters from the measured radioactivity in the monthly effluent samples. Discharge limits and a summary of the measurements of tritium in the sanitary sewer effluent from LLNL and the LWRP are reported in LLNL monthly reports. The maximum daily concentration for tritium of 0.134 Bq/mL[1] (3.64 pCi/mL) was far below the permit discharge limit of 12 Bq/mL (333 pCi/mL) (LLNL, 2015).

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[1] Becquerels are the international unit used to measure radioactivity. One Becquerel is the amount of a radioactive material that will undergo one transformation per second. Becquerels are not used to measure radiation dose or radiation exposure. The U.S. unit is the Curie (Ci). One curie is roughly the activity of one gram of Radium-226. Curies are not used to measure radiation dose. USEPA (2007). Radiation Protection Program - Radiation Glossary. Last Updated March 10, 2017.

Assuming that all beta emission is due to tritium, then the drinking water standard for beta particle emission of 4 milirem/yr[2] is equivalent to a tritium concertation of 740 Bq/L. The maximum daily concentration for tritium of 0.134 Bq/mL reported in the LLNL effluent is well below the drinking water standard. In addition, the pollution prevention and environmental programs at LLNL have been successful at reducing tritium concentrations in the LLNL discharge to the sewer. Since the 1970s, tritium concentrations in the LWRP effluent have decreased by over two orders of magnitude.

Regardless of the trend of decreasing tritium concentrations in LLNL effluent and the low levels relative to drinking water standards, tritium remains a public concern in the Tri-Valley area. This public concern should be a consideration in the development of an ESCP.

4.6 Water Balance

In order to provide detailed evaluations of multiple scenarios, Carollo's Blue Plan-it® Decision Support System (BPI) was used to simulate water flows, water qualities, and costs of various options. This planning tool is a water, pollutant, and energy balance model that simulates flow routing, treatment, distribution, and the associated costs. The model is very effective at analyzing complex and interconnected treatment and conveyance systems. The main purpose of the modeling effort for this project is to determine the most cost effective manner of implementing potable reuse. Costs in the model (developed in Chapter 5) include both treatment and infrastructure.

BPI was configured to incorporate existing wastewater and water facilities, and future facilities associated with potential potable reuse alternatives in the Tri-Valley. Figure 4.8 presents a schematic of the model. The schematic shows existing and future facilities/components in a generally left to right arrangement, from secondary effluent source to end use. The model is configured to simulate numerous options throughout the system, and includes the functionality to select options for a particular alternative. The functionality provided in the model includes:

- Sources of Secondary Effluent - Secondary effluent from the individual treatment plant or a combined source (regional).
- Storage - Storage (secondary effluent) options at both treatment facilities.
- Purification Facilities - Locations at the DSRSD WWTP, the LWRP, and other regional sites.
- Treatment Processes - Options to include FAT or FAT with additional treatment.
- Conveyance - Options to utilize natural systems (Cope Lake), existing/planned pipelines, or new pipelines.
- End use of Surface Recharge - Recharge in Lake I.
- End use of Injection Wells - Options for injection and recovery and for ASR.
- End use of Raw Water Augmentation - Options to augment PPWTP or DVWTP.

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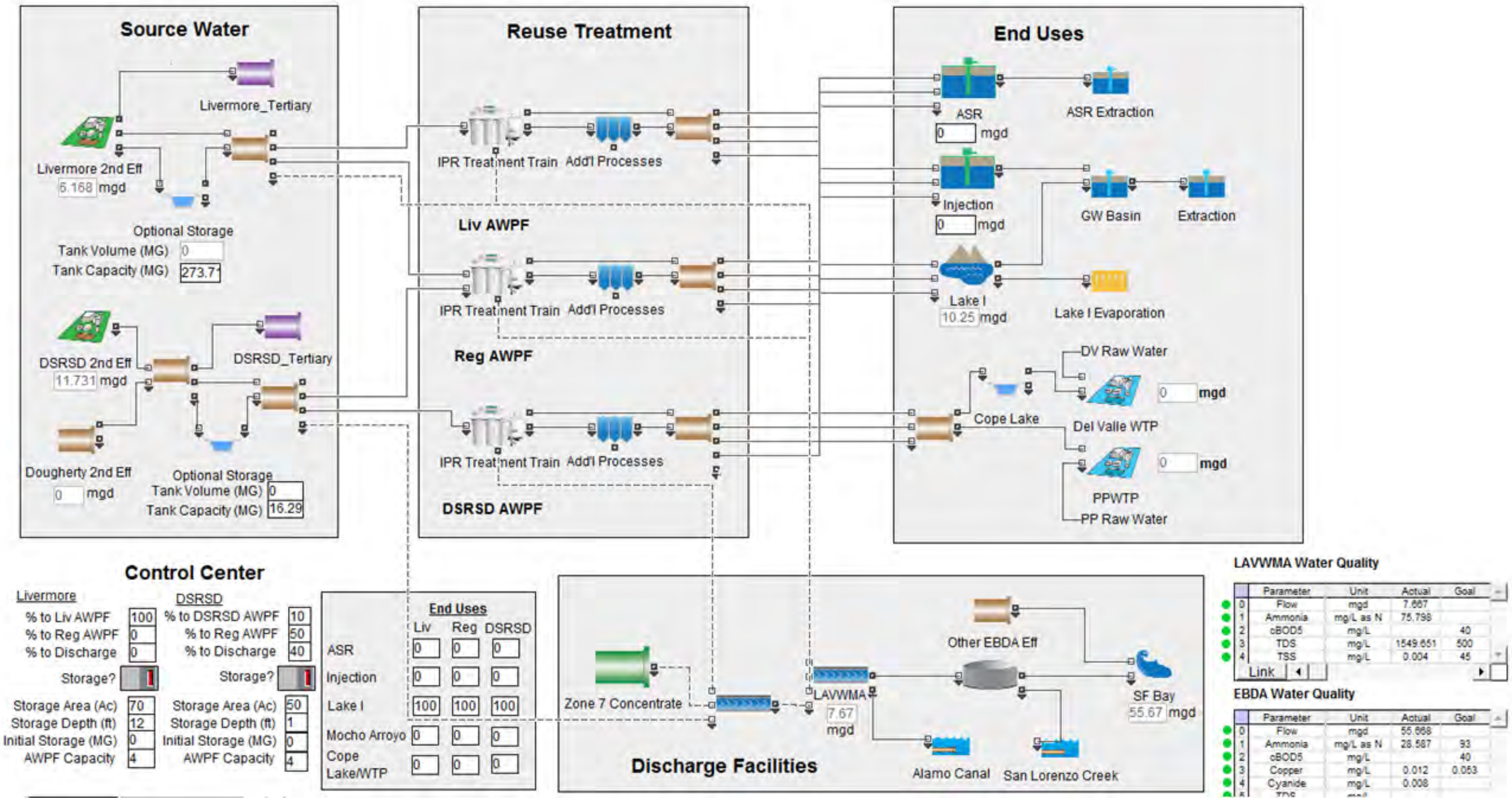
[2] The millirem is the U.S. unit used to measure effective dose. One millirem equals 0.001 rem. The international unit is milliSievert (mSv). Sievert: An international unit used to measure effective dose. The U.S. unit is rem



Control Center

Livermore

% to Liv AWPF 100
% to Reg AWPF 0
% to Discharge 0
Storage? ▮
Storage Area (Ac) 70
Storage Depth (ft) 12
Initial Storage (MG) 0
AWPF Capacity 4

DSRSD

% to DSRSD AWPF 10
% to Reg AWPF 50
% to Discharge 40
Storage? ▮
Storage Area (Ac) 50
Storage Depth (ft) 1
Initial Storage (MG) 0
AWPF Capacity 4

End Uses

	Liv	Reg	DSRSD
ASR	0	0	0
Injection	0	0	0
Lake I	100	100	100
Mocho Arroyo	0	0	0
Cope Lake/WTP	0	0	0

LAVWMA Water Quality

	Parameter	Unit	Actual	Goal
0	Flow	mgd	7.667	
1	Ammonia	mg/L as N	75.798	
2	cBOD5	mg/L		40
3	TDS	mg/L	1549.651	500
4	TSS	mg/L	0.004	45

Link

EBDA Water Quality

	Parameter	Unit	Actual	Goal
0	Flow	mgd	55.668	
1	Ammonia	mg/L as N	28.587	93
2	cBOD5	mg/L		40
3	Copper	mg/L	0.012	0.053
4	Cyanide	mg/L	0.008	
5	TDS	mg/L		

Figure 4.8 BPI Model Application

Along with this customized representation of the existing and potential future system, BPI requires input data and parameters. The BPI application to the Tri-Valley is described in detail in Chapter 5. However, the model provides a useful platform for discussing the water balance through the system, and preliminary estimates of yields and losses through various components of a potable reuse alternative. The data and assumptions presented in the following sections are used as input into the BPI model

4.6.1 Water Losses

Each alternative is evaluated based upon its modeled yield or potable water offset. Yield depends upon end use, conveyance mechanism, storage facility, and treatment technology, as there are losses through each of these components of an alternative.

4.6.1.1 Evaporation and Precipitation

For all alternatives with a portion of the storage or recharge located outdoors and uncovered, evaporation and precipitation play key roles in the determination of yield. Precipitation data for over 100 years and evaporation data measured since 1974 were compiled to create an average predicted evaporation/ precipitation trend. The precipitation was then subtracted from the evaporation to calculate a net evaporation in inches per month, and the resulting average monthly net evaporation is shown in Figure 4.9. Actual evaporative losses are calculated in BPI based upon the exposed surface area of the purified water.

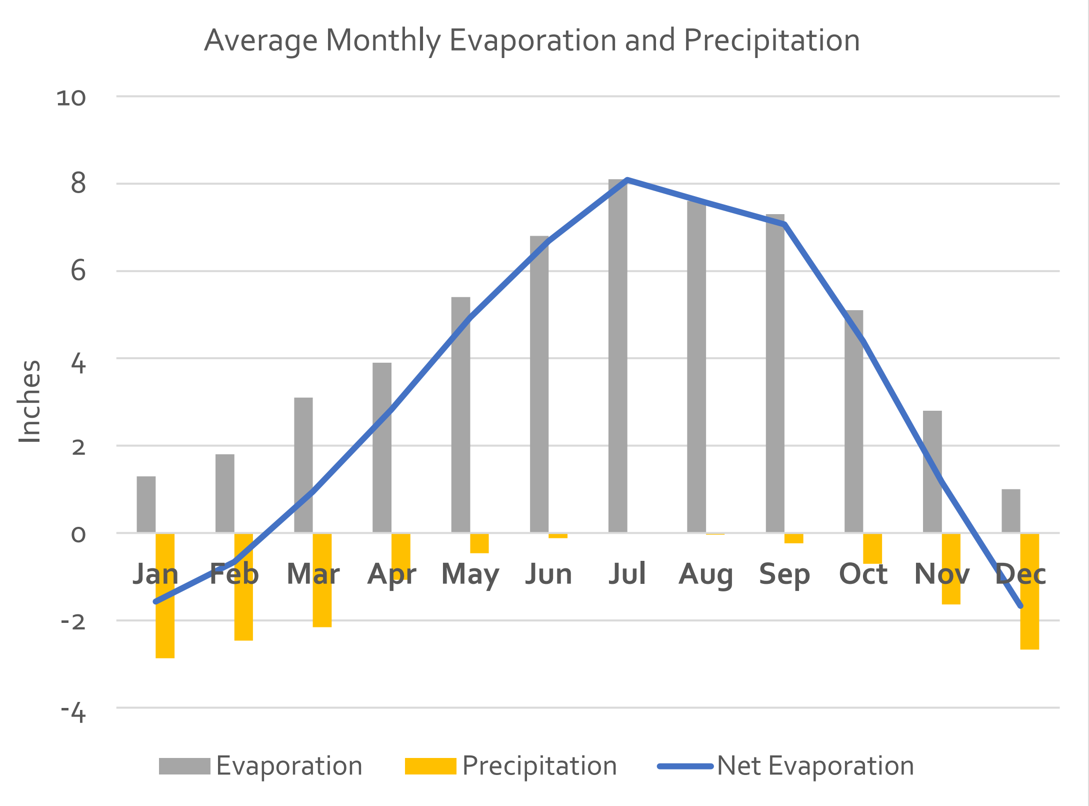


Figure 4.9 Average Monthly Evaporation and Precipitation

4.6.1.1 Seepage

For alternatives that include secondary effluent storage at Livermore and DSRSD, it is assumed that these facilities would be lined and therefore seepage loss would be negligible.

For alternatives that involve conveyance of water through Cope Lake to various end uses, there will be a seepage loss. Cope Lake was identified as being relatively isolated from the underlying groundwater basin due to accumulated silt (40 to -65 ft) at the bottom of the lake (Zone 7, 2014). However, more recent investigations suggest that there may be a more significant hydraulic connection to groundwater than previously documented (personal communication Zone 7, 2016). For this study, seepage loss through Cope Lake is estimated to range from 544 to 1,000 AFY (Stetson, 2004).

End uses include groundwater recharge by surface spreading in Lake I. In this case, the water that seeps into the underlying groundwater aquifer contributes to the yield of a groundwater recharge alternative, rather than a loss. Lake I capacity for groundwater recharge is addressed in Section 4.6.2.

4.6.1.2 Treatment Water Losses

Two main treatment processes are considered: traditional FAT and the additional processes required for a small environmental buffer (2 months or less). Traditional FAT consists of membrane filtration (MF or UF), reverse osmosis (RO), and an ultraviolet advanced oxidation process (UV AOP). Due to consistent cleaning and backwash cycles, recovery rates for MF/UF are assumed to be conservatively around 90 percent, but the backwash would be returned to the WWTP headworks. RO rejects approximately 20 percent of the feed water, creating a concentrate stream. UV AOP has no significant water loss through the process. The overall recovery rate for FAT is assumed to be 80 percent.

The additional processes required for raw water augmentation include a granular activated carbon (GAC) filter and an engineered storage buffer (ESB). Neither of these treatment processes is associated with major water losses. The assumed recovery rate through these processes is 100 percent.

4.6.1.3 Other Losses Associated with End Uses

There are losses associated with each potential end use considered within this project, including evaporative losses for Lake I recharge, groundwater losses for injection wells and ASR, and potential conveyance losses for all projects, especially those with raw water augmentation. For this preliminary yield analysis, all end uses are assumed to be 100 percent efficient. Groundwater modeling and other hydraulic modeling will unveil the losses per end use when the projects are more defined. Refer to Chapter 5 for an overview of the end uses and Chapter 6 for a detailed groundwater modeling analysis.

4.7 References

DSRSD, EBMUD and the City of Pleasanton (2016). DERWA Supplemental Supply Options Working Group Meeting No. 5.

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Chapter 5

PRELIMINARY ALTERNATIVES DEVELOPMENT

5.1 Purpose

This chapter lays out the alternatives for potable reuse in the Tri-Valley Area, which include groundwater augmentation (recharge/injection), reservoir (surface) water augmentation, and raw water augmentation and are defined according to Section 13561 of the Water Code:

- Groundwater augmentation - Planned placement of [purified] recycled water for replenishment of a groundwater basin or an aquifer that has been designated as the source of water supply for a public water system.
- Reservoir augmentation - Planned placement of [purified] recycled water into a raw surface water reservoir used as a source of domestic drinking water supply for a public water system, or into a constructed system conveying water to such a reservoir.
- Raw water augmentation - Planned placement of [purified] recycled water into a system of pipelines or aqueducts that deliver raw water to a drinking water treatment plant that provides water to a public water system.

This chapter presents a summary of the potable reuse alternatives development and evaluation process. Results of the following specific analyses are presented within:

- Potential treatment and end uses for potable reuse.
- Alternatives development and analysis through Blue Plan-it®
- Short-listed options selection.

The evaluations conducted at this stage in the feasibility study are high level and developed mainly for comparison purposes. The short-listed options identified within this Chapter are further developed in Chapter 7.

5.2 Screening Process

Within the Tri-Valley area, there are several options for source water, treatment type, treatment location, and end use in the development of potable reuse alternatives. Figure 5.1 shows the range of sources, treatment, locations, and end uses being considered through the alternative development process. With the number of project components possible, there could be a multitude of project combinations. The selection of a potable reuse project is therefore a stepwise process, as shown in Figure 5.2. The alternative development and evaluation discussed within this chapter is the first step towards narrowing down the many potential alternatives to approximately three alternatives, to be considered for a more detailed analysis. At key stages in the selection process, workshops with representatives from all project participants were convened to facilitate key decisions.

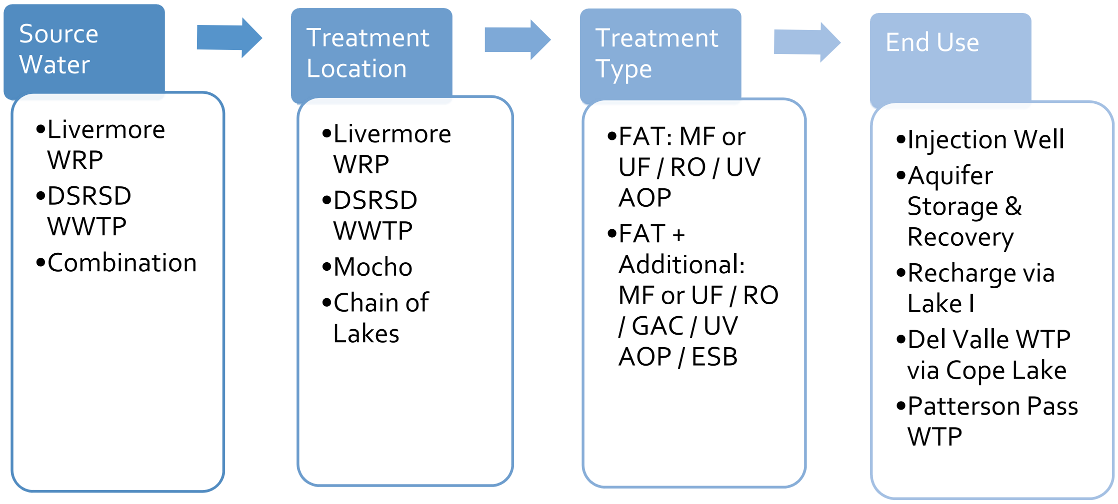


Figure 5.1 Alternative Development Process and Component Options

5.3 Evaluation Criteria

A preliminary set of evaluation criteria was developed to narrow the initial list of alternatives down to three for further investigation. These criteria are as follows:

- Yield (measured by acre-feet per year - AFY).
- Cost (Capital and Operations and Maintenance [O&M]).
- Improved Supply Reliability.
- Improved Delivered Water Quality.
- Improved Groundwater Basin Quality.
- Clear Regulatory Pathway.
- Minimizes Neighborhood Impacts.
- Ability to Phase the Project.
- Operational Flexibility.
- Ease of Construction.

As decided by the project management team, the main criteria for the initial screening were cost and yield. After the initial screening of alternatives, additional criteria were used in the more detailed analysis.

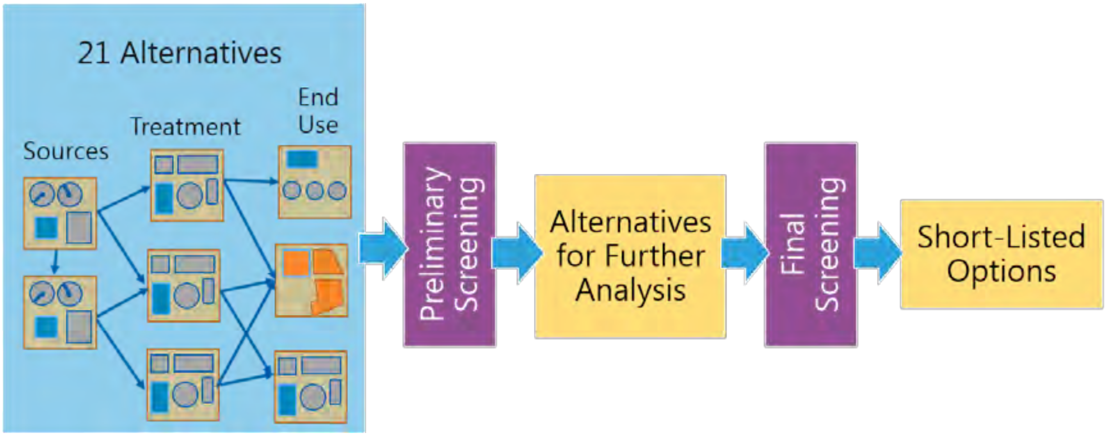


Figure 5.2 Project Selection Process

5.4 Water Availability and Source

Water for the future purification plant would come from one or both wastewater treatment facilities - DSRSD WWTP and the Livermore WRP. These facilities each have their own non-potable recycled water irrigation programs. The amount of water available from each plant for potable reuse was analyzed in detail in Chapter 4. Buildout projections for both wastewater flows and non-potable reuse growth were used to estimate the amount of available future source water for potable reuse. The amount of water available at both WWTPs is depicted graphically in Figure 5.3; the average is around 13.5 million gallons per day (mgd), with peak month flows of 20.9 mgd and average dry weather flows of approximately 6.1 mgd.

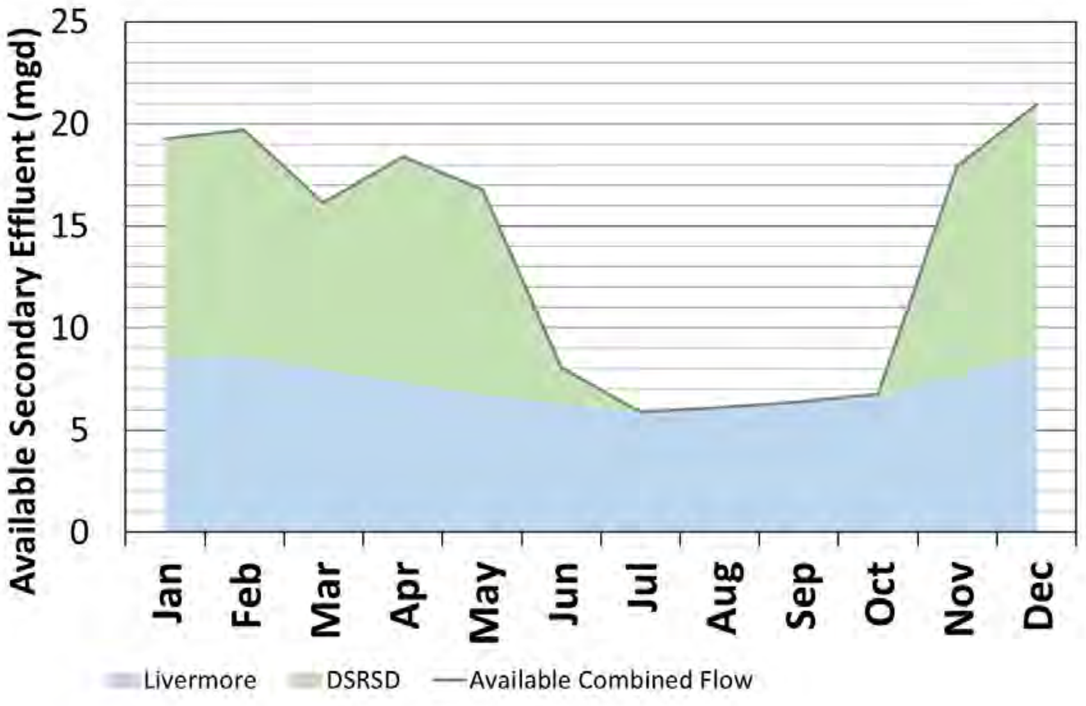


Figure 5.3 Combined Available Flow from the LWRP and DSRSD WWTP

As can be seen in Figure 5.3, due to the existing non-potable recycled water programs and natural seasonality of flow variations, there is significantly more water available in the winter and shoulder months than in the summer. Several flow/treatment strategies are considered to accommodate the variability in available flow, including:

- Limiting the flow for potable reuse to the flow available in the summer.
- Providing storage to supplement summer flows.
- Operating a treatment facility with seasonal variation of flows.

These options are further discussed in the alternatives development section.

5.5 Potable Reuse Yield Goals

As discussed in Chapter 1, Zone 7 completed the Water Supply Evaluation Update (WSE Update) in 2016. In the WSE Update, the upper end of what was estimated available from alternative future water supplies (potable reuse and desalination) was around 10,000 acre-feet per year (AFY), so this amount was used as the upper bookend for the analysis in this study. Note that there were other limiting factors (i.e., wastewater availability) to going beyond 10,000 AFY so this value is a reasonable estimate. A lower bookend value of 5,500 AFY was used as this is the amount of purified water that can be produced year-round from Livermore alone, allowing for a constant production rate.

5.6 Treatment Assumptions

The purification process train assumptions are based on end use, as described below.

- Groundwater augmentation via injection - Full advanced treatment (FAT), per the Title 22 Groundwater Recharge Regulations (Title 22) established in 2014, is assumed for groundwater augmentation via injection. FAT consists of a microfiltration or ultrafiltration membrane process (MF or UF), followed by reverse osmosis (RO), and an ultraviolet advanced oxidation disinfection process (UV AOP). The FAT assumption applies to groundwater injection scenarios where the estimated travel time to the nearest drinking water supply wells is at least 2 months.
- Groundwater augmentation via Aquifer Storage and Recovery (ASR) - ASR involves injection into an aquifer, storing that water in the aquifer for a minimum of 2 months, and then extracting the water for use. ASR is expected to be permitted under the existing Title 22 regulations, and would require FAT.
- Groundwater augmentation via Lake I - Title 22 regulations include treatment requirements for groundwater recharge via surface spreading. In the case of Lake I, there are three key conditions that influence the treatment requirements. The first condition is that Lake I is directly hydraulically connected to the groundwater aquifer. Therefore, under existing Title 22 regulations it would be considered equivalent to groundwater injection and require FAT. The second condition is that there may be minimal travel time between Lake I and the closest municipal water supply well, potentially less than the required two months. The third condition is that water in Lake I (and the connected Cope Lake and Lake H) is planned for potential use as an emergency supply for the DVWTP with the planned construction of a pipeline. Based on the last two conditions, recharge via Lake I is considered from a regulatory perspective as including both groundwater augmentation with short residence time, and reservoir augmentation. Regulations for potable reuse via reservoir augmentation and

groundwater augmentation with short travel times are under development. For this study, it is assumed that additional treatment beyond FAT, referred to in this report as "FAT+" will be required. The assumed additional treatment processes include granular activated carbon (GAC) and an engineered storage buffer (ESB). The GAC provides an extra barrier for attenuating chemical peak concentrations while also increasing reliability and redundancy. The ESB is a series of storage basins that allows for 30 minutes of monitoring time before distribution to the end use. This treatment train was developed under an assumption of certain stringent regulations. If these regulations change, the GAC and ESB may not be required, and treatment costs may be reduced.

- Reservoir augmentation - As mentioned above it is assumed that FAT+ will be required, however the treatment requirements may vary as the regulations develop.
- Raw Water Augmentation (RWA) involves a very short (if any) residence time in the raw water supply system before being delivered to the WTP. This type of potable reuse would require a FAT+ train. The alternatives which involve sending water to a WTP via Cope Lake would be labeled RWA instead of reservoir augmentation because sufficient residence time in Cope Lake is not guaranteed.

The treatment type (FAT or FAT+) selected for each end use is listed in Table 5.1.

Table 5.1 Tri-Valley Potable Reuse End Uses and Associated Required Treatment

End Use	Associated Treatment Type
Injection Wells - with greater than two months travel time to drinking water wells (1)	FAT Only
Injection Wells - less than two months travel time to drinking water wells (1)	FAT + Additional Treatment
Aquifer Storage & Recovery (ASR)	FAT Only
Groundwater Recharge via Surface Spreading - Lake I	FAT + Additional Treatment (2)
Reservoir Augmentation	FAT + Additional Treatment
Raw Water Augmentation	FAT + Additional Treatment

Notes:

(1) The regulations require 2 months travel time. A 4-month travel time is being used based on the lower credit given to groundwater modeling as a verification method.

(2) The groundwater recharge regulations do not require FAT for all surface spreading projects. However, due to the close proximity of Lake I to municipal potable water supply wells and connection with DVWTP's supply source, it is assumed that FAT and additional treatment will be required.

More information about treatment trains and performance can be found in Chapter 3. Regulatory information is detailed in Chapter 2.

5.6.1 Treatment Train Flow Recovery

The recommended treatment trains for potable reuse involve both MF or UF and RO. These treatment processes have typical water recovery rates of 90 percent and 80 percent, respectively. Overall recovery of influent to the purification facilities is 72 percent. For purification facilities located at the WWTPs, the backwash water from the MF/UF can be recovered by piping it back to the headworks, and thus the total treatment train recovery would be 80 percent. However, if the treatment facility is located at a place other than the WWTPs, the backwash water cannot be easily routed to the headworks of a treatment facility and would therefore be discharged in the waste stream to an outfall. The total recovery rate for this facility would then be around 72 percent. These recovery assumptions will result in yield differences between the individual alternatives.

5.6.2 Yield with Summer Available Flow

The projected buildout (2035) flows from Chapter 3 were combined with the expected recovery rates described above to estimate a potential yield per flow scenario. Due to seasonal variation in available flow from diversion to the existing non-potable recycled water programs, no water is available from the DSRSD WWTP in the summer months. Flow is still available from the Livermore WRP, approximately 6.1 mgd on a consistent (year-round) basis. One approach is to assume that approximately 6.1 mgd (year-round) would be used for potable reuse. With the assumption that the purification processes would be located at the LWRP, the system recovery would be about 80 percent, and the purified water yield would be approximately 5,500 AFY, as shown in Figure 5.4.

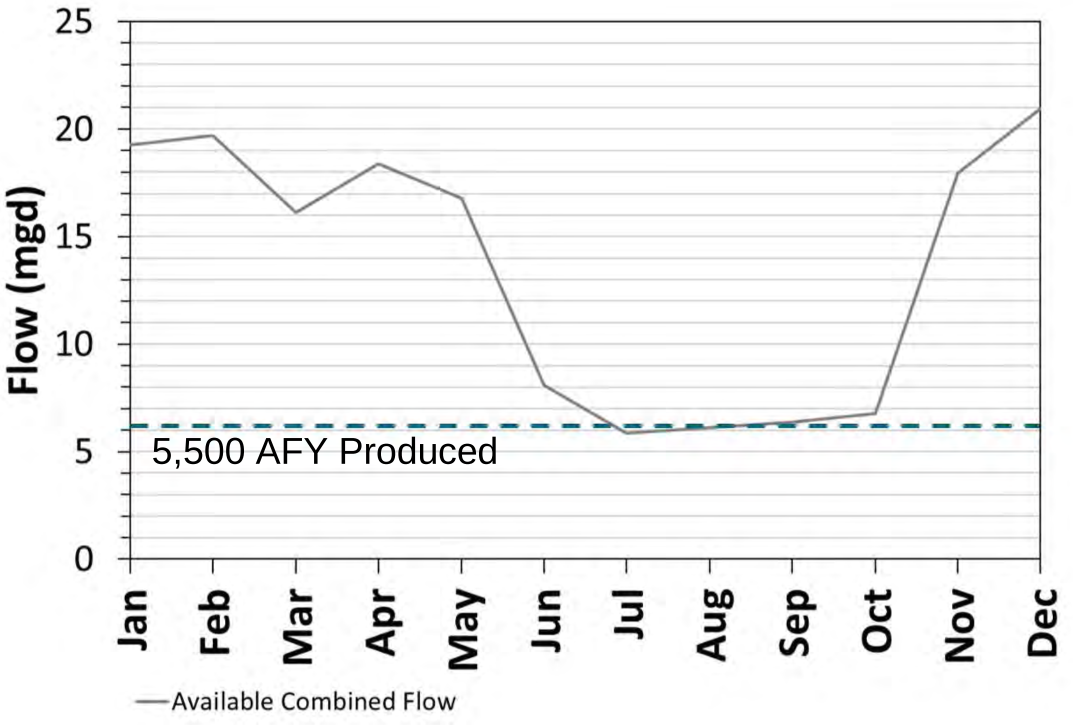


Figure 5.4 Year-Round Constant Summer Flow Strategy (2035 Projected Flows)

5.6.3 Yield with Seasonal Operation

Seasonal treatment is one approach to increasing the overall yield above 5,500-AFY. In winter months, secondary effluent from both treatment plants is estimated to be available up to 16-mgd consistently (using 2035 projected buildout flows). The seasonal operation approach involves greater production of purified water in the winter months and lower production of purified water in the summer months. The 10,000-AFY upper bookend can be achieved with seasonal operation.

Producing 10,000 AFY using seasonal variable flows would require a treatment plant sized for 15-mgd influent flow (12-mgd permeate flow). This facility would need the flexibility to turn down to 6.1 mgd influent flow (5-mgd permeate flow) during the summer months, as illustrated in Figure 5.5. These flows assume that the AWPF is located at one of the WWTPs.

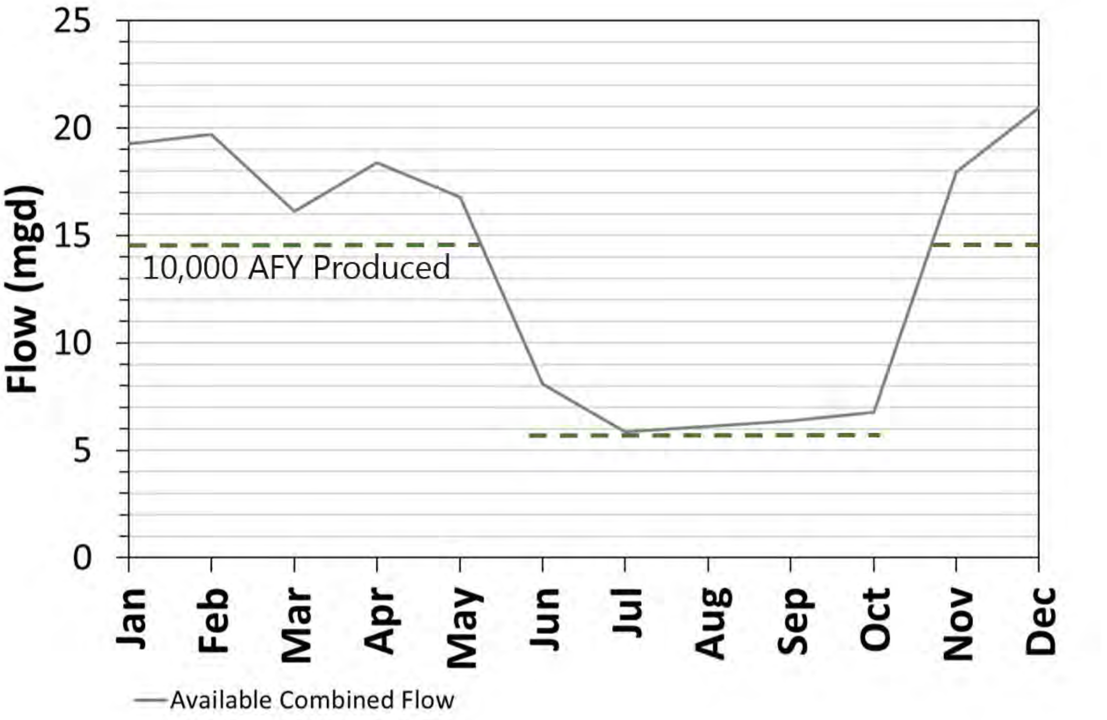


Figure 5. 5 Seasonal Treatment Flow Strategy (2035 Projected Flows)

A facility operating in a seasonal fashion would rotate through membrane trains on an hourly or daily basis to ensure that all membranes are used evenly and maintained at the same level. While this configuration is possible and being used at other facilities in the US, there is added operational complexity.

The available membrane capacity in the summer lower flow periods may have other potential uses. In future project development, it may be possible to consider supplementing summer WWTP flows through the treatment facility in order to create a higher-quality non-potable recycled water for irrigation, or aid in demineralizing groundwater. Furthermore, during a drought, available wastewater could be diverted from non-potable use towards potable use using the AWPF facility. These options are outside the scope of this effort, but may be considered in future discussions.

5.6.4 Yield with Storage

An alternate method of reaching 10,000 AFY of water with a more constant flow to treatment units is building storage. DSRSD has a dedicated land disposal (DLD) area that has been identified as a potential location for storage. If all of DSRSD's solids handling facilities (sludge lagoons and DLDs) were converted to mechanical processing, approximately 82 acres would be available. Due to the small size of Livermore's abandoned sludge lagoons when compared to the predicted amount of storage needed, it was decided that Livermore would not provide sufficient storage for the amount of effort required to convert the lagoons. Additionally, as is discussed later, if the AWPF were located at Livermore, it would likely be in the area of the sludge lagoons.

The combined area available for a storage facility at DSRSD WWTP is approximately 82 acres, less if an AWPF is located in that same area. A water balance was created using Blue Plan-it® to determine the size of storage necessary to produce a constant 10,000 AFY (8.9 mgd). The 82 acre value was used as an estimate to calculate evaporative losses. The results of the modeling showed that the storage basin would need to be approximately 450 million gallons (MG). The cost of a basin this size is approximately $65 million (total project cost), with an additional $10 million estimated for replacing the existing solids facilities with mechanical dewatering. Cost assumptions with detailed cost breakdowns are shown in Appendix A. If the AWPF must be located at the DLDs, then the storage facility would need to be deeper.

The estimated treatment cost for a FAT facility (groundwater augmentation via injection) at a flow of 8.9 mgd is approximately $110 million. With the necessary storage required to maintain the constant flow, this cost rises to $185 million. With the seasonal option discussed above, a treatment plant sized for 11.9 mgd would cost approximately $140 million. At $185 million for treatment and storage alone, an alternative requiring 450 MG of storage becomes cost-prohibitive. However, in order to investigate the option of storage fully, a breakpoint curve was created, to determine the storage - treatment combination which would be cost-competitive with the seasonal option. The breakpoint curve is shown in Figure 5.6.

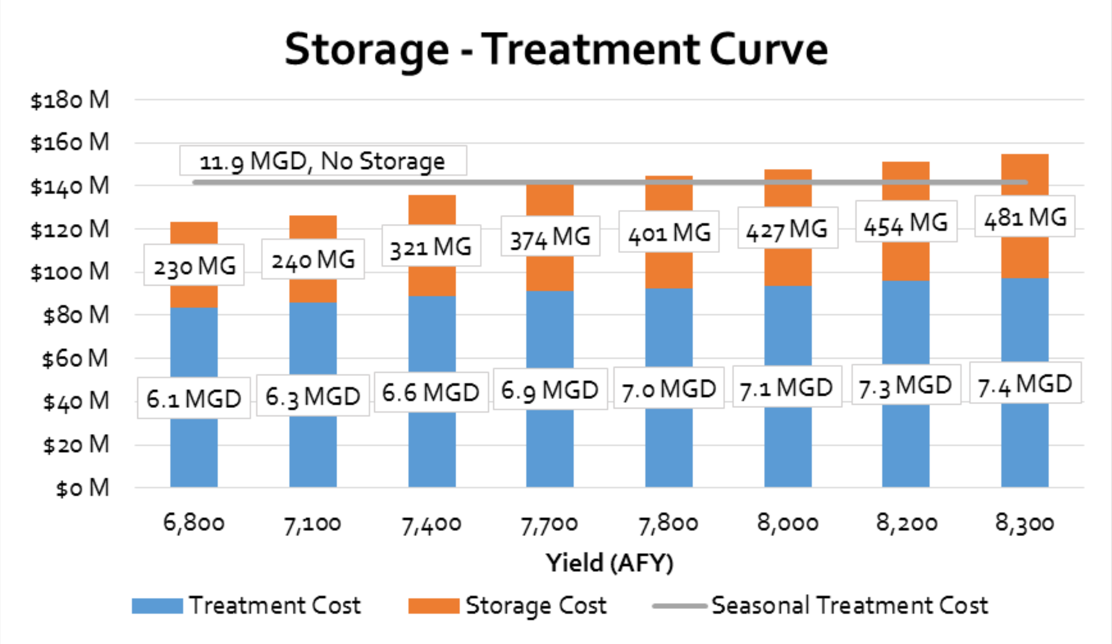


Figure 5.6 Storage and Treatment Breakpoint Calculation

With 370 MG of storage and a 7 mgd (permeate water) facility, approximately 7,700 AFY can be produced year round (see Figure 5.7). This option was chosen to represent the storage discussion in future model runs. In the project team workshop on April 18, 2017, project participants unanimously voted to remove the option of the 450-MG storage to reach 10,000 AFY in preference for the 7,700-AFY option. Table 5.2 shows the cost comparison between the seasonal treatment and both storage options.

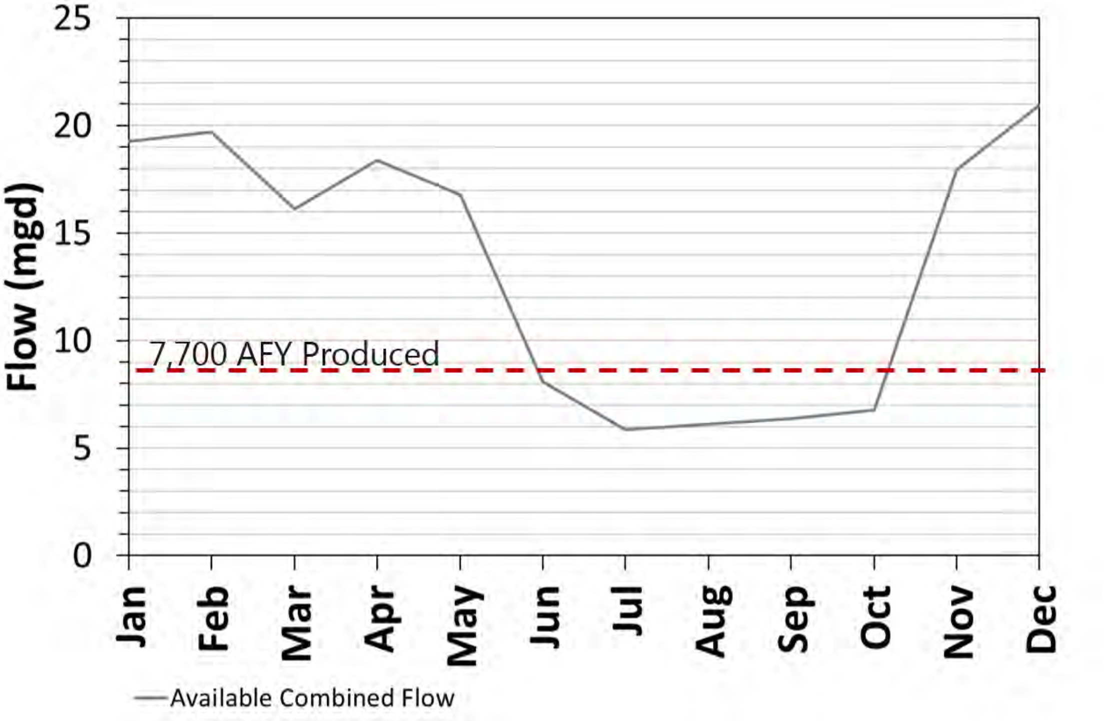


Figure 5.7 Treatment Flow Strategy with Storage (2035 Projected Flows)

Table 5.2 Storage and Treatment Cost Breakdown

Yield (AFY)	Additional Flow Option	Description	Cost for Treatment ($M)	Cost for Additional Water (Storage or EBDA) ($M)	Total Treatment and Storage Cost ($M)
10,000	Seasonal Treatment	5 months/ 7 months	$140	$0	$140
10,000	Storage at DSRSD	~450 MG	$110	$75 ($10 Solids + $65 Storage)	$185
7,700	Storage at DSRSD	~370 MG	$90	$50 ($10 Solids + $40 Storage)	$140

5.6.5 Treatment Location

Livermore secondary effluent flows through the LAVWMA pipeline to DSRSD where it is combined with DSRSD effluent and discharged to the San Francisco Bay through the EBDA pipeline. While both WWTPs have space available for a regional purification facility, treating DSRSD effluent would require pumping DSRSD effluent an additional six miles to the Livermore site.

An advanced treatment plant at DSRSD, however, could treat both Livermore and DSRSD secondary effluent with very minimal additional infrastructure because the LAVWMA pipeline already delivers Livermore flows to the DSRSD site.

Two potential additional regional locations for a purification facility have been considered. The first option is near the existing Mocho demineralization facility. The second location is a plot of land between Cope Lake and Lake I within the Chain of Lakes, near an existing Zone 7 well facility. These two locations were chosen due to the availability of land, proximity to potential end uses (discussed later), and preferred pipeline alignments. Both locations could receive Livermore effluent via the LAVWMA pipeline or a short new connection to the pipeline. DSRSD effluent would need a designated pipeline to be conveyed to each facility. The four potential purification facility locations are highlighted in Figure 5.8.

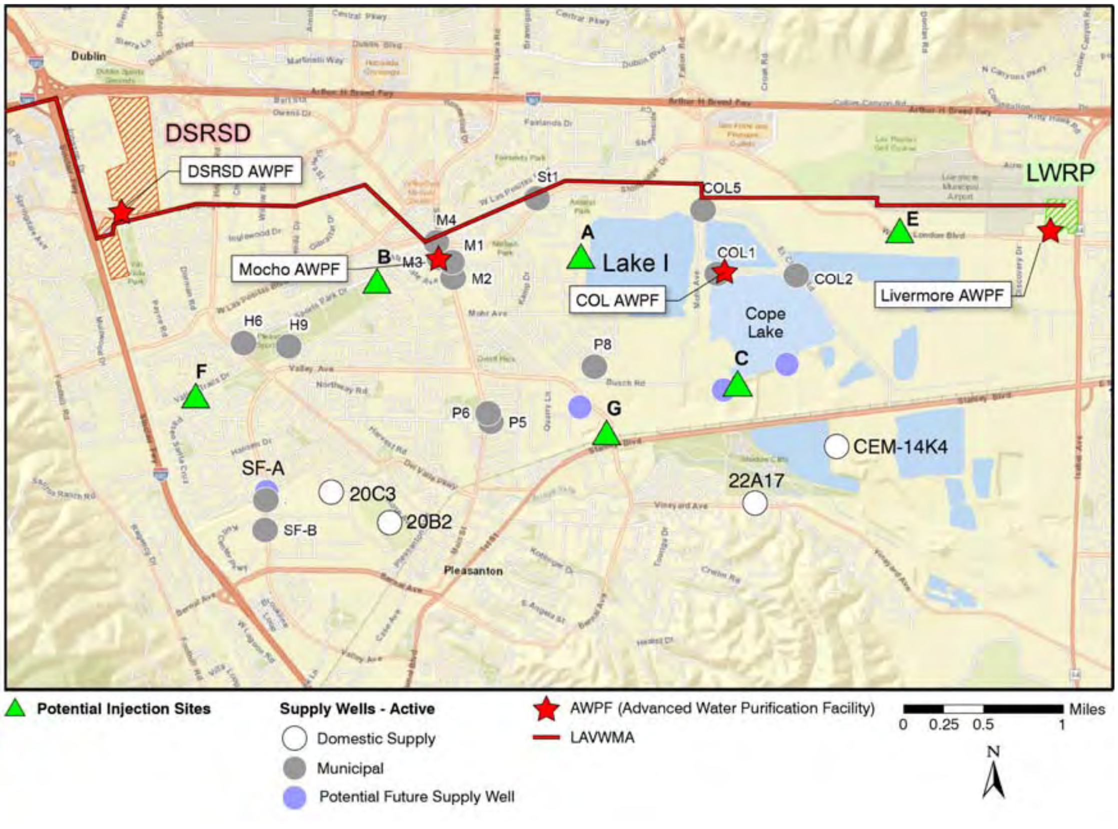


Figure 5.8 Potential Purification Facility Locations

5.6.6 Concentrate Treatment

In Chapter 4, it was determined that potable reuse, even with reverse osmosis concentrate, would not pose an issue with the EBDA Outfall effluent discharge limits. For the purposes of this study, it is assumed that concentrate treatment is not needed for the purposes of meeting existing effluent discharge limits. However, effluent discharge limits may be more stringent in the future. Other agencies that discharge to the EBDA pipeline may implement reuse projects of their own. Additional reuse upstream would concentrate the discharge stream. If other agencies pursue large recycled water programs (removing 20-40 percent of the flow from the EBDA discharge) it may still be possible to revise the EBDA discharge permit, increasing the dilution credit to a higher ratio than 80:1. This would not increase the loading of constituents into the Bay. The Basin Management Plan allows the RWQCB to increase permit limits if needed to support recycling projects. An adjusted permit is not expected or needed for the currently proposed projects.

Concentrate treatment for the short-listed options may be needed to prevent scaling on the LAVWMA line. However, since concentrate treatment is common to all alternatives, it is not a differentiator, and therefore it is not being considered within the preliminary alternative analysis.

5.6.7 Summary of Treatment Alternatives Evaluated

Table 5.3 summarizes the treatment processes and sizes that are evaluated in the alternatives analysis at each site. The location of the AWPF treatment affects the amount of water produced depending on whether it is co-located at a WWTP site or not. For those sites that are located at a satellite location (not at a WWTP), the 10 percent flow that is backwashed from the MF/UF membrane process is not recoverable and must be discharged. At this stage in the project, it is assumed that this waste could be combined with the RO concentrate and discharged to the LAVWMA line, thus lowering the total flow available for product water yield. It is assumed that this discharge can be permitted although this should be confirmed in future efforts. If not, the MF backwash would be returned to the sewer where it would remain be sent to the WWTP headworks. Sufficient capacity in the collection system must be shown before this option is pursued. The lower yield option of discharging directly to LAVWMA is assumed because it is conservative in yield projections.

Table 5.3 Treatment Alternatives Summary

Purified Water Design Flow (Permeate)	Annual Yield	Treatment Type	Seasonal or Constant Operation	Storage	Location
5 mgd	5,500 AFY	FAT, FAT+	Constant	None	Livermore WRP
6 mgd	6,900 AFY	FAT+	Constant	370 MG at DSRSD	Mocho and COL
7 mgd	7,700 AFY	FAT, FAT+	Constant	370 MG at DSRSD	DSRSD
12 mgd	10,000 AFY	FAT, FAT+	Seasonal	None	DSRSD, Mocho, and COL(1)

Notes:

(1) The regional facilities at Mocho and COL will have lower overall recovery rates through their treatment trains (72 percent assumed). This lowered rate is compensated by using a greater influent flow and enlarging the MF/UF membrane process, which is reflected in the costs.

At a WWTP, the 10 percent backwash flow would recycle back to the WWTP and be available again as influent to the AWPF. For the scenarios with storage where winter flows are stored to be used during summer months, this reduced yield phenomena occurs for the satellite locations because the AWPF is designed to run at a steady rate year round and the storage in effect limits the amount of feedwater available. However, the seasonal operation scenarios do not have a reduced yield for options at satellite locations because there is adequate winter flows to be able to account for the 10 percent backwash loss and design for higher flows in some months to meet an annual yield of 10,000 AFY.

5.7 End Use Evaluation

Five types of end uses were selected as viable options to supplement water supplies:

- Groundwater Recharge
  - Via injection wells
  - Via aquifer storage and recovery (ASR)
  - Via surface spreading in Lake I/Chain of Lakes
- Raw Water Augmentation via Cope Lake to the DVWTP
- Raw Water Augmentation of the PPWTP water supply

The assumptions in pursuing each end use option are discussed within this section.

5.7.1 Chain of Lakes

Zone 7 currently owns two former quarries or lakes (Lake I and Cope Lake), with more to be transitioned to Zone 7 through approximately 2060 to form the hydraulically-connected "Chain of Lakes". Lake H is planned for transition in the next few years. The Chain of Lakes will serve a variety of water management purposes, including groundwater recharge, surface water storage and conveyance, and flood management.

In addition to the COLs' existing and planned uses, the COL's area is being considered for potable reuse applications as discussed further below. The evaluation of these options considers the multiple existing and planned uses of Lakes H, I, and Cope; the connectivity of the lakes; future connection to DVWTP; and the connectivity of the lakes to the groundwater basin and water supply wells.

Some of the lakes are, or will be, directly connected to the Livermore Valley Groundwater Basin. Lake I, with a total storage volume of about 27,000 AF, serves as the key lake for groundwater recharge. Cope Lake (4,500 AF) has limited connectivity to the groundwater basin, while Lake H (6,000 AF) can accommodate recharge. A mining company currently discharges pumped groundwater into Cope Lake (see Section 5.7.2.3 for more detail); the water is then conveyed to Lake I for recharge via the Cope Lake-Lake I pipeline.

In the future, Cope Lake and Lake H may be used for stormwater detention. Lake H will also have a diversion structure, allowing diversions from Arroyo Mocho into Lake H. Lakes H and I are connected by a 30-inch pipeline. There are currently three water supply wells (COLs 1, 2, and 5) in the Lake H/Lake I/Cope Lake area, with two additional wells planned. A new pump station and 36-in pipeline connecting Lake H/Lake I/Cope Lake to the DVWTP and the South Bay Aqueduct is planned ("COLs pipeline", see Figure 5.9).The COLs pipeline would allow raw surface water to be brought into the COLs area for storage and recharge. It would also allow access to surface water stored in the COLs for use at the Del Valle Water Treatment Plant (DVWTP) in case of droughts and emergencies.

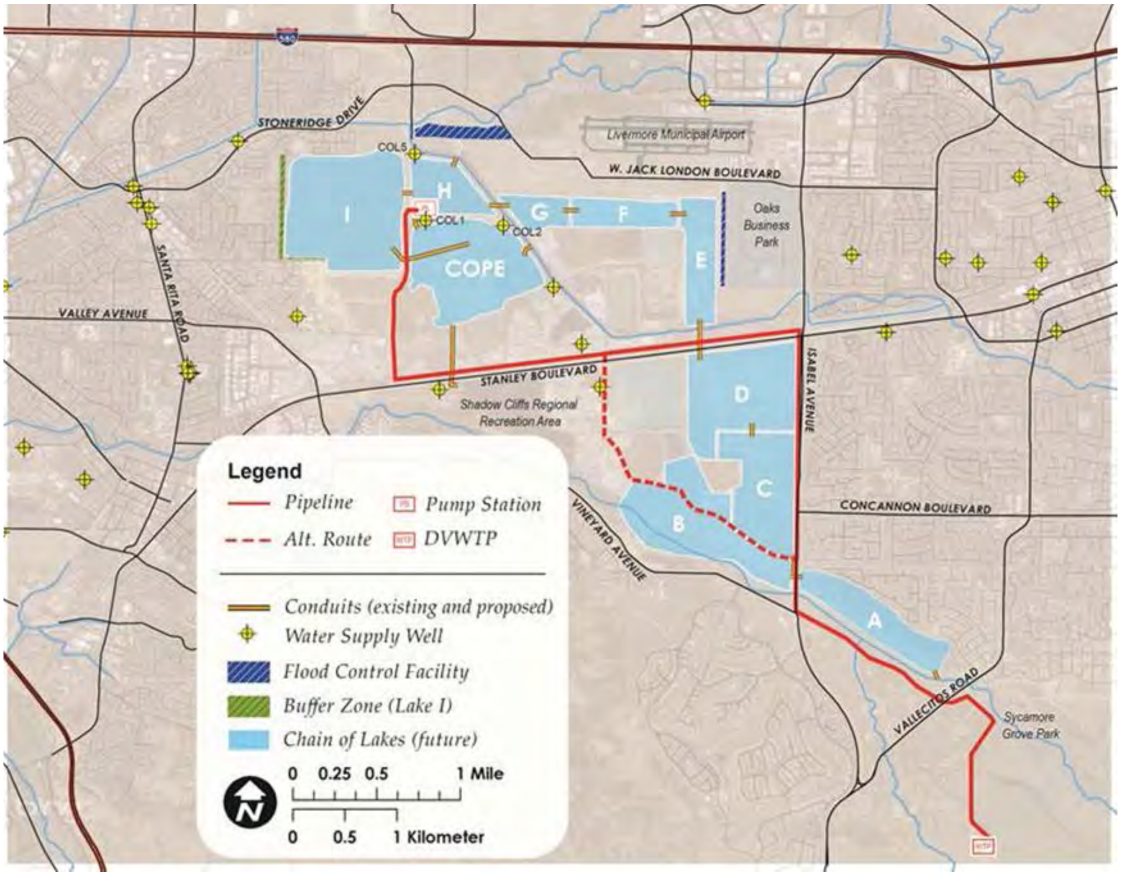


Figure 5.9 Potential Pipeline from COL to DVWTP (COLs Pipeline)

5.7.2 Groundwater Recharge

The primary goal of groundwater recharge is to replenish the groundwater aquifer for the purpose of subsequent extraction and use. The three different types of groundwater recharge discussed within this section vary based upon the method of delivering to and/or extracting water from the groundwater basin.

5.7.2.1 Injection Wells

Groundwater injection requires the use of dedicated injection wells hydraulically connected to the aquifer, recharging the aquifer through a screened casing. Groundwater is then monitored using down-gradient monitoring wells and recovered further down-gradient with extraction wells. This method of groundwater recharge has been widely used in southern California for many years. The DDW requires a minimum retention time in the aquifer of 2 months (Title 22); this retention time is equivalent to a travel time of 2 months to the nearest production well. The required retention time may increase depending on the type of verification used. For instance, if the travel time is calculated with a groundwater model, each month of travel time only gets a half credit, so a total of four months travel time is needed. A tracer study using an added tracer (not intrinsic) receives full credit.

The existing water extraction wells and potential sites investigated for groundwater recharge are shown in Figure 5.10. The potential injection sites were determined through discussions with Zone 7's Groundwater Section familiar with the existing groundwater conditions and quality.

Preliminary locations were also selected to meet the travel time requirement from existing wells using the well protection zones (2-years of estimated subsurface travel time) established in Zone 7's Drinking Water Source Assessment Reports. For wells without published assessment reports (production wells outside of Zone 7's jurisdiction), a conservative 2,000 foot radius around the well was assumed to be the protection zone, which equates to approximately 2-years of travel time. The potential injection well locations and existing wells are called out on Figure 5.10.

It is assumed that potential injections sites located outside of the delineated protection zones would have at minimum 6-month travel time to the nearest potable supply well and likely much longer.

Most of the delineated protection zones are based on the Calculated Fixed Radius method; protection zones for these wells are represented by a single red circle around the well locations shown in Figure 5.10. Protection zones for two wells, COL #1 and COL #2, were determined using the Modified Calculated Fixed Radius method, which determines an up gradient and downgradient distance from the wellhead based on the regional groundwater flow gradient. Because of seasonal changes to the groundwater flow gradient in the area of these wells, there are two potential radii that could be used, depending on the season. The larger radius is used for each well to ensure that injection sites are located outside of the protection zone.

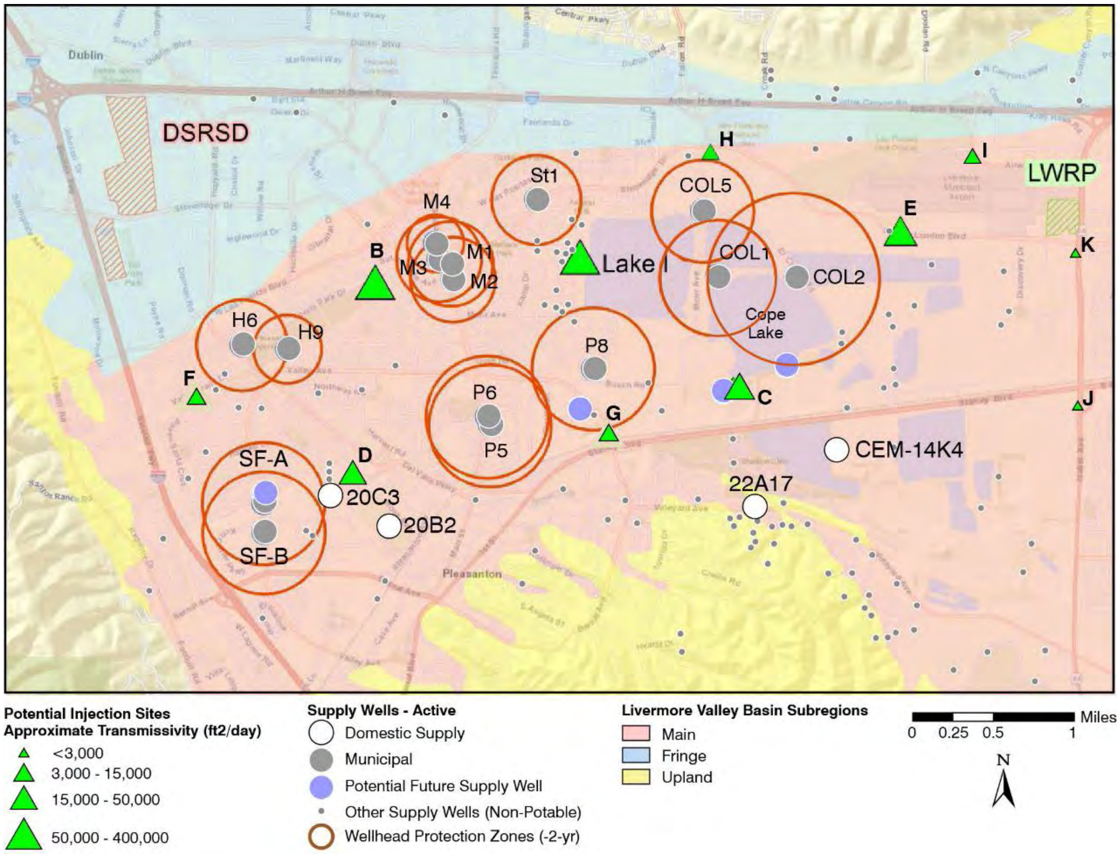


Figure 5.10 Potential Locations of Injection Wells

Transmissivity, defined as the product of hydraulic conductivity and aquifer thickness, is a hydraulic property of an aquifer that describes the water transmission capability of the entire thickness of an aquifer. For wells screened across a substantial portion of the thickness of a confined aquifer unit, the extraction and injection capacities of the well will be related to the aquifer's transmissivity at the well location. Therefore, the estimated transmissivity of the lower aquifer zone was used as a surrogate for well injection capacity for evaluating the initially identified potential injection locations.

Hydraulic properties for the Lower Aquifer Zone were extracted from the Zone 7 Groundwater Model of the Livermore-Amador Valley, version 3.0. Layer 3 of the model represents all of the interbedded water-bearing layers below the aquiclude found in the center of the groundwater basin. Extracted data included hydraulic conductivity and top and bottom elevations of the model layer. A grid of transmissivity values was calculated from the extracted data in ArcGIS using the same 500-ft grid as used in the groundwater model. Gridded transmissivity values ranged from 1.6 to 3,200,000 ft^2/day. Because of the large variation in calculated transmissivity values (over six orders of magnitude), the logarithm of transmissivity was calculated. The grid was then smoothed using a neighborhood mean with a radius of five grid cells because the initially identified injection locations are approximate in an area larger than a single model grid cell. Finally, the mean log transmissivity values were assigned to each potential injection location as shown in Figure 5.10 where the size of the well symbol is proportional to the mean log transmissivity at the location.

Another consideration for the siting of potential injection wells is the potential to improve groundwater quality by flushing lower-quality water out of the basin. Some of the highest TDS concentrations in both the upper and lower aquifers in the main basin are found in the areas generally west of the Chain of Lakes as shown in Figures 6-2 and 6-8 of the Zone 7 Annual Report for the Groundwater Management Program for Water Year 2015. Depending on the specific injection practices used, i.e. injection only or ASR, it is possible that injection of higher quality water can, over time, push higher TDS water toward production wells where it will be extracted. Potential injection sites identified in the western basin in Figure 5.10 were identified in part with this flushing of higher TDS groundwater in mind.

Based on the screening analysis of the potential injection sites the two wells with the lowest estimated transmissivities were eliminated (sites I, J, and K along Isabel avenue). Well D, located in the southwest part of the basin closest to the San Francisco wells, was also eliminated because of its proximity to these potable supply wells.

While site specific conditions including localized hydrogeology and available space will influence injection capacities and site suitability, a preliminary analysis of injection well capacities was conducted based on known extraction capacities at wells throughout Zone 7's water supply system. In general, injection capacity can be assumed to be approximately 50 to 80 percent of extraction capacity. Using this range and averaging the extraction capacities of the existing well system, a high and low injection capacity was determined per injection well. The capacity range is 2.2 mgd to 3.5 mgd per well. The conservative value of 2.2 mgd per well was assumed for the purposes of the model. At each site the number of wells and the individual injection well capacity will define the overall injection capacity of each potential location. These potential injection locations is assessed for sufficient travel time to the nearest well in Chapter 6. The injection capacity assumption is re-visited based on further investigations in Chapter 7.

With the exception of the well adjacent to Lake I (site A in Figure 5.10), it is assumed that the wells could be sited to meet the groundwater recharge regulations through providing a minimum 2 month travel time to the nearest water supply well. Further refinement of travel time and attainment of the 6-month criteria (conservative assumption for planning purposes) is presented in Chapter 6. It is assumed that FAT will be required for injection of purified water at these sites. For the well adjacent to Lake I, it is assumed that the proximity to the Zone 7 water supply wells will require additional treatment—such as GAC and engineered storage—beyond FAT.

Groundwater modeling can show the estimated travel time between the selected injection sites and extraction wells. The 2003 Well Master Plan identified seven potential locations for future wells under the preferred alternative to increase well production capacity to meet drought period demands. While not considered in the preliminary groundwater modeling and alternatives analysis, these additional wells will be considered in the future development of alternatives. Groundwater modeling is discussed briefly within this chapter but in detail in Chapter 6.

5.7.2.2 Aquifer Storage and Recovery (ASR)

ASR is the use of a system of wells to both inject potable or purified water and later extract the water from the same location (after a minimum retention time of two months). Typical ASR wells are located in aquifers with minor lateral hydraulic velocity, or where recovery of recharged water occurs on a regular basis. An ASR system requires several injection locations (minimum 3) to provide continual injection, holding, and extraction ability. These locations can be separated by a defined horizontal distance or by a semi-permeable or impermeable layer within the aquifer. ASR is advantageous on many levels: 1) having both the recharge and recovery components located within a small well site; 2) retaining recharged water within a "bubble" around the well, which allows for better control of water quality within the well; and 3) use of in-situ equipment to maintain recharge capacity, since all recharge facilities clog and need rehabilitation. ASR wells must be located far enough away from drinking water wells to prevent interference with the ASR operations. An example ASR operation is shown in Figure 5.11.

The identified locations for groundwater injection wells could potentially be similar for ASR wells. However, costs for ASR wells are higher than conventional groundwater injection wells. This is due to the additional infrastructure required to connect the wells to the existing distribution system. Since Zone 7 has an extensive existing well system with capacity to extract additional water, there is not a capacity incentive to pursue ASR. The groundwater area around Mocho does have water quality issues (high TDS) as discussed earlier, but these could potentially be resolved with conventional groundwater injection. Since ASR is not seen as essential for groundwater recharge and it is the more expensive option, it will not be individually investigated within this round of alternatives. ASR could potentially be an option later if hydrogeological investigations show that the soils are conducive to the operations. ASR is discussed more in Chapter 6.

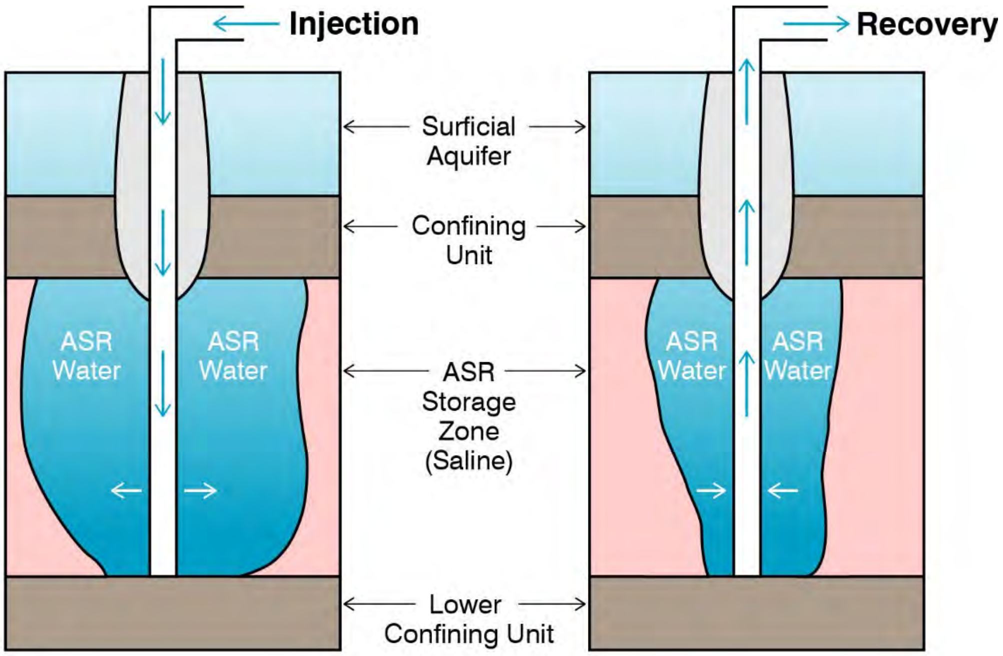


Figure 5.11 Aquifer Storage and Recovery (ASR) System (Adapted from NAP, 2005)

5.7.2.3 Surface Spreading - Lake I

Lake I is the westernmost lake in the Chain of Lakes system (COL). The COL is a series of 10 current and former quarry lakes that have been or will be turned over to Zone 7 for purposes of groundwater recharge, surface water storage, and stormwater management. Currently, Zone 7 owns Lake I and Cope Lake. The other lakes are still in the active mining or reclamation process and will be turned over to Zone 7 in future years once reclamation of lakes is complete.

In the 2014 Chain of Lakes Use Evaluation (Zone 7, 2014), Lake I was rated the highest among the COLs for groundwater recharge potential. It was designated in the 1981 Specific Plan for Livermore Amador Valley Quarry Area Reclamation (LAVQAR) as a recharge location. As a result, during mining and reclamation operations, the western sidewall was maintained as a recharge face. The bottom of the lake (average of 220 ft msl) is beneath the average groundwater surface elevation (approx. 300 ft msl). As a result, Lake I recharge rates are highly sensitive to water surface elevation (WSE), ranging from 0 to almost 18,000 AFY (16 mgd). Its total storage volume is approximately 27,000 AF. If Lake I levels are low enough, the water flow is reversed and groundwater begins to flow into the lake. Figure 5.12 shows the relationship between Lake I WSE, recharge rate, and volume. As the lake level drops, the head decreases, therefore the infiltration rate decreases.

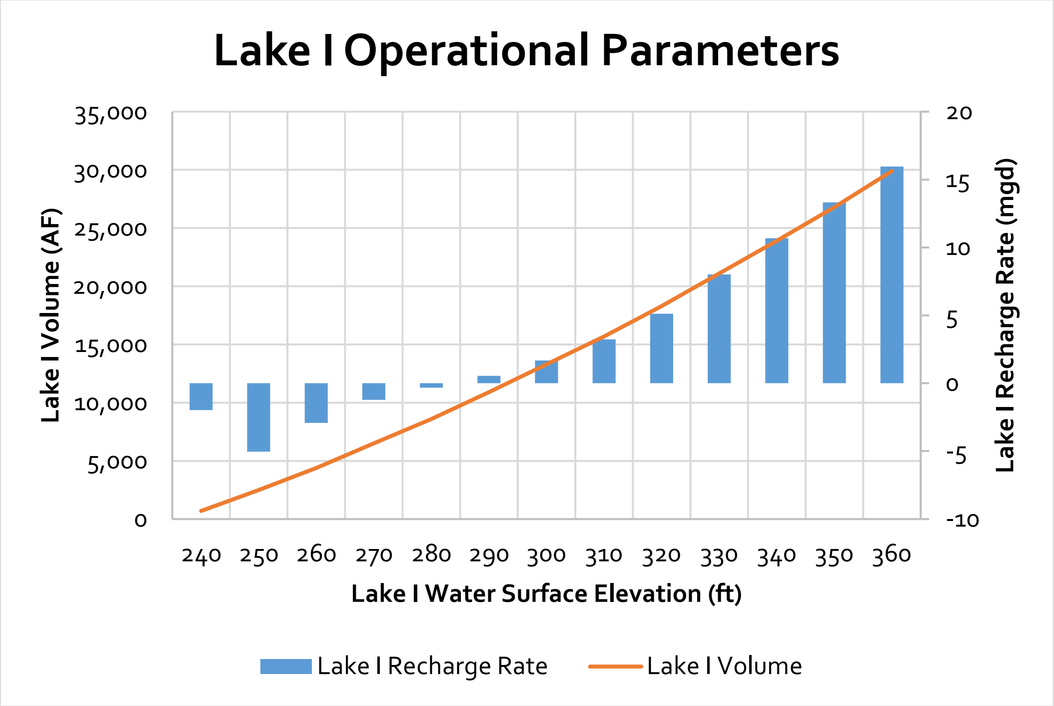


Figure 5.11 Lake I Recharge Rate, Volume, and Water Surface Elevation Relationship (Assumes Groundwater Level at 270 feet)

Vulcan Discharge

Vulcan Materials is currently using Lakes C through G - either actively mining or storing water. The company has a contract with Zone 7 to discharge dewatering and processing water into Lake I via Cope Lake.

The water is transferred through an existing Lake I-Cope Lake connecting pipeline. If Vulcan discharges the full capacity, then storage/recharge capacity in Lake I will be unavailable for purified water. Before Cope Lake or Lake I was available, Vulcan discharged to the Arroyo Mocho. Historical annual discharges are shown in Figure 5.13. The discharges vary by year depending on the mining operations. These discharges are not distributed evenly throughout the year and tend to be higher in winter months and lower in summer months. The average annual discharge volume is 2,000 AFY and the maximum amount of water that has been discharged between 1974 and 2015 in the COLs is 9,100 AFY. This discharge value was used in the alternatives analysis to model Lake I operations and the upper bookend of effects on recharge rate. The average discharge rate of 2,000 AFY was used to model operations with a lowered Vulcan discharge.

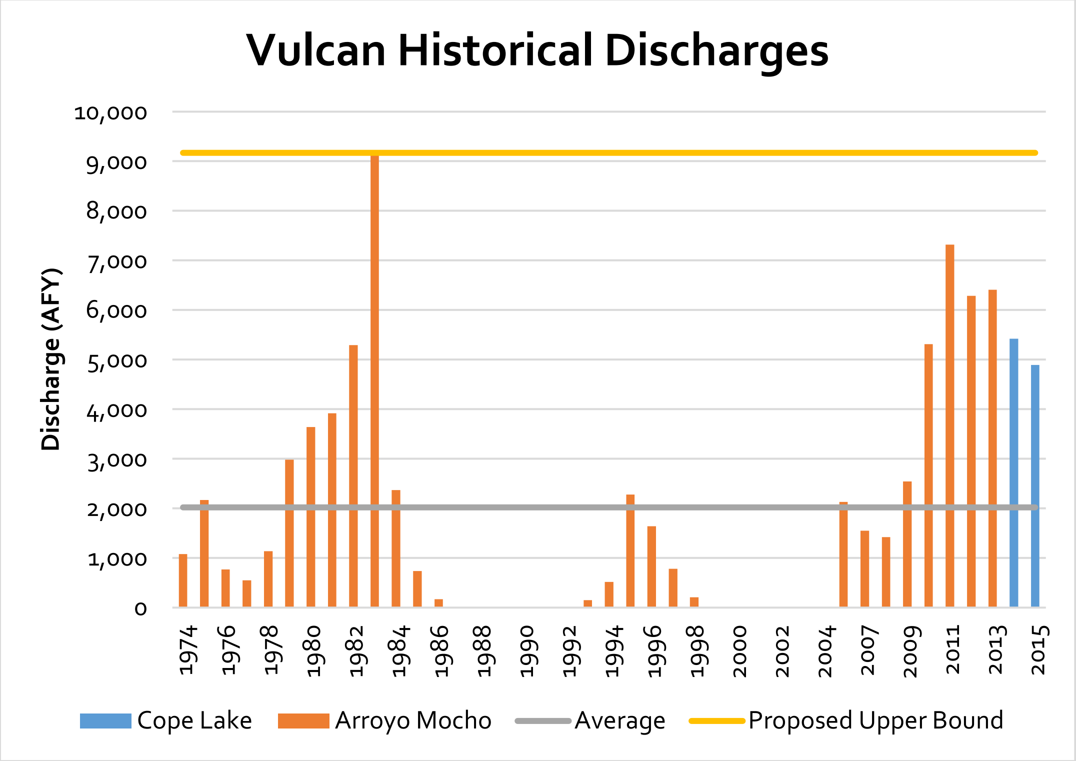


Figure 5.12 Vulcan Historical Discharges

The above section was accurate as of the publishing of the draft feasibility study in 2017. However, in water year 2017, Vulcan Materials discharged 13,500 AF. They have established a new National Pollutant Discharge Elimination System (NPDES) permit limit of 40 mgd and are considering adding a new discharge pipeline to increase capacity. If options involving Lake I discharge or even use of Cope Lake are considered in the future, future studies should investigate operational adjustments and institutional agreements that need to be made between the agencies and Vulcan Materials.

5.7.3 Reservoir and Raw Water Augmentation - DVWTP and PPWTP

Two WTPs treat surface water for distribution throughout Zone 7's service area - Del Valle WTP (DVWTP) and Patterson Pass WTP (PPWTP). DVWTP has an average capacity of 36 mgd. PPWTP has an average capacity of 19 mgd (to be expanded to 24 mgd by 2021).

5.7.3.1 Cope Lake to DVWTP

In a future potable reuse project, purified water could be sent to Cope Lake for a brief holding period before being transferred to DVWTP via the new COL pipeline. Purified water could potentially be sent directly to the pipeline to DVWTP, bypassing Cope Lake, but still utilizing a main portion of the pipeline. Since the volume of Cope Lake is so low, it may not provide enough storage time to be considered reservoir augmentation. All alternatives with delivery to DVWTP via Cope Lake or directly via the COL pipeline would be considered raw water augmentation. Note that the ability to discharge into Cope Lake allows for some flexibility in case DVWTP is unable to receive purified water (e.g., plant outage).

Cope Lake has a capacity of approximately 4,500 AF. To assess the residence time in Cope Lake, a water balance around the Cope Lake was developed. This water balance accounts for inflows and outflows from Cope Lake, including:

- Net evaporation.
- Seepage.
- Inflow from Vulcan mining operations.
- Purified water flow.
- Outflow to Lake I.

In addition, the following infrastructure limitations for flow in/out of Cope Lake were considered in this analysis:

- Outflow to Lake I - The connection between Cope Lake and Lake I is a 36-inch HDPE pipeline, starting at an elevation of 330 feet in Cope Lake and discharging into Lake I at 285 feet. Water flows from Cope Lake to Lake I at various speeds depending on the water elevation in the respective lakes. The maximum design flow between lakes is 34 mgd.
- Outflow to DVWTP - A 30-in pipeline from Cope Lake to DVWTP is currently included in the capital improvement plan for Zone 7. A 1,300-hp pump station is included in the plan as well. The planned capacity of the pump station and pipeline is 12 mgd.

The water balance was conducted on an annual basis, and assumes a steady state condition (no storage change). In recent years the Vulcan discharge has been approximately 4,900 AFY, with about 3,000 AFY conveyed to Lake I for recharge. Under this discharge condition, if an additional 4,100 AFY of purified water were conveyed through Cope Lake then the average residence time of the purified water in Cope Lake would be approximately 6 months. It is possible that future potable reuse regulations would consider a 6-month residence to be a sufficient environmental buffer and treatment requirements would be limited to FAT. However, there is some seepage from Cope Lake, and the lake is in close proximity to the Zone 7 municipal wells. Therefore, it is assumed that FAT, GAC, and engineered storage will be required.

While the residence time in Cope Lake may not provide a regulatory benefit in terms of treatment requirements, it can serve as an environmental buffer. A key variable in the residence time of purified water in Cope Lake is the volume of the Vulcan discharge into Cope Lake and subsequent outflow into Lake I. At Vulcan's permitted discharge volume of 21,000 AFY, the residence time would be on the order of 2 months. Furthermore, there would be potential issues with maintaining a steady state condition, as Lake I recharge capacity would likely be exceeded.

5.7.3.2 PPWTP Raw Water Augmentation

PPWTP has a 92-AF reservoir ahead of its facilities. At best, this reservoir would only be able to provide a few days' residence time. Therefore, alternatives considering PPWTP are also designated as raw water augmentation projects.

PPWTP is located approximately 7 miles east of Livermore WRP, the easternmost purification facility location. The infrastructure alone to distribute water from any of the other purification facilities to PPWTP could be cost prohibitive. Therefore, the only alternative that includes purified water sent to PPWTP is the 5 mgd treatment facility at Livermore WRP. As shown in Table 5.4, PPWTP has received sufficient historical flows to be able to meet the 50 percent blend requirement with flows from a purification facility at Livermore WRP.

5.7.3.3 Blending Requirement

Regulations for reservoir augmentation (also called surface water augmentation) were adopted in March 2018. Raw water augmentation regulations have not been established but are expected by December 2023. Prior to adoption of formal regulations, case by case projects may be permitted by the State. For the purposes of this evaluation, it is assumed that the blending percentage for purified water to raw water would be 50 percent for both raw water and reservoir augmentation. Historical production for each of the WTPs is shown in Table 5.4. It should be noted that 2014 was a drought year and surface water supplies were limited. DVWTP is able to meet the blend percentage with a seasonal flow of up to 12 mgd of purified water, which is the maximum potential purified water flow being investigated within this project.

Table 5.4 WTP Historical Flows

Year	PPWTP Flow (mgd)	DVWTP Flow (mgd)
2012	7.9	17.5
2013	11.2	18.5
2014	6.9	13.2
Overall Average	8.7	16.4

On a seasonal basis, the WTPs produce more water in summer months than in winter months, as is shown in Figure 5.14. With PPWTP, there may be a shortage of blending water in winter months. However, assuming that the annual allocation of water stays the same, operationally, the WTPs should be able to adjust to new flow patterns with the purified water addition.

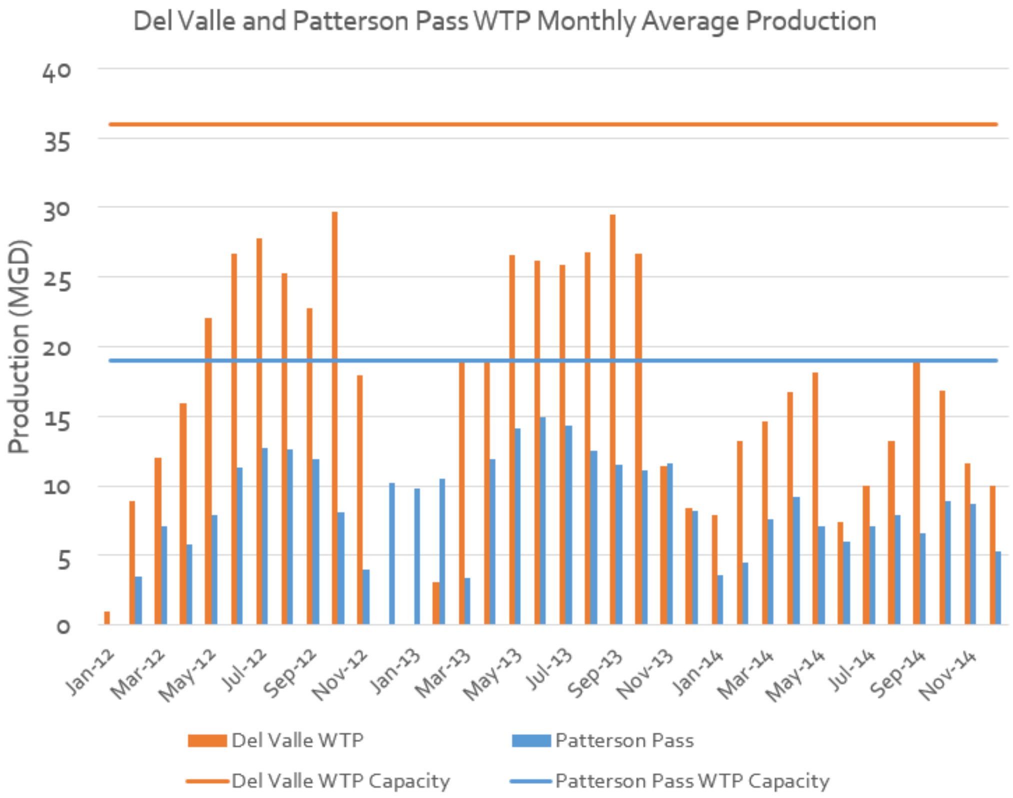


Figure 5.14 WTP Monthly Average Production

Cope Lake is sensitive to peak flows, smaller than Lake I, and (along with Lake H) may be used for stormwater detention in the future. At times when there is not enough capacity in Cope Lake or not enough source water available to meet the blend ratio, it may be necessary to divert purified water from Cope Lake to Lake I or to nearby injection wells. This flexibility must be considered in each alternative which uses Cope Lake.

5.8 Alternatives Development

In total, 21 preliminary alternatives were developed by the project management team. They are listed in Table 5.5. The intention of this initial alternatives analysis was to take a broad cross section of potential alternatives and evaluate them according to the preliminary evaluation criteria, narrowing down the group of alternatives to three short-listed options for further investigation. Alternatives developed within this section were compared in Carollo's master planning tool - Blue Plan-it® (BPI). The purpose of the BPI runs was to provide a bracket of potential costs across a range of alternatives. Not all of the 21 alternatives listed in Table 5.5 were analyzed in the BPI model because they were considered similar to other, more cost-effective alternatives.

For each alternative, preliminary pipeline alignments, treatment trains, and end use assumptions were developed to inform the cost estimate and modeling effort. Each alternative is described briefly within this section.

5.8.1 Alternatives at Livermore WRP

Four alternatives were evaluated with advanced treatment at Livermore WRP. Diversion of flow from DSRSD WWTP to Livermore WRP was briefly investigated. The diversion would require approximately 6.5 miles of pipeline adjacent to the existing LAVWMA line. The LAVWMA line would have to remain in place to convey discharge and waste streams to DSRSD. The additional infrastructure required to bring DSRSD flows was considered too extensive to consider in this round of alternatives. Therefore, all options with advanced treatment at Livermore WRP are sized only for Livermore flows. The flows are predicted to be sufficient for 5 mgd (5,500 AFY) year-round production of purified water. Alternative alignments are shown in Figure 5.15.

Treated concentrate would be discharged to the LAVWMA pipeline.

5.8.1.1 Alternative 1: Treatment at Livermore, Direct Injection at Well E

Alternative 1 includes the following components:

- 5 mgd FAT facility operating year-round.
- 6,100 LF of pipeline from the facility to Well E (alignment along Jack London Blvd).
- Three injection wells located at Well E Site.

Table 5.5 Preliminary Alternative List

ID	Source	Capacity (mgd)	Annual Yield (AFY)	Seasonal/Year Round	Purification Location	Treatment	Storage	End Use Location
1	L	5	5,500	Year Round	Livermore WRP	FAT	No	Well E
2	L	5	5,500	Year Round	Livermore WRP	FAT	No	Lake I
3	L	5	5,500	Year Round	Livermore WRP	FAT+	No	PPWTP
4	L	5	5,500	Year Round	Livermore WRP	FAT+	No	Cope Lake/ DVWTP
5	L + D	7	7,700	Year Round	Regional at DSRSD WWTP	FAT	370 MG	Well F
6	L + D	7	7,700	Year Round	Regional at DSRSD WWTP	FAT	370 MG	Well B
7	L + D	7	7,700	Year Round	Regional at DSRSD WWTP	FAT+	370 MG	Lake I
8	L + D	1212 (5 Summer)	10,000	Seasonal	Regional at DSRSD WWTP	FAT	No	Well F
9	L + D	1212 (5 Summer)	10,000	Seasonal	Regional at DSRSD WWTP	FAT	No	Well B
10	L + D	12 (5 Summer)	10,000	Seasonal	Regional at DSRSD WWTP	FAT+	No	Lake I
11	L + D	7	7,700	Year Round	Regional at DSRSD WWTP	FAT+	370 MG	Cope Lake /DVWTP
12	L + D	12 (5 Summer)	10,000	Seasonal	Regional at DSRSD WWTP	FAT+	No	Cope Lake /DVWTP
13	L + D	12 (5 Summer)	10,000	Seasonal	Regional at Mocho	FAT	No	Well B
14	L + D	12 (5 Summer)	10,000	Seasonal	Regional at Mocho	FAT+	No	Well A
15	L + D	12 (5 Summer)	10,000	Seasonal	Regional at Mocho	FAT+	No	Lake I
16	L + D	6	6,900	Year Round	Regional at Mocho	FAT+	370 MG	Cope Lake/DVWTP
17	L + D	12 (5 Summer)	10,000	Seasonal	Regional at COL	FAT	No	Well C
18	L + D	12 (5 Summer)	10,000	Seasonal	Regional at COL	FAT	No	Well H
19	L + D	12 (5 Summer)	10,000	Seasonal	Regional at COL	FAT+	No	Lake I
20	L + D	12 (5 Summer)	10,000	Seasonal	Regional at COL	FAT+	No	Well A
21	L + D	6	6,900	Year Round	Regional at COL	FAT+	370 MG	Cope Lake/DVWTP

Notes:
L = Livermore
D = DSRSD

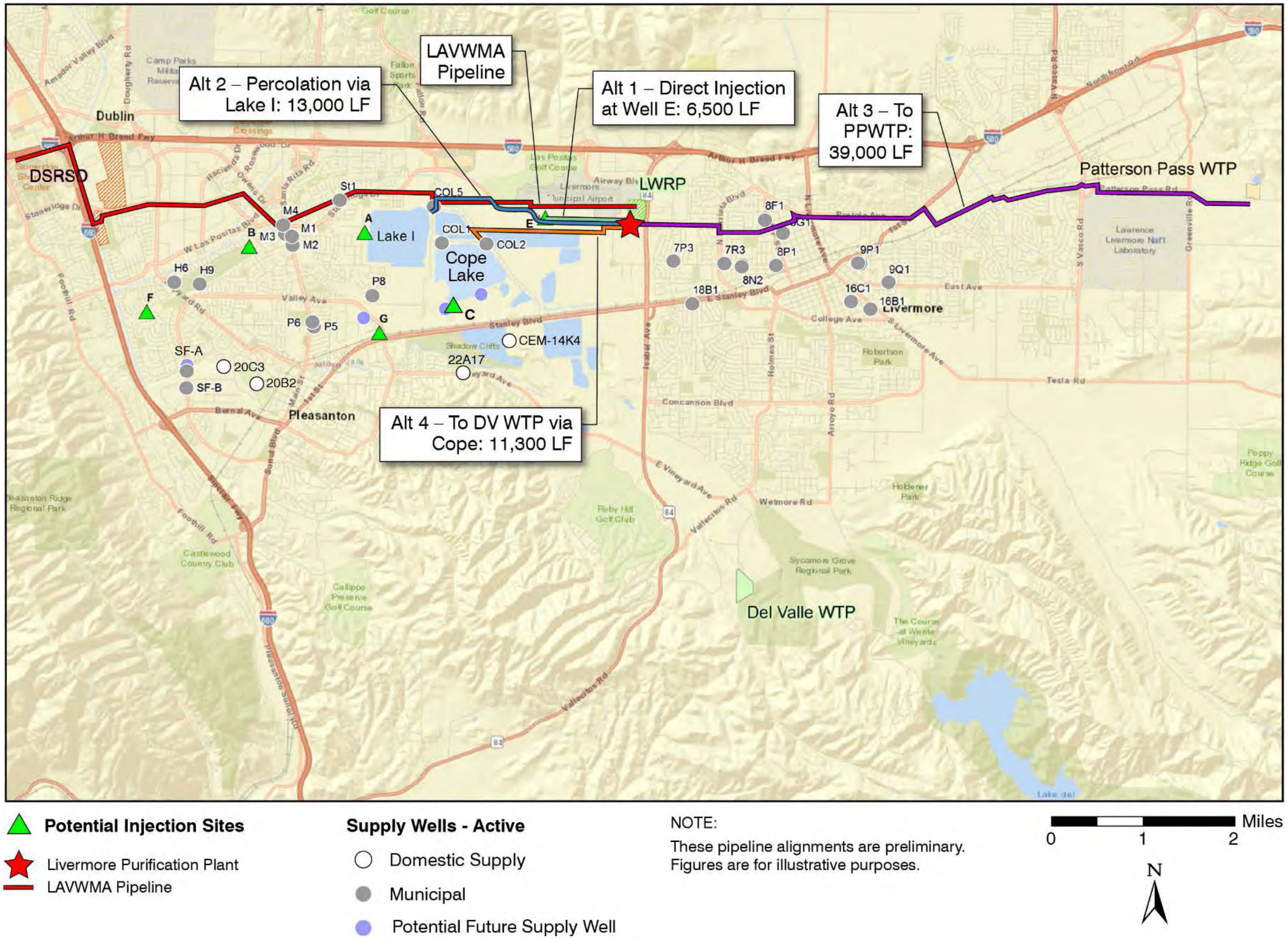


Figure 5.15 Alternative Alignments for Livermore Alternatives

5.8.1.2 Alternative 2: Treatment at Livermore, Surface Spreading via Lake I

Alternative 2 includes the following components:

- 5 mgd FAT+ facility operating year-round.
- 13,000 LF of pipeline from the facility to Lake I (alignment along Jack London Blvd).
- Flexibility to send water through Cope Lake to DVWTP.

5.8.1.3 Alternative 3: Treatment at Livermore, Blend at Patterson Pass WTP

Alternative 3 includes the following components:

- 5 mgd FAT+ facility operating year-round.
- 39,000 LF of pipeline from the facility to PPWTP (alignment follows East Jack London Blvd down to Portola Ave to Patterson Pass Road).
- Three injection wells located near the treatment facility in case of PPWTP shut down to provide flexibility.

5.8.1.4 Alternative 4: Treatment at Livermore, Blend at Del Valle WTP via Cope Lake

Alternative 4 includes the following components:

- 5 mgd FAT+ facility operating year-round.
- 11,300 LF of pipeline from the facility to Cope Lake (alignment follows Jack London Blvd).
- Additional $2 million to increase pump station capacity for diversion from Cope Lake to DVWTP.

5.8.2 Alternatives at DSRSD WWTP

A facility at DSRSD WWTP would be able to treat both Livermore and DSRSD effluent without constructing significant additional secondary effluent piping. Alternatives at DSRSD include both year-round constant production facilities as well as seasonal facilities. The year-round facilities will require 370 MG of storage and can produce up to 7 mgd. Seasonal facilities are sized to produce 12 mgd but will turn down to 5 mgd in summer months. Figure 5.16 shows alignments for all Alternatives 5 through 12.

5.8.2.1 Alternative 5: Year-Round Treatment at DSRSD, Direct Injection at Well F

Alternative 5 includes the following components:

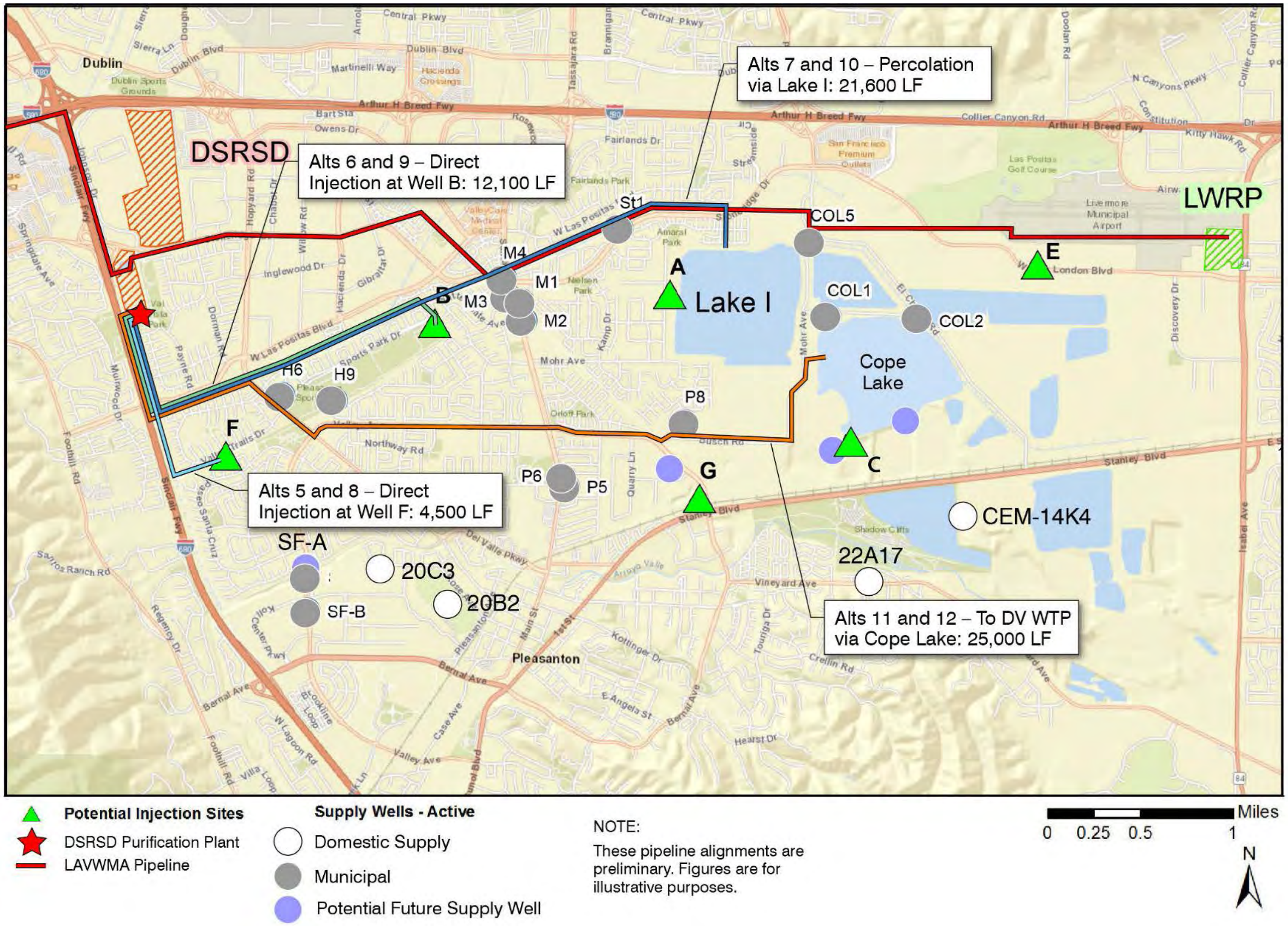
- 7 mgd FAT facility operating year-round.
- 370 MG of storage at DSRSD.
- 4,500 LF of pipeline from facility to Well F (alignment follows the Centennial bike trail).
- Four injection wells.

Well F was chosen for this alternative due to its proximity to DSRSD and the lower water quality (high TDS) reported from production wells in that area.

5.8.2.2 Alternative 6: Year-Round Treatment at DSRSD, Direct Injection at Well B

Alternative 6 includes the following components:

- 7 mgd FAT facility operating year-round.
- 370 MG of storage at DSRSD.



NOTE:

These pipeline alignments are preliminary. Figures are for illustrative purposes.

Figure 5.16 Alternative Alignments for DSRSD Alternatives

- 12,100 LF of pipeline from facility to Well B (alignment follows the Centennial and Arroyo Mocho bike trails).
- Four injection wells.

This alternative was not modeled in Blue Plan-it®, in favor of Alternative 5 which has a reduced pipeline length.

5.8.2.3 Alternative 7: Year-Round Treatment at DSRSD, Surface Spreading via Lake I

Alternative 7 includes the following components:

- 7 mgd FAT+ facility operating year-round.
- 370 MG of storage at DSRSD.
- 21,600 LF of pipeline from facility to Lake I (alignment follows the Centennial and Arroyo Mocho bike trails and turns down Trevor Parkway).
- Flexibility to send water through Cope Lake to DVWTP.

5.8.2.4 Alternative 8: Seasonal Treatment at DSRSD, Direct Injection at Well F

Alternative 8 includes the following components:

- 12 mgd FAT facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 4,500 LF of pipeline from facility to Well F (alignment follows the Centennial bike trail).
- Six injection wells.

5.8.2.5 Alternative 9: Seasonal Treatment at DSRSD, Direct Injection at Well B

Alternative 9 includes the following components:

- 12 mgd FAT facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 12,100 LF of pipeline from facility to Well B (alignment follows the Centennial and Arroyo Mocho bike trails).
- Six injection wells.

This alternative is not modeled in Blue Plan-it®.

5.8.2.6 Alternative 10: Seasonal Treatment at DSRSD, Surface Spreading via Lake I

Alternative 10 includes the following components:

- 12 mgd FAT+ facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 21,600 LF of pipeline from facility to Lake I (alignment follows the Centennial and Arroyo Mocho bike trails and turns down Trevor Parkway).
- Flexibility to send water through Cope Lake to DVWTP.

5.8.2.7 Alternative 11: Year-Round Treatment at DSRSD, Blend at Del Valle WTP via Cope Lake

Alternative 11 includes the following components:

- 7 mgd FAT+ facility operating year-round.
- 370 MG of storage at DSRSD.
- 25,000 LF of pipeline from the facility to Cope Lake (alignment follows Valley Road and El Charro Road).
- Additional $2 million to increase pump station capacity for diversion from Cope Lake to DVWTP.

5.8.2.8 Alternative 12: Seasonal Treatment at DSRSD, Blend at Del Valle WTP via Cope Lake

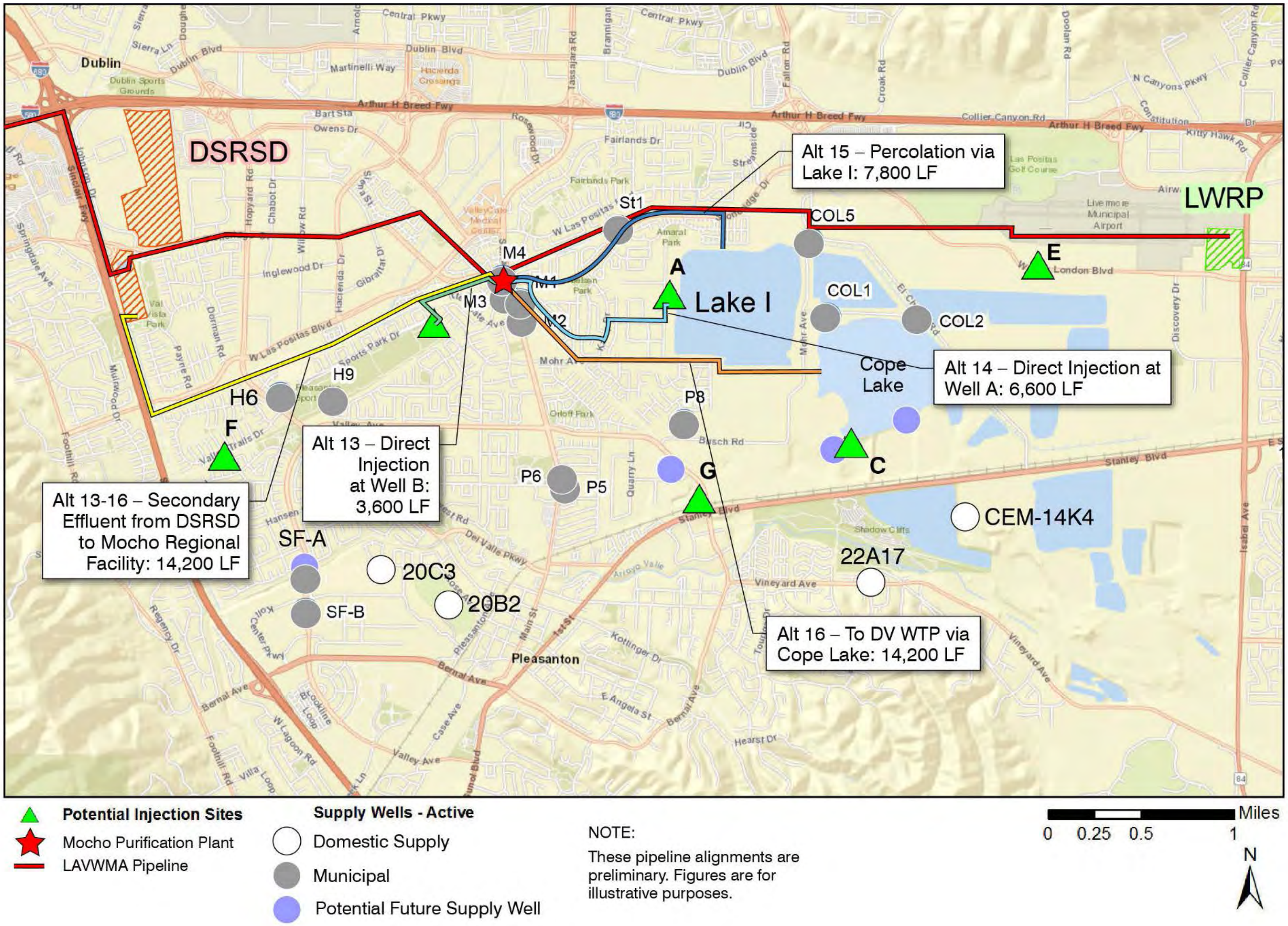
Alternative 12 involves the following components:

- 12 mgd FAT+ facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 25,000 LF of pipeline from the facility to Cope Lake (alignment follows Valley Road and El Charro Road).
- Additional $2 million to increase pump station capacity for diversion from Cope Lake to DVWTP.

5.8.3 Alternatives at Mocho

Zone 7 currently has a demineralization facility located at the Mocho site, at the intersection of Stoneridge Drive and Santa Rita Road (see Figure 5.17). Repurposing of the demineralization facility is not considered under these alternatives although it could be an option considered in the future. The purification facilities would be located south of the Mocho demineralization facility. DSRSD secondary effluent would be conveyed through a dedicated pipeline (14,200 LF) along the Arroyo Mocho Bike Trail as shown in Figure 5.18. Livermore effluent would come from the nearby LAVWMA line. All waste streams would be discharged into the LAVWMA line.

Figure 5.17 Mocho Regional Facility Overview



NOTE:
These pipeline alignments are preliminary. Figures are for illustrative purposes.

Figure 5.13 Alternative Alignments for Mocho Alternatives

The treatment train recovery rate for all facilities at Mocho will be slightly lower than those at Livermore WRP or DSRSD WWTP as discussed in Section 5.6.1 – closer to 72 percent than 80 percent, due to the inability to recapture reject flows. With the seasonal treatment options, the impact of the lower recovery rate is a slightly larger infrastructure size for transferring water to the treatment facility. With the year-round facility, however, the product flow will be reduced to 6 mgd because the amount of available year-round flow is limited by the storage size.

The total available land is estimated to be a little over 1.5 acres. Seasonal treatment facilities sized for 12 mgd at this location may need to have multiple floors in order to fit on the site. For the year-round treatment option, storage would be built at DSRSD WWTP. Figure 5.18 shows pipeline alignments for alternatives 13 through 16.

5.8.3.1 Alternative 13: Seasonal Treatment at Mocho, Direct Injection at Well B

Alternative 13 includes the following components:

- 12 mgd FAT facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 3,600 LF of pipeline to Well B.
- Six injection wells.

5.8.3.2 Alternative 14: Seasonal Treatment at Mocho, Direct Injection at Well A

Alternative 14 includes the following components:

- 12 mgd FAT+ facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 6,600 LF of pipeline to Well A.
- Six injection wells.

FAT+ is assumed to be necessary because of the proximity to Lake I and the short travel time to proximate distribution wells.

5.8.3.3 Alternative 15: Seasonal Treatment at Mocho, Surface Spreading via Lake I

Alternative 15 includes the following components:

- 12 mgd FAT+ facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 7,800 LF of pipeline from facility to Lake I.
- Flexibility to send water through Cope Lake to DVWTP.

5.8.3.4 Alternative 16: Year-Round Treatment at Mocho, Blend at Del Valle WTP via Cope Lake

Alternative 16 includes the following components:

- 6 mgd FAT+ facility operating year-round (lower production due to lower recovery rate).
- 370 MG of storage at DSRSD.
- 9,800 LF of pipeline from the facility to Cope Lake.
- Additional $2 million to increase pump station capacity for diversion from Cope Lake to DVWTP.

5.8.4 Alternatives at Chain of Lakes

A plot of land in between Lake H, Lake I, and Cope Lake was investigated as a potential site for a regional facility. The size of the available land is approximately 3.1 acres. There is an existing Zone 7 well facility near the potential facility site as shown in Figure 5.19. Since the site is surrounded by lakes and active groundwater recharge, the COL facility would need deep foundations, like piles, to ensure structural integrity.

Figure 5.19 COL Regional Facility Overview

Secondary effluent from DSRSD WWTP would be piped through 26,000 LF of pipeline to reach the facility. Livermore water would be conveyed via a 3,100 LF-long diversion from the LAVWMA line. Concentrate and waste streams would be piped back along a parallel pipeline to the LAVWMA line for discharge. As a satellite facility, the treatment train overall recovery rate is 72 percent. Preliminary alignments for alternatives with a treatment facility at COL are shown in Figure 5.20.

5.8.4.1 Alternative 17: Seasonal Treatment at COL, Direct Injection at Well C

Alternative 17 includes the following components:

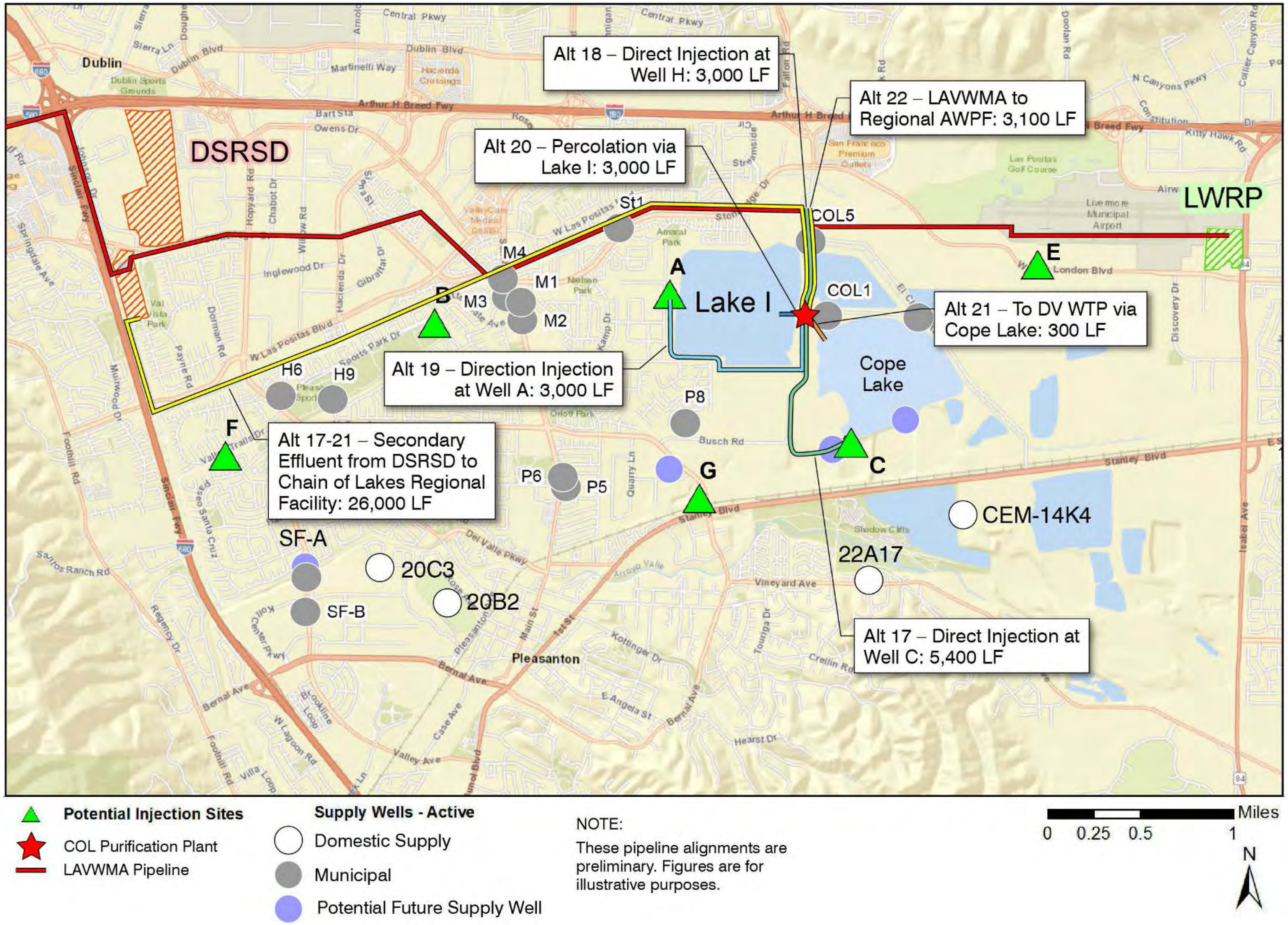
- 12 mgd FAT facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 5,400 LF of pipeline to Well C.
- Six injection wells.

This option is similar to Alternative 18, but with a slightly longer pipeline. For this reason it is not modeled in Blue Plan-it®.

5.8.4.2 Alternative 18: Seasonal Treatment at COL, Direct Injection at Well H

Alternative 18 includes the following components:

- 12 mgd FAT facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 3,000 LF of pipeline to Well H.
- Six injection wells.



NOTE:

These pipeline alignments are preliminary. Figures are for illustrative purposes.

Figure 5.14 Alternative Alignments for COL Alternatives

This alternative includes potentially 4 pipelines between Lake I and Lake H, in addition to the pipelines already in that vicinity. Realignment of pipelines during a route study may be necessary if this alternative is pursued.

5.8.4.3 Alternative 19: Seasonal Treatment at COL, Direct Injection at Well A

Alternative 19 includes the following components:

- 12 mgd FAT+ facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 7,000 LF of pipeline to Well A.
- Six injection wells.

A more feasible approach to get water into Well A from the facility is to use Lake I as a conveyance and provide an intake on the west side of Lake I right near Well A. Since Alternative 19 is similar to Alternative 20, it is not modeled in Blue Plan-it®.

5.8.4.4 Alternative 20: Seasonal Treatment at COL, Surface Spreading via Lake I

Alternative 20 includes the following components:

- 12 mgd FAT+ facility with seasonally varied flow operations (annual yield of 10,000 AFY).
- 300 LF of pipeline to Lake I.
- Flexibility to send water through Cope Lake to DVWTP.
- A well on the west side of the lake (Well A) could be included to inject excess water deeper into the aquifer and relieve a capacity burden.

5.8.4.5 Alternative 21: Year-Round Treatment at COL, Blend at Del Valle WTP via Cope Lake

Alternative 21 includes the following components:

- 6 mgd FAT+ facility operating year-round (lower production due to lower recovery rate).
- 370 MG of storage at DSRSD.
- 300 LF of pipeline from the facility to Cope Lake.
- Additional $2 million to increase pump station capacity for diversion from Cope Lake to DVWTP.

5.9 Preliminary Groundwater Modeling

The Zone 7 groundwater basin model was used to evaluate high-level feasibility of several injection and/or surface spreading scenarios.

The primary objectives of the regional modeling analysis were to:

- Quantify potential *relative* impacts to the groundwater basin resulting from injection of purified recycled water based on different injection sites and rates, and
- Evaluate the potential travel time to existing potable production wells.

To simplify the evaluation, the impacts of injecting purified recycled water at each of the potential injection sites were simulated assuming operation as recharge wells (not in ASR configuration).

A total of 21 project alternatives have been described previously; however, only those alternatives with a recharge component were considered for the modeling analysis. In addition, some project alternatives having similar recharge components, e.g., alternatives having the same end uses but different purification plant locations, can be evaluated with a single groundwater model scenario. From these 21 alternatives, a subset of five scenarios was identified for preliminary evaluation using the model, including a baseline/no recharge scenario, as shown in Table 5.6.

Table 5.6 Preliminary Groundwater Modeling Scenarios

Scenario	Recharge Site	Injection Rate
00-Baseline	None	0
01	Well E	5,500 AFY
08	Well F	10,000 AFY
13	Well B	10,000 AFY
10	Lake I	10,000 AFY

For each scenario, the Fall 2016 observed groundwater levels were used to define the initial conditions for the model. A 10-year simulation period was used for evaluating the effects of recharge. The observed water levels were interpolated to the model grid and used as initial conditions for a steady state model run. The output heads from this steady state model were used to define initial heads for the transient model. Semi-annual time steps are used in the transient model; a series of four initialization time steps are included at the beginning of the transient simulation period. Thus, the model includes 24 time steps for the simulations: 4 steady state time steps plus 20 transient time steps for 10 years.

The scenarios were based on average hydrologic conditions. Inflow and outflow components, including purified recycled water injection, are held constant throughout the simulation period, but may vary seasonally. Inflow components include natural stream recharge, Arroyo del Valle prior rights, artificial stream recharge, rainfall recharge, applied water recharge, and subsurface basin inflow.

Outflow components comprise of municipal pumping by Zone 7 and others, agricultural pumpage, mining use, and basin overflow. Zone 7 municipal pumpage is related to the volume of artificial recharge while municipal pumpage by other agencies is based on a quota derived from the basin natural sustainable yield. For this preliminary analysis, the basin water balance is not maintained, i.e., purified recycled water recharge is not offset by corresponding reductions in imports to the basin through the South Bay Aqueduct or increased municipal pumping by Zone 7. Further modeling efforts in the next phase will explore options to maintain the basin water balance.

The time of travel from an injection site to potable production wells can be evaluated by injecting a unit concentration in the recharge wells and determining the time for breakthrough to occur at the nearest affected production well. In accordance with potable reuse regulations, breakthrough is defined at a level of two percent of the injected concentration. Travel time of purified recycled water from the point of injection to a production well is evaluated through the use of a transport simulation using the Modular Transport 3-Dimensional method (MT3D). For this evaluation, the initial concentration is set to zero throughout the model domain, and a unit concentration of 100 is assigned to the injection well. Observed concentrations at the production wells are used to determine the time at which 2 percent of the injected concentration appears at each well.

The preliminary modeling results on impacts to groundwater levels and travel time are used to help refine the list of alternatives. The next phase of work will include more detailed feasibility analysis of specific sites and refined travel time estimates, as well as evaluation of groundwater quality, potential for contaminant mobilization, and plugging potential.

5.9.1 Preliminary Modeling Results

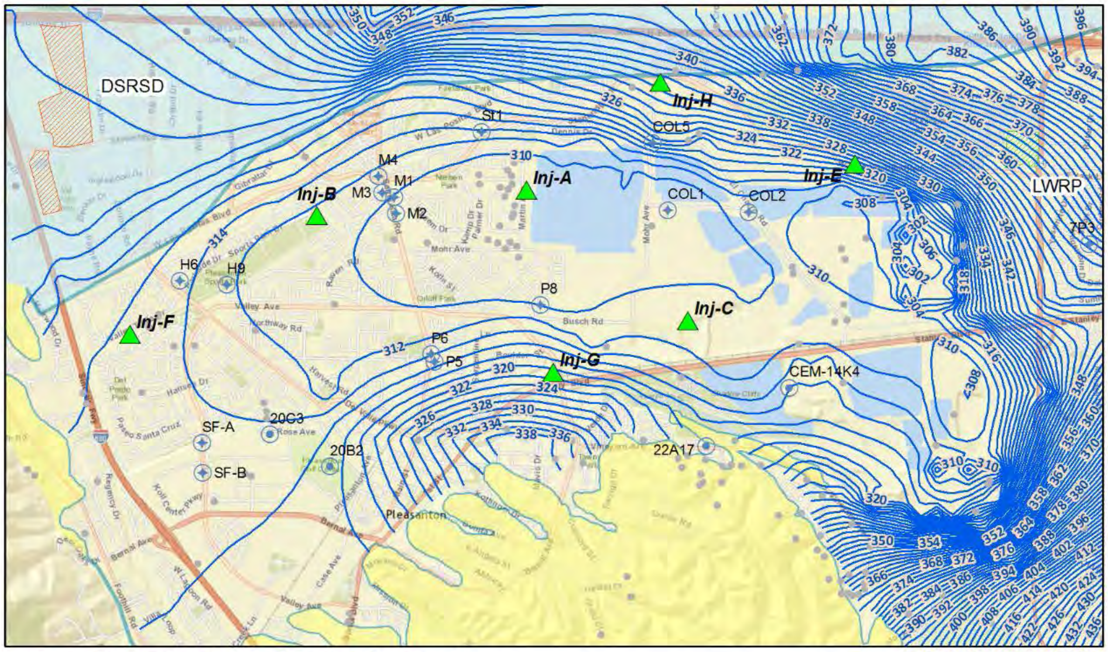
For the baseline scenario, the groundwater basin is at steady state with inflow equal to outflow. Water level contours at the end of the 10-year simulation period are shown in Figure 5.21. In the upper aquifer, layer 1 of the model, groundwater flows inward toward the center of the basin near Lake I with a minimum water level contour elevation of about 310 ft. In the lower aquifer (layer 3), groundwater flows from east to west under a head gradient that varies from about 314 ft in the east to about 298 ft in the west. Areas of localized drawdown are apparent surrounding some of the production wells shown in Figure 5.21. Results shown within this section are preliminary modeling results and are intended for comparative purposes only.

5.9.1.1 Groundwater Elevation Results

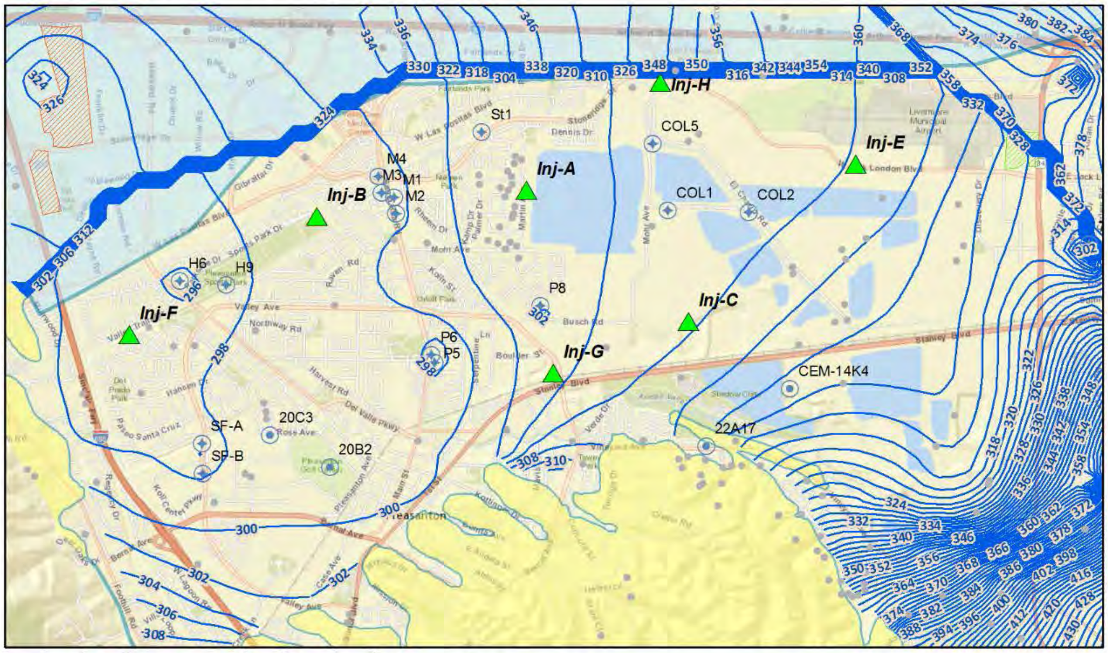
All of the injection scenarios demonstrated a significant increase in water levels throughout the basin in both aquifers. Water levels in the upper aquifer (layer 1) rose up more than 40 feet; and in the lower aquifer (layer 3) water levels increased nearly 50 feet across the basin. Figure 5.22 shows an example output after 10-years of injection for Scenario 13 with injection of 10,000 AFY at Well B. In this scenario, water levels in the upper aquifer increase up to about 44 ft, and an east-to-west flow gradient is established in the western basin. In the lower aquifer the flow gradient is maintained, but potentiometric heads increase by about 44 to 48 ft across the main basin.

Although the increase in water levels can be beneficial by increasing the volume of water in storage and improving production well yield and reliability, negative effects include impacts to mining operations in the central and eastern parts of the basin and potential flooding on some low-lying areas of the basin. For actual operations, injection of purified recycled water would need to be offset by operational changes to groundwater production and other recharge activities. The need for additional analysis of operational changes to maintain the groundwater basin balance is common across all of the groundwater recharge scenarios.

The modeling analysis of injection at Well F indicates higher groundwater elevations near well F, with decreasing elevations to the west of Well F. These results suggest that there is potential for some of the injected water to migrate out of the western edge of basin. In the alternatives evaluation, Well F is considered a relatively undesirable location for groundwater injection.

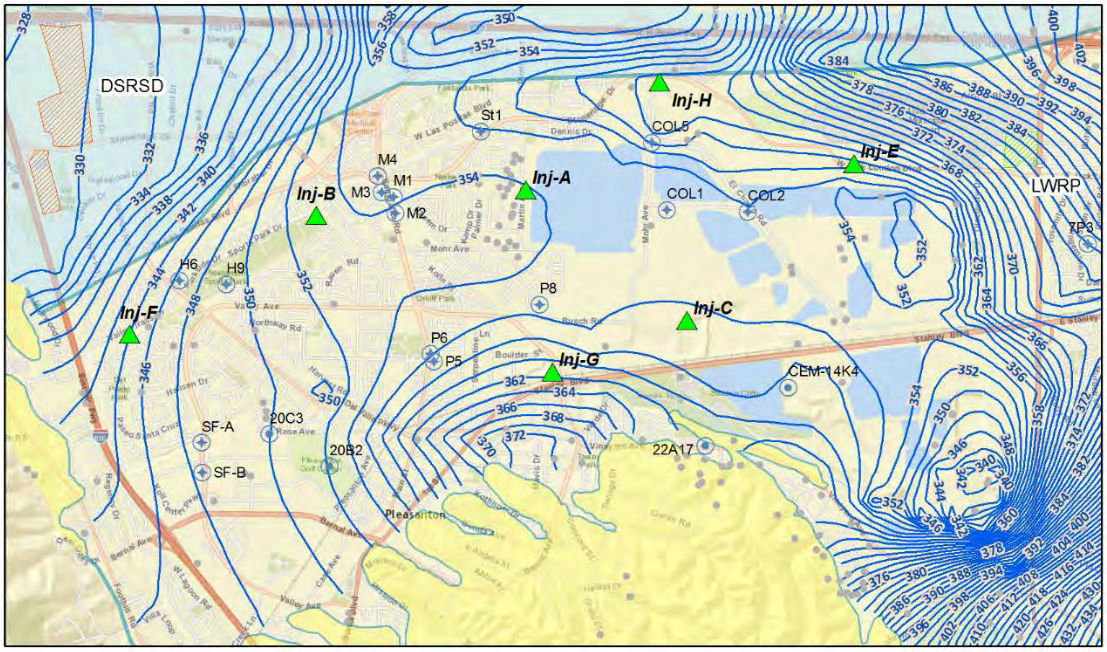


a. Simulated Water Table Elevation for Layer 1

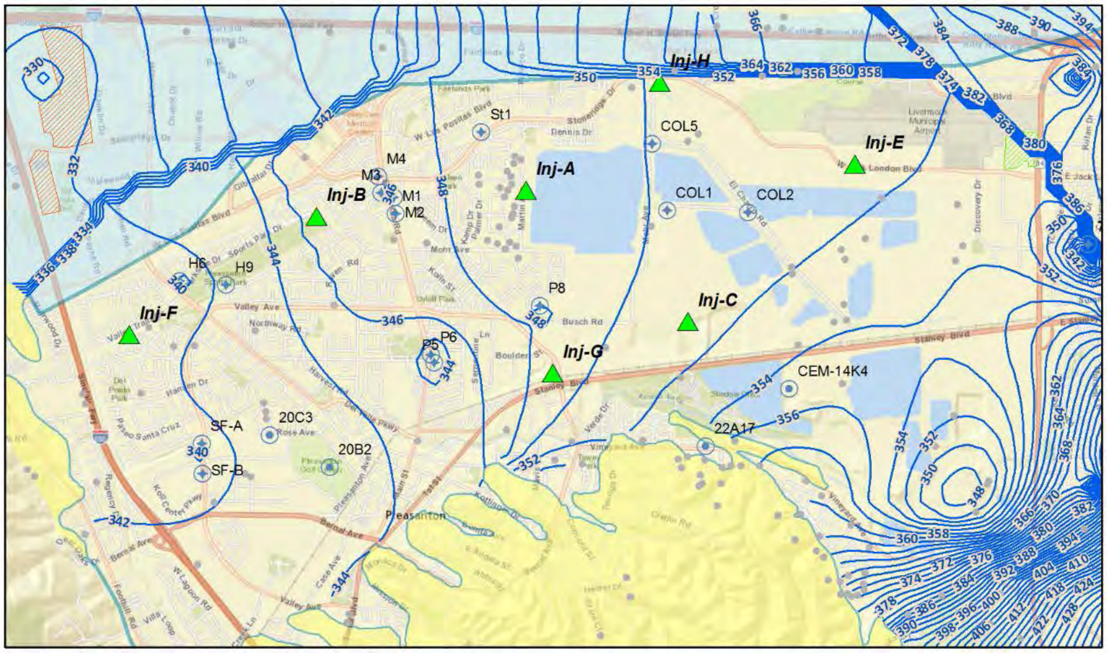


b. Simulated Water Table Elevation for Layer 3

Figure 5.15 Simulated Water Levels for the Baseline Scenario



a. Simulated Water Table Elevation for Layer 1



b. Simulated Water Table Elevation for Layer 3

Figure 5.22 Simulated Water Levels for the Scenario 13 (Injection at Well B)

5.9.1.2 Travel Time Results

The preliminary travel time analysis results are presented in Table 5.7. For each injection scenario, the table provides the production well where breakthrough is first observed and the time at which 2 percent of the injected concentration appears at each well. No results are presented for Scenario 10 with recharge through Lake I because a higher level of treatment is assumed for the effluent and the retention time requirement does not apply. Based on the required retention time of 2 months and numerical model uncertainty factor of 0.5, the minimum acceptable travel time is 120 days.

Table 5.7 Travel Time Summary

Scenario	Recharge Site	Breakthrough Location	2% Breakthrough Time, days
1	Well E	COL 2	473
8	Well F	HOP 7	170
10	Lake I	NA	NA
13	Well B	MOCHO 2	114

The travel time requirement is met for the all recharge scenarios that were examined through the preliminary modeling effort, with the exception of Well B. The retention time requirement is not met for injection at Well B where the breakthrough of 2 percent occurred after only 114 days. However, Well B was not eliminated from further consideration based on this analysis because the actual site of injection could be moved further from the Mocho production wells without changing the assumptions of this alternative. For example, moving the injection site the width of one model grid cell (500 ft) to the west increases the travel time to the MOCHO 2 production well to more than 150 days.

5.10 Alternatives Evaluation Approach

The alternatives evaluation was facilitated through the Blue Plan-it® using the groundwater modeling previously discussed as well as costs developed within the software. An overview of the alternatives evaluation approach is included within this section.

5.10.1 Basis of Cost

Cost estimates for each scenario were prepared for a Class 5 cost estimate in accordance with guidelines from the Association for the Advancement of Cost Estimating (AACE). As Class 5 estimates, the accuracy ranges from -50 to +100 percent. Tables 5.8 and 5.9 summarize cost assumptions in creation of the high level cost estimate. Appendix A contains detailed cost breakdowns.

Table 5.8 Contingencies and Assumptions

Line Item	Description	% of A
Total Direct Cost	A	100%
Contingency	30% of A	30%
Subtotal	B	130%
General Conditions	10% of B	13%
Subtotal	C	143%
Contractor Overhead & Profit	15% of C	14%
Subtotal	D	157%
Sales Tax	9.5% of B/2	6%
Total Construction Cost	**E**	**163%**
Project Cost Factor	30% of E	49%
Total Project Cost	**F**	**213%**

Table 5.9 Cost Estimate Assumptions

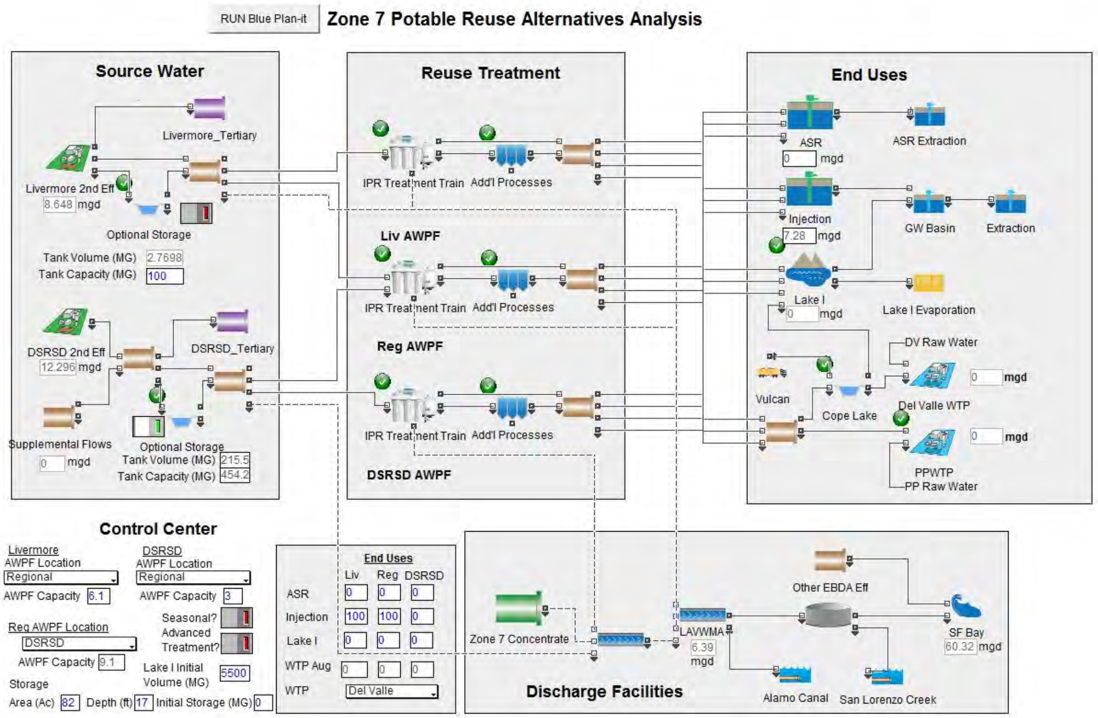
Line Item	Description
Amortization Interest Rate	5%
Payback Period	30 years
Power Cost	$0.14/kWh
ENR-CCI (San Francisco, January 2017)	11069

Other preliminary cost assumptions include:

- All alternatives involving Cope Lake add $2 million to increase the pump station capacity in the currently planned Cope - DVWTP connection pipeline.
- Alternatives with Lake I as an end location also include the extra $2 million to provide flexibility to discharge water into Cope Lake if capacity becomes an issue.
- Alternatives which include the facility at COL include the cost of land, estimated to be approximately $184,000 for the site, based on recent land purchases by Zone 7.

5.10.2 Blue Plan-it® Modeling

All of the treatment assumptions, alternatives, pipeline alignments, treatment processes, and costs discussed within the previous sections were input into Carollo's Blue Plan-it® Decision Support System (BPI). BPI is a tool Carollo developed to help clients manage complex, interconnected treatment and conveyance systems. This BPI tool simulates the water quality from secondary effluent through product water and all waste and discharge streams. BPI was used in the Chapter 4 water balance to determine the maximum amount of reuse water that could be used while complying with permit discharge limits. Using the custom built control panel within the process flow diagram (see Figure 5.23), all relevant alternatives were analyzed to determine facility sizing, capital and O&M costs, and overall yield (factoring in evapotranspiration and precipitation). Results from the BPI model runs were presented at the project team workshop on April 18, 2017.



Livermore 2nd Eff 8.648 mgd
Tank Volume (MG) 2.7698
Tank Capacity (MG) 100
DSRSD 2nd Eff 12.296 mgd
Supplemental Flows 0 mgd
Tank Volume (MG) 215.5
Tank Capacity (MG) 454.2
ASR 0 mgd
Injection 7.28 mgd
Lake I 0 mgd
DV Raw Water 0 mgd
PP Raw Water 0 mgd
LAVWMA 6.39 mgd
SF Bay 60.32 mgd

Livermore AWPF Location: Regional
AWPF Capacity 6.1
DSRSD AWPF Location: Regional
AWPF Capacity 3
Reg AWPF Location: DSRSD
AWPF Capacity 9.1
Seasonal?
Advanced Treatment?
Lake I Initial Volume (MG) 5500
Storage Area (Ac) 82 Depth (ft) 17 Initial Storage (MG) 0

End Uses	Liv	Reg	DSRSD
ASR	0	0	0
Injection	100	100	0
Lake I	0	0	0
WTP Aug	0	0	0

WTP: Del Valle

Figure 5.23 Blue Plan-it® Process Flow Diagram

5.10.2.1 Blue Plan-it® Modeling Assumptions

Many changing variables could influence the effectiveness of any future project. To aid in the decision making process, for the BPI model runs, a number of simplifying assumptions were made with regards to water availability, capacity limits, and project development. They are summarized below:

- The model was set up on a monthly time step using 2035/build out flow projections from DSRSD WWTP and Livermore WRP.
- Discharge to Lake I resulting from Vulcan mining processes was assumed to be the maximum historical annual discharge of 9,100 AFY. This flow was divided evenly throughout the year and is routed through Cope Lake before discharge to Lake I.
- Available storage near the DSRSD WWTP was assumed to be a maximum of 82 acres.
- Due to the sensitive nature of Lake I recharge, levels in the lake were iteratively increased until a steady state was reached. It is expected that, should a Lake I alternative be selected and pursued, Zone 7 would have to operate the lake accordingly to operate at a steady state. Lake levels can be increased or decreased through connections with Lake H and Cope Lake.
- For alternatives with direct injection, a single well site (with multiple wells based on the 2.2 mgd capacity per well assumption) was assumed to be sufficient for the entire flow. If groundwater modeling shows that too much mounding occurs within a specific location, it may be necessary to have multiple well sites.

5.11 Alternatives Evaluation

Table 5.10 shows the preliminary costs and yield for all alternatives evaluated in BPI. For the alternatives that were not run through the model, a comparable alternative is indicated.

5.11.1 Yield

As stated previously, the upper bookend for water supply reliability is 10,000 AFY based upon Zone 7's Water Supply Evaluation Update. While all alternatives add water to the basin, the seasonal options are the only options that provide 10,000 AFY. While achieving 10,000 AFY is not a specific objective of the project, yield is still a key evaluation criteria.

The modeling discussion reveals that not all injection or groundwater recharge alternatives benefit the basin in the same way, or in a way that is easily recoverable by Zone 7's current operations. Alternatives with Well F as the endpoint are less effective because the modeling shows that the groundwater may leave the basin or is harder to capture. Alternatives with lake discharge (Lake I or Cope Lake) are subject to minor evaporative losses. The most effective recharge options may be those with direct injection in other areas of the basin, like Wells E and B).

According to this analysis, the top yield alternatives are:

- Alternative 9: Seasonal Treatment at DSRSD, Direct Injection at Well B.
- Alternative 13: Seasonal Treatment at Mocho, Direct Injection at Well B.
- Alternative 14: Seasonal Treatment at Mocho, Direct Injection at Well A.
- Alternative 17: Seasonal Treatment at COL, Direct Injection at Well C.
- Alternative 18: Seasonal Treatment at COL, Direct Injection at Well H.
- Alternative 19: Seasonal Treatment at COL, Direct Injection at Well A.

5.11.2 Cost (Capital and O&M)

Capital, O&M, and unit costs ($/AF) are shown in Table 5.10. The highest unit costs occur with alternatives that have storage or large infrastructure requirements (Alternative 3). While seasonal treatment incurs a larger capital cost, the increased annual yield makes up for the difference. The best value alternatives (lowest unit cost) maximize the facility use, do not have storage, and have minimal infrastructure.

The lowest unit cost alternatives are:

- Alternative 1: Treatment at Livermore, Direct Injection at Well E ($1,900/AF).
- Alternative 2: Treatment at Livermore, Surface Spreading via Lake I ($1,900/AF).
- Alternative 4: Treatment at Livermore, Blend at Del Valle WTP via Cope Lake ($1,900/AF).
- Alternative 8: Seasonal Treatment at DSRSD, Direct Injection at Well F ($2,000/AF).
- Alternative 12: Seasonal Treatment at DSRSD, Blend at Del Valle WTP via Cope Lake ($2,100/AF).
- Alternative 13: Seasonal Treatment at Mocho, Direct Injection at Well B ($2,100/AF).

Table 5.10 Preliminary Alternatives Results

Alternative Number	Alternative Description	Treatment	Total Capital Cost	O&M Cost	Treatment Plant Sizing (mgd)	Yield (AF)	$/AF
1	Treatment at Livermore, Direct Injection at Well E	FAT	$93M	$4.3M	5	5,500	$1,900
2	Treatment at Livermore, Surface Spreading via Lake I	FAT	$95M	$4.3M	5	5,500	$1,900
3	Treatment at Livermore, Blend at PPWTP	FAT+	$138M	$4.8M	5	5,500	$2,500
4	Treatment at Livermore, Blend at DVWTP via Cope Lake	FAT+	$93M	$4.2M	5	5,500	$1,900
5	Year-Round Treatment at DSRSD, Direct Injection at Well F	FAT	$169M	$5.8M	7	7,700	$2,200
6	Year-Round Treatment at DSRSD, Direct Injection at Well B	FAT	Alternative 5				
7	Year-Round Treatment at DSRSD, Surface Spreading via Lake I	FAT+	$184M	$6.1M	7	7,700	$2,300
8	Seasonal Treatment at DSRSD, Direct Injection at Well F	FAT	$182M	$8.2M	12	10,000	$2,000
9	Seasonal Treatment at DSRSD, Direct Injection at Well B	FAT	Alternative 8				
10	Seasonal Treatment at DSRSD, Surface Spreading via Lake I	FAT+	$202M	$8.5M	12	10,000	$2,200
11	Year-Round Treatment at DSRSD, Blend at Del Valle WTP via Cope Lake	FAT+	$207M	$6.4M	7	7,700	$2,600
12	Seasonal Treatment at DSRSD, Blend at Del Valle WTP via Cope Lake	FAT+	$205M	$7.9M	12	10,000	$2,100
13	Seasonal Treatment at Mocho, Direct Injection at Well B	FAT	$199M	$8.4M	12	10,000	$2,100
14	Seasonal Treatment at Mocho, Direct Injection at Well A	FAT+	Alternative 15				
15	Seasonal Treatment at Mocho, Surface Spreading via Lake I	FAT+	$207 M	$8.6M	12	10,000	$2,200
16	Year-Round Treatment at Mocho, Blend at Del Valle WTP via Cope Lake	FAT+	$170M	$5.7M	6	6,900	$2,400
17	Seasonal Treatment at COL, Direct Injection at Well C	FAT	Alternative 18				
18	Seasonal Treatment at COL, Direct Injection at Well H	FAT	$227M	$8.5M	12	10,000	$2,300
19	Seasonal Treatment at COL, Direct Injection at Well A	FAT+	Alternative 20				
20	Seasonal Treatment at COL, Surface Spreading via Lake I	FAT+	$229M	$8.5M	12	10,000	$2,300
21	Year-Round Treatment at COL, Blend at Del Valle WTP via Cope Lake	FAT+	$182M	$5.6M	6	6,900	$2,500

5.11.3 Groundwater Basin Water Quality

Zone 7 distribution wells in the western edge of the basin (near the Hopyard wells) consistently have high TDS. The current mitigation measures include the demineralization facility and blending with surface water. Purified water, which is very low in TDS, would potentially improve the groundwater quality. Alternatives with direct injection can clearly provide a groundwater benefit versus raw water augmentation or surface spreading via Lake I. While surface spreading in Lake I does have an effect on groundwater quality, it is a much more subtle, diluted effect because the percolated water enters the upper aquifer and gradually migrates into the lower aquifer in contrast to injection of purified water directly into the lower aquifer.

The alternatives with the greatest potential for improving groundwater quality in the basin are:

- Alternative 1: Treatment at Livermore, Direct Injection at Well E.
- Alternative 6: Year-Round Treatment at DSRSD, Direct Injection at Well B.
- Alternative 9: Seasonal Treatment at DSRSD, Direct Injection at Well B.
- Alternative 13: Seasonal Treatment at Mocho, Direct Injection at Well B
- Alternative 14: Seasonal Treatment at Mocho, Direct Injection at Well A.
- Alternative 17: Seasonal Treatment at COL, Direct Injection at Well C.

5.11.4 Ease of Implementation

At the level of detail used in this analysis, only general implementation issues were identified, such as the small size of the site at Mocho, the saturated soils at COL, and the large infrastructure requirements to get to PPWTP. As the short-listed options are investigated in more detail, other, more critical implementation issues may arise.

Ease of implementation is also based upon the current regulations and the permitting required to execute a project plan. In that regard, alternatives with direct groundwater injection are easier to implement because the regulations are established and many similar projects across California exist or are currently underway.

The alternatives with the initial highest ease of implementation are those with established permitting procedures, minimal infrastructure requirements, and site locations without geotechnical or spatial restraints:

- Alternative 1: Treatment at Livermore, Direct Injection at Well E.
- Alternative 8: Seasonal Treatment at DSRSD, Direct Injection at Well F.
- Alternative 9: Seasonal Treatment at DSRSD, Direct Injection at Well B.

However, there is a narrow differentiation in ease of implementation between most of the alternatives at this level of analysis.

5.11.5 Alternatives Evaluation Workshop

The results of the preliminary evaluation were presented to the project team in a workshop on April 18, 2017. Representatives from Zone 7, DSRSD, Livermore, Pleasanton, and Carollo were present at the workshop. The team agreed that no additional alternatives needed to be analyzed to capture the full range of possibilities. There were several broad decisions made regarding short-listed options including: 1) do not evaluate further any storage options, 2) carry an option for each WWTP site as well as at least one regional non-WWTP site, and 3) carry a range of end-use options. After a discussion period, the workshop participants narrowed down and combined some alternatives to develop short-listed options for more detailed analysis.

1. Do not evaluate further storage options: This option was no longer considered since the capital cost investment to include storage did not significantly increase the yield and came with significant institutional and operational challenges in constructing large storage basins on DSRSD's existing solids facilities.
2. AWPF sites: All the agencies agreed on maintaining the options of a both WWTP sites and regional AWPF as it is not yet clear who would own or operate the facility and participants felt more comfortable with a wide range of siting options still being available.
3. Range of end-use of options: All the agencies agreed on maintaining the options of a regional AWPF agreed to carry all the end-use of options since this is a book-end study.

5.11.6 Short-listed Options

The short-listed options identified in the April 2017 workshop were refined at a Steering Committee workshop held in July 2017. Final options were chosen to give a wide range of feasible projects, covering the spectrum of end uses and treatment locations.

5.11.6.1 Short-listed Option 1 - Year-Round Treatment at the Livermore WRP

This option was selected to provide a year round Livermore only option. This option was selected based on the relatively low unit cost, and the flexibility to go to different end uses. An important limitation of this option is the relatively low yield of 5,500 AFY of product water.

Option 1a) Groundwater Recharge via Lake I and Raw Water Augmentation for DVWTP via Cope Lake

This short-listed option is a combination of alternatives 2 and 4. This option involves FAT+ at the Livermore WRP and conveyance to Lake I for groundwater recharge (primary use). Because of the planned connection between the COLs and the DVWTP (via the future COLs pipeline), this alternative incorporates the flexibility to blend with water in the COLs and conveyance to the DVWTP. This option provides flexibility to incorporate both groundwater recharge and raw water augmentation.

Option 1b) Groundwater Recharge via Injection at Well E

This option is a variation of Option 1a with the end use changed for groundwater injection into Well E which is located near the Livermore WRP. This option would be relatively easy to implement based on existing regulations and precedent for permitted groundwater injection systems.

5.11.6.2 Short-listed Option 2 - Seasonal Treatment at DSRSD

This option was selected based on the high yield (10,000 AFY) and flows from both DSRSD and Livermore with the location at DSRSD. The yield is achieved through seasonal treatment. It is recognized that there is some additional operational complexity involved with seasonal treatment.

Option 2a) Groundwater Recharge via Lake I and Raw Water Augmentation for DVWTP via Cope Lake

This short-listed option is a combination of alternatives 10 and 12. This option involves FAT+ at DSRSD and conveyance to DVWTP via Cope Lake. Given the planned connectivity of the COLs, this alternative incorporates the flexibility to convey water to Lake I for groundwater recharge; this will be useful especially when DVWTP is down for maintenance or other purposes. This option provides flexibility to incorporate both raw water augmentation and groundwater augmentation.

Option 2b) Groundwater Recharge via Injection at Well B

This option is a variation of Option 2a with the end use changed for groundwater injection into Well B. This option would be relatively easy to implement based on existing regulations and precedent for permitted groundwater injection systems.

5.11.6.3 Short-listed Option 3 - Seasonal Treatment at Mocho, Groundwater Recharge via Injection at Well B

This short-listed option involves seasonal treatment at the Mocho site and groundwater injection. This option was selected based on the high yield, relative ease of implementation (regulatory), and potential benefits of a purification treatment plant located offsite from a WWTP. While proximity to a WWTP can be convenient for staff, operations, and supplies, a satellite facility can be beneficial terms of public perception by providing distance between the wastewater plants and the purification plant at the Mocho site.

5.11.6.4 Short-listed Option 4 - Seasonal Treatment at Pleasanton, Groundwater Recharge via Lake I and Raw Water Augmentation for DVWTP via Cope Lake

This option was added after the July 2017 workshop with the intent to add an additional regional site. The Pleasanton Corp yard potentially has involves room to accommodate an AWPF. The end use for this site is conveyance to DVWTP via Cope Lake. Given the planned connectivity of the COLs, this alternative incorporates the flexibility to convey water to Lake I for groundwater recharge; this will be useful especially when DVWTP is down for maintenance or other purposes.

5.12 Next Steps for Analysis of the Short-listed Options

The short-listed options are further analyzed in more detail for hydrogeologic considerations in Chapter 6 and for general engineering and implementation considerations in Chapter 7. The additional analysis needed for these options generally includes:

- Development of site layouts.
- Revisiting the preliminary pipeline alignments.
- Detailed cost estimates.
- Groundwater modeling for travel time and injection capacity.

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Chapter 6

HYDROGEOLOGIC FEASIBILITY

This chapter details the groundwater modeling and other evaluations performed to assess the hydrogeologic feasibility of groundwater augmentation to recharge the aquifer for the purpose of subsequent extraction and use. The types of groundwater augmentation evaluated through modeling include: 1) injection by wells into the lower aquifer and 2) surface water recharge or percolation through Lake I. Groundwater augmentation end uses were previously discussed in Chapter 5.

Several aspects of the feasibility of groundwater augmentation were assessed through groundwater modeling. The model was used to quantify relative impacts to the hydraulics of groundwater flow in the basin, estimate the potential travel time to existing potable production wells, quantify relative impacts to the salt concentrations at potable productions wells, and investigate impacts on the overall basin salt balance. Modeling was conducted in phases with a preliminary phase looking at high-level feasibility of a number of scenarios, and then using a more detailed model to evaluate the impacts of groundwater augmentation once the short-listed options had been identified.

6.1 Preliminary Groundwater Modeling

For the first phase of modeling, the Zone 7 groundwater basin model was used to evaluate high-level feasibility of several injection and/or percolation scenarios. To simplify the evaluation, the impacts of injecting purified recycled water at each of the potential injection sites were simulated assuming operation as recharge wells (i.e., not in ASR configuration).

As described in Chapter 5, a total of 21 preliminary alternatives were developed by the project management team; however, only those alternatives with a recharge component were considered for the modeling analysis. In addition, some project alternatives having similar recharge components, e.g., alternatives having the same end uses but different purification plant locations could be evaluated with a single groundwater model scenario. From these 21 alternatives, a subset of five scenarios was identified for preliminary evaluation using the model, including a baseline/no recharge scenario, as shown in Table 6.1 and Figure 6.1.

Table 6.1 Preliminary Groundwater Modeling Scenarios

Scenario	Recharge Location	Recharge Volume (AFY)
0-Baseline	None	0
1	Well E	5,500
8	Well F	10,000
10	Lake I	10,000
13	Well B	10,000

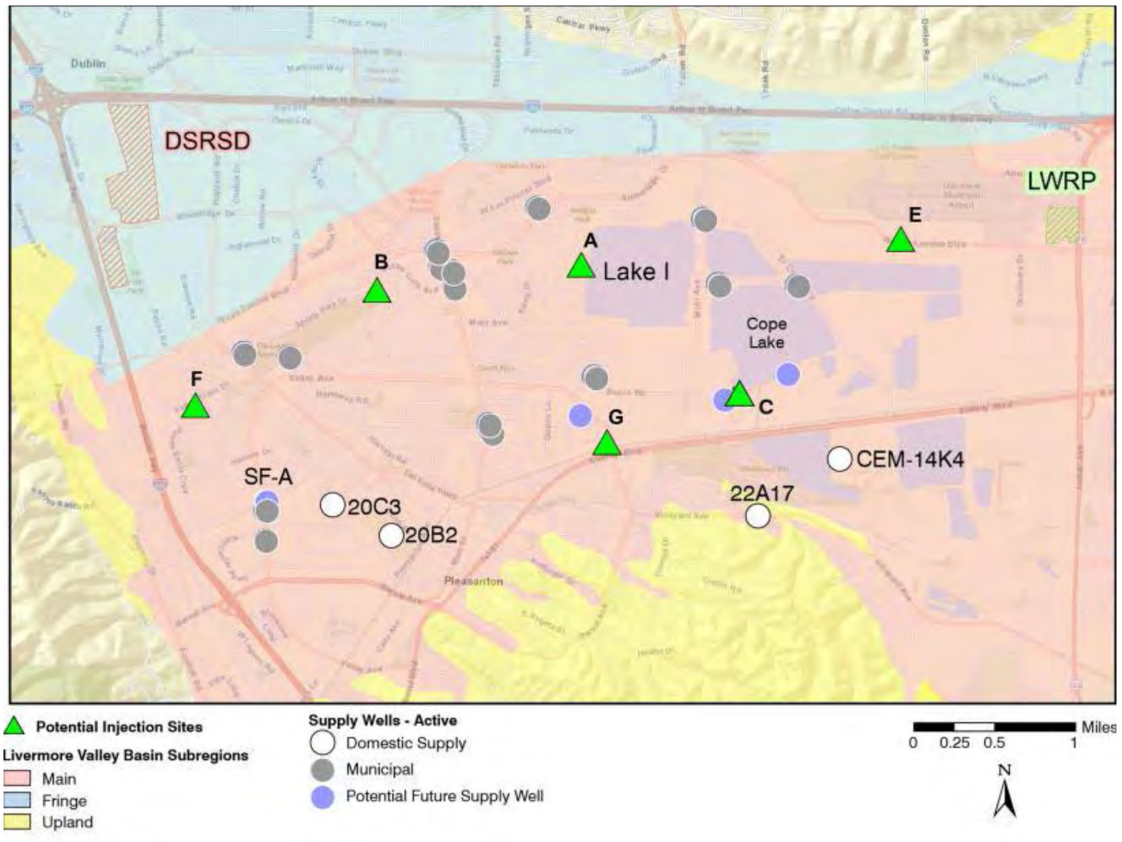


Figure 6.1 Potential Injection Locations

6.1.1 Model Description

As part of its Groundwater Basin Management Program, Zone 7 Water Agency maintains a numerical groundwater model of the basin for predicting the consequences of potential groundwater basin management actions on groundwater levels and salt concentrations in the basin. This model was recently upgraded to better meet the needs of Zone 7 for planning for conjunctive use of surface water and groundwater and for evaluating the salt balance of the basin (HydroMetrics 2016). However, this upgraded version of the model was not available at the time of the preliminary analysis (described in Chapter 5), so the previous version of the Zone 7 model was used.

In this report, the previous version of the model is referred to as the Zone 7 3-Layer Model because the model contained three active layers representing two aquifers, an upper unconfined aquifer and a lower confined aquifer that includes the many productive intervals used by local municipal wells, and an intervening aquitard. Layer thicknesses were based on mapped thicknesses of the aquifers and aquitard.

The Zone 7 3-Layer Model used MODFLOW, the U.S. Geological Survey modular finite-difference flow model, to solve the groundwater flow equation. Specifically, MODFLOW-NWT, a Newton-Raphson formulation for MODFLOW-2005 to improve solution of unconfined groundwater-flow problems, was used to simulate groundwater flow. MT3DMS, a modular three-dimensional transport model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems, was used to simulate the movement of injected solute.

6.1.2 Travel Time Analysis

Under the Title 22 rules for groundwater replenishment, the Division of Drinking Water (DDW) requires a 2-month minimum retention time in the aquifer for recycled water; this retention time is equivalent to a travel time of 2 months to the nearest production well. The required retention time may increase depending on the type of verification used. For instance, if the travel time is calculated with a groundwater model, each month of travel time receives one-half credit, so a total of four months travel time is needed. A tracer study using an added tracer (not intrinsic) would receive full credit. For this analysis, a 4 month travel time requirement is assumed (based on a 2-month minimum and half credit for modeling verification) and is used for comparison with the modeled travel times for various scenarios.

The time of travel from an injection site to potable production wells can be evaluated by injecting a unit concentration in the recharge wells and determining the time for breakthrough to occur at the nearest affected production well. In accordance with potable reuse regulations, breakthrough is defined at a level of two percent of the injected concentration.

Travel time of purified recycled water from the point of injection to a production well was evaluated through the use of a solute transport simulation using MT3D. For this evaluation, the initial concentration was set to zero throughout the model domain, and a unit concentration of 100 was assigned to the injection well. Observed concentrations at the production wells were used to determine the time at which two percent of the injected concentration appears at each well.

6.1.3 Preliminary Modeling Results

As discussed in Chapter 5, the preliminary modeling results were used for comparative purposes only to narrow down the range of alternatives to "bookends" that represent feasible options for implementation. Since pumping was not increased in the preliminary model runs, all of the injection scenarios demonstrated a significant increase in water levels throughout the basin in both upper and lower aquifers. This finding was used to modify the alternatives for more detailed evaluation by adding additional pumping to keep the basin in balance.

The preliminary travel time analysis results are presented in Table 6.2. As discussed in Chapter 5, the travel time requirement of 120 days was met for the all the injection scenarios that were examined through the preliminary modeling effort with the exception of Well B. For the detailed alternatives analysis, the Well B location was moved by one model grid cell to the south and west (about 700 ft) to increase the travel time to the MOCHO 2 production well to more than 120 days.

Table 6.2 Travel Time Summary

Scenario	Injection Site	Breakthrough Location	2% Breakthrough Time (days)
1	Well E	COL 2	473
8	Well F	HOP 7	170
13	Well B	MOCHO 2	114

6.2 Detailed Modeling of Short-listed Options

The preliminary modeling results on impacts to groundwater levels and travel time were used to help refine the list of alternatives. The results of the preliminary modeling evaluation were presented to the Steering Committee in a workshop in April 2017. The field of alternatives was narrowed down to three options selected to give a wide range of feasible projects covering the spectrum of end uses and treatment locations. These three options were presented to the Steering Committee in a workshop in July 2017. Based on feedback from the workshop, the three selected options were expanded to six options with different siting locations for each.

Four of the short-listed options (1a, 1b, 2b, and 3) include an end use of groundwater recharge as shown in Table 6.3. The other two short-listed options (2a and 4) include conveyance to DVWTP via the Chain of Lakes as the end use, but incorporate flexibility for groundwater recharge via Lake I. Therefore, all six of the short-listed options were evaluated using the groundwater model. Because the recharge location (end use) and recharge volume is the same for some of the short-listed options, only four modeling scenarios were required. A baseline model scenario was also included.

Table 6.3 Project Options Selected for Detailed Modeling Evaluation

Option	Recharge Location	Recharge Volume (AFY)	Seasonal/Year Round
1a	Lake I	5,500	Year Round
1b	Well E	5,500	Year Round
2a/4	Lake I(1)	10,000	Seasonal
2b/3	Well B	10,000	Seasonal

Note:
(1) The end use for these options is conveyance to DVWTP via Cope Lake, but incorporates flexibility to convey water to Lake I for groundwater recharge.

The model was used to evaluate the travel time from the injection locations to existing production wells. Potential future production well locations identified in the Zone 7 Well Master Plan (CH2M Hill 2003) were not included; however, based on the identified future well locations the existing wells are likely to see breakthrough first from the recharge sites considered through this analysis. In addition to evaluation of travel time, the model was used to assess the overall water and salt balance within the basin and how injection of recycled water affects groundwater flow and salt concentrations. For this analysis, simulation results of the model with injection and increased groundwater production were compared to results of a baseline model without injection or increased production. The comparison included quantification and analysis of groundwater levels, flow conditions in the upper and lower aquifers, and impacts on production wells.

6.2.1 10-Layer Model Description

Another outcome of the April 2017 workshop was the decision to employ the upgraded Zone 7 groundwater model for this analysis. Revisions to the model included addition of the ability to simulate flow and transport in streams and lakes to allow for direct simulation of flow interactions between surface and ground water features and increase of the number of model layers from three to ten to improve the model's capability for simulating salt transport. Use of the upgraded model for this analysis was preferable because the additional layers in the model provided a better representation of flow in the lower aquifer and therefore provided more accurate and reliable results, particularly with respect to assessment of travel time. The model was not used for this study to simulate surface water, only groundwater. In this report, the upgraded version of the model is referred to as the Zone 7 10-Layer Model.

Increasing the number of layers in the model improved the model's capability for simulating salt transport because layers that represent the basin's gross hydrostratigraphy were too thick to accurately represent the depth variation of salt concentrations. The refined model layers better represented clay overburden in the southwestern portion of the basin and the variability of well screen placements and TDS concentrations with respect to depth in the lower aquifer. By simulating the low conductivity overburden and aquitard layers within the upper and lower aquifer units, the model was better able to simulate delays in downward salt migration. An example cross-section and schematic of model layers are shown in Figure 6.2.

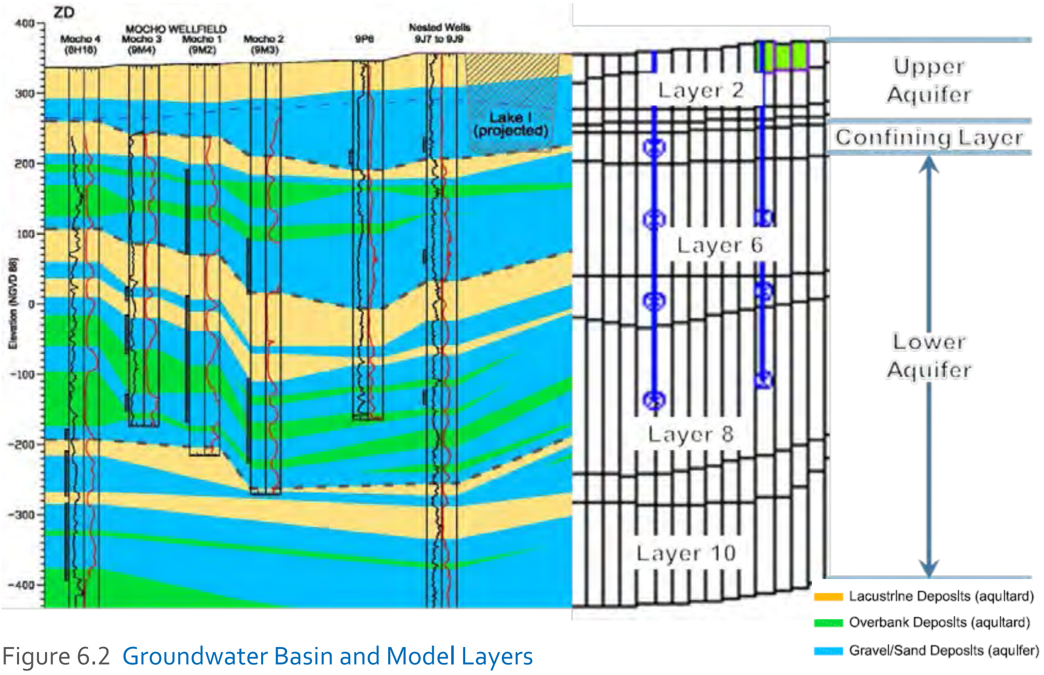


Figure 6.2 Groundwater Basin and Model Layers

Groundwater flow was modeled by the Zone 7 10-Layer Model using MODFLOW-NWT. Surface water and groundwater interactions were modeled using the SFR and LAK MODFLOW packages. Salt transport as represented by total dissolved solids (TDS) was modeled using MT3D-USGS with the LKT and SFT packages to simulate groundwater and surface water (lakes and streams) interactions. Zone 7 funded development of these recently developed packages that were included in the public release of MT3D-USGS, a USGS-updated release of MT3DMS that includes new transport modeling capabilities to accommodate flow terms calculated by MODFLOW packages that were previously unsupported by MT3DMS and to provide greater flexibility in the simulation of solute transport and reactive solute transport (Bedekar, 2016).

Limitations of the model included a recommendation to not use the transport model to predict groundwater TDS concentrations at specific wells because localized sources of salt were not included in the model (HydroMetrics, 2016). Use of surface water results from the model should also be limited because the inclusion of surface water flow and transport packages was meant only to simulate surface water effects on groundwater conditions. Furthermore, using the model to plan operation of future recharge lakes will likely require additional calibration.

Based on these stated limitations, the 10-Layer Model was used to assess general trends in TDS concentrations at locations across the basin and predicted relative differences in salt concentrations at production well locations between the baseline and purified recycled water recharge scenarios. The 10-Layer Model was also used to assess travel time from injection locations to production wells.

6.2.2 Model Revisions

The upgraded model was received from HydroMetrics on June 1, 2017, and Carollo and Zone 7 staff began working to set up the model for simulation of the short-listed options. Initial and boundary conditions and setup of stress periods from the previous simulations based on the Zone 7 3-Layer Model were used in the 10-Layer Model. For salt balance simulations, the simulation period was extended to 25 years using a total of 54 semi-annual stress periods (four initialization stress periods followed by 50 semi-annual stress periods) to better assess long-term trends.

6.2.2.1 Conjunctive Use of Surface Water and Groundwater

Zone 7 currently uses surface water, including imported water from the State Water Project, to recharge the groundwater basin via a network of streams or arroyos, and, in the future, the Chain of Lakes. The surface water supply is a critical component of Zone 7's Groundwater Management Plan for maintaining balance of the groundwater basin. When less surface water supply is available during droughts, groundwater storage is used to meet demand in the basin. Groundwater is also regularly used to meet diurnal and seasonal peak demands. Conversely, when excess surface water is available, groundwater storage is replenished through recharge. Zone 7 has well capacity to meet normal peak demands of 32 mgd, plus additional capacity of 11 mgd for use during emergency or drought conditions. These wells can provide up to 28,000 AFY. Zone 7 plans to install additional wells in the future.

For the purposes of groundwater modeling, the model input was revised to incorporate increased groundwater production to offset quantities of purified recycled water recharge directly (i.e., 10,000 AFY of recharge would be offset by 10,000 AFY of additional pumping). The increase in pumping for each recharge scenario was introduced in the model by increased pumping from existing Zone 7 production wells. Individual well production was generally increased proportionately based on the fraction of total Zone 7 pumpage (5,940 AFY) assigned to each well in the baseline scenario. The maximum amount of pumping assigned to each well was limited to 50 percent of the estimated well capacity as reported in the Zone 7 2011 Water Supply Evaluation; therefore, the production assigned to some wells was proportionally higher than for others. The annual pumping assigned to each of the Zone 7 production wells is shown in Table 6.4 for the baseline model with 5,940 AFY of total pumping and for the recharge scenario models with additional pumping to offset recycled water recharge. These assumptions were made for modeling purposes only and while are physically possible based on well capacity, operational considerations of the water supply system were not evaluated. Actual pumping operations would be modified to meet multiple objectives including maintaining groundwater elevations, maintaining system water quality and maintaining system pressure. In addition, new wells have been identified in a Well Master Plan. These new wells could be used in place of the modeled use of existing wells.

Table 6.4 Annual Pumping Assigned to Zone 7 Production Wells

Well	Estimated Capacity$^{(1)}$ (AFY)	Annual Withdrawal (AFY)		
		Baseline Scenario	5,500 AFY Recharge	10,000 AFY Recharge
Chain of Lakes 1	3600	40	1144	1594
Chain of Lakes 2	5100	340	1144	1594
Hopyard 6	5500	1500	1903	2651
Hopyard 9	--	200	385	537
Stoneridge	6600	400	1716	2391
Mocho 1	3300	1000	1144	1594
Mocho 2	3200	1000	1144	1594
Mocho 3	6100	1000	1716	2391
Mocho 4	5300	460	1144	1594
Total		**5,940**	**11,440**	**15,940**

Notes:
(1) From Table 4-1, Zone 7 2011 Water Supply Evaluation.

The seasonal variations in pumping and recharge showed a strong influence on model results. The model is based on six-month stress periods roughly corresponding to Winter and Summer or a wet and dry season. Groundwater pumping is greater in the dry period (April through September) to meet peak demands, while recycled water recharge is greater during the wet period for the options involving a seasonal component to recharge (i.e., 10,000 AFY options). Note that existing recharge activities were assumed to continue (assumed conservatively at about 6,000 AFY for the model); the recharge amounts shown on Figure 6.2 only reflect the additional amounts from potable reuse. Thus, the variations in pumping and recharge are seasonally opposed as illustrated in Figure 6.3. These seasonal fluctuations are exaggerated somewhat by the use of semi-annual stress periods in the model and it is expected that monthly variations would exhibit less drastic variations.

For the water quality modeling scenarios, the recycled water was assumed to have a TDS concentration of 100 mg/L. This concentration was based on recent operational data obtained from the Ventura demonstration pilot recycled water facility that showed an average TDS of 56 mg/L in the RO effluent and a maximum of 120 mg/L. The selected value of 100 mg/L is within this range but higher than the average and is conservative in the sense that simulated water quality improvements based on this value should be biased high. In addition, the 100 mg/L assumption accounts for the potential increase in TDS due to stabilization of RO permeate prior conveyance/injection into the water supply system. The OCWD Groundwater Replenishment System includes decarbonation and lime stabilization of RO permeate prior to groundwater injection. The combination of decarbonation and lime stabilization raises the pH and adds hardness and alkalinity to make the purified recycled water less corrosive and more stable (OCWD, 2017). This process adds approximately 25 mg/L of TDS to the RO permeate. Assuming an average RO TDS concentration of 56 mg/L, the addition of 25 mg/L due to stabilization results in a TDS concentration of approximately 75 mg/L, which is below the assumption of 100 mg/L.

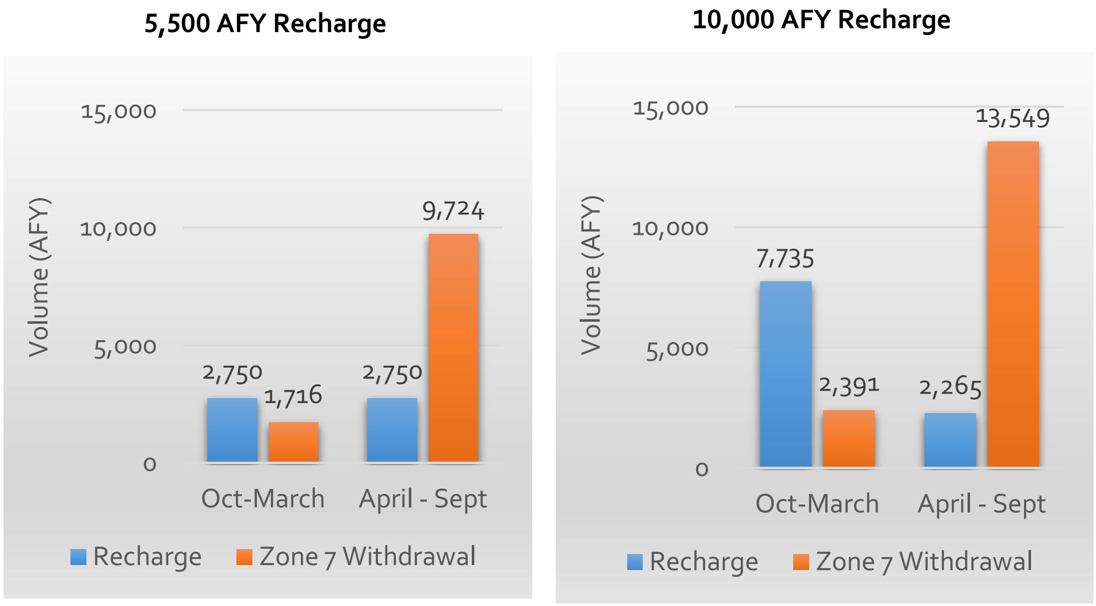


Figure 6.3 Seasonal Pumping and Recharge Volumes for Recharge Scenarios

6.2.3 Modeling Results

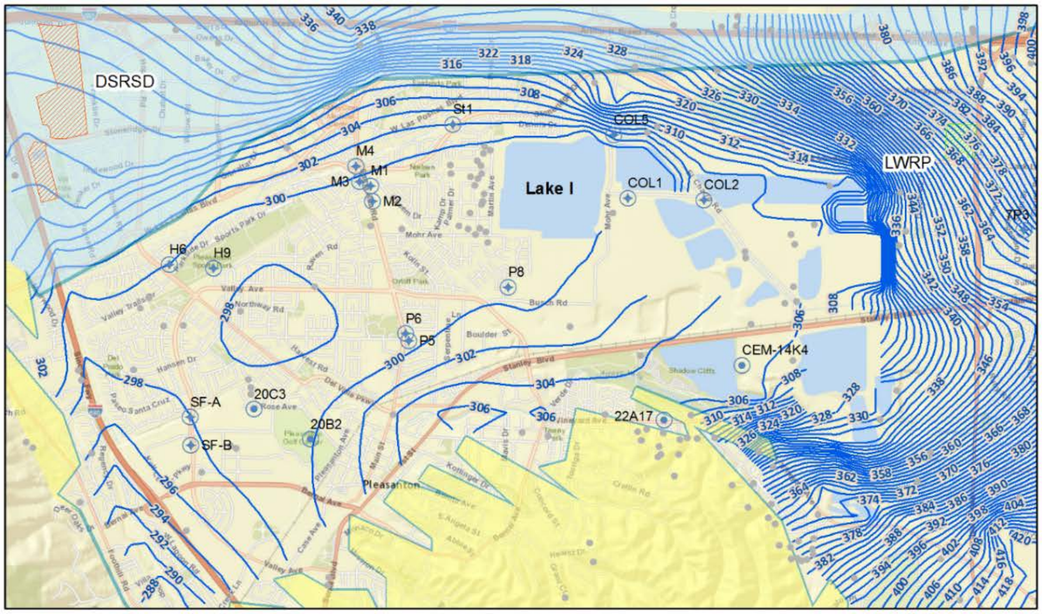
6.2.3.1 Baseline Simulation of Groundwater Flow

Simulated water levels for the baseline scenario from the 10-Layer model are shown in Figure 6.4. For this figure, simulated heads for the final two stress periods of the simulation, representing the Winter and Summer seasons, were extracted from model layers four and six representing the upper and lower aquifer, respectively. The simulated head values for the two stress periods were averaged for each layer and contours were generated to produce a representation of the annual average flow. The upper map shows that groundwater in the Upper Aquifer entered from the north, east, and southeast and generally flowed inward toward the Chain of Lakes in the eastern part of the basin and to the southwest in the western part of the basin. In the middle of the basin, groundwater flowed inward under the influence of a very low hydraulic gradient. This inward flow may reflect the downward movement of water into the Lower Aquifer to replenish groundwater extracted by production wells.

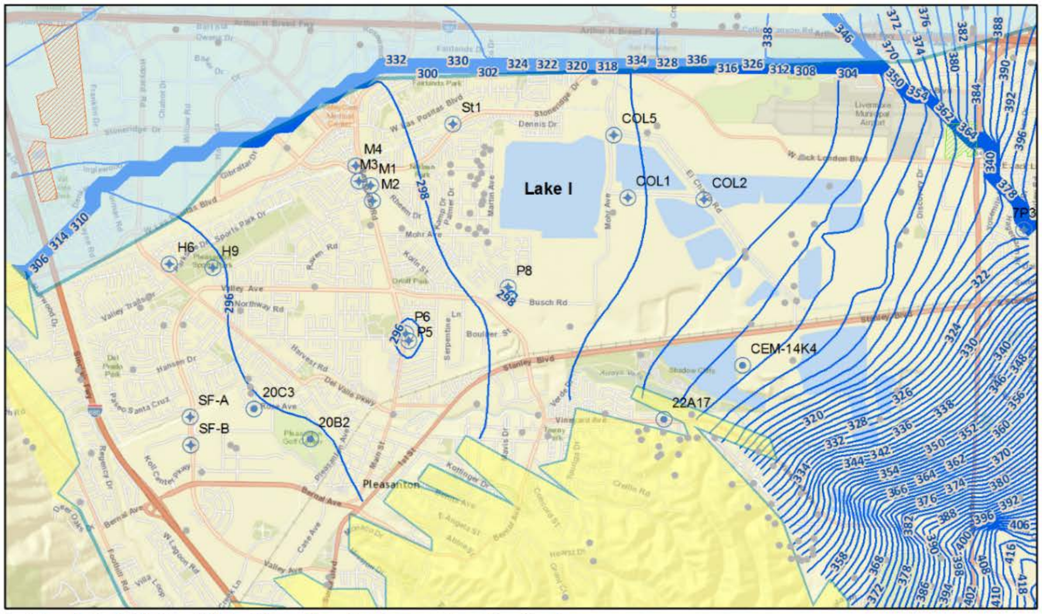
Flow in the Lower Aquifer was generally from east to west with a steeper hydraulic gradient east of the Chain of Lakes. Localized cones of depression were evident around some of the production wells.

6.2.3.2 Injection at Well B

Short-listed options 2b and 3 include injection of 10,000 AFY of recycled water at Well B on a seasonal basis. Well B would be screened through one or more intervals within the Lower Aquifer.



a. Simulated Water Table Elevation for Upper Aquifer System



b. Simulated Water Table Elevation for Lower Aquifer System

Figure 6.4 Simulated Water Levels for the Baseline Scenario, 10-Layer Model

Groundwater Flow

Simulated average water levels in the Lower Aquifer for the Well B injection scenario are shown in Figure 6.5. Compared to the baseline simulation, flows east of the Chain of Lakes were generally the same. A mound was evident near the injection site with flow away from the injection well to the east, west, and south. Localized cones of depression were evident around the Hopyard and Pleasanton production wells. The hydraulic gradient was nearly flat between the injection site and the Chain of Lakes.

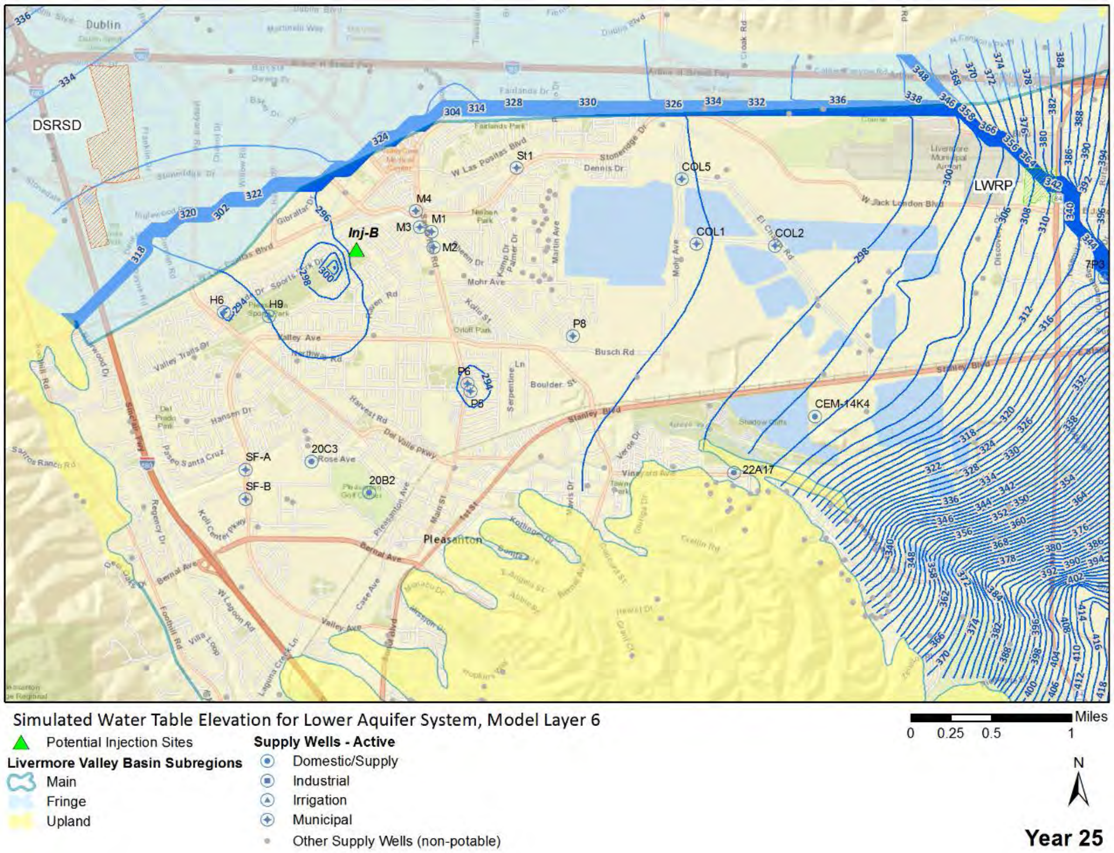


Figure 6.5 Simulated Water Levels in the Lower Aquifer, 25 Years, 10,000 AFY in Well B

Travel Time Analysis

The model was used to evaluate injection at Well B into various layers of the lower aquifer. Based on results of the preliminary travel time modeling, the location of Well B was adjusted slightly by moving the well one model cells to the south and west (about 700 feet) to increase the distance from the injection site to the Mocho well field. For the travel time analysis, a unit concentration was assigned to the injected water at Well B, and breakthrough of the concentration was observed at the production wells. Breakthrough was observed at the Mocho wells, as shown in Figure 6.6. Breakthrough of two percent of the injected concentration occurred at well Mocho 3 after 370 days of injection, exceeding the required four month travel time by more than three times. The travel time predicted by the 10-Layer Model was significantly longer than predicted by the 3-Layer Model, but the travel times simulated by both models were longer than required under Title 22.

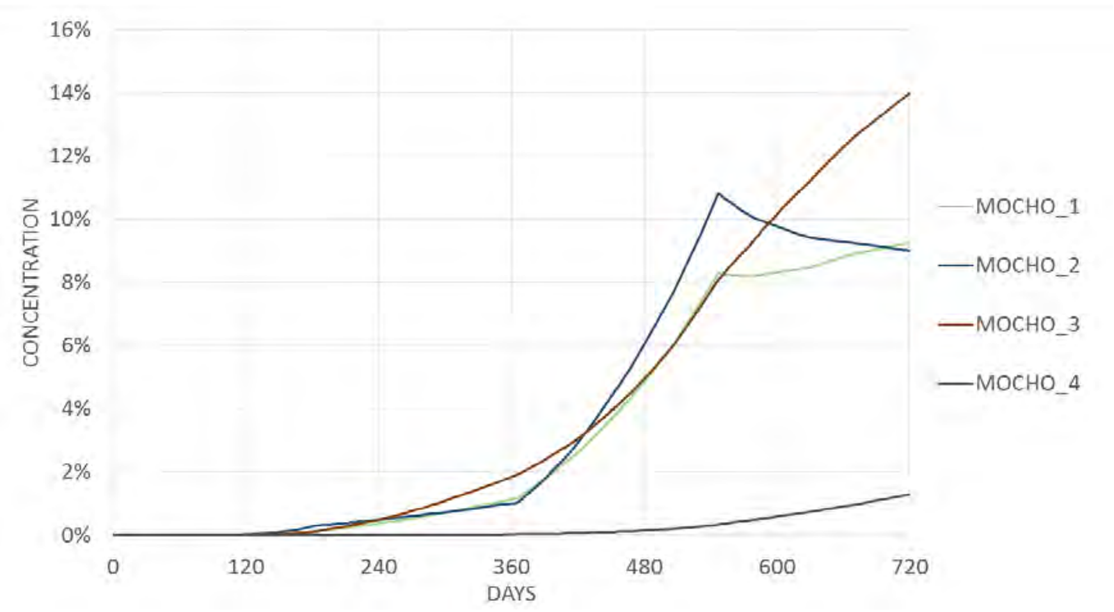


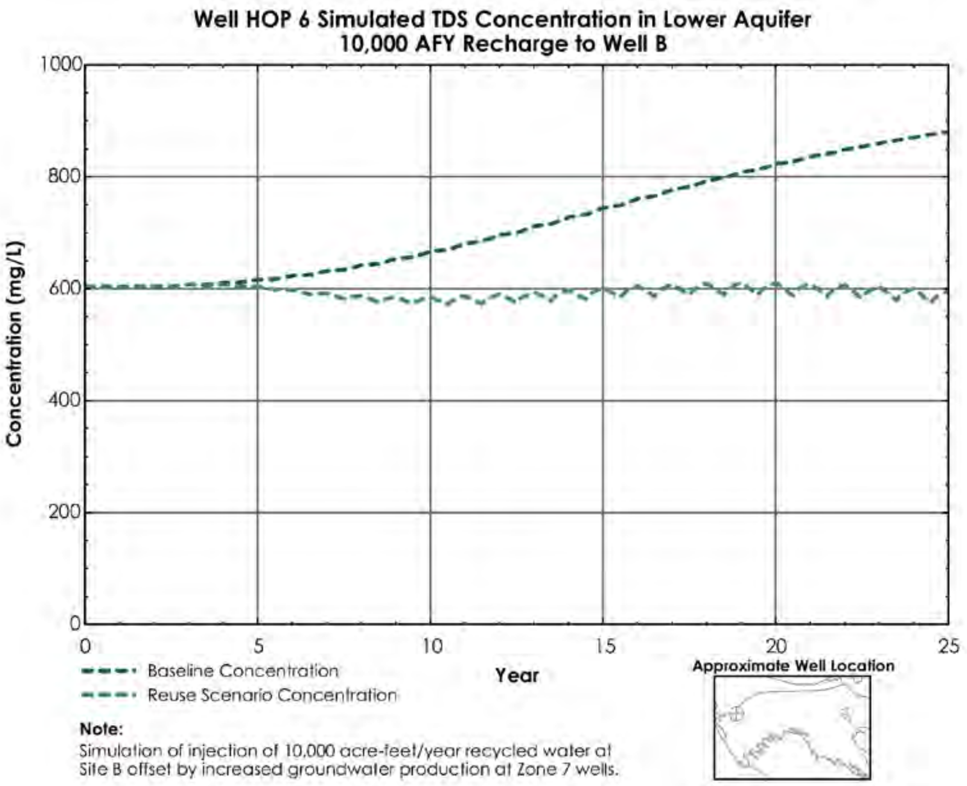
Figure 6.6 Simulated Breakthrough at Mocho Wells, 10,000 AFY Injection at Well E

The breakthrough shown in Figure 6.6 is based on the average concentration at the production wells extracted water from multiple model layers. The output from the 10-Layer Model was also checked to ensure that simulated breakthrough in a single layer was not significantly less; the simulated travel times for individual layers were similar to the average. Simulating injection into only one or two of the Lower Aquifer layers also did not significantly affect the travel time.

Impacts on Salt Balance

The effects of recycled water injection on the salt balance within the groundwater basin as assessed by looking at the predicted changes in TDS concentrations at the production wells over time and the change in TDS concentration in the lower aquifer after 25 years of injection. Trend charts showing the simulated change in TDS over time at selected production wells are shown in Figure 6.7 and Figure 6.8. Note that these figures should only be interpreted to show the relative change in concentration over time between the scenarios with and without recharge and do not indicate predictions of actual concentrations at these wells. A summary table of the net change in TDS concentrations at the end of the 25-year simulation period for all recharge scenarios is provided in Table 6.5. Charts of TDS trends for additional wells are provided in Appendix C.

Figure 6.6 shows the simulated trends in TDS concentration for the baseline and injection scenario at well Hopyard 6 west of the injection site at Well B. In the baseline model, TDS concentrations were expected to gradually increase over time by almost 300 mg/L over the 25-year simulation period. In the injection scenario, TDS at Hopyard 6 was expected to remain relatively stable over time resulting in a net reduction in TDS at this location of about 290 mg/L.

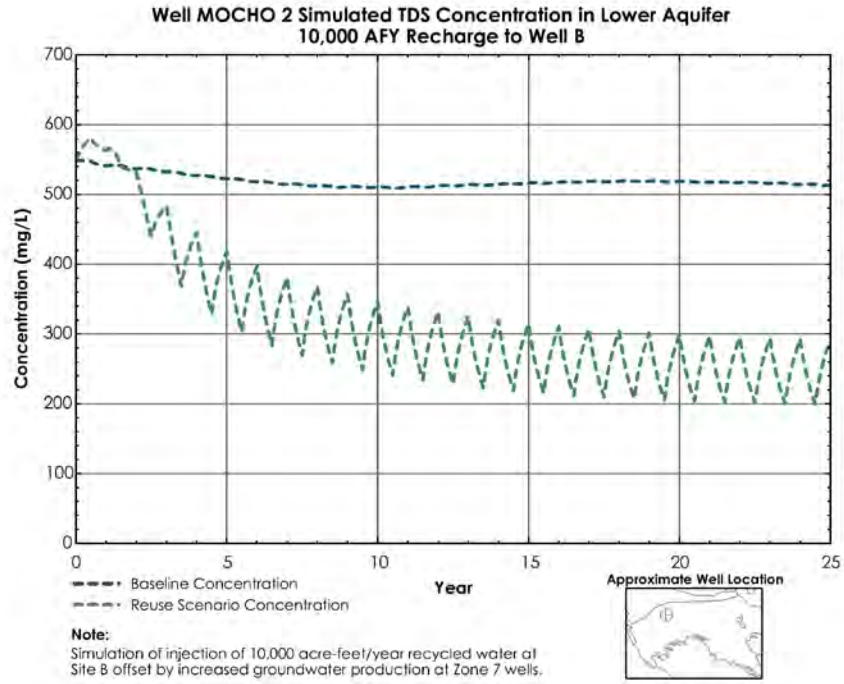


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Site B offset by increased groundwater production at Zone 7 wells.

Figure 6.7 Comparison of Simulated TDS Concentrations at Well Hopyard 6, 10,000 AFY at Well B

Figure 6.8 shows the simulated trends in TDS concentration for the baseline and injection scenario at well Mocho 2 east of the injection site at Well B. In the baseline model, TDS concentrations remained relatively stable over time. In the injection scenario, TDS at Mocho 2 exhibited a strong seasonal fluctuation of about 100 mg/L because of the large seasonal difference in the volume of injection and extraction. As noted previously, this fluctuation is an artifact of the use of semi-annual stress periods in the model; although concentrations would likely vary seasonally, such drastic fluctuations would not be expected to occur if a shorter time period was used. TDS at this well was expected to decline over time for roughly the first 15 years of injection, then stabilized resulting in a net reduction in TDS at this location of about 270 mg/L.

Figure 6.9 shows the simulated change in TDS concentrations in the lower aquifer between this scenario and the baseline after 25 years of injection. On this figure, areas of net decrease in TDS are shaded green while areas of net increase in TDS are shaded orange. The shaded colors have contour intervals of approximately 25 mg/L TDS representing the general changes in water quality that are expected. The darkest green and innermost contour represents more than 500 mg/L decrease in TDS, whereas the darkest orange and innermost contour over the COLs represents a 125 mg/L increase in TDS. This figure shows that after 25 years of injection, water quality improvements occurred over an area extending from Hopyard 6 west of the injection site to the Mocho wells east of the injection site. The influence of injection on TDS was likely limited beyond these wells by the extraction of groundwater at these wells. This figure also shows that a net increase in TDS occurred in some areas of the basin beyond this extent, likely due to the displacement of higher-TDS water with lower-TDS water near the injection site. The largest net increase was observed at wells Pleasanton 5 and 6 with a net increase of 50 mg/L. Although the difference in concentration between the baseline and injection scenarios showed a net increase, simulated TDS concentrations in the injection scenario at Pleasanton 6 are expected to decline over time relative to the baseline, as shown in Figure 6.10.


Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B

Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Site B offset by increased groundwater production at Zone 7 wells.

Figure 6.8 Comparison of Simulated TDS Concentrations at Well Mocho 2, 10,000 AFY at Well B

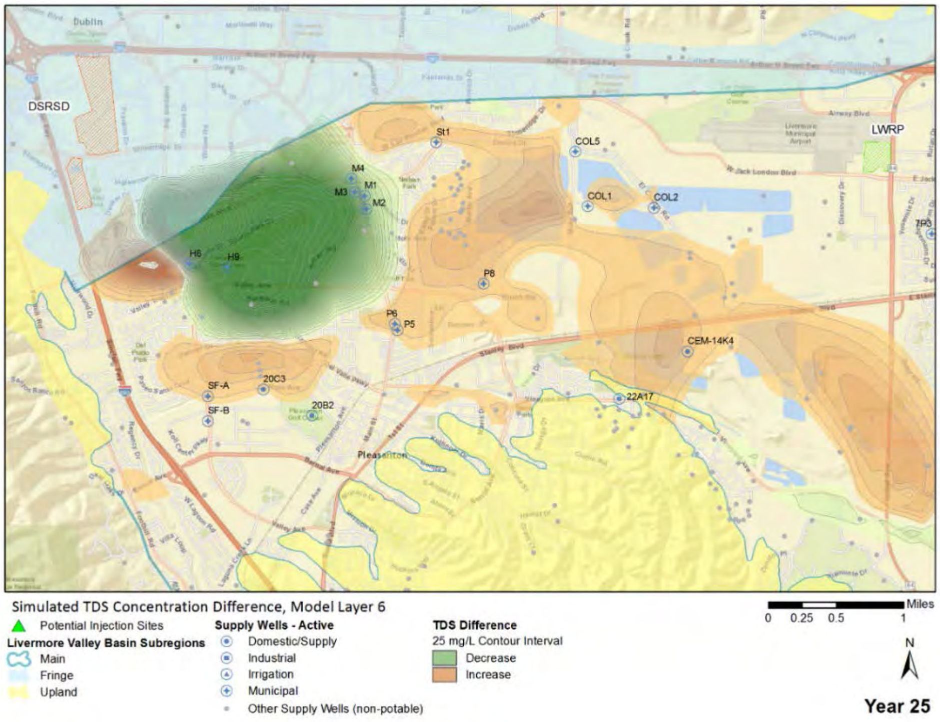

Simulated TDS Concentration Difference, Model Layer 6

Figure 6.9 Simulated Change from Baseline TDS Concentrations in Lower Aquifer After 25 Years, 10,000 AFY in Well B Scenario

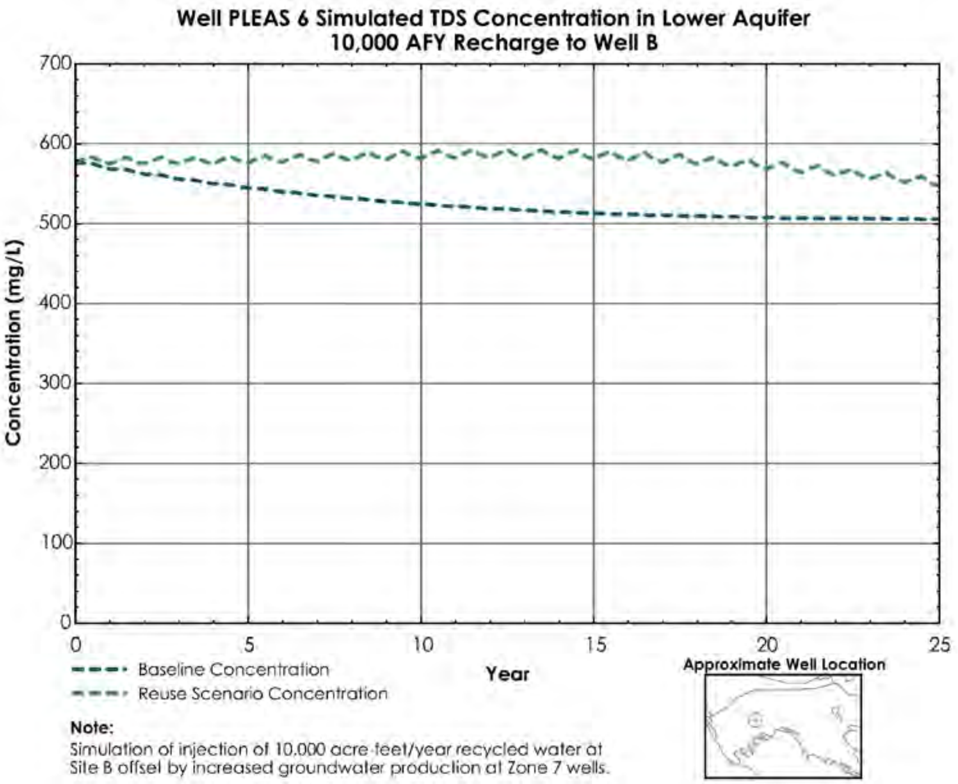


Figure 6.10 Comparison of Simulated TDS Concentrations at Well Pleasanton 6, 10,000 AFY at Well B

6.2.3.3 Injection at Well E

Short-listed option 1b includes injection of 5,500 AFY of recycled water at Well E on a year round basis. Well E would be screened through one or more intervals within the Lower Aquifer.

Groundwater Flow

Simulated average water levels between scenario and the baseline in the Lower Aquifer for the Well E injection scenario are shown in Figure 6.11. Compared to the baseline simulation, flows east of the Chain of Lakes were generally the same except for the mound evident near the injection site with flow away from the injection well primarily to the west. The hydraulic gradient from the Chain of Lakes area to west of the Mocho well field was steeper than the baseline. Localized cones of depression were evident around the Hopyard and Pleasanton production wells.

Travel Time Analysis

The model was used to evaluate injection at Well E into the lower aquifer. For the travel time analysis, a unit concentration was assigned to the injected water at Well E, and breakthrough of the concentration was observed at the production wells. Breakthrough was observed at the Chain of Lakes wells, as shown in Figure 6.11. Breakthrough of two percent of the injected concentration occurred at well COL 2 after 665 days of injection, exceeding the required four month travel time by more than five times.

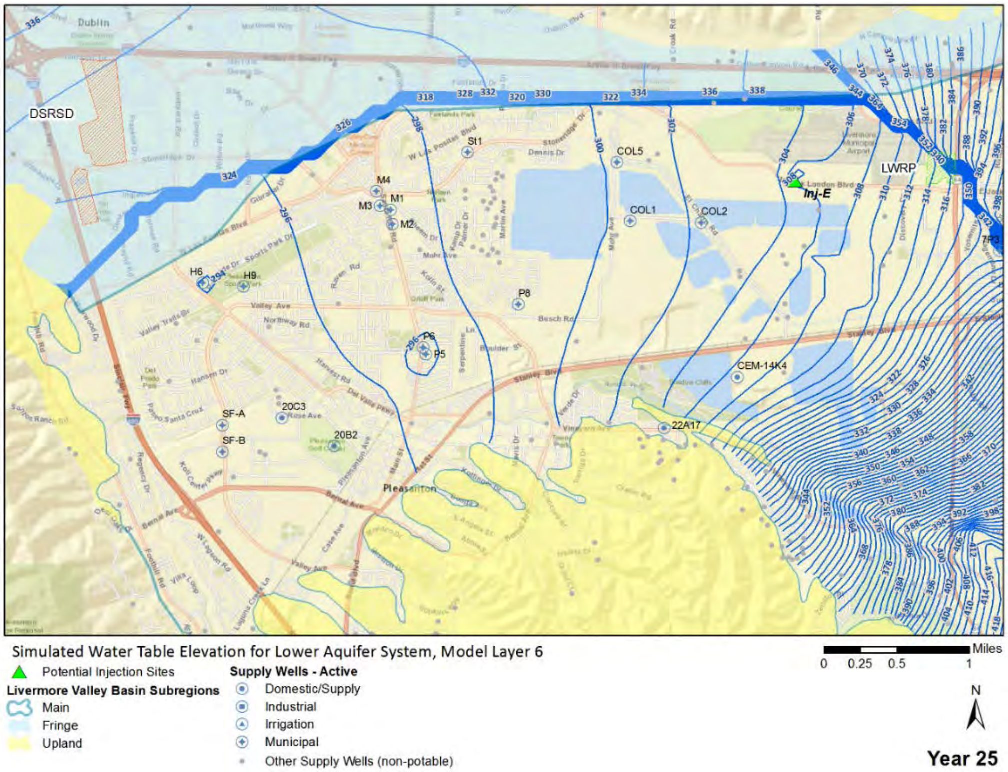


Figure 6.11 Simulated Water Levels in the Lower Aquifer, 25 Years, 5,500 AFY in Well E

The breakthrough shown in Figure 6.12 is based on the average concentration at the production wells extracted water from multiple model layers. The output from the 10-Layer Model was also checked to ensure that simulated breakthrough in a single layer was not significantly less; the simulated travel times for individual layers were similar to the average.

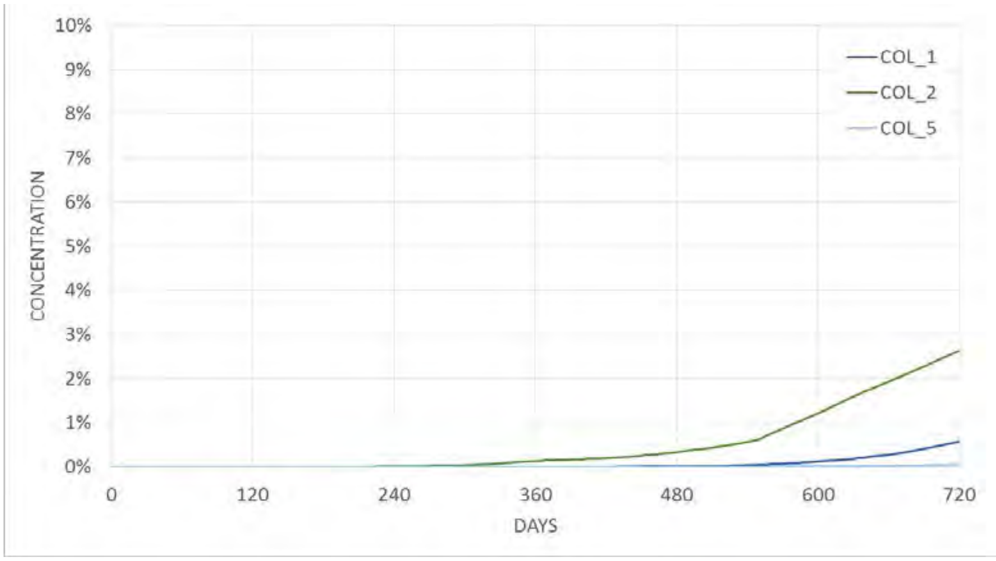


Figure 6.12 Simulated Breakthrough at Chain of Lakes Wells, 5,5000 AFY Injection at Well E

Impacts on Salt Balance

Trend charts showing the simulated change in TDS over time at selected production wells are shown in Figures 6.13 and 6.14. A summary table of the net change in TDS concentrations at the end of the 25-year simulation period for all recharge scenarios is provided in Table 6.5.

Figure 6.13 shows the simulated trends in TDS concentration for the baseline and injection scenario at well COL 1 west and slightly south of the injection site at Well E. In the baseline model, TDS concentrations declined over time with a net decline of about 100 mg/L over 25 years. In the injection scenario, TDS at COL 1 exhibited a rapid decline after about 3 years when the front of injected water reached the well location. Following this sharp decline, TDS stabilized after about 8 years and declined only slightly through the end of the simulation. A net reduction in TDS of about 90 mg/L was observed at this location, although a decline of 350 mg/L was observed at nearby COL 5 located further north and directly downgradient of the injection site.

Figure 6.14 shows the simulated trends in TDS concentration for the baseline and injection scenario at well Mocho 2 east of the injection site at Well E. In the baseline model, TDS concentrations remained relatively stable over time. In the injection scenario, TDS at Mocho 2 exhibited a declining trend after about 10 years of injection indicating when the front of injected water reached the well location. Simulated concentrations at this location continued to decline through the end of the simulation with a net reduction in TDS at this location of about 150 mg/L.

Figure 6.15 shows the simulated change in TDS concentrations between scenario and the baseline in the lower aquifer after 25 years of injection. In this scenario, water quality improvements occurred over an area extending from the injection site to beyond the Mocho wells and also south to the Pleasanton wells. Because the groundwater flowed from east to west through the basin and pumping in the central parts of the basin occurred downgradient of the site of injection, injection reduced the TDS across a much larger area of the basin as compared to the Well B scenario. No net increase greater than 10 mg/L was observed at any of the production wells, and significant declines in TDS of more than 100 mg/L were observed at several wells.

6.2.3.4 Recharge through Lake I

Short-listed option 1a includes recharge of 5,500 AFY of recycled water through Lake I on a year round basis. Short-listed options 2a and 4 include an end use of conveyance to DVWTP via Cope Lake, but incorporate flexibility to convey water to Lake I for groundwater recharge. The recharge amount for these options is 10,000 AFY on a seasonal basis. Recharge through Lake I enters the Upper Aquifer through a seepage face on the western side of the lake, and the rate of recharge is proportional to the head difference between the lake water level and groundwater levels in the aquifer. For these simulations, recycled water was added to the lake, and the actual rate of recharge to the aquifer was determined by the model.

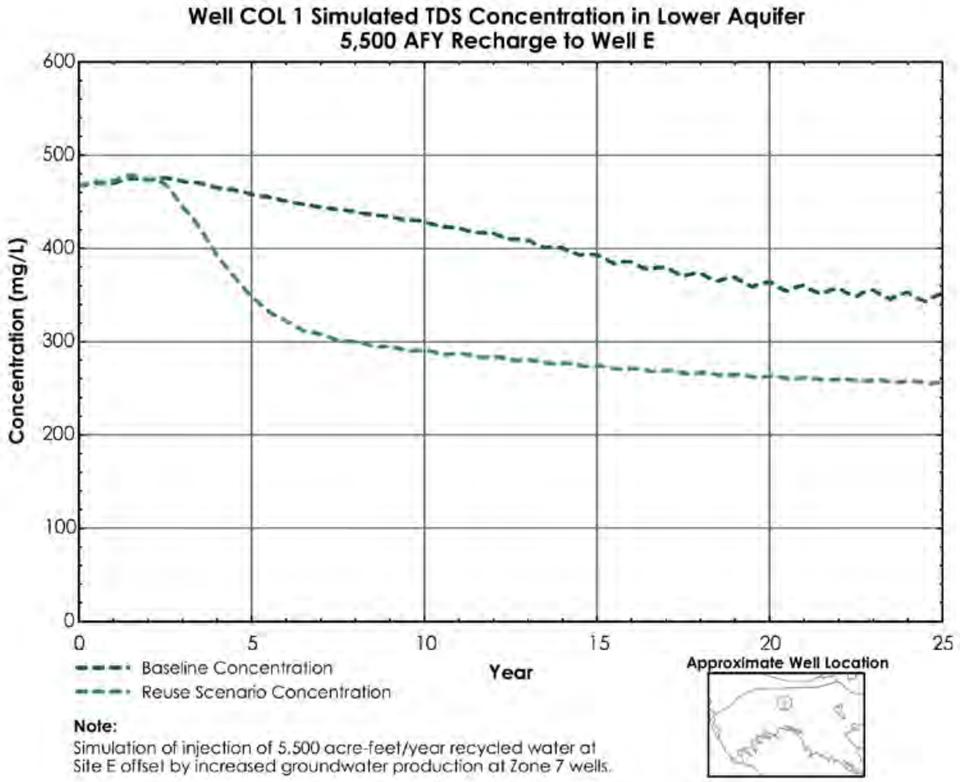


Figure 6.13 Comparison of Simulated TDS Concentrations at Well COL 1, 5,500 AFY at Well E

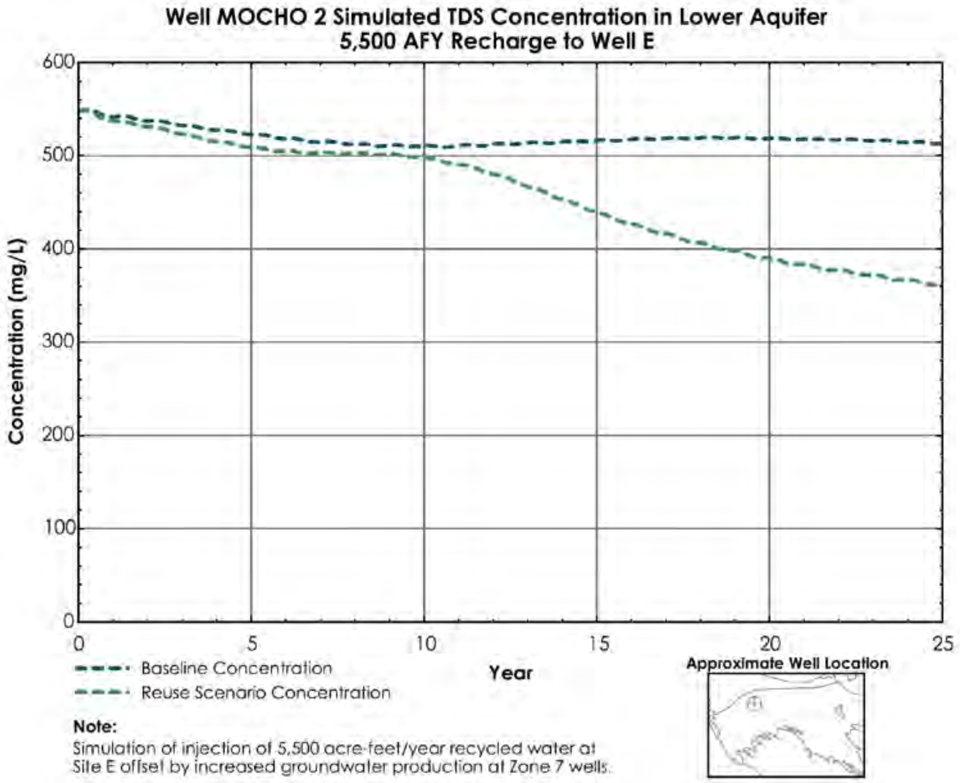


Figure 6.14 Comparison of Simulated TDS Concentrations at Well Mocho 2, 5,500 AFY at Well E

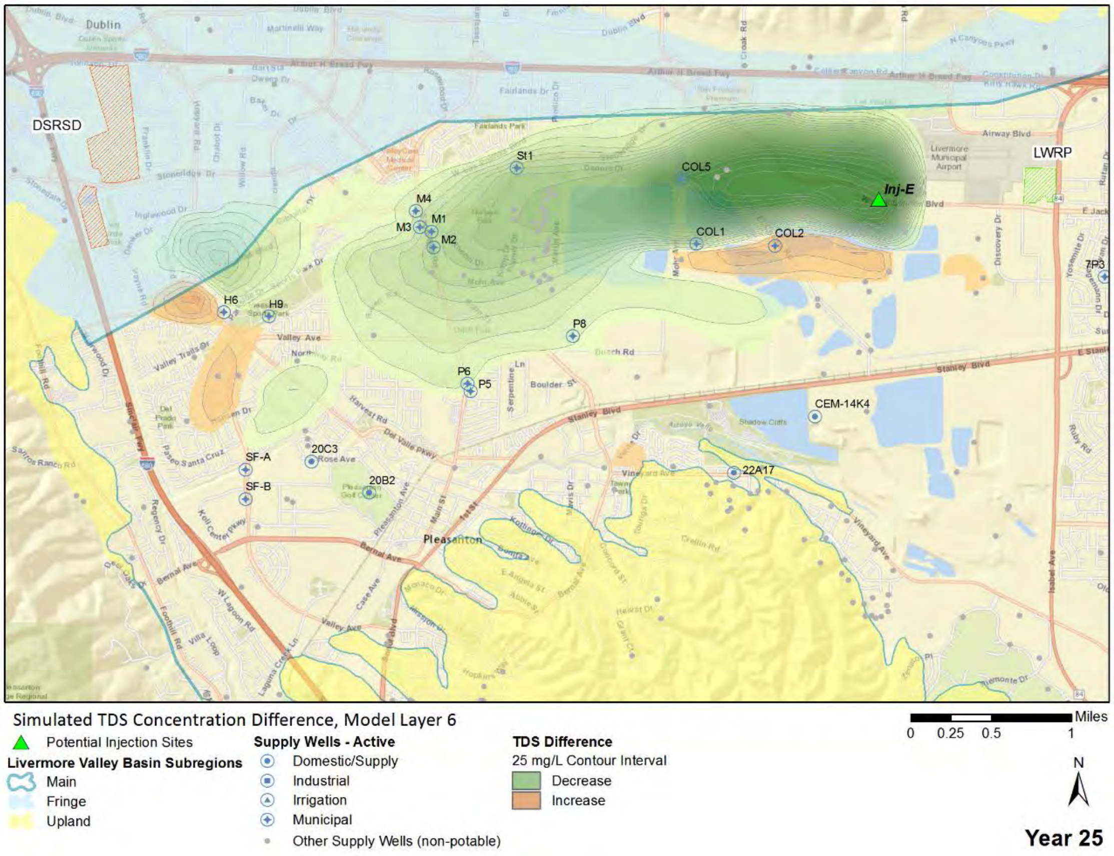


Figure 6.15 Simulated Change from Baseline TDS Concentrations in Lower Aquifer After 25 Years, 5,500 AFY in Well E Scenario

Lake I Recharge: 5,500 AFY

Figure 6.16 shows the simulated TDS concentration and change in storage volume in Lake I for the 5,500 AFY scenario. In the baseline scenario, TDS concentration in the lake increased steadily throughout the simulation. In the recharge scenario, the concentration in the lake declined for about eight years after discharge to the lake begins, then remained constant through the end of the simulation. By maintaining the TDS concentration of the lake, the simulated salt load to the groundwater basin was reduced.

The average simulated lake volume was the same for both scenarios, and both scenarios indicated that lake levels would exhibit a seasonal fluctuation in response to the seasonal variation in pumping from the groundwater basin.This seasonal fluctuaction was exaggerated in the recharge scenario because the addition of recycled water to the lake increased the lake volume during the wet season and allowed more recharge from the lake during the dry season. Note that the change in storage volume is shown in Figure 6.16 because simulated Lake I volumes are higher than the actual capacity of the lake because of the limitations of discretization of the model grid.

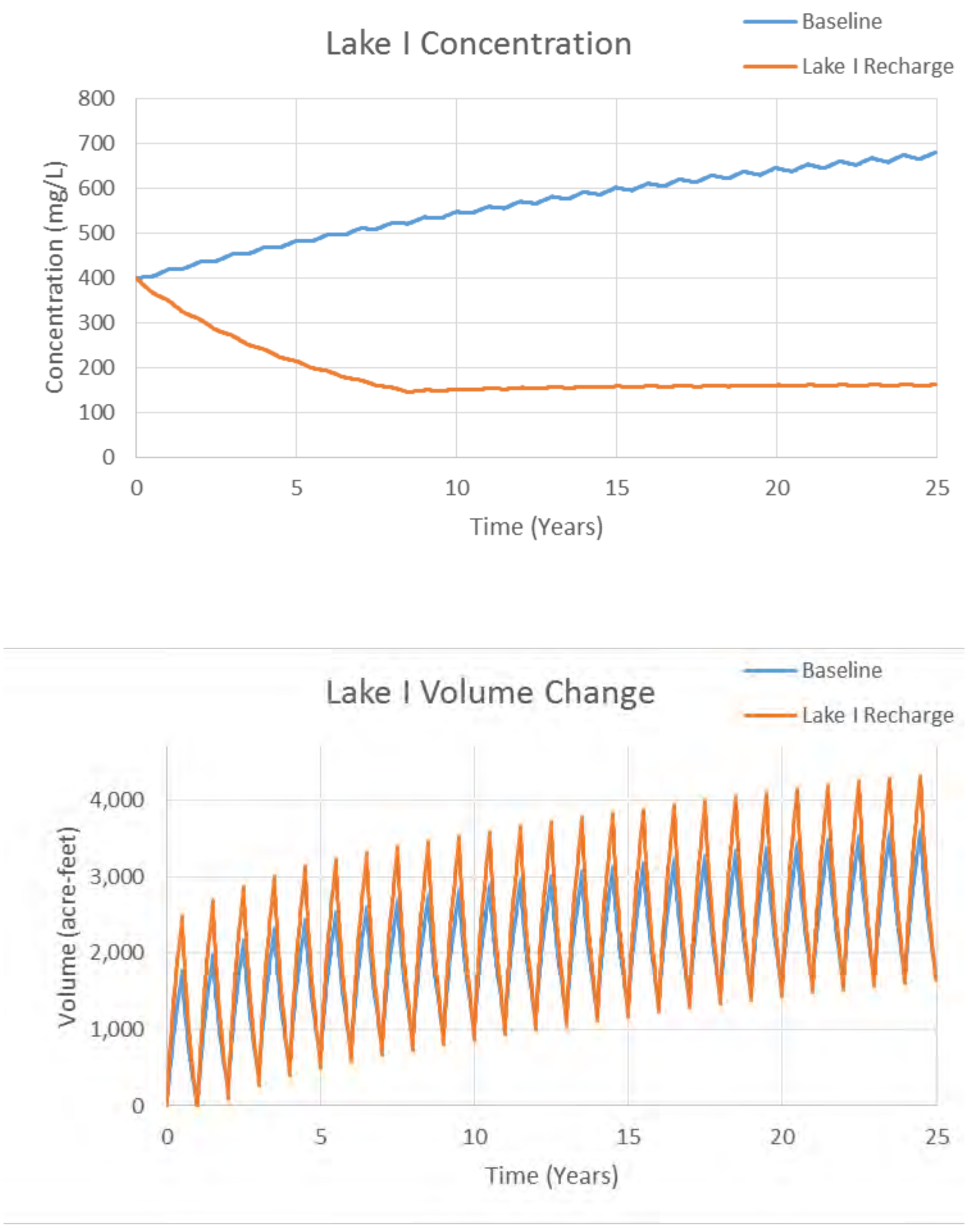
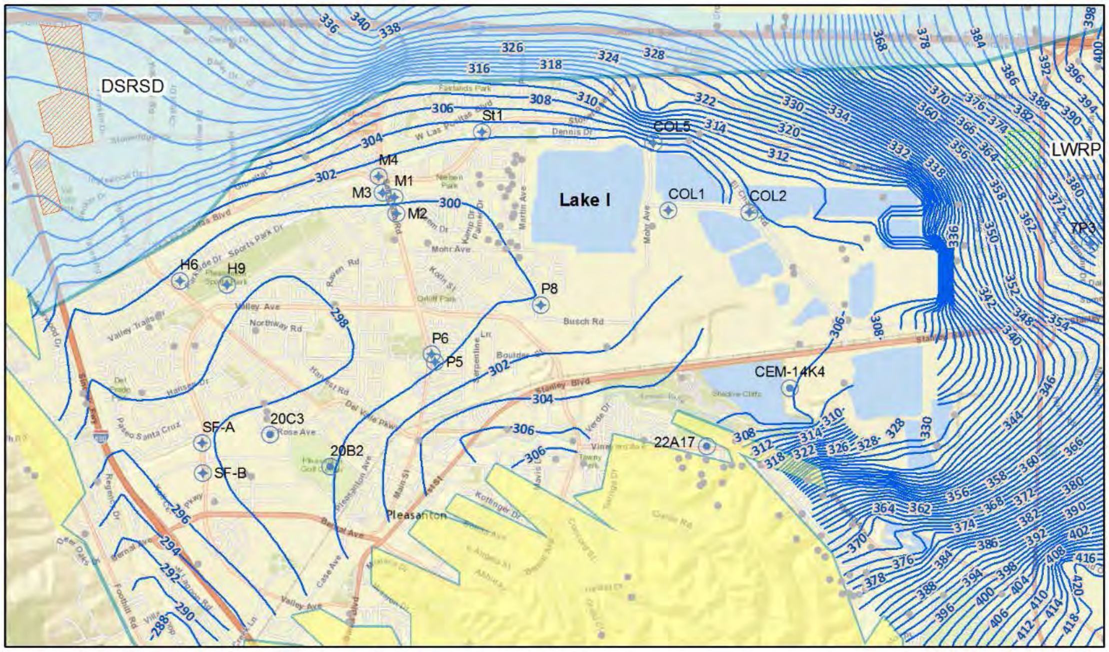


Figure 6.16 Comparison of Simulated TDS Concentration and Volume in Lake I, 5,500 AFY Recharge

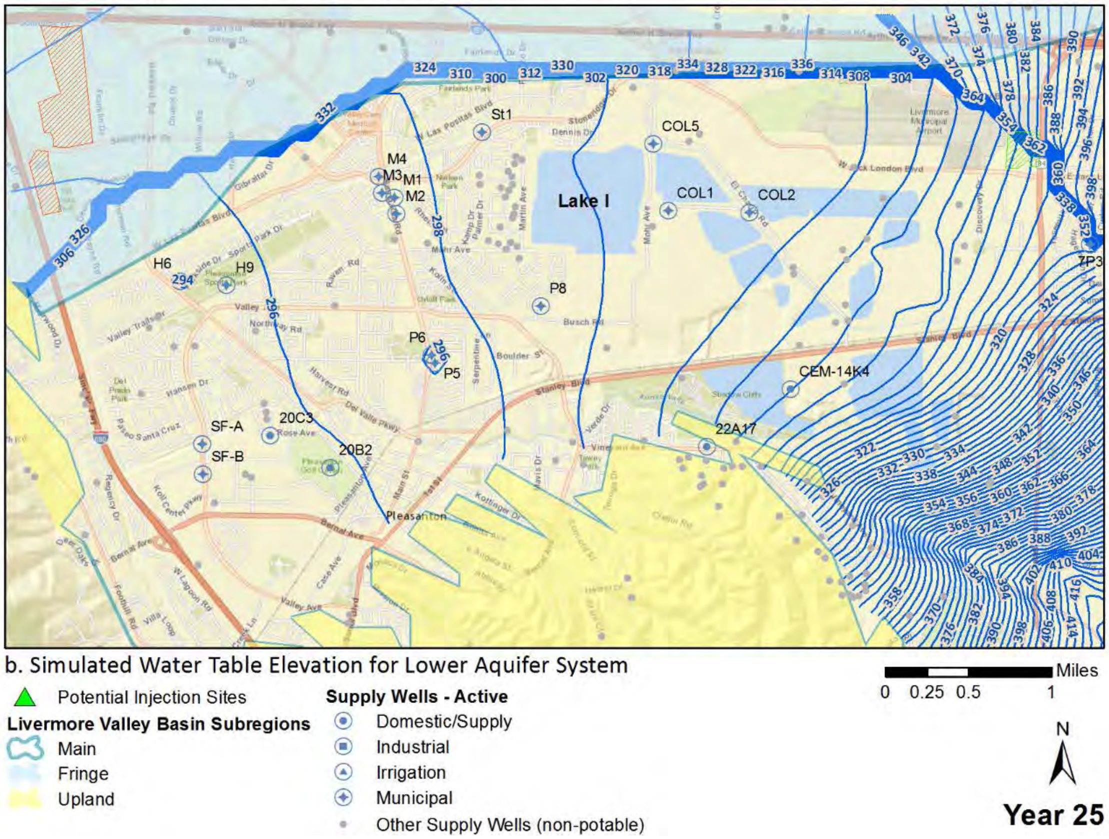
Groundwater Flow

Simulated average water levels for the 5,500 AFY recharge in Lake I scenario are shown in Figure 6.17. The upper map shows that groundwater elevations in the Upper Aquifer near Lake I and to the west were about two feet higher than in the baseline scenario, and the area of inward flow was smaller with the hydraulic gradient pushing flow to the west across the basin.

In the Lower Aquifer, groundwater levels beneath Lake I were higher than the baseline creating a stronger hydraulic gradient toward the Mocho wells and slowing incoming flow from the east upgradient of the Chain of Lakes wells.



a. Simulated Water Table Elevation for Upper Aquifer System



b. Simulated Water Table Elevation for Lower Aquifer System

Figure 6.17 Simulated Water Levels, 25 Years, 5,500 AFY in Lake I

Impacts on Salt Balance

Trend charts showing the simulated change in TDS over time at selected production wells are shown in Figures 6.18 and 6.19. A summary table of the net change in TDS concentrations at the end of the 25-year simulation period for all recharge scenarios is provided in Table 6.5.

Figure 6.18 shows the simulated trends in TDS concentration for the baseline and recharge scenario at well COL 1 just east of Lake I. In the baseline model, TDS concentrations declined over time with a net decline of about 115 mg/L over 25 years. In the recharge scenario, TDS at COL 1 exhibited similar behavior to the baseline scenario with a slightly smaller decrease at the end of the simulation of about 90 mg/L. A net increase in TDS of about 30 mg/L was observed at this location. Because of the proximity of this well to Lake I, one might expect a decrease in TDS; however, the well is completed in the Lower Aquifer, whereas recharge from Lake I entered the Upper Aquifer. In addition, the well is upgradient of the lake, and unlike in the injection scenarios, recharge in the lake only occurred in response to a simulated head gradient rather than under pressure when injected from a well.

Figure 6.19 shows the simulated trends in TDS concentration for the baseline and recharge scenario at well Mocho 2 west of Lake I. In the baseline model, TDS concentrations remained relatively stable over time. In the recharge scenario, TDS at Mocho 2 exhibited a strong declining trend for about the first 15 years of recharge followed by a continued more gradual decline through the end of the simulation with a net reduction in TDS at this location of about 200 mg/L. These results indicate that although recharge from the lake primarily entered the Upper Aquifer, the recycled water migrated downward through the aquitard to the Lower Aquifer relatively quickly under the influence of a downward gradient created by the extraction of groundwater from the Lower Aquifer.

Figure 6.20 shows the simulated change in TDS concentrations between scenario and the baseline in the Upper Aquifer after 25 years of recharge. In this scenario, water quality improvements occurred over an area extending from Lake I to the west and southwest following the flow gradient in this direction. This figure also shows a decrease in TDS in the Upper Aquifer west and northwest of the Shadow Cliffs Lake. This reduction in TDS was not directly related to the recharge in Lake I, but may be indirectly affected by the discharge of recycled water to Lake I. The model input files were reviewed to confirm that this was not caused by an error in the input data, but no errors were identified.

Figure 6.21 shows the simulated change in TDS concentrations between scenario and the baseline in the Lower Aquifer after 25 years of recharge. In this scenario, water quality improvements occurred over an area extending from Lake I to the west, northwest, and southwest following the flow gradient and influences of wells pumping in this aquifer. Because the groundwater flowed from east to west through the basin and pumping in the central parts of the basin occurred downgradient of the recharge site, recharge through Lake I reduced the TDS across a large area of the basin. No net increase greater than 30 mg/L was observed at any of the production wells, and significant declines in TDS of up to 250 mg/L were observed at the Mocho, and Stoneridge wells.

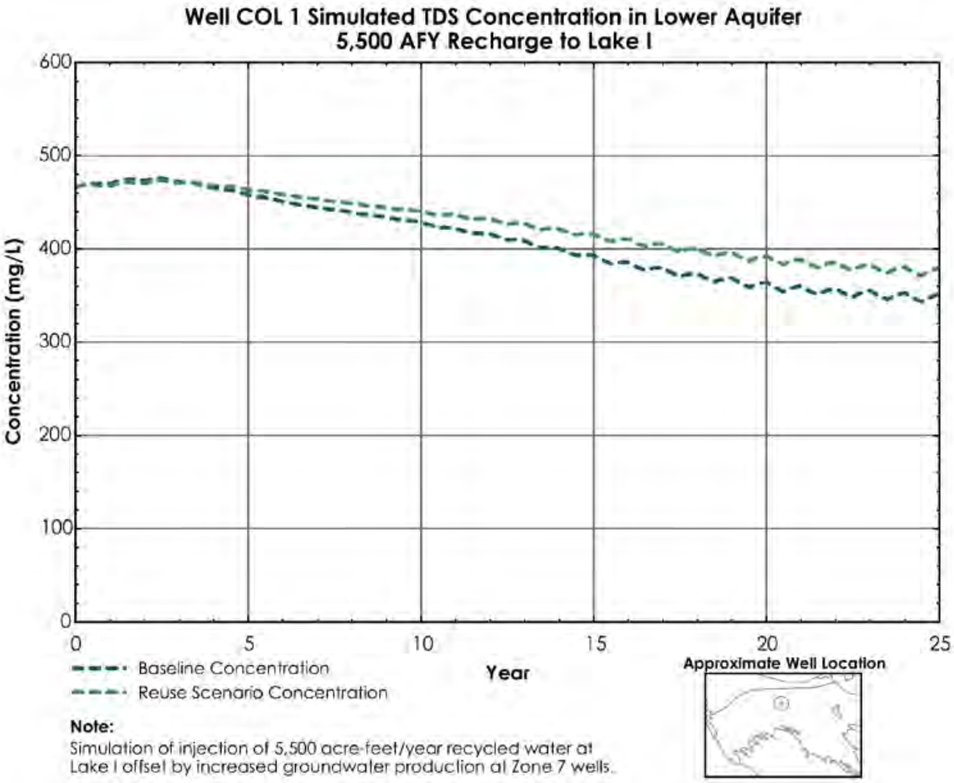


Figure 6.18 Comparison of Simulated TDS Concentrations at Well COL 1, 5,500 AFY in Lake I

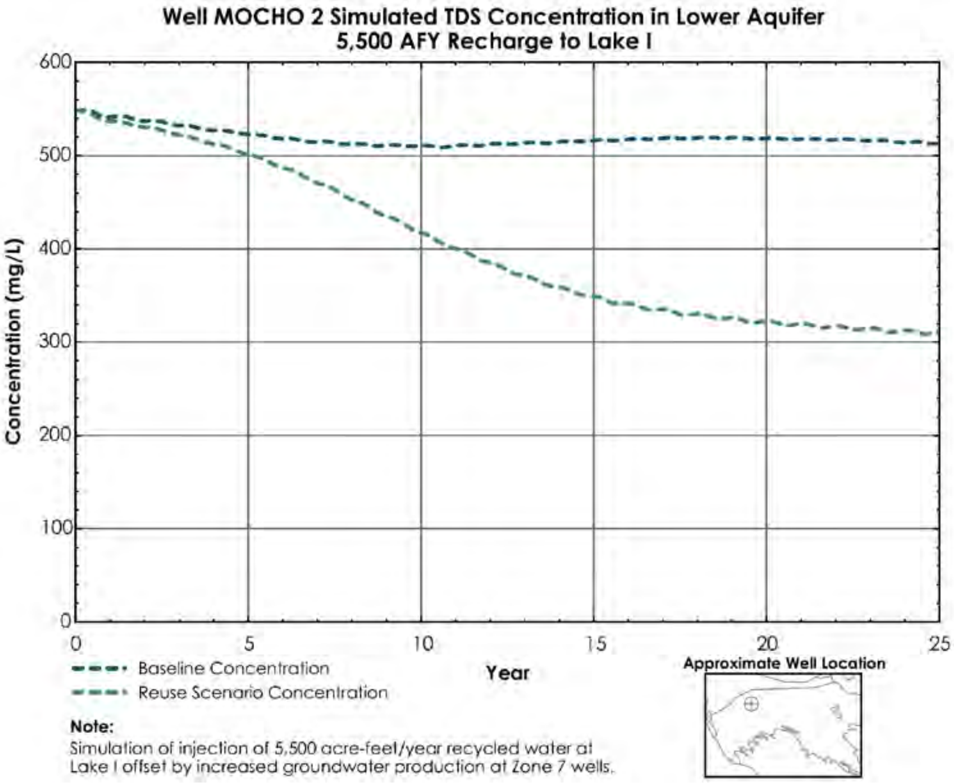


Figure 6.19 Comparison of Simulated TDS Concentrations at Well Mocho 2, 5,500 AFY in Lake I

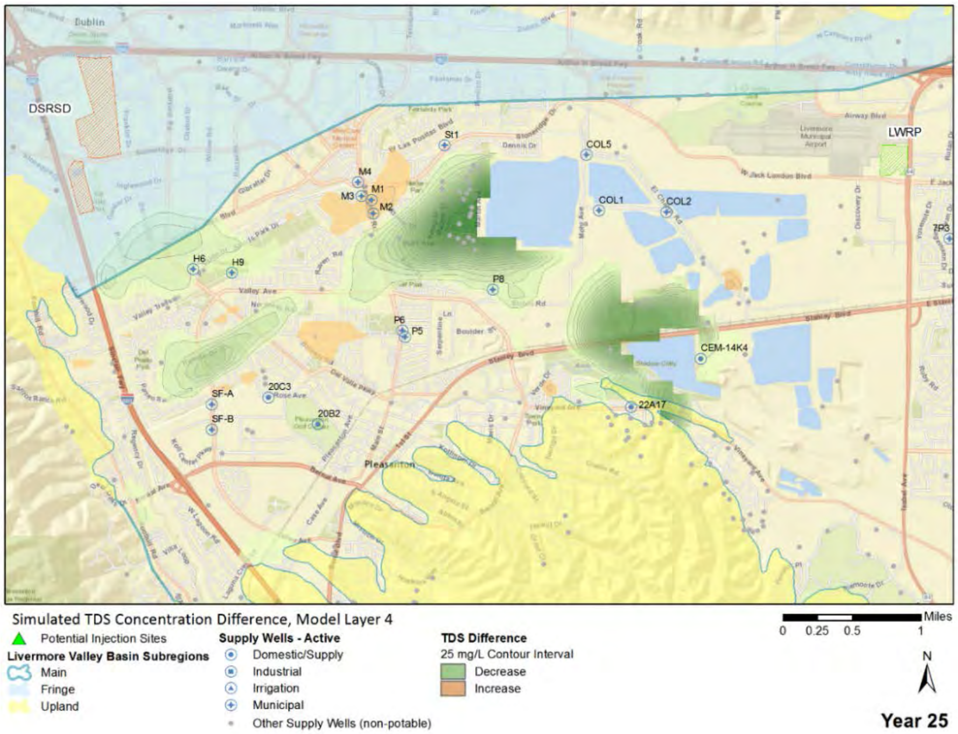


Figure 6.20 Simulated Change from Baseline TDS Concentrations in Upper Aquifer After 25 Years, 5,500 AFY in Lake I Scenario

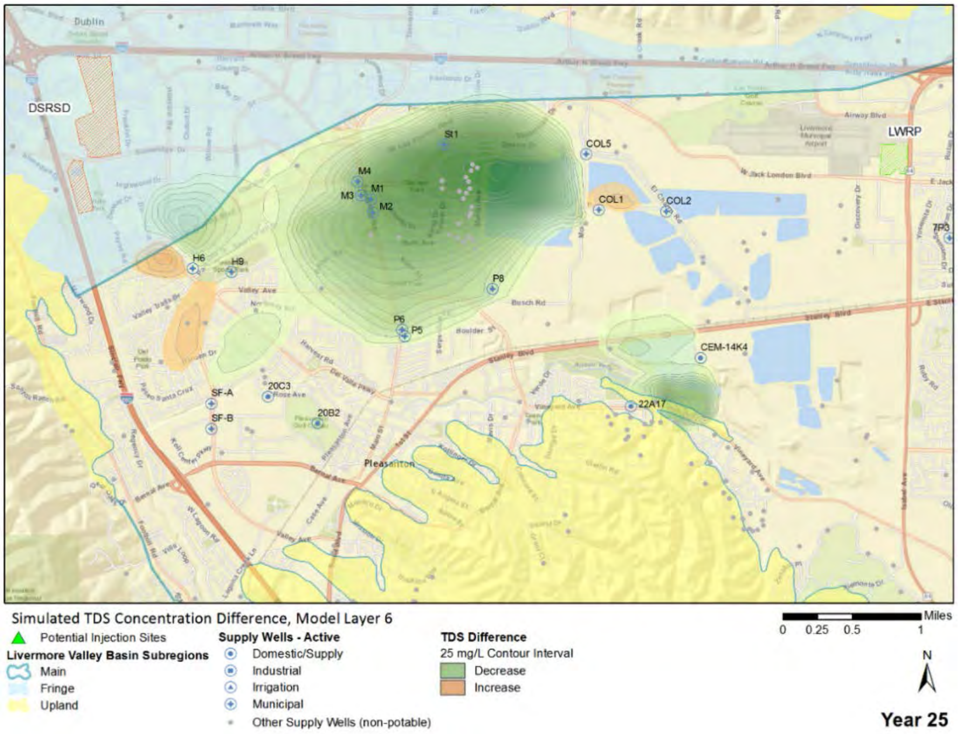


Figure 6.21 Simulated Change from Baseline TDS Concentrations in Lower Aquifer After 25 Years, 5,500 AFY in Lake I Scenario

Lake I Recharge: 10,000 AFY

Figure 6.22 shows the simulated TDS concentration and volume of storage in Lake I for the 10,000 AFY scenario. In the baseline scenario, the TDS concentration in the lake increased steadily throughout the simulation. In the recharge scenario, the concentration in the lake declined for about eight years after discharge to the lake begins, then remained constant through the end of the simulation. This simulation shows that by adding purified water the TDS concentration of the lake stays at a lower level resulting in the simulated salt load to the groundwater basin being reduced.

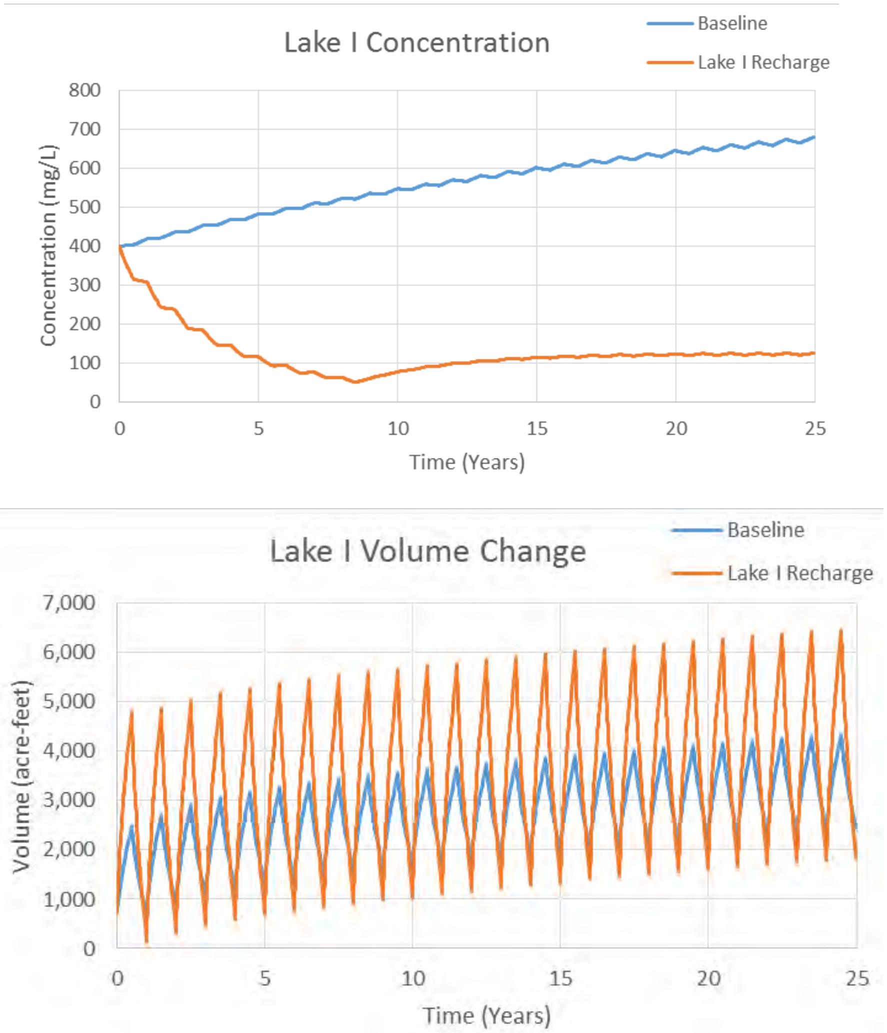
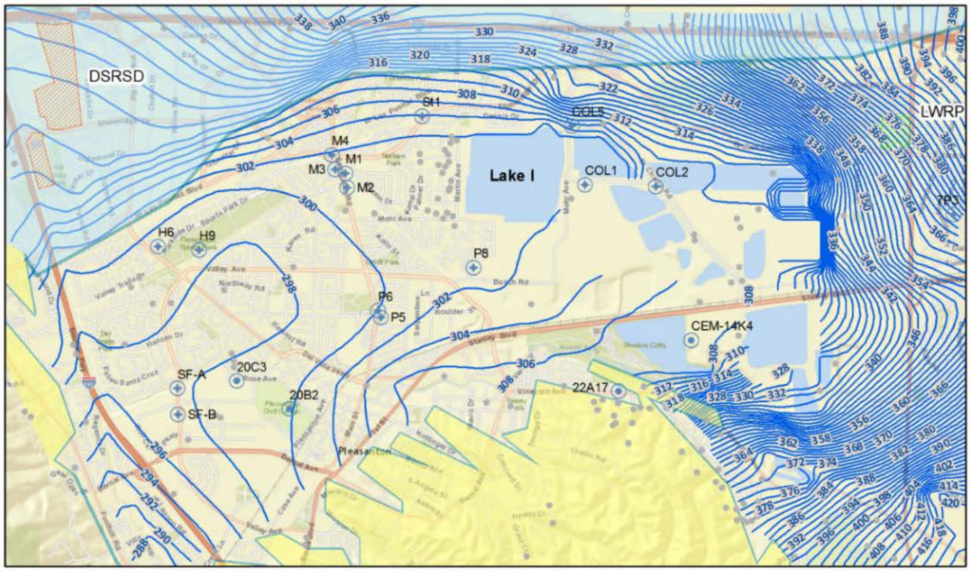


Figure 6.22 Comparison of Simulated TDS Concentration and Volume in Lake I, 10,000 AFY Recharge

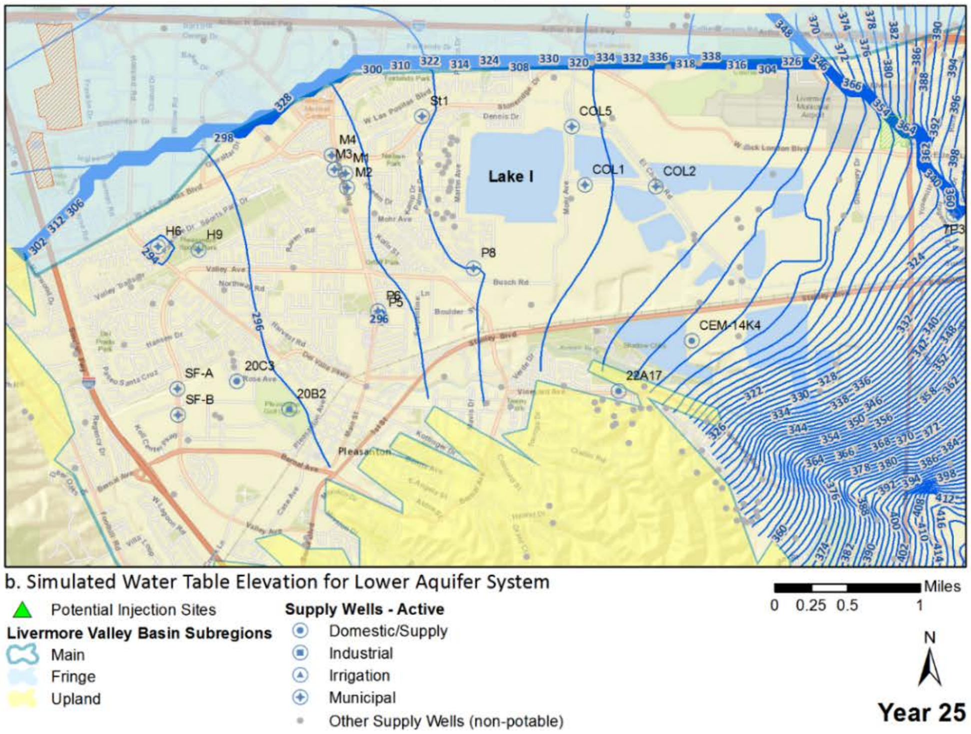
The trend in average simulated lake volume was the same for both the baseline and recharge scenarios although the simulated lake volume for the recharge scenario was higher, and both scenarios indicated that lake levels would exhibit a seasonal fluctuation in response to the seasonal variation in pumping from the groundwater basin.This seasonal fluctuaction was exaggerated in the recharge scenario because of the combined effects of higer recharge during the wet season and higher pumping during the dry season. The addition of recycled water to the lake increased the lake volume during the wet season and allowed more recharge from the lake during the dry season.

Groundwater Flow

Simulated average water levels for the 10,000 AFY recharge in Lake I scenario are shown in Figure 6.23. The upper map shows that groundwater elevations in the Upper Aquifer near Lake I and to the west were about two feet higher than in the baseline scenario, and the area of inward flow was smaller with the hydraulic gradient pushing flow to the west across the basin.



a. Simulated Water Table Elevation for Upper Aquifer System



b. Simulated Water Table Elevation for Lower Aquifer System

▲ Potential Injection Sites

Livermore Valley Basin Subregions
- Main
- Fringe
- Upland

Supply Wells - Active
- Domestic/Supply
- Industrial
- Irrigation
- Municipal
- Other Supply Wells (non-potable)

Figure 6.23 Simulated Water Levels, 25 Years, 10,000 AFY in Lake I

In the Lower Aquifer, groundwater levels beneath Lake I were about four feet higher than the baseline creating a stronger hydraulic gradient toward the Mocho and Hopyard wells and slowing incoming flow from the east upgradient of the Chain of Lakes.

Impacts on Salt Balance

Trend charts showing the simulated change in TDS over time at selected production wells are shown in Figures 6.24 and 6.25. A summary table of the net change in TDS concentrations at the end of the 25-year simulation period for all recharge scenarios is provided in Table 6.5.

Figure 6.24 shows the simulated trends in TDS concentration for the baseline and recharge scenario at well COL 1 just east of Lake I. In the baseline model, TDS concentrations declined over time with a net decline of about 115 mg/L over 25 years. In the recharge scenario, TDS at COL 1 exhibited similar behavior to the baseline scenario with a smaller decrease at the end of the simulation of about 70 mg/L. A net increase in TDS of about 45 mg/L was observed at this location. Because of the proximity of this well to Lake I, a decrease in TDS was expected. However, the well is completed in the Lower Aquifer, whereas recharge from Lake I entered the Upper Aquifer. In addition, the well is upgradient of the lake, and unlike in the injection scenarios, recharge in the lake only occurred in response to a simulated head gradient rather than under pressure when injected into a well.

Figure 6.25 shows the simulated trends in TDS concentration for the baseline and recharge scenario at well Mocho 2 west of Lake I. In the baseline model, TDS concentrations remained relatively stable over time. In the recharge scenario, TDS at Mocho 2 exhibited a strong declining trend for about the first 15 years of recharge followed by a continued more gradual decline through the end of the simulation with a net reduction in TDS at this location of about 290 mg/L. These results indicate that although recharge from the lake primarily entered the Upper Aquifer, the recycled water migrated downward through the aquitard to the Lower Aquifer relatively quickly under the influence of a downward gradient created by the extraction of groundwater from the Lower Aquifer.

Figure 6.26 shows the simulated change in TDS concentrations in the Upper Aquifer after 25 years of recharge. In this scenario, water quality improvements occurred over an area extending from Lake I to the west and southwest beyond the Mocho wells following the flow gradient in this direction. Unlike for the 5,500 AFY recharge scenario, the decrease in TDS in the Upper Aquifer west and northwest of the Shadow Cliffs lake was not observed in this scenario.

Figure 6.27 shows the simulated change in TDS concentrations in the Lower Aquifer after 25 years of recharge. In this scenario, water quality improvements occurred over an area extending from Lake I to the west, northwest, and southwest extending to the Hopyard and Pleasanton wells following the flow gradient and influences of wells pumping in this aquifer. Because the groundwater flowed from east to west through the basin and pumping in the central parts of the basin occurred downgradient of the recharge site, recharge through Lake I reduced the TDS across a large area of the basin. No net increase greater than 40 mg/L was observed at any of the production wells, and significant declines in TDS of up to levels of 340 mg/L were observed at the Mocho, Stoneridge, and Pleasanton wells.

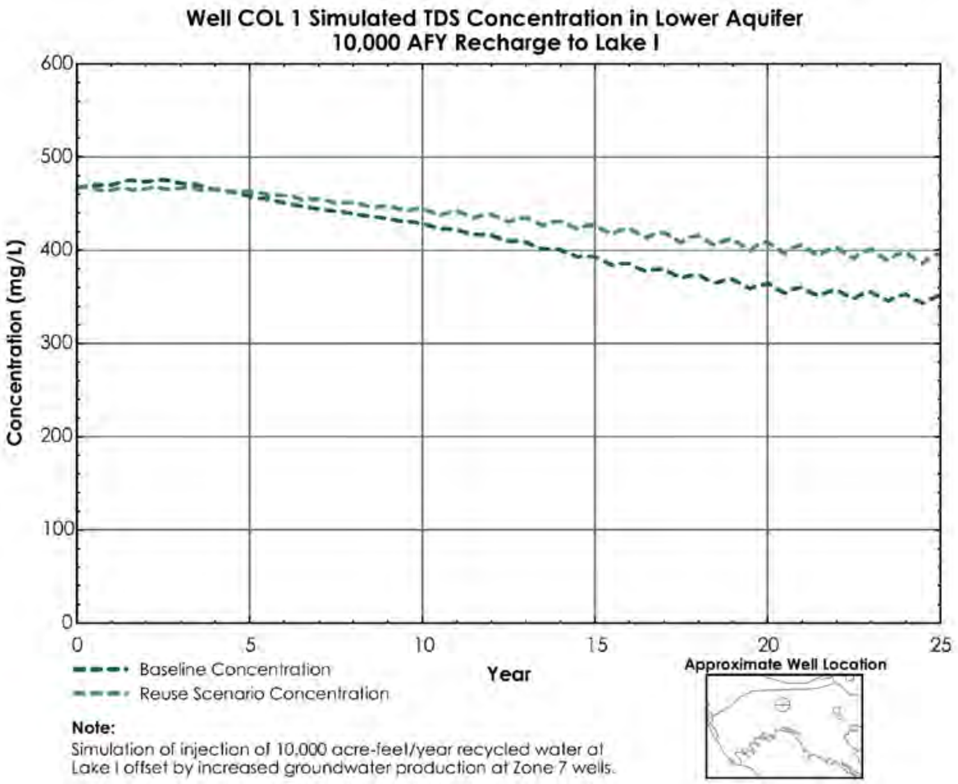


Figure 6.24 Comparison of Simulated TDS Concentrations at Well COL 1, 10,000 AFY in Lake I

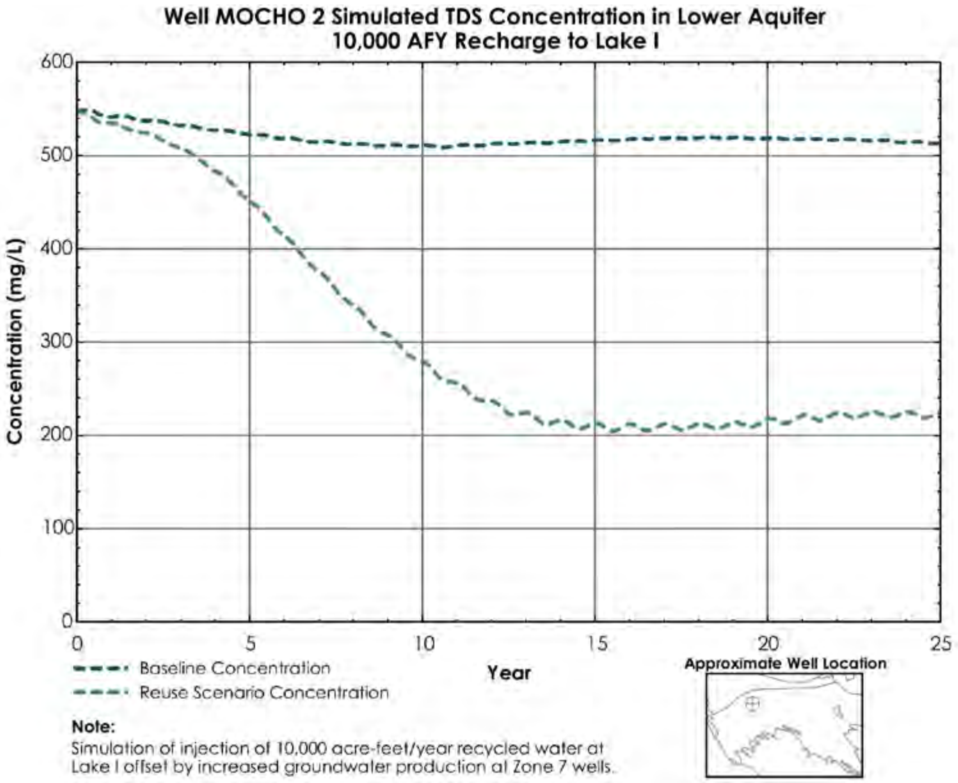


Figure 6.25 Comparison of Simulated TDS Concentrations at Well Mocho 2, 10,000 AFY in Lake I

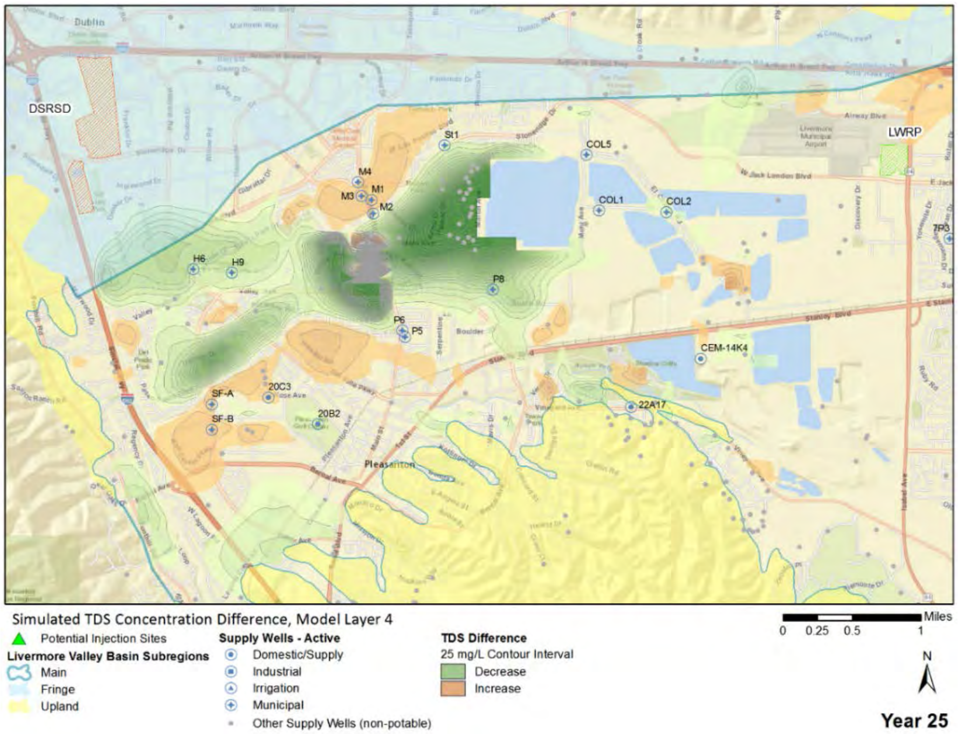


Figure 6.26 Simulated Change from Baseline TDS Concentrations in Upper Aquifer After 25 Years, 10,000 AFY in Lake I Scenario

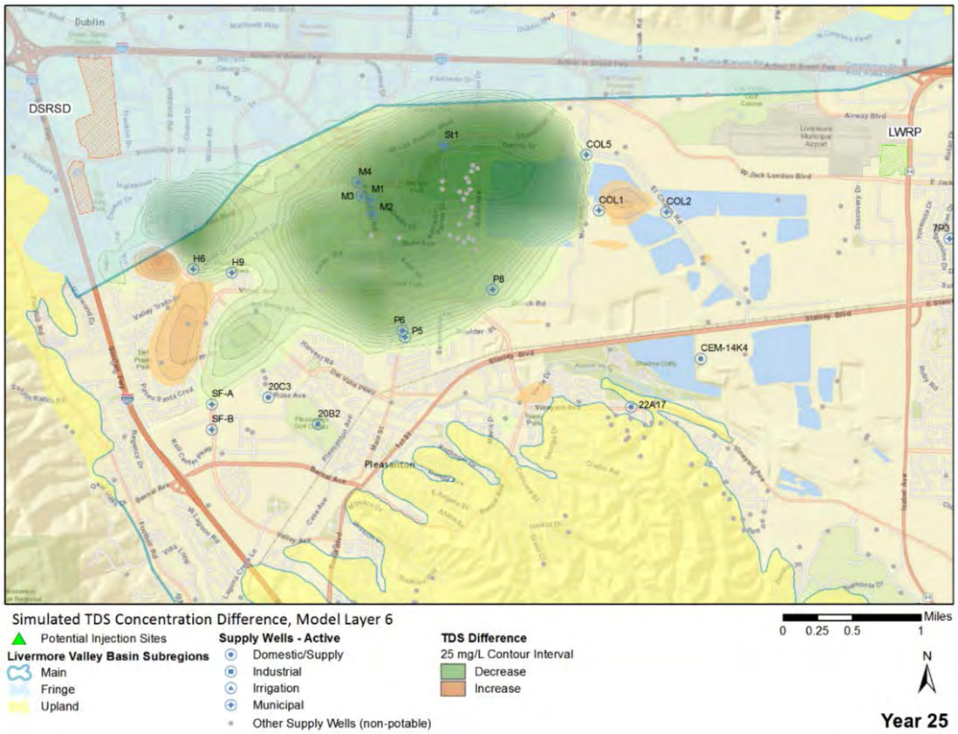


Figure 6.27 Simulated Change from Baseline TDS Concentrations in Lower Aquifer After 25 Years, 10,000 AFY in Lake I Scenario

6.3 Summary of Salt Balance Results

A summary table of the net change in TDS concentrations at the production wells at the end of the 25-year simulation period for all recharge scenarios as compared to baseline is provided in Table 6.5. Table 6.6 provides the flow-weighted average TDS concentration at the nine active Zone 7 productions wells in the simulations. Comparisons of simulated concentrations at wells COL 1 and MOCHO 2 for all five scenarios are shown in Figures 6.28 and 6.29, respectively. Production well locations are shown in Figure 6.30. Review of the modeled net change in TDS indicates that the largest increase in TDS at a production well is 50 mg/L after 25 years of injection with the Pleasanton and Chain of Lakes wells experiencing the greatest increases. For all recharge scenarios, significant water quality benefits are expected at the majority of the production wells with most benefits beginning within about 10 years after the start of recharge. Injection of 10,000 AFY at Well B produces the largest decreases in TDS at locally affected wells although due to proximity of extraction wells, this location has less basin wide benefit. In contrast, injection of 5,500 AFY at Well E produces the most widespread water quality benefits. Substantial decreases in TDS were observed in some wells for all of the recharge scenarios investigated.

The flow-weighted average concentrations shown in Table 6.6 show that, as expected, recharge of lower TDS recycled water into the groundwater basin decreases the average TDS concentrations in the basin over time. Greater decreases in TDS are observed as the annual volume of recycled water injected increases; however, Table 6.6 also shows that the location of recharge also affects the simulated changes in TDS. The largest decline in average TDS occurs with recharge of 10,000 AFY through Lake I resulting in a simulated reduction of 200 mg/L after 20 years compared to the baseline scenario. It is important to note that the TDS concentration differences shown in Tables 6.5 and 6.6 are based on modeling estimates only and are meant to illustrate relative impacts. These predictions also do not reflect changes in operations or production from each well due to new recharge projects. The concentrations of TDS may change based upon updated production. Charts of TDS trends at the production wells for all recharge scenarios are provided in Appendix C.

Localized reductions in TDS, especially near the Mocho Wells, could affect the long term efficacy of Zone 7's demineralization facility and may affect plans/need for a future second demineralization facility. While the existing demineralization facility has significant useful life left and therefore little opportunity for cost avoidance is possible, the avoidance of building the planned second demineralization facility could be a significant cost savings. The impacts to operations of these and other existing facilities need to be carefully considered when siting and implementing a project.

Table 6.5 Simulated Change from Baseline TDS Concentrations After 25 Years of Recharge

Production Well	Difference from Baseline in TDS Concentration (mg/L)			
Recharge Location	Well B	Well E	Lake I	
Recharge Volume (AFY)	10,000	5,500	5,500	10,000
COL 1	40	-90	30	40
COL 2	20	-20	10	10
COL 5	30	-350	20	30
Hopyard 6	-290	10	0	-10
Hopyard 9	-530	10	0	-10
Mocho 1	-250	-150	-230	-310
Mocho 2	-270	-150	-200	-290
Mocho 3	-310	-110	-140	-240
Mocho 4	-330	-100	-80	-170
Pleasanton 5	50	-20	-30	-80
Pleasanton 6	50	-20	-40	-100
Pleasanton 7	-400	10	10	0
Pleasanton 8	20	-20	-30	-80
Stoneridge 1	20	-200	-250	-340

Table 6.6 Flow-Weighted Average Concentrations

Scenario	Simulated TDS Concentration (mg/L)
Baseline, Initial	564
Baseline after 20 Years	588
Well B, 10,000 AFY	428
Well E, 5,500 AFY	463
Lake I, 5,500 AFY	445
Lake I, 10,000 AFY	388

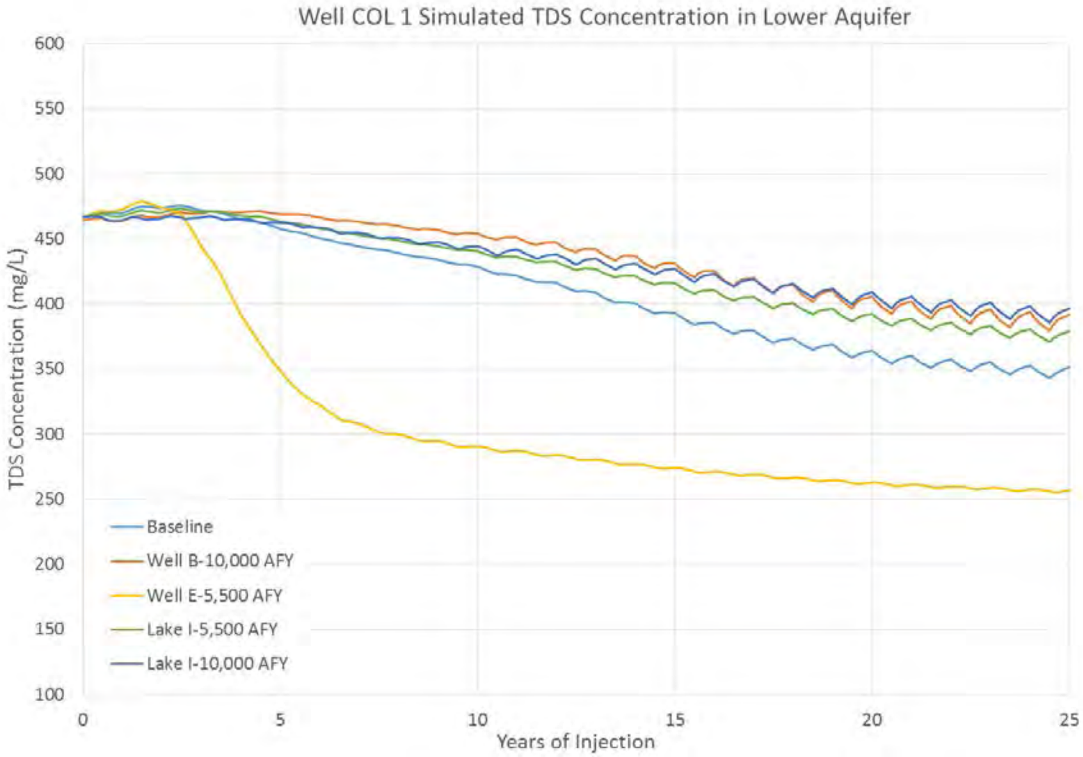


Figure 6.28 Comparison of Simulated TDS Concentrations at Well COL 1

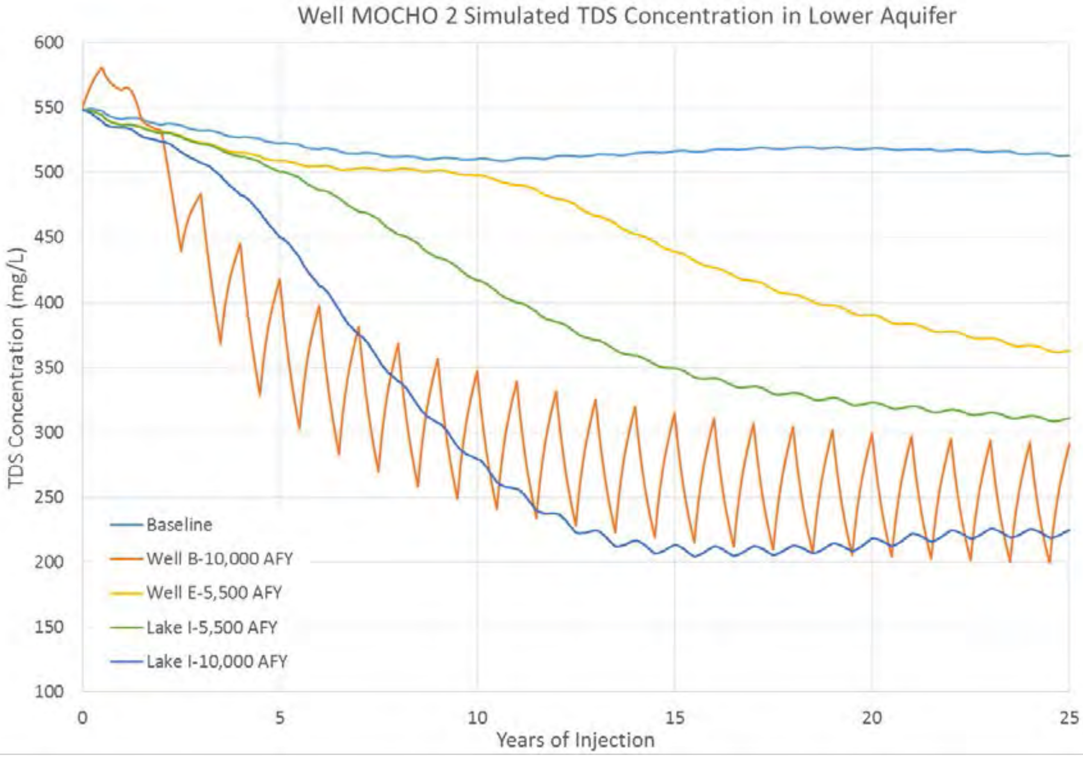


Figure 6.29 Comparison of Simulated TDS Concentrations at Well MOCHO 2

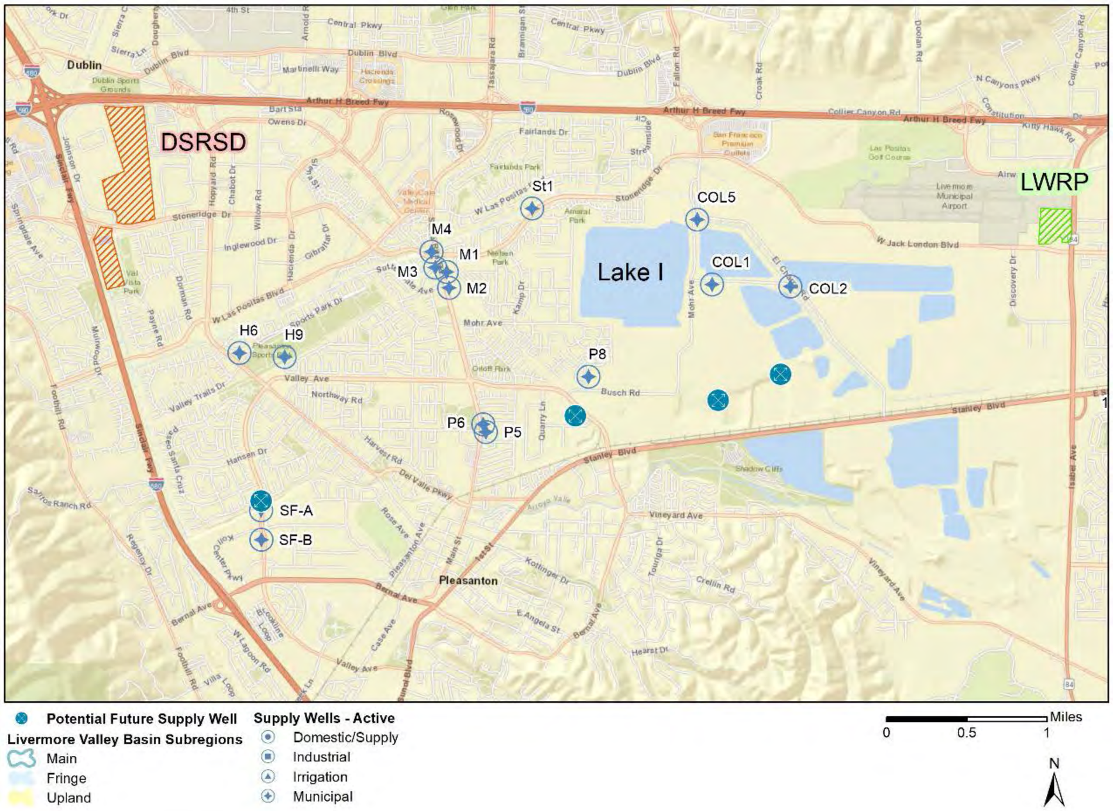


Figure 6.30 Production Well Locations

6.3.1 Basin-Average Salt Concentrations

Basin-average salt concentrations in groundwater were calculated using output from the Zone 7 Groundwater Basin Model. The model output includes simulated TDS concentrations across the groundwater basin. A basin-average concentration can be calculated from model output by calculating the total salt mass in the basin then dividing by the total volume of groundwater. The total salt mass was determined as the salt concentration in each model grid cell multiplied by the water volume in the cell, then summing the mass for all cells in the model grid. The water volume in each grid cell was calculated as the area of the cell multiplied by the layer thickness multiplied by the porosity. Similar to total salt mass, the total water volume was calculated as the sum of the water volume in all grid cells. These calculations were performed by layer, and only the primary water-bearing layers in the lower aquifer, i.e., layers 6, 8, and 10, were included. As specified in the Zone 7 Salt Management Plan, average salt concentrations were determined for the Main Basin only.

Basin-average salt concentrations are shown in Figure 6.31 for the baseline and four different groundwater augmentation scenarios. Results for all four groundwater augmentation scenarios indicate a decline in average salt concentrations relative to the baseline scenario. For the baseline scenario, the average salt concentration in the lower aquifer declines from 516 mg/L TDS to 493 mg/L after 25 years or about 4 percent decline. By comparison, declines ranged from about 7 to 9 percent for the groundwater augmentation scenarios. Figure 6.31 shows that the greatest declines in salt concentrations were observed for the Well E injection scenario. Basin-average changes in salt concentration were substantially less than the changes observed at the Zone 7 production wells which indicated declines ranging from 19 to 36 percent. These differences are expected however because the basin-average results included the entire Main Basin whereas the production wells are more centrally located within the basin and therefore were more strongly influenced by the addition of purified water.

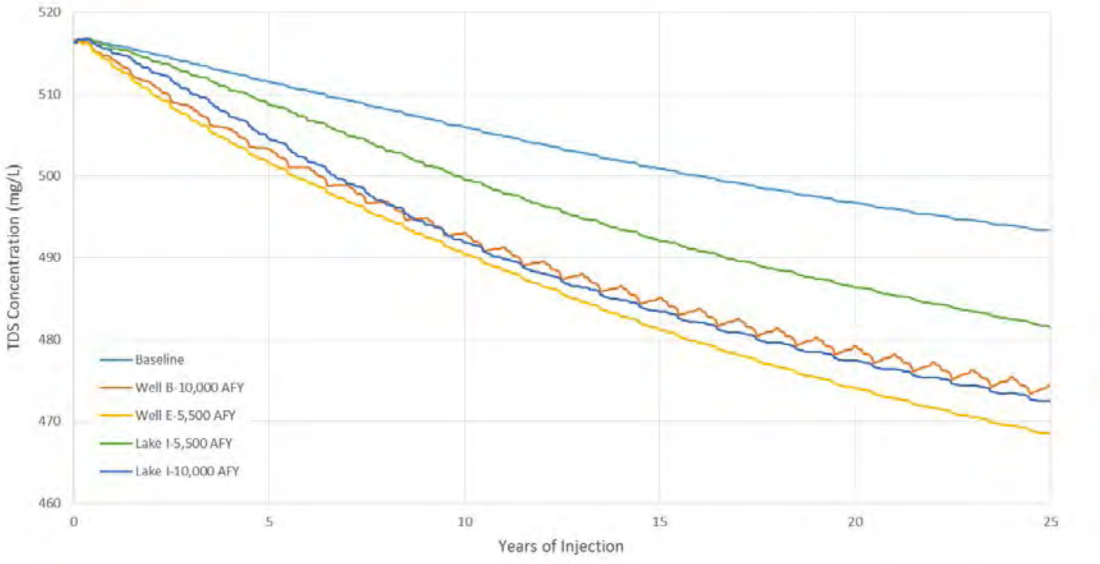


Figure 6.31 Average Salt Concentration in the Main Basin Lower Aquifer

6.4 Subsurface Water Storage Approaches

Two subsurface water storage approaches are under consideration for meeting Zone 7 goals for storage and recovery of purified water that meets all drinking water standards and other regulations for potable reuse in the state of California. One is a recharge approach in which purified recycled water would be injected into one or more sand intervals of the Lower Aquifer System. This water would then flow to downgradient production wells located at a sufficient distance so that a travel time of at least 60 to 120 days is ensured to meet potable reuse regulations. The stored water, blended with native water in the aquifer, would eventually be pumped from production wells for potable water supply. A reduction in salinity of the produced water is reasonably expected. The modeling analysis discussed previously provides an analysis of this approach.

In the other approach, known as aquifer storage and recovery or ASR, purified recycled water would be stored within one or more sand intervals of the Lower Aquifer System and recovered from the same, or adjacent, wells after storage for at least 60 to 120 days. Recovered water would then be blended with water produced from other sources for drinking water. Because of limitations of the basin-wide model, ASR was not evaluated with the model.

There are several advantages and disadvantages of each type of recharge/storage approach, as shown in Table 6.7.

Table 6.7 Recharge Project Comparisons

Recharge with Downgradient Extraction	Aquifer Storage and Recovery
Can help improve overall basin quality	Can preserve quality of injection water
Can result in mobilization of contaminants	Easier to control mobilization through formation of underground bubble of water
Can have long term clogging and maintenance of injection well	Designed to both inject and extract which may reduce clogging and allows for maintenance with in-situ equipment

As part of this study, technical input was solicited from ASR Systems. The President of ASR Systems, David Pyne, is a pioneer in ASR and groundwater recharge alternatives and has implemented groundwater recharge/ASR projects throughout the United States as well as in other countries. The following information is summarized from a Technical Memorandum prepared by ASR Systems. The complete memorandum is provided in Appendix D.

For an ASR well, the well design would likely be in one or more of the three, thick sand intervals comprising Layers 6, 8, or 10 of the Zone 7 10-layer Model. Alternatively, a cluster of three ASR wells could be constructed with one screened in each major sand interval, instead of a single ASR well in one or more sand intervals. Water stored in an ASR well would be recovered after 60 or 120 days of storage, as approved by regulatory agencies. Stored water may be recovered from the same ASR well or, depending on confining layer hydraulic characteristics, could be recovered from an adjacent layer, providing supplemental soil aquifer treatment. Recovered water would be blended as needed to meet Zone 7 needs for peak water supplies and/or for reducing salinity. Any water that is not recovered from the ASR wells, due to lateral movement of the stored water, would not be lost. It would be eventually recovered from the downgradient production wells.

For a recharge well, the well design would likely be open to all three sand intervals. Other than periodic backflushing to maintain hydraulic performance, no water would be recovered from a recharge well. Instead, it would be recovered months later at a downgradient production well. Depending on the location of recharge, the injected water may or may not reduce salinity of the produced drinking water; however it would improve the basin salinity overall.

Potential problems with either approach include well clogging and loss of injection capacity and mobilization of naturally occurring constituents in the aquifer materials into the groundwater through geochemical reactions, possibly resulting in exceedance of drinking water standards. Prior experience at Zone 7 indicates the potential for both to occur in the Livermore Valley Groundwater Basin. In 1997, arsenic, manganese, and boron were found at varying concentrations in different depth intervals in the recently constructed Hopyard 7 well, one of several planned ASR wells to be used to store surplus treated surface water. Also in 1997, Zone 7 began ASR cycle testing with surface water at well Hopyard 6. Although not originally constructed as an ASR well, the well was retrofit for ASR purposes for surface water recharge and recovery. Over a series of five ASR cycles of injection, storage, and recovery, the specific capacity (a measure of well efficiency and performance) of the well progressively declined culminating in an acute clogging event in March 2000. Insufficient data are available to determine the cause of ASR failure. Well clogging occurred, but the reasons for that are unclear, whether physical, microbial or geochemical, or some combination of these clogging mechanisms. Physical clogging due to air entrainment is likely to have been a significant factor contributing to both the acute clogging incident that occurred during March 2000 and the chronic clogging that occurred during the cycle testing program from 1997 to 2000. Air entrainment may have had a secondary effect of contributing to geochemical clogging that probably also occurred. Regardless of the reasons for this perceived failure, the results effectively dampened local enthusiasm for ASR as a potential water management tool for achieving water supply reliability.

ASR wells and recharge wells have several unique design features that differentiate them from production wells. Equipping ASR wells and recharge wells is also different when compared to production wells. For example, downhole flow control valves are typically recommended for ASR wells where cascading of recharge water may otherwise occur. This ensures a small pressure at the wellhead, regardless of the recharge flow rate, so that air entrainment does not occur. Understanding these differences is important for ensuring ASR success and to not repeat the clogging at Hopyard 6. It is important to note that for this project, the water quality is entirely different for AWPF product water versus surface water and that any future project would be designed using equipment and procedures specific to an ASR operation rather than retrofitting an existing well.

At least 500 ASR wells and about 130 ASR wellfields are currently operational in at least 20 states, plus many more in other countries. About 18 ASR wellfields and about 63 ASR wells are currently in operation in California. If implemented today, an ASR or recharge well program for Zone 7 would most likely be successful, providing water supply reliability during droughts, meeting peak demands, and reducing salinity. The best guarantee of success would be to follow a proven procedure for successful ASR or recharge wellfield development consistent with procedures developed and implemented during the past thirty years at many ASR and recharge wellfield sites, particularly at those where there has been no prior well recharge experience. The underlying principle is to develop such a project in phases, collecting reliable data, and with "go, no-go" decision points along the way. Any project working hundreds of feet below ground has inherent risks and uncertainties, but these can be managed and minimized. Such an approach is an effective way to manage risk.

Phased implementation of an ASR or recharge well test program following a proven, logical path, with facilities designed for project purposes and a commitment to obtaining necessary, reliable data would help ensure project success. Wells would be designed based upon extensive, site-specific data to guide storage interval selection, screen design, filter pack design to maximize well efficiency, and operational procedures to efficiently achieve program goals. Wellfield design and operations, such as well spacing, would be based upon a well-informed local model, based on site-specific data regarding groundwater velocities, leakage of confining layers, and pressures in different sand intervals. Wellhead facilities would be designed to maximize flow rates and thereby minimize unit operating costs. Pretreatment would be implemented if necessary to control well clogging. Unique backflushing and well development procedures would be implemented to maximize well recharge and recovery rates.

Through appropriate equipping of the wells with use of downhole control valves, air entrainment would be eliminated as a potential cause of chronic and acute well clogging and would also further reduce the potential for geochemical clogging due to calcium carbonate precipitation.

Well casing and column pipe would avoid the use of mild steel, thereby eliminating a potential source of corrosion products that can clog a well screen while stimulating microbial activity downhole. Corrosion products from mild steel also tend to increase the duration and frequency of backflushing required to maintain well performance, and the volume of backflush water that requires disposal.

A disinfectant residual would be maintained downhole at all times, not only during recharge periods but also during extended periods of no recharge and no recovery exceeding about one week. This would be achieved through a trickle flow of disinfected water during extended storage periods. Disinfection byproduct attenuation would occur during the 60-day to 120-day storage periods underground.

If needed, pretreatment of the recharge water could be implemented to reduce well clogging. This might be through pH adjustment to eliminate calcium carbonate precipitation or to avoid destabilization of clays. If bypass filter testing indicates occasional slugs of poor quality water reaching the wellhead, such as may occur due to flow reversal in a long transmission pipeline, a simple wellhead filtration system could be installed as a supplemental pretreatment device.

ASR or recharge wells would be designed and equipped to provide for efficient backflushing and redevelopment procedures, maximizing the energy available to periodically purge particulates from around the well screens and to stabilize the filter pack material for both recharge and recovery.

Due to the highly corrosive nature of RO permeate; stabilization of the purified water would be required for protection of pipelines as well as to reduce the potential for leaching of chemicals naturally present in the soils, such as arsenic. Orange County Water District has developed a stabilization mix that has been effective and continues to do research into ways to prevent leaching of chemicals into the injected recharge water (personal communication). Recent experience with ASR wells in Florida, a state with approximately 40 ASR well fields in operation, has also demonstrated that the mobilization of arsenic and other naturally occurring metals can be controlled. Mobilization control requires a proper geochemical and mineralogical study that provides the information needed to design operational procedures to maintain the stability of aquifer minerals.

6.5 Conclusions/Summary

The hydrogeologic feasibility of developing a potable reuse project with groundwater recharge was evaluated in this chapter and found to be feasible. Major findings are:

- Both Zone 7's 3-layer model and 10-layer model were used to assess feasibility and found suitable conditions for recharge operations.
- Subsurface travel times between injection sites and existing extraction wells can meet regulatory requirements through proper selection of injection sites.
- Recharge with low TDS water from an AWPF can significantly improve water quality conditions in the groundwater basin on both a local and basin-wide scale, with varying amounts of quality improvement depending on input location.

- Aquifer Storage and Recovery has been found to be effective at many other locations and provides an option to maintain control over the water quality and quantity without migration downgradient. The agencies may want to consider this option in the future.
- Methods to control mobilization of contaminants in the groundwater include stabilization of the purified water and proper geochemical and mineralogical studies once an injection location is identified.
- System wide operational modifications would be needed if a groundwater recharge project were to be implemented. Modifications to groundwater pumping and use of the groundwater supply would be needed to manage groundwater levels. Consideration of long-term system water quality would also be required with the potential for avoiding the costs to construct the second demineralization facility and to consider the best use of the existing demineralization facility.

Specific recommendations related to future hydrogeologic studies are included in Chapter 8.

6.6 References

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Chapter 7

SHORT-LISTED OPTIONS DETAILED ANALYSIS

7.1 Background

This Chapter evaluates the feasibility of the short-listed potable reuse project option(s) for the Tri-Valley. Information gathered in the prior Chapters was used in compiling the project options presented within this Chapter.

The following work was conducted to form the body of this Chapter:

- Project option reconfiguration and selection.
- Operational impact investigations.
- Development of site layouts.
- Revision of preliminary pipeline alignments.
- Concentrate management development.
- Refinement of the capital and O&M cost estimates.

7.2 Project Component Development

The three short-listed options selected in Chapter 5 were presented to the Steering Committee in a workshop in July 2017. During the presentation of alternatives at the workshop, it became apparent that the original regional facilities (at Mocho and at COL) were highly spatially constrained and would present significant construction issues. These sites were the only available alternatives at the time. However, at the meeting, representatives from the City of Pleasanton announced that their facility could be a potential third option for a regional facility. The site at Pleasanton was added, but since there was not as in depth of a site study conducted on the Pleasanton site, the option with an AWPF at Mocho was kept to provide at least one thoroughly investigated regional option.

Additionally, it was decided that both flow-based bookends (5,500 AFY and 10,00 AFY) should incorporate both a groundwater recharge via injection well option as well as a connection to surface water through the COLs. Based on this feedback from the workshop, the three projects were expanded to six options with different siting locations for each, as listed in Table 7.1. The purpose of evaluating these options is to provide the Tri-Valley Water Agencies a range of potential projects, with variations in flow, location, end use, and their corresponding costs. ***These options "book-end" the types of potable reuse combinations that may be considered in the Tri-Valley, but do not eliminate the future consideration of other options, locations, end uses or combinations/permutations of options.***

Table 7.1 Project Options for Detailed Evaluation

Option	Location	Capacity (mgd)	Source Water	Treatment Train	End Use
1a	Livermore	5	LWRP	FAT+	COL (Lake I)
1b				FAT	Well E
2a	DSRSD	12	DSRSD WWTP + LWRP	FAT+	COL (Cope Lake)/ DVWTP
2b				FAT	Well B
3	Regional at Mocho	12	DSRSD WWTP + LWRP	FAT	Well B
4	Regional at Pleasanton	12	DSRSD WWTP + LWRP	FAT+	COL (Cope Lake)/ DVWTP

Each option involves construction of an AWPF, using secondary effluent from either LWRP or DSRSD WWTP. All alternatives include either a FAT or FAT+ process train, but vary in the end use and location of the treatment train. The regulations are not fully developed yet for the raw water augmentation options so assumptions have been conservatively made regarding treatment trains with the recognition that required treatment and associated costs may be reduced in the future as regulations are finalized. Detailed development of these alternatives is discussed in Chapter 5.

7.2.1 End Uses

Three separate end uses continue to be investigated within this project: groundwater augmentation or recharge via injection wells, groundwater augmentation or recharge via surface spreading and reservoir augmentation, and raw water augmentation as defined below:

- Groundwater recharge via injection wells is where purified water is pumped into specific layers of the groundwater basin in order to supplement later extraction of groundwater for drinking water purposes.
- Groundwater recharge via surface spreading allows purified water to percolate to the groundwater basin below through maintained recharge faces. The projects that use Lake I would be considered surface spreading, with the note that Lake I is directly hydraulically connected to the aquifer and there is no intervening vadose zone for percolation and treatment as commonly found in surface spreading applications. Therefore additional treatment processes have been added (FAT+).
- Raw water augmentation is the planned placement of (purified) recycled water into a system of pipelines or aqueducts that deliver raw water to a drinking water treatment plant that provides water to a public water system.

The key difference among these uses is the amount and type of environmental buffer between the AWPF and Zone 7's treated water transmission system. The results shown within this section are based on the preliminary groundwater modeling shown in Chapter 5 and the detailed modeling in Chapter 6. For more introductory information about the end uses shown within, refer to Chapter 5.

7.2.1.1 Groundwater Recharge using Injection Wells

Through preliminary groundwater modeling and use of Zone 7's Water Supply Risk Model, it was determined that recharge of the basin appears to be both operationally and technically feasible and may have some water quality benefits. In Chapter 5, six potential groundwater injection sites (Figure 7.1) were evaluated. When forming the three short listed options, only Well B was initially selected to represent the injection scenario for the evaluation of book-end options. This site was chosen due to its proximity to the source waters (LWRP and DSRSD WWTP), travel time to nearest extraction wells (at least 2 months required by regulations), efficiency of recharge, and potential to improve the nearby groundwater that has high TDS values. As noted above, the three options were presented to the Steering Committee in a workshop in July 2017. Based on feedback from the workshop, the three selected options were expanded to six options with different siting locations for each. Based on feedback at the July 2017 workshop, Well E was added back in for a Livermore only injection well option to represent an injection well site in the eastern end of the basin and better book-end the injection options. Because the groundwater flows from east to west through the basin and pumping in the central parts of the basin occur downgradient of the site of injection, modeling of injection at Well E showed reduced TDS across a much larger area of the basin as compared to the Well B scenario.

In the initial alternative development, an injection capacity of 2.2 mgd was assumed. This value was based on the conservative assumption that injection capacity is approximately 50 percent of production capacity. However, in the more detailed analysis, a more aggressive recharge assumption of 80 percent is being used. This assumption is based upon the improved technology over the past few years, as exemplified by the City of Phoenix's ASR program, which has been running successfully since 2010 using an 80 percent injection to extraction ratio - with some wells operating up to 90 percent. With improved well technology and understanding of local hydrogeology, it is therefore feasible that the injection to extraction ratio can be increased to 80 percent, which means that the assumed capacity of each well in this study can be assumed to be 3.5 mgd. This new assumption will require a closer level of monitoring in order to track specific capacity and fine-tune operations.

7.2.1.2 Groundwater Augmentation through Lake I

Groundwater modeling revealed that recharging purified water through Lake I results in effective increase of levels throughout the nearby groundwater basin. This efficiency, combined with the ability to transfer water to and from Cope Lake and Lake H, makes Lake I a desirable end use. As was discussed in Chapter 5, since Lake I is hydraulically connected to the groundwater basin and has an increased risk of not meeting the minimum two months of subsurface travel time before reaching a production well, more advanced treatment would be required for this alternative.

7.2.1.3 Use of Cope Lake - Raw Water Augmentation of DVWTP or Reservoir Augmentation

Raw water augmentation involves adding purified water to the intake system of a water treatment plant; reservoir augmentation requires a minimum holding time within a reservoir upstream of the treatment plant. Purified water sent to DVWTP can be routed through Cope Lake (reservoir augmentation, if appropriate conditions are met below) or directly through the future COLs pipeline (raw water augmentation) (see Figure 7.2). In either case, the primary end use for the purified water is blending with raw water influent to the DVWTP.

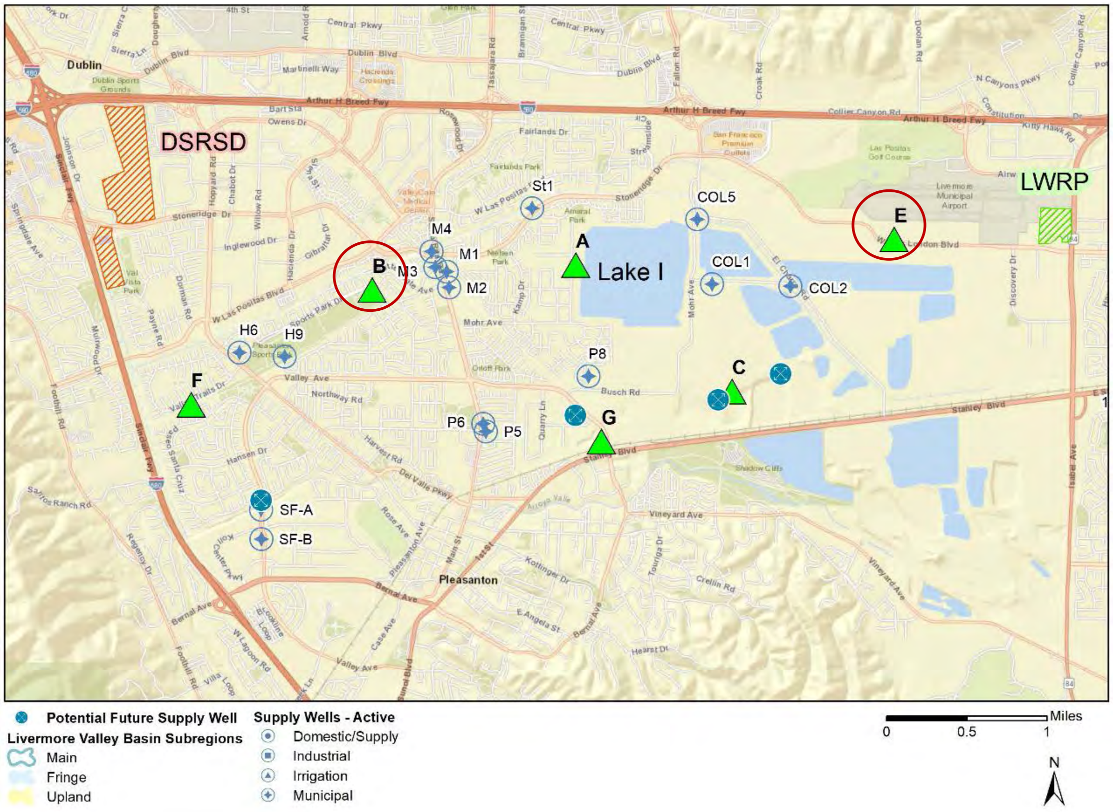


Figure 7.1 Potential Injection Locations

The final State Water Board's Surface Water Augmentation (SWA) regulations were adopted in March 2018. According to the regulations, a FAT process (instead of a more robust FAT+) is allowable if a retention time in a reservoir of 180 days can be shown. This lowered requirement would only apply to the option of an AWPF at Livermore with a product flow of 5 mgd going to Cope Lake. The following final requirements would apply to a reservoir (such as Cope Lake) in order for it to be considered in a reservoir augmentation project:

- A purified water residence time of 180 days, defined by a total volume of the reservoir divided by outflow. This value could be decreased to a minimum of 60 days. However, an additional 1-log reduction of pathogens is required.
- The reservoir must have been used as a drinking water reservoir for a recommended time of five years to establish a quality baseline before the addition of purified water. This time could be decreased to two years during discussions with the State or Regional Board.
- In operations of DVWTP, Zone 7 must ensure that the contribution of purified water within any 24-hour period to the DVWTP does not exceed 10 percent by volume. If the purified water contribution is lower than one percent consistently, then less stringent treatment requirements can be applied.

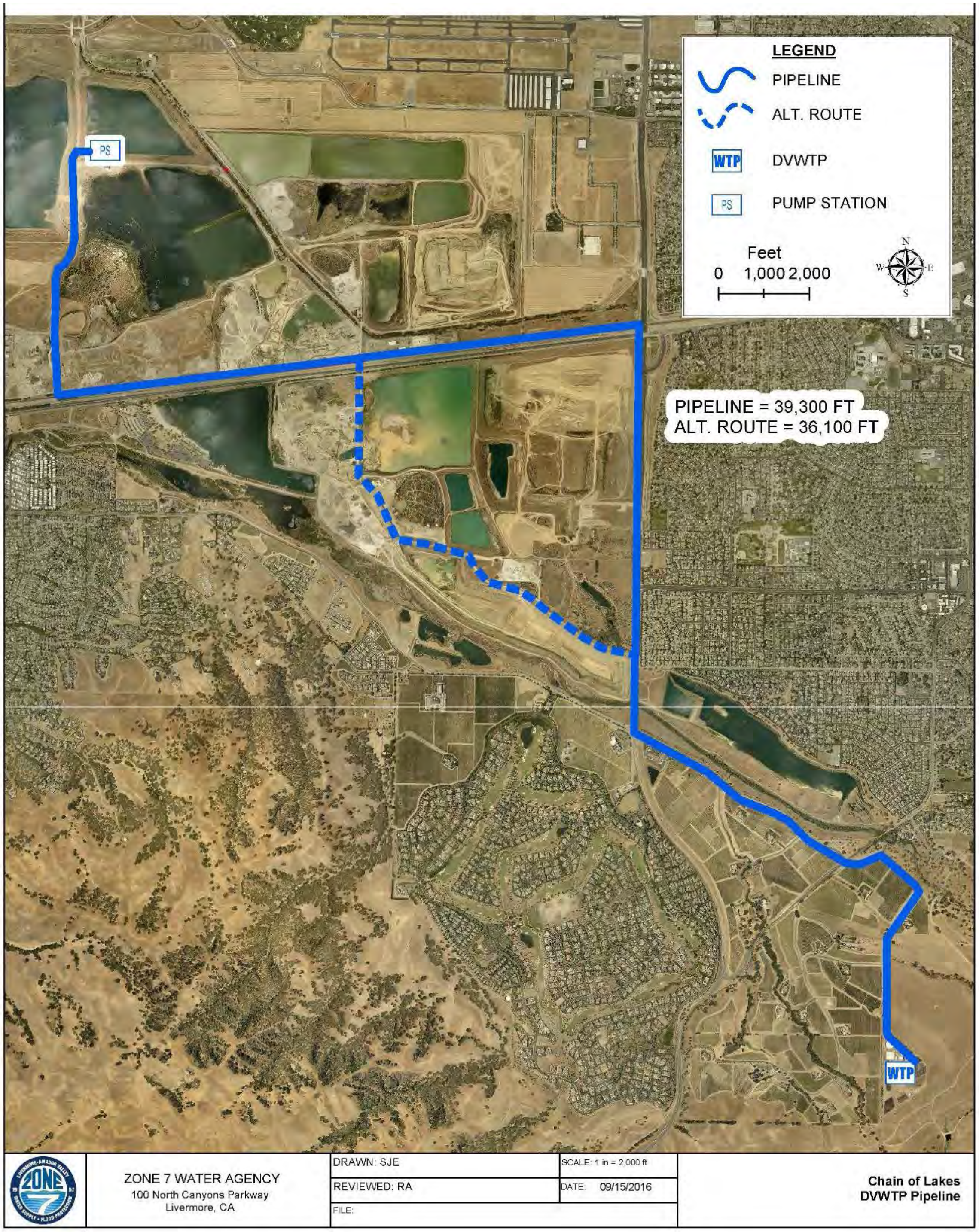


Figure 7.2 Potential Pipeline Connecting COL to DVWTP and the South Bay Aqueduct (COLs Pipeline)

Cope Lake has a capacity of approximately 4,500 AF (1,075 MG). This means that the maximum flow that it could accept and meet the 180 days minimum residence time is 6 mgd. To pursue use of Cope Lake as a reservoir, hydraulic modeling and potentially tracer studies would be needed to ensure that there is no short-circuiting in the reservoir or connectivity to wells. Additionally, all discharges and inputs into Cope Lake besides the purified water would need to be characterized to allow for calculation of the purified water contribution. If necessary, baffles might need to be installed to guarantee the residence time. Lastly, Zone 7 would need to build the COLs pipeline and operate the system for 2-5 years to establish the required baseline, or appeal to the regulatory board for an exception to this rule.

Under the current guidelines, use of Cope Lake alone would not be qualified for reservoir augmentation for flows higher than 6 mgd, unless an exception is approved by the RWQCB, in which case, additional treatment would be necessary. Use of Cope Lake is assumed to be reservoir augmentation for flows under 6 mgd and raw water augmentation for flows above 6 mgd.

Note that Cope Lake is hydraulically connected to Lake I, which has a larger storage volume; however, Lake I is directly connected to the groundwater basin. Use of the COLs for potable reuse will need to be further evaluated in the future, as other water management uses of the lakes (e.g., stormwater capture) are implemented.

7.2.2 Treatment Train Design Criteria

The treatment train requirements are based on end use and corresponding regulations. More information on technology and regulations is provided in Chapters 2 and 3. The two treatment trains being considered are:

- Full Advanced Treatment (FAT) - Microfiltration (MF), reverse osmosis (RO), and ultraviolet light advanced oxidation process (UV AOP).
- Full Advanced Treatment plus additional treatment (FAT+) - MF, RO, granular activated carbon (GAC), UV AOP, and an engineered storage buffer (ESB).

As shown in Chapter 3, these treatment trains meet the current and anticipated regulations for potable reuse in California. The process design criteria shown in this section are applicable to the selected six short-listed alternatives.

7.2.2.1 Design Flows

The amount of water available for potable reuse depends on the source water. The associated flows with each source water are shown in Table 7.2.

Table 7.2 Source Water and Design Flows

Source	Design Flow	Flow Variability
LWRP	5 mgd	Constant Year-Round
LWRP & DSRSD WWTP	12 mgd	Seasonal (12 mgd in winter months, 5 mgd in summer months)

7.2.2.2 Microfiltration (MF)

The MF system is one of the multiple barriers used in the AWPF to produce purified water. As shown in the water quality goals section the MF system is anticipated to achieve a 4-log removal of *Cryptosporidium* and *Giardia*. The MF system also serves as a pre-treatment to remove particulate matter from the feed water that would otherwise foul the RO membranes. For this study, the design criteria for the MF system for the three options are shown in the Table 7.3.

Table 7.3 Microfiltration Design Criteria

Design Criteria	5 mgd	12 mgd
Membrane Flux (gfd)	25	25
System Recovery (%)	94	94
Number of Racks	5	10
Membrane Modules Per Rack	100	100
Membrane Modules	335	814
Membrane Area per Module (ft^2)	800	800
Membrane Life (years)	5	5

7.2.2.3 Reverse Osmosis (RO)

The RO process in a potable reuse treatment train provides for removal of salt (measured as electrical conductivity (EC)), organics (measured as total organic carbon (TOC)), and pathogens. RO removes ~95 percent of incoming salt. Alongside with salt and TOC removal, RO removes trace level pollutants. Table 7.4 summarizes the RO design criteria. More detail can be found in Appendix E.

Table 7.4 Reverse Osmosis Design Criteria

Design Criteria	5 mgd	12 mgd
Membrane Flux (gfd)	12	12
System Recovery (%)	80	80
Membrane Area per Element (ft^2)	400	400
Number of Elements per Pressure Vessel	7	7
Number of Pressure Vessels per Train	54	54
Number of Pressure Vessels (Total)	145	352
Number of Trains (Total)	3	7
Membrane Life (years)	5	5

RO Concentrate Management

All potable reuse treatment trains included in this study involve RO as a key part of the process. RO is required by all current potable reuse regulations. However, RO produces a concentrate that requires treatment and/or disposal. The cost of concentrate management is not included in the cost estimate. Further studies should be developed to determine the benefits and limitations of each of the potential sites. The proposed RO concentrate disposal approach is to use the LAVWMA pipeline with final discharge via the EBDA outfall to San Francisco Bay.

RO concentrate has the potential to scale the insides of pipelines, reducing efficiency and causing extra friction. This issue can be managed with appropriate operational adjustments. While it is not anticipated to be necessary, antiscalant can be added to RO concentrate to protect the insides of pipelines. A pipe loop study would determine if antiscalant is necessary, and the appropriate doses.

Other concerns include the potential effects of discharging RO concentrate into the San Francisco Bay, specifically on the compliance of the EBDA discharge with the NPDES permit. For the discharge of RO concentrate, the critical issue for compliance is the dilution with other waters. As of 2017, enough secondary effluent from other treatment plants is being discharged within the EBDA pipeline to dilute the RO concentrate from a potential new Tri-Valley AWPF. Regardless of which Tri-Valley option is selected, as long as there is dilution from other EBDA participants' continued discharge, at the current rates the RO concentrate is not anticipated to cause an exceedance of the EBDA NPDES permit, as shown in Chapter 4. However, if other dischargers decide to pursue reuse projects or significantly reduce their effluent discharge, it may be necessary to implement a concentrate management project or update the NPDES permit (e.g., changing to mass-based limits or obtaining higher effluent limits based on higher dilution credits). There are several options for concentrate management:

- Third-stage RO to increase recovery and reduce concentrate stream moving toward a zero liquid discharge (or not using outfall but instead moving toward land disposal).
- Concentrate softening to produce calcium carbonate pellets, which can be disposed of or sold.
- Deep well injection.
- Evaporation pond.
- Land application.

Some of these options are not feasible for the Tri-Valley Area due to lack of land or an unfavorable groundwater structure. Of these alternatives, concentrate softening seems to be promising, if expensive. It has been successfully implemented with the Chino II Desalter located in Jurupa Valley, CA. These options will need to be further evaluated in the future.

7.2.2.4 Granular Activated Carbon (GAC)

GAC provides a polishing step after the RO process. It also provides an additional barrier for an FAT+ process in case of a chemical spike through the RO. It can quench the chloramines, which are added before the RO process to prevent fouling. Presence of excess chloramine could adversely affect operation of the UV/AOP system by exerting additional demand for chlorine (NaOCl). Table 7.5 shows the design criteria for the GAC system.

Table 7.5 Granular Activated Carbon Design Criteria

Design Criteria	5 mgd	12 mgd
System Configuration	Single Pass	Single Pass
Loading Rate	6 gpm/sf	6 gpm/sf
Carbon per Vessel	20,000 lbs	20,000 lbs
Number of Vessels	5	12

7.2.2.5 Ultraviolet Light / Advanced Oxidation Processes (UV AOP)

UV process provides for a high level of disinfection. Adding an oxidant before a high dose UV results in the generation of hydroxyl radicals during treatment, providing an advanced oxidation process (AOP). The UV AOP provides destruction of a range of pollutants that may pass through RO. Either hydrogen peroxide (H_2O_2) or sodium hypochlorite (NaOCl) can be used as an oxidant for this application. H_2O_2 is a more common oxidant than NaOCl for UV AOP applications. NaOCl presents benefits such as increased disinfection due to the presence of free chlorine, lower chemical cost, and operator familiarity. An additional benefit of the UV/NaOCl AOP is a more efficient generation of hydroxyl radicals at a low pH (<6), and RO permeate is typically in this pH range. Both the NaOCl and H_2O_2 UV advanced oxidation processes are controlled by oxidant dose and UV dose (UV intensity, UV Transmittance, or Power). However, the NaOCl UV process is also controlled by the influent pH to the UV reactor and is sensitive to ammonia residual through the RO process, which has a high NaOCl demand, thereby requiring a higher oxidant dose. Free chlorine concentration and pH should be closely monitored to ensure the UV AOP design dose is met. Design criteria for the UV AOP are presented in Table 7.6.

Table 7.6 UV/AOP Design Criteria

Design Criteria	5 mgd	12 mgd
Number of Reactors (1 Redundant)	3	8
UV Lamps (Duty)	408	972
UV Lamps Replaced per Year	255	608
UV Replacement Frequency (years)	1.6	1.6
UV Ballast	41	97
UV Ballast Replacement Frequency (years)	1	1
UV Sleeves	408	972
UV Sleeves Replacement Frequency (years)	20	49
Oxidant	NaOCl	NaOCl
Oxidant Dose (mg/L)	3	3

7.2.2.6 Engineered Storage Buffer (ESB)

An ESB is a series of three holding tanks which operate in a filling, holding, distributing cycle to allow time for monitoring and reacting to any potential issues in the upstream processes. The ESB not only replaces the environmental buffer with a more sterile environment but also provides additional contact time for disinfection. The design criteria for the ESBs are shown in Table 7.7.

Table 7.7 Engineered Storage Buffer Design Criteria

Design Criteria	5 mgd	12 mgd
Hold Time	30 min	30 min
Number of Tanks	3	3
Volume (each)	110,000 gal	250,000 gal
Diameter	35 ft	50 ft
Height	17 ft	19 ft
Freeboard	2 ft	2 ft

7.2.2.7 Post-Treatment

Water that is processed through an FAT or FAT+ treatment train has very low amount of minerals, TDS, and alkalinity in the water. Essentially, the water is so pure that it is aggressive or corrosive, which means that it could leach metals and minerals from the soils. It is necessary, therefore to stabilize the water after treatment, through decarbonation towers and lime addition. The decarbonation serves to remove excess dissolved carbon dioxide, increasing the pH of the water and decreasing the corrosiveness. The addition of lime helps to raise the alkalinity and hardness. These steps combine to stabilize the water and prevent corrosion of pipelines and leaching of metals in the aquifer. Soil column tests, using injection site specific cores, would be recommended to determine the appropriate level of stabilization required.

7.2.2.8 Staffing Assumptions

Due to the highly technical processes and high level of monitoring required, it is anticipated that the AWPF must be staffed 24 hours a day. An expected breakdown of the staffing requirements is shown in Table 7.8. A total of 16 full time employees or contractors are expected to be needed. O&M costs presented later on in the Chapter are based on the assumption of hiring a staff of 16. The costs associated with this value do not assume any "sharing" of staff with Livermore, DSRSD, and/or Zone 7, although this could be an option to reduce costs and should be evaluated in future evaluations. Depending on the project chosen and the amount of residence time in the environment, it may be possible to incorporate a higher amount of automation in exchange for a lower staffing requirement. This adjustment would be the result of discussions with DDW during project permitting. A detailed staffing memo is included in Appendix F.

Table 7.8 Staffing Summary

Staff Title	Number
Grade V	1
Grade III	5
Grade II	5
Mechanics	1
Electrician	1
Instrument Tech	1
Lab Tech	1
Admin	1
Total	**16**

7.2.2.9 Administrative Building

An operational/administrative building is needed to provide facilities for these staff members. In addition to an admin building, the Tri-Valley Agencies expressed interest in having a learning center or a place where members of the community could gather and learn about the AWPF. Additionally, a well-equipped laboratory would be necessary to meet the advanced monitoring requirements for the facility. This operations/administrative building was estimated to require approximately 7,000 square feet. This footprint includes office spaces, break rooms, facilities for staff, a small visitor center, as well as a small well-equipped lab. The lab would be equipped to handle the expected daily monitoring requirements, but weekly and monthly compliance samples may have to be sent to an outside lab. Future evaluations should consider whether existing labs (e.g., Zone 7's Water Quality Lab) could handle the additional workload from a potable reuse facility.

7.2.2.10 Footprint

These treatment processes are expected to require approximately 2.5 or 5 acres, for a 5 mgd and 12 mgd facility, respectively. A smaller footprint could be accommodated with a multi-story process building or creative repurposing of existing facilities.

7.2.3 Advanced Water Purification Facility Location

The proposed AWPF locations were chosen based on the ease of conveying the secondary effluent from the two water sources as well as distance to the proposed end uses. Three sites were selected from the initial set of four locations – LWRP, DSRSD WWTP, and a regional location at Mocho. A fourth site, a second regional location, was proffered in the July 2017 workshop, the City of Pleasanton Corp Yard. These locations provided a variety of potential options for consideration, supporting the book-end approach, but does not preclude consideration of other options in the future. A more detailed description of the sites and other considered sites can be found in the Site Memos delivered after the visits (Appendix G).

The four potential purification facility locations are highlighted in Figure 7.3 and are discussed in the following sections.

7.2.3.1 Alternative 1 - LWRP Site Location

The preferred location for the AWPF at the LWRP is the abandoned facultative sludge lagoons (FSLs) site located in the southwest edge of the LWRP (Figure 7.4 and Figure 7.5). Approximately 150,000 square feet (3.5 acres) of space is available if the three FSLs are drained and reclaimed. The two northern lagoons have already been dredged. However, the larger lagoon will need to be dredged and reclaimed. The solids from the smaller ponds were dewatered and hauled off without any disposal restrictions due to metals or contamination. Therefore, no restrictions are anticipated for the larger pond reclamation/solids removal. Currently, all lagoons have a reclaimed water cap, which will need to be drained. Additionally, the site should be leveled during construction.

Benefits of this site include the ability to repurpose the FSLs, visibility and ease of access for public, and the availability of utilities near the site (potable and fire water, process water, and fiber optic for SCADA system). The switchgear at the LWRP has enough electrical capacity for the predicted AWPF electrical loads. However, it is assumed that the AWPF will have its own dedicated power supply. More details about the LWRP site visit can be found in Appendix G.

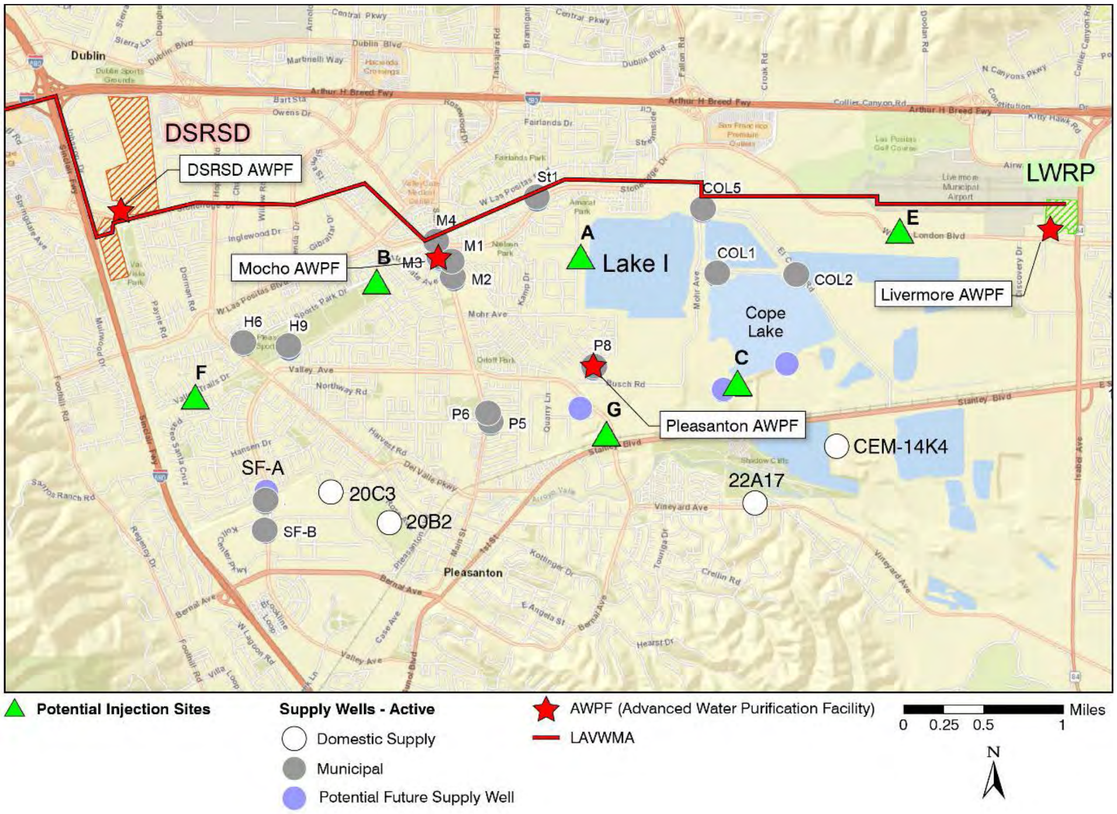


Figure 7.3 Four Potential Purification Facility Locations

Figure 7.4 Abandoned Facultative Sludge Lagoons

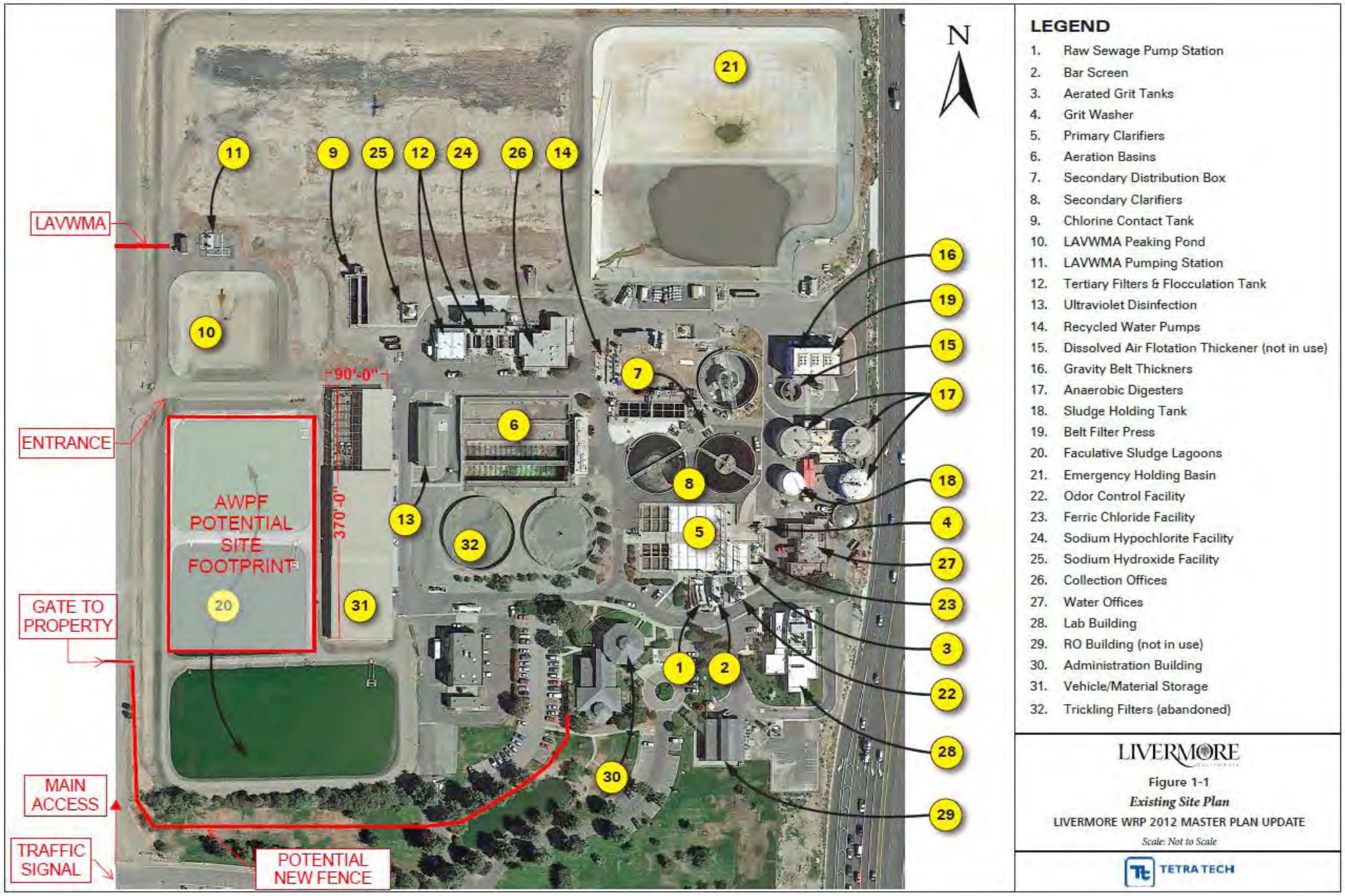


Figure 7.5 LWRP Site Map

7.2.3.2 Alternative 2 - DSRSD WWTP Location

The best location for the AWPF identified during the site visit to the DSRSD WWTP was the southwestern corner of the dedicated land disposal area (DLD, Site 3, Figure 7.6, Figure 7.7). The total DLD area is approximately 55 acres. The AWPF is anticipated to need about 5 acres. Use of this site requires decommissioning a portion of DSRSD's existing solids handling process. The site is accessible, both for visitors and deliveries. The road next to the site, Johnson Drive will be widened in the near future to accommodate planned development projects. To bring water to the site, a pump station would need to be installed at the LAVWMA facilities. This takes advantage of the equalization available in the LAVWMA ponds. Alternatively, the nearby 27-inch Livermore effluent pipeline and 42-inch DSRSD effluent pipelines could be tapped to bring water to the site; however, a new tank would be needed to provide equalization.

Since the AWPF would remove a portion of DSRSD's solids handling capacity, compensation may need to be provided to allow DSRSD to transition to mechanical dewatering or other solids handling adjustments. Mechanical dewatering could increase the solids percentage from three to six percent and therefore, reduce the area needed for land application.

To keep stormwater runoff contained on the DLDs, the entire site was constructed about 10 feet below grade. Construction of a new AWPF 10 feet below grade is not ideal for access. Solutions to this limitation could include raising the site or re-grading the site. For the purposes of this study, it is assumed the AWPF site will be raised 5 feet above the DLD levels. A new drainage plan for the site would be needed to keep runoff within the DLD boundaries for compliance with DSRSD's NPDES permit.

There is the potential to repurpose DSRSD's existing MF/RO building (Figure 7.8) for at least the MF membranes. However, splitting operations of the advanced treatment facilities is not ideal, so a cost-benefit analysis should be conducted before pursuit of this option. Layouts and costs for this option assume all treatment in one location.

A site visit was conducted by the project team. The write-up of this visit and more site details can be found in Appendix G.

7.2.3.3 Alternative 3 - Mocho Well Location

An alternate location for the AWPF is at the Mocho Well site (Figure 7.9) south of the Zone 7 Mocho Groundwater Demineralization Facility. The site contains two parcels, one owned by the City of Pleasanton, and one owned by DSRSD. In addition to the two owners, Zone 7 has several easements on the property, one of which includes a drinking water well and a disinfection building. The available space is approximately 74,000 square feet (1.7 acres). This site would provide high visibility of the project, being located on major roads. All relevant utilities are available because of the existing well facilities on the Mocho site. It should be determined if these utilities can be expanded to meet the AWPF needs. Regarding the electrical needs, an electrical power sharing agreement may potentially be arranged with Zone 7, depending on the ultimate ownership of the AWPF. Despite the convenient location from a utilities perspective, the site availability is limited to 1.7 acres (only about 70 percent of 2.5 acre site is useable). A two-story process building would be required to fit a large facility on the site.

The existing building also poses a constructability challenge; while the building could potentially be moved, Zone 7 prefers not to relocate the extraction well contained within the building.

Figure 7.6 DSRSD Site Layout with Potential AWPF Locations

Figure 7.7 View of Access Road from the Dedicated Land Disposal (DLD) area

Figure 7.8 DSRSD Microfiltration (MF) Building

Figure 7.9 Mocho Well Site Potential AWPF Location

Additionally there are several pipelines and easements which crisscross the site - one of which is a high-pressure petroleum line (Figure 7.10). Other considerations include the surrounding residential development, the presence of the Iron Horse Trial, and the park/open space that exist there presently. More information about the Mocho site is included in Appendix G.

7.2.3.4 Alternative 4 - Pleasanton Corp Yard

In the July 2017 workshop, when the short-listed options were presented, a fourth location was presented to the project team - the Pleasanton Corp Yard. Representatives from the City of Pleasanton mentioned that many buildings on the site were going to be replaced and potentially moved. If this occurred, there would be sufficient space to fit an AWPF. Additionally, the site is relatively close to the Chain of Lakes, which would reduce the purified water pumping requirement.

However, the Pleasanton site is not close to either WWTP, so source water pipelines and corresponding concentrate pumping would be necessary to bring water to and from the site.

The entire site includes both City of Pleasanton Facilities as well as a training ground for police and firefighters (Figure 7.11Figure 7.). The City of Pleasanton facilities could be rearranged potentially; however, the police and firefighter training ground would not be moveable.

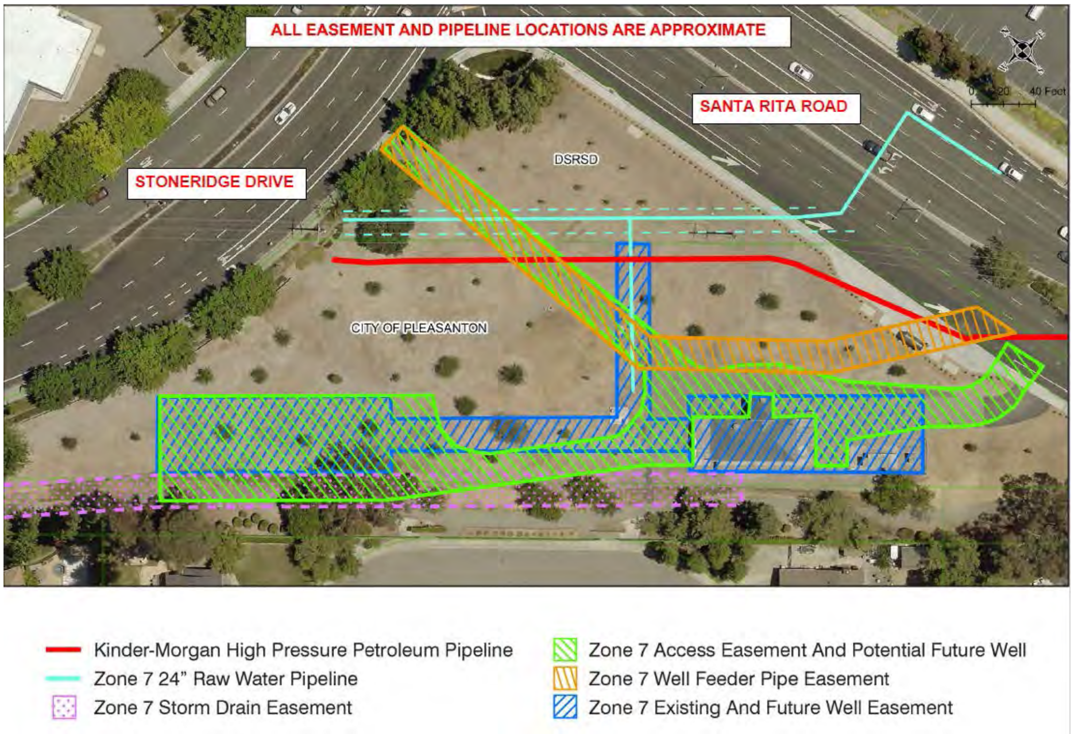


Figure 7.10 Existing Easements on Mocho Well Location

Figure 7.11 Pleasanton Corp Yard

7.3 Detailed Project Discussion

The identified alternatives were chosen to give a wide range of feasible projects, covering the spectrum of end uses and treatment locations. Six project options were selected for further investigation, including the three alternatives chosen during Workshop 3. They are listed below and in Table 5.1:

- Option 1a - Year-Round 5 mgd Livermore AWPF to COL/Lake I Recharge.
- Option 1b - Year-Round 5 mgd Livermore AWPF to Well E Injection.
- Option 2a - Seasonal 12 mgd DSRSD AWPF to COL/DVWTP.
- Option 2b - Seasonal 12 mgd DSRSD AWPF to Well B Injection.
- Option 3 - Seasonal 12 mgd Mocho AWPF to Well B Injection.
- Option 4 - Seasonal 12 mgd Pleasanton AWPF to COL/DVWTP.

7.3.1 Option 1a - Year-Round 5 mgd Livermore AWPF to COL/Lake I Recharge

This option involves FAT+ at the LWRP and conveyance to Lake I recharge. Because of the existing connection between Lake I and Cope Lake as well as the planned connection between the COLs and the DVWTP (via the future COLs pipeline), this alternative also incorporates the flexibility to route flows from Lake I to either Cope Lake or to DVWTP via the COL pipeline (costs are included for the upsized pump station for the connection to DVWTP). Option 1 was selected due to its low capital cost and relatively low unit cost. However, the low capital cost is due to the lower yield of 5,500 AFY of product water. From a regulatory perspective, recharging Lake I does not qualify as reservoir augmentation since its primary purpose is groundwater recharge. However, some water from Lake I/Cope Lake could be sent to DVWTP in emergency situations, which could be considered reservoir augmentation or raw water augmentation, depending on amount of hold time allowed; this type of use would need to be vetted with DDW and may require a special exemption. Lake I does not have enough travel time to fully qualify for the groundwater recharge regulations for potable reuse. This scenario poses an interesting regulatory issue, which could be resolved with the additional treatment explained earlier.

Another potential end use from an AWPF at Livermore, is to convey purified water to the Arroyo Mocho for groundwater recharge. As shown in Figure 7.12, this end use would require a pipeline from the Livermore AWPF to the Arroyo Mocho, with the closest location being south of the LWRP in the vicinity of Arroyo Mocho crossing and Isabel Avenue. Zone 7 conducts artificial recharge with South Bay Aqueduct (SBA) water along this reach of the Arroyo Mocho, taking advantage of available SBA water and available capacity in the Arroyo Mocho. Conveyance of purified water to the Arroyo Mocho for recharge is not considered a standalone end use because of potential capacity limitations. On a seasonal basis, Zone 7 may take advantage of all or nearly all of the Arroyo Mocho capacity for recharge of SBA water. However, by coordinating purified water recharge and recharge of SBA water, there is potential to recharge purified water via the Arroyo Mocho during some portion of the year and to utilize an alternative end use (such as Lake I recharge or Well E injection) when capacity is not available in the Arroyo Mocho. To maximize water supply, Zone 7 could also store excess SBA water in Semitropic, making the Arroyo Mocho capacity available for purified water. Combining purified water recharge via the Arroyo Mocho provides some potential advantages with respect to operational flexibility, public perception (i.e. subsurface environmental buffer) and environmental benefits (additional in-stream flow in the Arroyo Mocho when needed). Should a project move forward with an AWPF located at

Livermore, this option could be considered further; costs to discharge into the Arroyo Mocho are not included in this version of the project cost estimate.

7.3.1.1 Pipeline Alignments

The pipeline from the Livermore AWPF to Lake I is shown in Figure 7.12. It has a nominal diameter of 18 inches and is approximately 16,000 lineal feet (LF). In Workshop 3, it was mentioned that there is an unused 12-inch recycled water pipeline that also follows Jack London Boulevard. While this line is smaller than what is required, it may be possible to repurpose this pipeline. Additionally, it may be possible to use a portion of the LAVWMA line easement or pipeline to convey purified water, either repurposing the line or adding an additional pipeline within the existing LAVWMA line. A more detailed hydraulic and regulatory assessment should be conducted before determining if it is possible to use either pipeline, especially considering the need for peak wet weather flow conveyance in the LAVWMA line. Current pipeline requirements are shown in Table 7.9. These requirements assume new pipelines and no use of existing lines.

Table 7.9 Livermore AWPF to COL Infrastructure Requirements

Item	Unit	Value
Source Water Pipeline		
Diameter	in	20
Length	LF	200
Pumping Requirement	hp	0
Concentrate/Waste Pipeline		
Diameter	in	10
Length	LF	300
Pumping Requirement	hp	20
Purified Water Pipeline		
Diameter	in	18
Length	LF	16,000
Pumping Requirement	hp	190

Notes:
(1) Pumping requirement based on a 70% pump efficiency.

7.3.1.2 Layout

A layout for the Livermore AWPF is shown in Figure 7.13, and Figure 7.14.

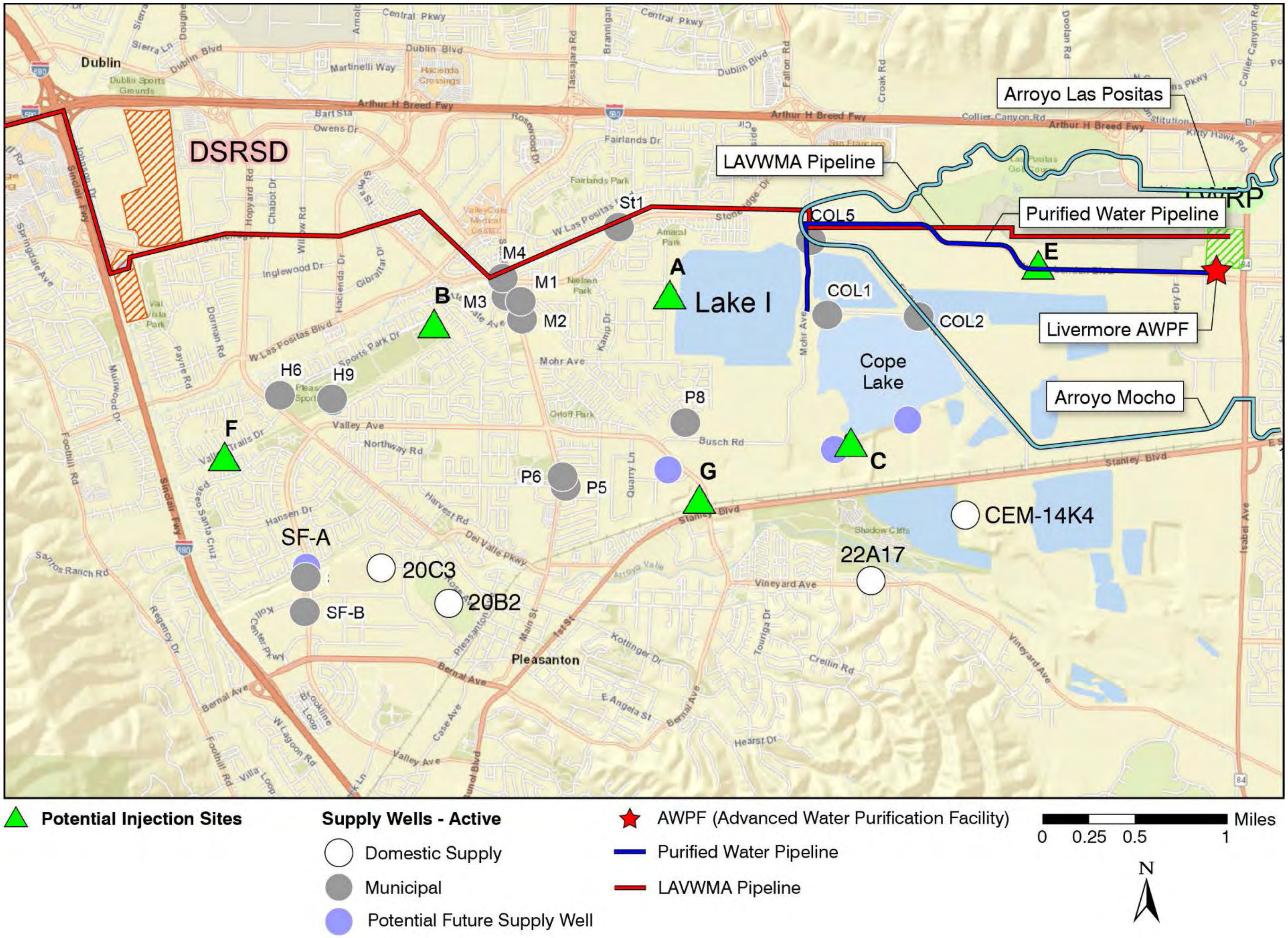


Figure 7.12 Livermore AWPF to COL

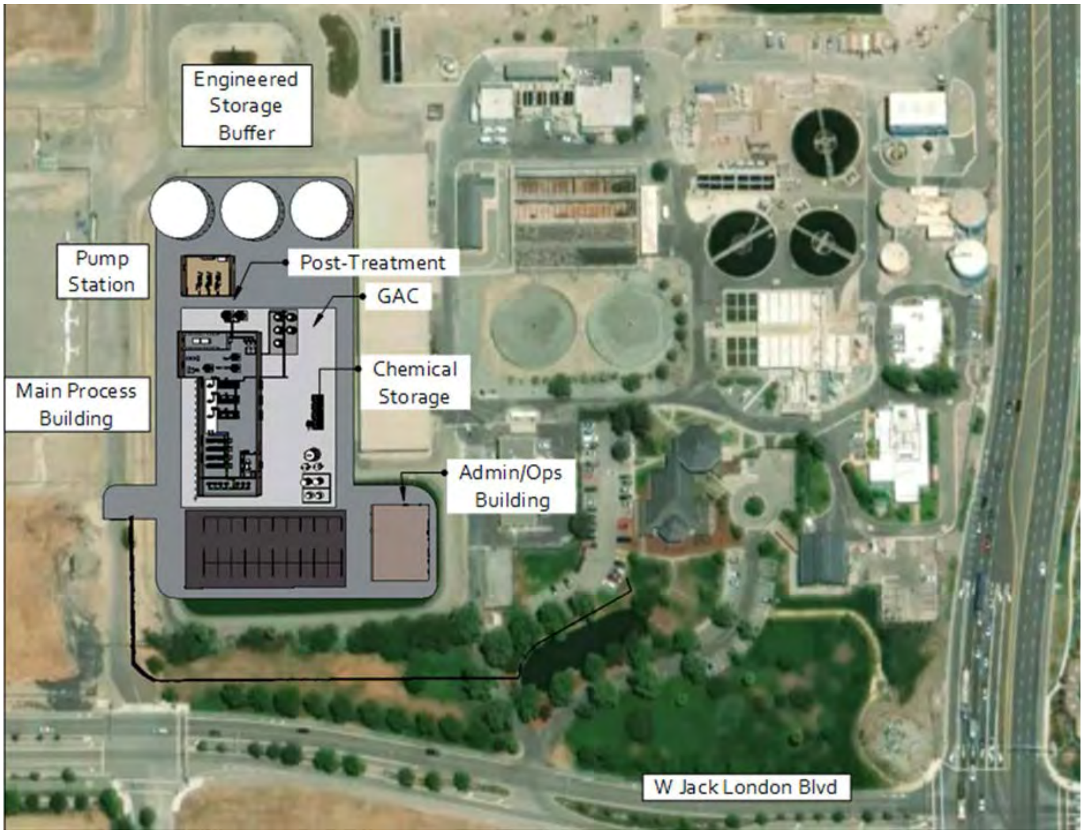


Figure 7.13 Livermore AWPF Layout - Top View

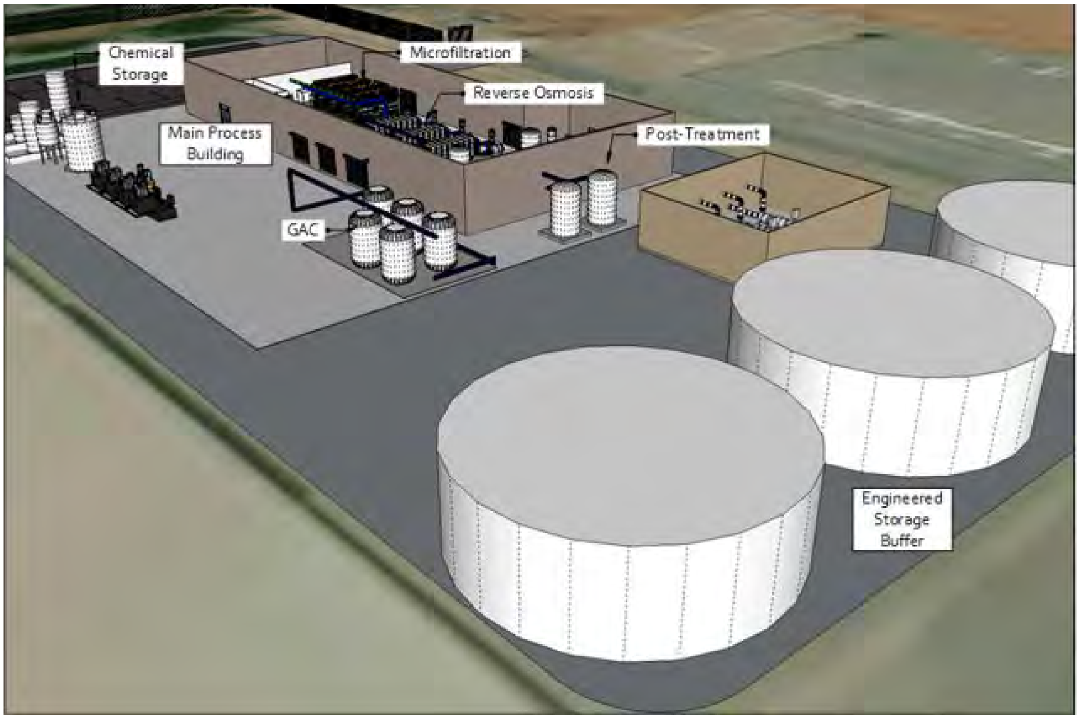


Figure 7.14 Livermore AWPF Layout (Iso View)

7.3.2 Option 1b - Year-Round 5 mgd Livermore AWPF to Well E Injection

This option involves FAT at the LWRP and conveyance to Well E Injection area (Figure 7.15). This option was added to explore a less expensive alternative due to lower treatment requirement (no ESB or GAC). Additionally, since regulations are fully in place for this type of potable reuse, the implementation process will likely be simpler and require less time. This option also provides the opportunity to evaluate impacts of injection in another part of the basin. ASR at this well injection site is a potential option in the future, if desired, depending on site conditions.

As discussed in Option 1a, another potential end use from an AWPF at Livermore, is to convey purified water to the Arroyo Mocho for groundwater recharge (see Figure 7.12). In this case, recharge purified water via the Arroyo Mocho could be conducted when capacity is available, and conveyed to Well E for groundwater injection when capacity is not available. Recharge of purified water via the Arroyo Mocho provides some potential advantages with respect to operational flexibility, public perception (i.e. subsurface environmental buffer) and environmental benefits (additional in-stream flow in the Arroyo Mocho when needed). In addition, there is potential for reduced O&M costs by eliminating injection well pumping during the portion of the year when purified water is conveyed to the Arroyo Mocho. The cost to bring a pipeline to the Arroyo Mocho is not included in the current project cost estimate.

7.3.2.1 Pipeline Alignments

The source water pipeline is approximately 200 feet, with no additional pumping necessary. The purified water pipeline is almost 10,000 LF shorter than Option 1a, although an extension to the COLs could be considered in the future. The current infrastructure requirements are shown in Table 7.10.

Table 7.10 Livermore AWPF to Well E Infrastructure Requirements

Item	Unit	Value
Source Water Pipeline		
Diameter	in	20
Length	LF	200
Pumping Requirement	hp	0
Concentrate/Waste Pipeline		
Diameter	in	10
Length	LF	300
Pumping Requirement	hp	20
Purified Water Pipeline		
Diameter	in	18
Length	LF	6,500
Pumping Requirement	hp	130
Injection Well	No.	2
Monitoring Well	No.	4

Notes:
(1) Pumping requirement based on a 70% pump efficiency.

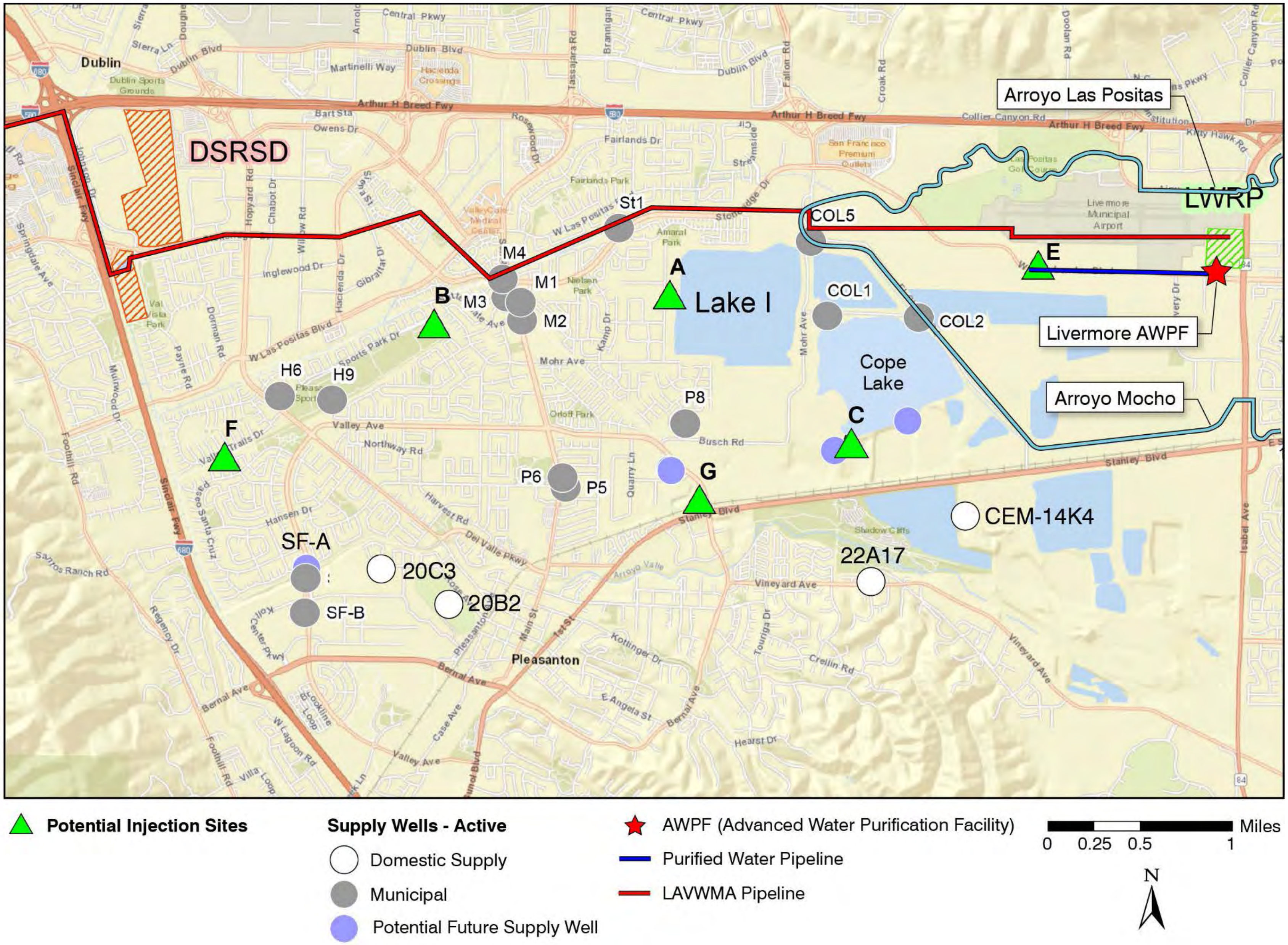


Figure 7.15 Livermore AWPF to Well E

7.3.2.2 Layout

A layout for the Livermore AWPF is shown in Figure 7.16 and Figure 7.17.

Figure 7.16 Livermore FAT AWPF Layout

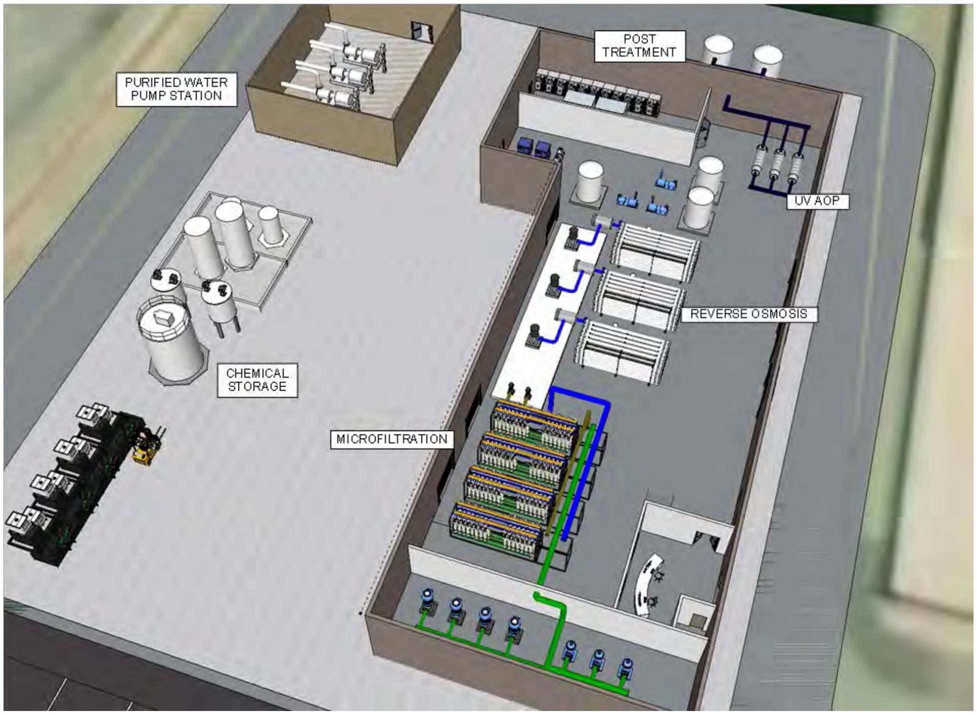


Figure 7.17 Livermore FAT AWPF Layout (Side View)

7.3.3 Option 2a - Seasonal 12 mgd DSRSD AWPF to COL/DVWTP

This option involves FAT+ at DSRSD and conveyance to DVWTP via Cope Lake for raw water augmentation, as shown in Figure 7.18. Given the connectivity of the COLs, this alternative incorporates the flexibility to convey water to Lake I for recharge as well, which will be useful to provide flexible operations. This option was selected based on the high yield (10,000 AFY), and the flexibility it provides to incorporate raw water augmentation (primarily) and groundwater recharge. The yield is achieved through seasonal treatment. However, it is recognized that there is some additional operational complexity involved with seasonal treatment.

7.3.3.1 Pipeline Alignments

Source water could be brought either from the LAVWMA system (approx. 1,000 LF away) or the two parallel wastewater effluent pipelines could be tapped to bring water to the treatment facility. In this study, it is assumed that the water comes from LAVWMA, where the ponds can provide equalization of variable flows. Concentrate would be returned to the LAVWMA effluent pump station. The 30-inch purified water pipeline to Cope Lake is approximately 23,000 LF. Infrastructure requirements are shown in Table 7.11.

Table 7.11 DSRSD AWPF to COL/DVWTP Infrastructure Requirements

Item	Unit	Value
Source Water Pipeline		
Diameter	in	30
Length	LF	1,000
Pumping Requirement	hp	275
Concentrate/Waste Pipeline		
Diameter	in	16
Length	LF	1,500
Pumping Requirement	hp	40
Purified Water Pipeline		
Diameter	in	30
Length	LF	23,000
Pumping Requirement	hp	690

Notes:
(1) Pumping requirement based on a 70% pump efficiency.

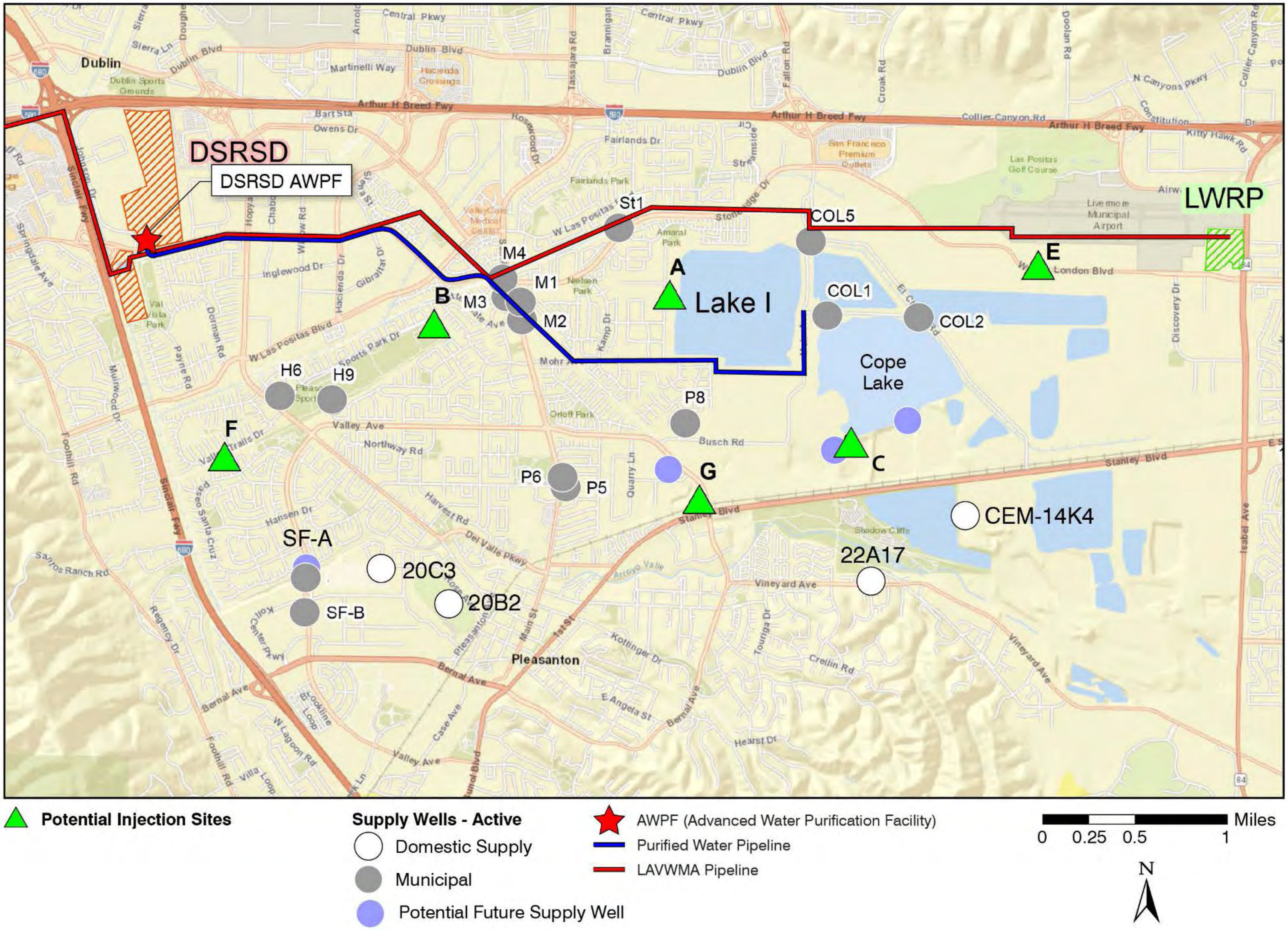


Figure 7.18 DSRSD AWPF to COL/DVWTP Overview

7.3.3.2 Layout

The layout for the potential FAT+ AWPF is shown in Figures 7.19, 7.20 and 7.21. The site occupies approximately five acres of the existing DLDs. This corresponds to about 10 percent of the DLDs. In return for use of the land, DSRSD may need to be compensated for the loss of 10 percent of their solids disposal mechanisms. In DSRSD's 2017 Wastewater Treatment and Biosolids Facilities Master Plan, several alternative solids handling and disposal alternatives were evaluated. The most promising alternative - mechanical dewatering of a portion of FSL solids for offsite disposal in winter - was chosen as the most viable option. For this analysis, the cost of using 10 percent of the DLDs includes 10 percent of the costs to implement the alternative solids handling project ($14,600,000 total construction for the whole project; a value of $1,460,000 is used for this project cost).

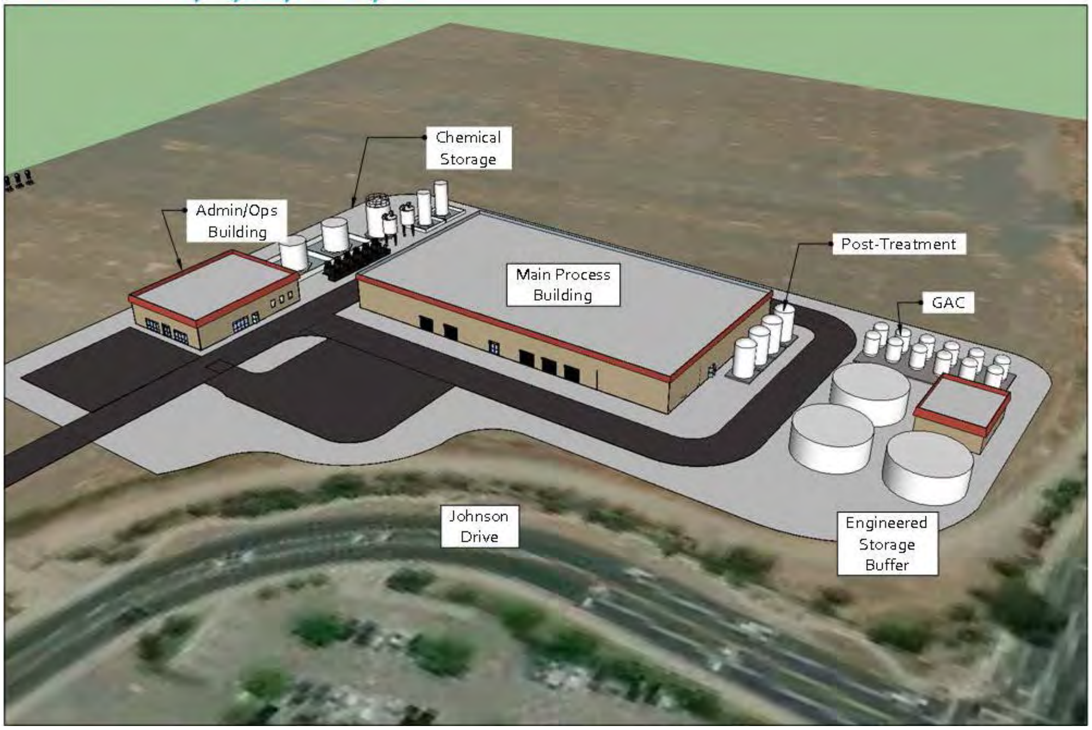


Figure 7.19 DSRSD AWPF Layout (Far View)

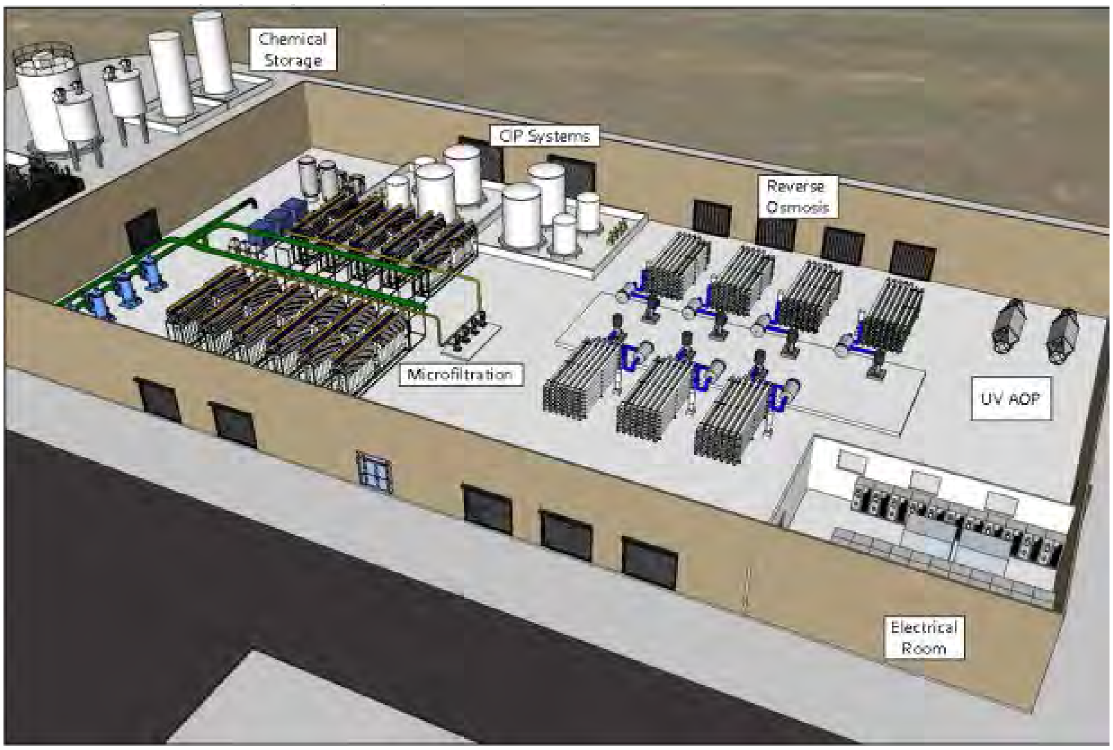


Figure 7.20 DSRSD AWPF Process Building

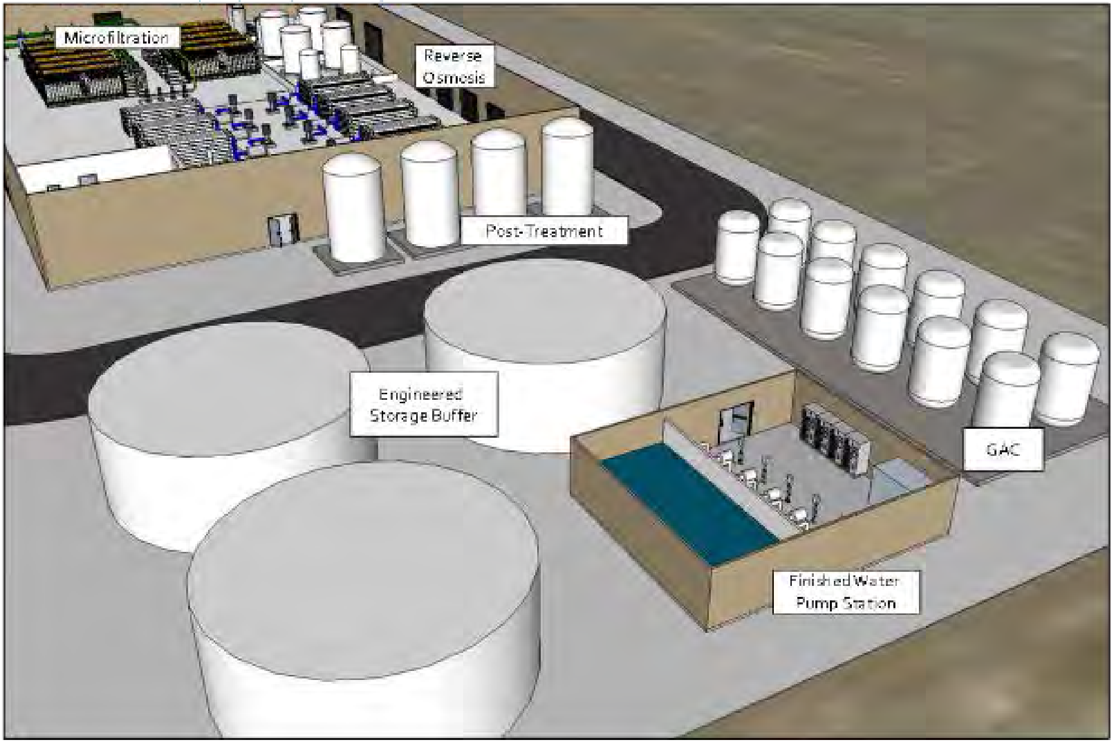


Figure 7.21 DSRSD AWPF Additional Processes

7.3.4 Option 2b - Seasonal 12 mgd DSRSD AWPF for Well B Injection

This option involves FAT at DSRSD and groundwater augmentation at Well B area. The pipeline alignment is shown in Figure 7.22. This project was added based on the lower cost due to lower treatment requirement (no ESB or GAC) and a shorter conveyance pipeline. Additionally, since regulations are fully in place for this type of potable reuse, this alternative provides the benefit of relative ease of implementation.

7.3.4.1 Pipeline Alignment

The source water pipeline is still the same as in short-listed Option 2a. However, the purified water pipeline is only 11,000 LF (12,000 LF shorter). The infrastructure requirements are shown in Table 7.12.

Table 7.12 DSRSD AWPF to Well Injection Infrastructure Requirements

Item	Unit	Value
Source Water Pipeline		
Diameter	in	30
Length	LF	1,000
Pumping Requirement(1)	hp	275
Concentrate/Waste Pipeline		
Diameter	in	16
Length	LF	1,500
Pumping Requirement(1)	hp	40
Purified Water Pipeline		
Diameter	in	31
Length	LF	11,100
Pumping Requirement(1)	hp	400
Injection Well	No.	4
Monitoring Well	No.	8

Notes:
(1) Pumping requirement based on a 70% pump efficiency.

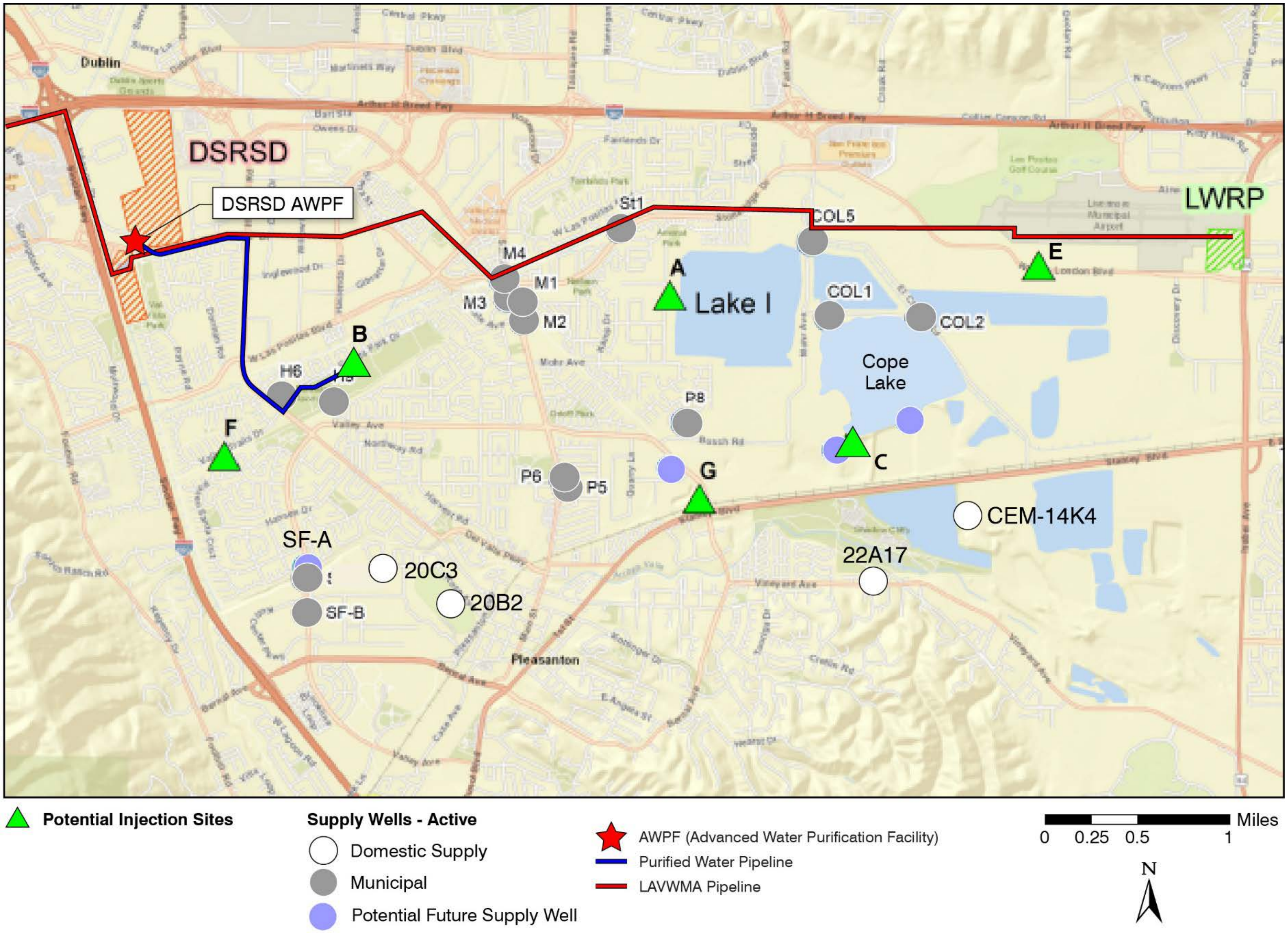


Figure 7.22 DSRSD AWPF to Injection Well Site B

7.3.4.2 Layout

Unlike short-listed Option 2a, this option does not have GAC or an ESB. As a result, the required area for the plant can be reduced to 4.3 acres, as shown in Figures 7.23 and 7.24.

Figure 7.23 DSRSD AWPF Layout (Zoomed Out)

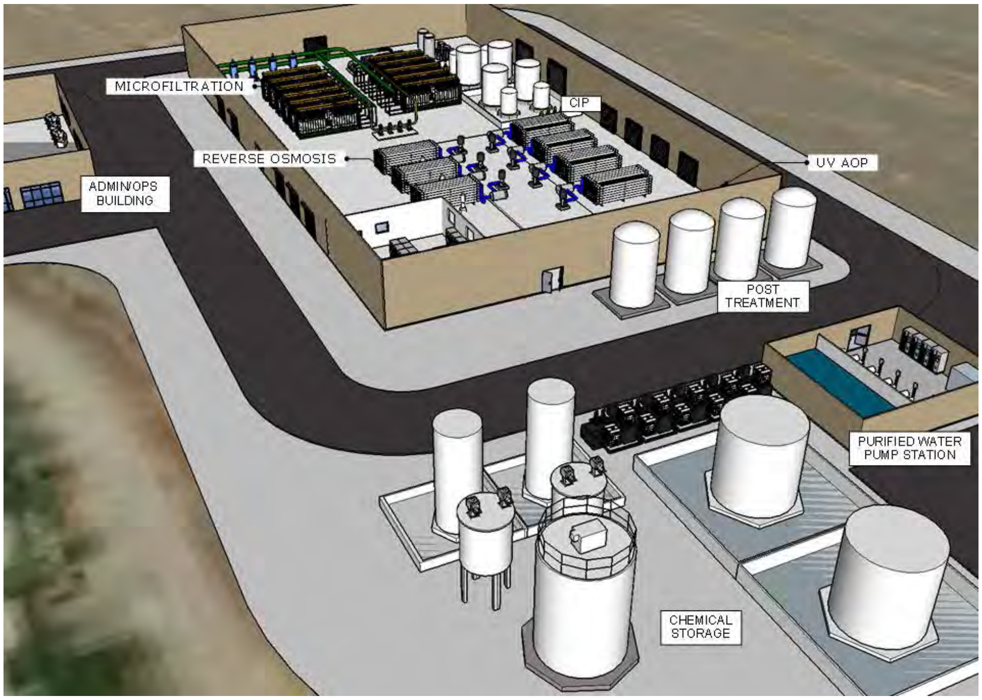


Figure 7.24 DSRSD AWPF Layout (Iso View)

7.3.5 Option 3 - 12 mgd Mocho AWPF for Well B Injection

This short-listed option involves FAT at the Mocho site and groundwater injection at Well B (see Figure 7.25. This option was selected based on the high yield (10,000 AFY seasonal operation receiving water from both LWRP and DSRSD WWTP), relative ease of implementation (regulatory), and potential benefits of a purification treatment plant located off-site from a WWTP. The relative ease of implementation is based on existing regulations and precedent for permitted groundwater injection systems. The benefits of an off-site treatment facility are related to public perception. While proximity of the AWPF to a WWTP can be convenient for staff, operations, and supplies, a satellite facility can be beneficial terms of public perception by providing distance between the wastewater plants and the purification plant. It is also easier to delineate roles and responsibilities of project participants with a regional site.

7.3.5.1 Pipeline Alignment

The 27-inch pipeline from LWRP passes almost directly through the Mocho site. It may be possible to tap into the pipeline and direct source water into the influent equalization tank for the site. Water from DSRSD would have to be pumped via a separate new 24-inch pipeline. This pipeline would be approximately 13,000 LF. Concentrate and MF backwash would be sent to the LAVWMA Pipeline downstream of the extraction of the LWRP flows. It is assumed within this report that, even though the waste stream from the facility may exceed the LAVWMA limits in terms of TSS and turbidity, the overall dilution provided by other facilities within EBDA would allow this discharge to be permitted. It may be possible to send the MF waste flows to the collection system nearby, but capacity of the collection system would need to be verified. Infrastructure requirements are shown in Table 7.13.

Table 7.13 Mocho AWPF to Injection Wells

Item	Unit	Value
Source Water Pipeline		
Diameter	in	24
Length	LF	13,000
Pumping Requirement	hp	620
Concentrate/Waste Pipeline		
Diameter	in	16
Length	LF	500
Pumping Requirement	hp	70
Purified Water Pipeline		
Diameter	in	30
Length	LF	6,300
Pumping Requirement	hp	320
Injection Well	No.	4
Monitoring Well	No.	8

Notes:
(1) Pumping requirement based on a 70% pump efficiency.

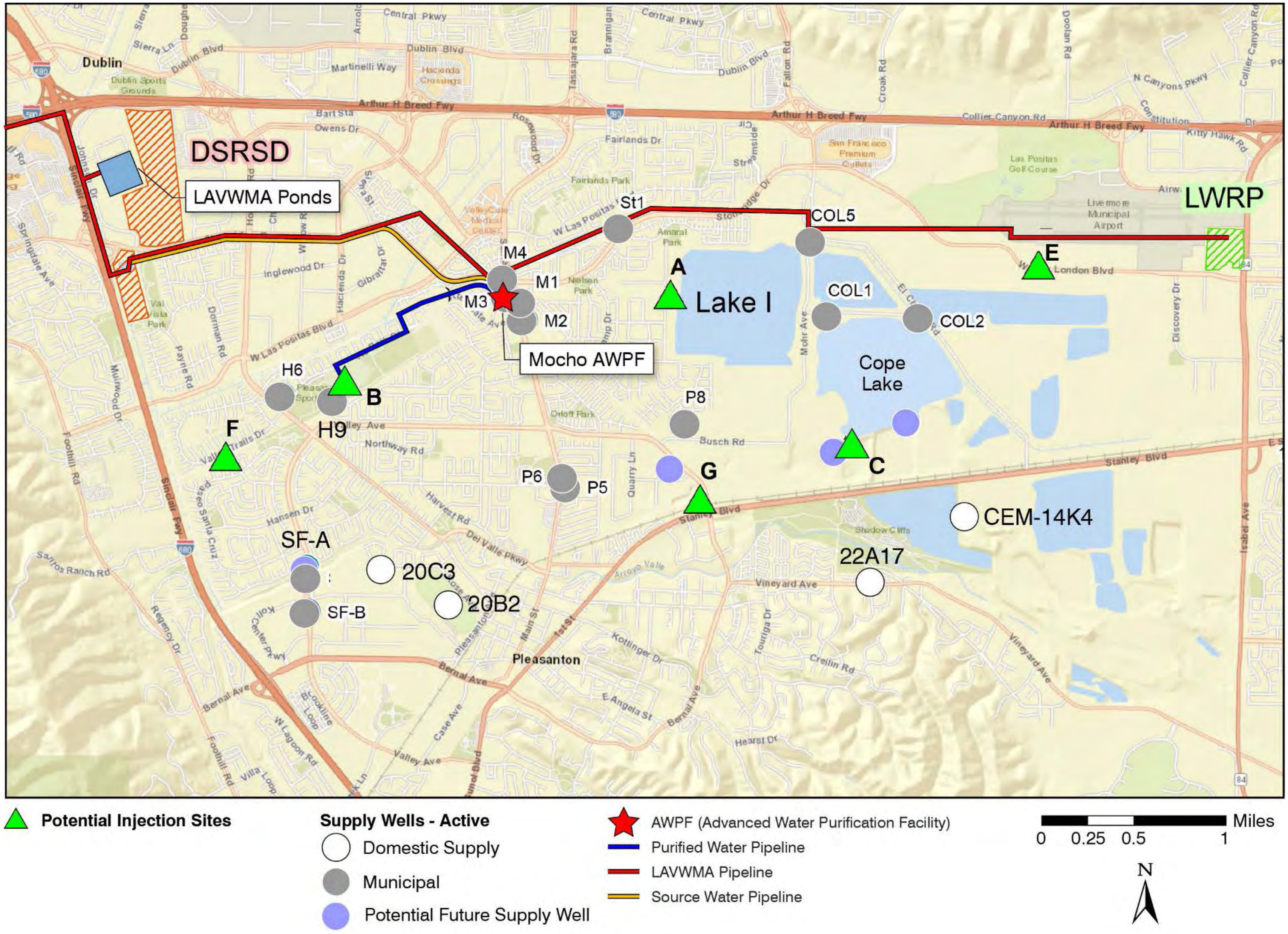


Figure 7.25 Mocho AWPF to Injection Well Site B Overview

7.3.5.2 Layout

Due to the extreme site constraints discussed earlier, it is necessary to put the processes in a two story building. All break tanks are assumed to be buried, but there may be limited space on the site to bury them due to the amount of utilities on the site. Due to the residential nature of the site, it is recommended to put the chemicals inside a building. Layouts for the Mocho site are shown in Figures 7.26, 7.27, and 7.28.

Figure 7.26 Mocho AWPF Layout

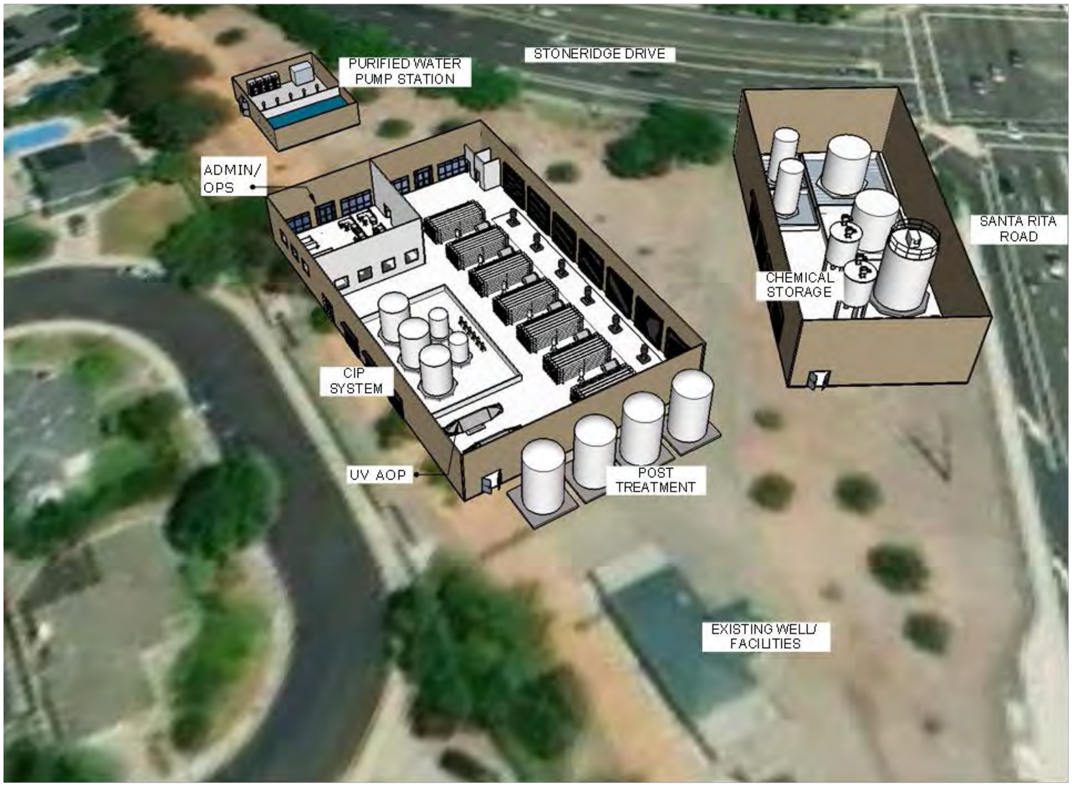


Figure 7.27 Mocho AWPF Layout (First Floor)

Figure 7.28 Mocho AWPF Layout (Second Floor)

7.3.6 Option 4 - Pleasanton AWPF to COL/DVWTP

This alternative incorporates a 12 mgd seasonally operating FAT+ AWPF and COLs/DVWTP augmentation, shown in Figure 7.29. As discussed for the other options, Lake I recharge could also be utilized. The Pleasanton AWPF was added after Workshop No. 4 to provide an alternate regional location which did not have the extreme site constraints of the Mocho site or the access difficulty of the COL location (discussed in Chapter 5). The Pleasanton Corp Yard would either need to be rearranged in order to accommodate the AWPF or the treatment processes would be separated. The City of Pleasanton has expressed that it will pursue a master plan for the site in the near future. If the project is pursued, space for the AWPF could be incorporated into future plans. Costs to relocate buildings are not included in the cost estimate.

7.3.6.1 Pipeline Alignments

The Pleasanton Corp Yard requires a 20,000 LF pipeline to bring source water from DSRSD. As the 24-inch pipeline crosses the existing LWRP effluent discharge line, it connects to that line and is then expanded to 30 inches to be able to convey the Livermore effluent as well. Concentrate and MF backwash must be returned via a separate pipeline to the LAVWMA line downstream of the intake. The same potential permitting and discharge options apply in this scenario as in Section 7.3.5.1. Infrastructure requirements are shown in Table 7.14.

Table 7.14 Pleasanton AWPF to Lake I Infrastructure Requirement

Item	Unit	Value
Source Water Pipeline Segment 1		
Diameter	in	24
Length	LF	13,000
Pumping Requirement	hp	520
Source Water Pipeline Segment 2		
Diameter	in	30
Length	LF	7,000
Concentrate/Waste Pipeline		
Diameter	in	16
Length	LF	8,900
Pumping Requirement	hp	120
Purified Water Pipeline		
Diameter	in	30
Length	LF	6,150
Pumping Requirement	hp	330

Notes:
(1) Pumping requirement based on a 70% pump efficiency.

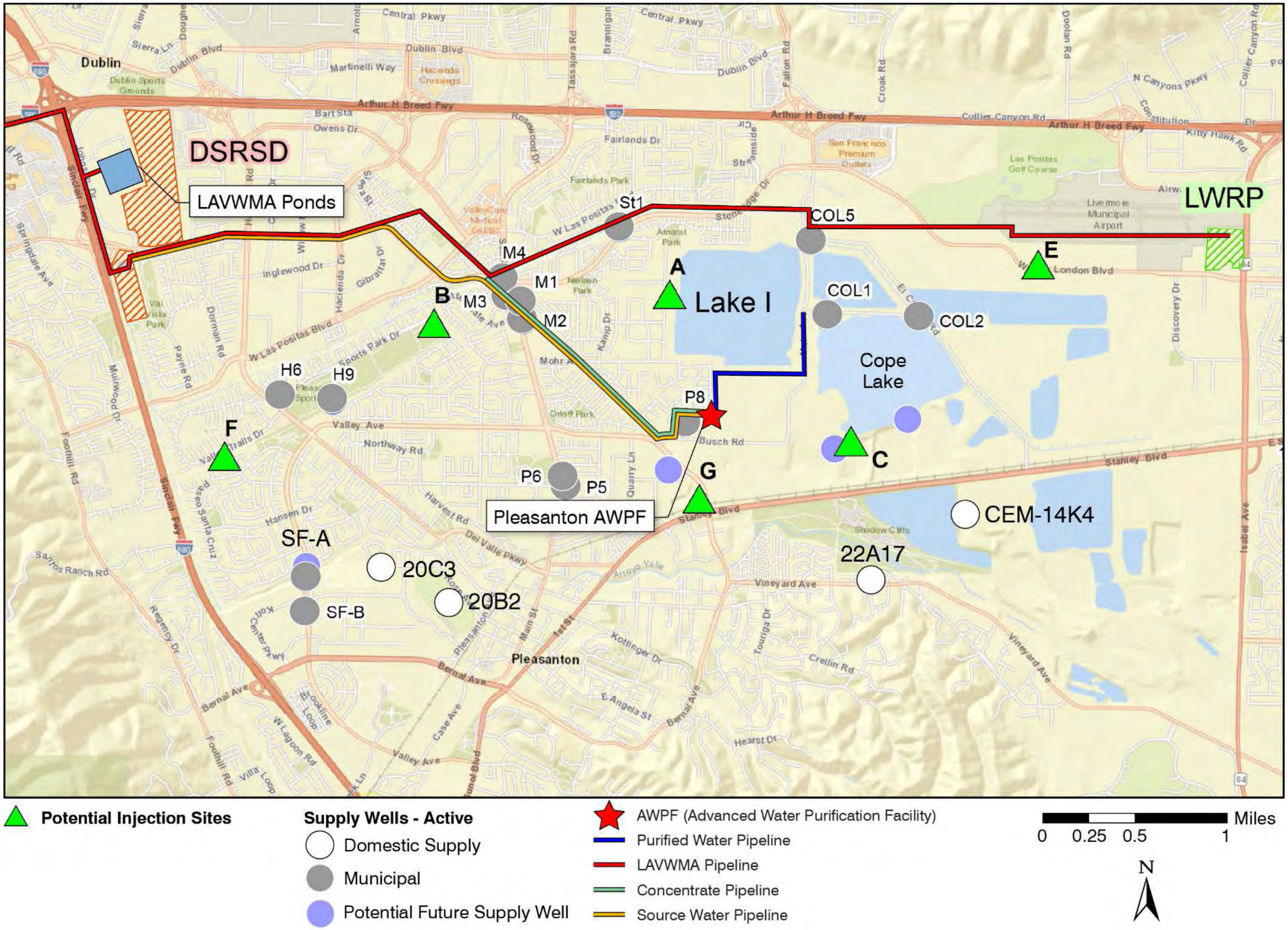


Figure 7.29 Pleasanton AWPF to COL/DVWTP

7.3.6.2 Layouts

The AWPF layout area was selected for the northeast corner of the Pleasanton Corp Yard. This layout is for planning purposes only. The City of Pleasanton will have to decide the buildings that can be re-arranged and which ones need to remain. The AWPF will require approximately 5 acres of space. Figures 7.30, and 7.31 show the AWPF layout at Pleasanton Corp Yard.

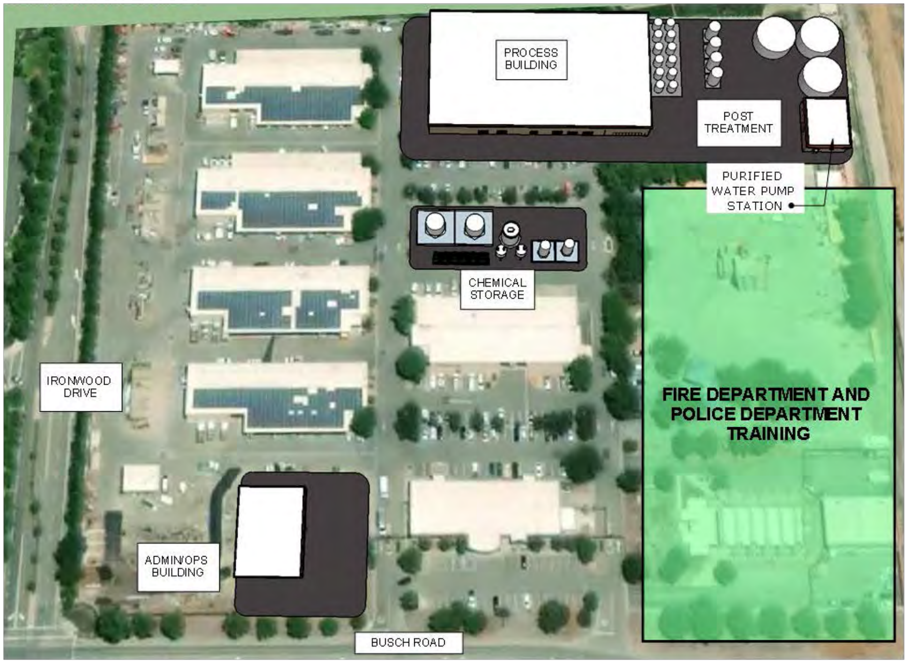


Figure 7.30 Pleasanton AWPF Layout

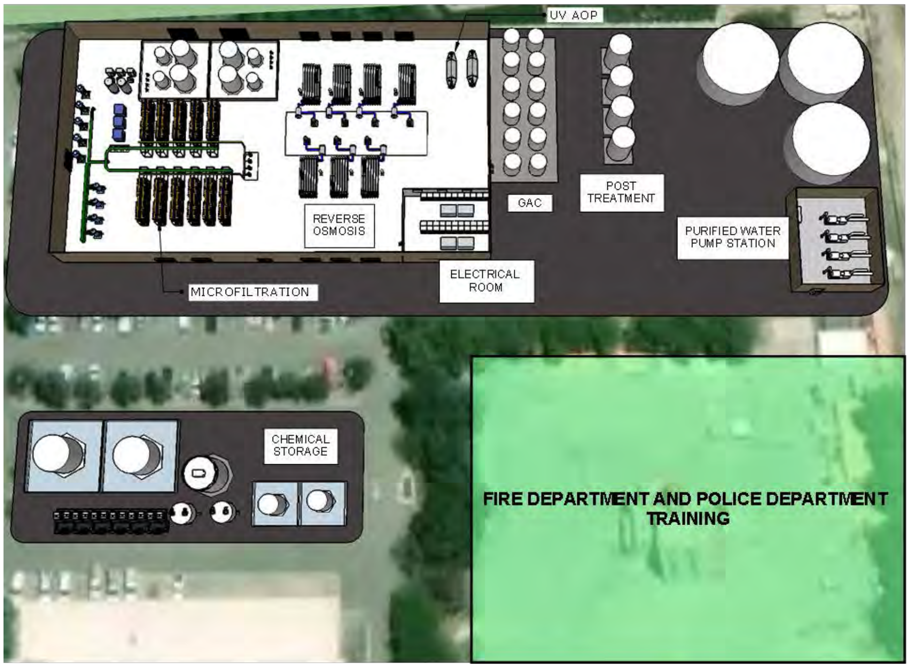


Figure 7.31 Pleasanton AWPF Process View

7.4 Cost Estimates

7.4.1 Basis of Cost

Cost estimates for each scenario were prepared for a Class 5 cost estimate in accordance with guidelines from the Association for the Advancement of Cost Estimating (AACE). As Class 5 estimates, the accuracy ranges from -50 to +100 percent. Tables 7.15 and 7.16 summarize cost assumptions in the development of the high level cost estimate. Appendix H contains detailed cost breakdowns.

Table 7.15 Cost Estimate Assumptions

Line Item	Description
Amortization Interest Rate	5%
Payback Period	30 years
Power Cost	$0.14/kWh
ENR-CCI (San Francisco, January 2017)	11069

Table 7.15 Contingencies and Assumptions

Line Item	Description	% of A
Total Direct Cost(1)	A	100%
Contingency	30% of A	30%
Subtotal	B	130%
General Conditions	10% of B	13%
Subtotal	C	143%
Contractor Overhead & Profit	15% of C	14%
Subtotal	D	157%
Sales Tax	9.5% of B/2	6%
Total Construction Cost(2)	**E**	**163%**
Project Cost Factor(3)	30% of E	49%
Total Project Cost	**F**	**213%**

Notes:
(1) Based on vendor quotes, estimating guides, and construction costs of similar facilities
(2) Sales tax is applied on 50% of the direct costs plus contingency, which is assumed, at this level to be equivalent to amount of materials/equipment purchased for this project. Sales tax is not applied on labor or overhead
(3) Project Cost Factor includes all legal, environmental, administrative, engineering, and construction management.

7.4.2 Cost Assumptions

Other identified cost assumptions include:

- All alternatives involving COL add $2 million to allow for an increase in the planned pump station capacity for the COL pipeline (as currently included in Zone 7's Capital Improvement Program), allowing flexibility to accommodate potable reuse applications.

- No land costs are included at this time. Note that all identified siting options are located on public agency owned land; cost sharing agreements to provide credits to the land owner may be considered should a project move forward.
- Converting the DLDs at DSRSD to an AWPF site requires a separate line item to allow DSRSD to pursue alternative methods of solids handling. In this study, a portion ($1,460,000) of the cost for new dewatering is added to projects at DSRSD as a proportionate amount of DLD capacity impacted.

7.4.3 Cost Comparisons

Table 7.17 presents the costs for each of the short-listed options discussed above. Detailed cost estimates are included in Appendix H.

Given a unit cost range from $2,160 to $2,530 per AF, and a cost uncertainty range of -50 to +100 percent, unit cost is not a key differentiator among the book-end options. However, capital costs range widely from $112M for Option 1a to $222M for Option 2a. While these options offer different amounts of recycled water, the capital cost is an important consideration from financial and project phasing perspectives.

7.5 Qualitative Evaluation

In addition to economic analysis many qualitative factors were considered for each short-listed option. Each factor was scored using a positive (+), negative (-), and neutral (0) sign. The number of signs implies a larger positive or negative impact. They are discussed within this section.

7.5.1 Yield (measured by acre-feet per year - AFY)

As discussed in Chapter 5, supplemental water supplies are meant to bolster the water supply reliability of the Zone 7 water portfolio. As can be expected, Zone 7's Risk Model shows that 10,000 AFY increases resiliency and reduces risk to a far better extent than a 5,500 AFY project (i.e., the greater the additional supplies, the greater the water supply reliability).

7.5.2 Improve Water Supply Reliability

All short-listed alternatives will improve water supply reliability compared to a no-project scenario. However, the impact on reliability can be differentiated based on the end use. Zone 7's Risk Model was used to consider the impact of each option on the overall water supply reliability. The methods used for evaluation are consistent with the 2016 Water Supply Evaluation Update (WSE Update) to allow for direct comparison with the results from that document. Each scenario was modeled using a Monte Carlo simulation that provided measures of water supply reliability and risk. Each Monte Carlo simulation ran 1,000 trials. In total, 48,000 separate forecasts were made to achieve the comparative results. This analysis updates the assumptions used in the WSE Update's Portfolio B, which included 'purified recycled water' or potable reuse. Every option performed better than the baseline portfolio from the WSE Update (i.e., the "Current Plan" portfolio, which includes existing planned capital improvement projects, but no potable reuse projects. Various water supply portfolios with varying amounts of potable reuse were analyzed with the model concurrent with this study. Note that the modeling reflects Zone 7's current operations, which relies largely on surface water deliveries supplemented by groundwater as needed.

Table 7.17 Cost Estimates and Unit Cost Comparison

	Livermore AWPF to COL Option 1a	Livermore AWPF to Well E Option 1b	DSRSD AWPF To COL/DVWTP Option 2a	DSRSD AWPF to Well B Option 2b	Mocho AWPF to Well B Option 3	Pleasanton AWPF to COL /DVWTP Option 4
CAPITAL COSTS						
Water Purification Facility	$72,620,000	$65,290,000	$139,530,000	$120,360,000	$121,420,000	$130,930,000
Infrastructure	$13,460,000	$13,390,000	$29,820,000	$27,670,000	$39,890,000	$28,110,000
Total Construction Cost	**$86,080,000**	**$78,680,000**	**$169,350,000**	**$148,030,000**	**$161,310,000**	**$159,040,000**
Engineering & Contract Admin (30%)	25,824,000	23,604,000	50,805,000	44,409,000	48,393,000	47,712,000
Additional Costs(1)	500,000	500,000	2,210,000	2,006,000	750,000	750,000
Total Project Cost	**$112,404,000**	**$102,784,000**	**$222,365,000**	**$194,445,000**	**$210,453,000**	**$207,502,000**
ANNUAL COSTS						
Amortized Annual Cost (5% for 30 Years) (2)	7,310,000	6,690,000	14,470,000	12,650,000	13,690,000	13,500,000
Operation and Maintenance:						
AWPF Operational Cost	6,374,000	6,374,000	8,215,000	8,215,000	8,026,000	8,079,000
Infrastructure Energy and Maintenance	256,000	256,000	840,000	693,000	764,000	851,000
Total Annual Cost	**$13,940,000**	**$13,320,000**	**$23,525,000**	**$21,558,000**	**$22,480,000**	**$22,430,000**
Available Project Yield, mgd	5.0	5.0	12	12	12	12
Actual Project Yield, AF/yr (3)	5,500	5,500	10,000	10,000	10,000	10,000
Unit Cost of Water ($ per ac-ft) (3)	$2,530	$2,420	$2,350	$2,160	$2,250	$2,240

Notes:

(1) Additional costs include costs to bring electricity to sites and additional solids handling compensation, if necessary.

(2) Costs based on a 5% interest rate and a 30-year payback period - typical of bond financing.

(3) Actual yield based upon year round operation for Livermore plants and seasonal operation for options which treat both DSRSD and Livermore effluent.

Based on the model results, while any potable reuse project would generally improve supply reliability and reduce the impact of droughts and outages, the addition of water into the system via DVWTP (raw water augmentation) had the most benefit in the worst-case supply scenario when surface water supplies are severely limited. Groundwater augmentation via well injection (Options 2b and 3) provided the highest average reliability overall as it maintained a fuller groundwater basin. As noted, these results are based on Zone 7's current operational scheme that largely relies on surface water with groundwater supplement as needed during daily and seasonal peaking, emergencies, and limited surface water conditions. If potable reuse via groundwater augmentation is implemented, Zone 7's operations could potentially be modified to optimize the benefits from this type of end use of purified water. The Risk Model results for this study are shown in Appendix I.

7.5.3 Improved Delivered Water Quality

The implementation of potable reuse has the potential to change delivered water quality. The changes in future delivered water quality, relative to the future (+25 years) baseline scenario, were estimated for the groundwater augmentation and raw water augmentation scenarios. Delivered water quality is represented by the flow weighted average TDS concentration of the combined groundwater and surface water supplies used to meet the projected demand of 51,330 AFY. The analysis is based on Zone 7's current operational scheme that largely relies on surface water with groundwater supplement as needed during daily and seasonal peaking, emergencies, and limited surface water conditions. If potable reuse via groundwater augmentation is implemented, Zone 7's operations could potentially be modified to optimize the benefits—including delivered water quality benefits—from this type of end use of purified water.

This analysis involved predicting the water supplies used to meet the projected demand and the quality of these supplies. The Zone 7 Water Supply Risk Model was used to predict the use of groundwater to meet demands under the future baseline, groundwater augmentation, and raw water augmentation scenarios. The use of surface water was assumed to be the difference between the projected demands and the groundwater supply. Table 7.18 presents the predicted use of groundwater and surface water supplies in the future condition for each of the scenarios.

Groundwater quality was estimated using the Zone 7 Groundwater Basin Model. The model output includes predicted TDS concentrations at each well. The groundwater model includes long term average production estimates from each of Zone 7's groundwater wells, and the relative production of each well to the total production was calculated. The resulting relative production of each well was assumed for the future scenarios. The flow weighted average groundwater concentrations were calculated using the projected total groundwater production, projected concentrations, and relative production of each well. Table 7.18 presents the predicted average groundwater concentrations for each scenario.

Surface water quality was estimated based on the average TDS concentrations for treated water from the DVWTP and the PPWTP, as reported in Zone 7's consumer confidence reports. Reported TDS concentrations from 2012, 2013, and 2016 were used to calculate the average TDS concentration of 298 mg/L. Years 2014 and 2015 were not used, as drought conditions influenced TDS concentrations of the treated water from DVWTP and PPWTP. The purified water used for raw water augmentation was assumed to have a TDS concentration of 100 mg/L.

Table 7.16 Water Quality Summary for the Baseline and Potable Reuse Scenarios

Future Baseline (25+ Years)			Future Groundwater Augmentation Scenarios						Future Raw Water Augmentation Scenarios	
			Options 2B, and 3		Option 1B		Option 1A		Options 2A and 4	
			DSRSD or Mocho to Well B		Livermore AWPF to Well E		Livermore AWPF to COL		DSRSD or Pleasanton to COL/DVWTP	
			10,000 AFY		5,500 AFY		5,500 AFY		10,000 AFY	
	Normal Year Supply	Simulated Concentration	Normal Year Supply	Simulated Concentration	Normal Year Supply	Simulated Concentration	Normal Year Supply	Simulated Concentration	Normal Year Supply	Simulated Concentration
Existing Supply	AFY	TDS (mg/L)	AFY	TDS (mg/L)	AFY	TDS (mg/L)	AFY	TDS (mg/L)	AFY	TDS (mg/L)
Surface Water	43,130	298	38,130	298	41,330	298	14,030	298	33,530	398
Groundwater	8,200	603	13,200	372	10,000	510	9,300	484	7,800	603
Raw Water Augmentation									10,000	100
Cumulative (Total Volume, Weighted Average TDS)	**51,330**	**346**	**51,330**	**317**	**51,330**	**339**	**51,330**	**331.**	**51,330**	**306**
Percent Change in Average TDS				**-9%**		**-2%**		**-4%**		**-12%**

The results are summarized in the Table 7.17. It is important to recognize the potential potable reuse projects contribute only 10 to 20% of the total supply. Therefore, changes in the weighted average TDS concentration of the total supply are relatively subtle. However, comparison of these relative changes can be used to evaluate difference between the scenarios.

The changes in water quality on a percentage basis were calculated relative to the baseline scenario. A negative percentage change in TDS concentration indicates a decrease in TDS concentrations. For the raw water augmentation scenarios, the purified water with a TDS of 100 mg/L is blended with existing surface water supplies, and therefore has a direct impact on average TDS concentrations. For the groundwater augmentation scenarios, the change in delivered water quality is dependent on the migration of the injected groundwater to each well and the resulting change in groundwater quality at each well. The groundwater augmentation volume and location impacts the change in TDS concentration at each well.

TDS reductions in delivered water quality range from 2 percent to 12 percent depending on the scenario, as presented below:

- 10,000 AFY raw water augmentation (Options 2a and 4) - 12% TDS reduction
- 10,000 AFY groundwater augmentation (via injection at well B) (Options 2b and 3) - 9% TDS reduction
- 5,500 AFY groundwater augmentation via recharge at the COLs (Option 1a) - 4% TDS reduction
- 5,500 AFY groundwater augmentation via injection at well E (Option 1b) - 2% TDS reduction

The estimated delivered water quality TDS concentrations are a gross estimate of potential delivered water quality impacts and would need to be evaluated in more detail in future studies, which could also incorporate potential operational modifications; however, it is reasonable to assume that the water quality benefits from the 10,000 AFY raw water augmentation and groundwater augmentation options are similar and that the benefits from the 5,500 AFY groundwater augmentation options are similar. That is, larger amounts of purified water generally lead to larger benefits to delivered water quality.

7.5.4 Improve Groundwater Basin Water Quality

There are areas of the groundwater basin with high TDS values. These values may be lowered with the injection of lower TDS water into the groundwater basin via wells or recharge through Lake I or the Arroyo Mocho. Chapter 6 showed the results of the recharge options on basin quality. The Well B area is closer to the groundwater basin area with higher TDS values and may be desirable for that reason. However, Lake I recharge and Well E injection provide a more widespread benefit to the groundwater basin.

All groundwater recharge were given a single plus (+) score recognizing that any recharge of a high quality water improves the groundwater quality. Raw Water Augmentation is scored with a neutral sign (0) since it has neither a positive or negative impact on groundwater basin quality. Water quality concerns related to leaching of metals from the soils into the groundwater would be addressed through post-treatment stabilization of the water, discussed in Section 7.2.2.7.

7.5.5 Clear Regulatory Pathway

Groundwater augmentation via injection wells has been established in many areas across the country. The regulations for these projects have been set since 2014 so there is a streamlined approach for permitting them. This category will therefore be assigned two plus (++) signs.

Surface water/reservoir augmentation regulations were finalized in early 2018. Raw water augmentation regulations have not yet been created but are mandated to be developed by 2023. However, the DDW has stated that they will permit projects on a case by case basis in the interim. The permitting process is therefore likely to be more complex for raw water augmentation compared to the other two potable reuse end use options with adopted regulations. However since there is a clear regulatory pathway, raw water augmentation is given a single plus (+) while groundwater augmentation is given a double plus (++).

7.5.6 Minimizes Neighborhood Impacts

This factor will be rated based on the amount of neighborhood impact, which depends on the zoning of the lot, existing industry or utilities nearby, and the potential visibility of the site.

The Mocho site is immediately next to a neighborhood. While it is across the street from an existing demineralization plant, the building itself will be very visible (2-stories tall) to neighbors. This location will also replace an existing park. The impact on the neighborhood is significant, therefore it is scored with a negative (-) sign.

Both Livermore and DSRSD AWPF sites would be on existing utility property in either commercial or industrial areas. These locations will have minimal impact on the surrounding neighborhood and therefore are scored with two (++) plus signs. The Pleasanton site would be within an existing corporation yard; however, there are homes that border the north and west side of the existing yard. This location is scored with one (+) plus sign. .

7.5.7 Ability to Phase the Project

The purpose of constructing a project in phases is to appropriately match facility size with available water supply. This allows for a quicker return on investment and a more immediate benefit. However, phasing a project is only practical if there is a significant difference between the initial flows and the ultimate buildout flows. The phasing considered within this project only refers to adapting one location for an AWPF to buildout flows. Other phasing options could include adjusting sources, like building a small AWPF at Livermore and then a separate site at DSRSD later to facilitate use of both sources over time, or it could involve supplementing the source water flow with existing tertiary recycled water flows in the event of a severe drought. These alternative phasing definitions should be investigated separately as they were not examined in this study. The initial to buildout phasing for each site is discussed within this section.

For projects at LWRP, the available flow is expected to reach a buildout of 6.1 mgd as shown in Figure 7.32. While current flows hover around a minimum of 3 mgd, flows are expected to reach 4.7 mgd by the time a project could be expected to come online. The phasing options for LWRP are such small increments that it is not likely to be cost-effective, so options at the LWRP are not considered favorable for phasing. In addition, the ultimate buildout capacity at LWRP is limited to 6.1 mgd, further decreasing the ability to phase the project at that site (Table 7.19). Note, however, that a future evaluation could consider a project at LWRP as Phase 1 of a larger potable reuse project should the project participants want to have multiple AWPF sites or want to consider pumping water from the west side of the valley east for treatment at Livermore. These options were not considered in this study and cost estimates were not performed; however, building two separate facilities or pumping tertiary effluent eastwards are likely to increase costs relative to the options evaluated in this study.

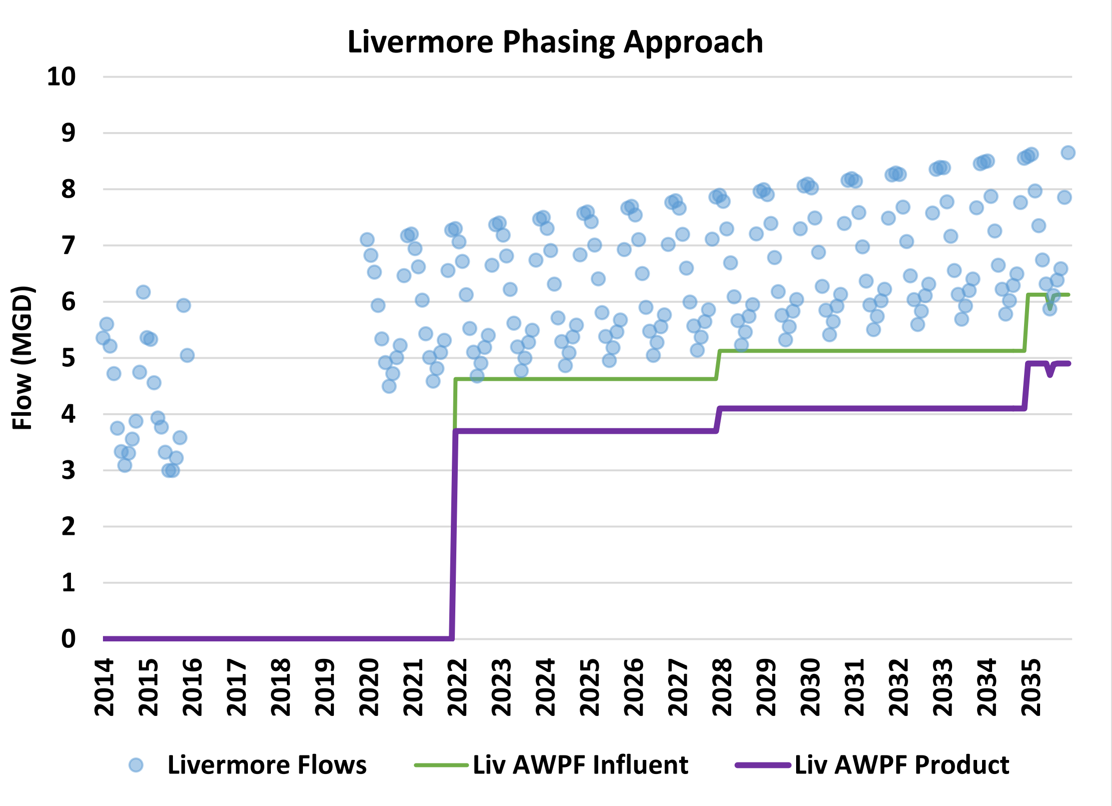


Figure 7.32 Livermore AWPF Flow Projections and Potential Phasing

Table 7.17 Livermore AWPF Potential Phasing Options

Phase	Start Date	Design Flow (mgd)
1	2022	3.7
2	2028	4.1
3	2035	5.0

Treatment plants using both LWRP effluent and DSRSD effluent can be phased first to design around a consistent flow (5 mgd effluent, expected around 2035) and then be increased in future years to provide higher winter level treatment to achieve the 10,000 AFY goal. Flow projections for DSRSD and LWRP combined are shown in Figure 7.33 and one potential phasing plan is shown in Table 7.20, although others could be considered.

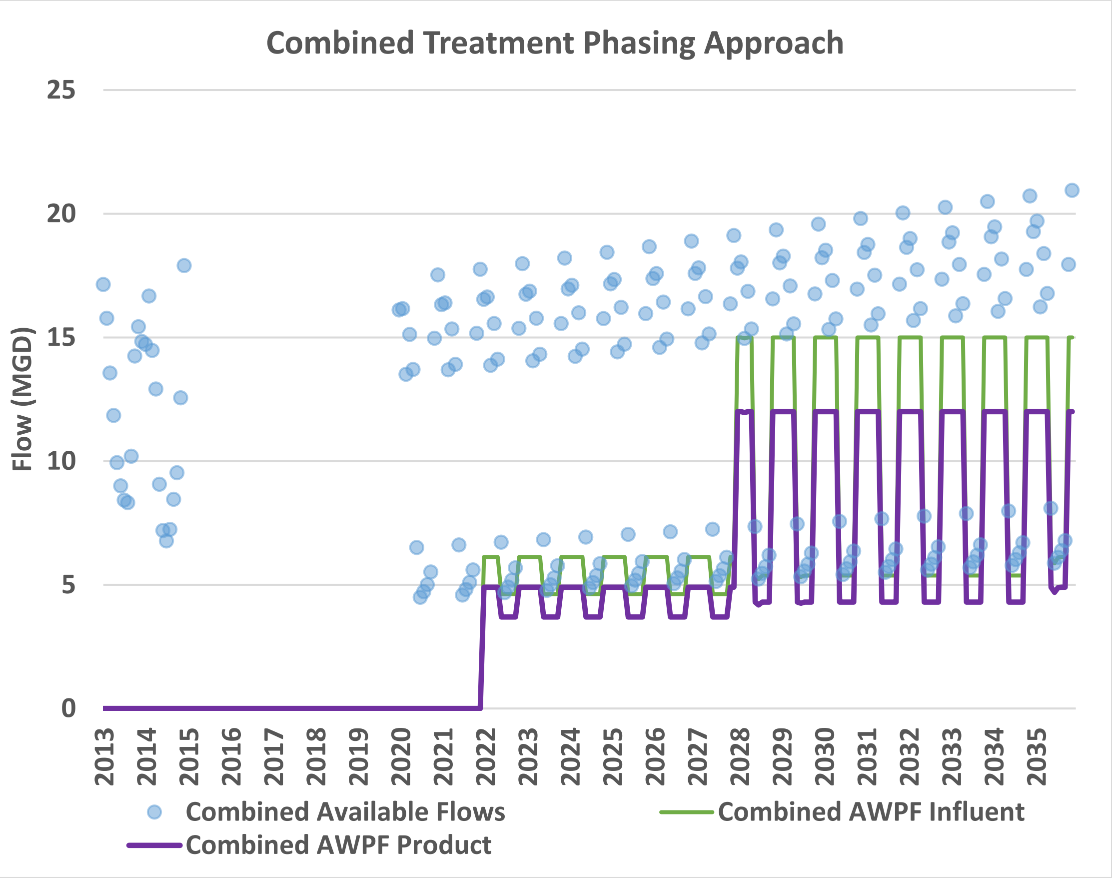


Figure 7.33 DSRSD/Mocho/Pleasanton AWPF Flow Projections and Potential Phasing

Table 7.20 Potential Combined AWPF Phasing Options

Phase	Start Date	Summer Design Flow (mgd)	Winter Design Flow (mgd)
1	2022	3.7	5
2	2028	4.3	12
3	2035	5	12

While all alternatives could start with smaller flows and expand to the buildout flow of that site, it may not be cost-effective. The larger the ultimate buildout flow for a site, the greater opportunity to phase. Livermore options were given a neutral (0) score due to minimal opportunity to phase (given the definition of phasing used in this study) while the other options with 10,000 AFY yield were given a single plus (+) for the relative ease in which design flows could start smaller (5,000 AFY) and then be increased to 10,000 AFY.

7.5.8 Operational Considerations

Operations could potentially be complicated by the following factors:

- Variances of flow - for instance, running the AWPF at two different flow setpoints would complicate chemical deliveries, equipment rotations, and pipeline usage.
- Physical separation of AWPF from support centers - while each AWPF will have an operations center, locating an AWPF nearer to an existing utility would provide an additional source of 'on-site' operators as backup.

In the scoring of alternatives, LWRP was given positive scores for both running at a constant flow and being located near an existing utility. DSRSD was given a positive score for being located near an existing utility but a negative score for seasonal operation, thereby equaling out to an overall neutral score. Both Pleasanton and Mocho options were given negative scores for both seasonal operation and location away from an existing facility.

7.5.9 Ease of Construction

Impacts to construction include:

- Amount of staging space available (physical constriction of the site).
- Ease of access for construction vehicles.
- Amount of site work required - working around existing structures vs. greenfield site.
- Sludge management

The locations that have easy access and require minimum modification or extra work are scored with double (++) plus signs. Alternatives at DSRSD are rated ++ because while the site needs filling and a berm, the soils are available locally within the DLDs. While Livermore requires lagoon draining and sludge hauling in addition to importing soil from off-site, the site is still easily accessible and unconstrained. Livermore sites were given a double (++) plus sign. The Pleasanton site was given a single plus sign as well because it is easy to access, being along main roads. However, construction at the site would require working around existing buildings or relocating buildings. Mocho received a negative (-) sign because the construction site is very small, with little to no staging area available. Additionally, several utility pipelines cross underground, which should be carefully considered during construction.

Table 7.21 qualitatively scores each alternative based on the above criteria.

Table 7.21 Qualitative Alternatives Evaluation

	Livermore AWPF to COL/Lake I	Livermore AWPF to COL/DVWTP(1)	Livermore AWPF to Well E	DSRSD AWPF To COL/DVWTP	DSRSD AWPF to Well B	Mocho AWPF to Well B	Pleasanton AWPF to COL/DVWTP
Yield	5,500	5,500	5,500	10,000	10,000	10,000	10,000
Cost, $million	$112.4	$112.4	$102.8	$222.4	$194.5	$210.5	$207.5
Unit Cost, $/AF	$2,530	$2,530	$2,420	$2,350	$2,160	$2,250	$2,240
Improve Supply Reliability	+	++	+	+++	++	++	+++
Improve Delivered Water Quality	+	++	+	++	++	++	++
Improve Groundwater Basin Quality	+	o	+	o	+	+	o
Clear Regulatory Pathway	+	+	++	+	++	++	+
Minimizes Neighborhood Impacts	++	++	++	++	++	-	+
Ability to Phase the Project	o	o	o	+	+	+	+
Operational Flexibility	++	++	++	o	o	-	-
Ease of Construction	++	++	++	++	++	-	+

+ positive impact **-** negative impact **o** neutral impact

Notes:

(1) This option is the same in cost and infrastructure requirement as Livermore AWPF to COL / Lake I. However, there is a higher benefit to delivered water quality overall, and no impact on groundwater quality. This option is included in the qualitative table because it may qualify as a surface water augmentation project (reservoir augmentation) under the new regulations. If Cope Lake is allowed to be used as a reservoir, the treatment requirement for the AWPF at Livermore may be decreased, which would result in a lower capital and O&M cost.

7.6 Conclusion

The analysis presented in this chapter supported 1) a more detailed evaluation of the feasibility of the options, 2) a book-ending of the potential benefits and challenges of the options and 3) a comparison of the project options based on both quantitative (e.g., cost) and qualitative (e.g., ease of construction) considerations. Given the complex nature of some of the metrics used, the qualitative assessment as presented in Table 7.21 is subjective; however, it provided a useful framework for the identification of potential benefits and challenges of the options and their relative comparison. The overall conclusion is that all of the options are found to be viable, realistic alternatives that could be implemented, with varying levels of benefits and challenges. Recommendations for next steps are summarized in Chapter 8.

Chapter 8

RECOMMENDED NEXT STEPS

8.1 Summary of Major Findings and Overall Recommendations

The Tri-Valley Water Agencies have set out to evaluate the technical feasibility of potable reuse for the Tri-Valley through this project. Options evaluated include potable reuse through groundwater augmentation (recharge/injection), reservoir augmentation, and raw water augmentation to a connection upstream of the Zone 7 DVWTP. This study has found that potable reuse in the Tri-Valley is a technically feasible method to increase water supply, improve water supply reliability and to improve water quality of the groundwater basin and/or delivered water depending on the selected end use.

This study expanded on initial evaluations conducted as part of Zone 7's 2016 Water Supply Evaluation Update (WSE Update). For that work, Zone 7 used its Water Supply Risk Model that assessed potential impacts to system-wide water supply reliability and water shortage risk. This new analysis updates the assumptions used in the WSE Update's Portfolio B, which included 'purified recycled water' or potable reuse. Every potable reuse option evaluated in this new effort provided better water supply reliability than the baseline portfolio from the WSE Update (i.e., the "Current Plan" portfolio, which includes existing planned capital improvement projects, but no potable reuse project). Various water supply portfolios with varying amounts of potable reuse were analyzed with the Risk Model concurrent with this study. In the WSE Update, the upper end of what was estimated available from future water supplies (potable reuse and desalination) was around 10,000 AFY, so this amount was used as the upper bookend for the analysis in this study. Note that there were other limiting factors (i.e. wastewater availability) to going beyond 10,000 AFY so this value is a reasonable estimate.

Working with the Project Management team and Steering Committee, both comprised of members from each water agency, a wide range of alternatives was considered in this study to develop "bookends" of feasible potable reuse options. Twenty-one alternatives were considered and evaluated in Chapter 5 and screened down to six options that were developed in more detail in Chapter 6 and Chapter 7. Table 8.1 summarizes the options evaluated at a higher level of detail.

This chapter lays out the process if the Tri-Valley Water Agencies choose to pursue a potable reuse project further, and details a number of subsequent decisions and action items necessary to successfully implement a potable reuse project. A schematic of the decision process that needs to be followed for the agencies to move forward with potable reuse is shown in Figure 8.1. The future work items required can be classified into three categories: Technical, Institutional, and Outreach. Note that this study focused on technical issues only; however, potable reuse projects are widely recognized to involve complex institutional and public outreach issues that need to be addressed early in the project implementation process. Some examples of recommended next steps for the institutional and outreach components are provided in

Appendix J for future consideration by the Tri-Valley Water Agencies should they choose to proceed with a project.

Table 8.1 Summary of Feasible Project Options Evaluated in Detail

Option	Location	Capacity (mgd)	Source Water	Treatment Train	End Use	Total Project Cost/	Annual Yield (AFY)	$/acft
1a	Livermore	5	LWRP	FAT+	COL (Lake I)/ DVWTP	$112 M	5,500	$2,530
1b				FAT	Well E	$103 M	5,500	$2,420
2a	DSRSD	12	DSRSD WWTP + LWRP	FAT+	COL (Cope Lake)/ DVWTP	$222 M	10,000	$2,350
2b				FAT	Well B	$194 M	10,000	$2,160
3	Regional at Mocho	12	DSRSD WWTP + LWRP	FAT	Well B	$210 M	10,000	$2,250
4	Regional at Pleasanton	12	DSRSD WWTP + LWRP	FAT+	Cope Lake/ DVWTP	$208 M	10,000	$2,240

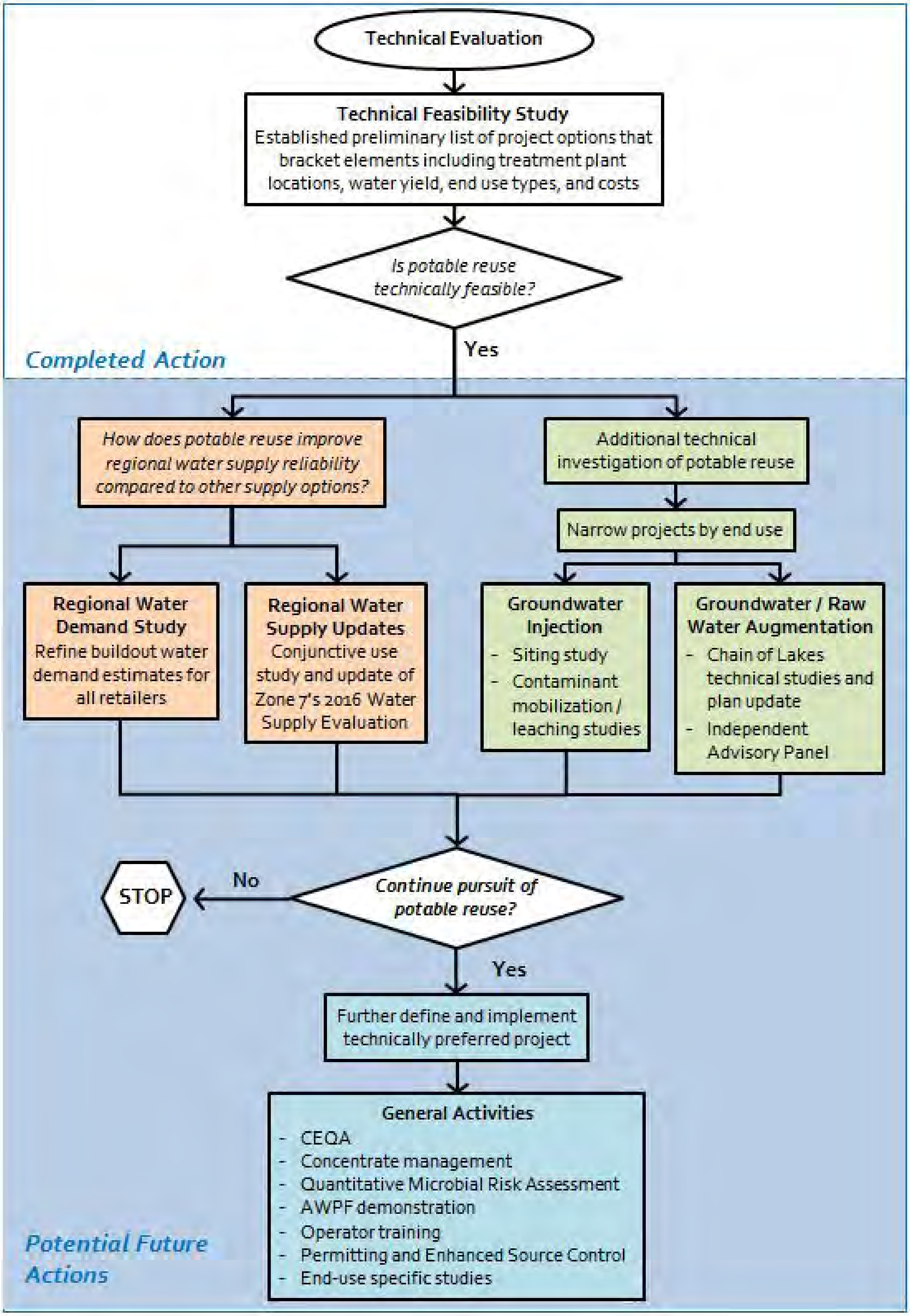


Figure 8.1 Decision Process Schematic

8.2 Technical Next Steps

There are several key technical efforts needed to move a potable reuse project forward, as summarized below.

8.2.1 All Projects

Regardless of the type of potable reuse project, there are several key next steps:

- **Regional Water Demand Study** - This study would apply a consistent land-use based method to the region that accounts for the state's long-term conservation framework. This will help determine the amount of additional water supply needed and timing for the Tri-Valley area.
- **Zone 7 Conjunctive Use Study** - Zone 7's water system was built primarily as a surface-water based system. This study would evaluate the potential shift to greater groundwater use if groundwater recharge is increased significantly (e.g., if potable reuse via groundwater augmentation is implemented). Impacts on the transmission, treatment plant, and well facilities will be evaluated, as well as on salt management and delivered water quality.
- **Zone 7's Water Supply Evaluation Update** - Zone 7 will incorporate new data and new supplies that have become available since the WSE Update was completed in 2016 (e.g., timing and yield of CA WaterFix, Sites Reservoir, results of potable reuse study). Data from the conjunctive use study would also be incorporated. This will allow comparison of potable reuse to other water supply options based on yield, cost, reliability, and other metrics.

8.2.2 Groundwater Augmentation/Recharge

There are a series of next steps required for implementing a groundwater recharge project, summarized here:

- **Siting Study -** Preferred site selection includes hydrogeological evaluation, expected travel time to adjacent production wells, infrastructure proximity and availability, and land area to support construction and operation of the injection wellfield/s. It would also consider optimization of salt management strategies, including the existing demineralization facility and plans for additional facilities as needed. Site selection should be carefully coordinated with the Conjunctive Use Study, the Contaminant Mobilization Study and the Leaching Study.
- **Contaminant Mobilization Study** - Sampling of native groundwater and prediction of water qualities of potential recharge water, including averages and variabilities of the constituents.
    - Geochemical analysis of the soil sample should be conducted. These analyses may include up to 50 proposed water quality constituents of interest for geochemical analysis.
    - Use of Geochemist's Workbench software to conduct a geochemical model analysis of mixing between the recharge water quality, the native groundwater quality, and the potential short term and long term impact of the chemical reactions (including potential contaminant mobilization) occurring between the mixture and the mineralogy of each layer.

- **Leaching Study (and Core Sampling) –** Samples taken from surface to a sufficient depth (approximately 700 feet) below the Lower Aquifer System to characterize the soils and geologic layers. Perform geochemical analysis and contaminant mobilization/leaching studies with cores. Samples can be obtained from drilling of injection and/or monitoring wells. Assume use of 2 cores, four columns (two of each site) and a minimum of a 1 month study with weekly sampling.
- **Injection and Monitoring Well Design and Construction –** Design and construction of wells for injection study (including recharge rates) as well as water quality analysis. Construct individual monitoring wells in various layers of the aquifer. The primary purpose of these monitoring wells would be to obtain water qualities for geochemical analysis, including contaminant mobilization or leaching studies with RO permeate. These wells can be used for tracer studies and permitting efforts as well as ongoing monitoring for compliance purposes.
- **Tracer Study –** Conduct tracer study using monitoring wells to verify travel time in aquifer for permitting purposes.

The above recommendations apply to groundwater recharge in general and specifically to recharge involving injection wells. For recharge involving Lake I, other steps would include:

- **COLs Water Quality Analysis** - Characterization of Lake H/I/Cope water quality throughout the year, and projected potential water quality impacts of various source waters, including purified water. The water quality from AWPFs treating municipal wastewater is relatively well characterized and predictable. However, in order to assess the effects of the blending of COL water with purified water, the new blended water quality should be predicted based on scenarios developed from the COL management scheme.
- **COLs Hydraulic Modeling/Water Balance -** Hydraulic modeling and water balance in the Lake H/I/Cope complex, incorporating recharge rates, projected Vulcan discharges, groundwater levels, Arroyo Mocho and Arroyo Valle/SBA diversions, and potentially stormwater and purified water storage.
- **COL Management Plan Update -** Incorporate scenarios and results from the COLs water quality and hydraulic modeling/water balance analyses. Consider other potential uses such as recreation and planned facilities such as the diversion structure/s and COLs pipeline.
- **Tracer Studies -** Conduct tracer studies using previously constructed monitoring wells alongside Lake I. The results from the tracer study will be used to develop permitting documents.

8.2.3 Raw Water Augmentation

A project that included delivery to DVWTP as a raw water augmentation would require a few different steps than more common potable reuse projects (i.e., groundwater augmentation).

- **Independent Advisory Panel** - While not necessary, a committee comprising experts in the area of potable reuse and regulation of projects would bring credibility to the project as well as address public concerns. This body would provide an unbiased perspective and would not have a political agenda.
- **Regulatory Criteria-** Since the regulations for raw water augmentation have not yet been developed by the State, first and foremost, the agencies should decide whether to

pursue this option, with the understanding that it could potentially (depending on the timing of the project pursuit) drive regulations. There is currently a five-utility potable reuse regulatory project underway with the National Water Research Institute focusing keenly on such action. As California regulators move ahead with raw water augmentation, these types of potable reuse projects could be required to have higher levels of analysis, potentially including:

- Quantitative Microbial Risk Assessment (QMRA)
- Additional Treatment Barriers
- Additional Monitoring Barriers
- Additional Water Quality Sampling for Emerging Pollutants

8.2.4 General Activities

- **Demonstration facility** - An AWPF demonstration project would provide an opportunity to do site specific water quality analysis on product water as well as concentrate. In addition a demonstration is an important strategy for public education and outreach.
- **Pipe Loop Studies -**
  - Purified water for raw water augmentation may not be stabilized in the same way that it would be for groundwater recharge. However, to protect piping and conveyance infrastructure, some stabilization would be necessary. Pipe loop studies would be able to provide information on the long-term effects of the purified water on pipeline infrastructure under various stabilization strategies.
  - Pipe loop studies should be conducted with both purified water as well as blended purified water and Cope Lake water.
  - These studies would ideally be done as part of a potable water reuse demonstration facility. Alternatively other sources of purified or RO water (such as from the Mocho Demin facility) could be used but may require transport costs.
- **CEQA** - Using the information currently developed in this report, environmental documentation could begin that included alternatives considered and potential impacts associated with building a project. Project-specific details would be required for CEQA compliance and may require additional engineering efforts.
- **Source Control** - A potable reuse system requires a more rigorous approach to source control with advanced monitoring and additional sampling/testing. The reason for the enhanced source control is to protect the new water supply from any illicit discharges of contaminants that could impact the drinking water supply. The wastewater agencies could begin the process of evaluating their existing source control programs now in preparation for implementing a potable reuse program.
- **Permitting** - An initial meeting with staff from the Regional Water Quality Control Board and the CA DDW to inform them of a potential project is recommended. A Report of Waste Discharge and an Engineer's Report will be needed to support development of permits for a new potable reuse facility. These permitting documents will require detailed information on treatment processes, water quality, operations, source control, groundwater protection (if applicable) and other issues.
- **Operator Training** - It will be necessary to train staff to run a new potable reuse program. A new Advanced Water Treatment operator training program is being developed by CA/NV AWWA and is being recommended by CA DDW for future system operations programs. It is anticipated that both certified water and wastewater

operators can apply for the AWT certification program. Training materials are under development by the Water Environment and Research Foundation, as well as other training providers. The operation of a demonstration treatment facility would provide the ideal opportunity for existing operations staff to train and become comfortable with the treatment processes.

- **Supplemental Studies**
  - **Concentrate Management Investigation** – While the analysis within this project documented that RO concentrate can be discharged to the EBDA outfall for release into the San Francisco Bay, this conclusion should be verified through discussions with other EBDA dischargers as well as the RWQCB. If the RWQCB or EBDA denies the discharge of untreated concentrate into the outfall, a new concentrate management study should be conducted to evaluate RO concentrate treatment and disposal options. However, this possibility is not expected based on previous water balance calculations.
  - **Pipeline Alignment Study** - the initial alignments shown within this study were chosen based on a preliminary set of criteria. A detailed pipeline alignment study would include discussion of right-of-way, existing utilities, and future capital improvement plans.
- **Standard Engineering Tasks**
  - Preliminary Design
  - Land Acquisition
  - Right-of-Way
  - Legal Risk Analysis
  - Final Design
  - Construction
  - Startup

8.2.5 Estimated Cost of Next Steps

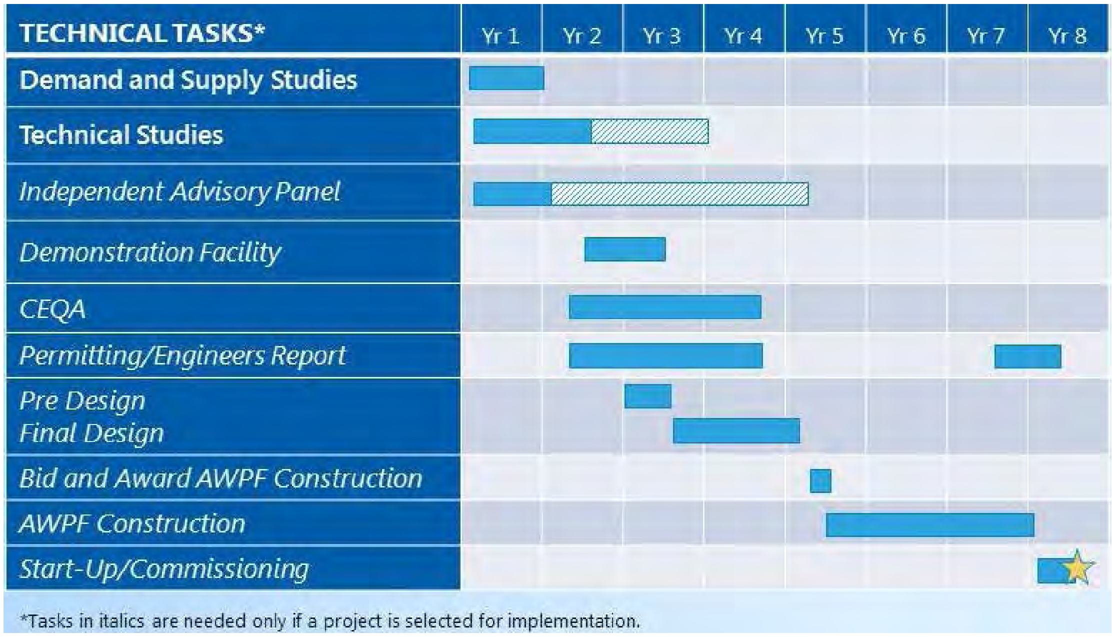
The estimated time requirement and approximate costs for the next steps are shown in Table 8.2. Costs for design and construction activities are not shown and would be dependent on selected project.

Table 8.2 Potential Next Steps and Estimated Costs/Timing

Step	Timing	Estimated Consultant Cost
How Does Potable Reuse Improve Regional Water Supply Reliability vs. Other Supply Options?		
Regional Water Demand Study	6-9 months	$200,000-300,000
Zone 7 Conjunctive Use Study	4-6 months	$100,000-$150,000
Zone 7 Water Supply Evaluation Update	4-6 months	Zone 7
	Subtotal	**$300,000-$450,000**
Narrow Projects by End Use		
Groundwater Injection		
Siting Study	6-8 months	$100,000
Desktop Contaminant Mobilization Study	4 months	$50,000 - $70,000
Leaching Study	4 months	$250,000 - $310,000
Groundwater Augmentation and Raw Water Augmentation (COL/ DVWTP)		
Independent Advisory Panel	12 months	$50,000
COLs Water Quality Analysis	8 months	$50,000
COLs Hydraulic Modeling/Water Balance	8 months	$100,000 - $150,000
COL Management Plan Update	12-16 months	$200,000
	Subtotal	**$800,000 - $930,000**
Further Define and Implement Technically Preferred Project		
CEQA	12-24 months	$1,00,000 - $1,500,000
Concentrate Management Investigation	6-8 months	$300,000
Quantitative Microbial Risk Assessment (QMRA)	6 months	$40,000
AWPF Demonstration	12 months	$500,000 - $1,000,000
Operator Training	6 months	$100,000
Permitting and Enhanced Source Control	12 months	$300,000 - $500,000
Groundwater Injection - If GW Injection Selected		
Injection and Monitoring Well Construction (1-2000 gpm)	24 months	$3,900,000 - $4,200,000
Tracer Study / Groundwater sampling	12 months	$100,000
COL - If Lake I recharge is selected		
Lake I Tracer Studies	4 months	$50,000
	Subtotal	**$6,300,000 - $7,800,000**

8.3 Schedule for Implementation

As discussed above, there are a number of additional studies and efforts required before a decision on proceeding with potable reuse in the Tri-Valley and before a specific project can be selected. Many of the technical studies can be conducted in parallel along with additional outreach and institutional efforts. One potential implementation schedule is shown in Figure 8.2 showing a project could be online in as little as 8 years if so desired.



*Tasks in italics are needed only if a project is selected for implementation.

Figure 8.2 Potential Implementation Schedule

8.4 Potential Funding Opportunities

The adequate funding of capital costs is a primary constraint in implementing a major construction project. There are funding sources available, typically through competitive grants and loans from State and Federal programs that could be applied to a Tri-Valley potable reuse project. A potable reuse project would likely be eligible for funding as it meets the following general requirements and objectives:

- Consistent with the California Water Action Plan (CWAP).
- Helps meet the State Recycled Water Policy objectives.
- Protects groundwater resources.
- Demonstrates regional cooperation and partnerships with partners and stakeholders.
- Consistent with objectives of US Bureau of Reclamation Title XVI program to reclaim and reuse wastewaters and naturally impaired ground and surface water in the 17 Western States and Hawaii.

Grants and low interest loans are highly competitive. Competitive funding programs require enhanced programs to meet as many of the following objectives as possible:

- Regional Partnerships
- Integrated project benefits.

- Water conservation.
- Renewable energy improvements.
- Economic stimulus:
  - Job creation.
  - Job preservation.
- Protects and prevents the spread of contamination in an aquifer that serves as a source of drinking water.

8.4.1 Summary of Funding Options

Costs for implementing a Tri-Valley Potable Reuse Project consist of two components – (1) capital cost for construction of facilities, and (2) annual O&M expenditures for both treatment and distribution systems/end uses.

The funding sources available range from traditional funding options such as pay-as-you-go funding, bond funding, grants, and State assisted loans to non-traditional funding sources such as market-based programs. These funding options are detailed in Appendix J. The following list summarizes a sample of other California utilities that are currently working on their potable reuse programs and how they are planning to fund them:

- Soquel Creek Water District - Prop 1 Groundwater grant (for preventing seawater intrusion), Title XVI grants, and SRF loans.
- Morro Bay - WIFIA loans and SRF loans
- Santa Clara Valley Water District - Public/Private partnership

The State of California is working on another water bond, so additional grant funding may be made available should that water bond pass in the future.

8.5 Conclusions

This study has shown preliminarily from a technical basis that a potable reuse project is feasible in the Tri-Valley area. In order to pursue any of these projects, several studies would need to be finalized, including the Regional Water Demand Study, Zone 7 Conjunctive Use Study, and the Zone 7 Water Supply Evaluation Update. If those studies show that potable reuse is needed for future water supply reliability, the appropriate potable reuse project would be pursued, with project specific investigations, including water quality analyses, groundwater/reservoir modeling, and site studies. Appropriate institutional, outreach, and funding next steps (as detailed in Appendix J) should be pursued concurrently with the technical studies.

Chapter 9

SUMMARY

9.1 Introduction and Purpose

The Water Supply Evaluation Update (2016 WSE Update) completed by Zone 7 Water Agency (Zone 7) in February 2016 underscored the need to pursue water supply options to enhance long-term water supply reliability for the Livermore-Amador Valley. Potential future water supply options identified in the WSE Update include the California WaterFix, desalination, and potable reuse. On February 11, 2016, participants in the Tri-Valley Water Policy Roundtable—including elected representatives from the cities of Dublin, Livermore, Pleasanton, San Ramon, DSRSD, and Zone 7—agreed to proceed in a more detailed study of potable reuse, which would be a local and drought-resistant supply. In response, the Tri-Valley Water Agencies, described further below, jointly funded and oversaw the effort to complete the Joint Tri-Valley Potable Reuse Technical Feasibility Study.

The primary goals of this study are: 1) to evaluate the feasibility of a wide range of potable reuse options for the Tri-Valley based on technical, financial, and regulatory considerations and 2) assuming that potable reuse is found to be technically feasible, to recommend next steps for the agencies.

9.1.1 Existing Facilities

Zone 7 supplies water to the Tri-Valley using both raw imported water (State Water Project), local water (Arroyo Valle), and groundwater. Raw water is treated at either the Patterson Pass Water Treatment Plant (PPWTP) or the Del Valle Water Treatment Plant (DVWTP) before distribution (locations shown in Figure 9.1). Zone 7's wells are primarily located in the western portion of the service area. Some groundwater in the Mocho area with high total dissolved solids (TDS) is treated through a demineralization plant before distribution. Additional Zone 7 water facilities include the Chain of Lakes (COL), a series of existing or former gravel quarries that are in the process of reclamation or have been reclaimed as storage or recharge lakes. Zone 7 currently owns Cope Lake and Lake I, with the rest of the ten lakes due to be transferred to Zone 7 in the future. Lake H is expected to be transferred for Zone 7's use over the next few years. Zone 7 will use the COL for a variety of water resource management activities.

Existing wastewater facilities include the DSRSD wastewater treatment plant (WWTP) and the Livermore Water Reclamation Plant (LWRP) as shown in Figure 9.1. Both DSRSD and Livermore have existing non-potable recycled water irrigation programs. Secondary effluent that is not used for producing recycled water is discharged to the San Francisco Bay through the Livermore-Amador Valley Water Management Agency (LAVWMA) and East Bay Dischargers Authority (EBDA) facilities.

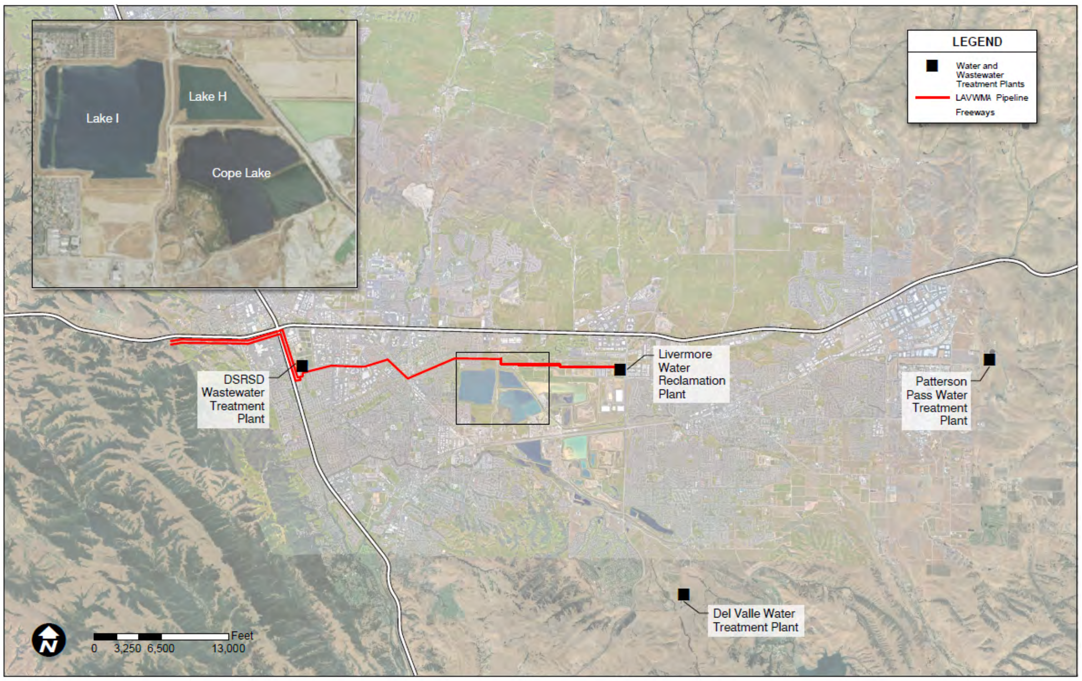


Figure 9.1 Existing Water and Wastewater Facilities

9.2 Alternative Development Method

Due to the numerous possibilities of potable reuse projects, with various source water, treatment locations, and end uses, a step-wise decision process was used to evaluate the potential Tri-Valley potable reuse projects, as is shown in Figure 9.2. At key stages in the selection process, workshops with representatives from all project participants were convened to facilitate key decisions.

9.2.1 Evaluation Criteria

A preliminary set of evaluation criteria was developed to narrow the initial list of alternatives down to three for further investigation. These criteria are as follows:

- Yield (measured by acre-feet per year - AFY).
- Cost (Capital and Operations and Maintenance [O&M]).
- Improved Supply Reliability.
- Improved Delivered Water Quality.
- Improved Groundwater Basin Quality.
- Clear Regulatory Pathway.
- Minimizes Neighborhood Impacts.
- Ability to Phase the Project.
- Operational Flexibility.
- Ease of Construction.

As decided by the project management team, the main criteria for the initial screening were cost and yield. After the initial screening of alternatives, additional criteria were used in the more detailed analysis.

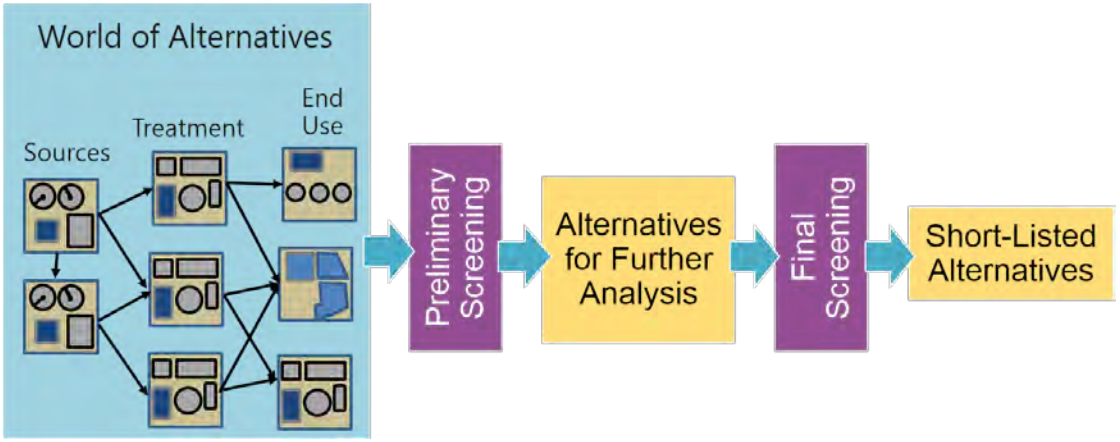


Figure 9.2 Alternative Development Process

9.3 Potable Reuse Status, Regulations and Treatment

Potable reuse has been utilized successfully by California agencies over 30 years as a means to extend water supplies. Other states have also successfully implemented potable reuse while being protective of public health. Project-specific permits for potable reuse have been issued in California for many years, although now regulations are clearly defined for groundwater recharge by the 2014 Groundwater Replenishment Reuse Projects (GRRPs) requirements included in Title 22 and the draft surface water augmentation (SWA) regulations were adopted following a public comment period in March 2018. The September 2016 draft report by the State Water Resources Control Board (SWRCB), titled "Investigation on the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse," found that it is feasible to develop uniform water recycling criteria that would incorporate a level of public health protection as good as or better than what is currently provided in California by conventional drinking water supplies (SWRCB, 2016). The state is now moving forward with developing regulations for other types of potable reuse in addition to groundwater augmentation/recharge and surface water augmentation.

9.3.1 Potable Reuse Definitions

The term "potable reuse" incorporates all types of reuse whereby recycled water is safely incorporated into potable water supplies. For the purposes of this study, the term "potable reuse" refers to the practice of using purified water derived from wastewater effluent to supplement water supplies.

The definitions below were compiled from the Framework for Direct Potable Reuse and California Assembly Bill 574 to reflect the recent changes in the terminology and for the specific terminology used in this study.

Groundwater Recharge: planned used of purified recycled water for replenishment of a groundwater basin or an aquifer that has been designated as a source of water supply for a public water system.

Raw Water Augmentation: planned placement of purified recycled water into a system of pipelines or aqueducts that deliver raw water to a drinking water treatment plant that provides water to a public water system.

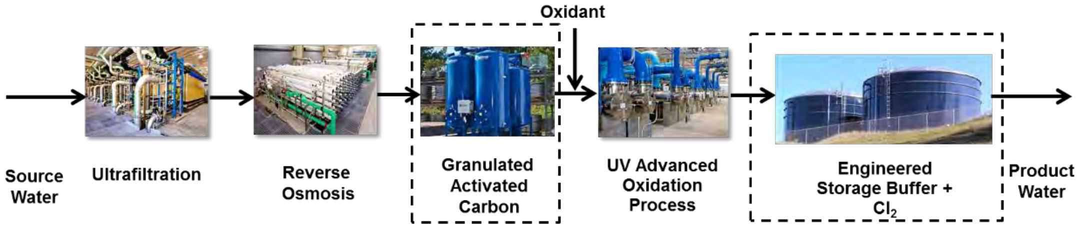
9.4 Treatment Technology

An advanced water purification facility (AWPF) is required for any potable reuse operation. Potable water reuse uses multiple barriers for reliable purification. The multiple barriers concept was designed to ensure public health and the reliability of the process. Each treatment technology has different capabilities in removing pathogens, contaminants of emerging concern (CECs), and meeting drinking water standards (Maximum Contaminant Levels [MCLs]) so combining them adds layers of safety as shown in Table 9.1. The treatment trains for Groundwater Recharge and Raw Water Augmentation are defined below using either existing regulations or industry experience and are shown in Figure 9.3.

A treatment train that meets regulatory guidance for groundwater recharge has been established by Title 22, termed Full Advanced Treatment (FAT). This widely accepted and regulatory approved treatment process train for potable reuse includes membrane filtration (MF/UF, micro or ultra-filtration), reverse osmosis (RO), followed by an ultraviolet light/advanced oxidation process (UV/AOP) step. The proposed treatment train for Raw Water Augmentation involves the addition of Granular Activated Carbon (GAC) after the RO process to prevent any contaminant spikes that might pass through the RO from getting to the finished water. An engineered storage buffer (ESB) is also included at the end of the treatment train. This ESB is a series of three tanks, which provides additional monitoring time to be able to respond to any issue in the treatment train upstream. This treatment train, called FAT+, when combined with the downstream WTPs, greatly exceeds expected regulatory goals.

Table 9.1 Treatment Technologies Target Removal and Multiple Barrier Concept

Target	UF	RO	GAC	UV AOP	ESB + Cl_2
Protozoa	X	X		X	
Virus		X		X	X
MCLs		X	X	X	
CECs		X	X	X	



Note: (Dashed lines show additional treatment technologies required for FAT+)

Figure 9.3 Advanced Water Purification Facility (AWPF) Treatment Train

9.5 Alternatives Identification

Alternatives were developed by combining various sources of water, treatment locations and different end uses as discussed below.

9.5.1 Source Water and Potential Yield

There are two sources of water for the purified water projects, LWRP and DSRSD WWTP. These two WWTPs have existing non-potable recycled water programs, which are planned to be continued even when a purified water project comes online. This limits the amount of available flow for the advanced water purification facility (AWPF). The available flow for potable reuse is seasonally variable and depending on the use of the source can affect the yield of the project as is shown in Figure 9.4.

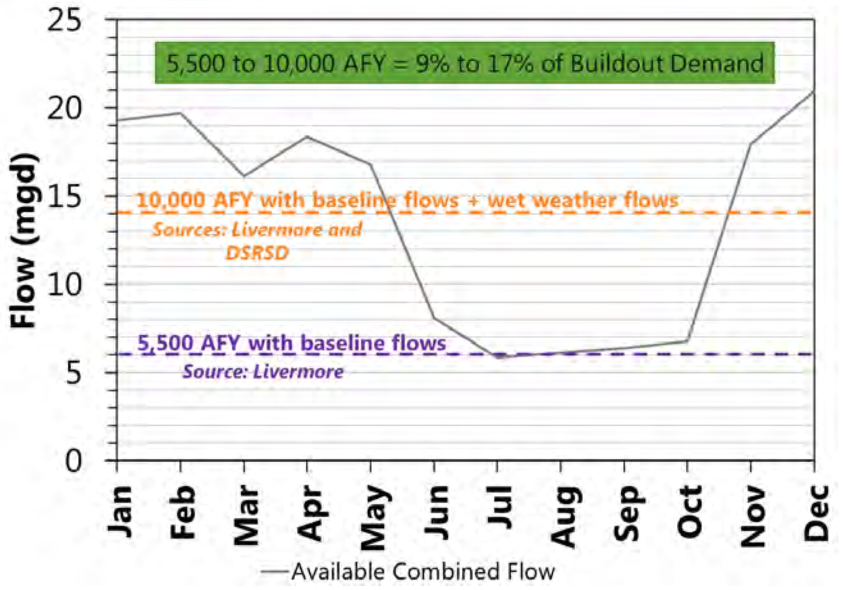


Figure 9.4 Projected Available Secondary Effluent Flows

The potential annual yield in acre-feet per year (AFY) was calculated using the proposed treatment trains described above, with an estimated 80 percent recovery rate (due to the RO recovery rate). Different possible flow scenarios and annual yields for potable reuse were created using buildout flow projections for LWRP and DSRSD WWTP:

- LWRP only flows = 5,500 AFY of purified water.
- Combination of DSRSD WWTP and LWRP flows, operating seasonally = 10,000 AFY of purified water.

A scenario to use seasonal storage to increase available flows for purified water was eliminated due to the high cost and the complication of the elimination of all of DSRSD's solids facilities to accommodate storage at the DSRSD WWTP site.

The remaining bookend scenarios of 5,500 to 10,000 AFY of purified water would provide between 9 to 17 percent of buildout potable water demands in the Tri-Valley.

9.5.2 Potential Treatment Locations

Criteria for selecting treatment locations included available space, proximity to source water, proximity to end uses, and site accessibility. Each WWTP has available space for an AWPF. Additionally, a few regional sites were proposed. With these criteria in mind, five preliminary options were chosen for potential AWPF location:

- DSRSD WWTP – in space currently used as a dedicated land disposal (DLD).
- LWRP – in the abandoned on-site facultative sludge lagoons (FSLs).
- Mocho – near Zone 7's existing Mocho Demineralization Facility.
- Chain of Lakes (COL) – between Cope Lake and Lake H.
- Pleasanton Corp Yard (added in July 2017).

All AWPF locations evaluated are shown in Figure 9.5.

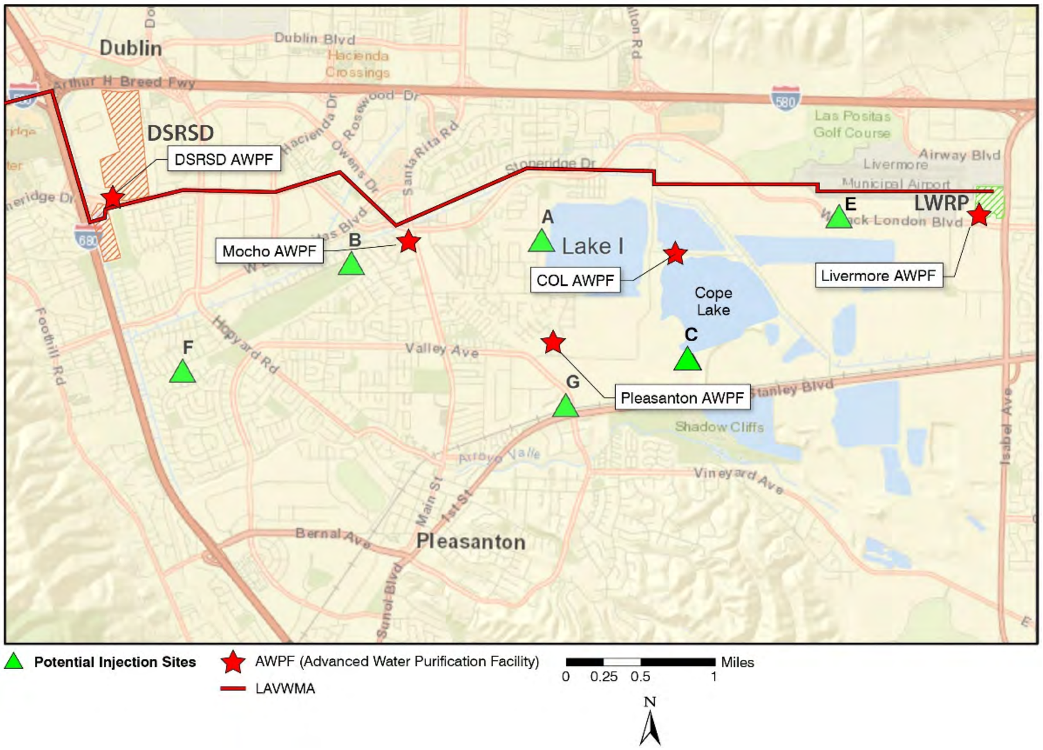


Figure 9.5 Five Potential Purification Facility Locations

9.5.3 End Use Selection

This study investigated three potential end uses for purified water:

- Groundwater augmentation or recharge via injection wells at two locations - one in the eastern side of the basin in Livermore and one in the western side in Pleasanton near the Mocho Demineralization facility
- Groundwater recharge via Lake I (Chain of Lakes) surficial recharge
- Raw water augmentation via Chain of Lakes to DVWTP (or directly to DVWTP)

Raw water augmentation via PPWTP was eliminated due to the long distance to convey purified water to the PPWTP from any of the AWPF sites evaluated.

9.5.3.1 Groundwater Injection

Several injection sites were identified based on proximity to treatment location, distance from production wells, potential to improve groundwater quality, and estimated transmissivity. These wells are shown in Figure 9.6. According to regulations, purified water must travel for a minimum of two months in an aquifer before reaching a production well. However, this travel time must be verified with a tracer study in order to receive full credit. If a tracer study cannot be conducted, six months of travel time via groundwater modeling is assumed within this study to be a minimum travel distance. Figure 9.6 shows an estimated two year travel time buffer around each production well indicating that the identified recharge well locations are outside of these buffer zones and would therefore meet the six- month travel time requirement. Placement of planned new supply wells would also need to consider the travel time requirements.

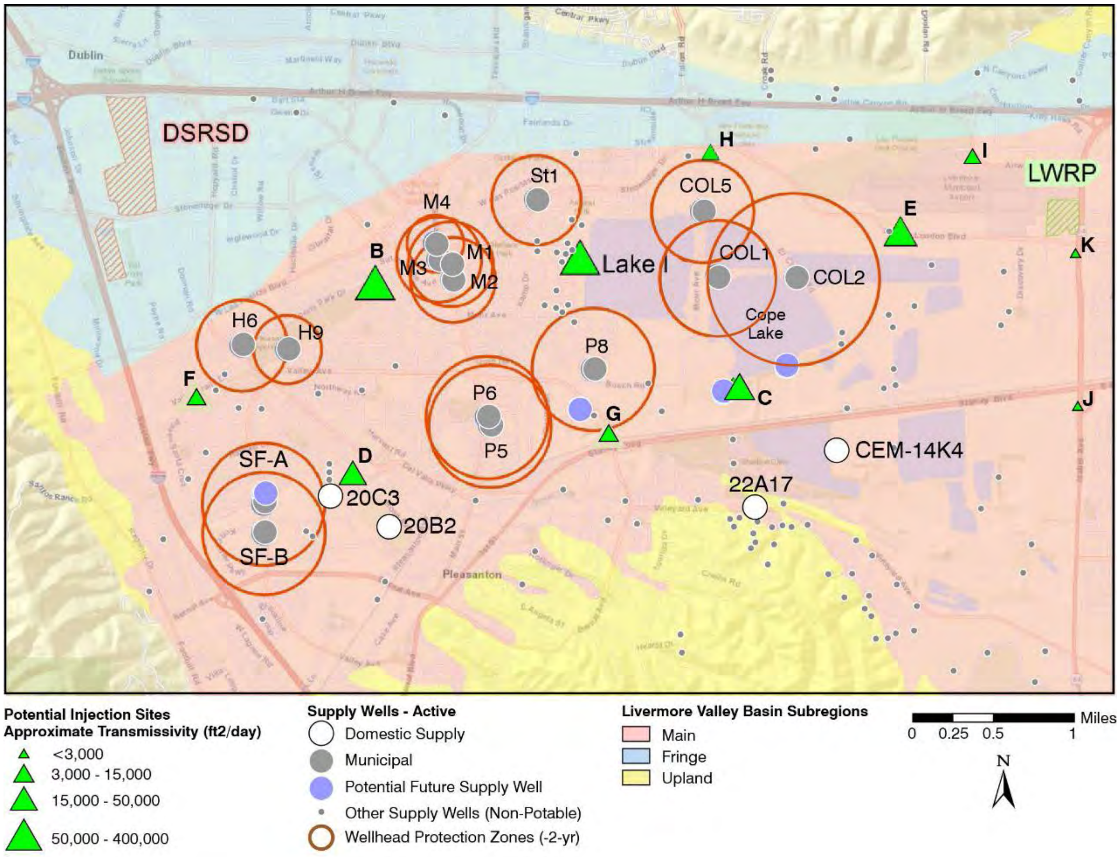


Figure 9.6 Potential Injection Well Locations

9.5.3.2 Groundwater Investigations

The hydrogeologic feasibility of developing a potable reuse project with groundwater recharge was evaluated and found to be technically feasible. Major findings are:

- Both Zone 7's 3-layer and 10-layer groundwater models were used to assess feasibility and found suitable conditions for recharge operations.
- Subsurface travel times between injection sites and existing extraction wells can meet regulatory requirements through proper selection of injection sites.

- Recharge with low TDS water from an AWPF can significantly improve water quality conditions in the groundwater basin on both a local and basin-wide scale, with varying amounts of quality improvement depending on input location.
- Aquifer storage and recovery (ASR) has been found to be effective at many other locations in the country and provides an option to maintain control over groundwater quality and quantity without migration down-gradient. It is recommended for further investigation in future studies.
- Methods to control mobilization of contaminants in the groundwater include stabilization of the purified water and proper geochemical and mineralogical studies once an injection location is identified.
- System wide operational modifications may be needed if a groundwater recharge project were to be implemented, as greater annual groundwater extraction would be required to maintain reasonable groundwater levels in the basin. Long-term groundwater and delivered water quality impacts should also be considered, as they may impact use of the existing Mocho Demineralization Facility and the need for and design of a second facility.

9.5.3.3 Raw Water Augmentation Using Chain of Lakes

The COL can be used in two separate ways – as a surficial recharge for the aquifer (via Lake I) or as a holding point before delivery to DVWTP (via Cope Lake and a planned COL pipeline). Since there is an existing connection between Lake I and Cope Lake, alternatives which send water to one of the lakes can, in effect, use both lakes as potential end uses.

Recharge Via Lake I

Lake I was identified in the 2014 Chain of Lakes Evaluation (Zone 7, 2014) as the highest among the COL for groundwater recharge potential. Lake I is hydraulically connected to the groundwater layer, so there is no vadose zone to provide separation or treatment. Recharge into Lake I would likely not meet the two month minimum travel time required by groundwater recharge regulations. Furthermore, recharge via Lake I would be considered raw water augmentation (with potential emergency use of Lake I to supplement surface water supplies) and the associated treatment train would be FAT+. Additional considerations for recharging Lake I include the existing discharge into Cope Lake (and ultimately transferred to Lake I) by Vulcan Materials Company that could take up available capacity.

Cope Lake to DVWTP

Zone 7 has identified a future capital improvement project to construct a pipeline and pump station at Cope Lake to connect the COLs to DVWTP. Alternatives sending water to Cope Lake assume the use of this connection to convey purified water to DVWTP for additional treatment and distribution. Cope Lake has a storage capacity of approximately 4,500 AF. To qualify as reservoir augmentation (per regulations), at least 180 days of storage in the reservoir must be shown. With most of the flow scenarios investigated, the hold time would be much less than 180 days. Therefore, alternatives using Cope Lake are considered Raw Water Augmentation.

9.6 Alternative Screening and Development

The flow scenarios, treatment trains, and end uses described above were analyzed through Carollo's master planning tool – Blue Plan-it®, which allows the user to investigate various alternative combinations and create potentially endless scenarios. Twenty-one viable scenarios were produced and evaluated primarily based on overall yield, total capital cost, and unit costs to narrow down to viable scenarios for further analysis.

Based on the analysis from the Blue Plan-it® planning tool, three alternatives were recommended for further detailed analysis. These three alternatives were expanded to six options in the July 2017 workshop. During this workshop, the Pleasanton Corps Yard was offered as a potential regional location. These options are summarized in Table 9.2. ***Note: the selected options were intended to provide bookends for the analysis, allowing evaluation of a range of sources, yields, AWPF locations, and end uses. They are not intended to preclude other options for future consideration.***

Table 9.2 Short-Listed Options for Detailed Evaluation

Option	Location	Capacity (mgd)	Operational Timing	Source Water	Treatment Train	End Use
1a	Livermore	5	Year-Round	LWRP	FAT+	COL (Lake I)/ DVWTP
1b					FAT	Well E
2a	DSRSD	12	Seasonal	DSRSD WWTP + LWRP	FAT+	COL (Cope Lake)/ DVWTP
2b					FAT	Well B
3	Regional at Mocho	12	Seasonal	DSRSD WWTP + LWRP	FAT	Well B
4	Regional at Pleasanton	12	Seasonal	DSRSD WWTP + LWRP	FAT+	COL (Cope Lake)/ DVWTP

Options 1a and 1b are the only projects that involve a year-round operation at a constant flow of 5 mgd. Options 2 through 4 have larger 12-mgd AWPFs which are intended to operate at full capacity during winter months (October through April) and at a reduced flow of 5 mgd in summer months (May through September). During the reduced flow periods, unused membranes would be stored in solution and rotated in and out of operation.

In the detailed investigations, site visits were conducted to all of the potential AWPFs (except for Pleasanton) and preliminary site layouts were developed for both FAT and FAT+ treatment trains. Preliminary design criteria for each treatment process were also established. A preliminary staffing assessment showed that a minimum of sixteen full time staff may be required for continuous operation. This number could decrease with a sufficient amount of automation.

9.6.1 Alternatives Comparison

The short-listed options were evaluated based on both qualitative and quantitative criteria. Table 9.3 presents the cost estimates for each short-listed project. Table 9.4 shows a qualitative comparison of the short-listed projects using the established evaluation criteria. For the purposes of the qualitative analysis, Option 1a was broken up into end use at the COL (Lake I) and end use as raw water augmentation to DVWTP to recognize their different impacts on reliability and groundwater quality.

Table 9.3 Cost Estimate for Short-Listed Options

	Livermore AWPF to COL/DVWTP Option 1a	Livermore AWPF to Well E Option 1b	DSRSD AWPF To COL/DVWTP Option 2a	DSRSD AWPF to Well B Option 2b	Mocho AWPF to Well B Option 3	Pleasanton AWPF to COL /DVWTP Option 4
Total Capital Cost	$112M	$103M	$222M	$194M	$210M	$208M
Annualized Capital Cost(1)	$7M	$7M	$15M	$13M	$14M	$14M
Annual O&M Costs	$7M	$7M	$9M	$9M	$9M	$9M
Actual Project Yield (AFY) (2)	5,500	5,500	10,000	10,000	10,000	10,000
Unit Cost of Water ($ per acft) (2)	$2,530	$2,420	$2,350	$2,160	$2,250	$2,240

Notes:

(1) Annualized capital costs based on a 5% interest rate and a 30-year payback period - typical of bond financing. Includes O&M.

(2) Actual yield based upon year round operation for Livermore plants and seasonal operation for options which treat both DSRSD and Livermore effluent.

9.7 Summary of Findings

Based on the book-end approach of considering alternatives, the major findings of this study are:

- Potable reuse for the Tri Valley is technically feasible. There were no fatal flaws identified by this technical evaluation.
- All alternatives increase water supply reliability, with the degree of benefit varying depending on yield (5,500 – 10,000 AFY) and, to a limited extent, end use (e.g., via groundwater recharge versus raw water augmentation).
- All alternatives improve drinking water quality and some improve the overall groundwater basin quality.
- There are good options available to site the AWPF facility.
- Regulatory pathways exist for all options.
- There is some variability in the overall operational flexibility and constructability depending on the option.
- Cost ranges for the book-end options:
    - Capital costs = $103 to $222 million
    - Operations and Maintenance Costs = $6.5 to $9M/year
    - Overall unit costs = $2,200-2,500/AF

Table 9.4 Qualitative Comparison of Short-Listed Projects

	Livermore AWPF to COL$^{(2)}$	Livermore AWPF to DVWTP$^{(2)}$	Livermore AWPF to Well E	DSRSD AWPF To COL/ DVWTP	DSRSD AWPF to Well B	Mocho AWPF to Well B	Pleasanton AWPF to COL/DVWTP
Yield (AFY)	5,500	5,500	5,500	10,000	10,000	10,000	10,000
Capital Cost (M$)	112	112	103	222	195	210	208
Improve Supply Reliability	+	++	+	+++	++	++	+++
Improved Delivered Water Quality	+	+	+	++	++	++	++
Improve Groundwater Basin Quality	+	o	+	o	+	+	o
Clear Regulatory Pathway	+	+	++	+	++	++	+
Minimizes Neighborhood Impacts	++	++	++	++	++	-	+
Ability to Phase the Project (1)	o	o	o	+	+	+	+
Operational Flexibility	++	++	++	o	o	-	-
Ease of Construction	++	++	++	++	++	-	+
+ positive impact impact			- negative impact				**o** neutral

Notes:

(1) Phasing in this report only refers to the ability to expand on one site, not the potential to build in phases at two different locations.

(2) For the purposes of the qualitative analysis, Option 1a was broken up into end use at the COL (Lake I) and end use as raw water augmentation to DVWTP to recognize their different impacts on reliability and groundwater quality.

9.8 Recommendations/Next Steps

If the partnering agencies wish to continue pursuing potable reuse, there are a number of technical efforts necessary. In the near-term, to narrow the best end use option, further studies and other efforts are needed to evaluate the best candidates for siting injection wells; to characterize the potential for contaminant mobilization in the groundwater basin using models and field test; and to determine the ability of the COL to receive, store, and recharge purified water in conjunction with other potential uses of the COL.

A broader effort refining regional demand projections would also help determine the need for the various water supply options available to the Tri-Valley—including potable reuse—and the target yield for those options. To place potable reuse in the context of other water supply options, the 2016 WSE update should be updated to reflect the findings from this study as well as new data and options that have developed since 2016.

While this study focused on technical issues, there are also major institutional and public outreach components to potable reuse implementation that would need to be addressed.

Appendix A

COST ESTIMATES

ID	Source	Capacity (MGD)	Annual Yield (AFY)	Seasonal/Year Round	Purification Location	Treatment	Storage	End Use Location	Treatment Cost	Pipeline / Pumps Cost	Well Cost	Storage Cost	Total Infrastructure Cost	Total Capital Cost	O&M Cost
1	L	4.9	5,500	Year Round	Livermore WRP	FAT	No	Well E	$71.1M	$9.8M	$11.7M	$0.0M	$21.5M	$93M	$4.3M
2	L	4.9	5,500	Year Round	Livermore WRP	FAT	No	Lake I	$79.7M	$15.3M	$0.0M	$0.0M	$15.3M	$95M	$4.3M
3	L	4.9	5,500	Year Round	Livermore WRP	FAT+	No	PPWTP	$79.7M	$46.7M	$11.7M	$0.0M	$58.4M	$138M	$4.8M
4	L	4.9	5,500	Year Round	Livermore WRP	FAT+	No	Cope Lake / DVWTP	$79.7M	$13.6M	$0.0M	$0.0M	$13.6M	$93M	$4.2M
5	L + D	6.9	7,700	Year Round	Regional at DSRSD WWTP	FAT	370 MG	Well F	$91.5M	$11.6M	$15.6M	$50.7M	$77.8M	$169M	$5.8M
6	L + D	6.9	7,700	Year Round	Regional at DSRSD WWTP	FAT	370 MG	Well B							
7	L + D	6.9	7,700	Year Round	Regional at DSRSD WWTP	FAT+	370 MG	Lake I	$104.5M	$29.2M	$0.0M	$50.7M	$79.8M	$184M	$6.1M
8	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at DSRSD WWTP	FAT	No	Well F	$143.0M	$16.6M	$23.4M	$0.0M	$40.0M	$183M	$8.2M
9	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at DSRSD WWTP	FAT	No	Well B							
10	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at DSRSD WWTP	FAT+	No	Lake I	$166.8M	$35.3M	$0.0M	$0.0M	$35.3M	$202M	$8.5M
11	L + D	6.9	7,700	Year Round	Regional at DSRSD WWTP	FAT+	370 MG	Cope Lake / DVWTP	$104.5M	$51.5M	$0.0M	$50.7M	$102.2M	$207M	$6.4M
12	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at Mocho	FAT+	No	Cope Lake / DVWTP	$166.8M	$37.9M	$0.0M	$0.0M	$37.9M	$205M	$7.9M
13	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at Mocho	FAT	No	Well B	$145.5M	$30.5M	$23.4M	$0.0M	$53.9M	$199M	$8.4M
14	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at Mocho	FAT+	No	Well A							
15	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at Mocho	FAT+	No	Lake I	$169.9M	$37.1M	$0.0M	$0.0M	$37.1M	$207M	$8.6M
16	L + D	6.9	7,700	Year Round	Regional at Mocho	FAT+	370 MG	Cope Lake / DVWTP	$96.0M	$23.2M	$0.0M	$50.7M	$73.9M	$170M	$5.7M
17	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at COL	FAT	No	Well C							
18	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at COL	FAT	No	Well H	$152.8M	$50.8M	$23.4M	$0.0M	$74.2M	$227M	$8.5M
19	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at COL	FAT+	No	Lake I							
20	L + D	11.8 (4.9 Summer)	10,000	Seasonal	Regional at COL	FAT+	No	Well A	$177.2M	$51.4M	$0.0M	$0.0M	$51.4M	$229M	$8.5M
21	L + D	6.9	7,700	Year Round	Regional at COL	FAT+	370 MG	Cope Lake / DVWTP	$101.6M	$29.5M	$0.0M	$50.7M	$80.2M	$182M	$5.6M

Notes:

(1) L = Livermore; D= DSRSD

(2) Annual costs based on an interest rate of % and an expected payback period of years, consistent with bond funding.

(3) Costs are estimated based upon the January San Francisco ENR-CCI of 11069

(4) This is a class 4 budget estimate as defined by the AACEI's Revised Classification () with an expected accuracy range of + or - percent. The cost estimate is based upon the Engineer's perception of current conditions in the project area and is subject to change as variances in the cost of labor, materials, equipment, services provided by others, or economic conditions occur. Since the Engineer has no control over these factors, he or she cannot warrant or guarantee that actual bids will not vary from the costs presented herein. This estimate does, however, reflect the Engineer's professional opinion of accurate costs at the time.

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Appendix B

WORKSHOP NO. 3 MEETING MINUTES

MEETING MINUTES

TRI-VALLEY POTABLE REUSE FEASIBILITY STUDY

Zone 7 Water Agency

Date: April 18, 2017

Project No.: 10414A.00

Purpose:	Discussion of preliminary alternatives		
Attendees:	**Zone 7:**	**Carollo Team:**	**DSRSD:**
	Amparo Flores, Jill Duerig, Wes Mercado, Colter Anderson, Carol Mahoney	Lydia Holmes, Elisa Garvey, Andy Salveson, Christina Casler, Jeff Stovall, Jeff Mosher- WE&RF	Rhodora Biagtan, Dan McIntyre, Judy Zavadil
	Pleasanton:	**Livermore:**	
	Kathleen Yurchak, Dan Martin	Darren Greenwood	
Distribution:	Attendees, Helen Ling		

Discussion:

The following is our understanding of the subject matter covered in this conference. If this differs from your understanding, please notify us.

Meeting Minutes

1. **NWRI and WE&RF overview**
    a. Both Zone 7 and DSRSD have provided funding for potable reuse research.
    b. Jill - note that Zone 7 supported reuse under the WRRF not under WateReuse. We were not comfortable contributing to a project that was promoting water reuse solely and were more stating that there needs to be more research in this area.
    c. AB 574 (Quirk) bill - come up with definitions for potable reuse, not keeping the "Indirect" and "Direct" in there. Titles are more based on the application.
        i. Deadline is 2021
2. **Decisions made and background**
    a. Discussion about flexibility in Cope Lake
        i. Currently 12 mgd project planned to build pipe between Cope Lake and DVWTP. Can be used to push water in either direction for treatment or for storage.
        ii. For the alternatives, it was recommended to increase the pump station to 20 mgd (the pipeline has sufficient capacity to handle this flow). Will allow use of pipeline for potable reuse while preserving current planed uses of the pipeline for emergencies, etc.
    b. Discussion on the 10,000 AFY assumption
        i. Amparo - 10,000 AFY comes from the Water Supply Evaluation Update & UWMP, identified as potential future water supply so a good upper bracket for the analysis. Would get Zone 7 to a certain amount of reliability.

        ii. Judy- is the 10,000 afy satisfying a potential discrepancy in water demand and supply?
        iii. Amparo - Essentially, yes, the 10,000 AFY meets the demand and supply discrepancy. However, Zone 7's approach is not simply to look at a water demand and supply balance under normal conditions and calculate the difference. We identify possible water supply options—with their associated amounts and timing—and use those as inputs to the water supply risk model, then run the model to see if reliability goals are achieved with those options. In the WSE Update, the upper end of what was estimated available from both desal and potable reuse was around 10,000 AFY. Note that while the 10,000 AFY was used as a bookend for the analysis for this study, there were other limiting factors to going beyond 10,000 AFY so this number appeared reasonable.
        iv. Carollo to solidify the rationale for the 10,000 afy number .

3. **Alternatives Development Discussion**
    a. Seasonal vs Constant Flow
        i. Amparo - what about the operational difficulty with seasonal treatment?
            1. Jeff M - we have El Paso that operates with 4 modules that rotate in and out of use and it works fine.
        ii. Storage
            1. **Decision** - As a group decided to delete the option to get to 10,000 AFY constant flow with 450 MG of storage.
    b. **Decision -** For cost estimates - switch to San Francisco ENR-CCI to be consistent with WSE Update.
    c. End Use discussion - groundwater wells
        i. Jill - what was our basis for injection well locations? Well master plan has new wells that we are planning, we should incorporate these when placing well locations and calculating travel time.
            1. **Decision -** The original well placement was developed through discussion with the PM team and Zone 7 groundwater staff, but in future developments of alternatives, we should also consider the additional wells to be constructed by Zone 7.
        ii. Jill - concern about ability to inject.
        iii. Jill - did you incorporate some years when we couldn't use recharge as an option, when the basin is full?
            1. Amparo – Carollo's analysis has not included this yet. This is something that can be analyzed using the water supply risk model during the more detailed analysis of short-listed options.
        iv. Jeff M - would you not increase your groundwater production if you had excess groundwater?
            1. Jill - no we don't normally - groundwater is not as good of quality and demin facility is only a certain size.
            2. Jill - groundwater recharge with purified water may increase release of chromium, arsenic, or other metals from the soils into groundwater.
                a. Note - next task of work will evaluate this issue.

        v. Judy - we need to balance our concerns about water quality - while injection could potentially worsen the groundwater quality due to contaminant mobilization, it could also benefit and be in line with the salt and nutrient management plan.

4. **Regional Modeling Discussion**
    a. Water level elevation - about 310 feet.
    b. Well C was not modeled in this run because of limited time.
    c. **Decision -** We would have to consider mining activities if we're bringing groundwater elevations up by 25 ft . Could affect their operations and need to dewater.
        i. They have permits to discharge going out to 2060.
    d. Operations staff has expressed preference in increasing storage and groundwater recharge in the COL area.
    e. Judy - did we have a maximum groundwater level assumption?
        i. For this preliminary modeling, no.
    f. Amparo – The WSE update may have assumed an 80% limit to groundwater operational storage until mining is done. Staff can check this. The preliminary groundwater modeling is only being used to compare impacts across the alternatives, and not to predict actual levels in the groundwater basin. The water supply risk model could be used to evaluate impacts to the groundwater basin when the detailed analysis is done for the short list of alternatives.
    g. **Decision -** for future analysis, we need to add to considerations for groundwater recharge - like modifying operations. We will likely need to modify operations with all alternatives, WTP, Lake I, Injection wells (e.g., changing groundwater/surface water blend).
5. **Alternatives Discussion and Screening**
    a. Discussion question 1 - Do we have any more alternatives we want to run?
        i. **Decision -** Group agrees no more alternatives need to be analyzed.
    b. Discussion question 2 - Any alternatives that need modification? Combined?
        i. Combinations could include modular regional approach or we could have a plant at Livermore and then a second plant at DSRSD.
    c. Discussion on question 3 - Recommended Alternatives
        i. Carry forward at least one GW well alternative and one WTP alternative.
        ii. Carry forward at least one 10,000 afy option for groundwater recharge.
        iii. **Decision -** Group agrees to remove any alternative that requires storage (Alternatives 5, 7, 11, 16, and 21).
        iv. **Decision** - Pair Lake I with Cope/DVWTP. Provides flexibility for operations.
        v. **Decision** - Team would like Alt 2 (Livermore to Lake I), combined with Alt 4 (Livermore to DVWTP).
        vi. Need to select lower capital cost alternatives and not just lower $/AF. Will be difficult for Valley to pay for project over $200M.
        vii. Location of purification facilities:
            1. There's more operations support for something at an existing facility.
            2. Zone 7 operations folks were not concerned about the location difference.
            3. Is there any public perception regarding collocating a WWTP and a purification facility?
                a. Jeff M - In El Paso, they're building a wall between the two facilities but they are on the same site.
        viii. Yield - as alternatives are refined, we don't have to get all 10,000 afy into the ground it's not a magic number. Determine what makes sense technically.

            ix. **Group Decides on Recommended alternatives**
                1. **Option 1 - Alternatives 2 and 4 combined - Livermore to Lake I, Cope and DVWTP**
                2. **Option 2 - Alternative 12 - DSRSD Seasonal operation to Surface Water Augmentation (Cope/DVWTP)**
                3. **Option 3 - Alternative 13 - Mocho Seasonal operation to GW well (but adjust well location for travel time)**

6. Joint Liaison Committee meeting next week
    a. Decision: Provide an overview of potable reuse regulatory framework and projects and overview of current project status (e.g., range of end use alternatives, bookends of water supply amounts). Slide on the AB 574 would be a good backpocket slide.

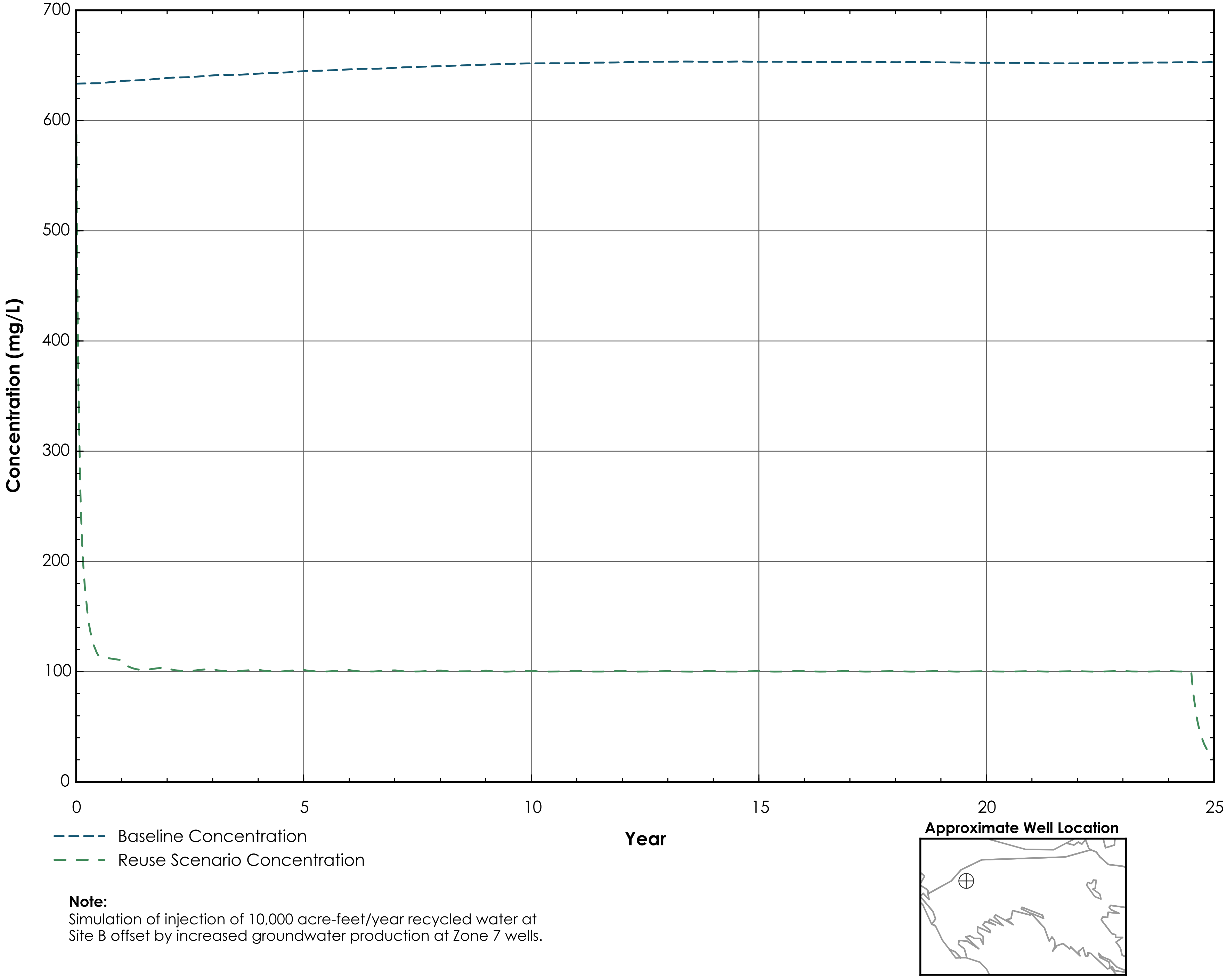
Action Items:

- Carollo/PM team
    - Adjust ENR-CCI to be SF and not 20-Cities.
    - Clarify rationale for 10,000 AFY bookend
    - Continue detailed analysis on recommended alternatives - Option 1 (Alts 2 & 4 combined), Option 2 (Alt 12) and Option 3 (Alt 13)
    - Detailed analysis needs to include the following
        - Existing and planned wells for travel time calculations
        - Impacts of groundwater levels on mining and recharge operations – confirm whether groundwater basin should only be kept at 80% full until mining is done
    - Need to evaluate operational strategies for each of the recommended alternatives. These new strategies should be incorporated into the groundwater model.
        - Zone 7 to run Risk Model to evaluate impacts of alternatives to the groundwater basin and storage options
    - Presentation/slides for meeting next week with slimmed down discussion

Appendix C

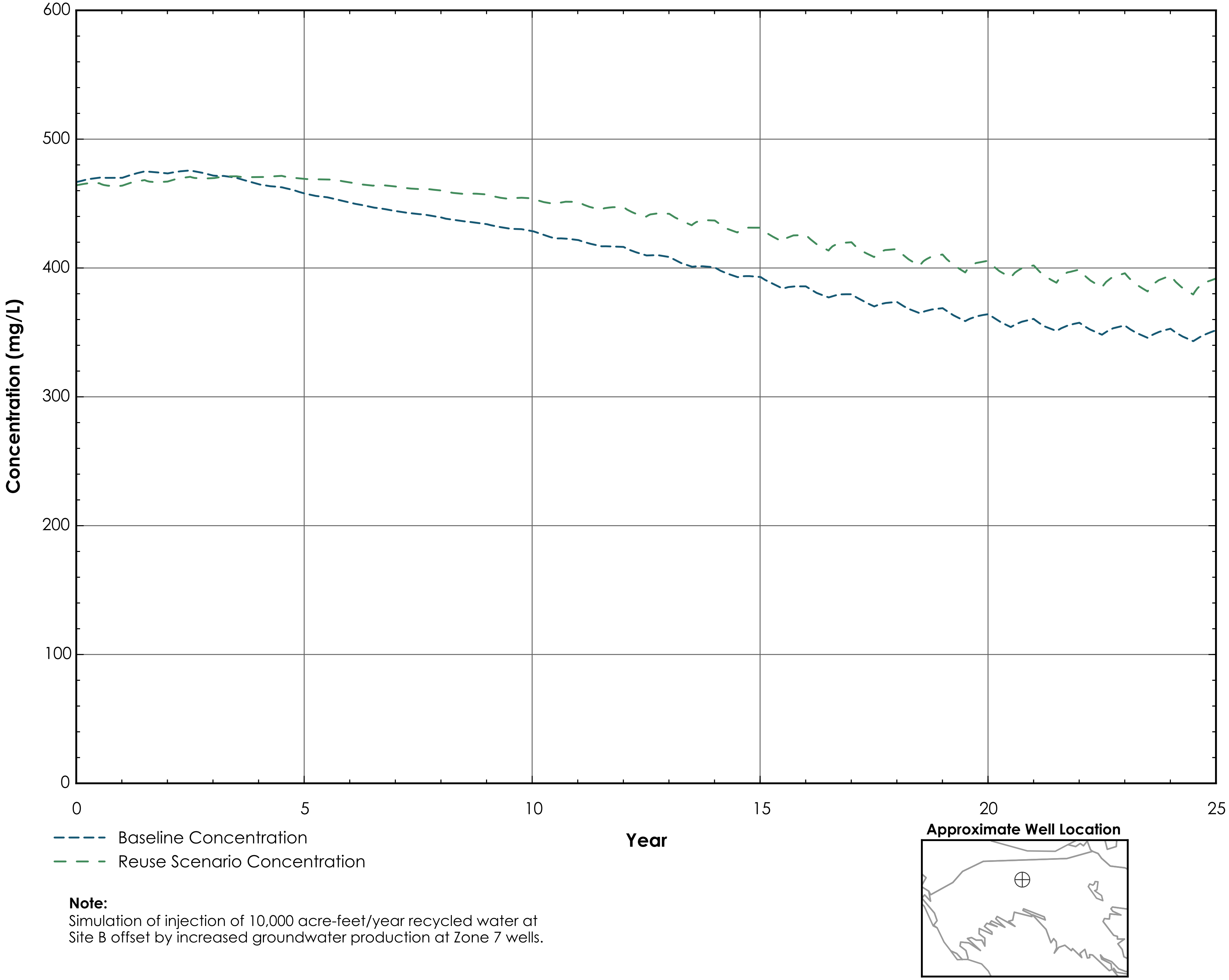
SIMULATED TDS CONCENTRATIONS IN PRODUCTION WELLS

Well Inj B Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



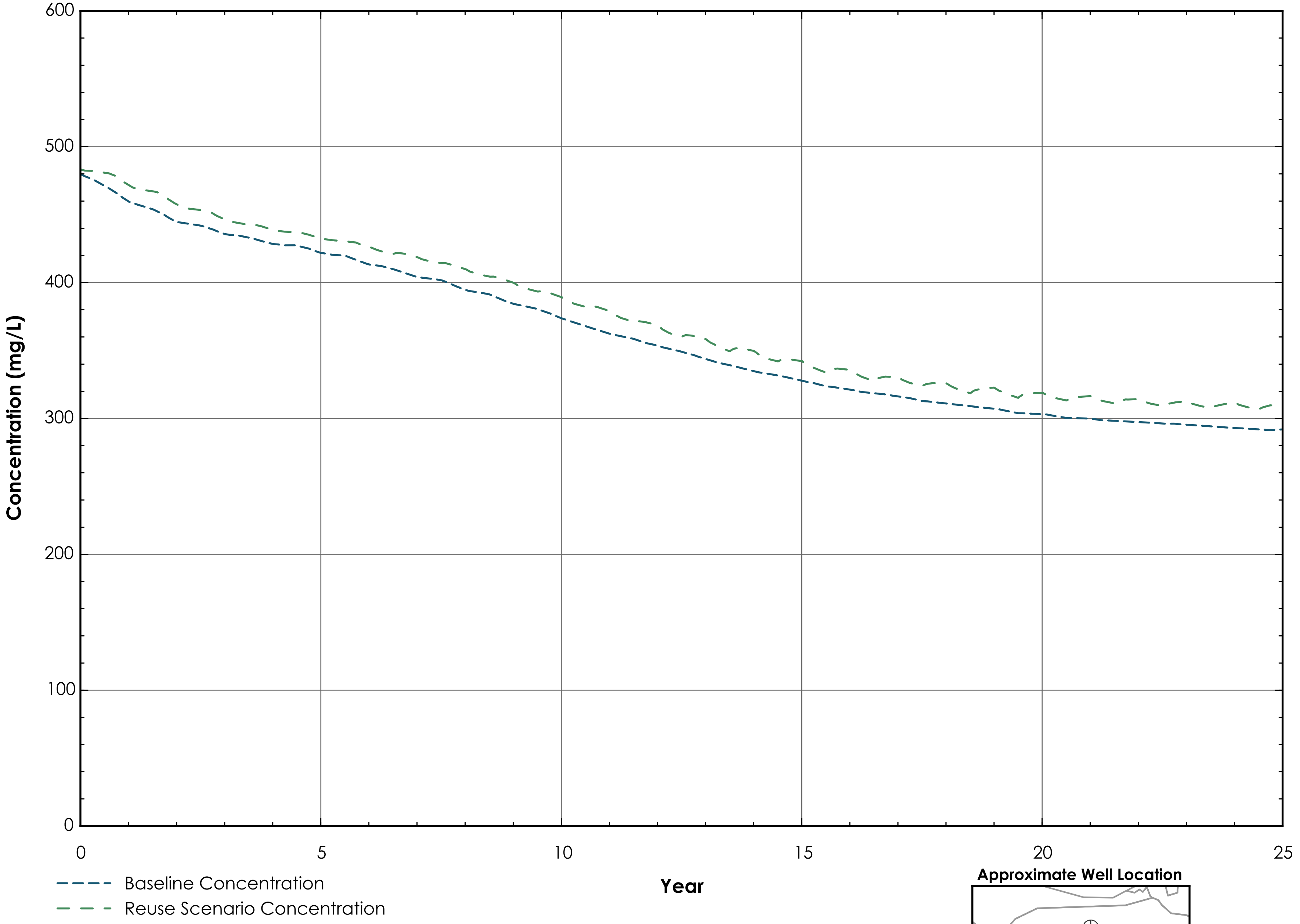
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Site B offset by increased groundwater production at Zone 7 wells.

Well COL 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B

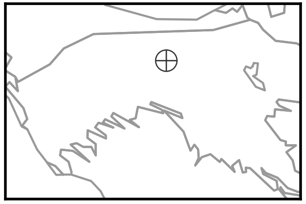


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Site B offset by increased groundwater production at Zone 7 wells.

Well COL 2 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B

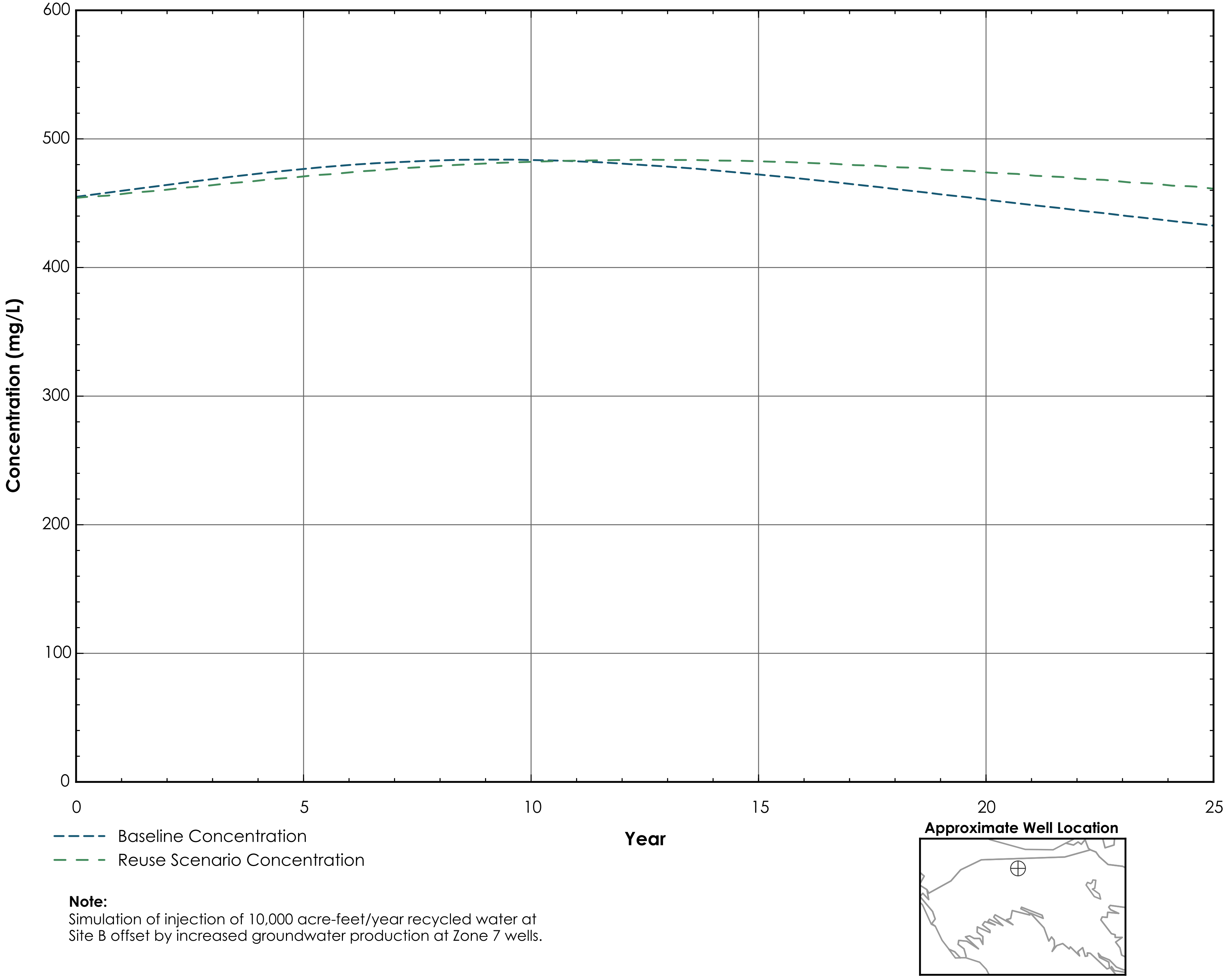


Approximate Well Location



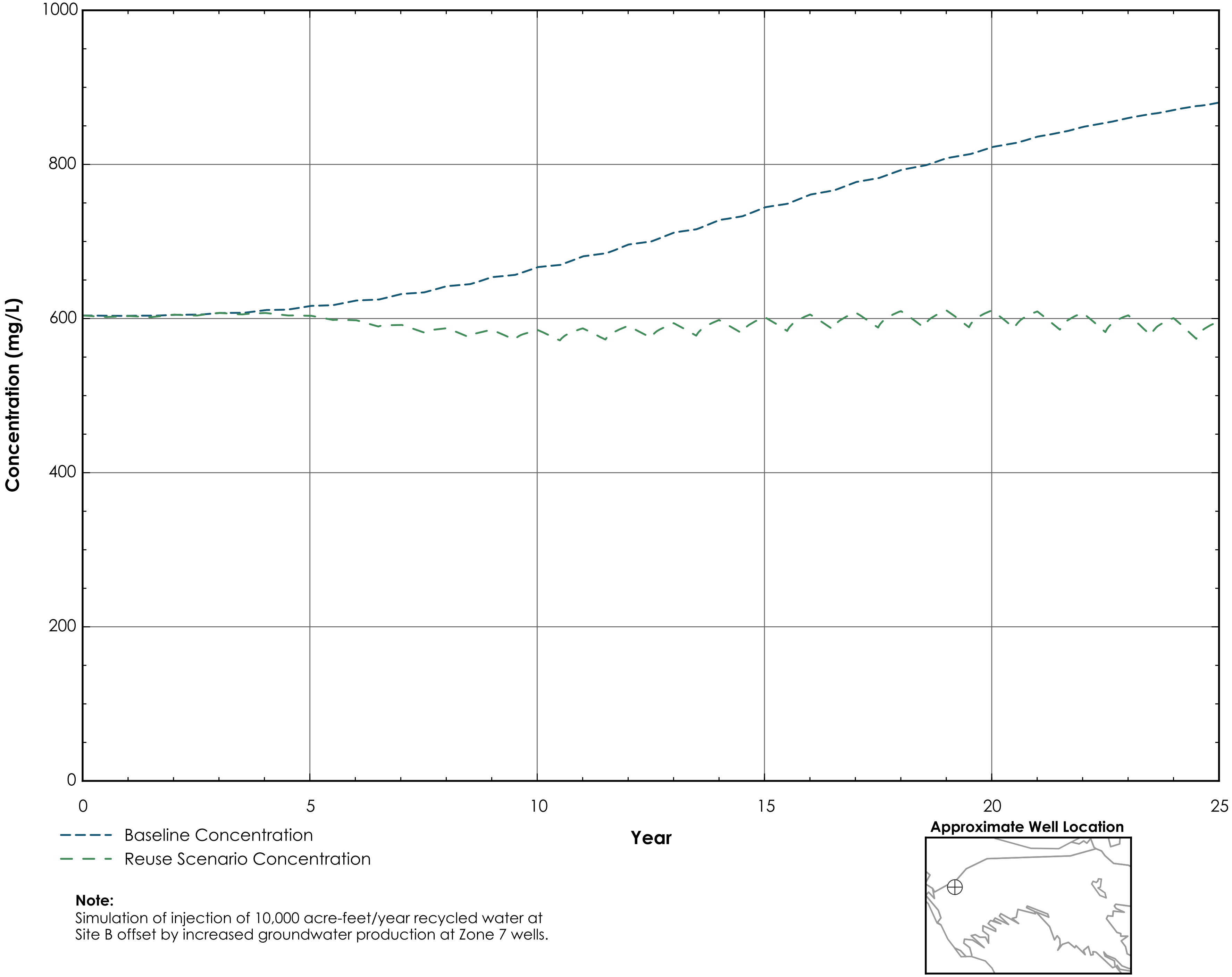
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Site B offset by increased groundwater production at Zone 7 wells.

Well COL 5 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



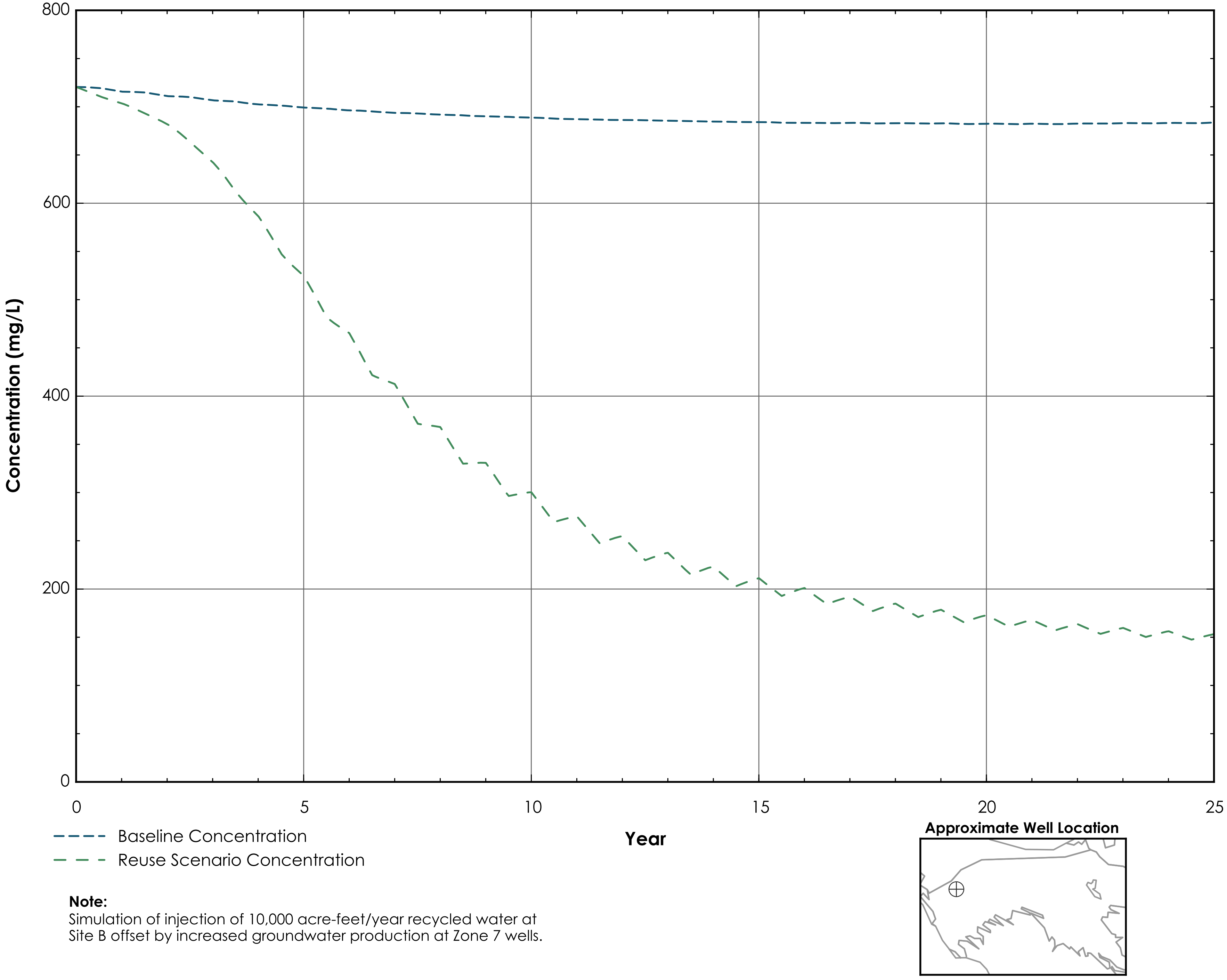
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Site B offset by increased groundwater production at Zone 7 wells.

Well HOP 6 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



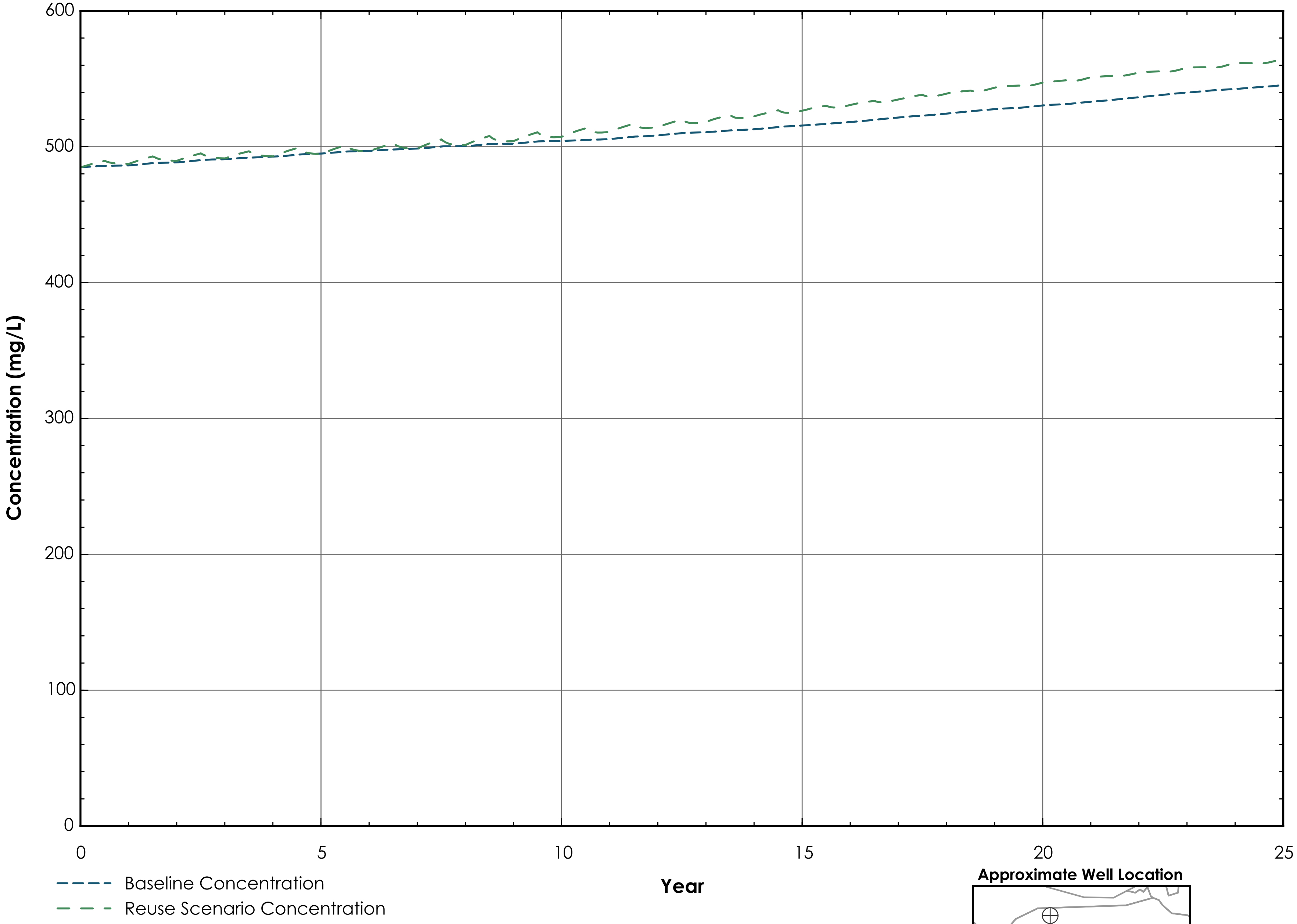
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Site B offset by increased groundwater production at Zone 7 wells.

Well HOP 9 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



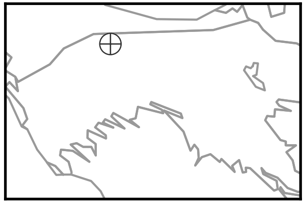
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Site B offset by increased groundwater production at Zone 7 wells.

Well STONERIDGE 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B

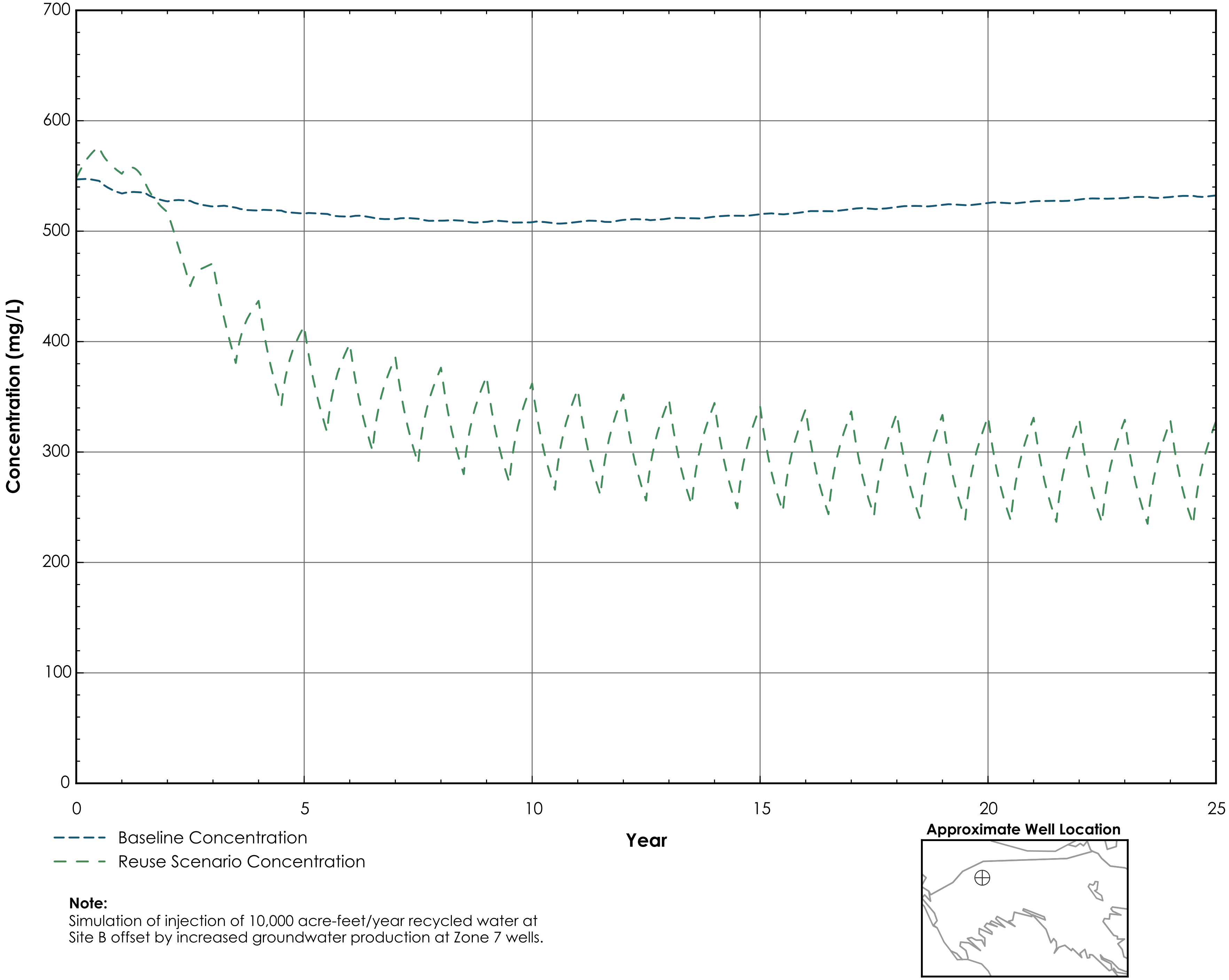


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Site B offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

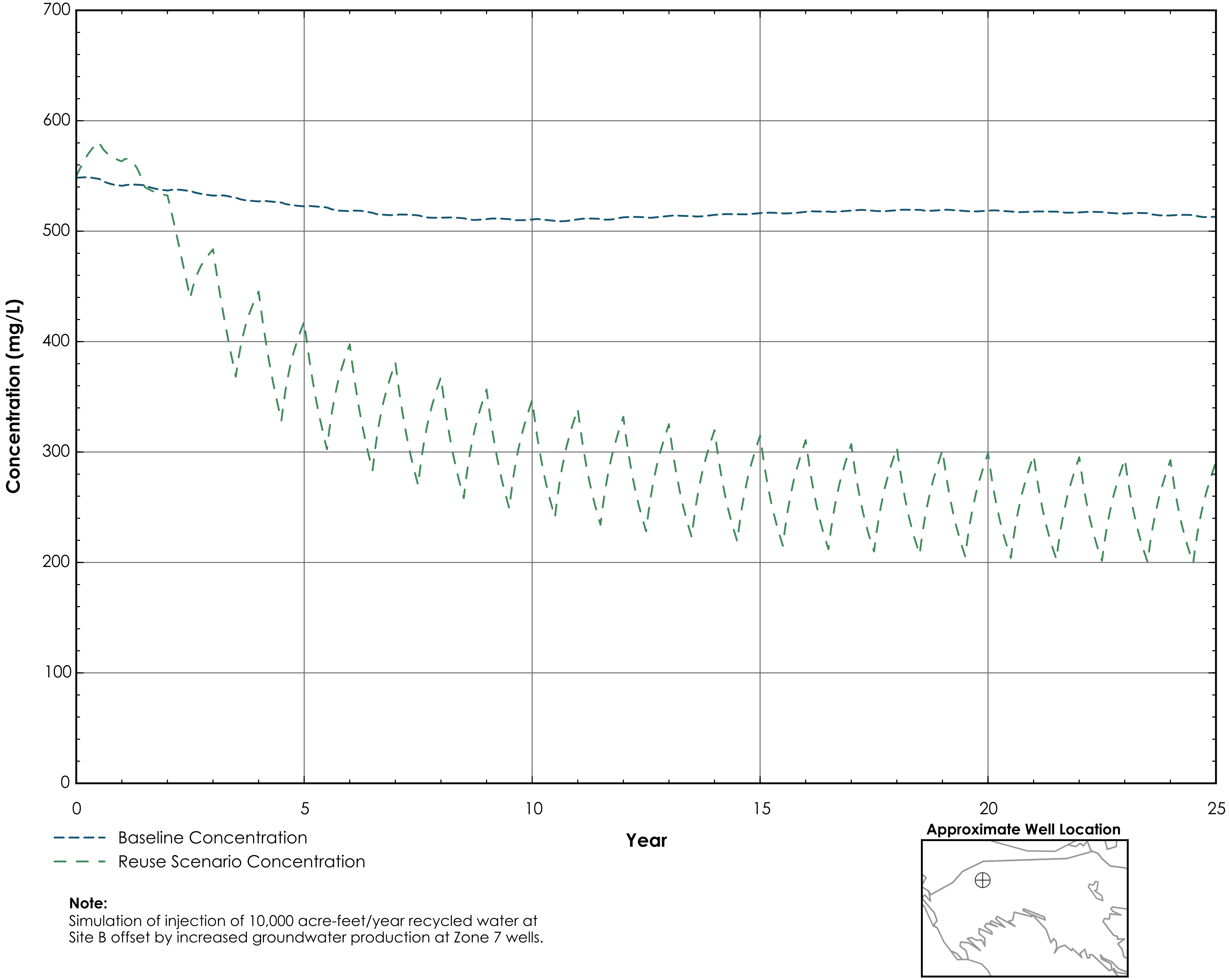


Well MOCHO 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



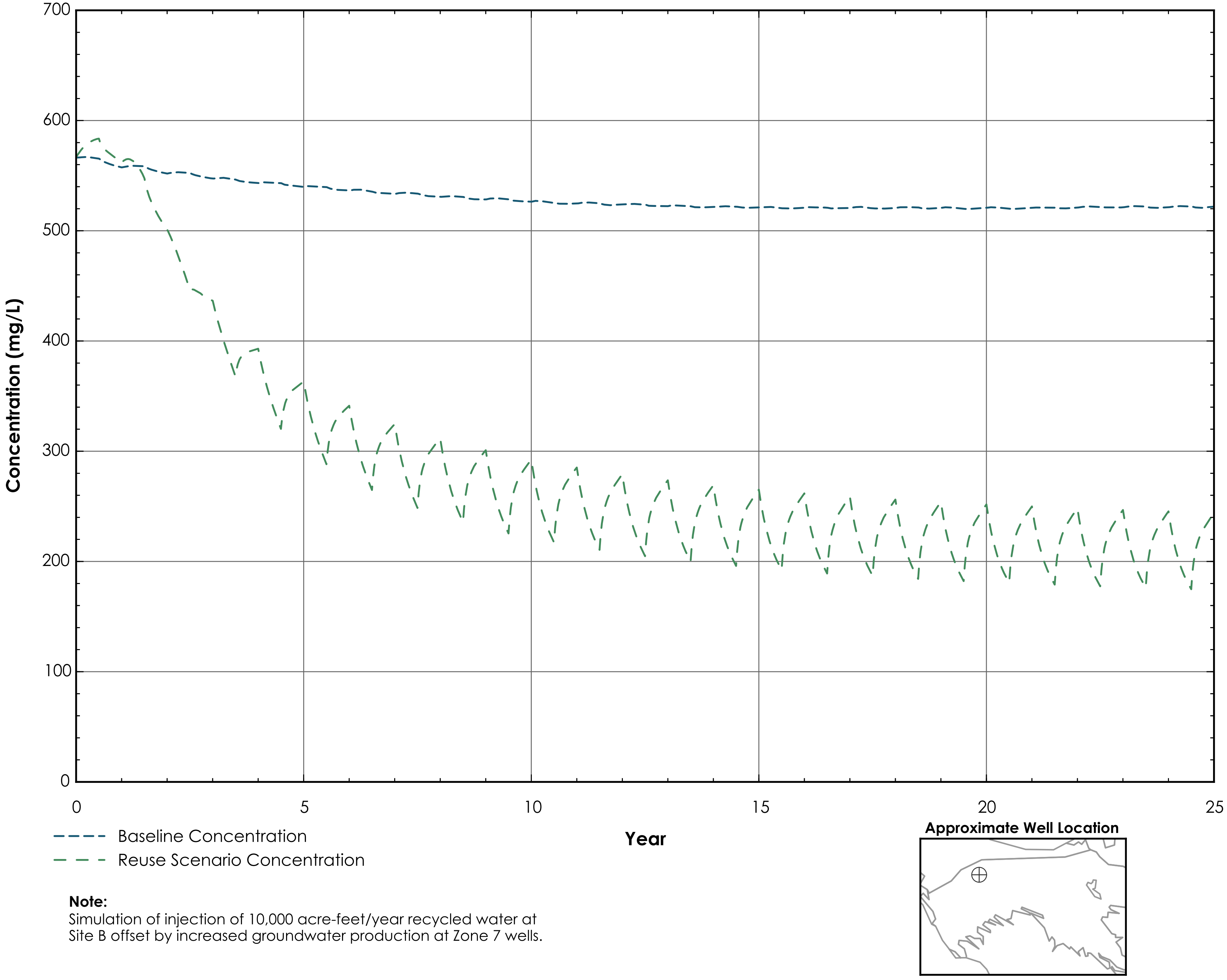
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Site B offset by increased groundwater production at Zone 7 wells.

Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



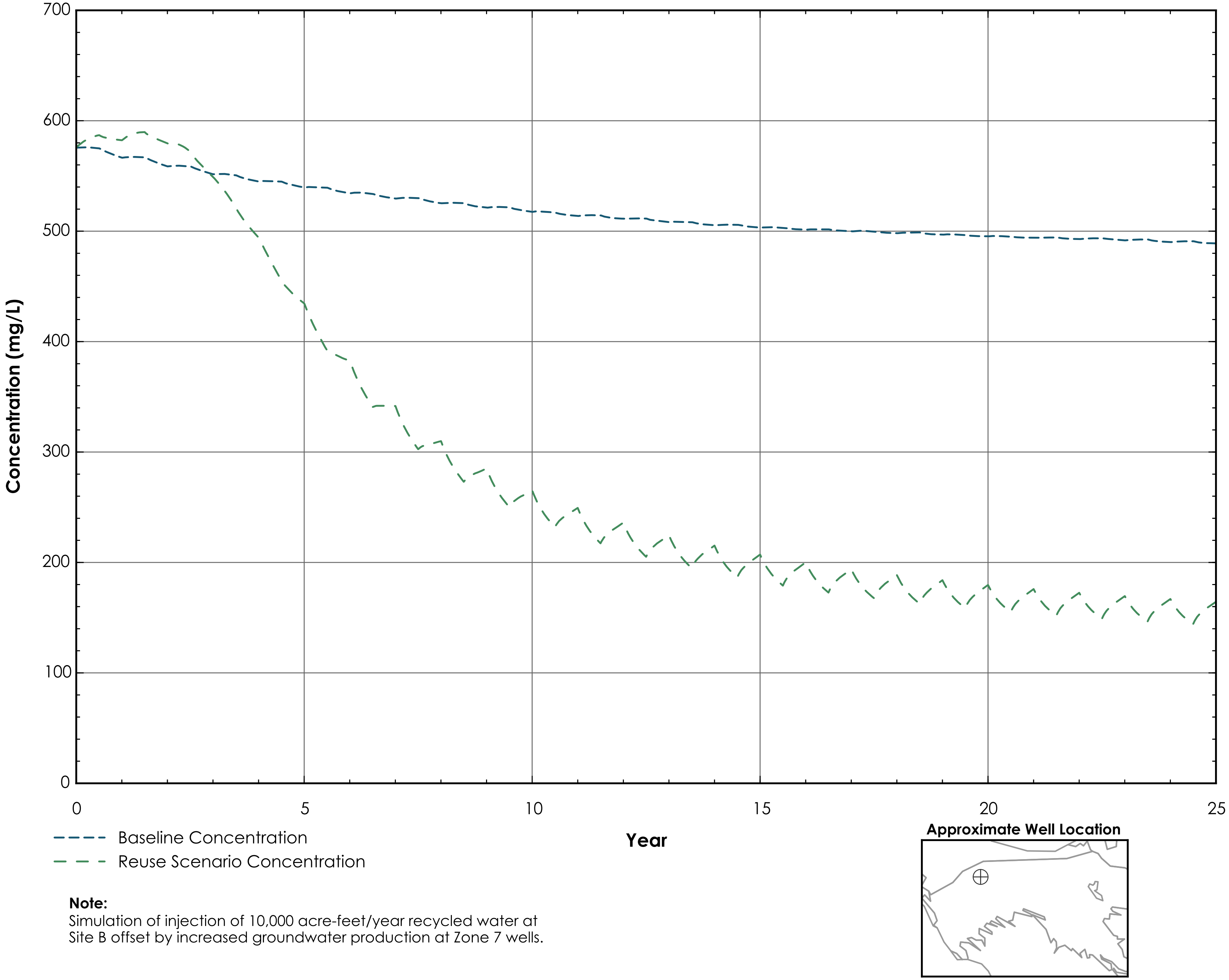
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Site B offset by increased groundwater production at Zone 7 wells.

Well MOCHO 3 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



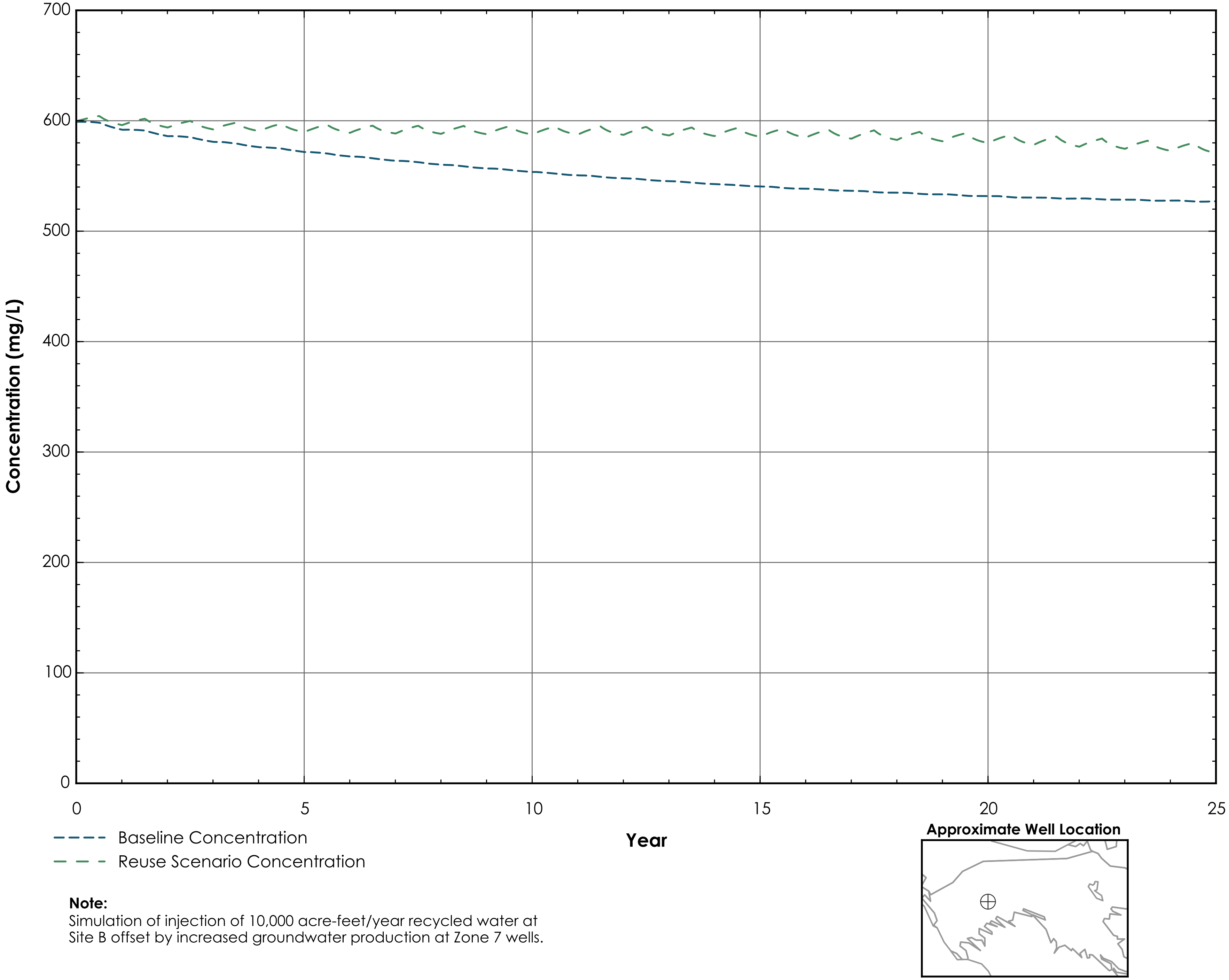
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Site B offset by increased groundwater production at Zone 7 wells.

Well MOCHO 4 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



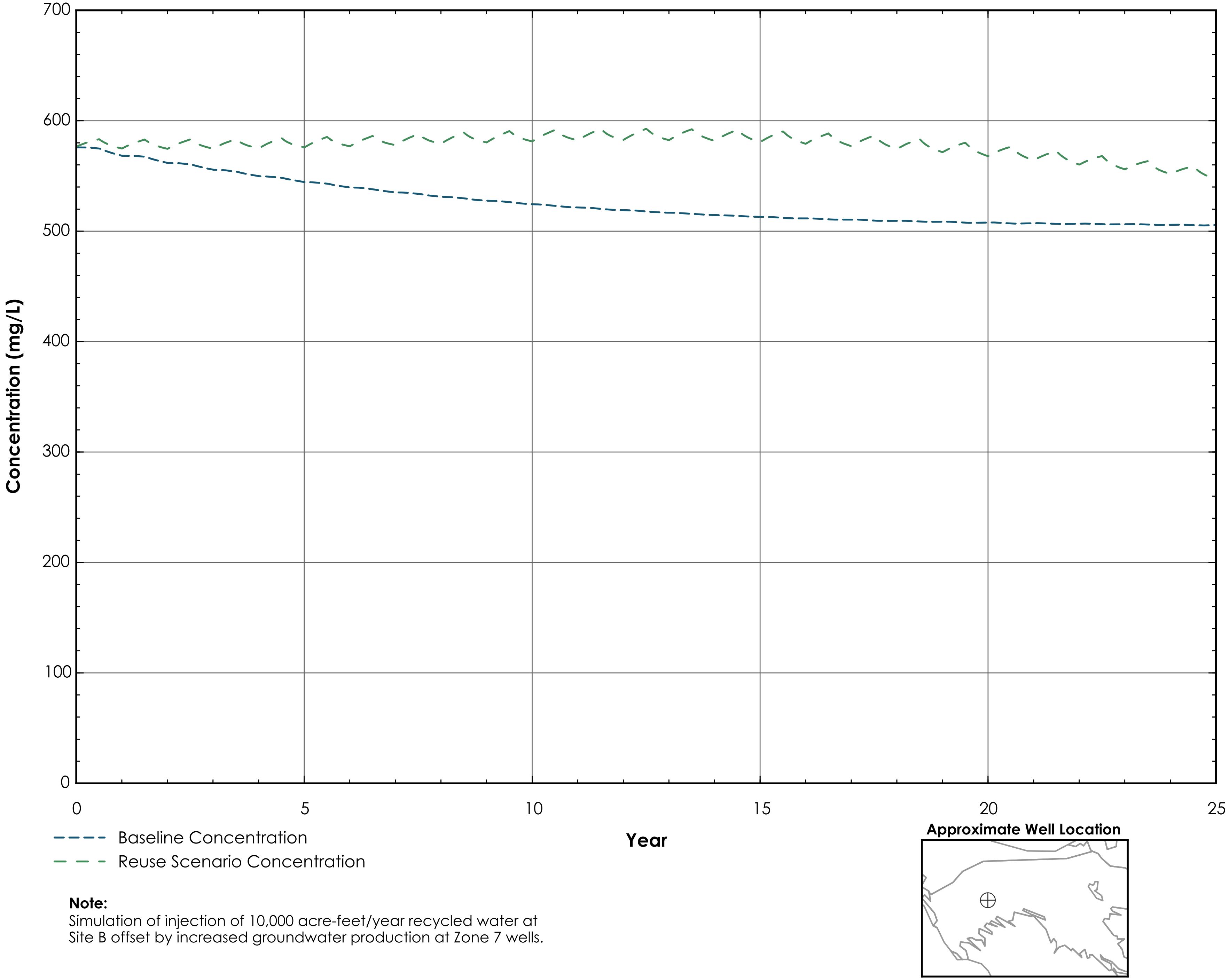
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Site B offset by increased groundwater production at Zone 7 wells.

Well PLEAS 5 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



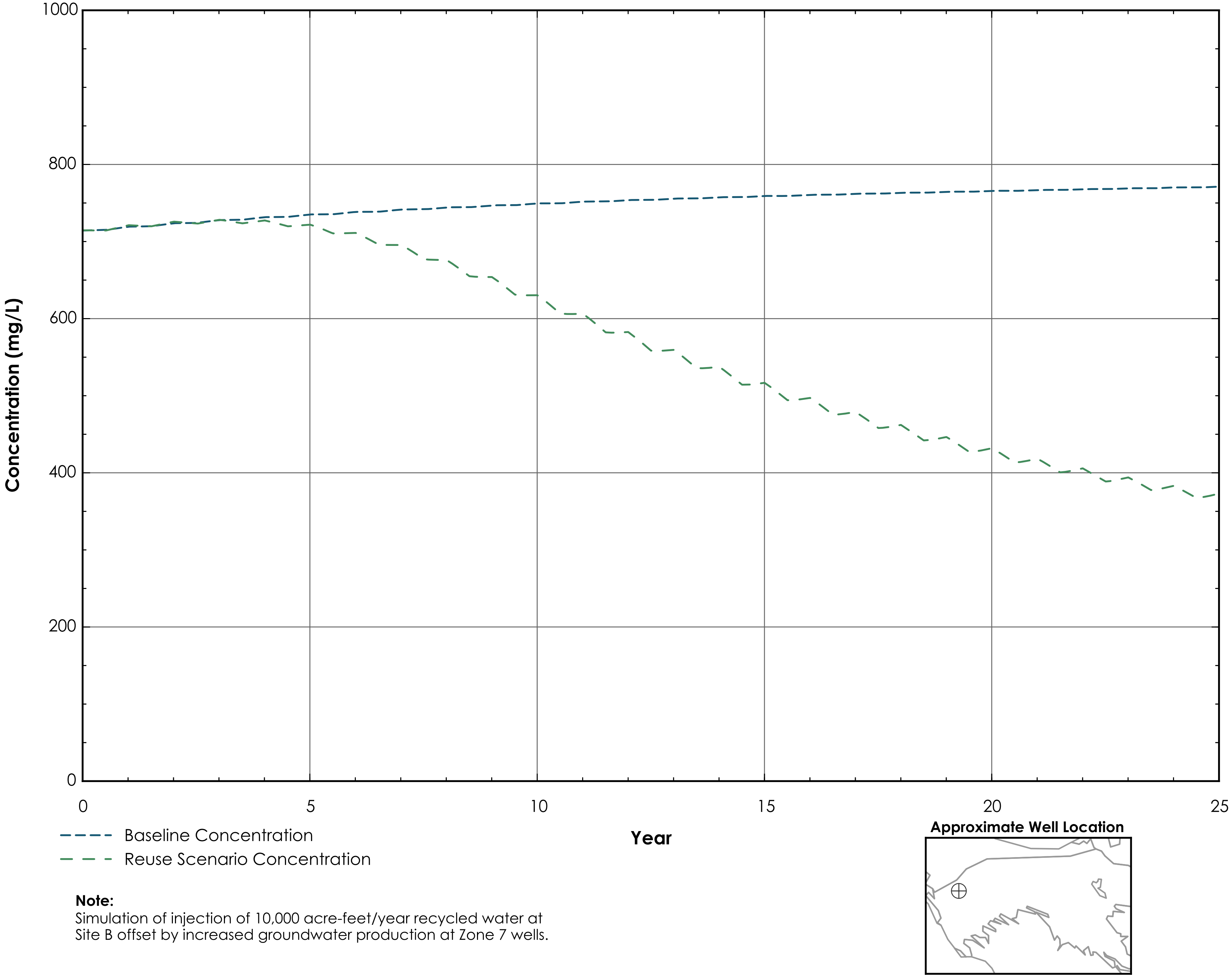
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Site B offset by increased groundwater production at Zone 7 wells.

Well PLEAS 6 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



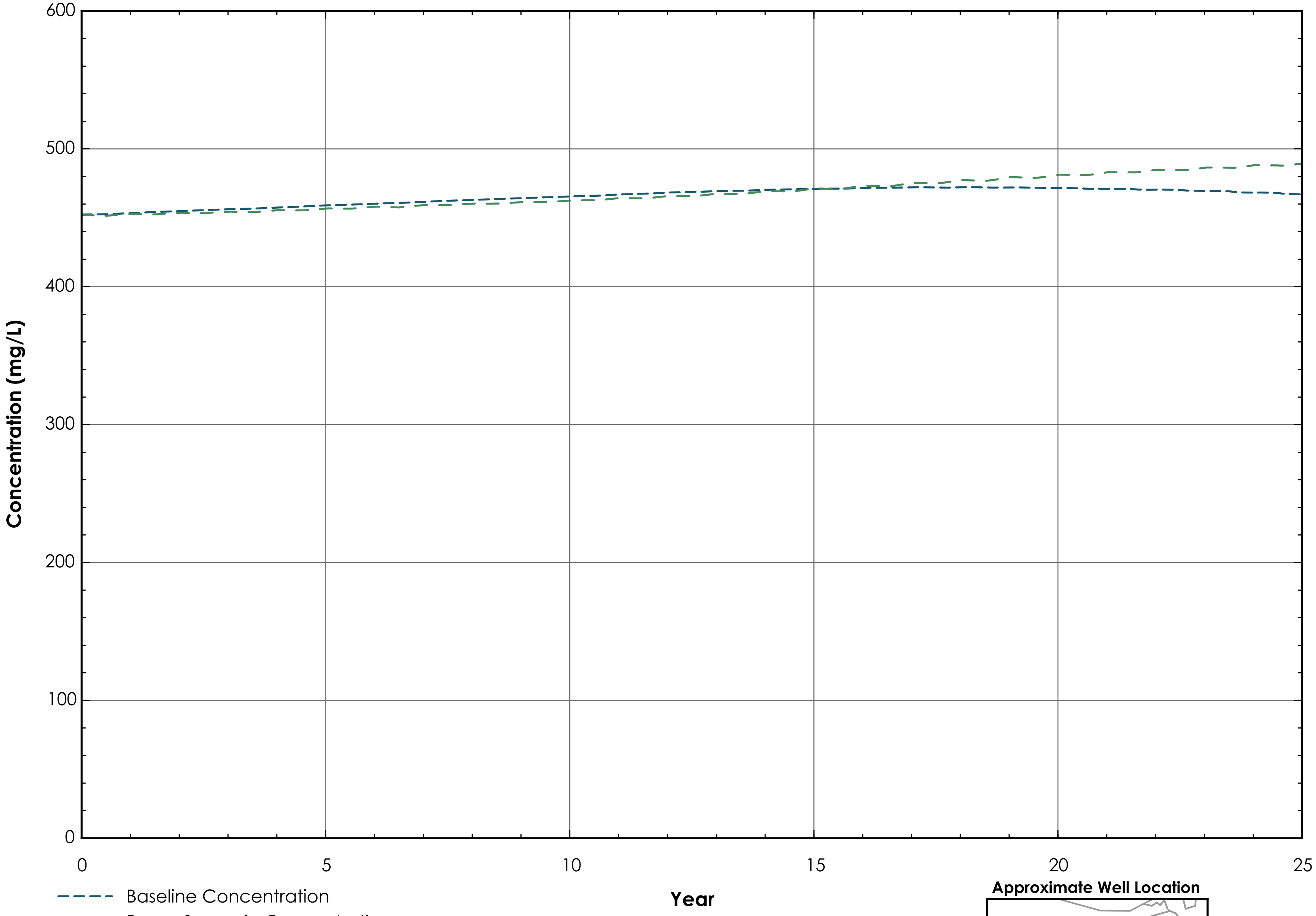
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Site B offset by increased groundwater production at Zone 7 wells.

Well PLEAS 7 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Site B offset by increased groundwater production at Zone 7 wells.

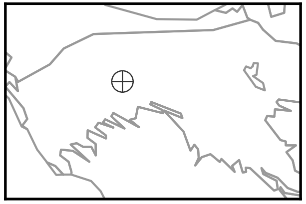
Well PLEAS 8 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Well B



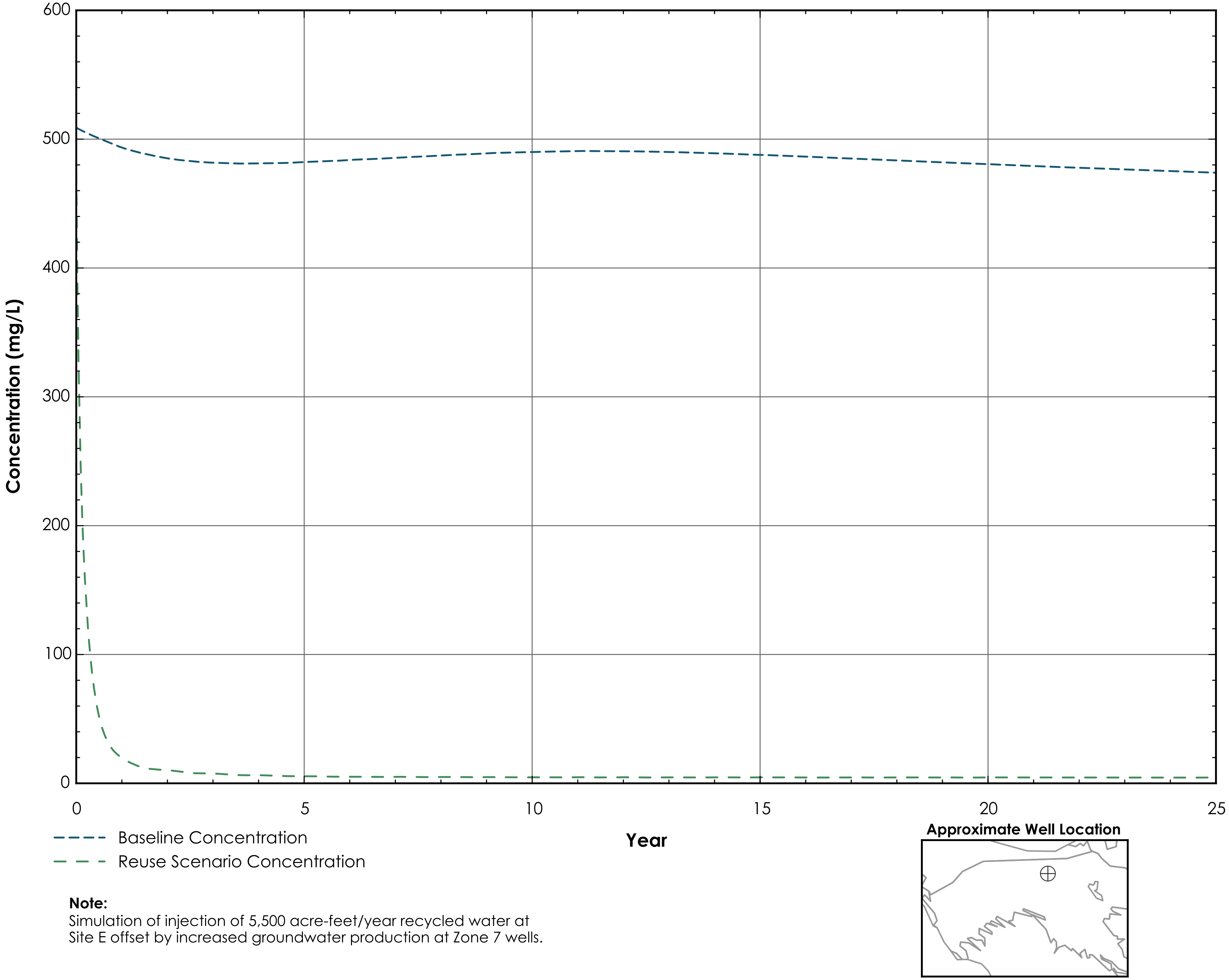
- - - Baseline Concentration
- - - Reuse Scenario Concentration

Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Site B offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

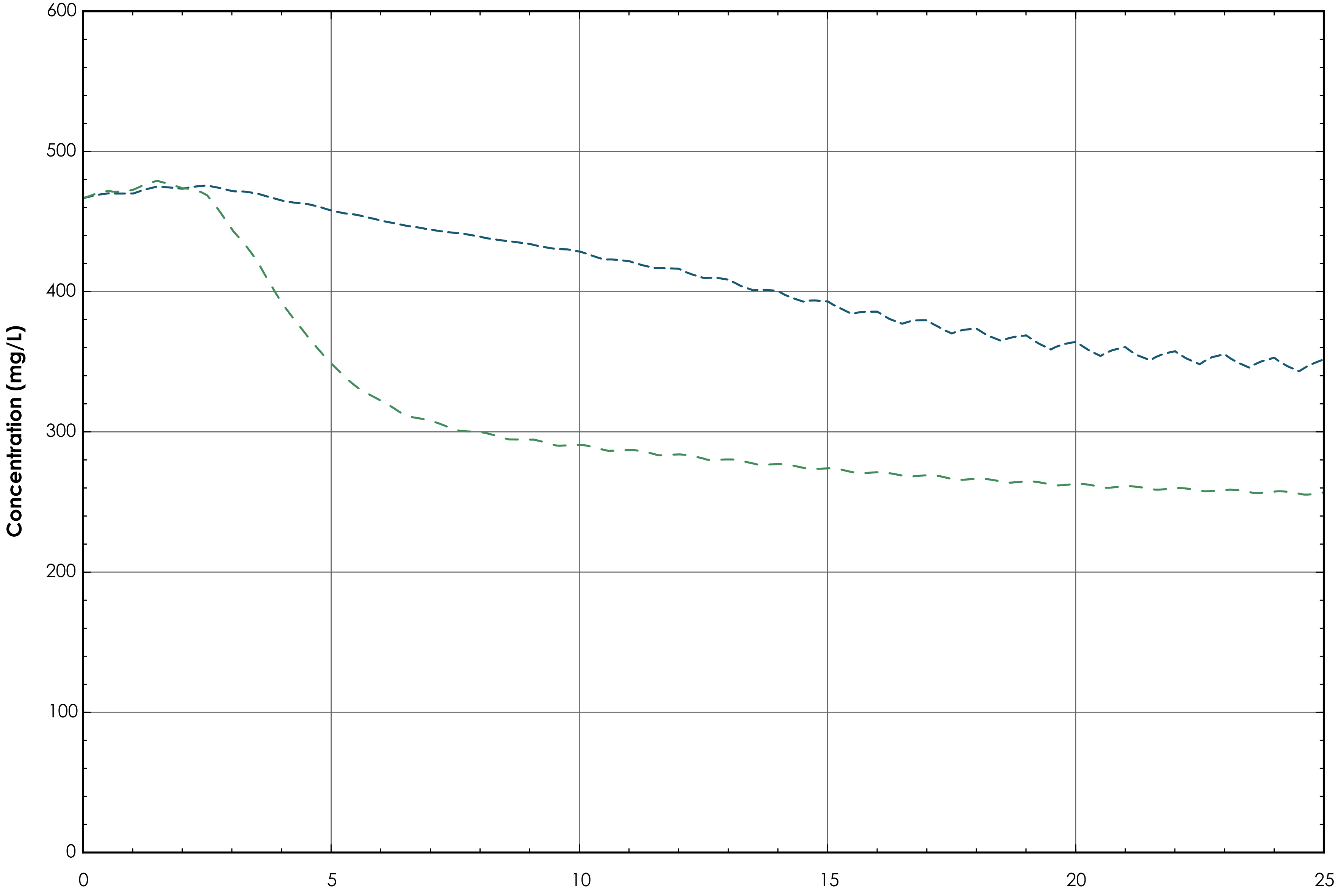


Well Inj E Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

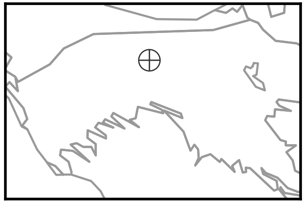


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well COL 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

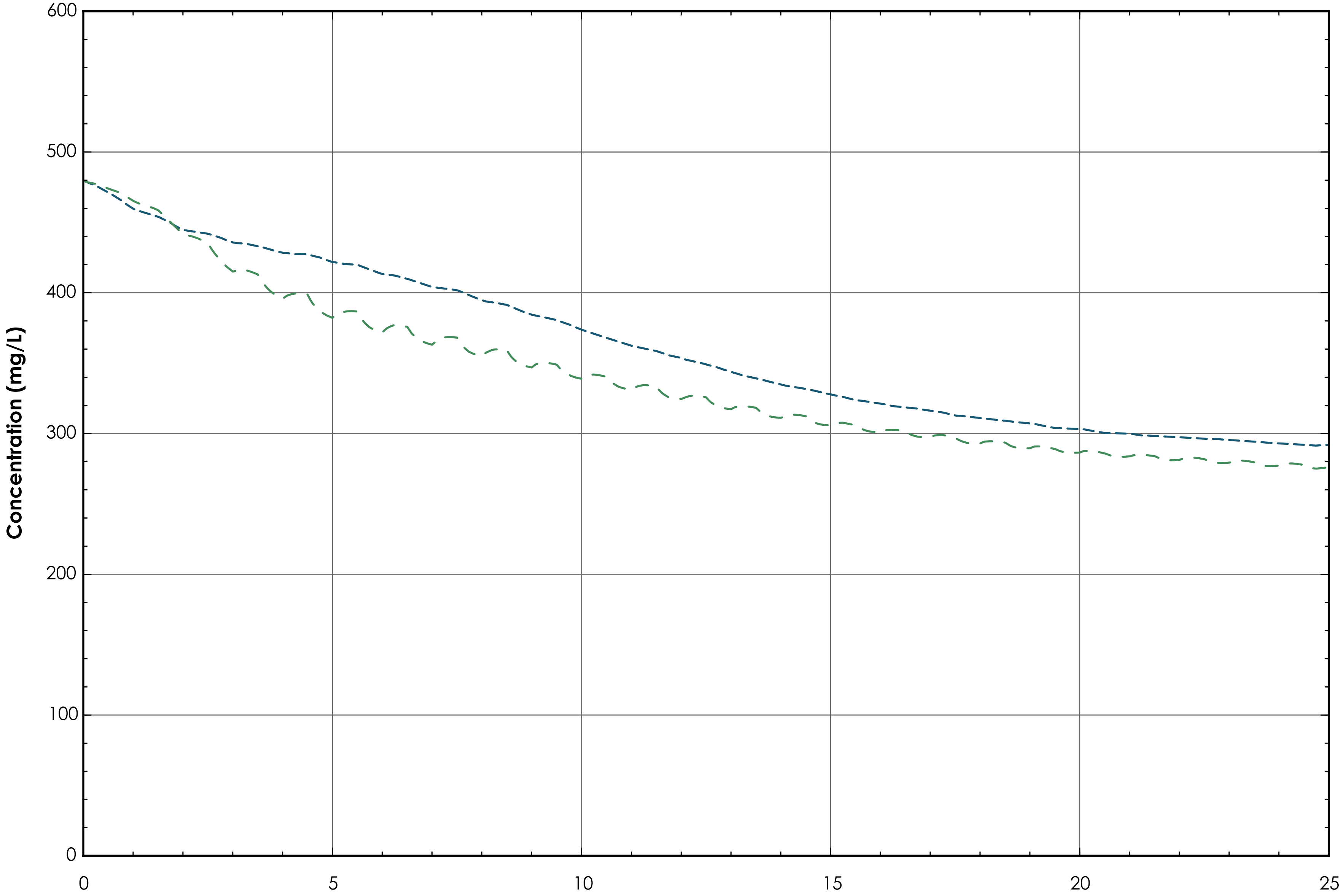


Approximate Well Location

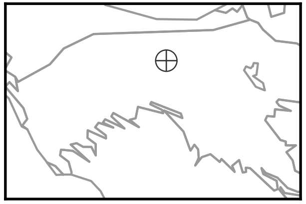


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well COL 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

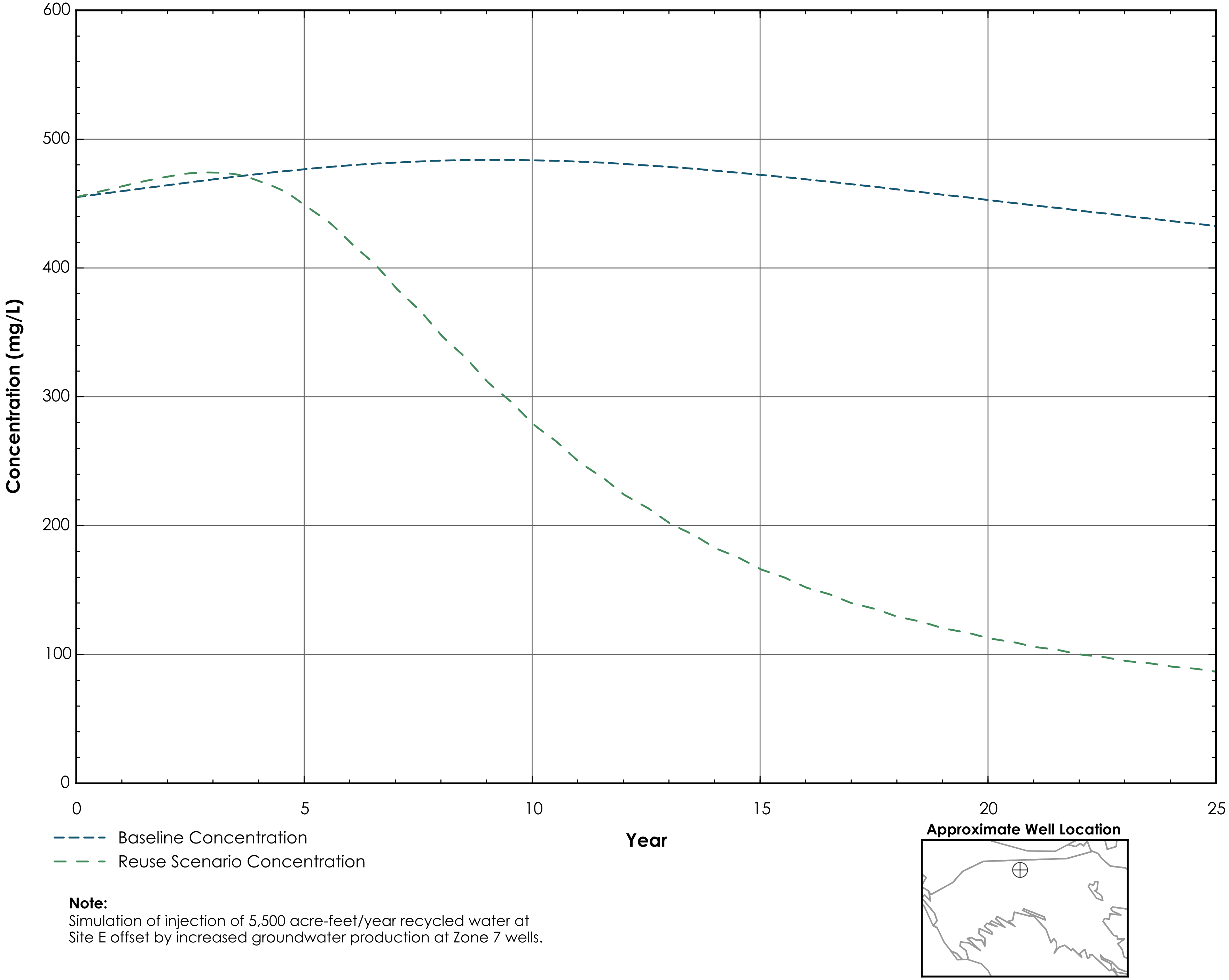


Approximate Well Location



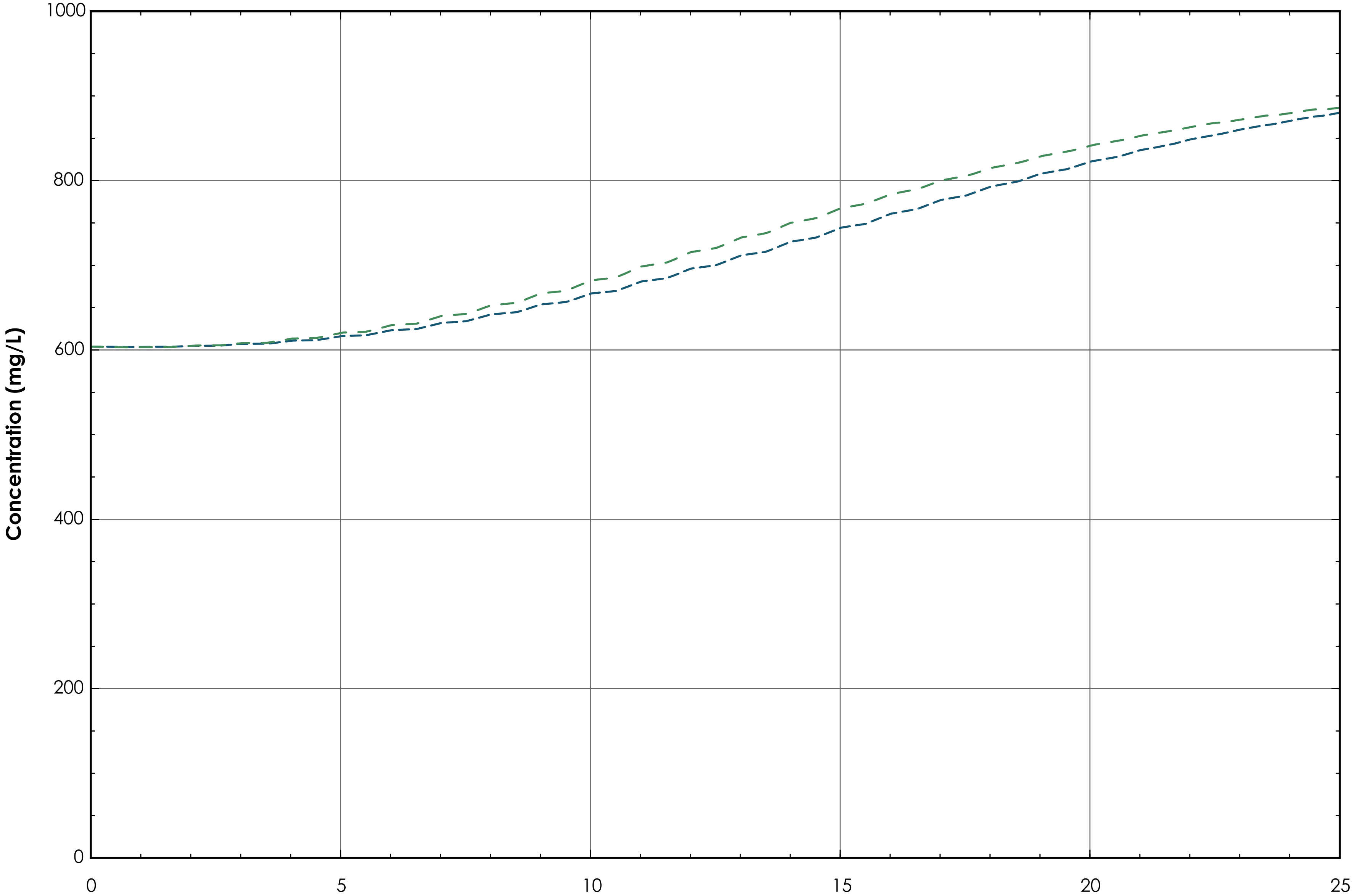
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well COL 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well HOP 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

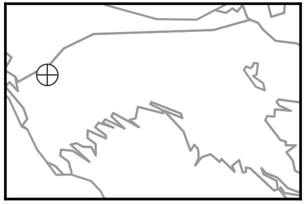


Year

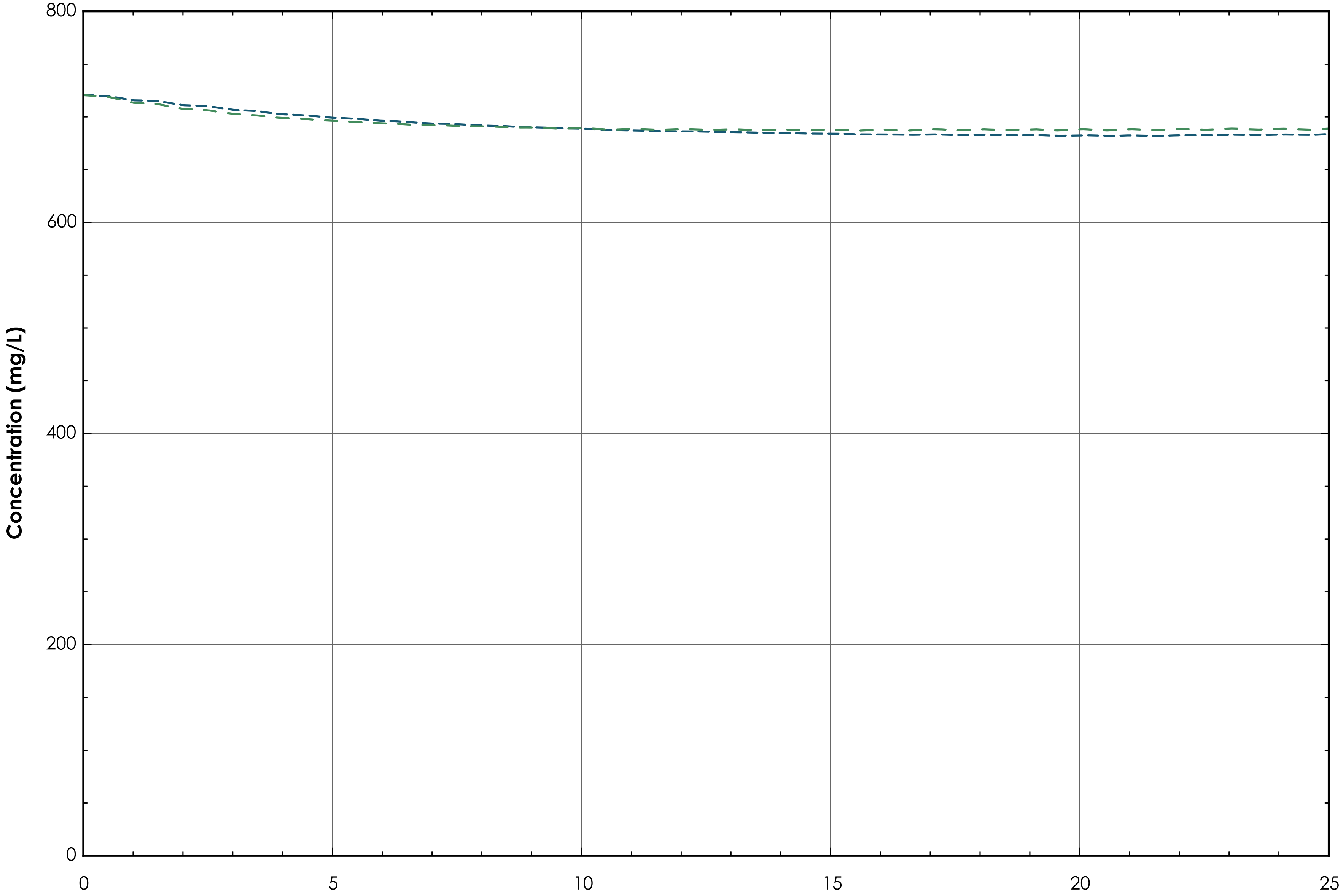
- - - Baseline Concentration
- - - Reuse Scenario Concentration

Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

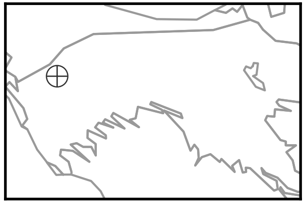


Well HOP 9 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

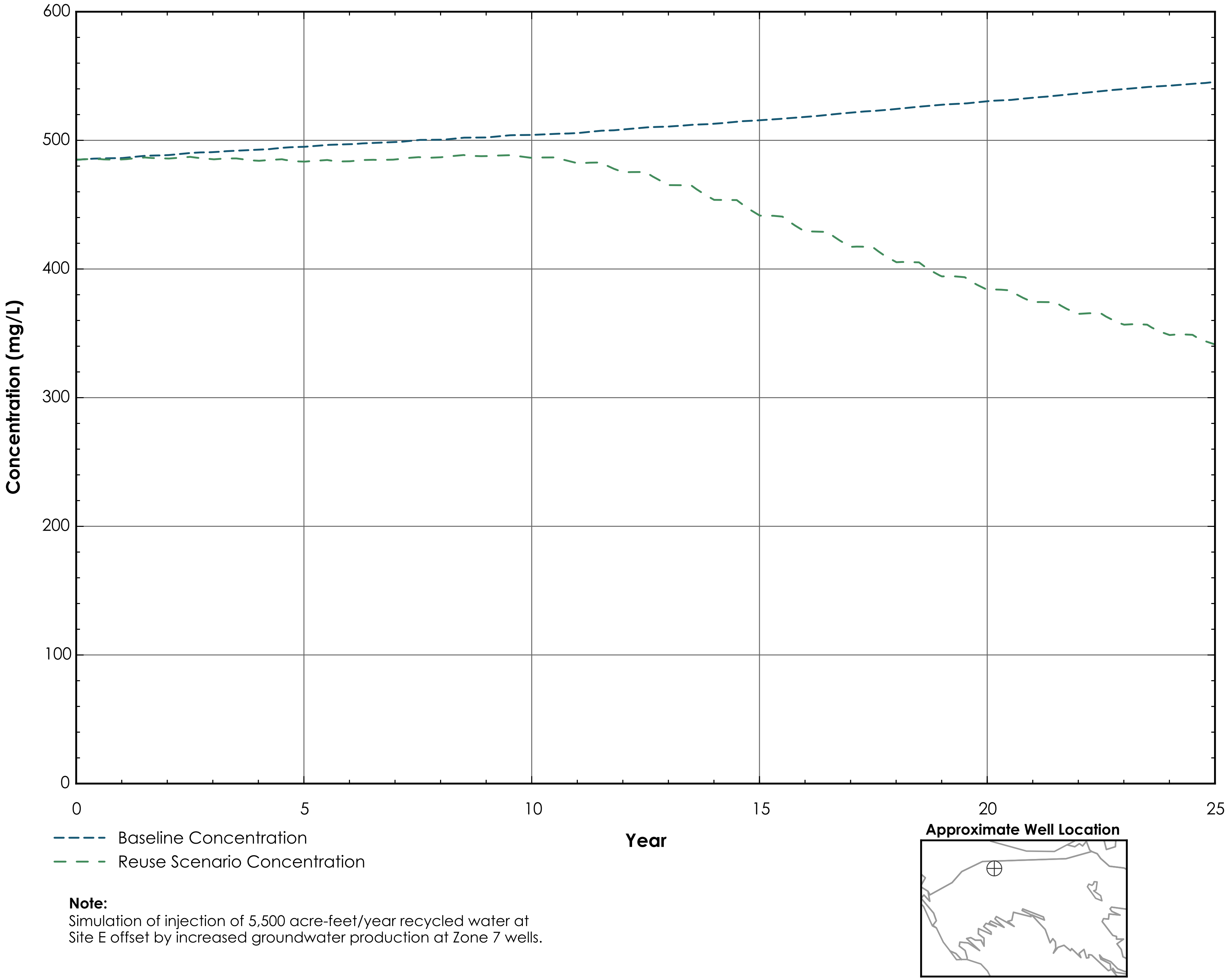


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

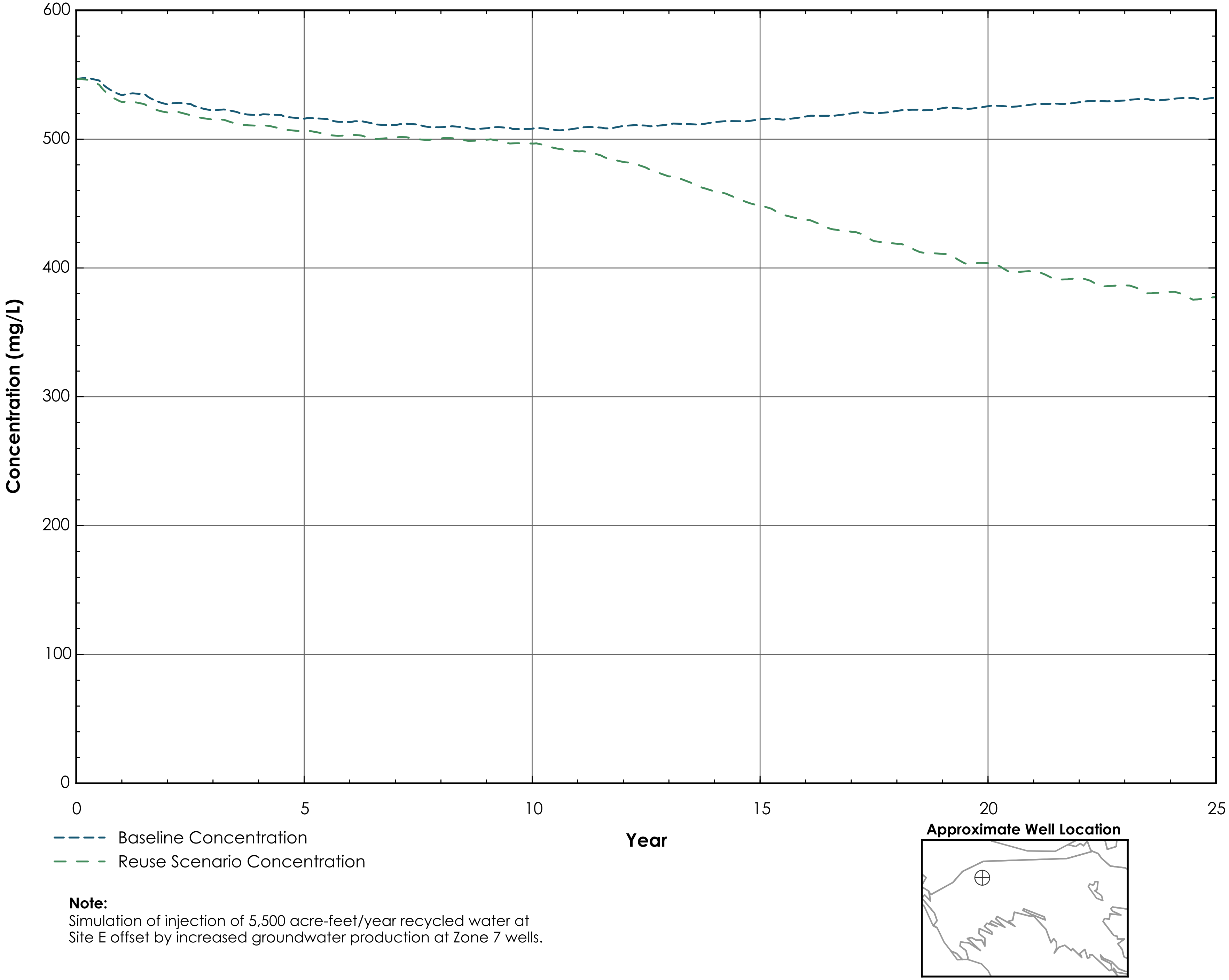


Well STONERIDGE 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



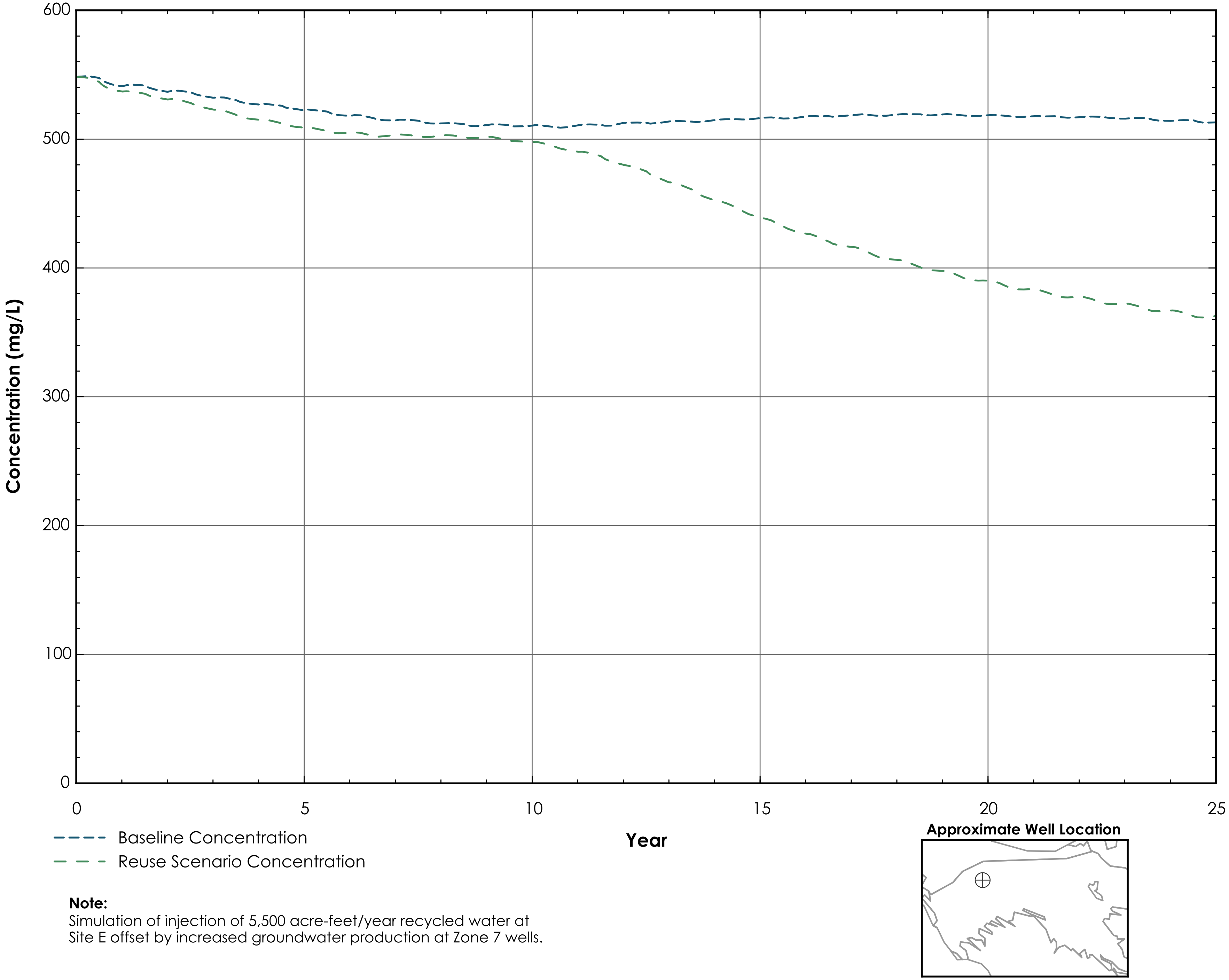
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



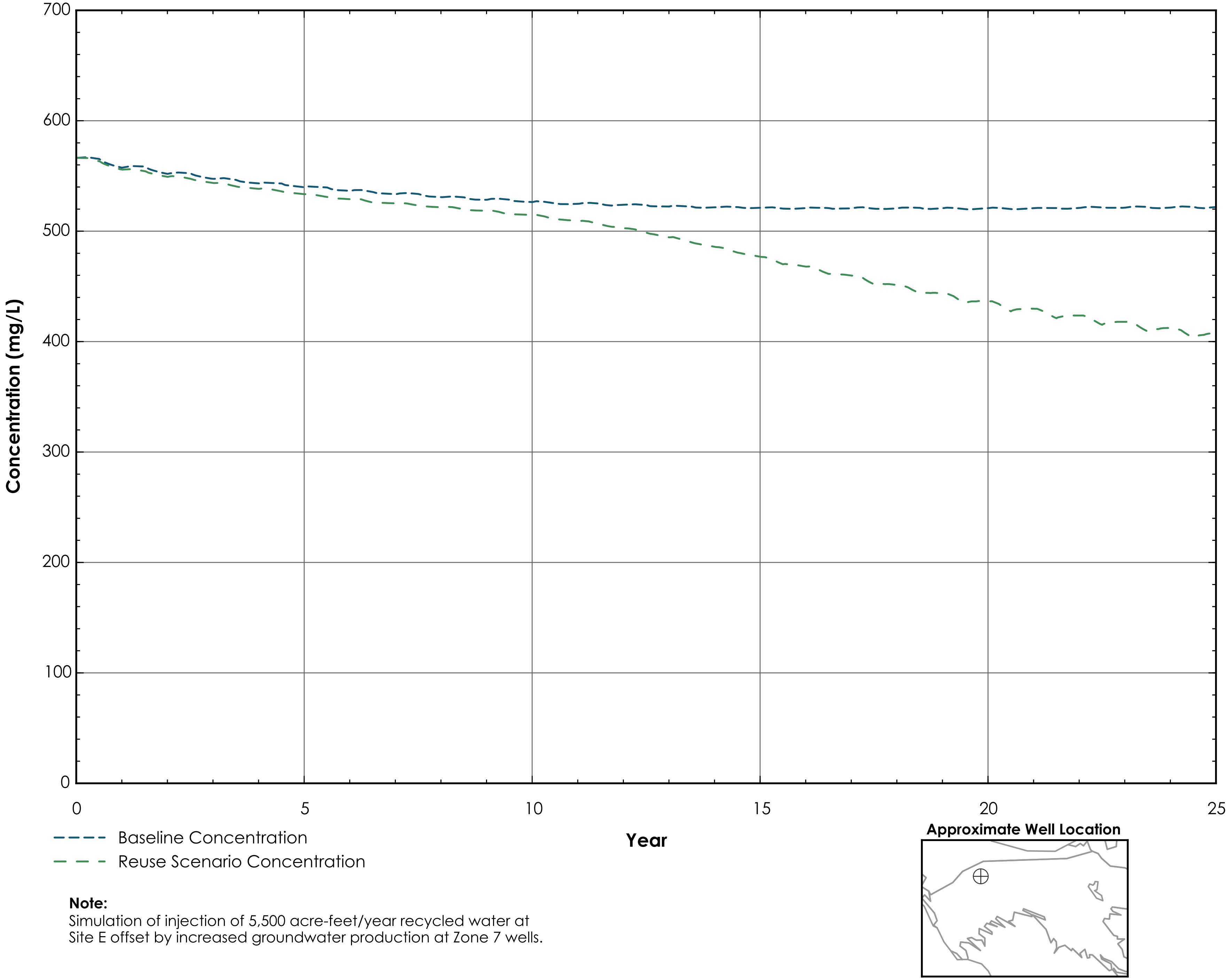
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



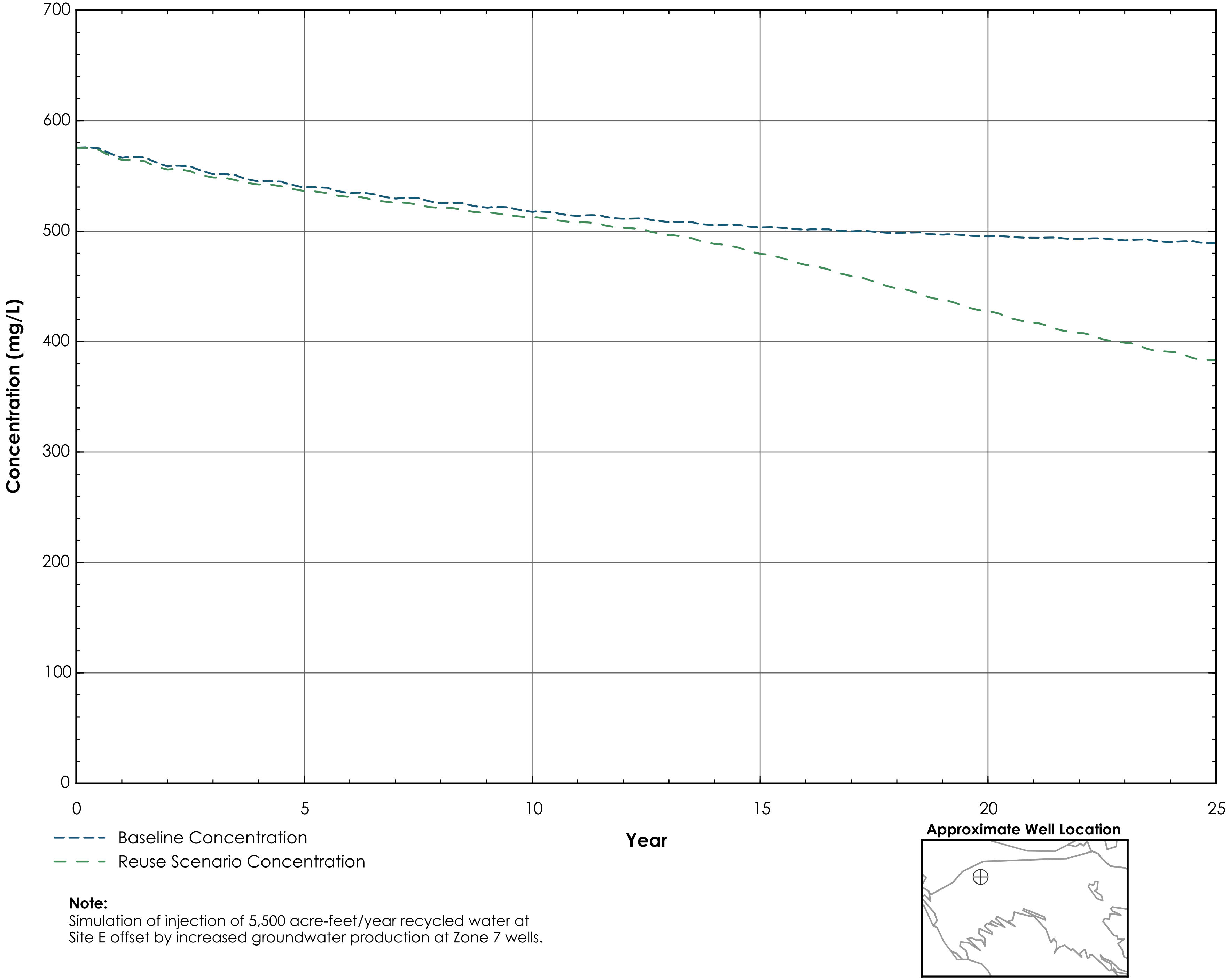
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 3 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



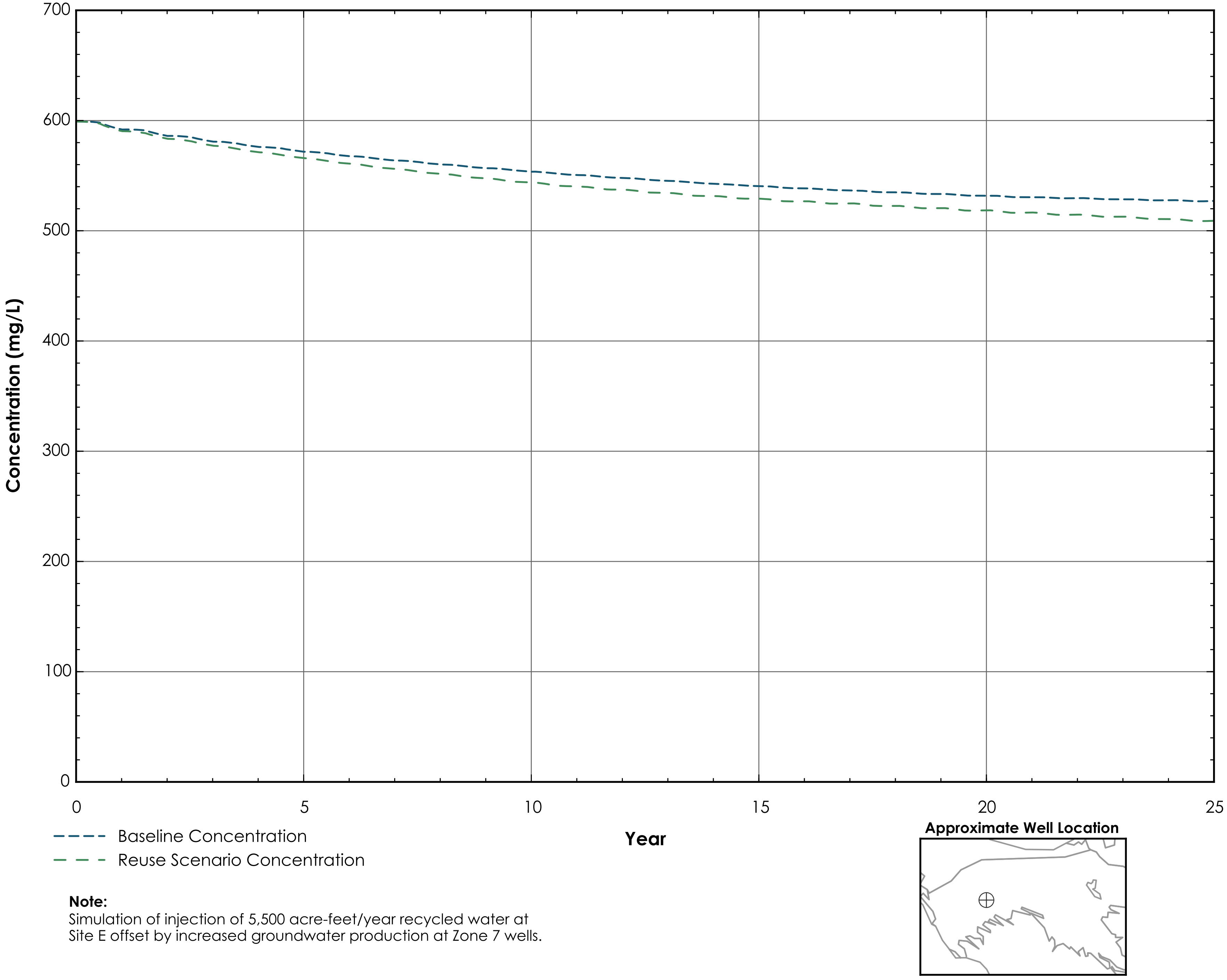
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 4 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



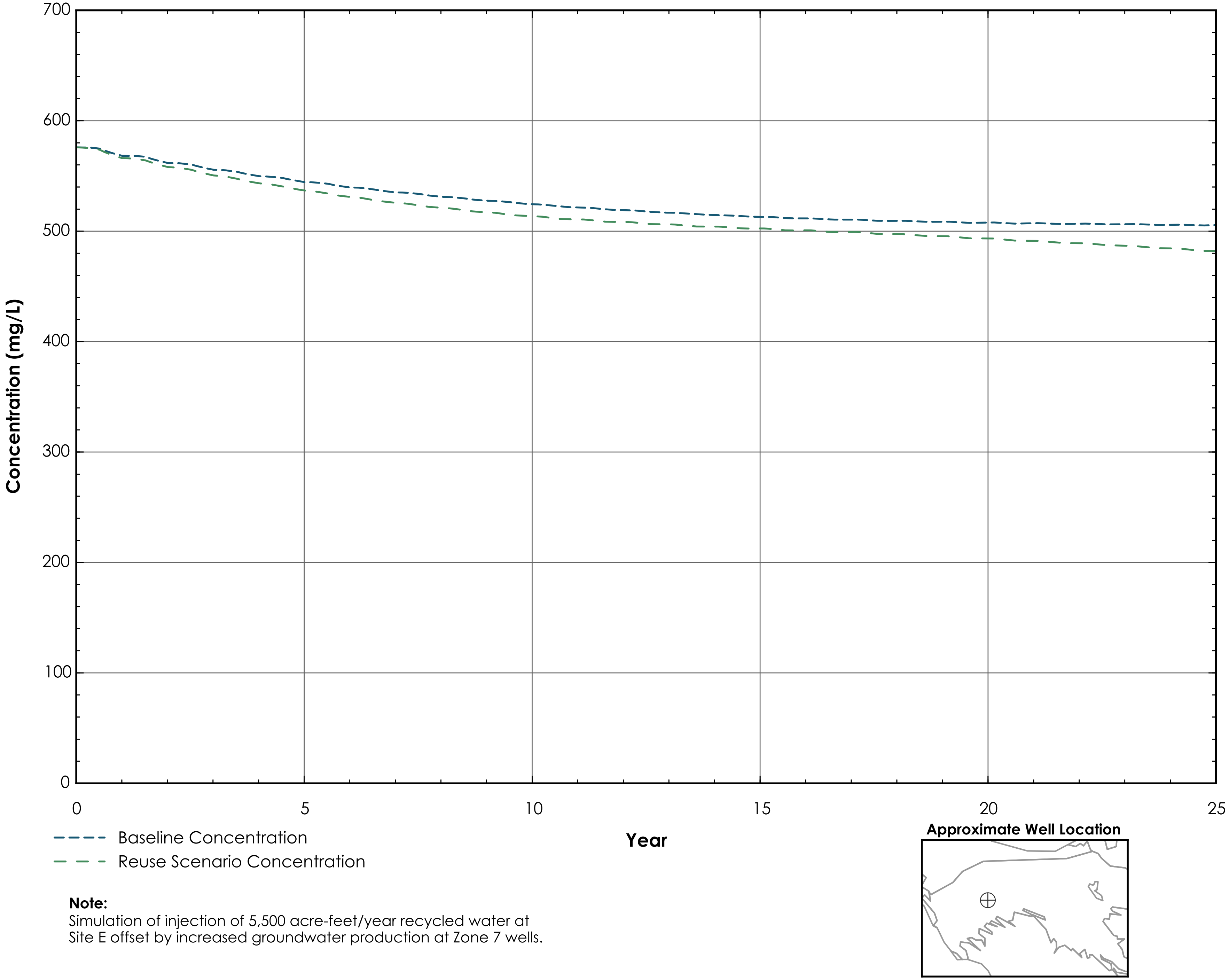
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



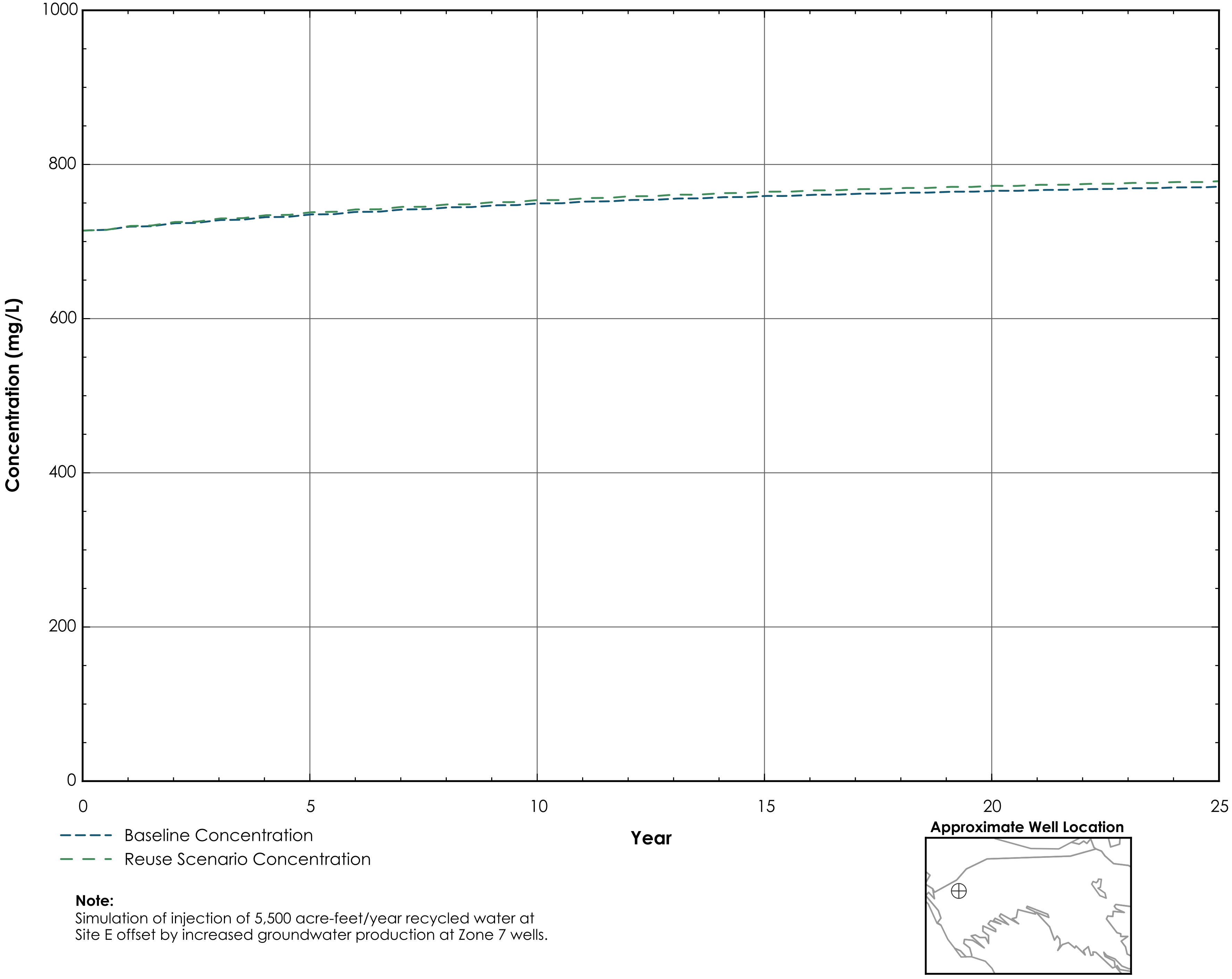
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



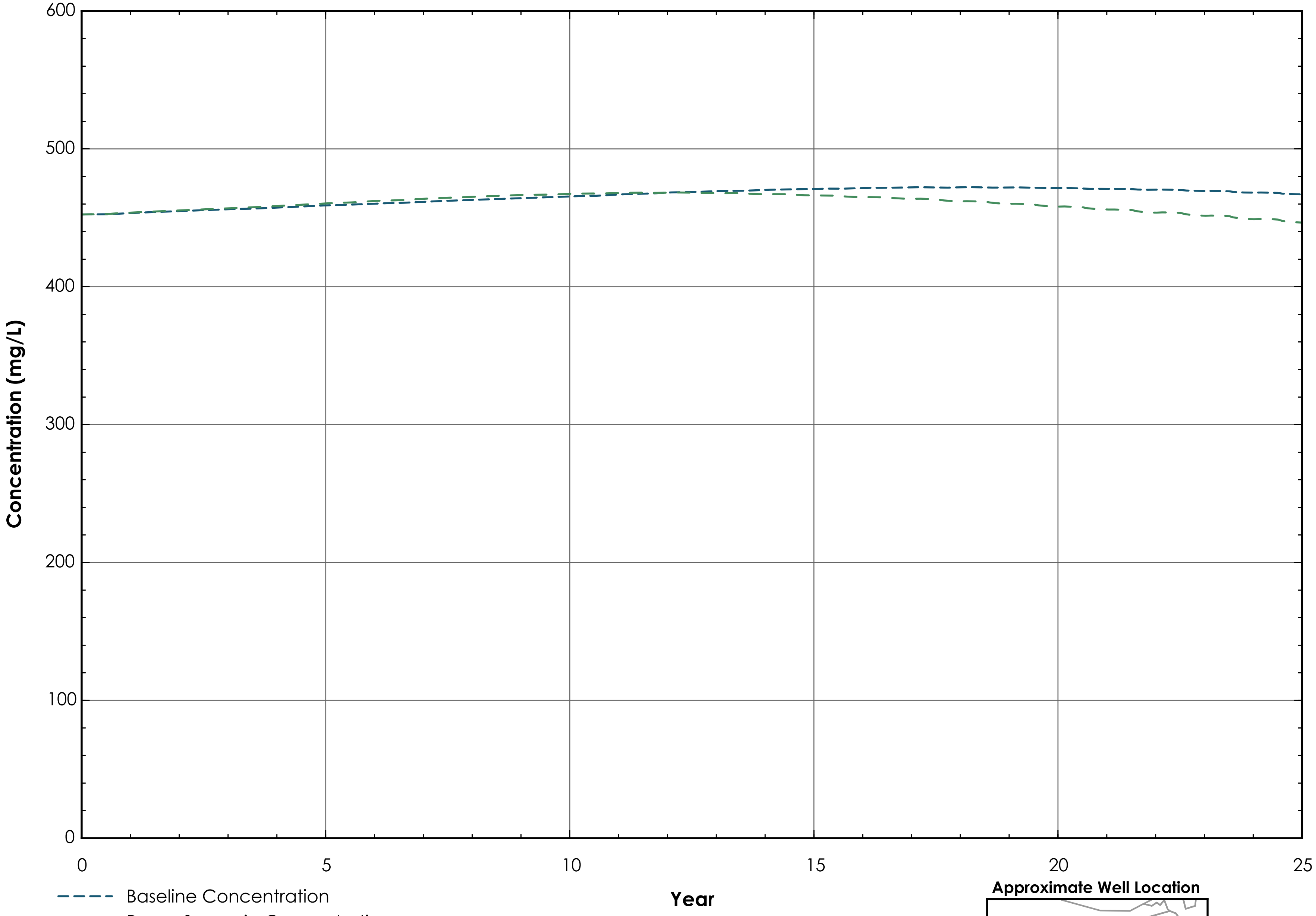
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 7 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



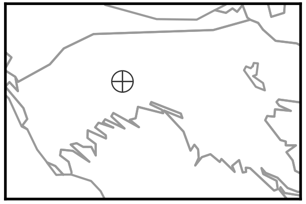
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 8 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

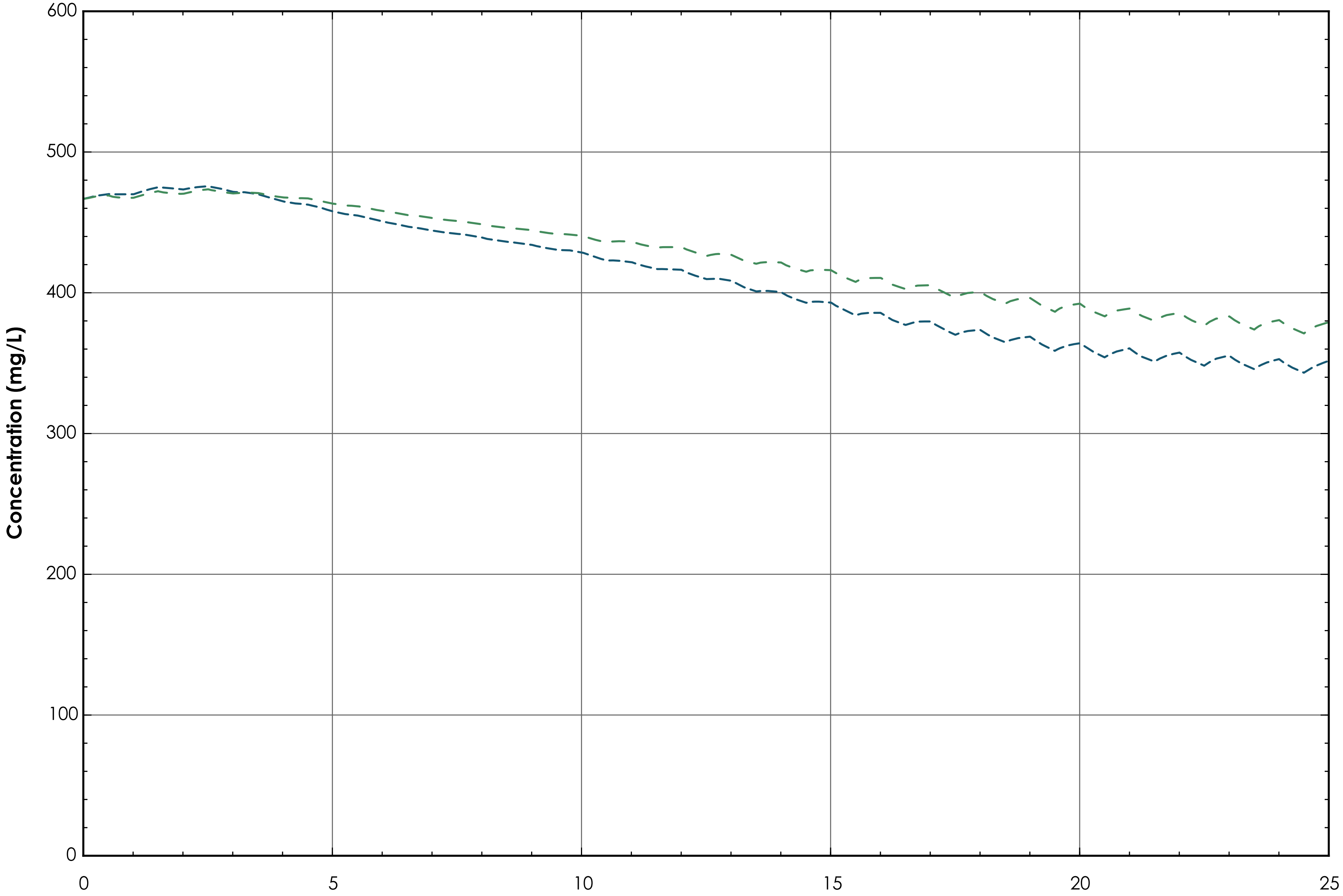


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

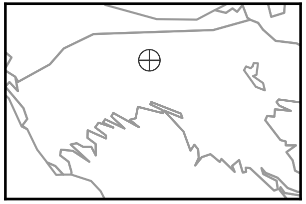


Well COL 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

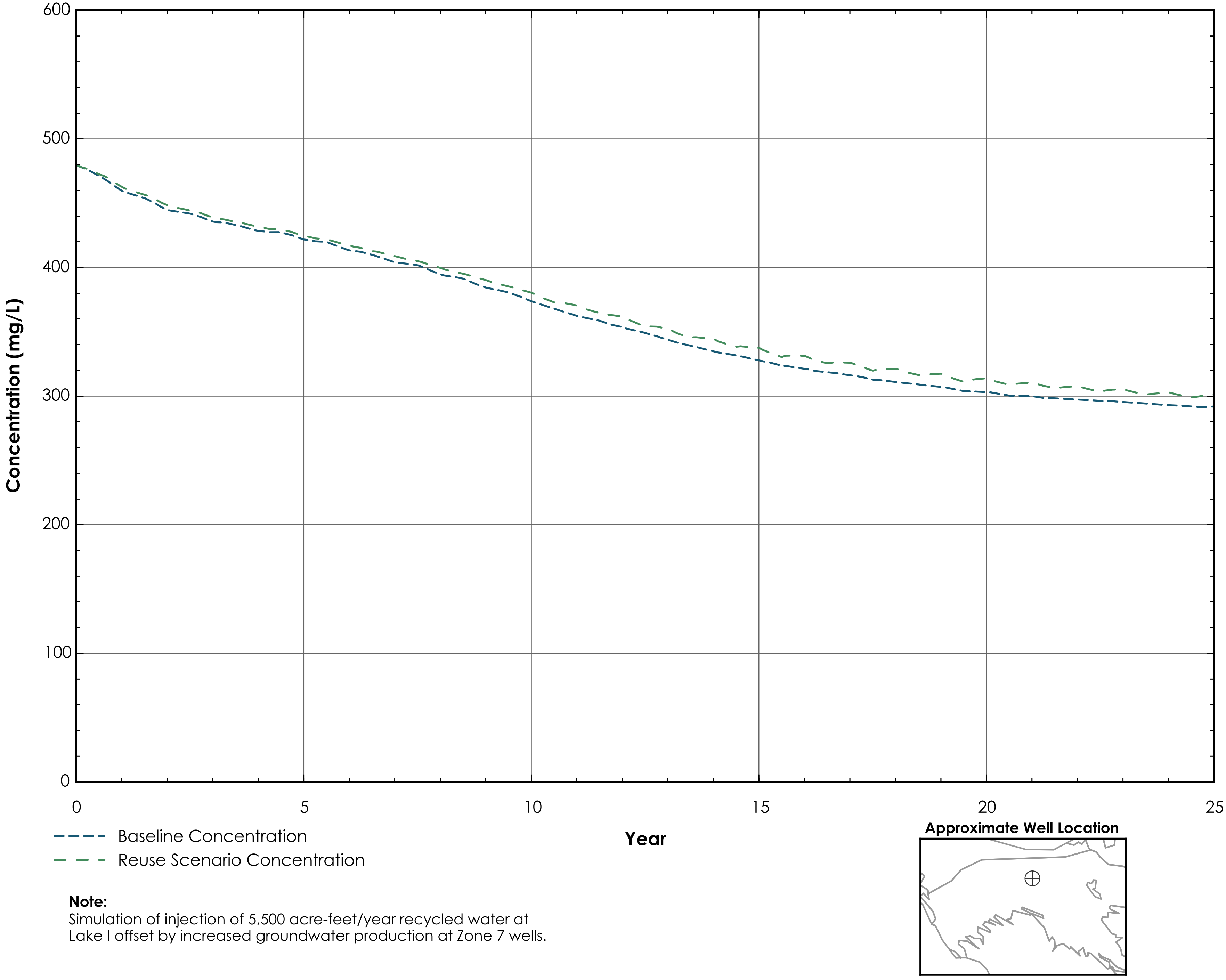


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

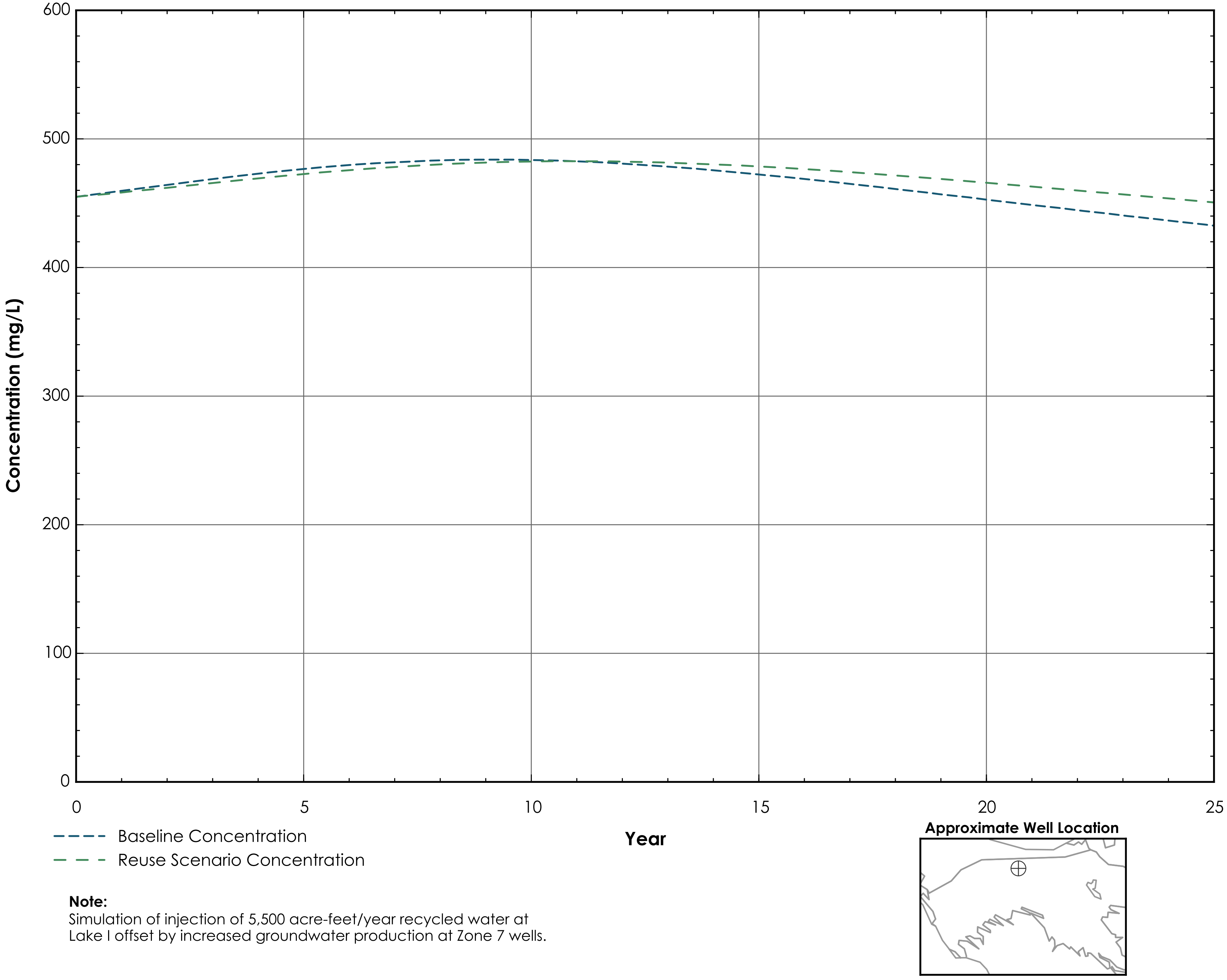


Well COL 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



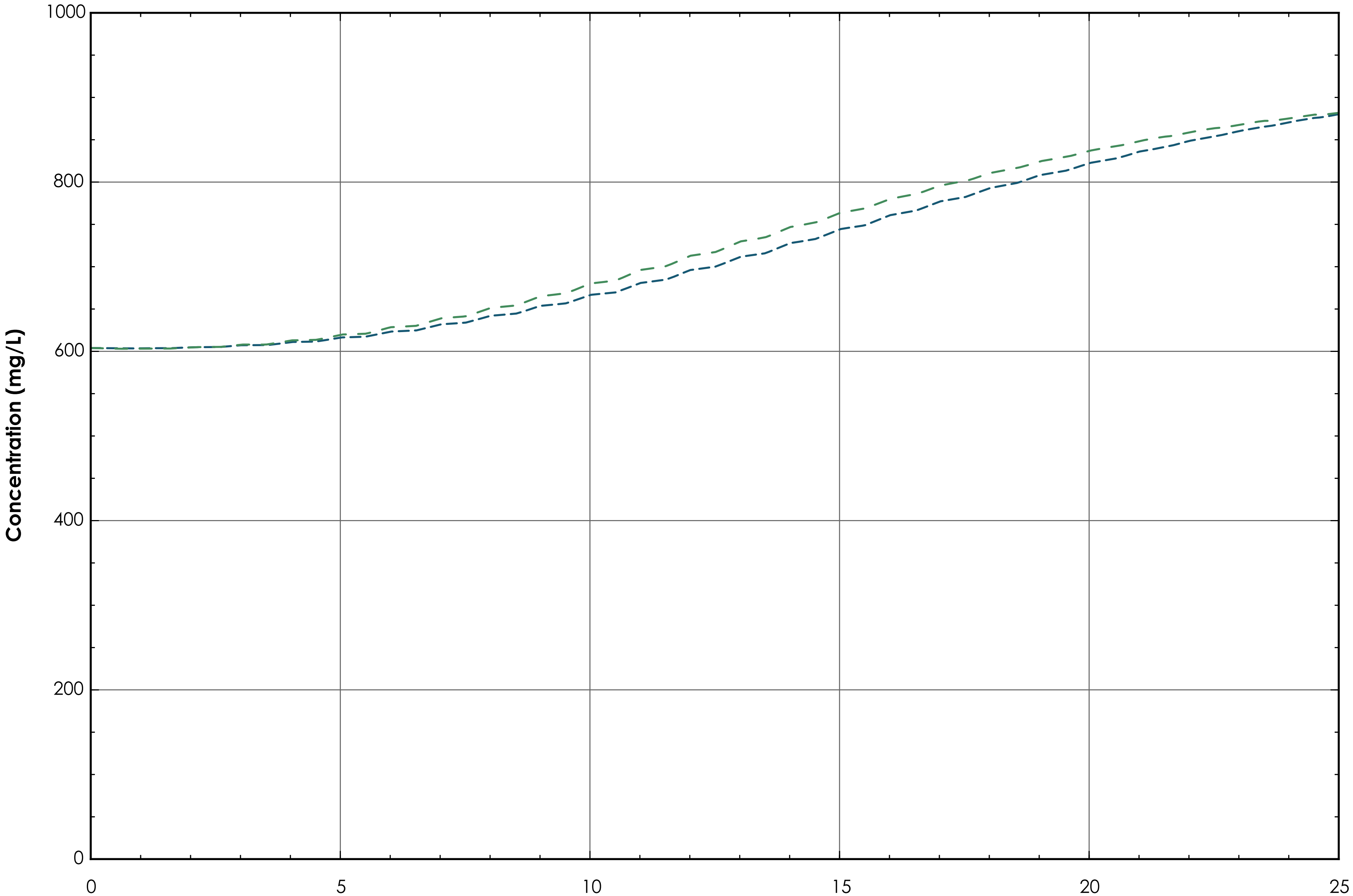
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well COL 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well HOP 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

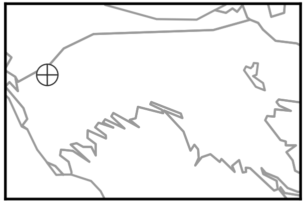


Year

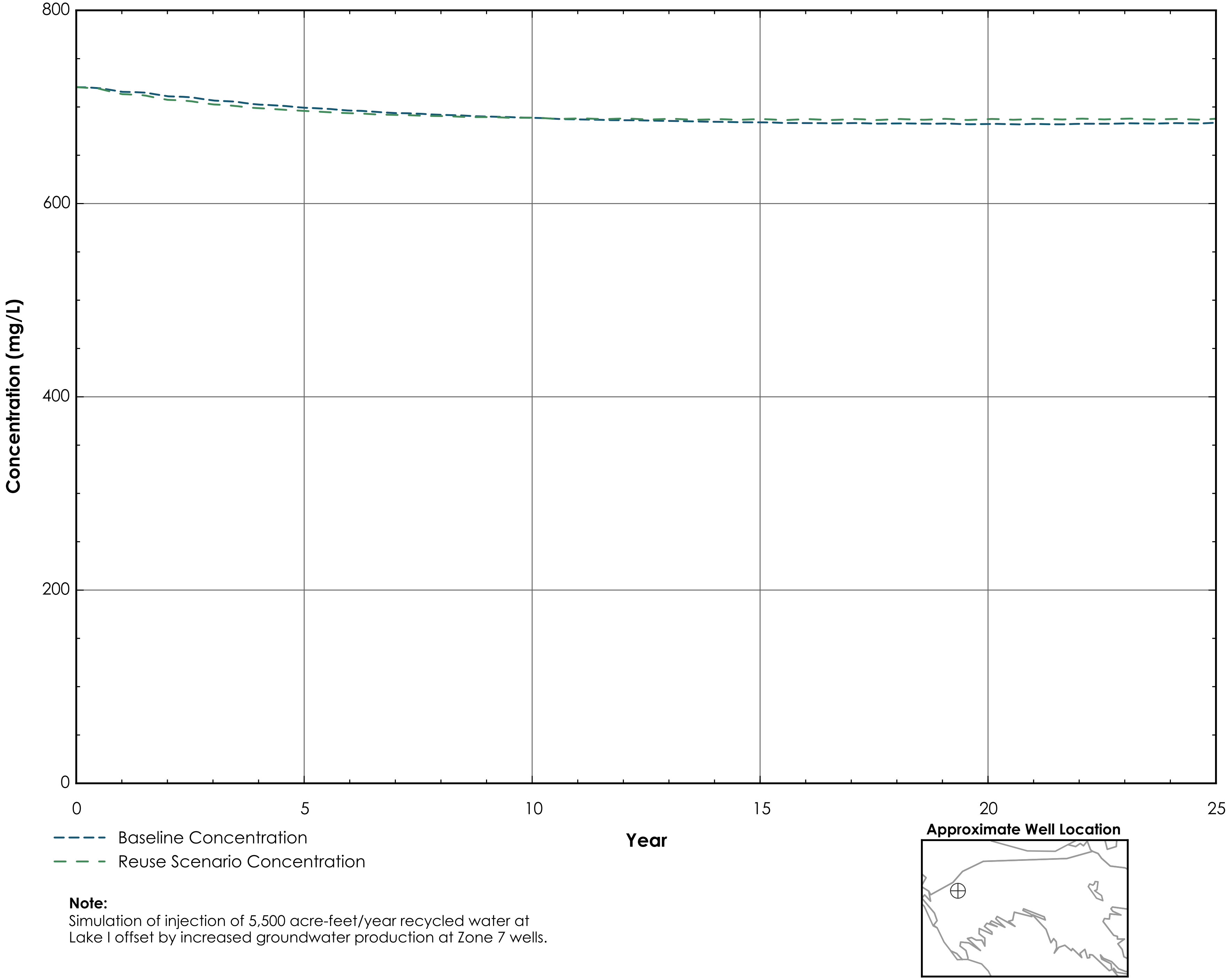
- - - Baseline Concentration
- - - Reuse Scenario Concentration

Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

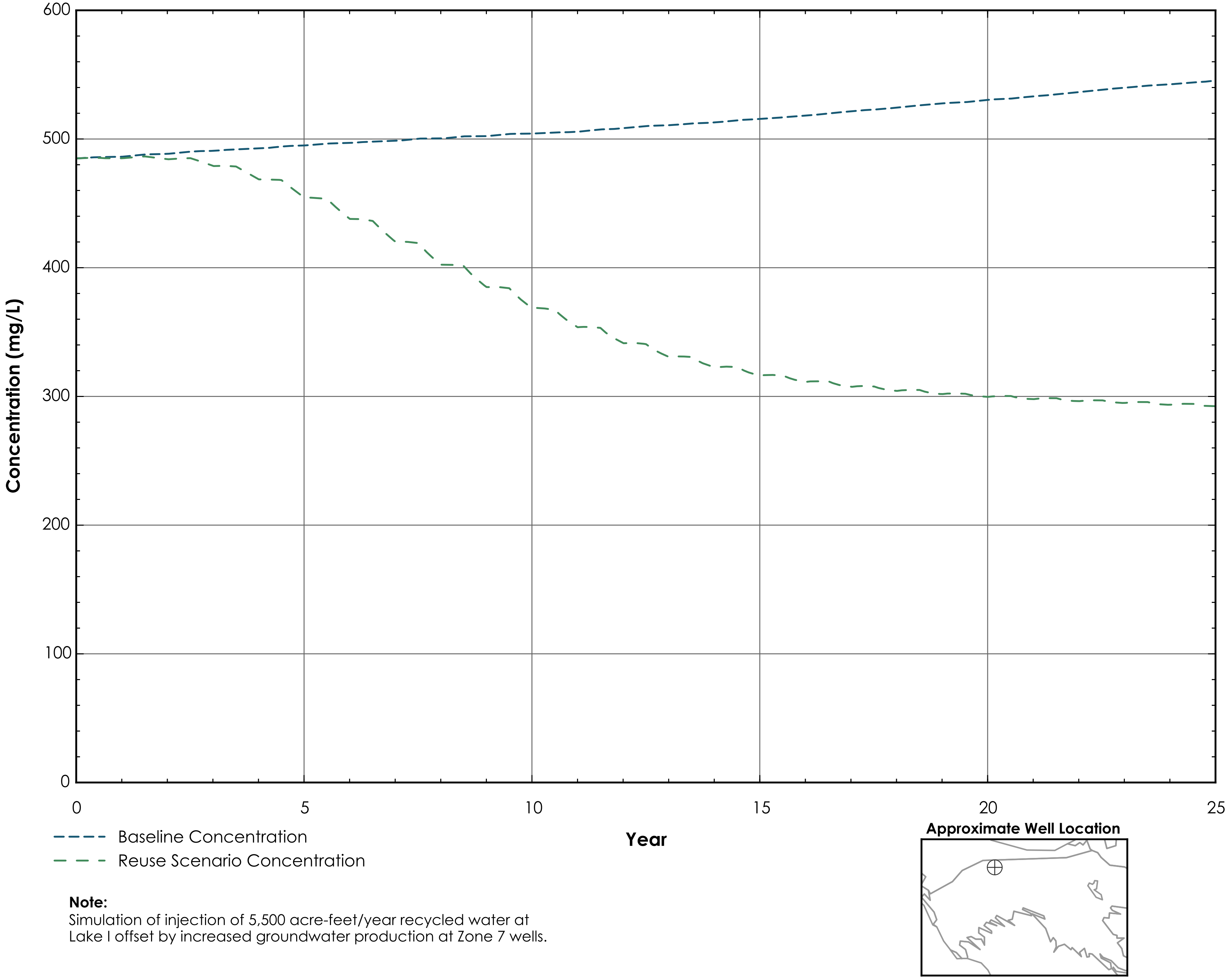


Well HOP 9 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



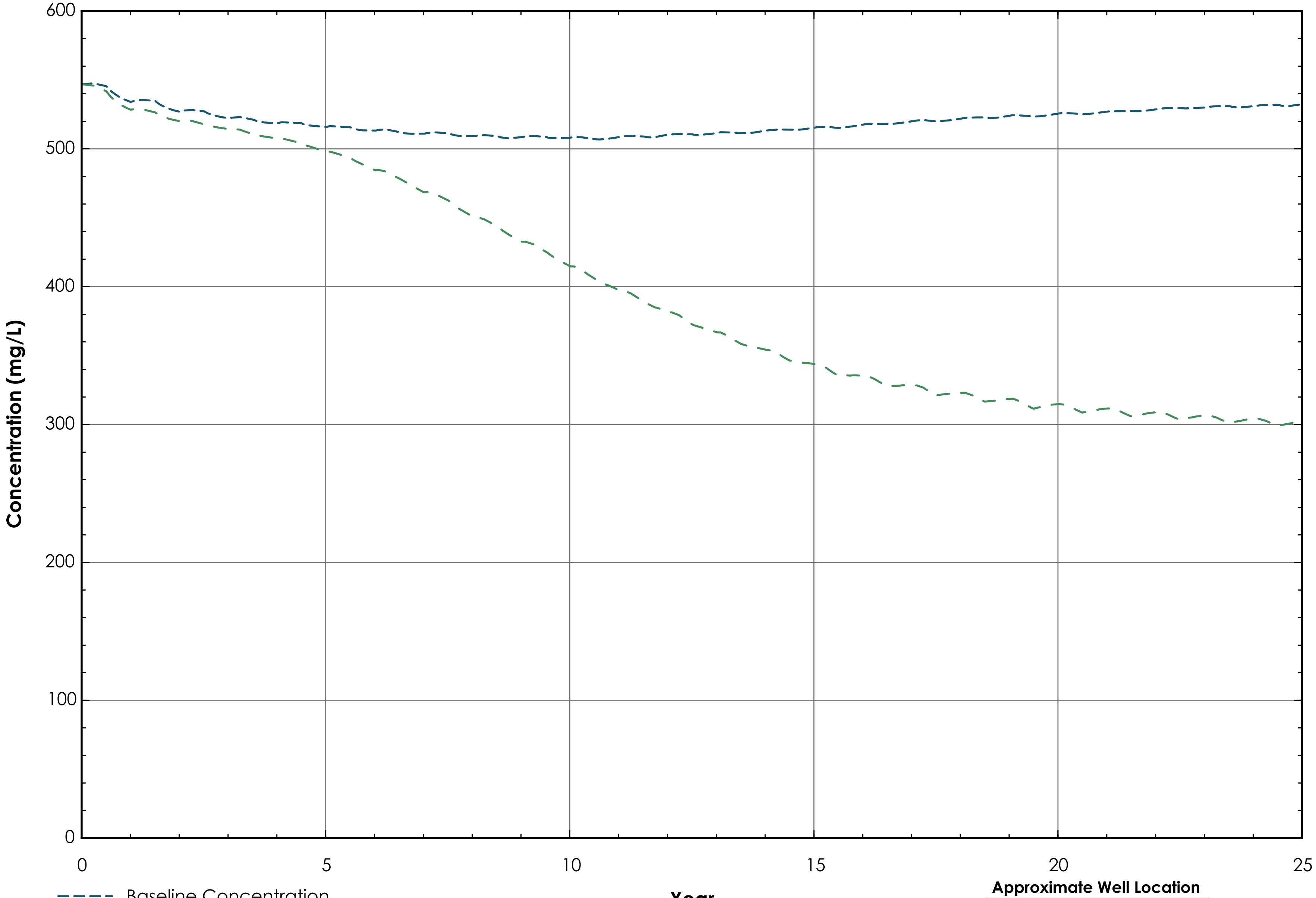
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well STONERIDGE 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



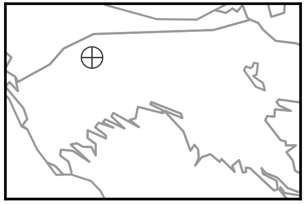
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

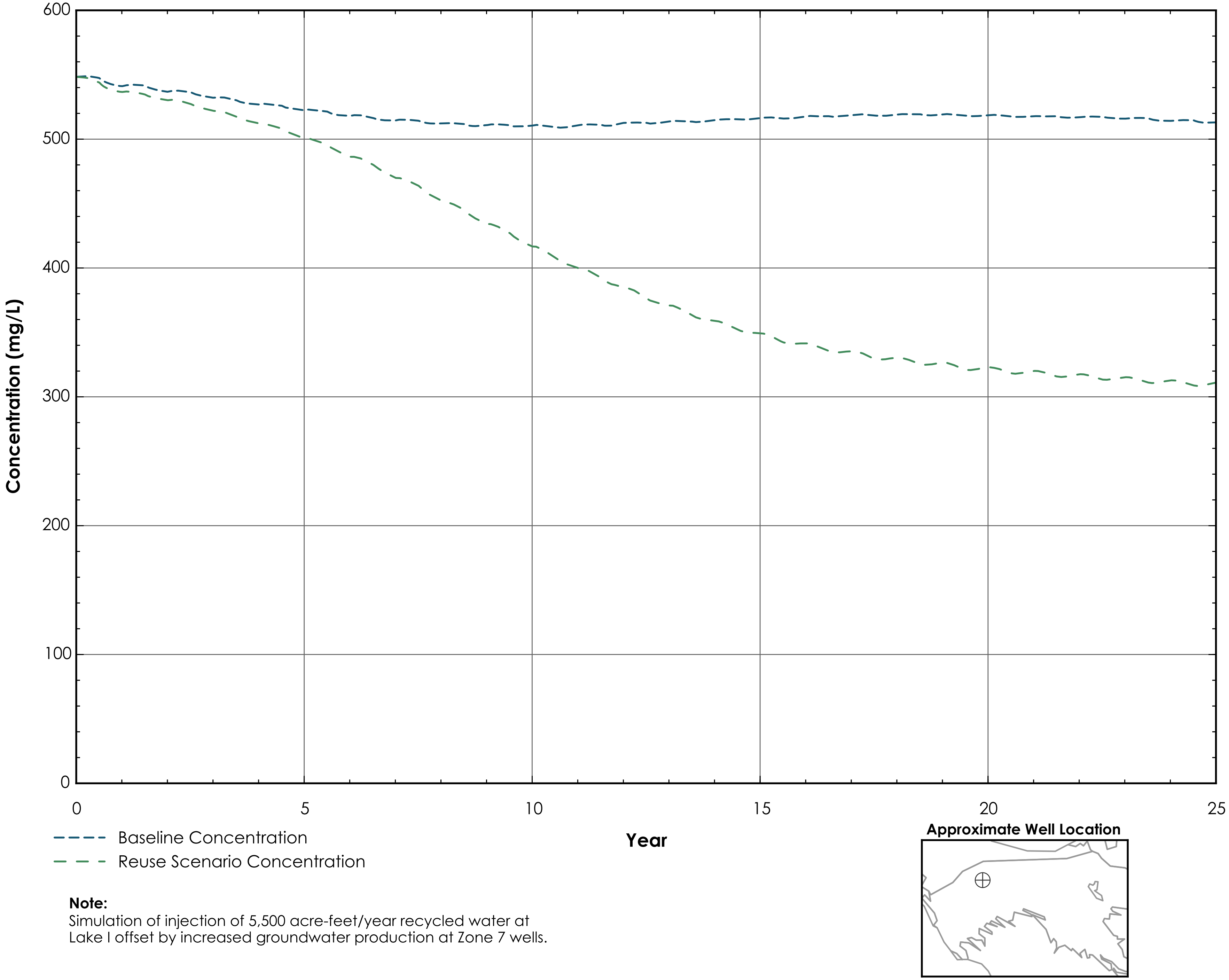


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

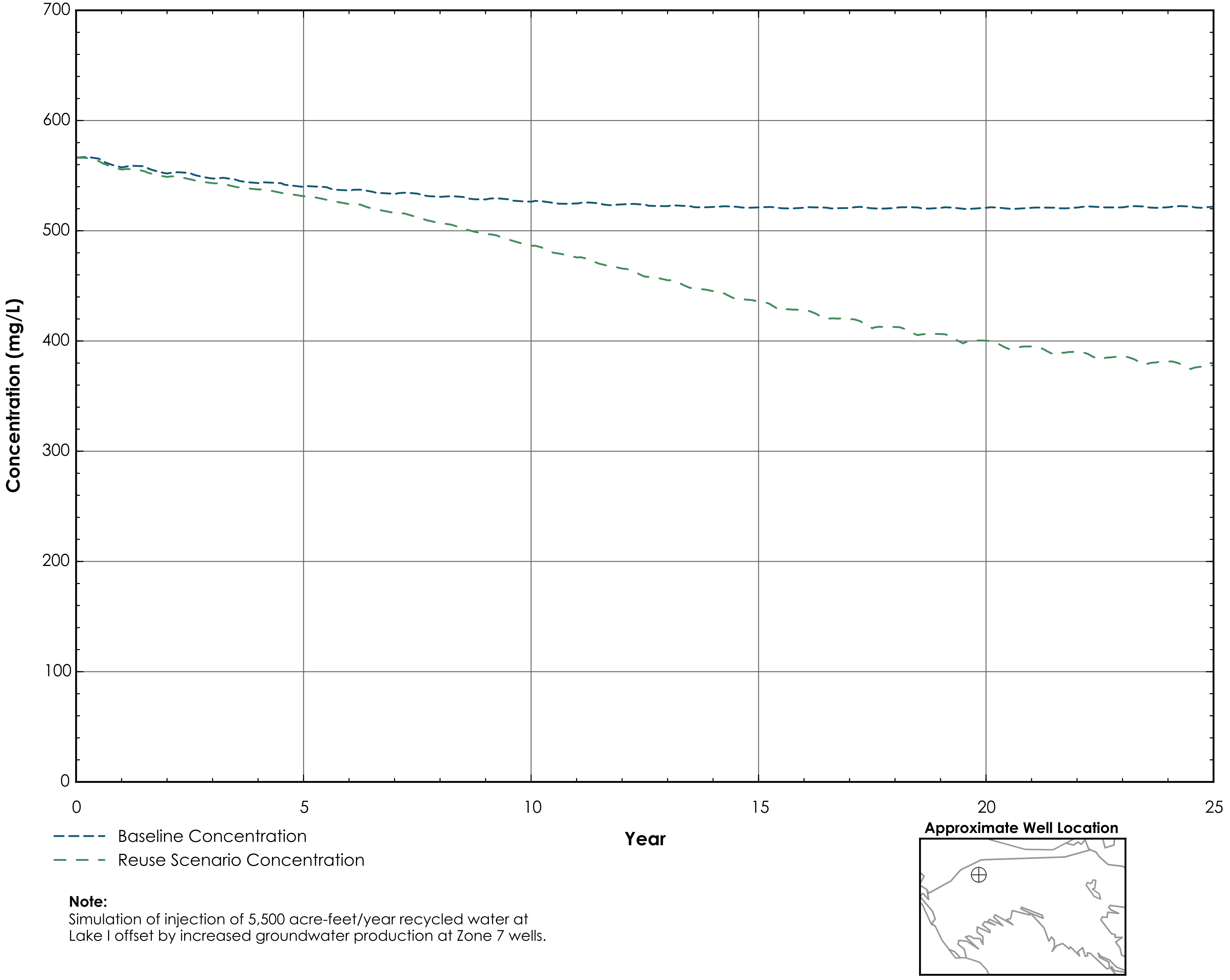


Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



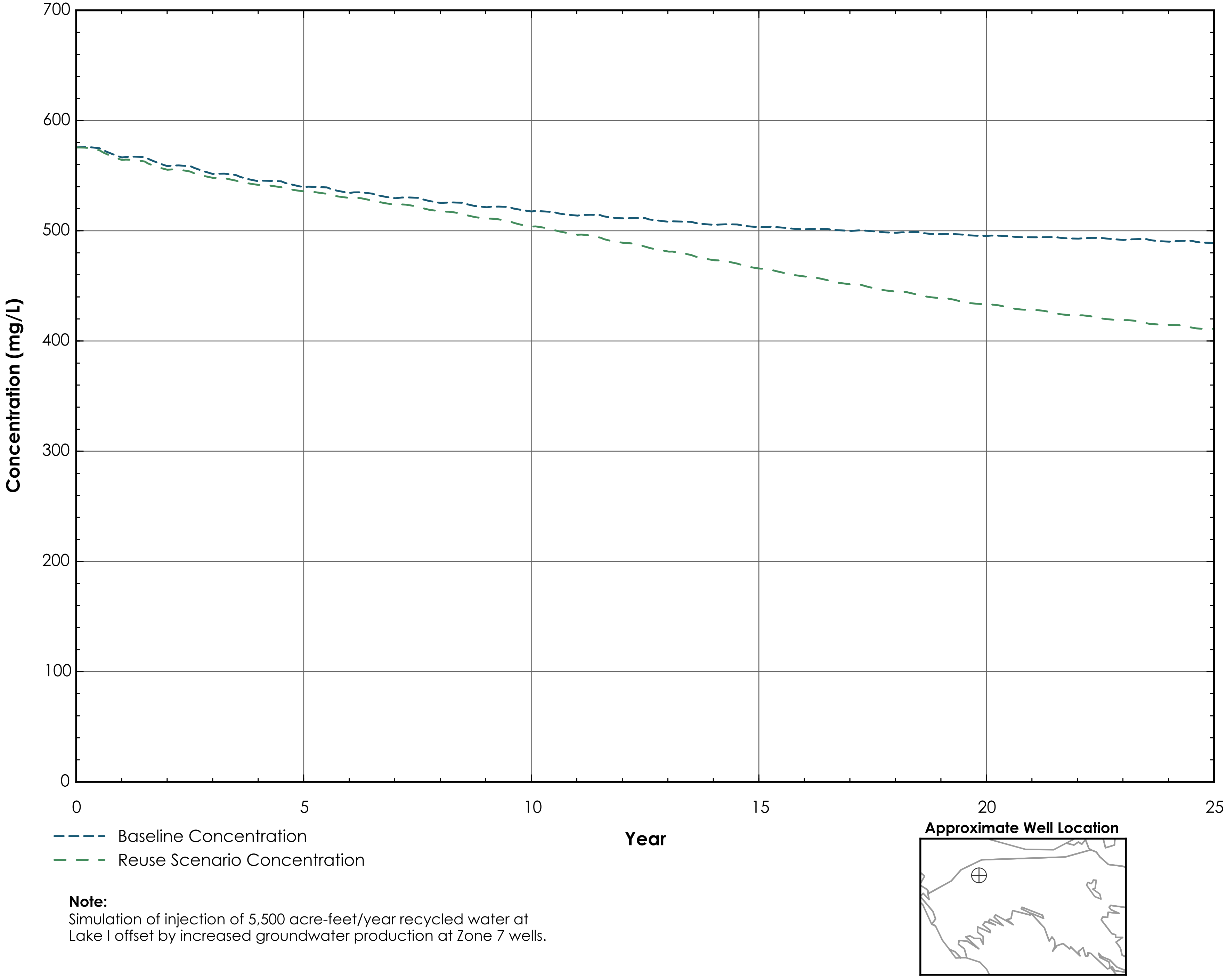
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 3 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



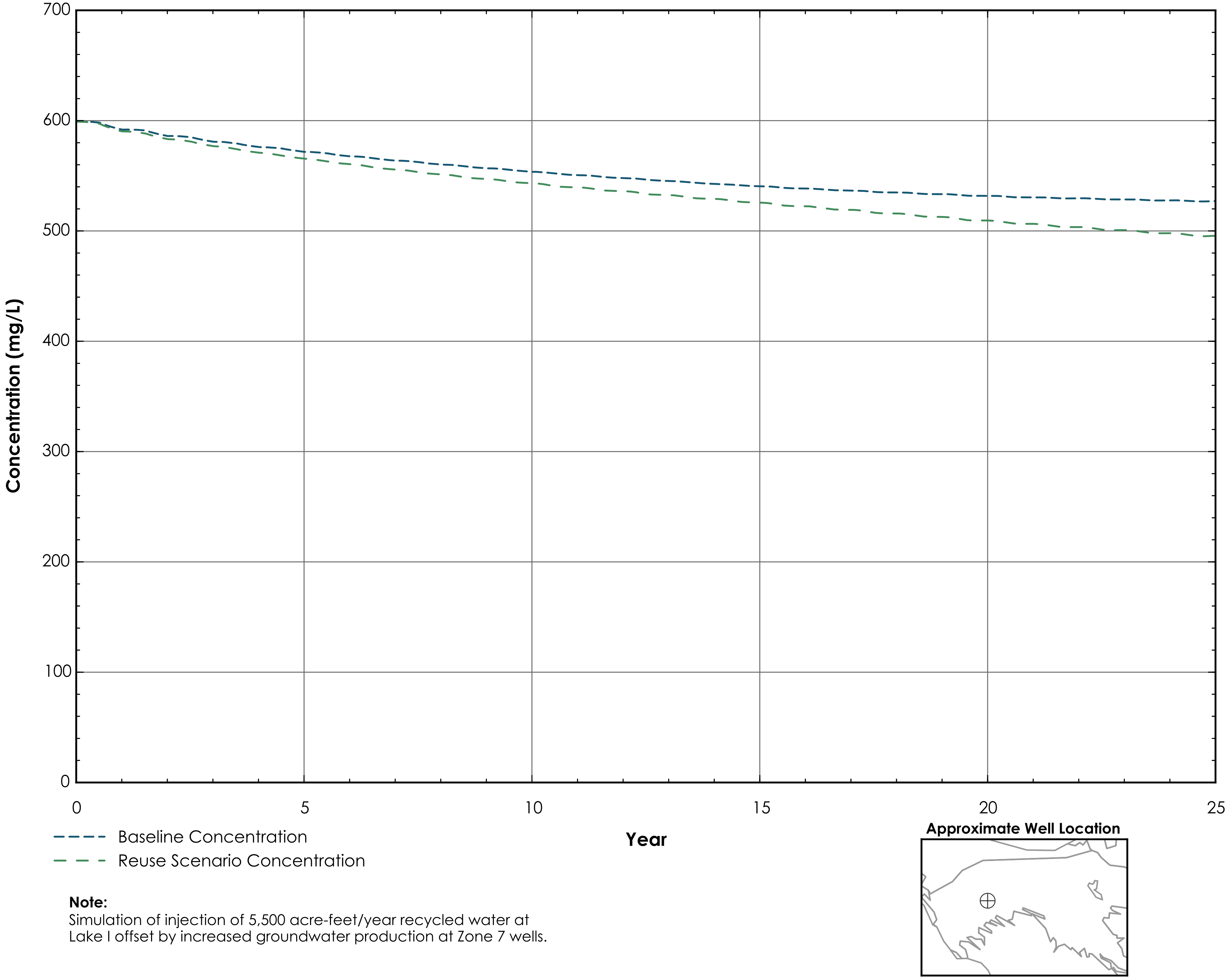
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 4 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



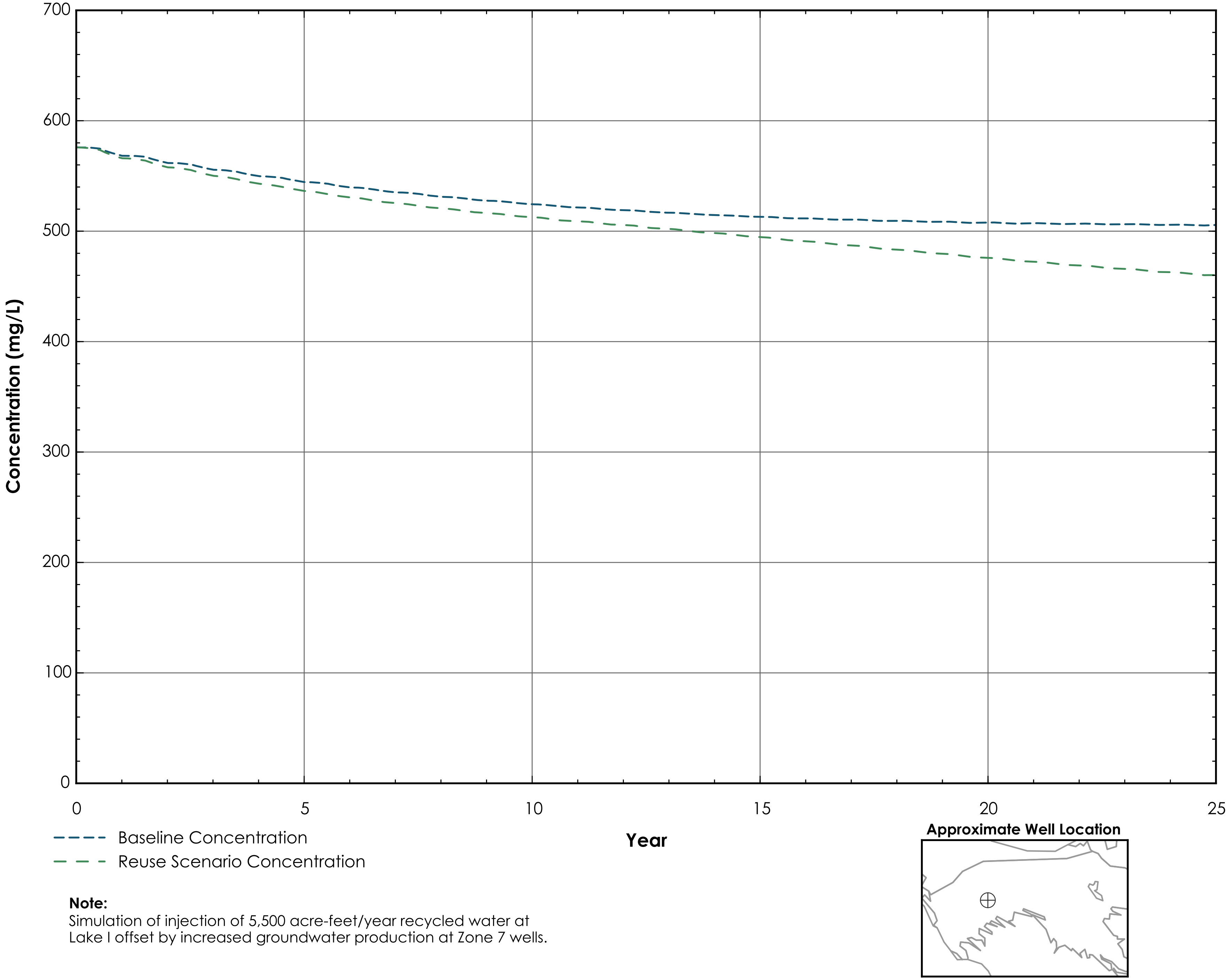
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



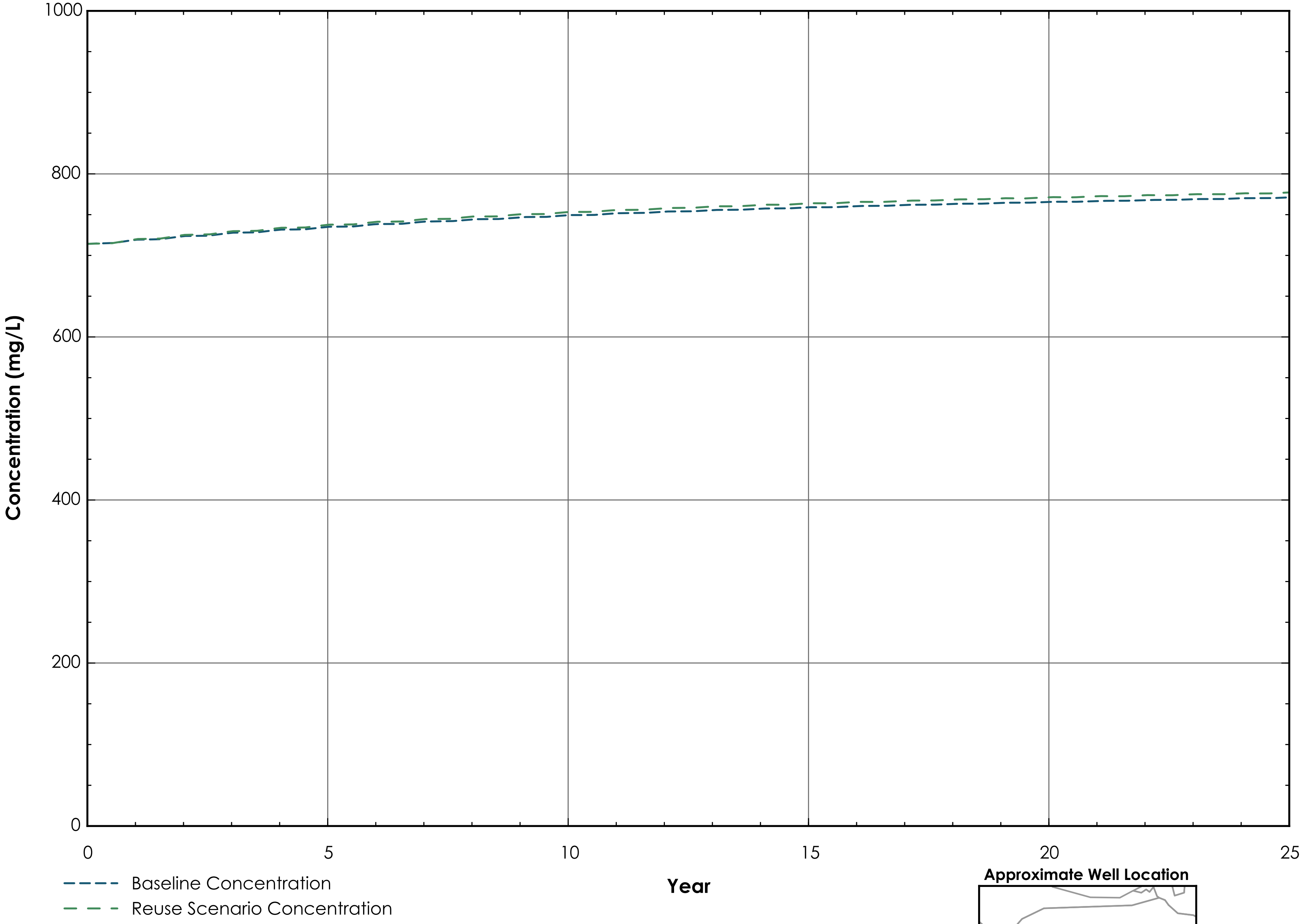
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

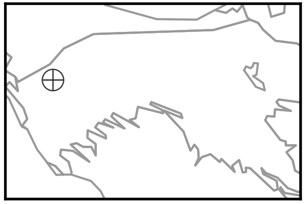


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 7 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

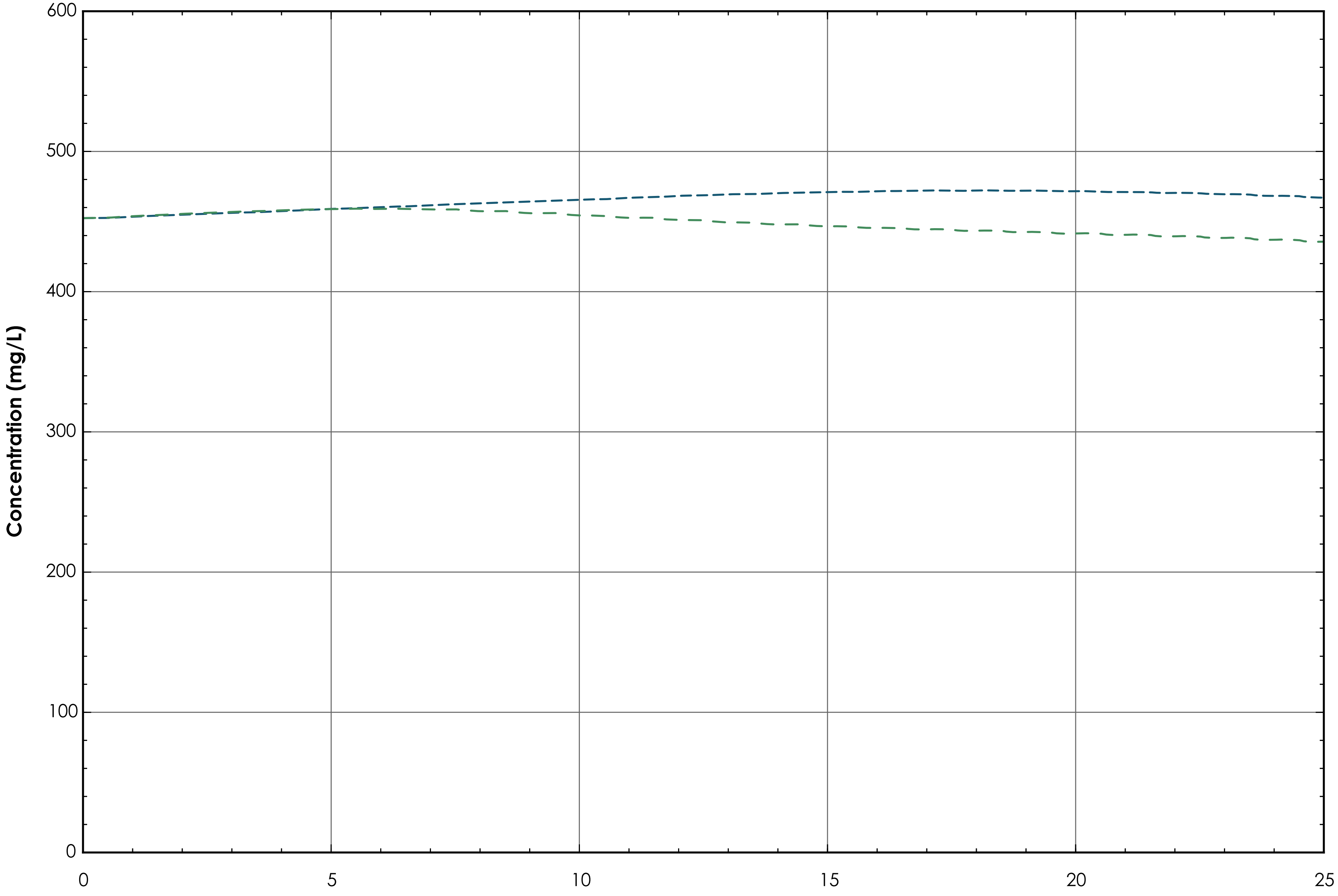


Approximate Well Location



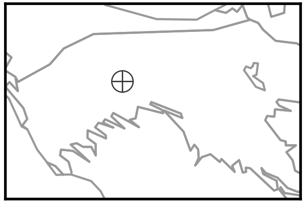
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 8 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

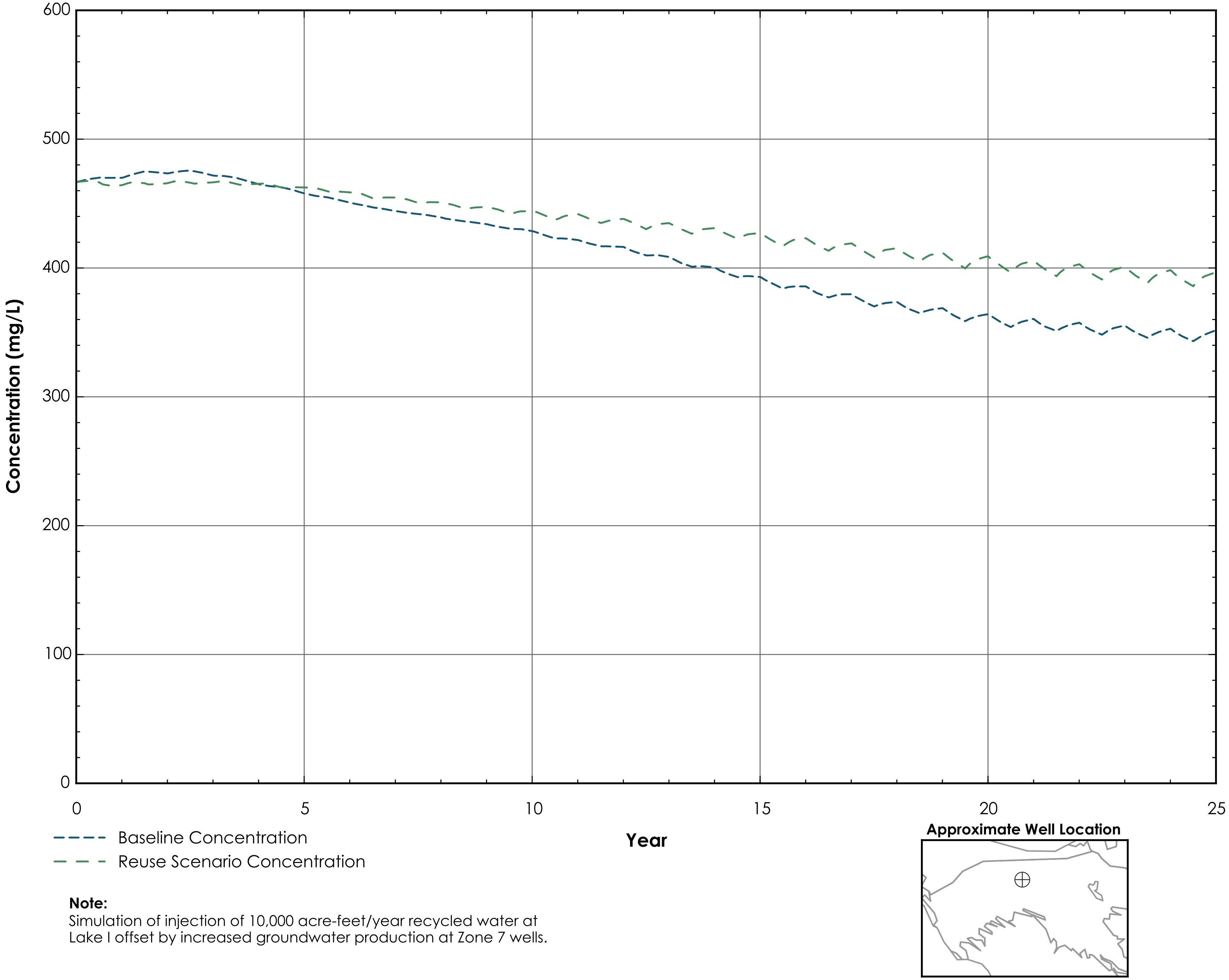


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

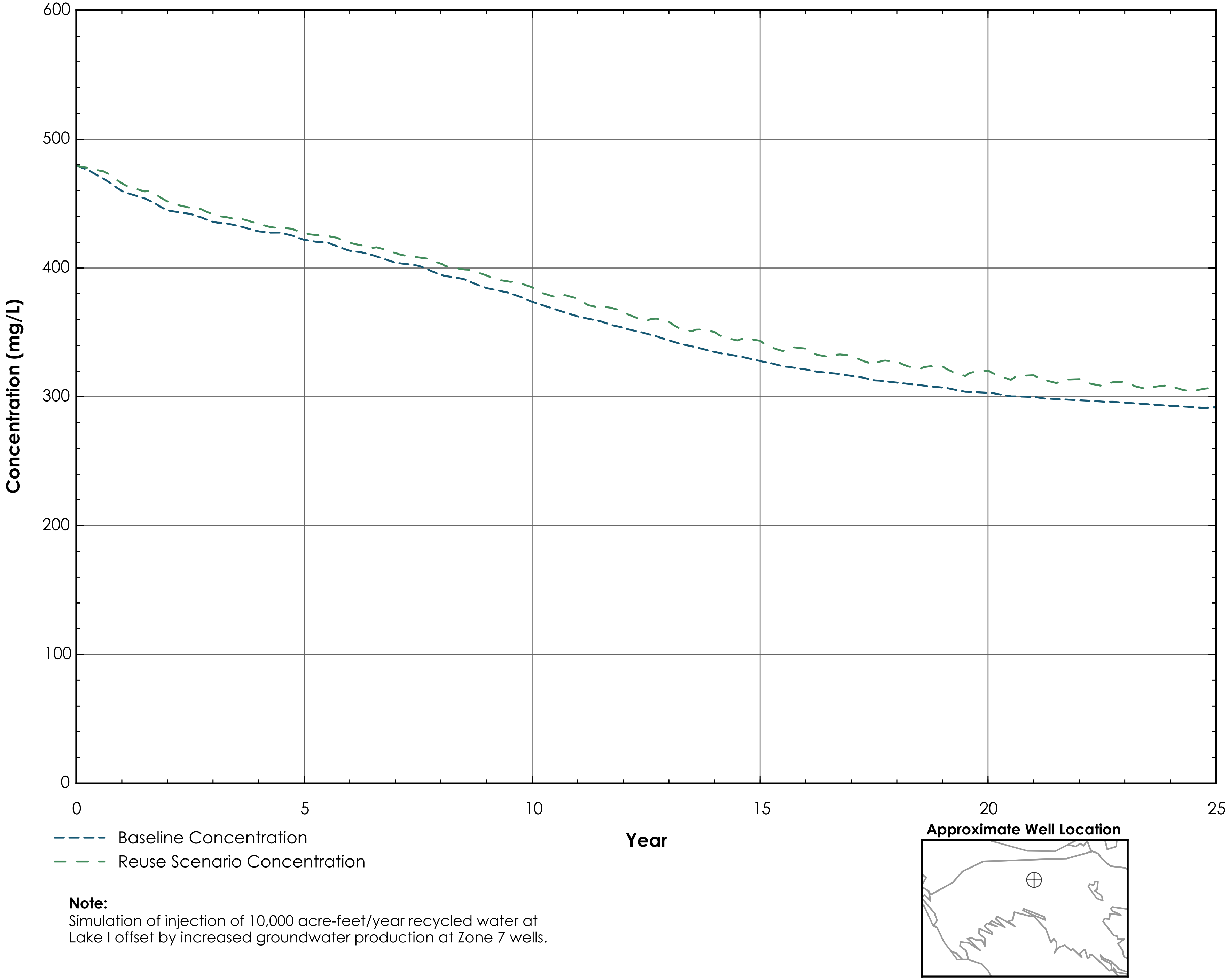


Well COL 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



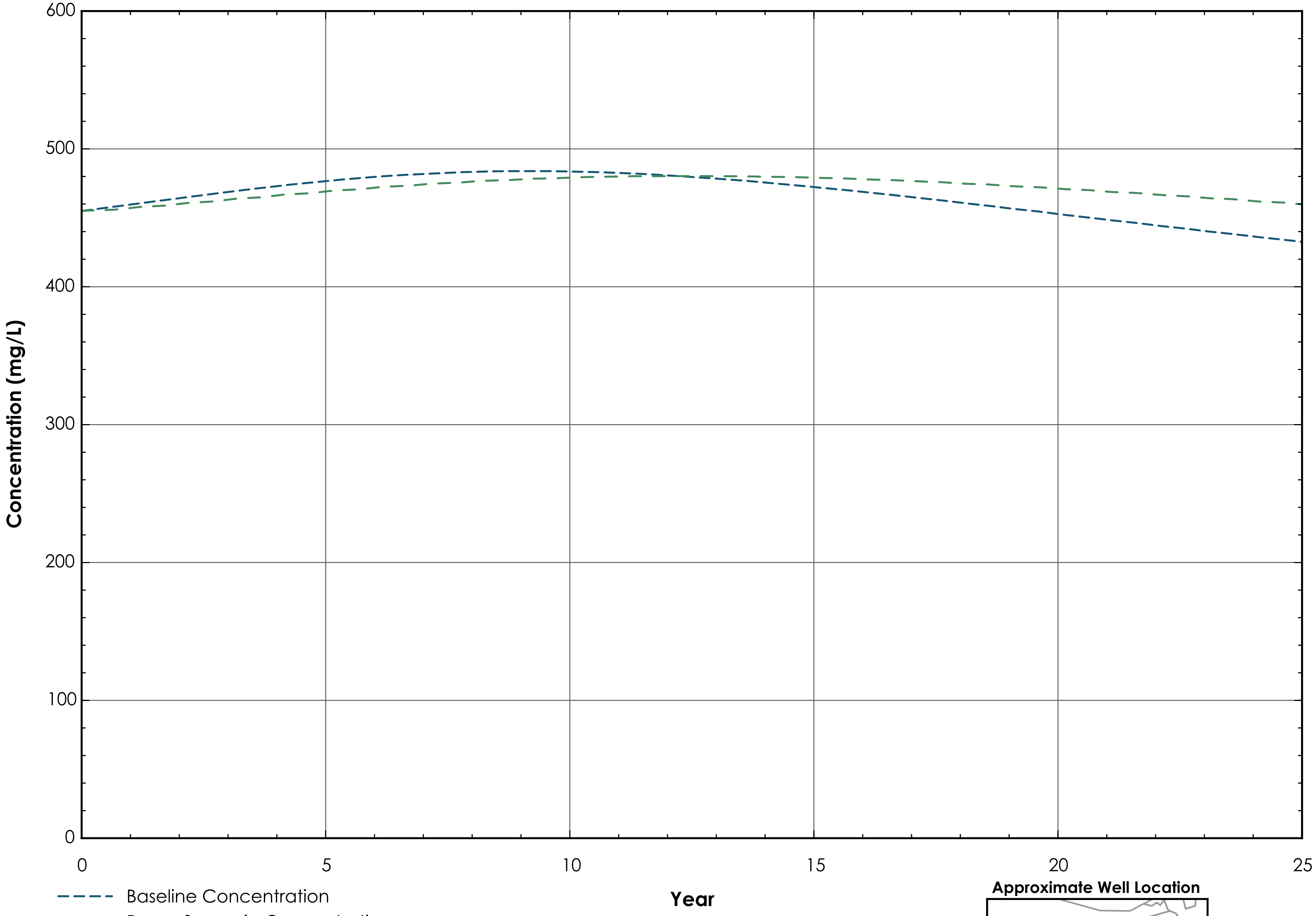
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well COL 2 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

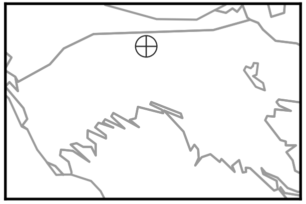


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well COL 5 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

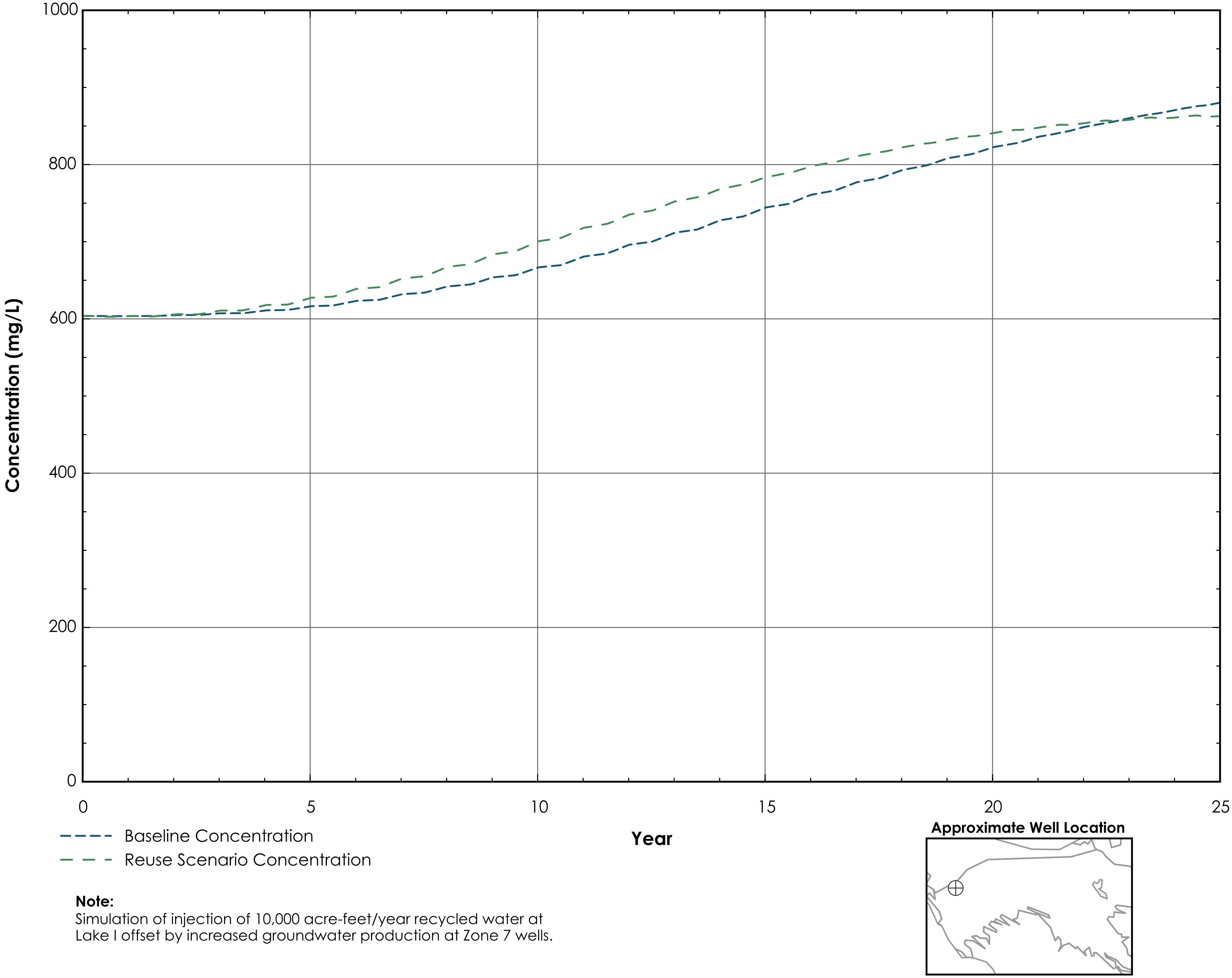


Approximate Well Location



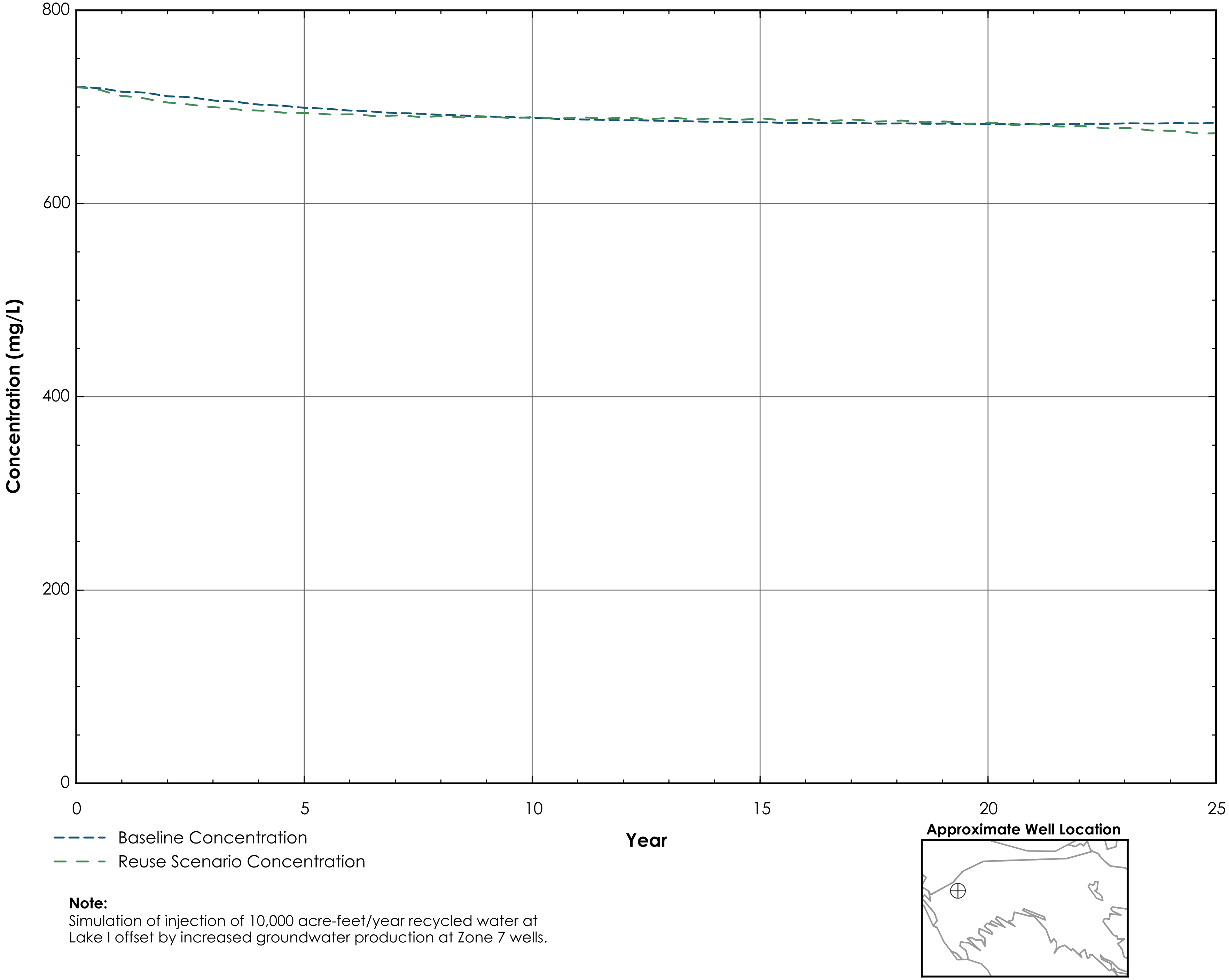
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well HOP 6 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



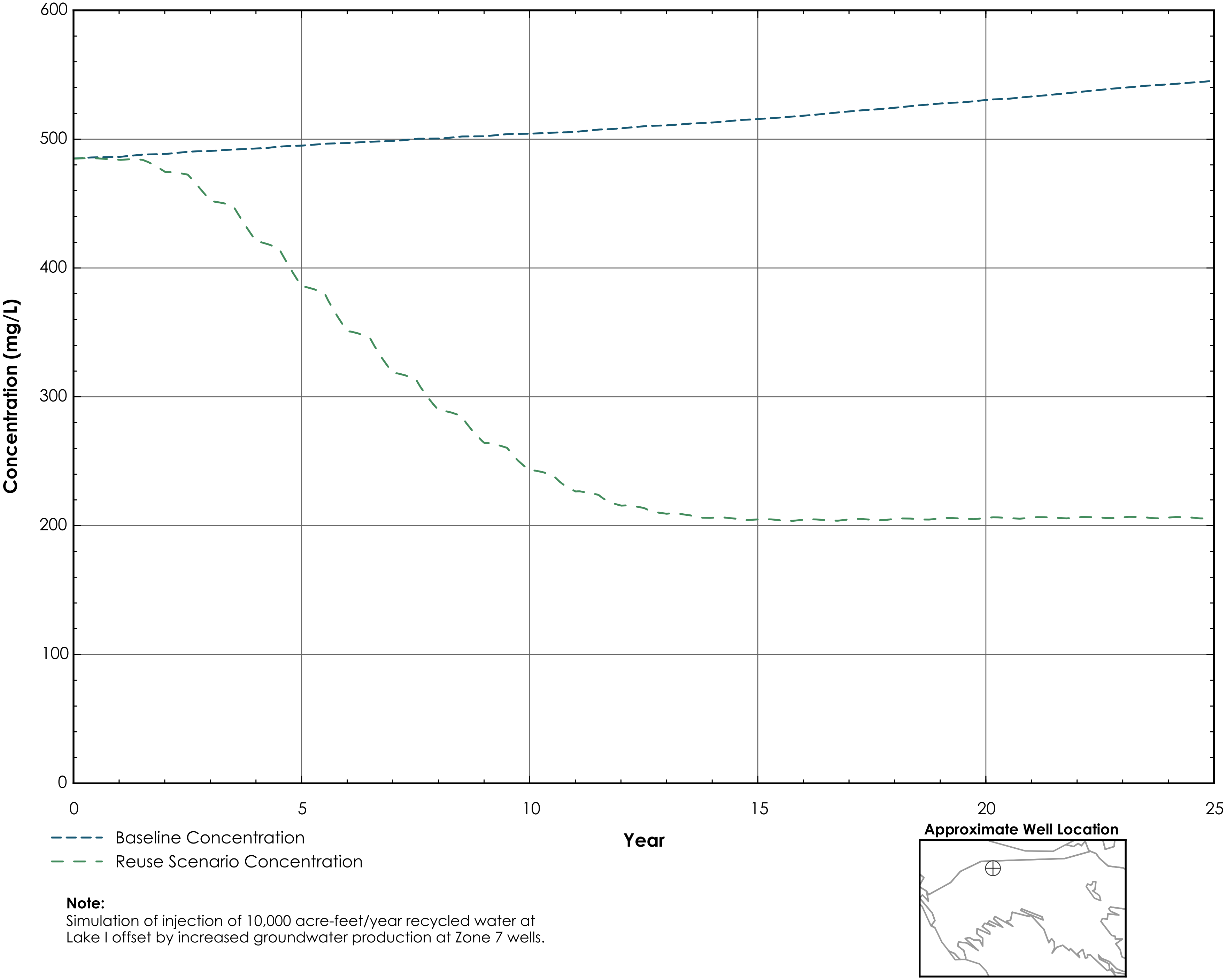
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well HOP 9 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



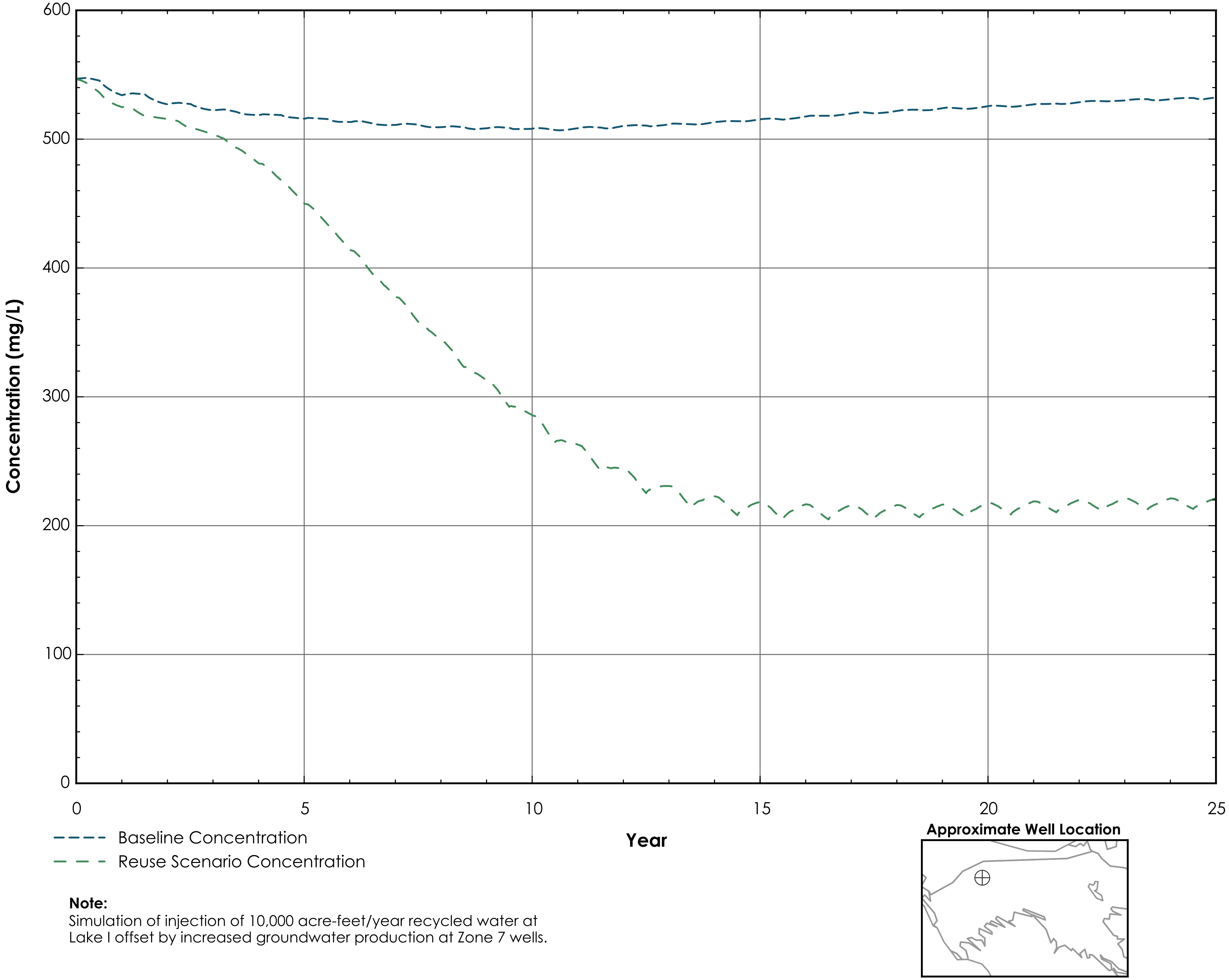
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well STONERIDGE 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



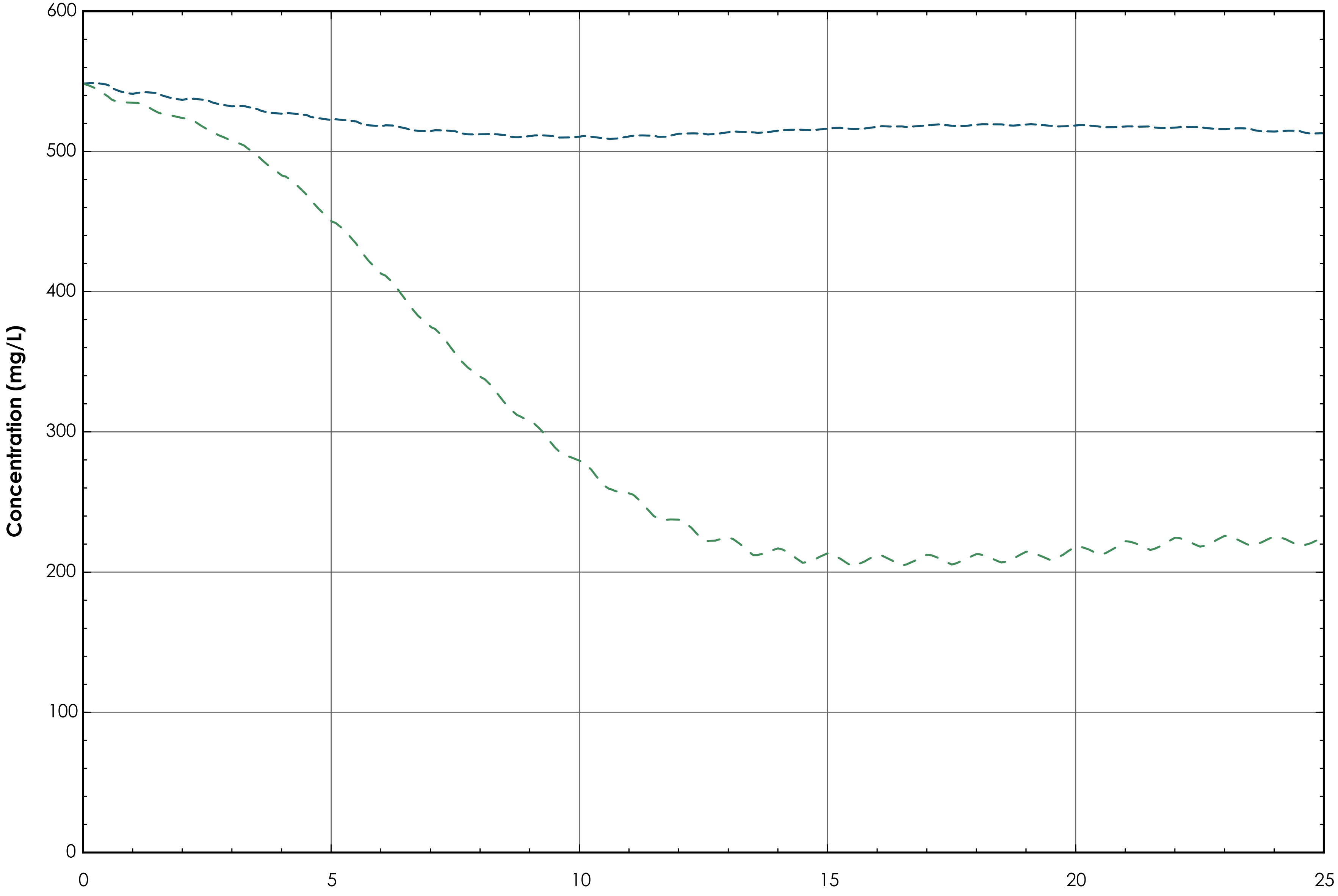
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



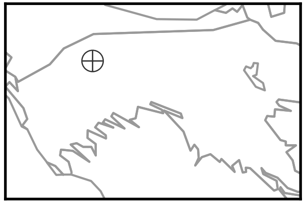
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

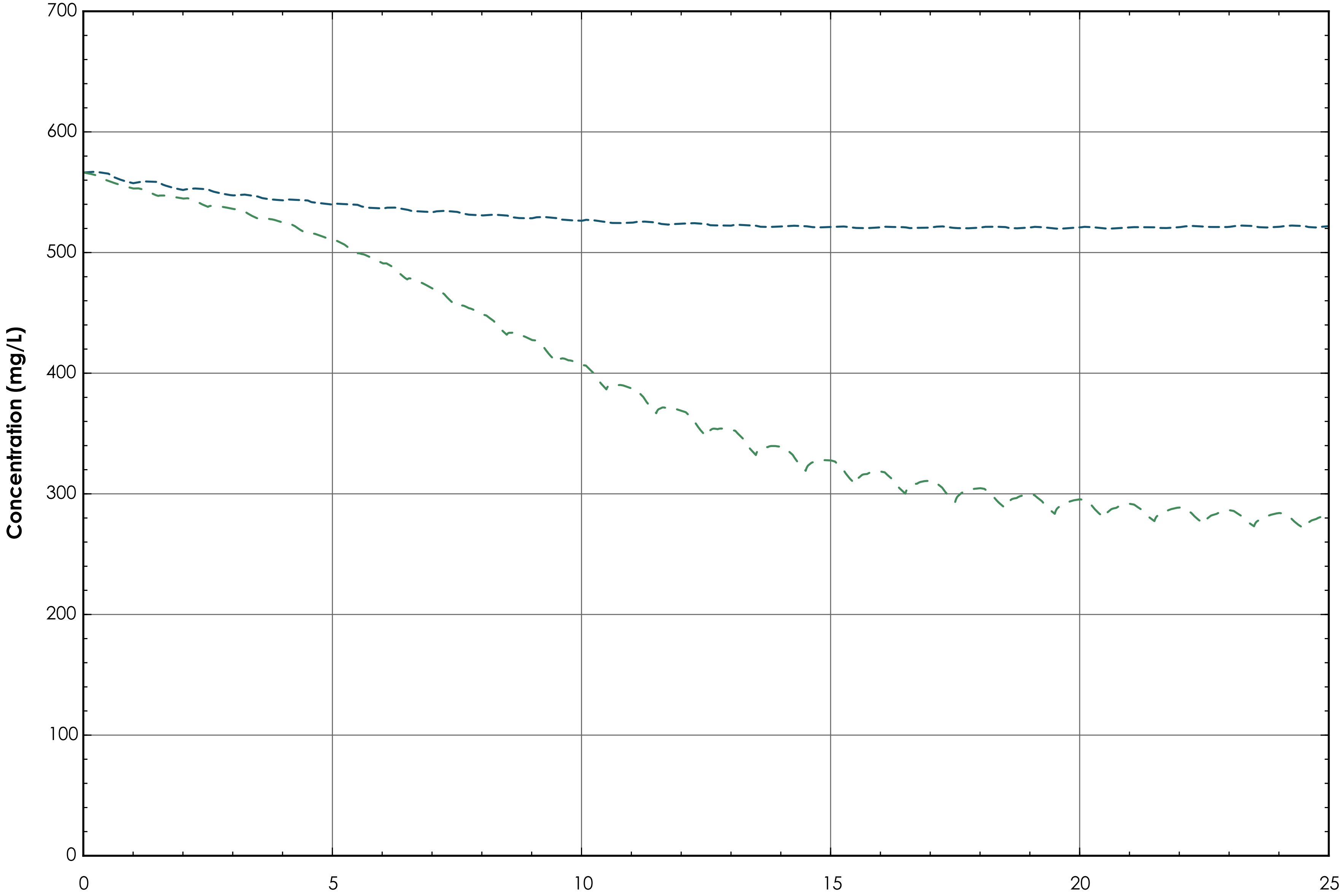


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

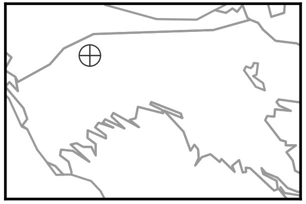


Well MOCHO 3 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

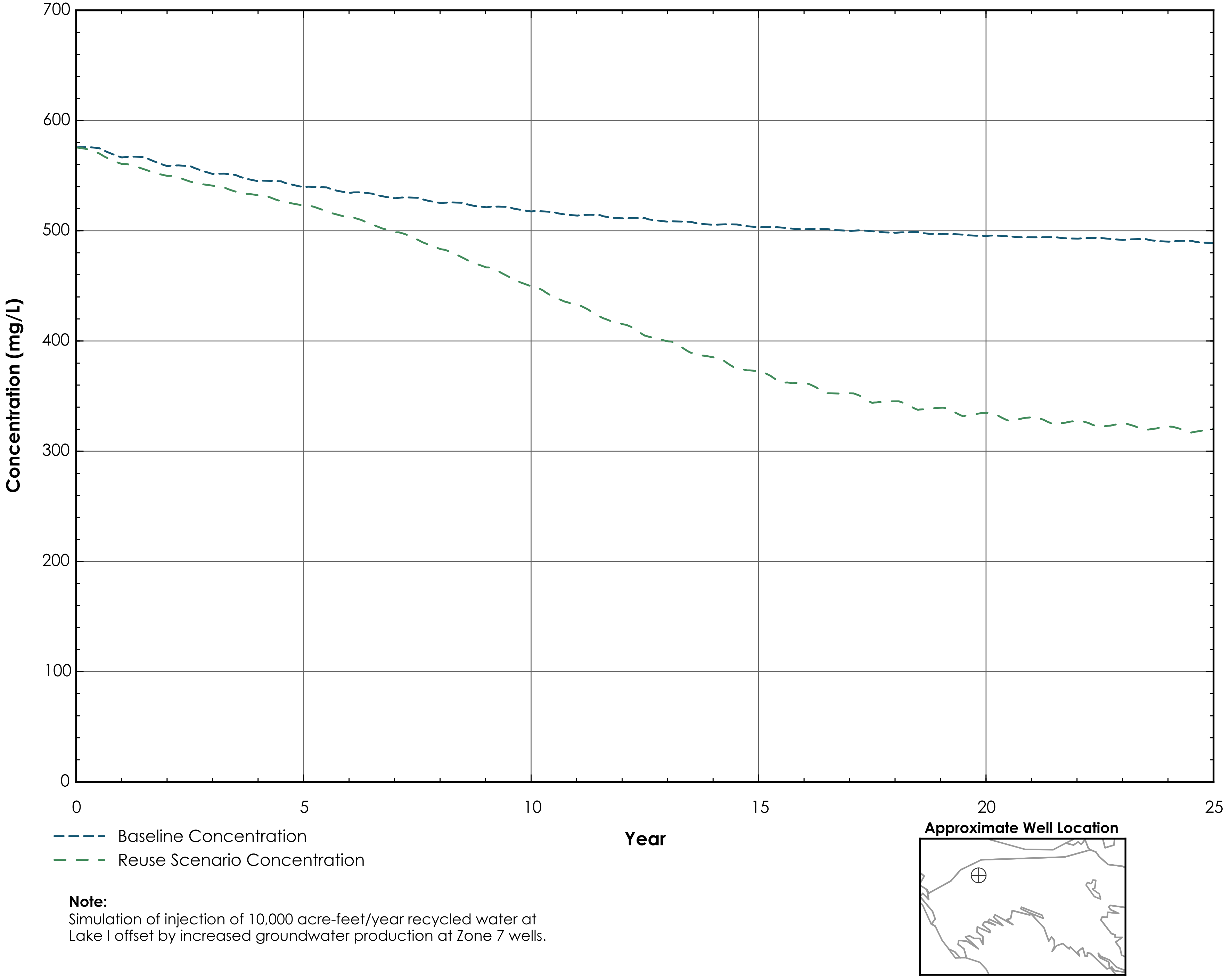


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

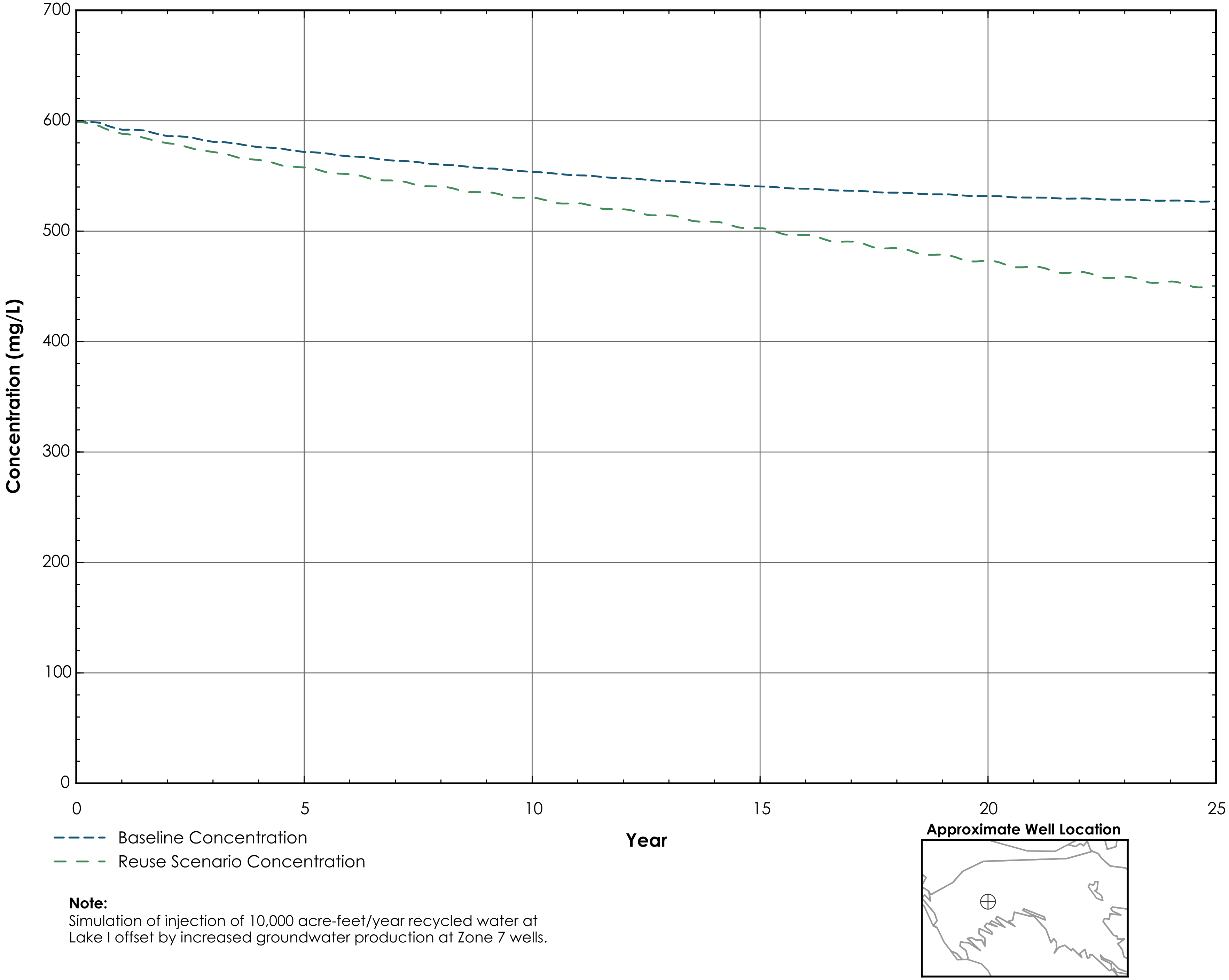


Well MOCHO 4 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



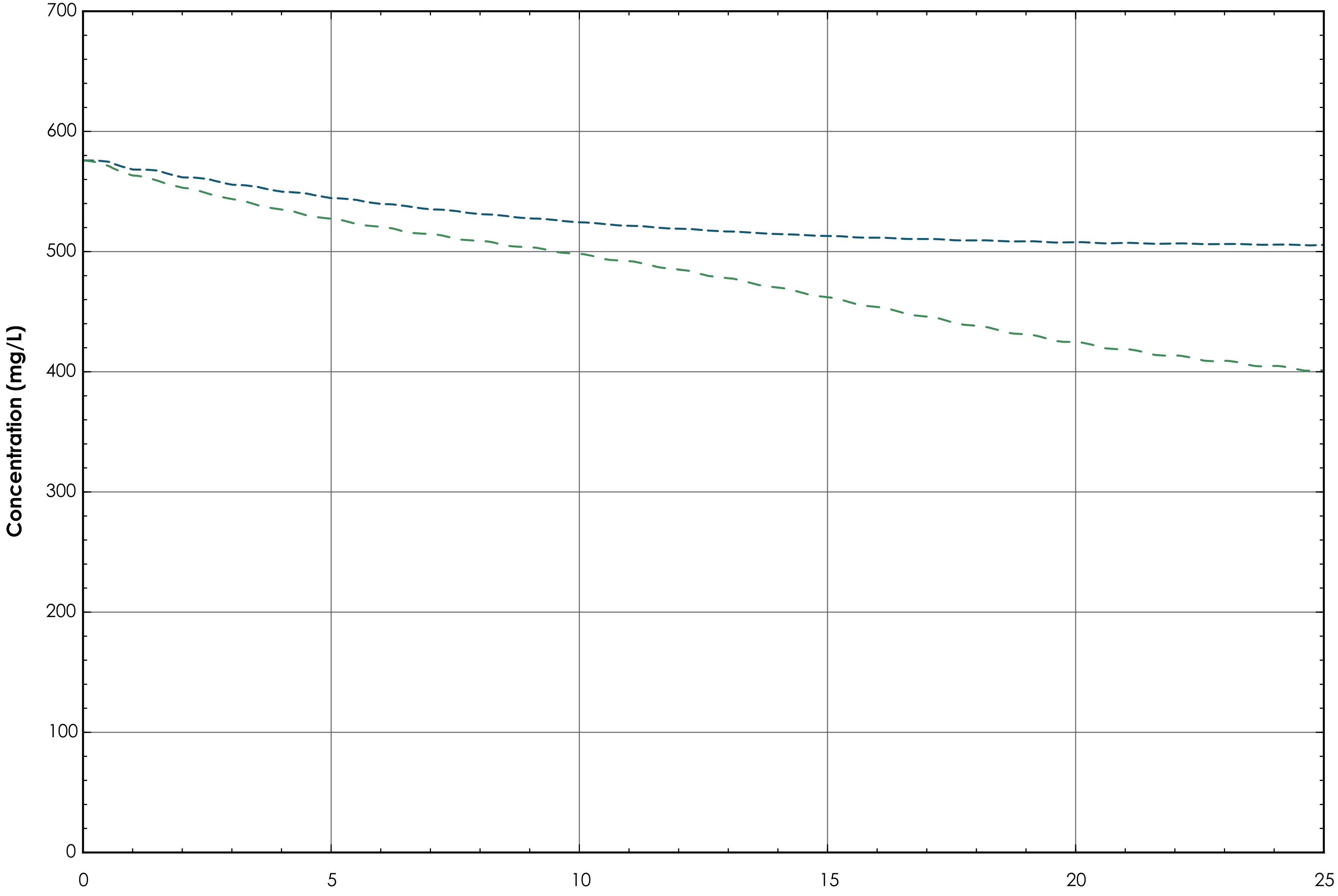
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 5 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



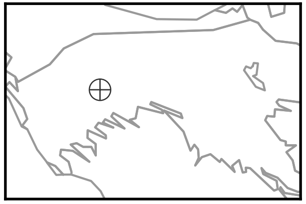
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 6 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

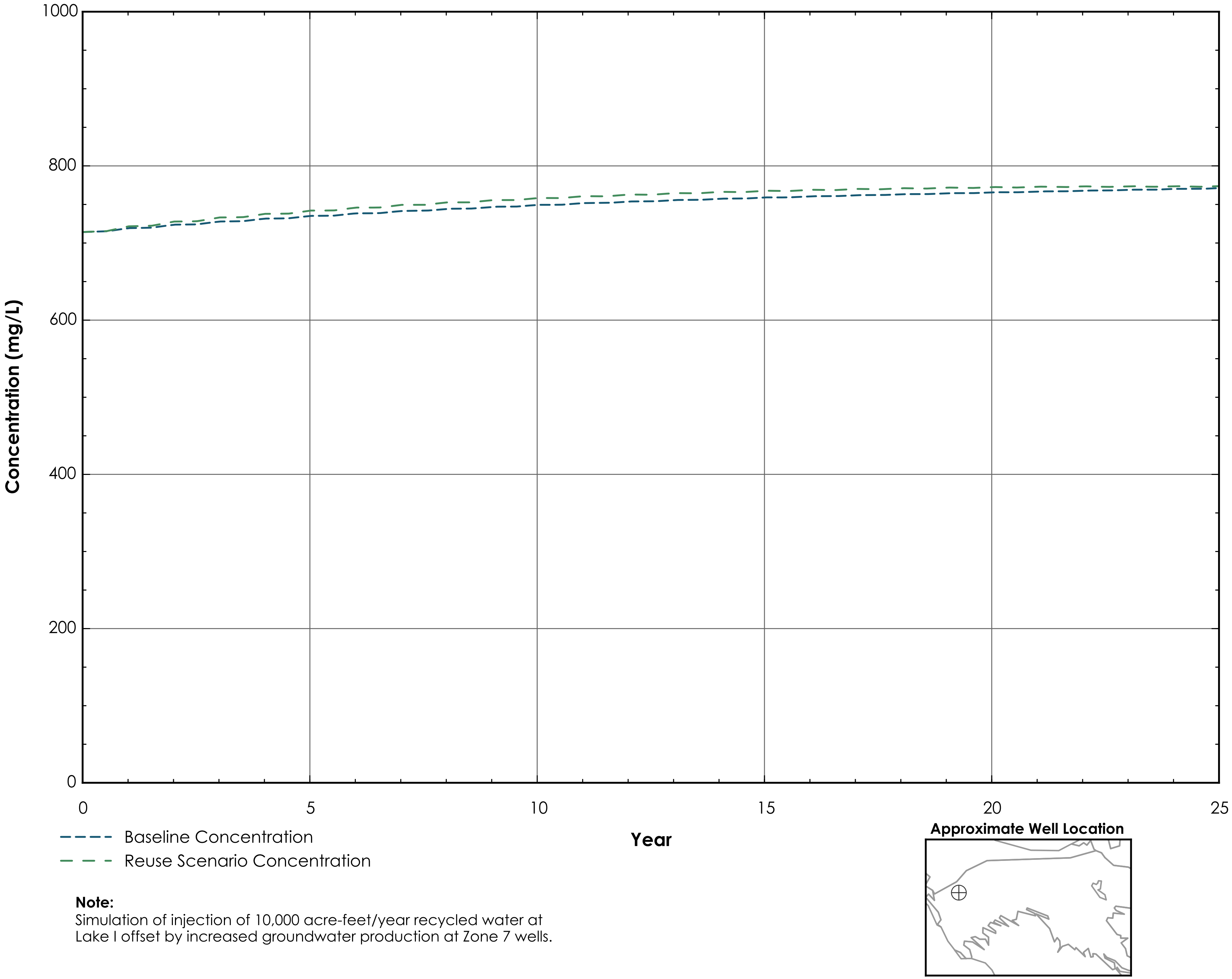


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

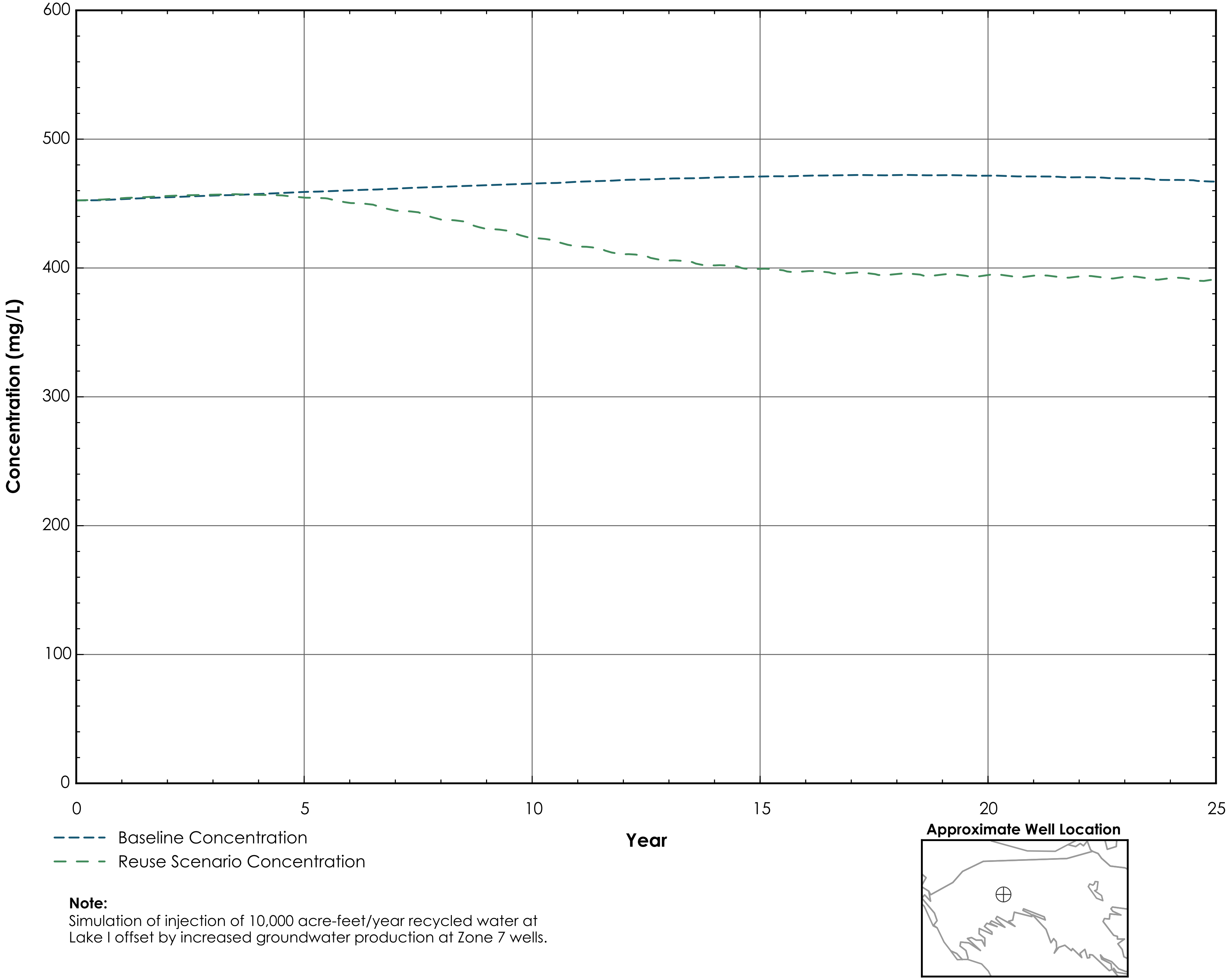


Well PLEAS 7 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



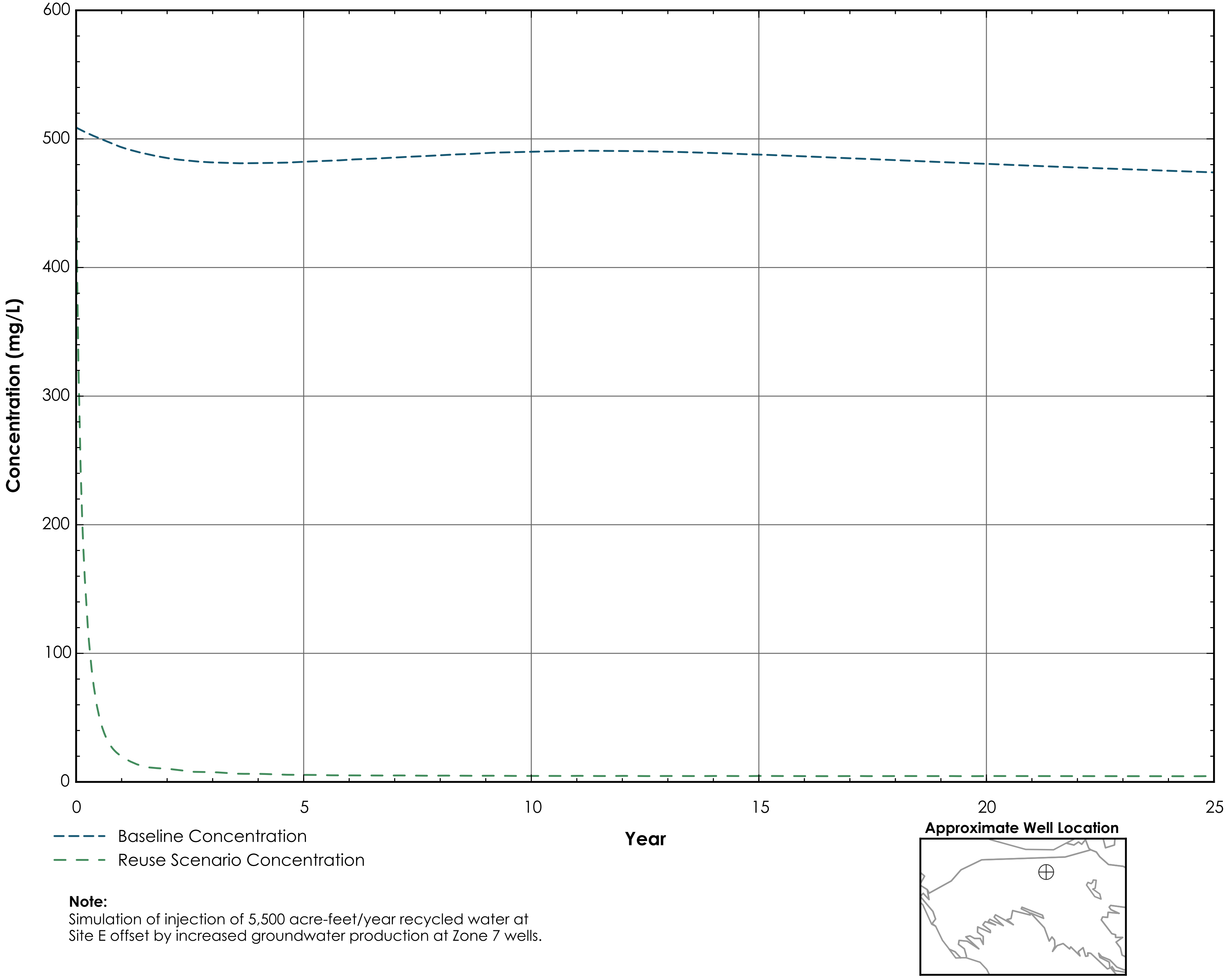
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 8 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



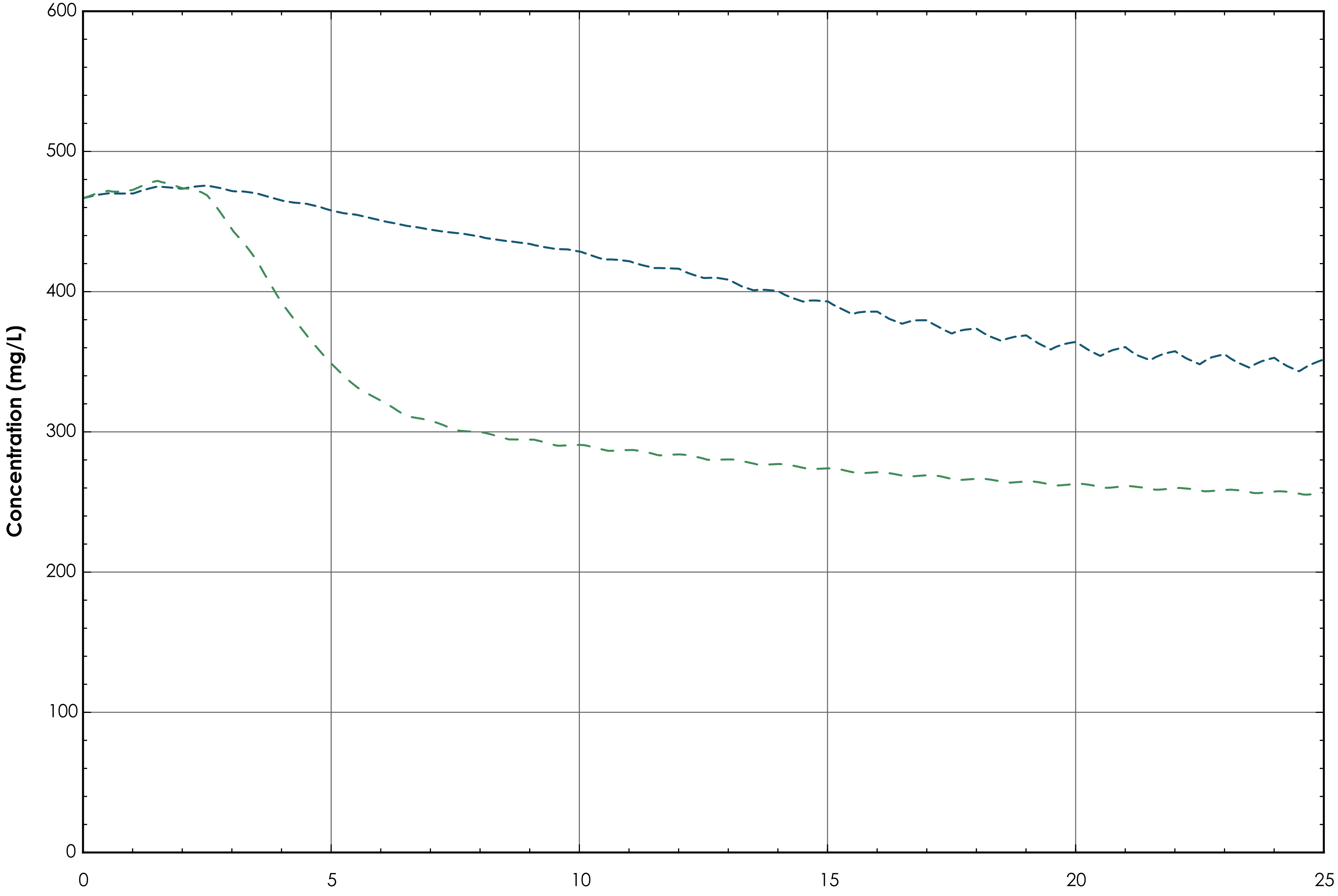
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well Inj E Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

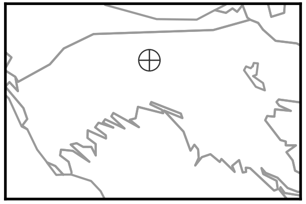


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well COL 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

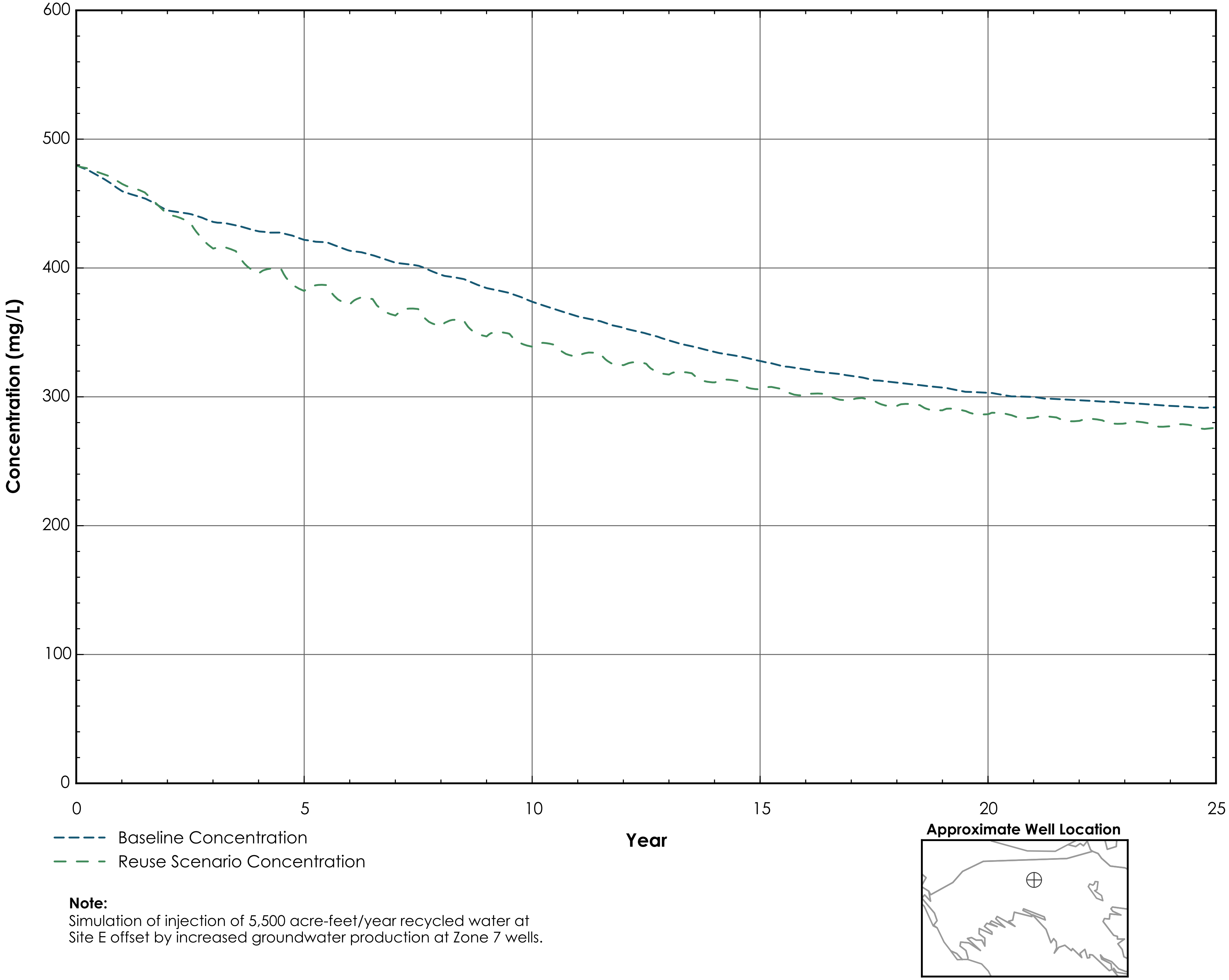


Approximate Well Location



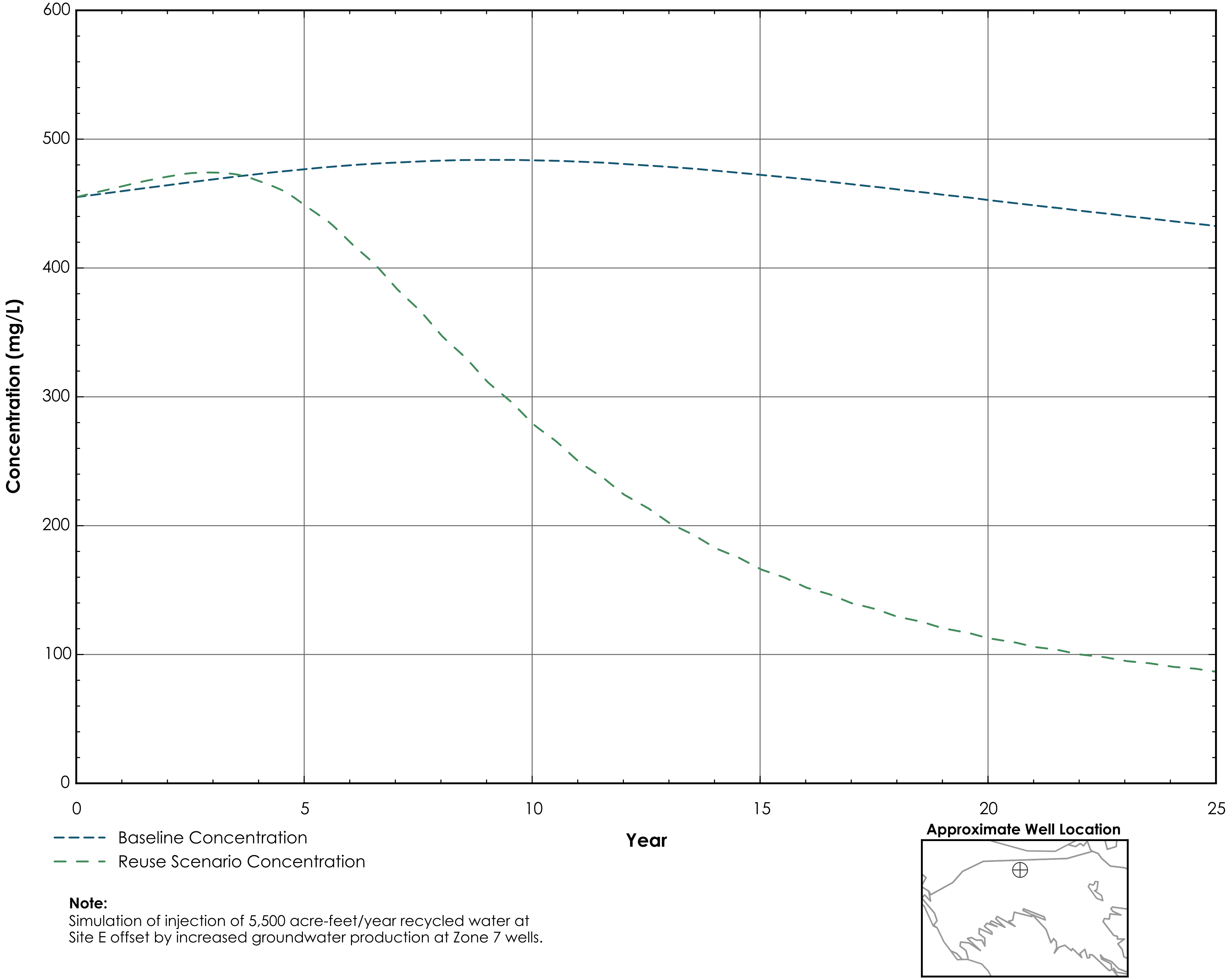
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well COL 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



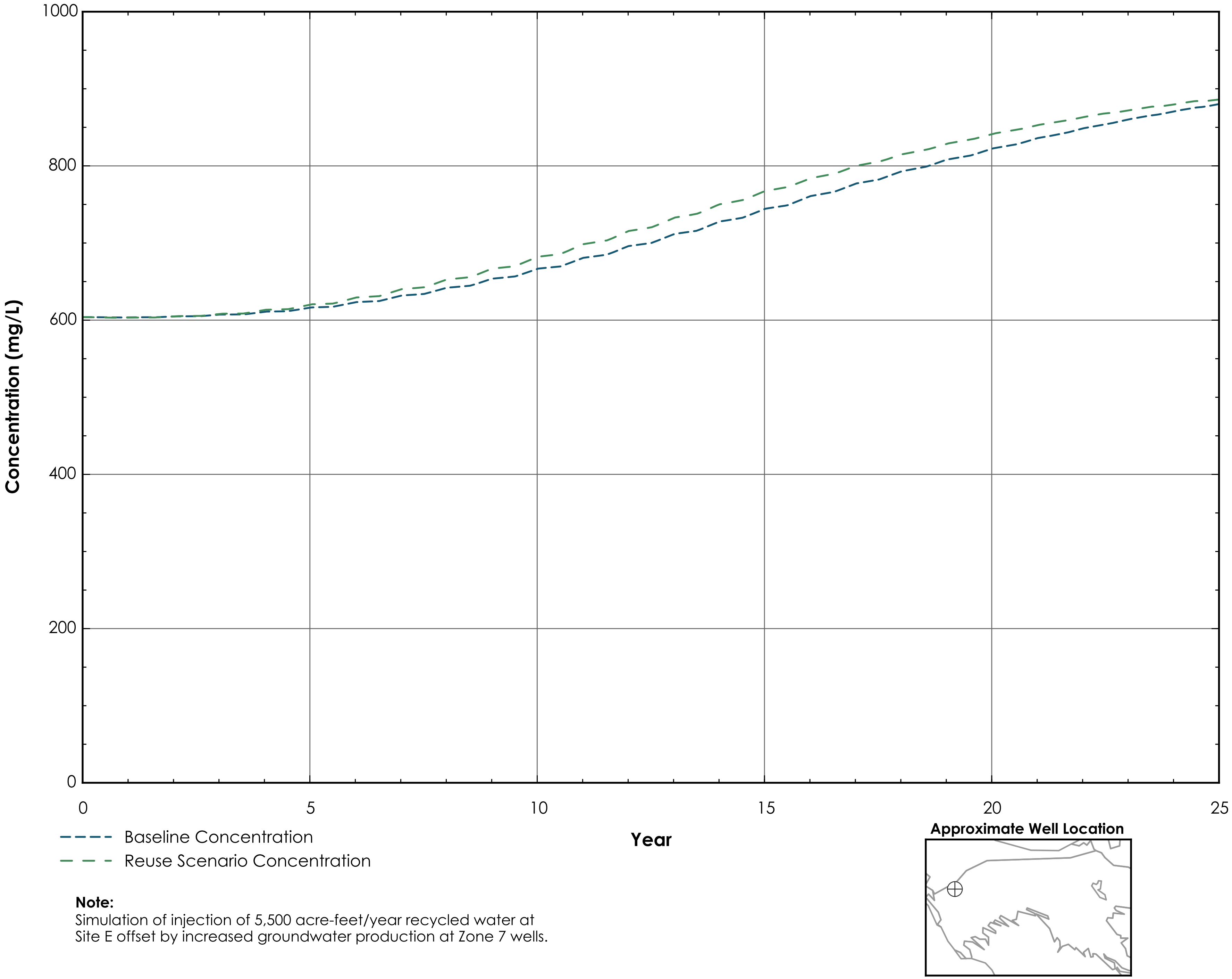
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well COL 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



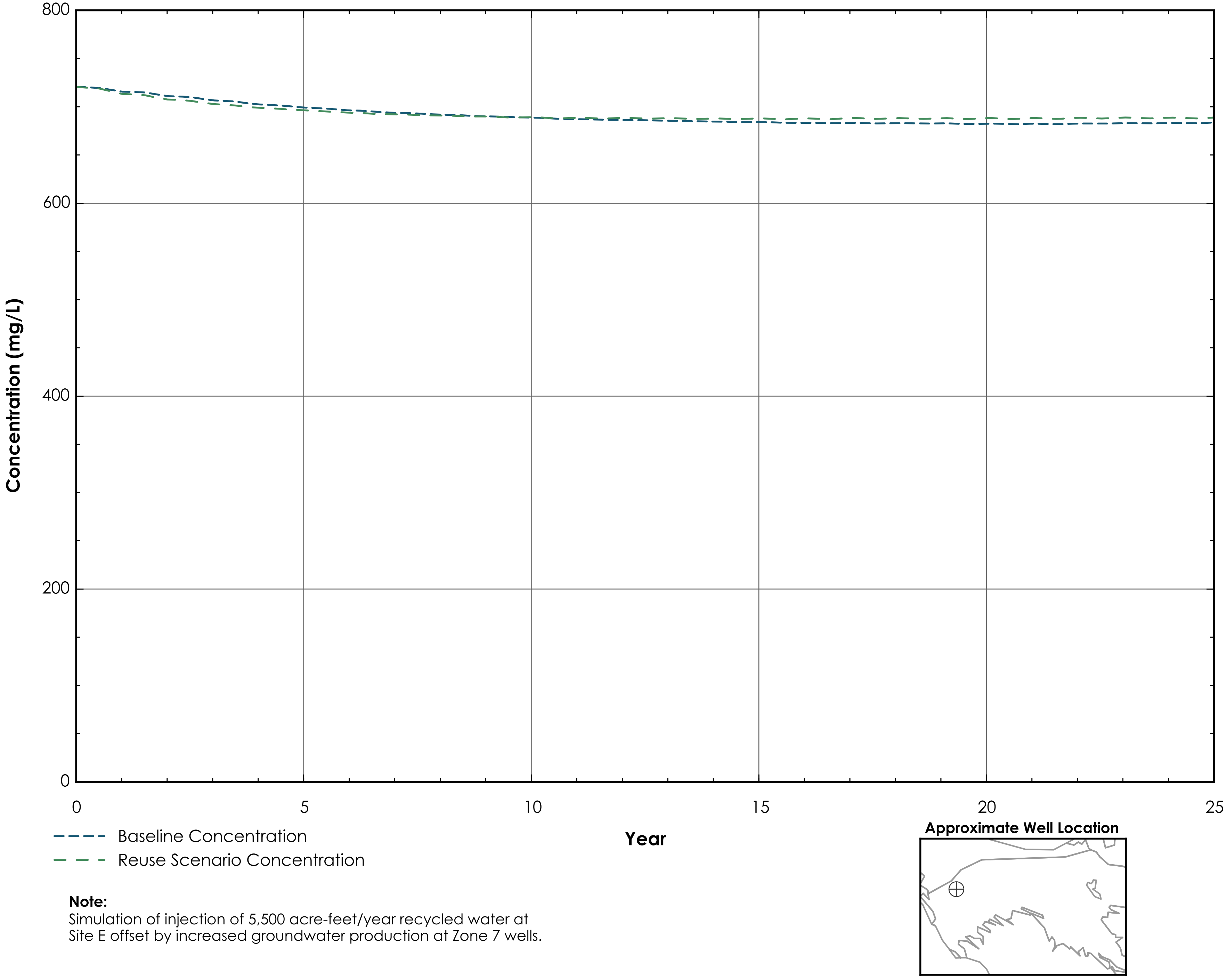
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well HOP 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



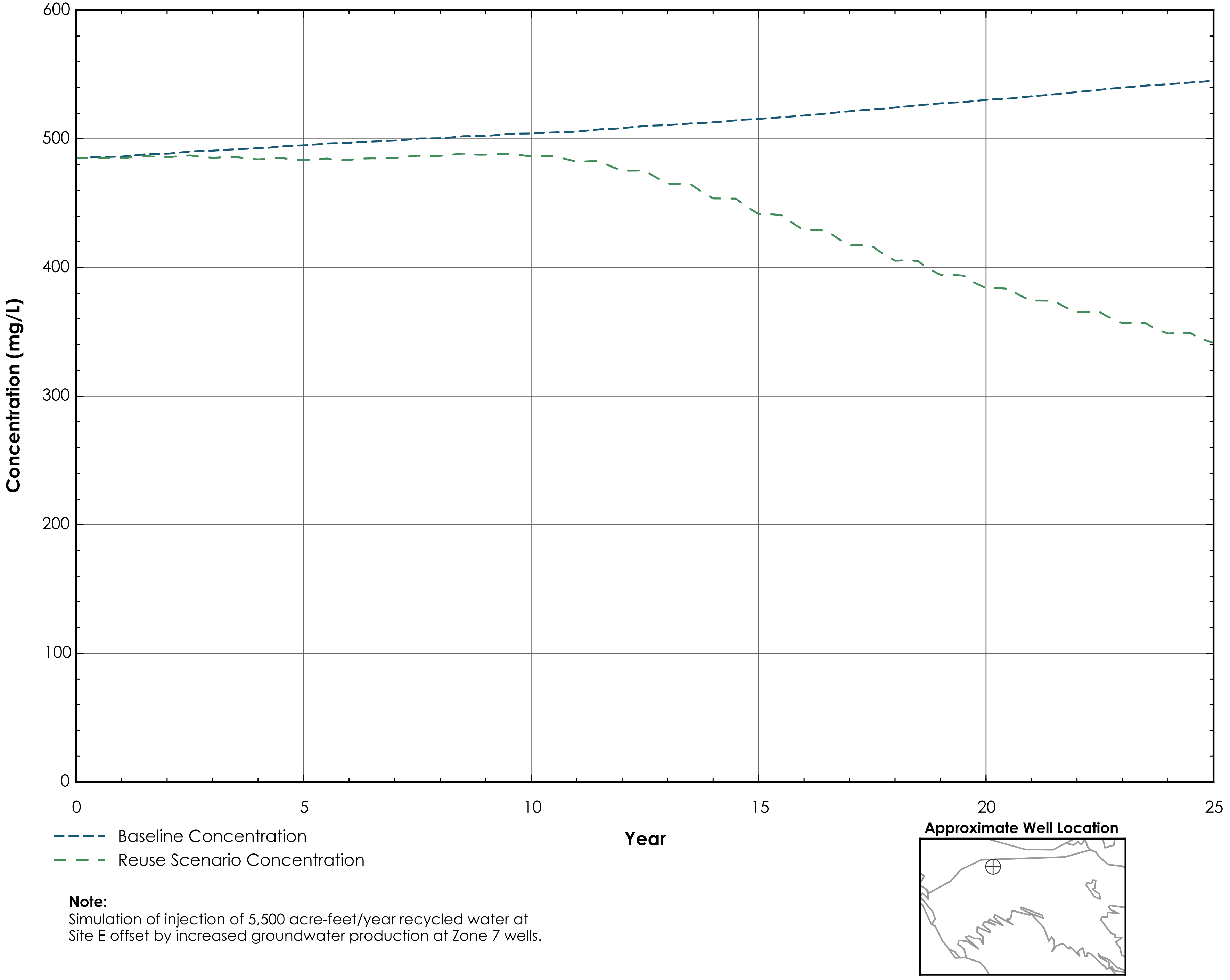
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well HOP 9 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



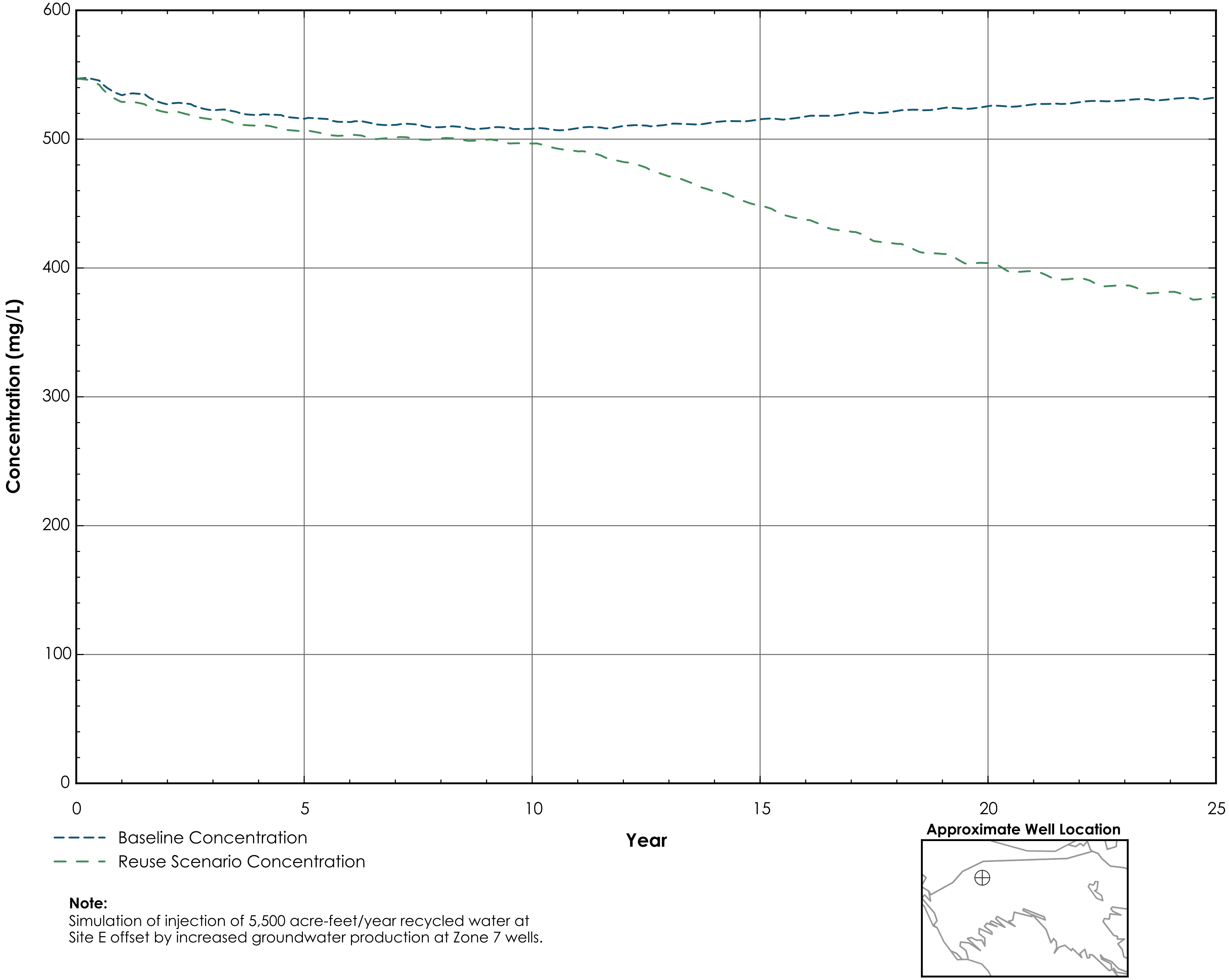
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well STONERIDGE 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



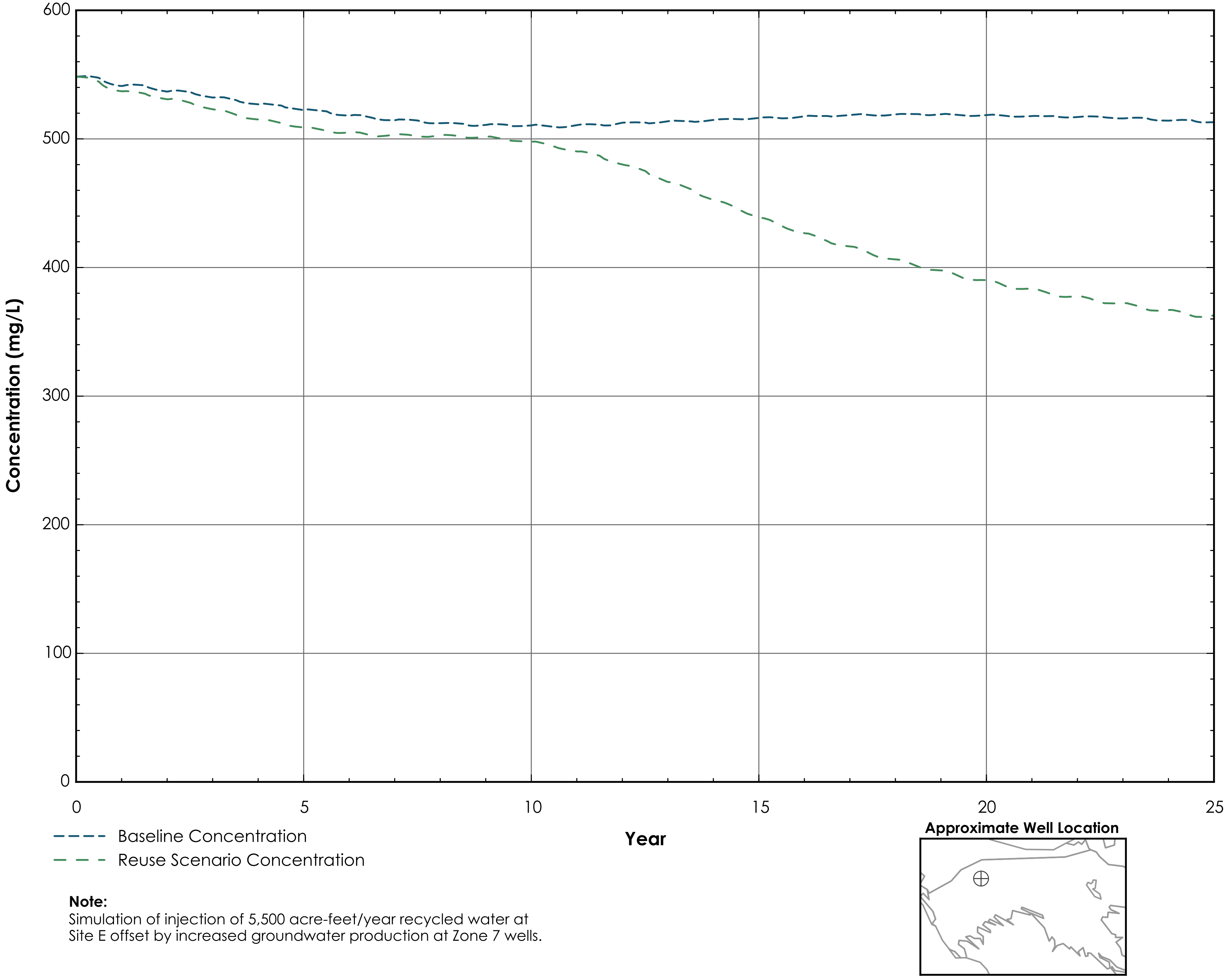
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



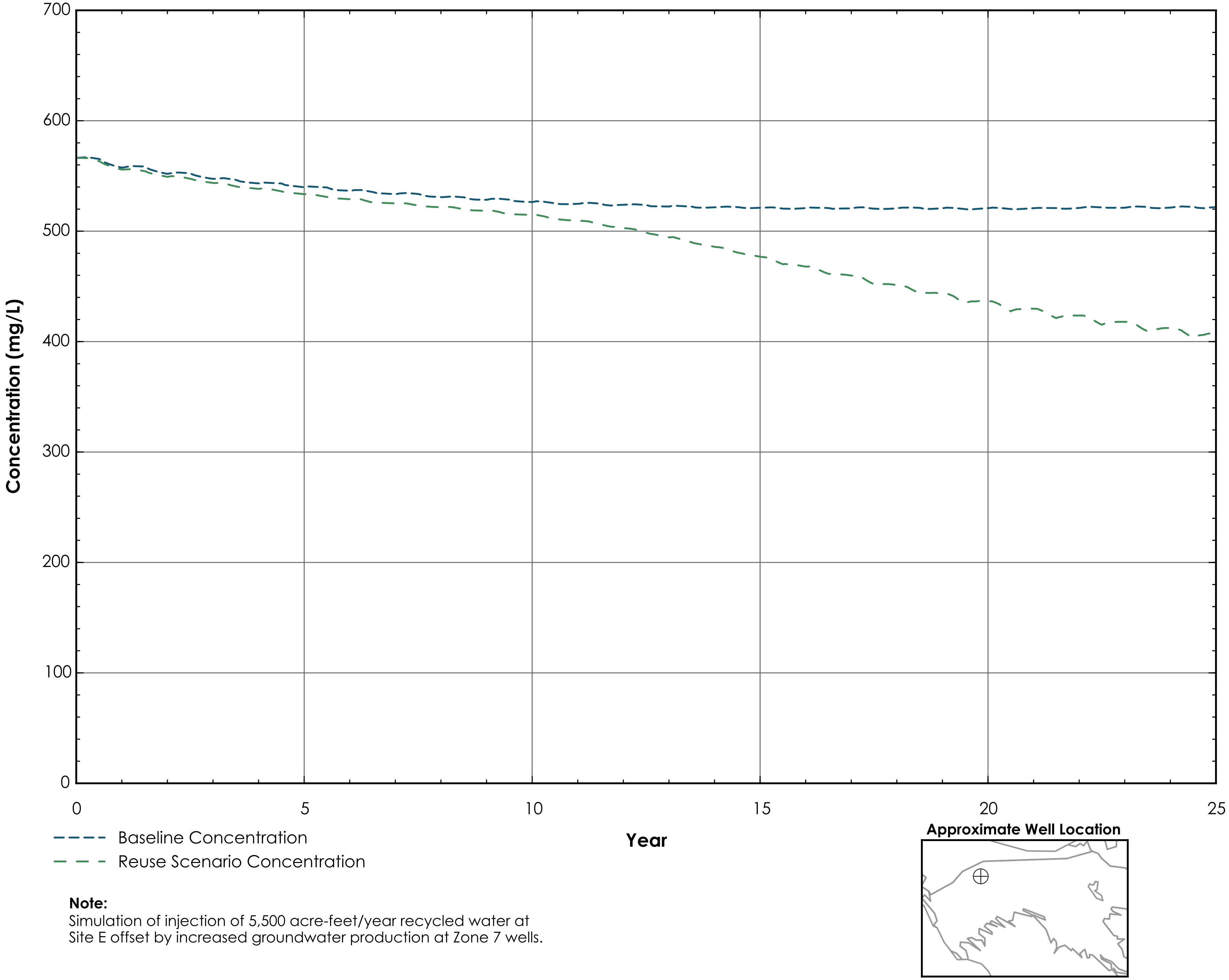
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



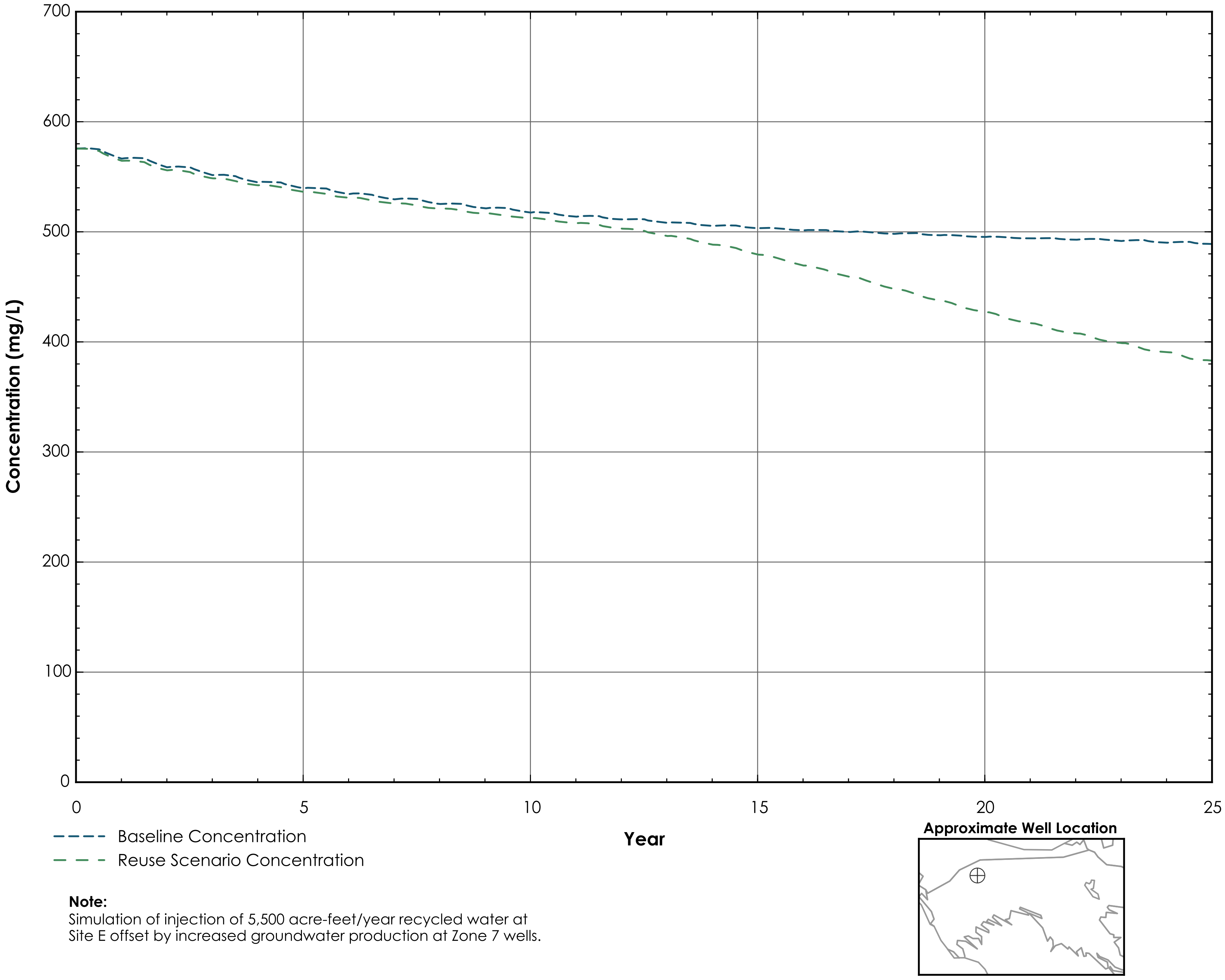
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 3 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



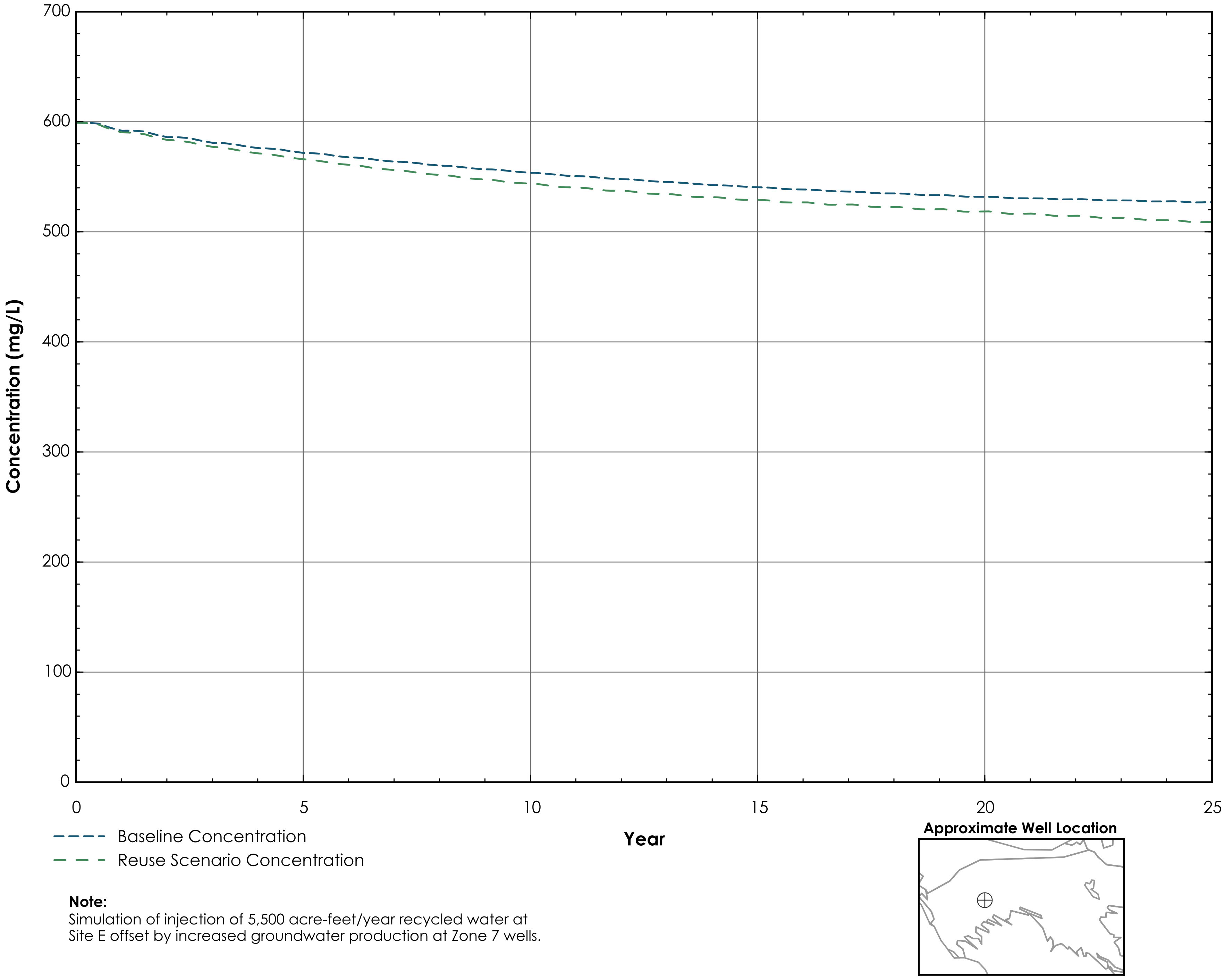
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 4 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



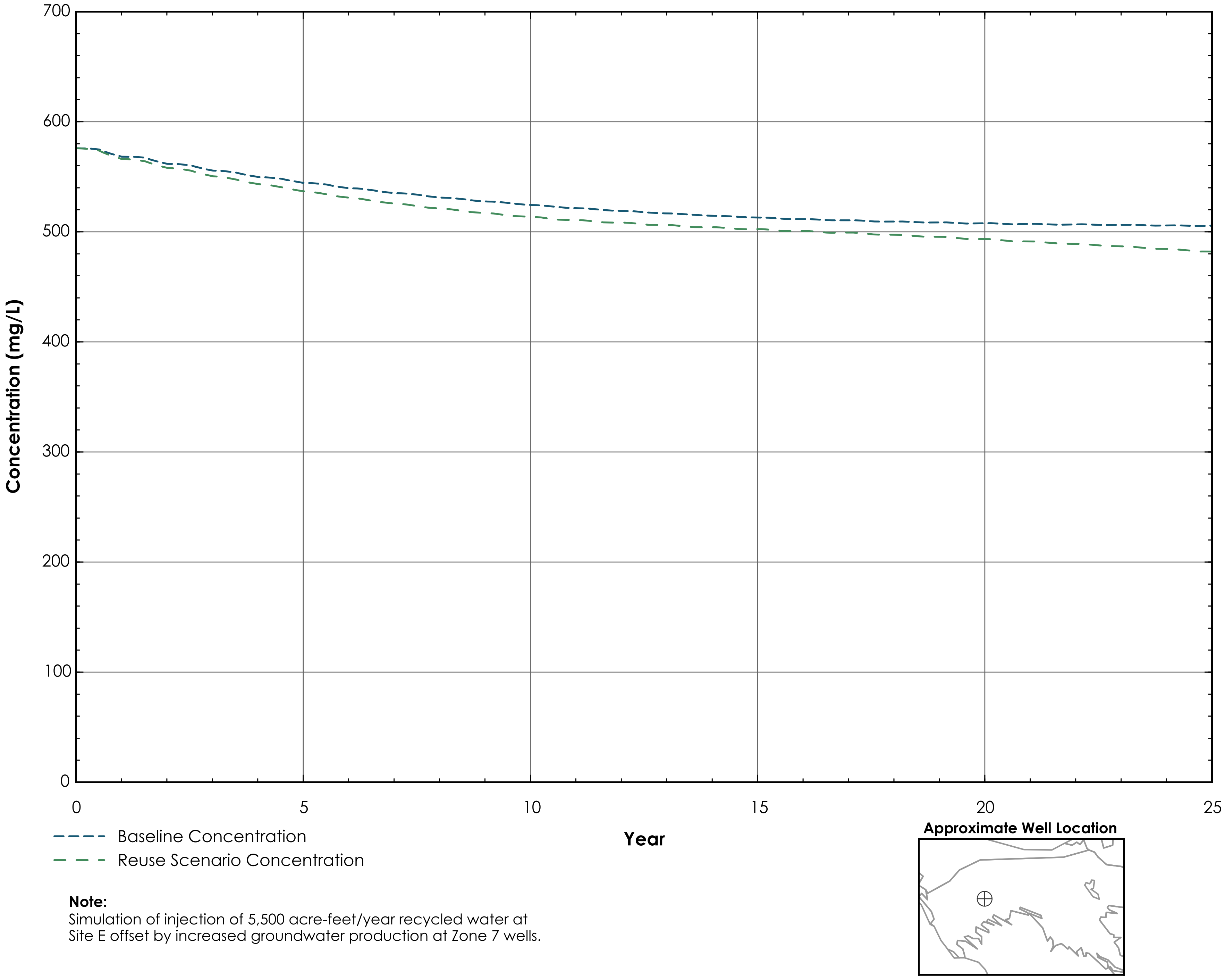
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



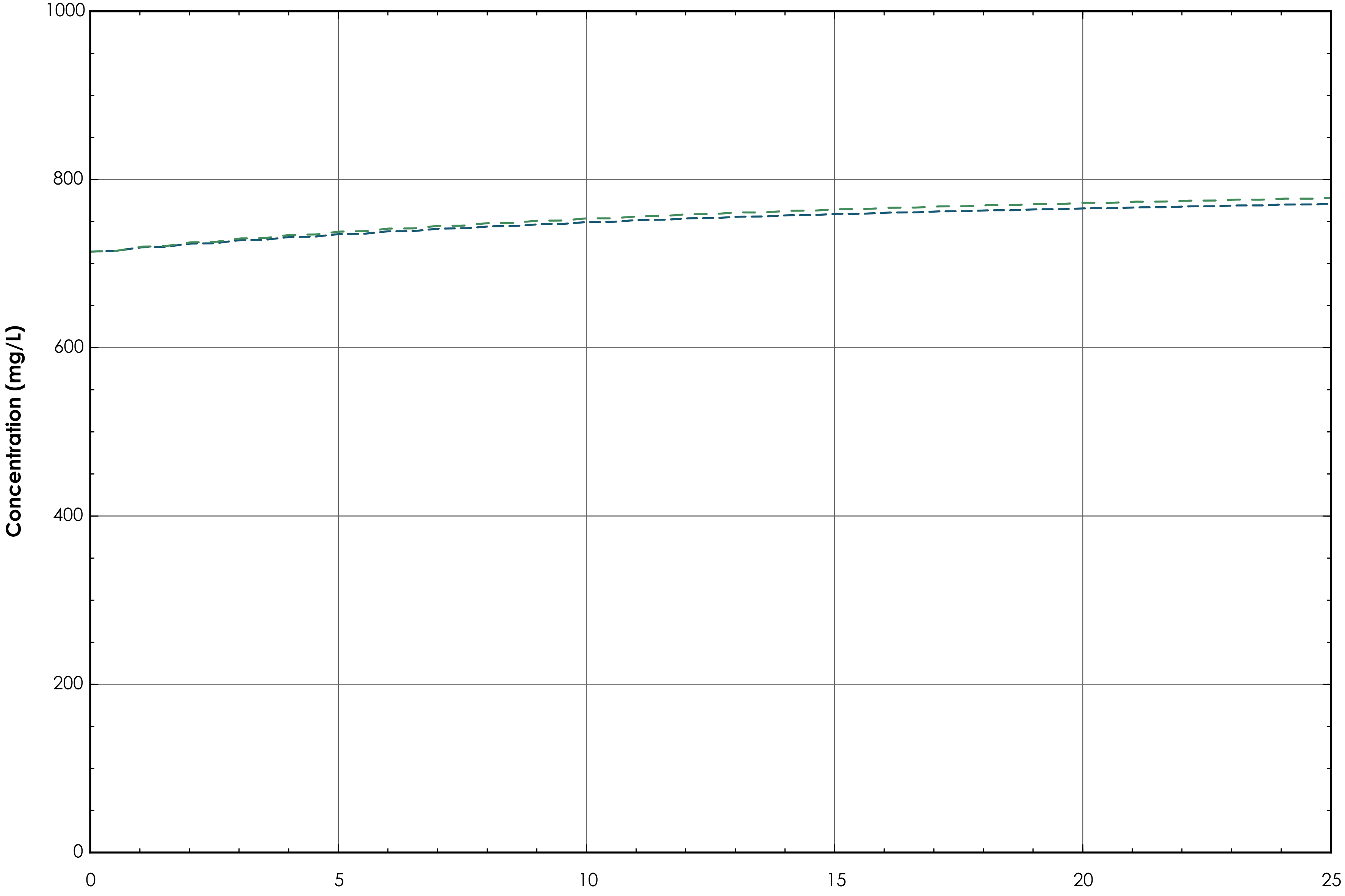
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

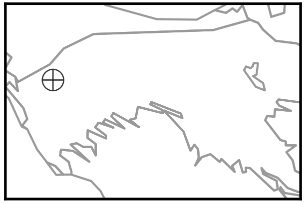


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 7 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

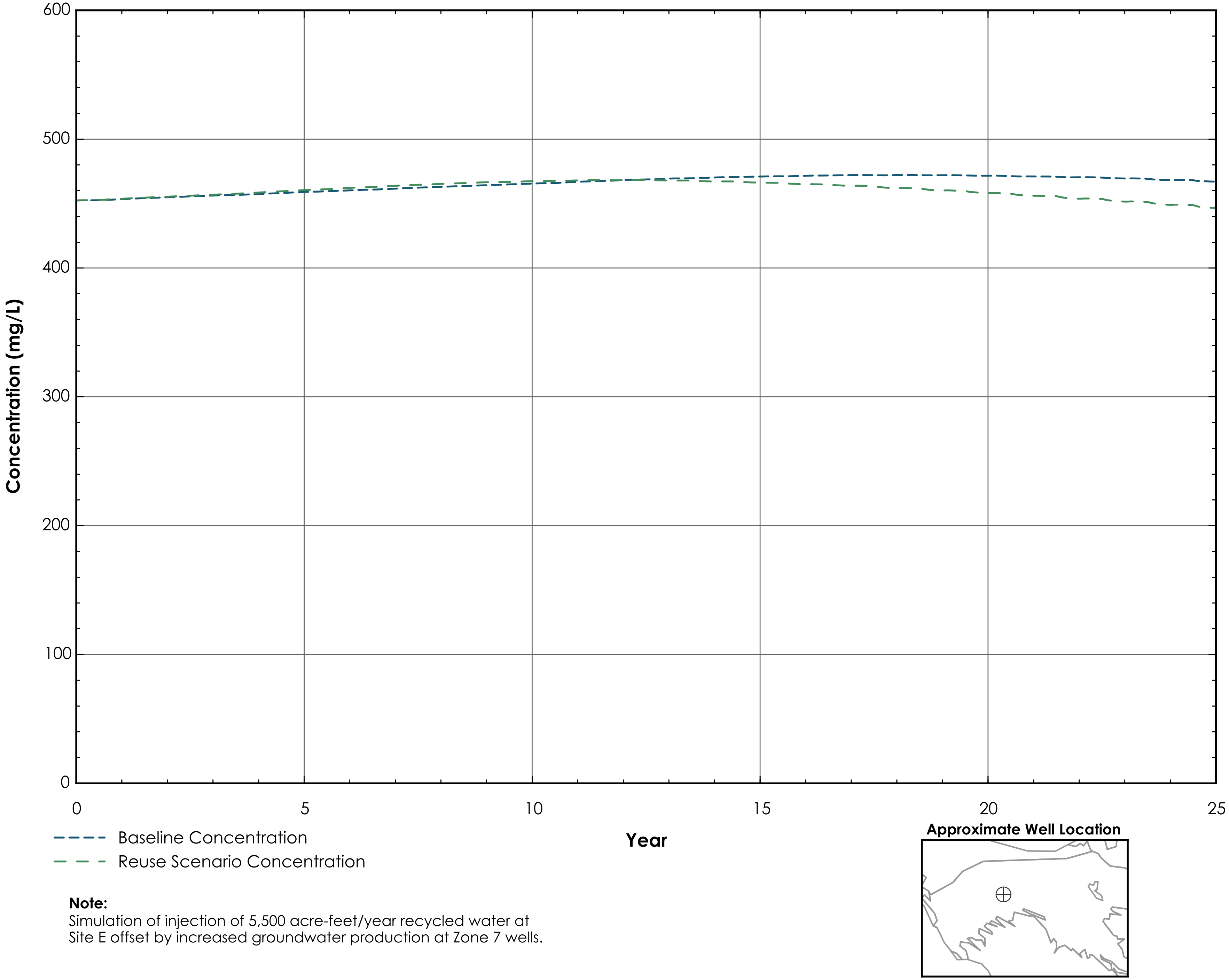


Approximate Well Location



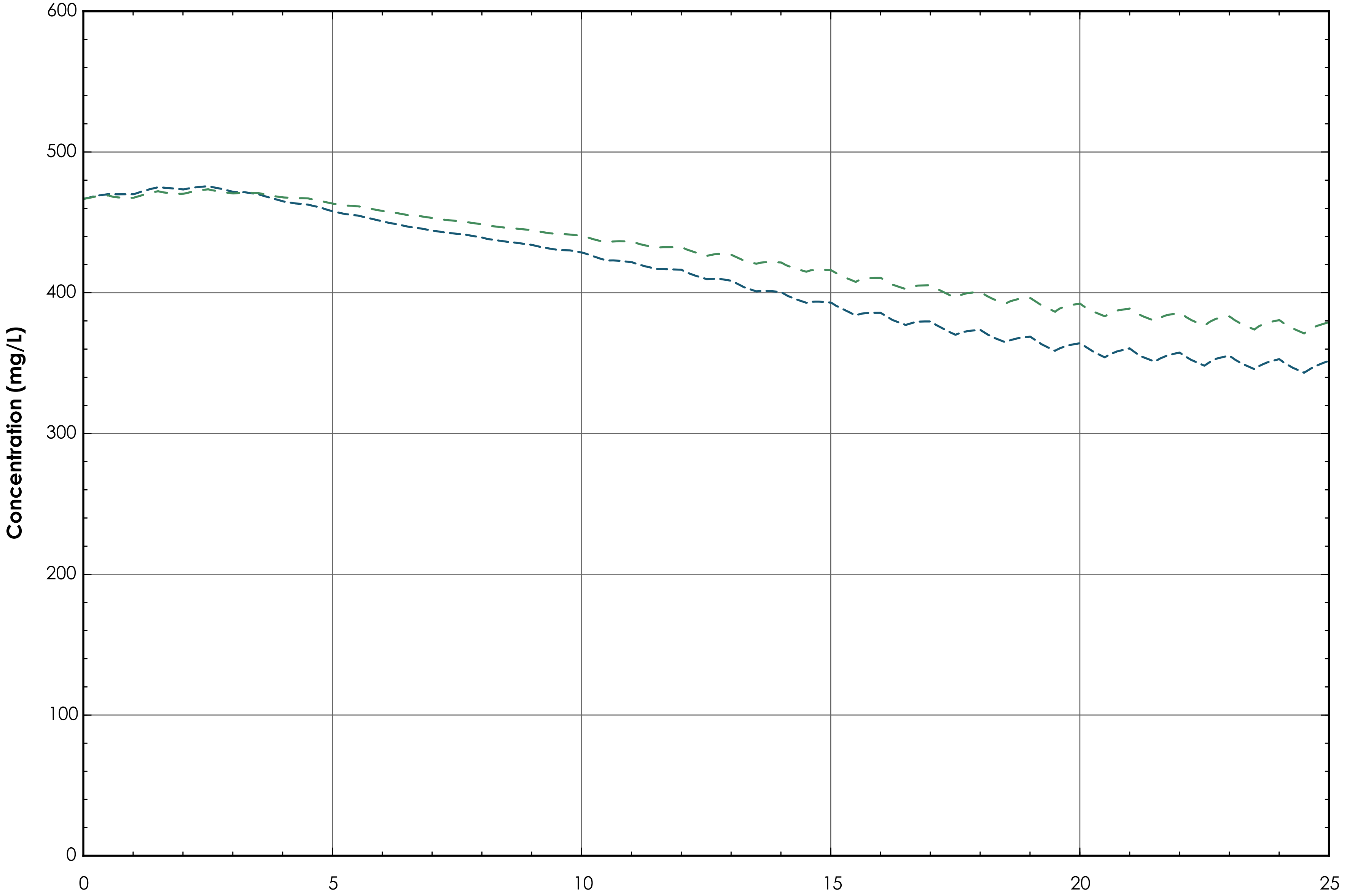
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 8 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well COL 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



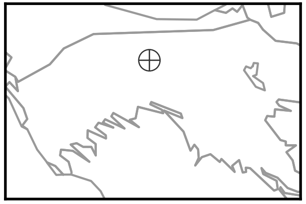
Year

-- Baseline Concentration

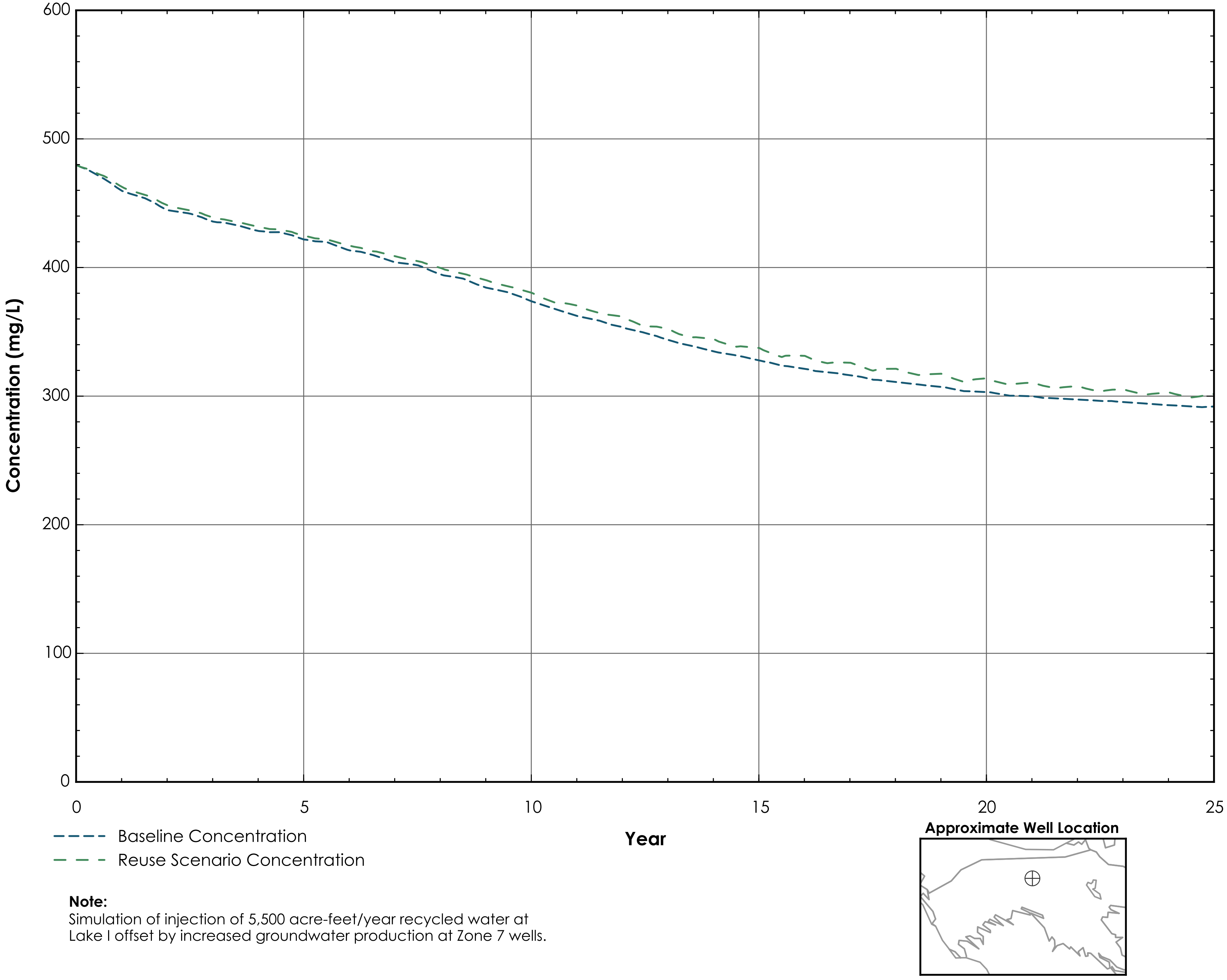
-- Reuse Scenario Concentration

Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

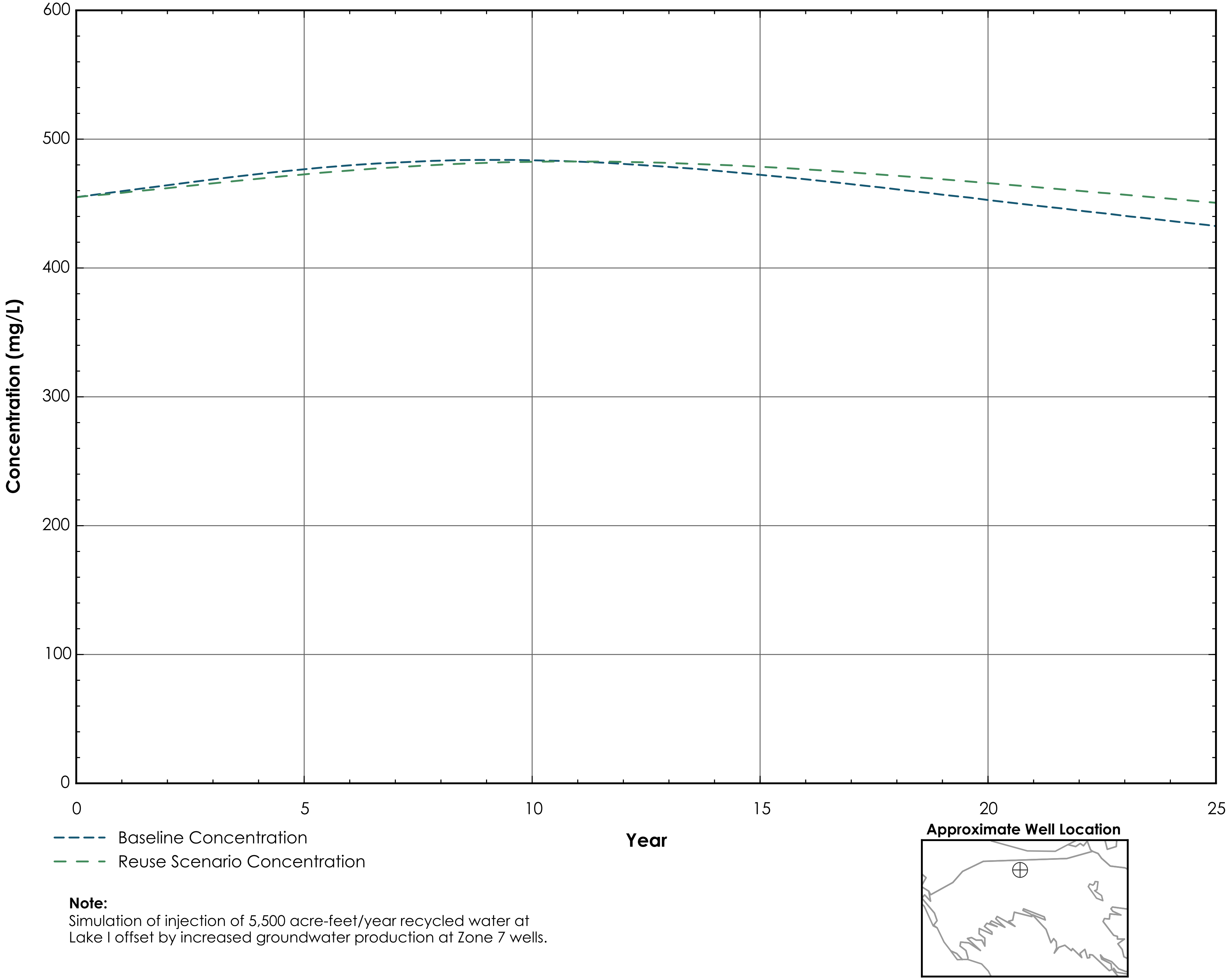


Well COL 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



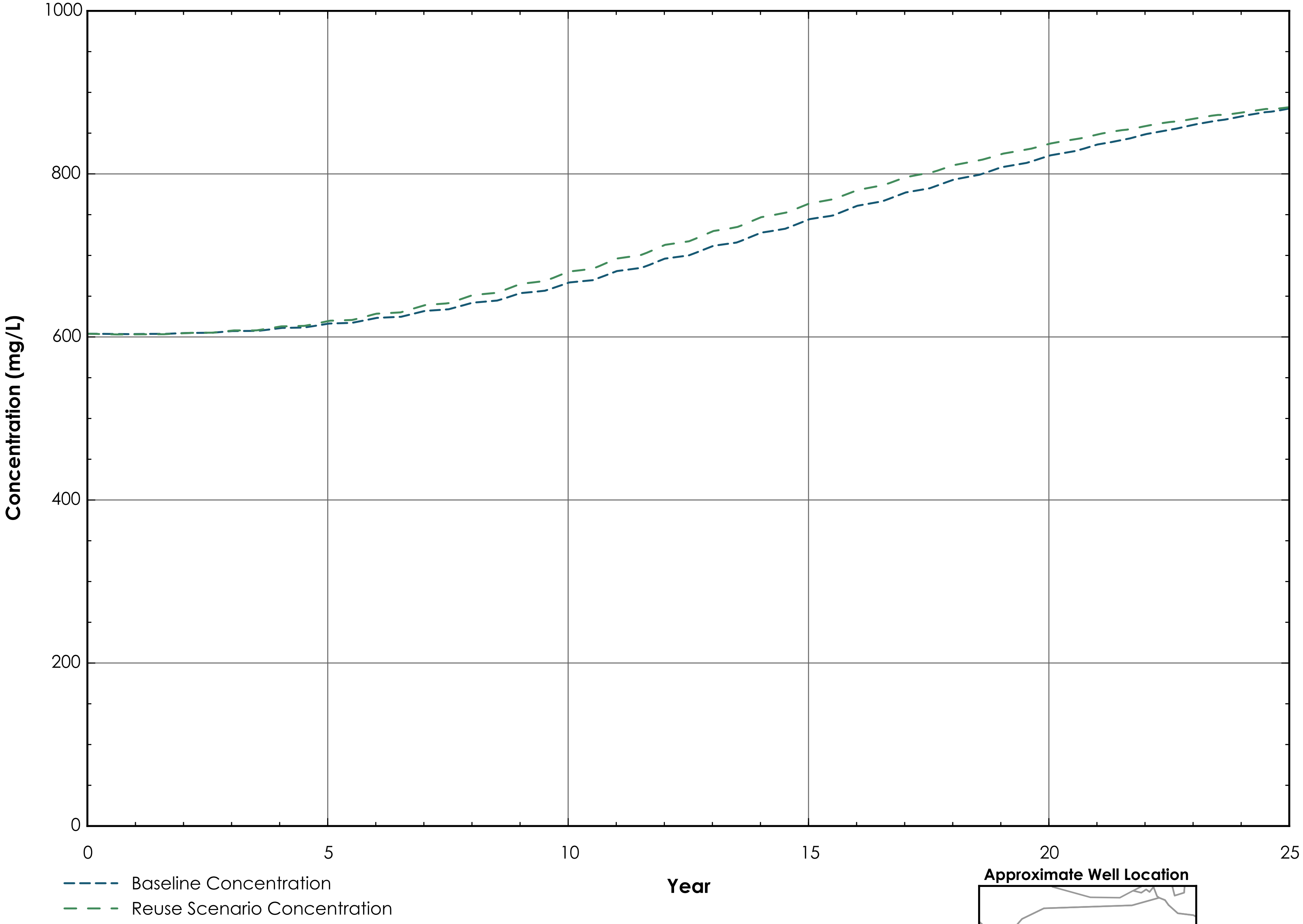
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well COL 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

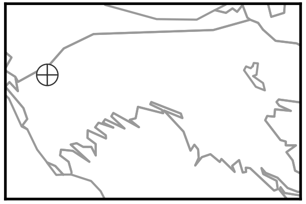


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well HOP 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

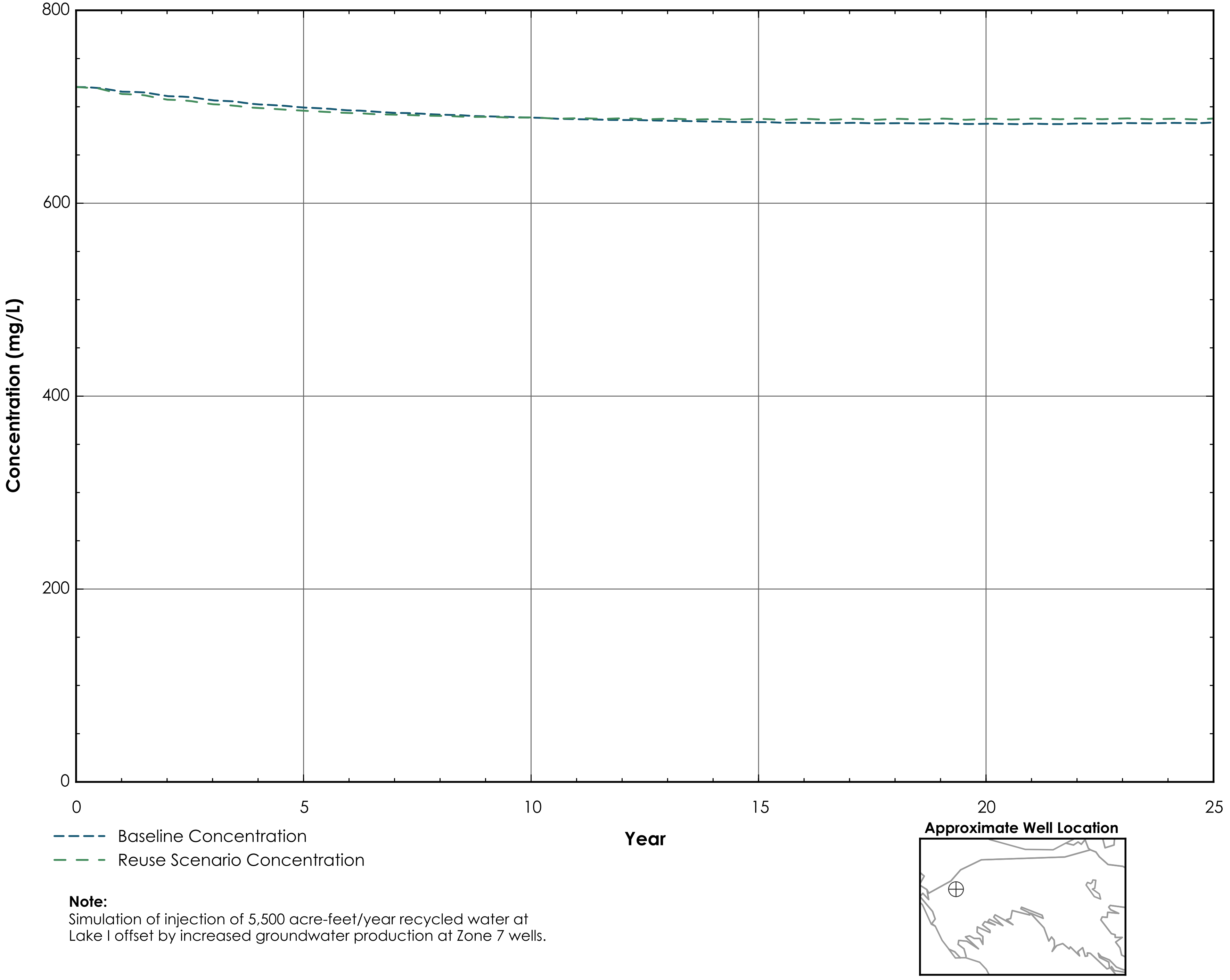


Approximate Well Location



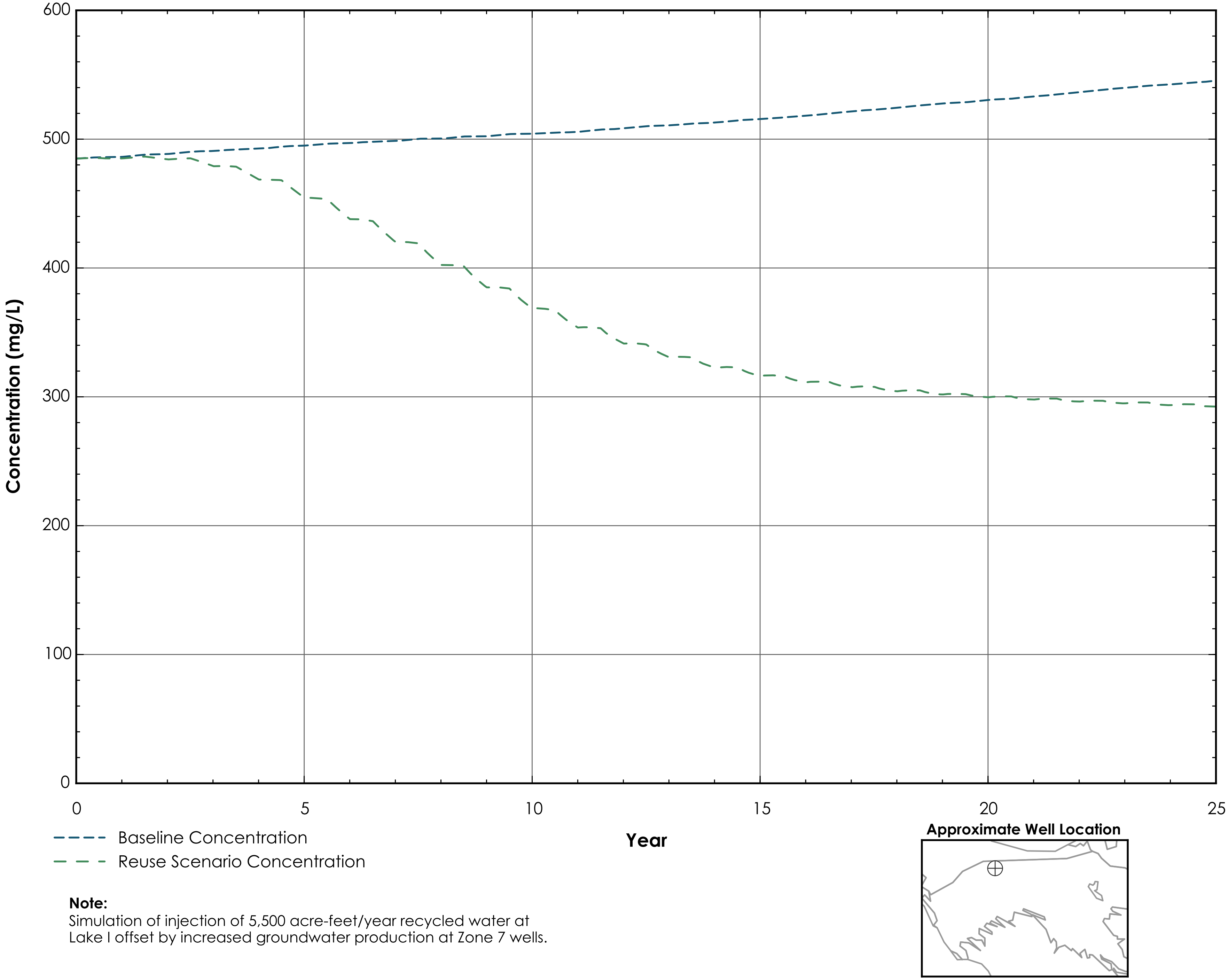
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well HOP 9 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



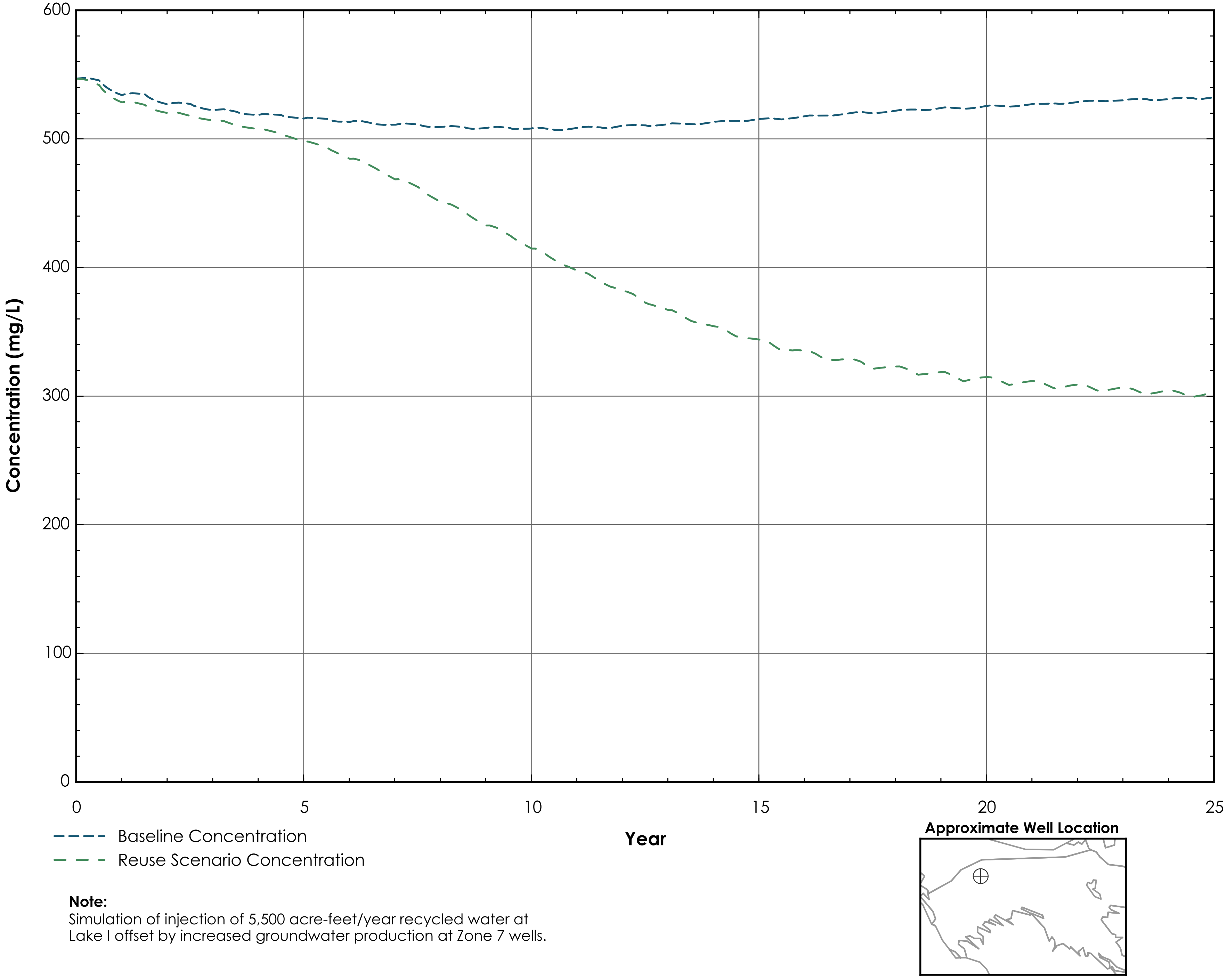
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well STONERIDGE 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



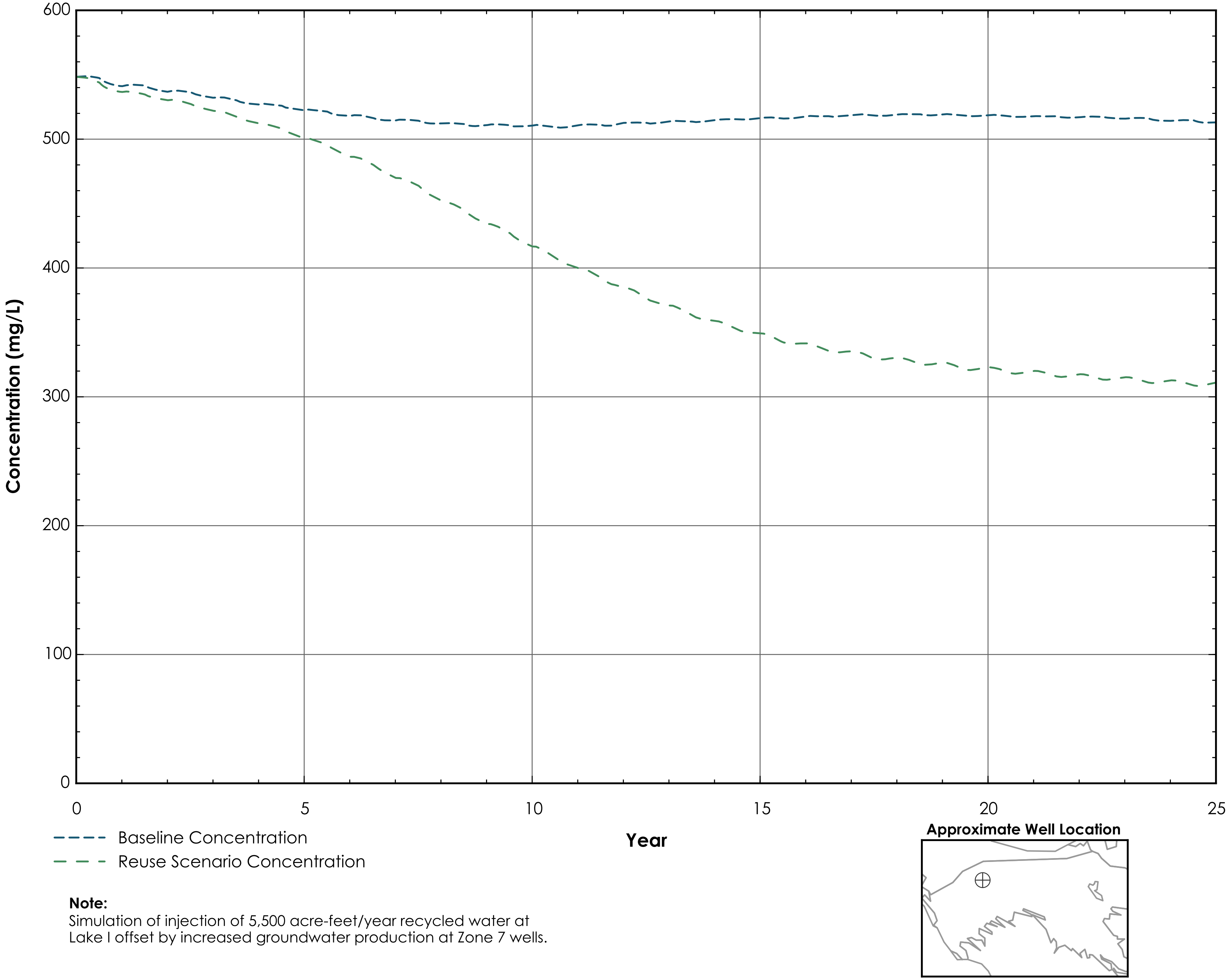
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



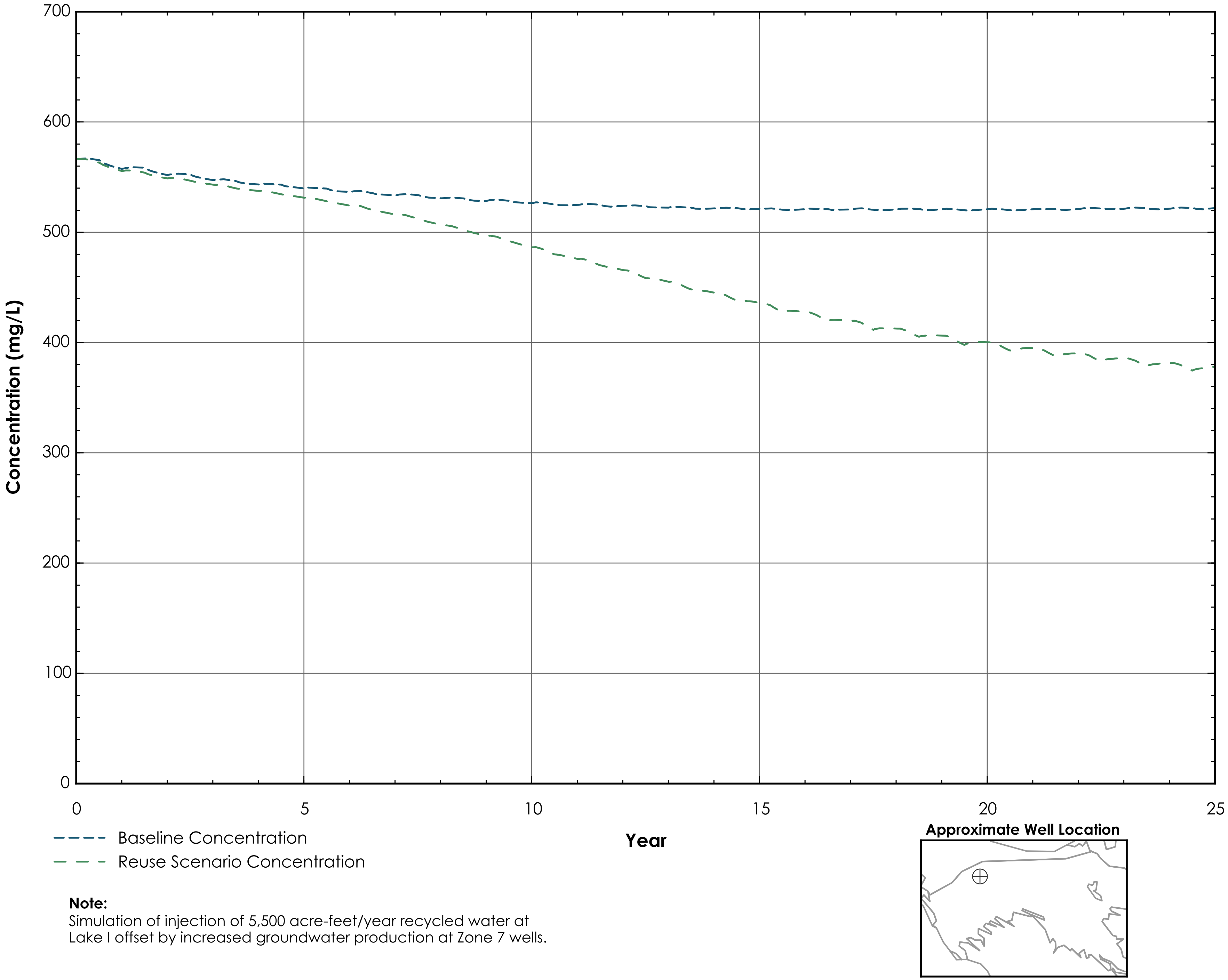
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



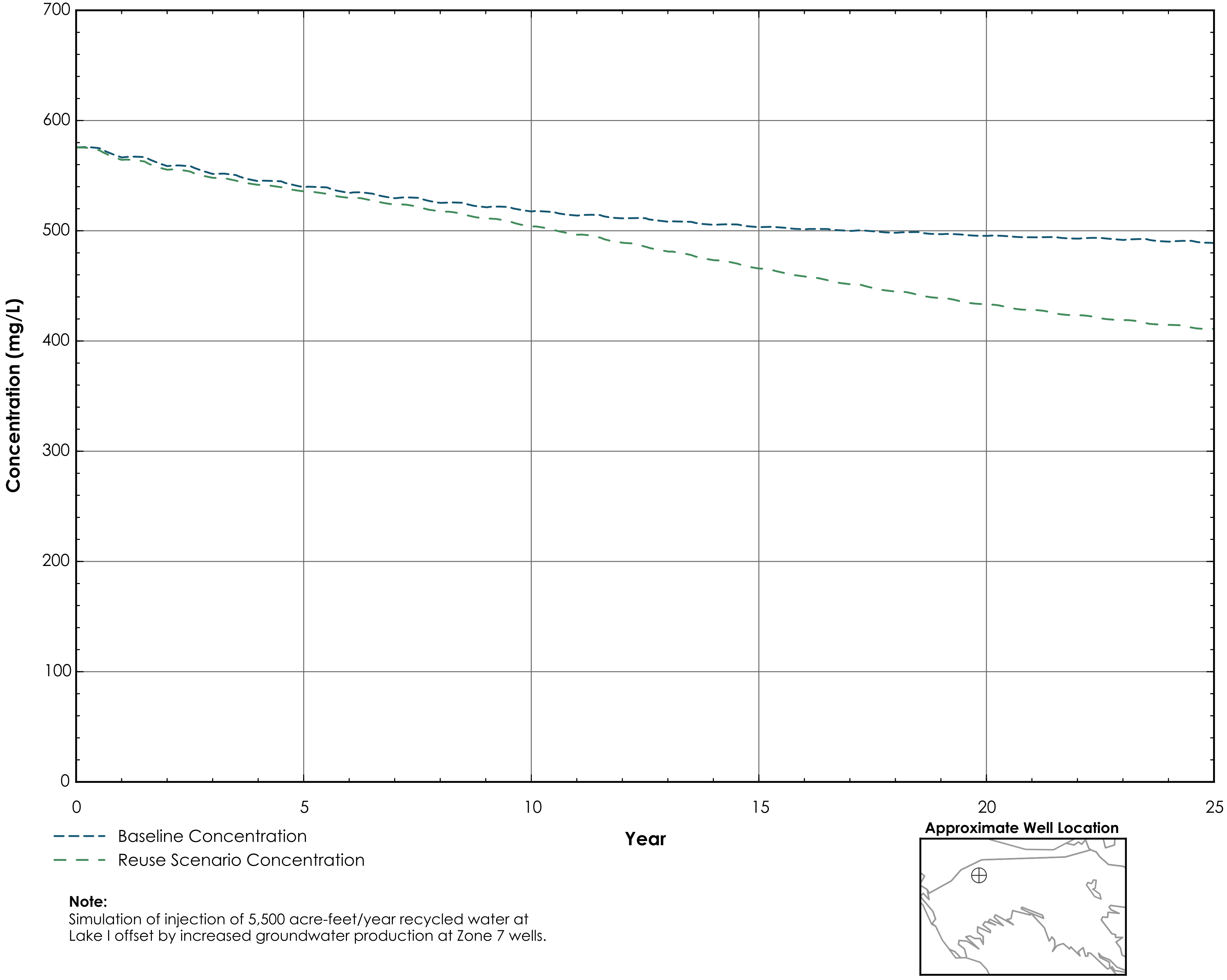
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 3 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



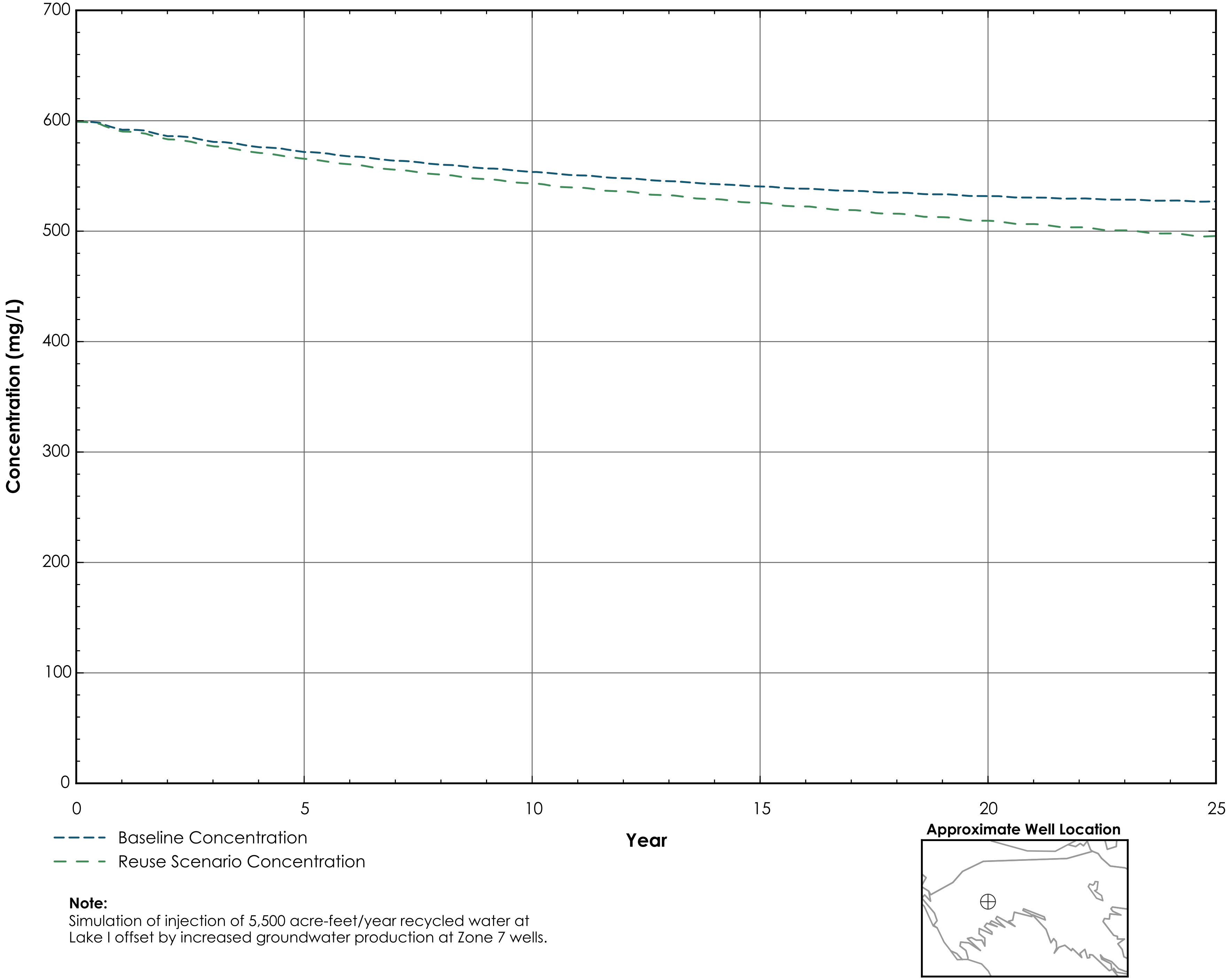
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 4 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



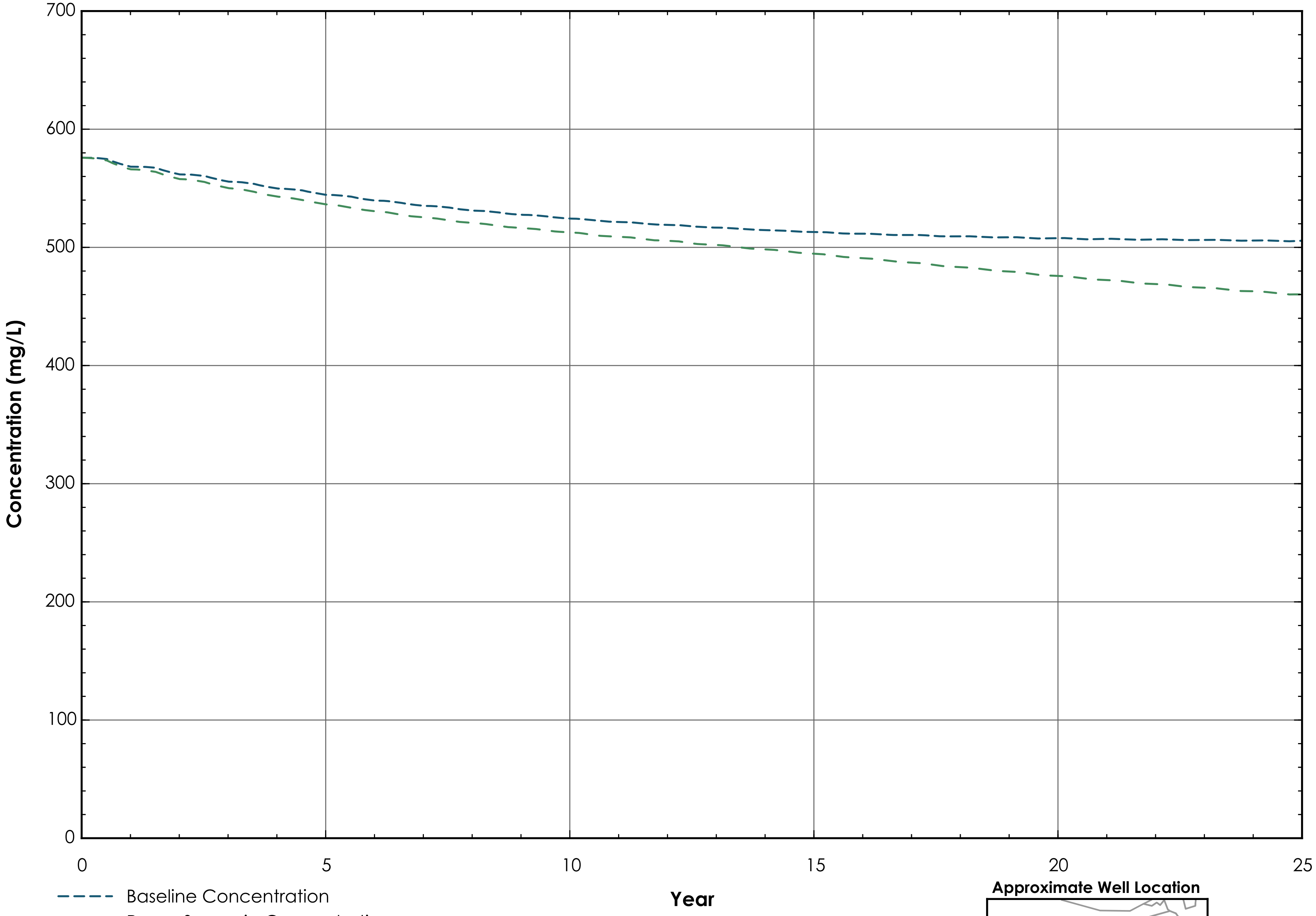
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

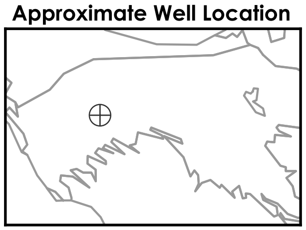


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

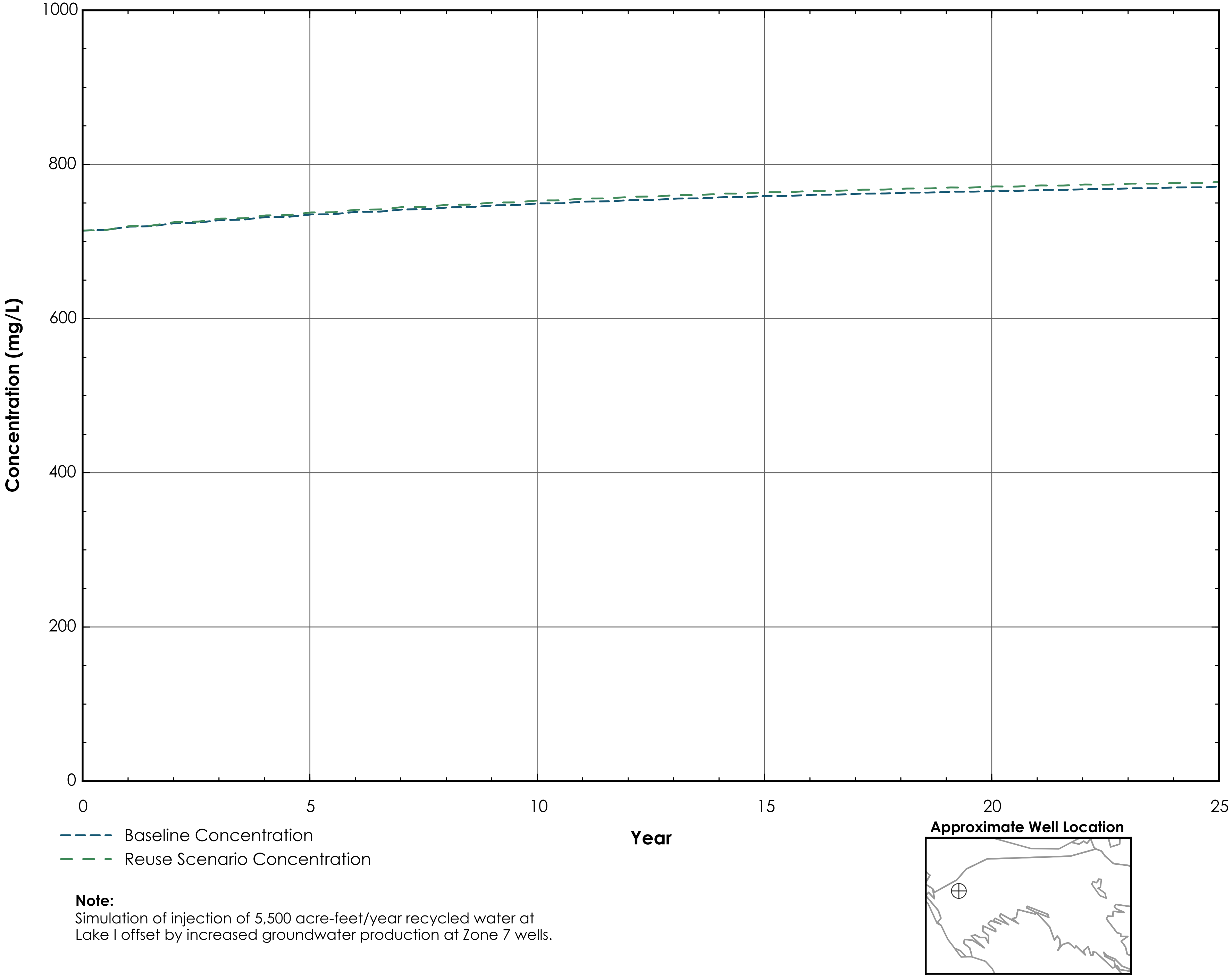
Well PLEAS 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

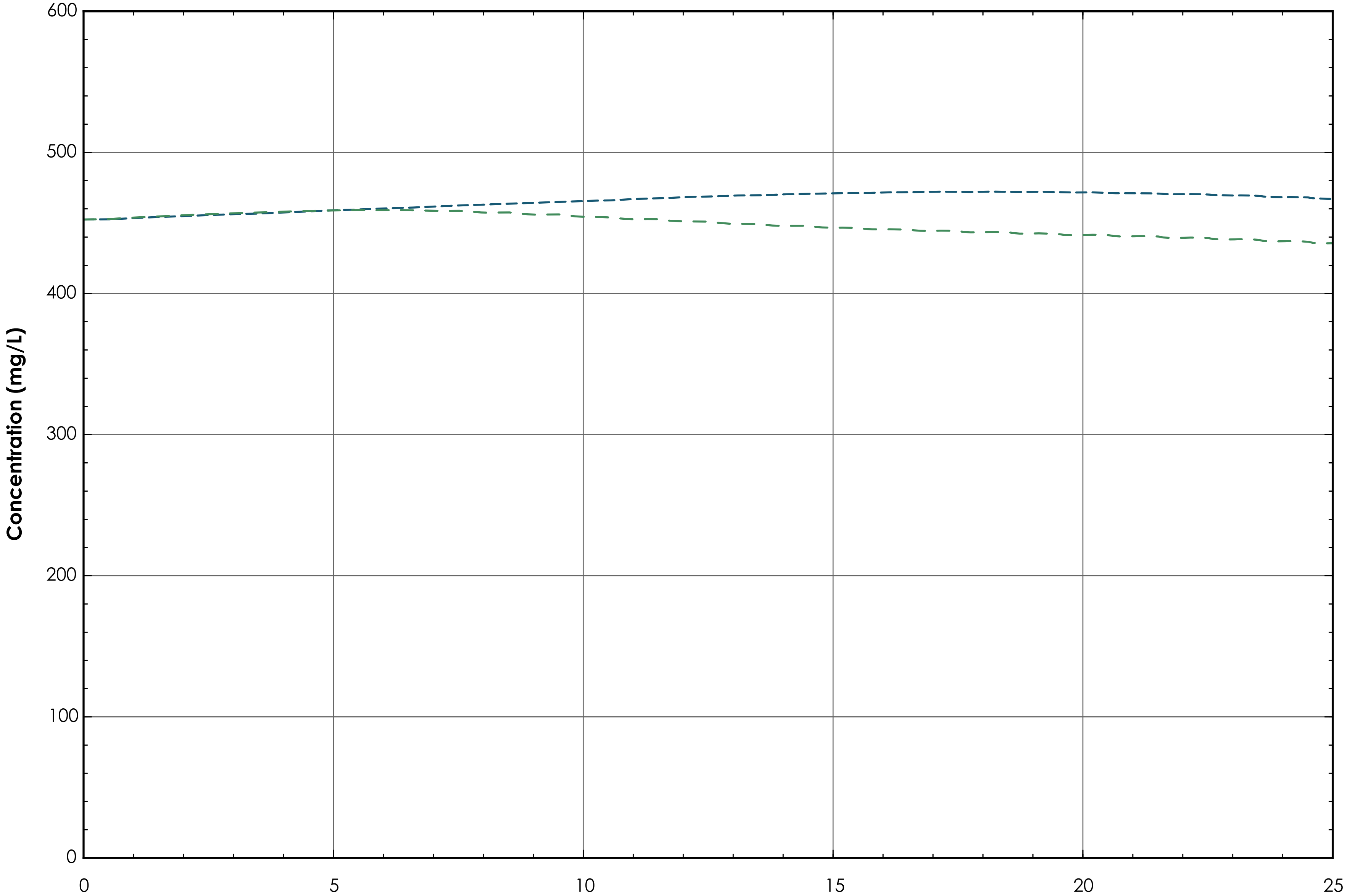


Well PLEAS 7 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



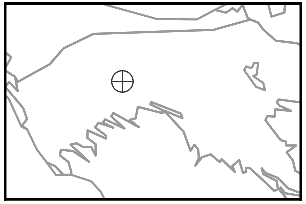
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 8 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

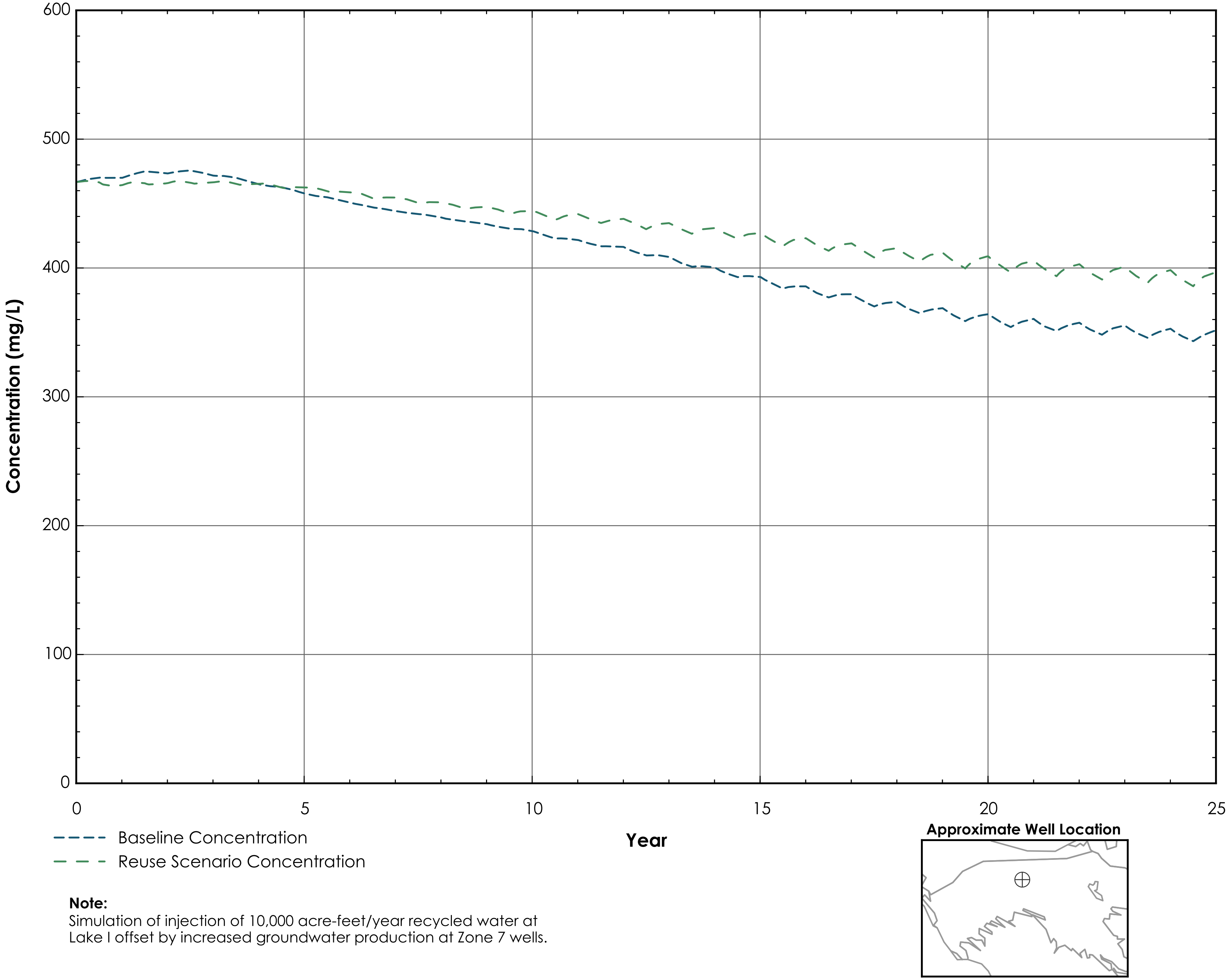


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

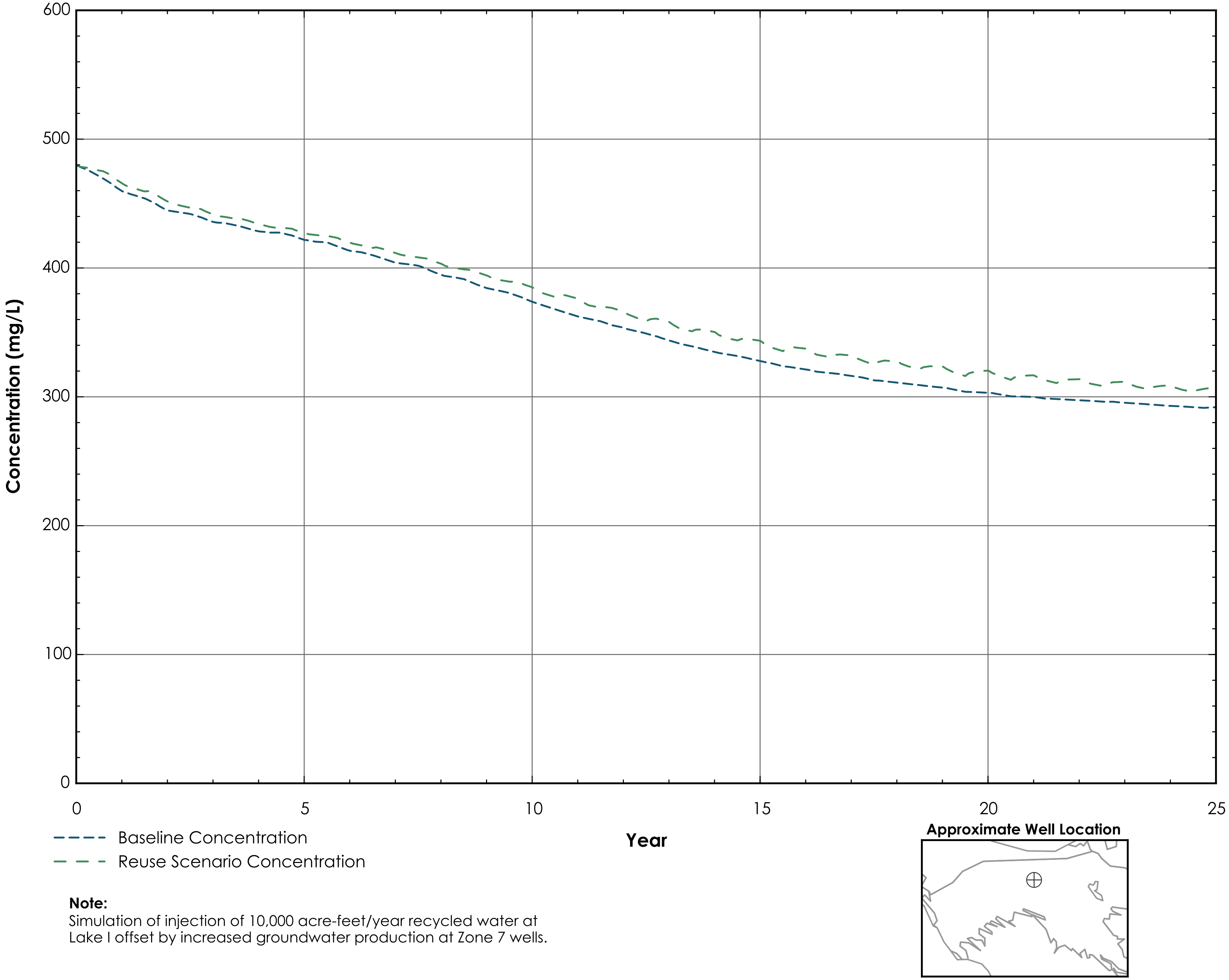


Well COL 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



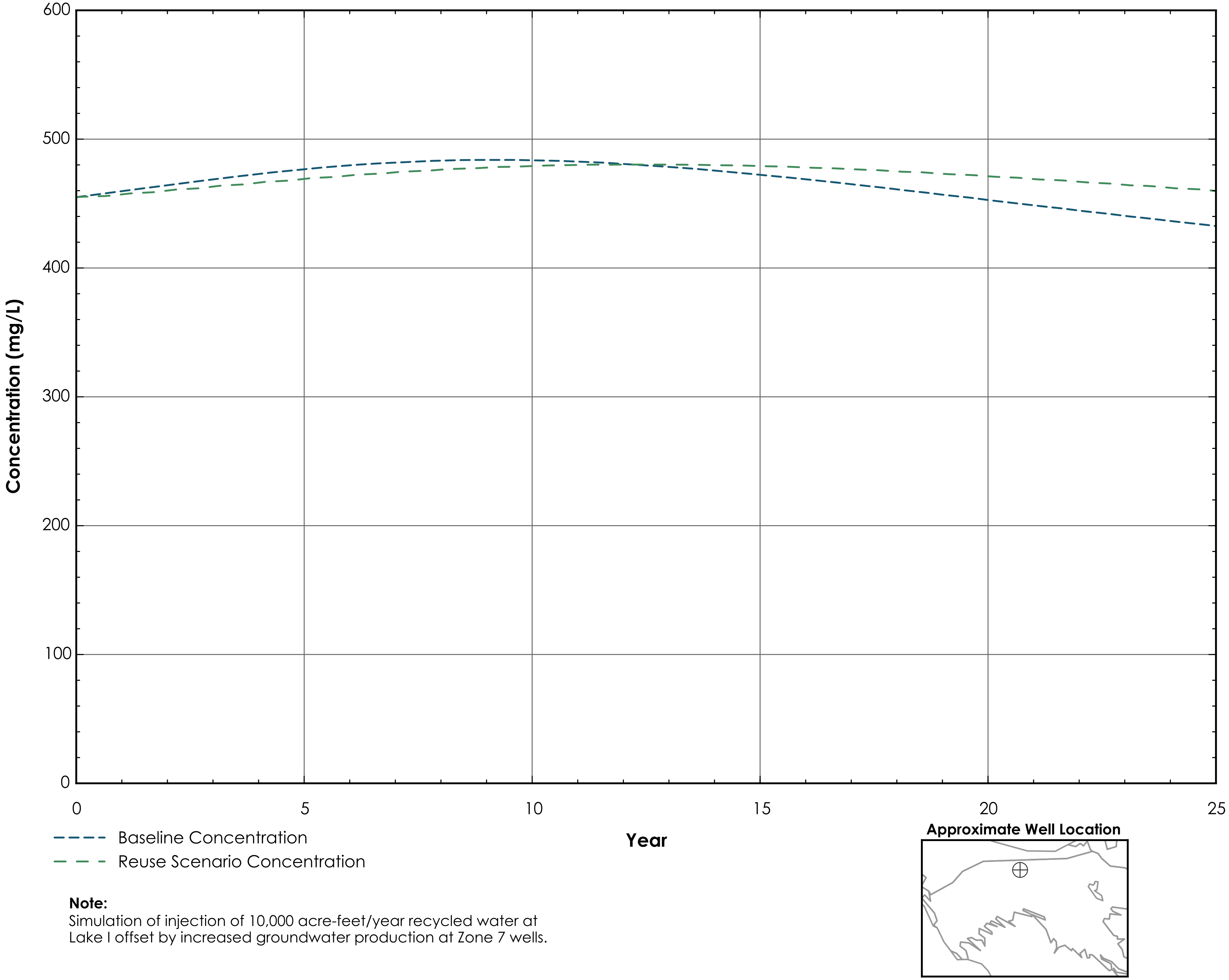
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well COL 2 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



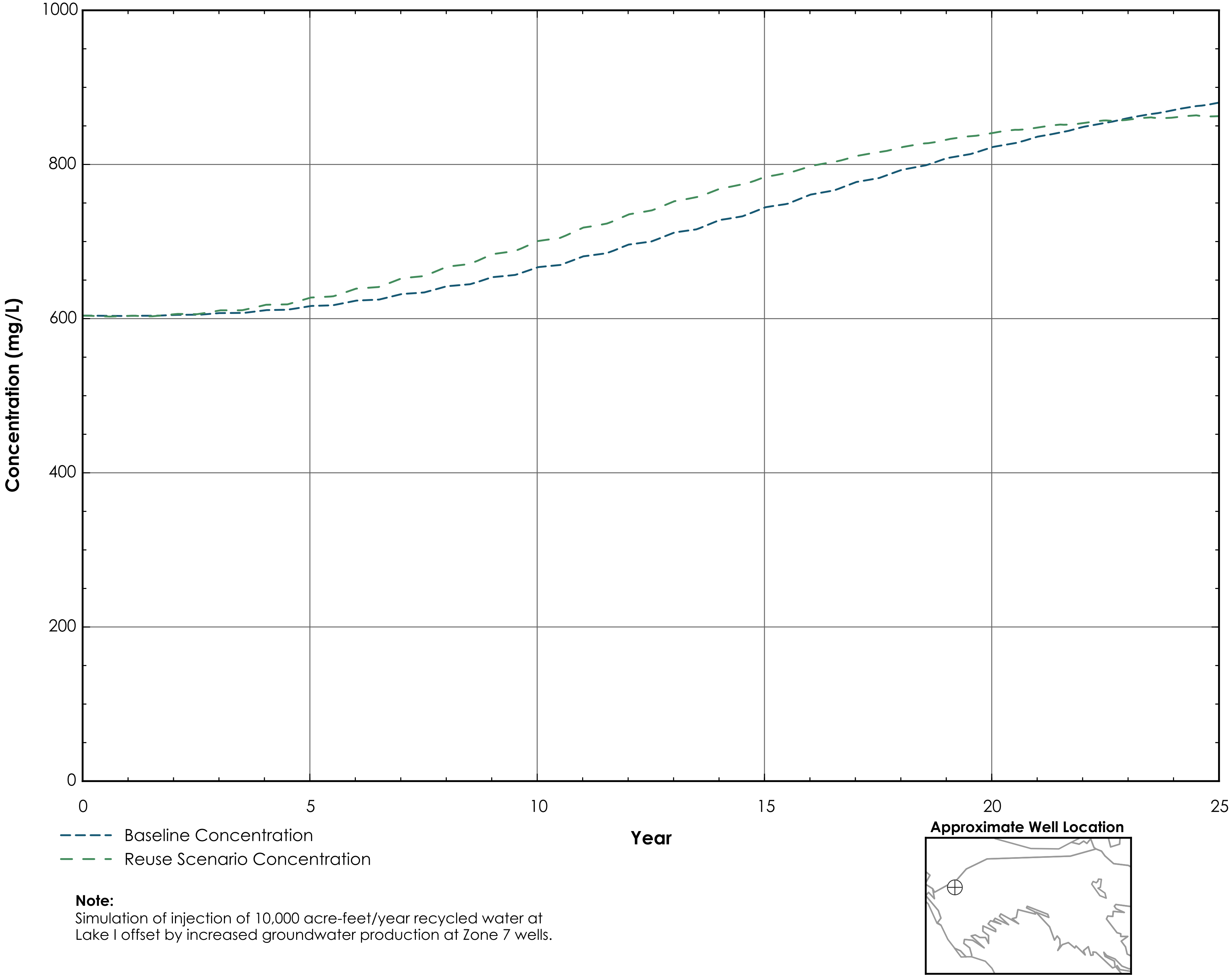
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well COL 5 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



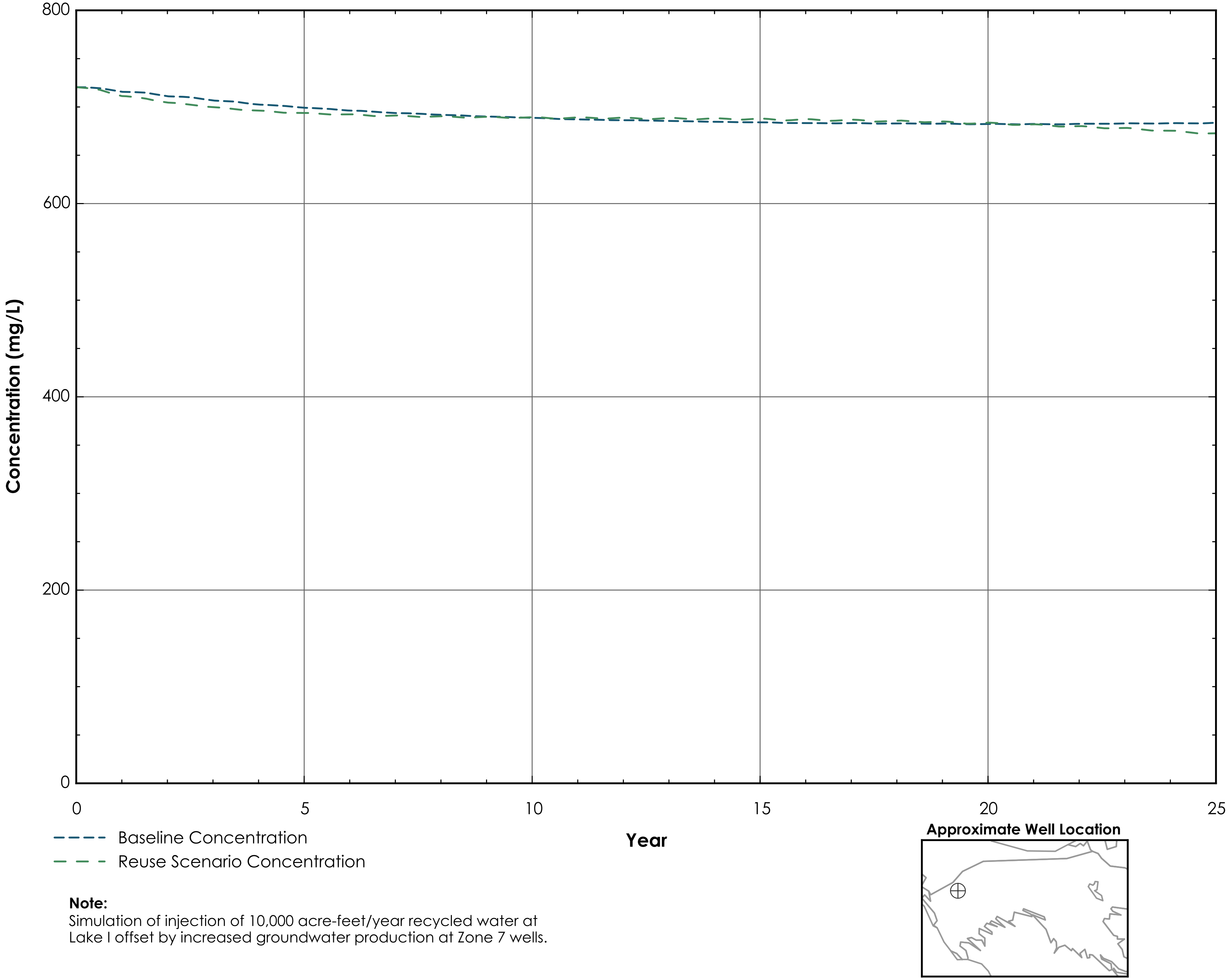
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well HOP 6 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



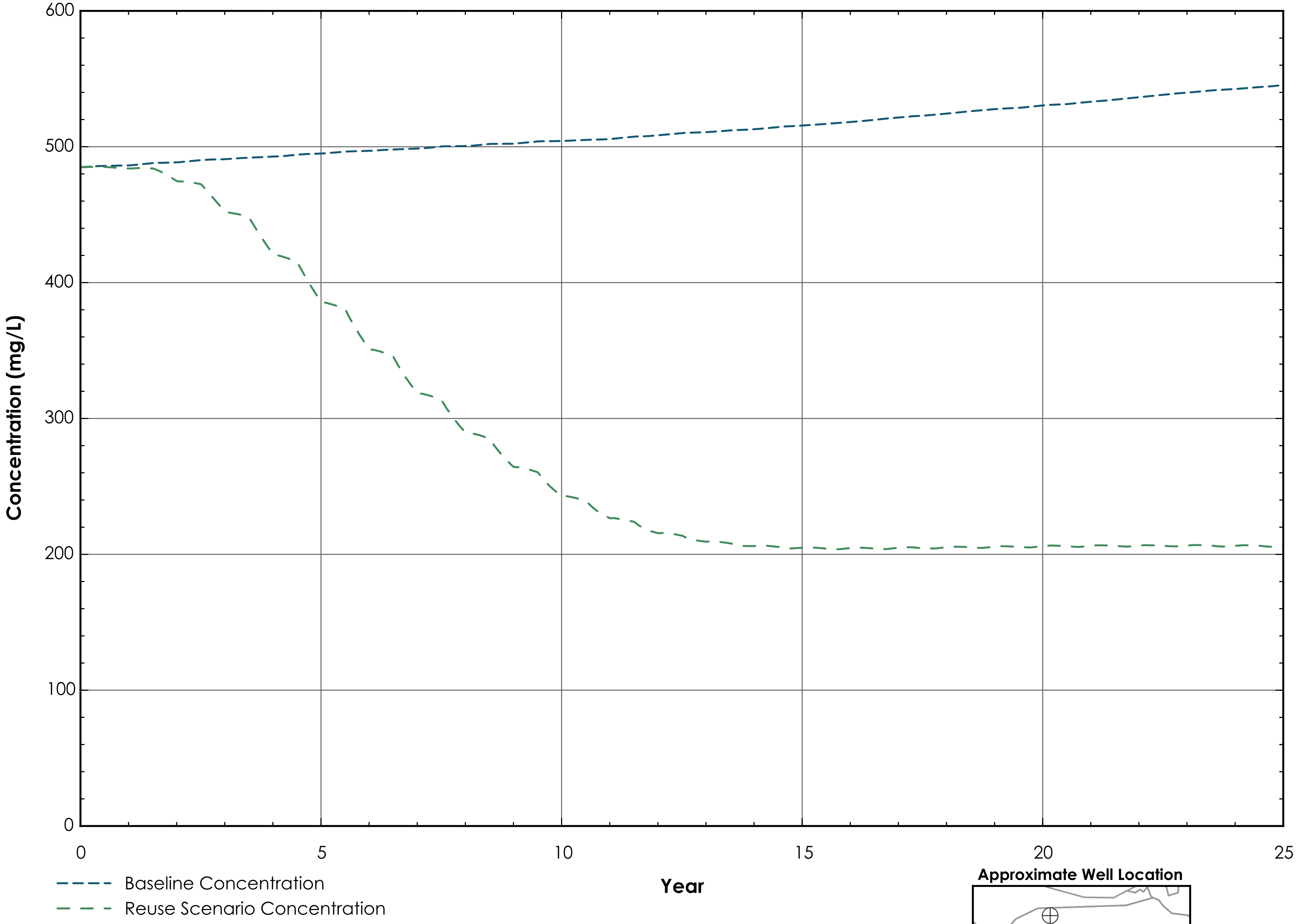
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well HOP 9 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



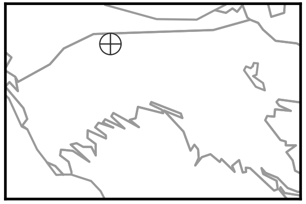
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well STONERIDGE 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

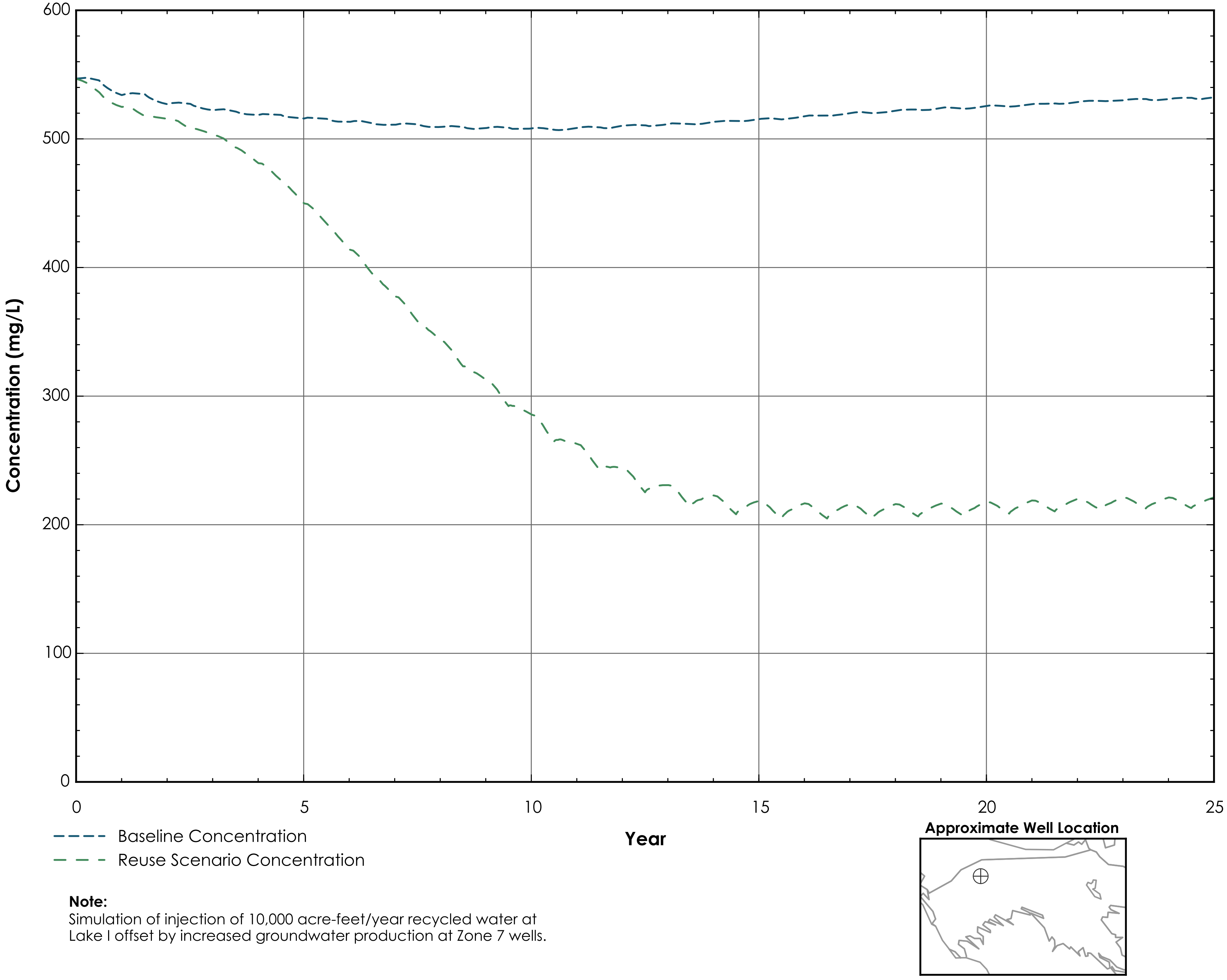


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

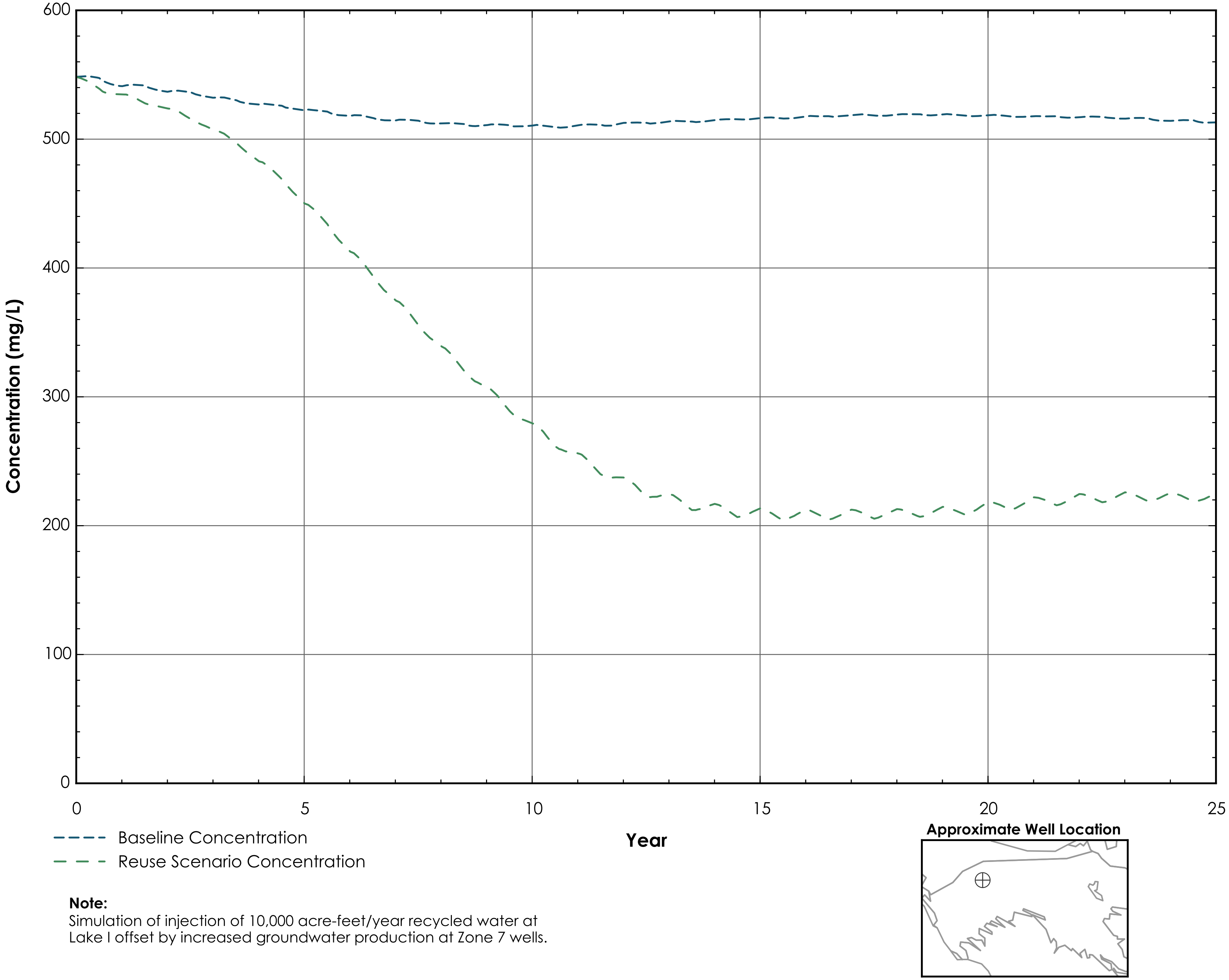


Well MOCHO 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



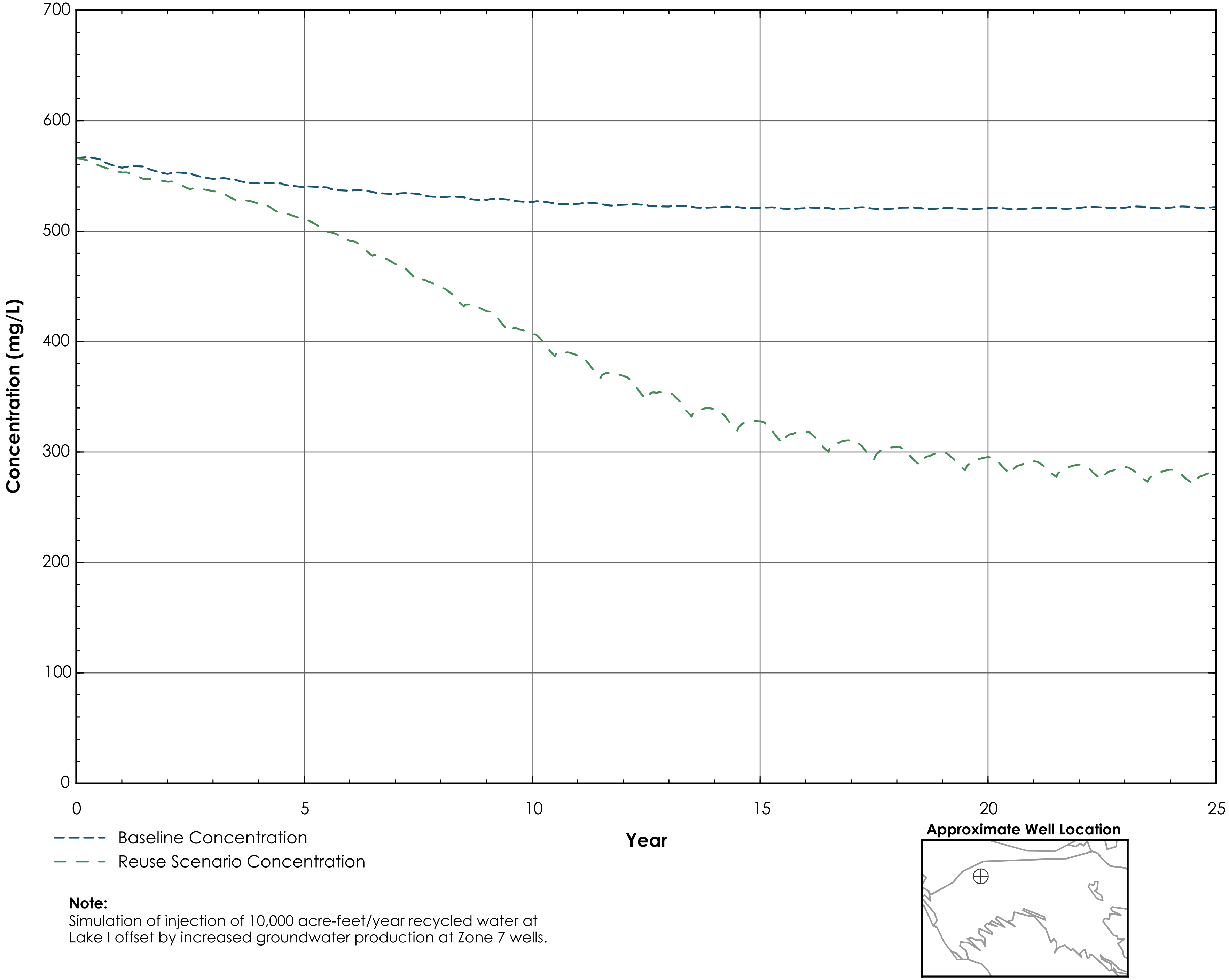
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



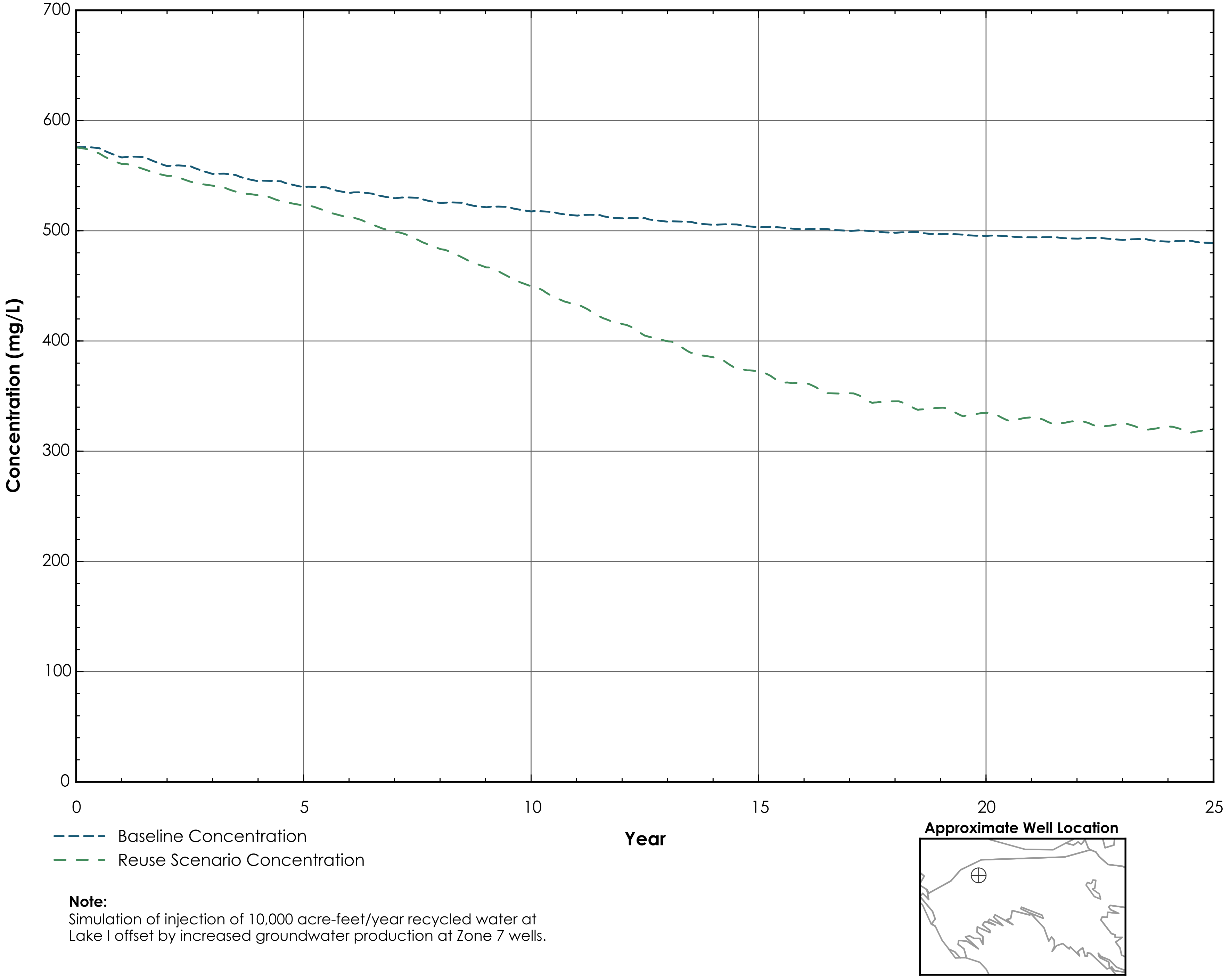
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 3 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



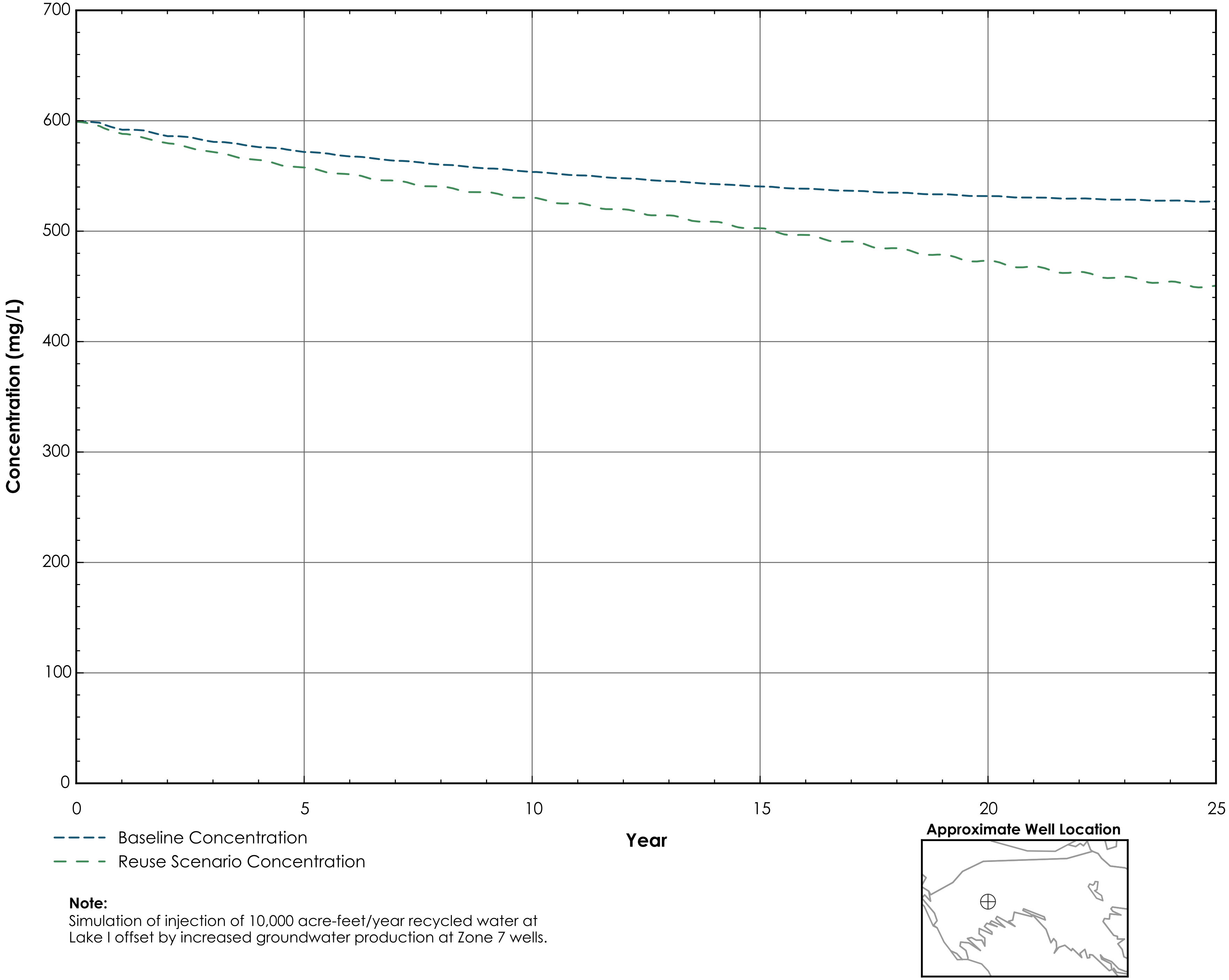
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 4 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



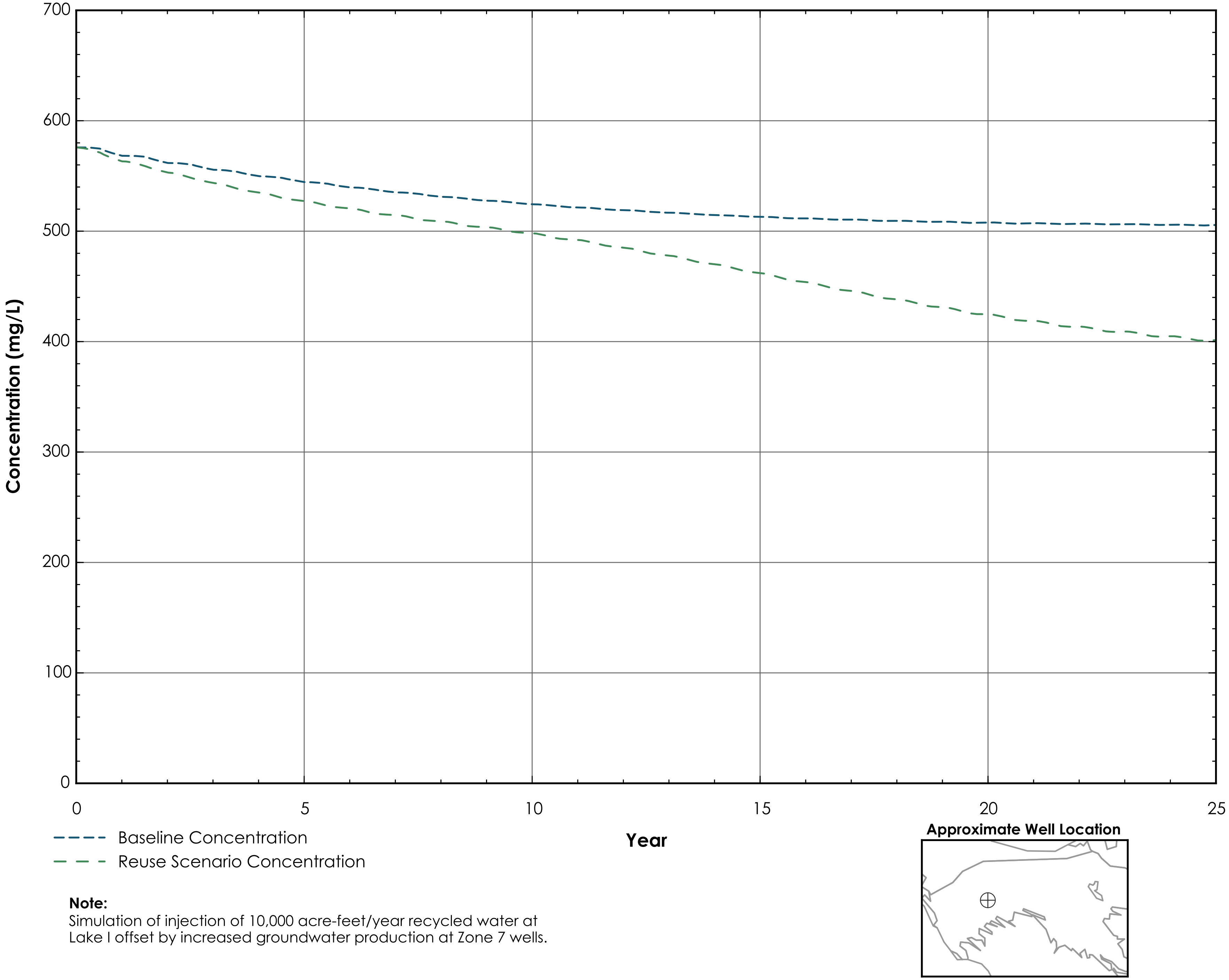
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 5 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



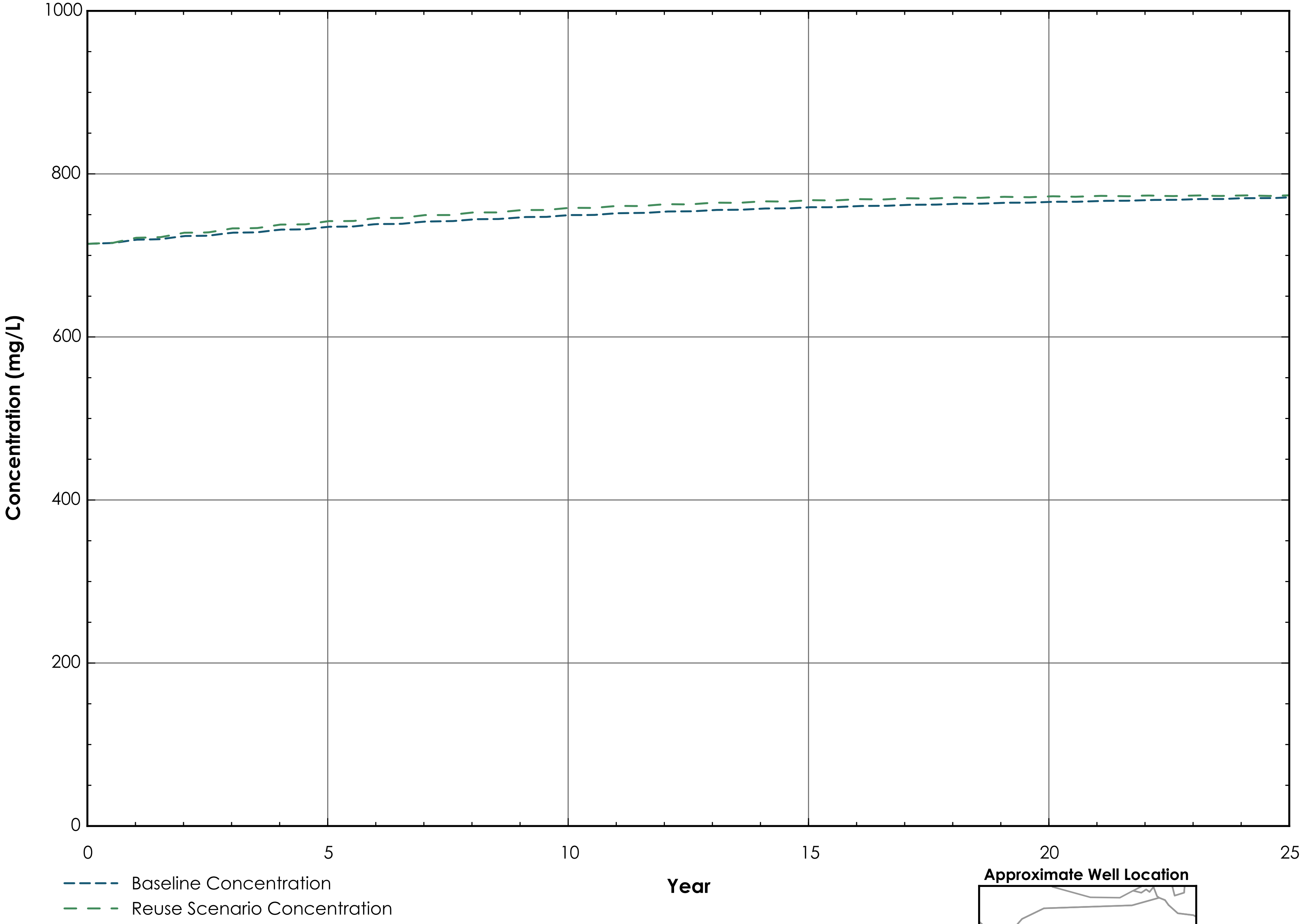
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 6 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



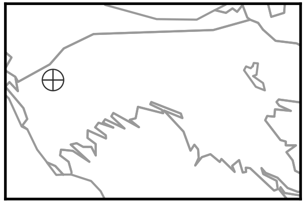
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 7 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

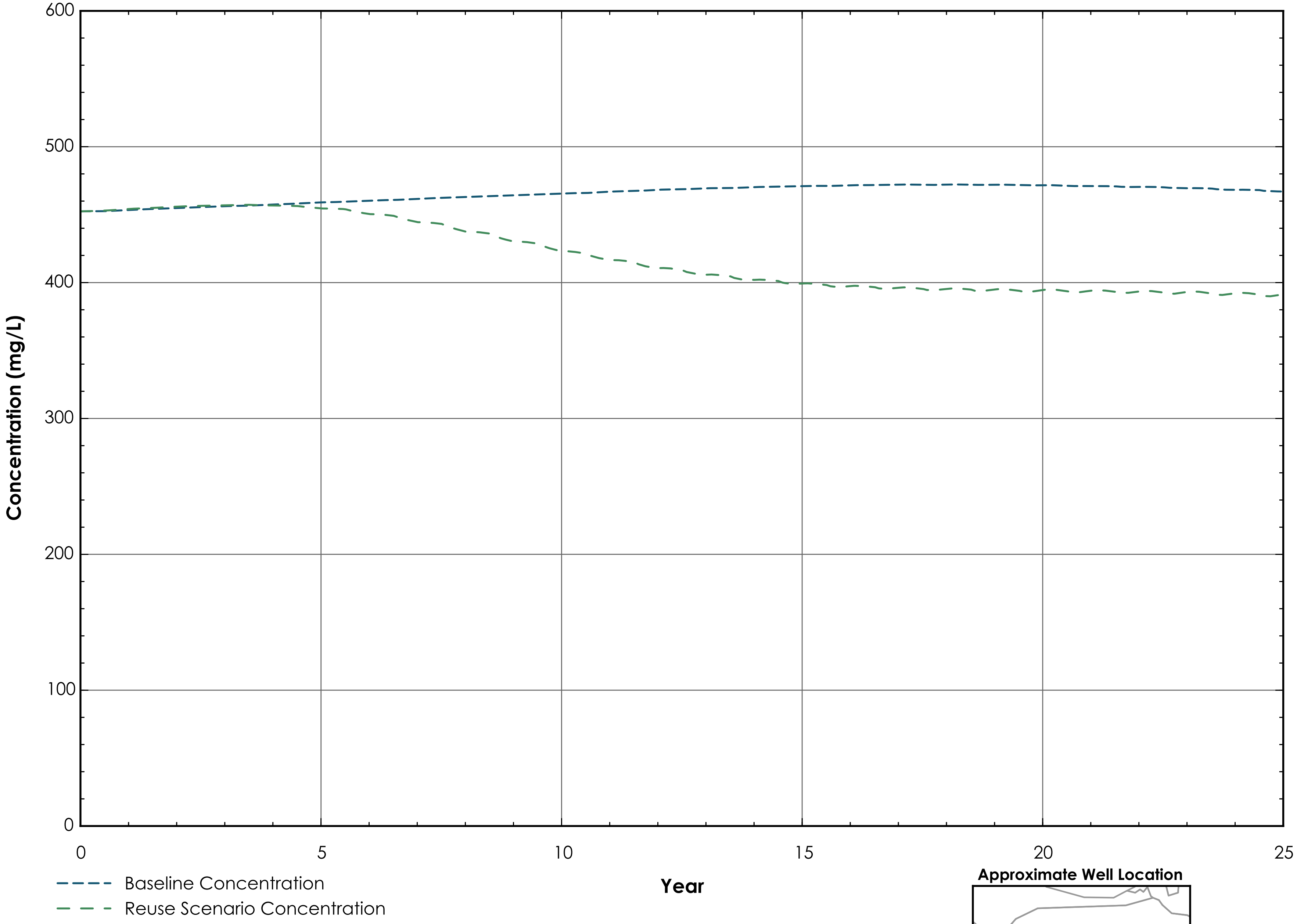


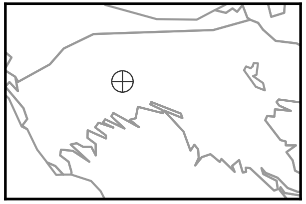
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location



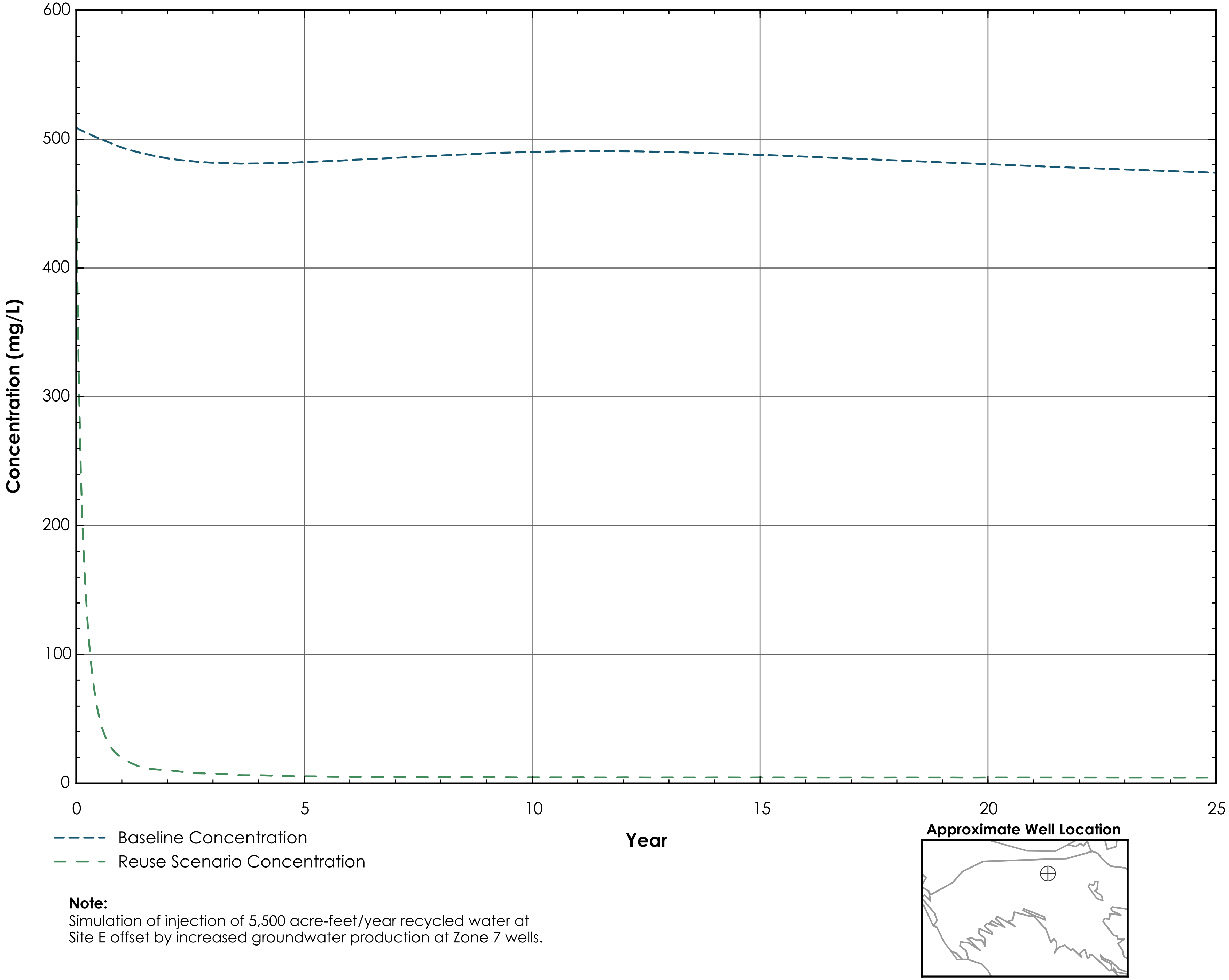
Well PLEAS 8 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I




Approximate Well Location

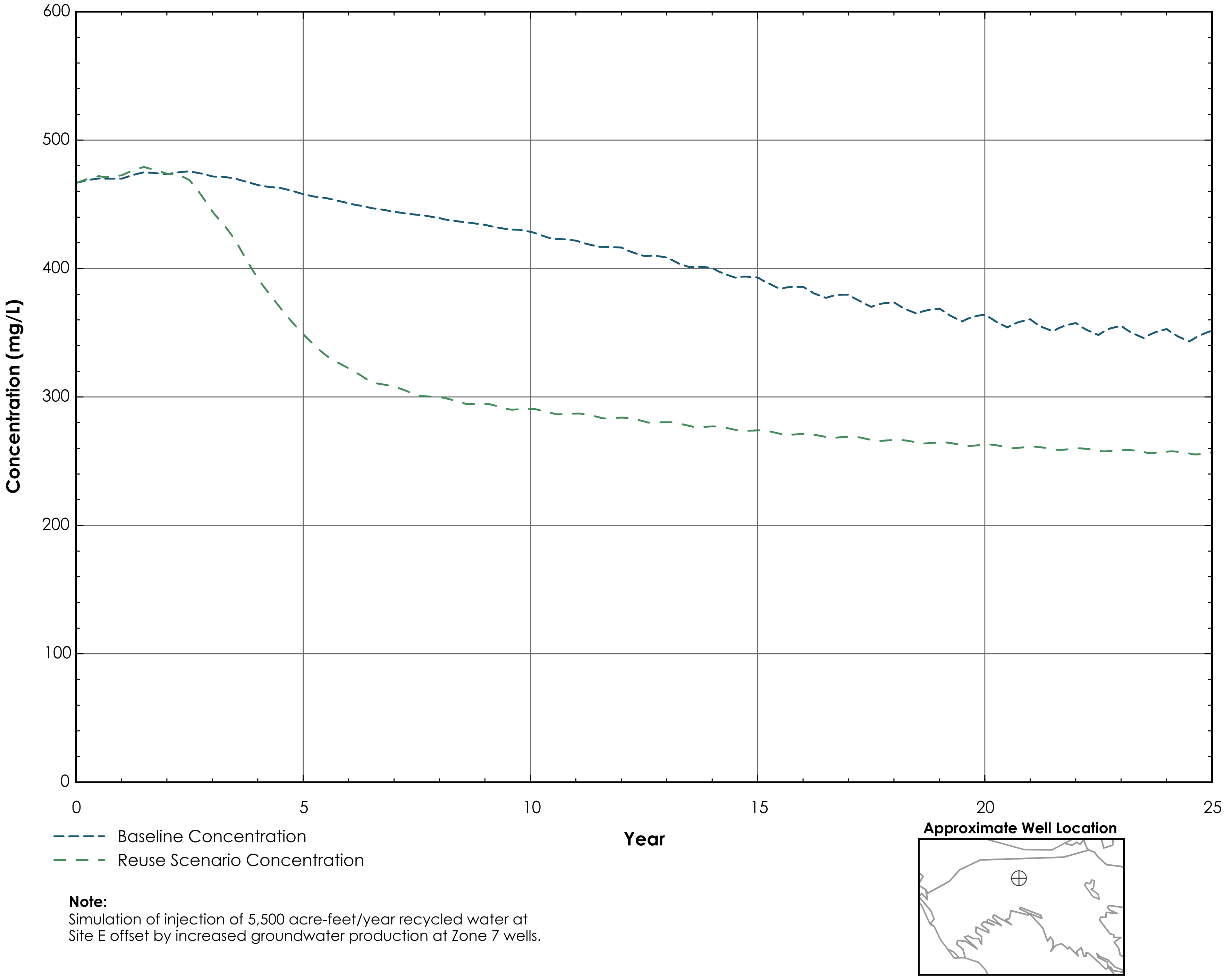
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well Inj E Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



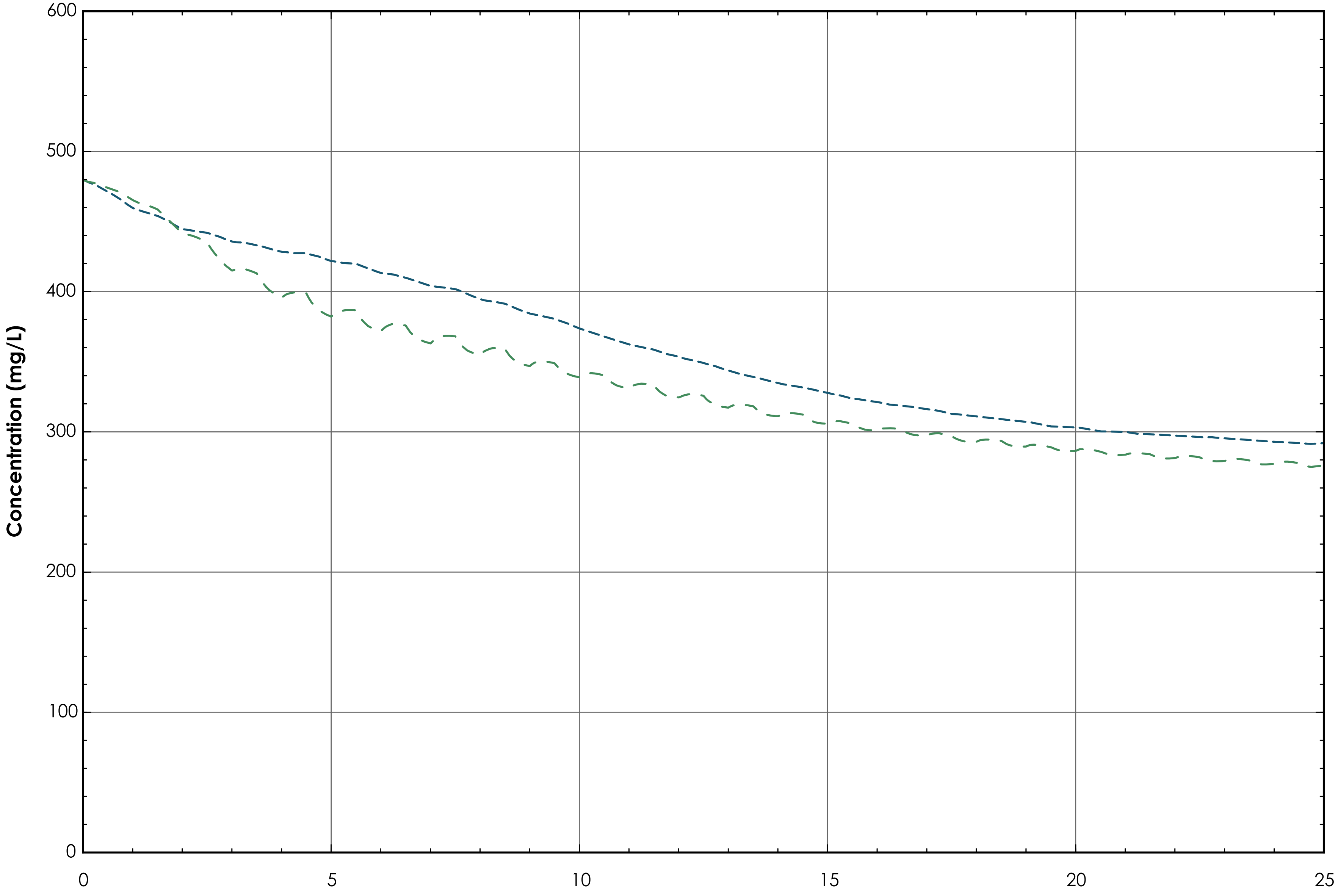
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well COL 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

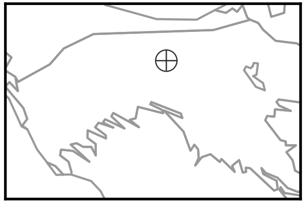


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well COL 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

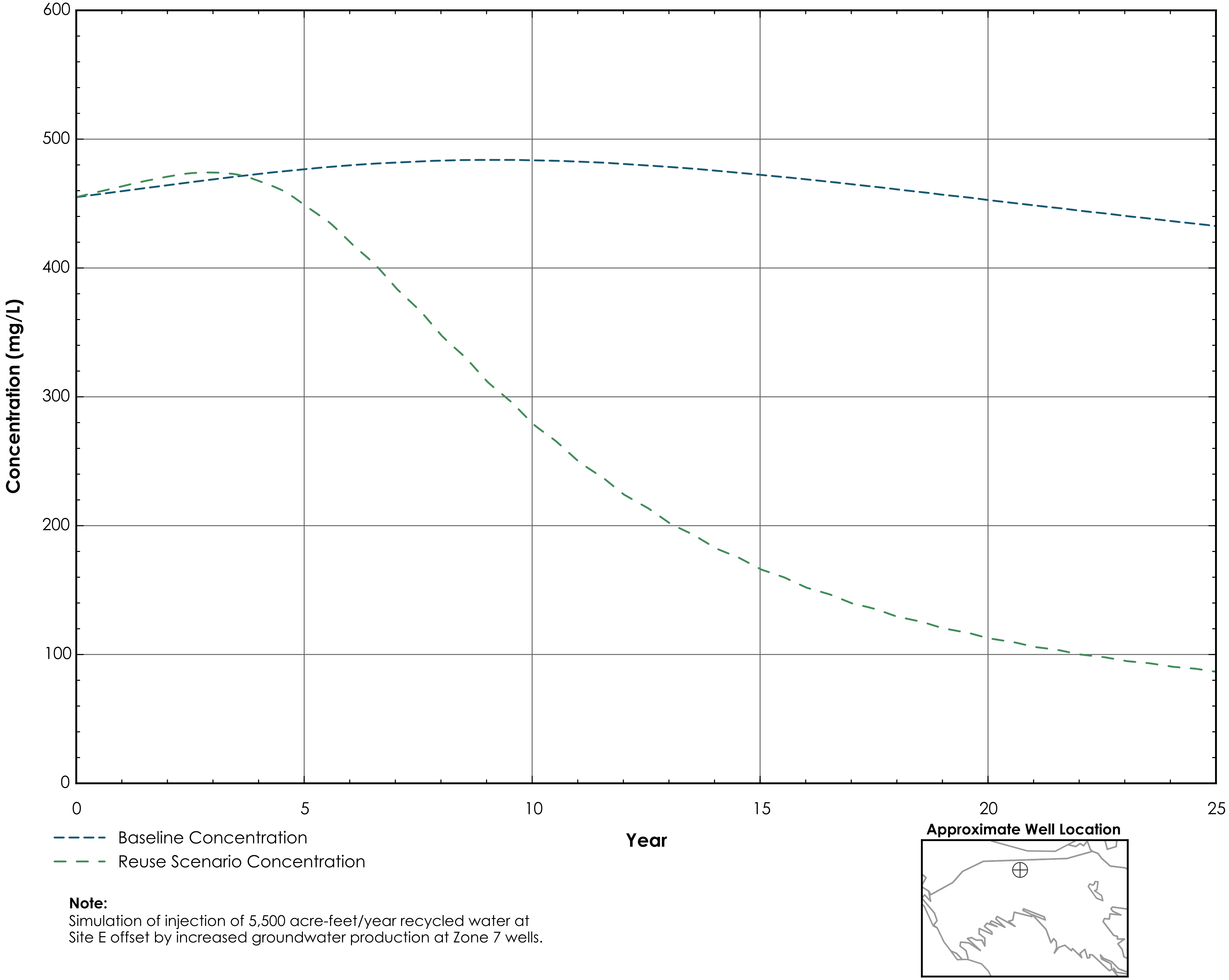


Approximate Well Location



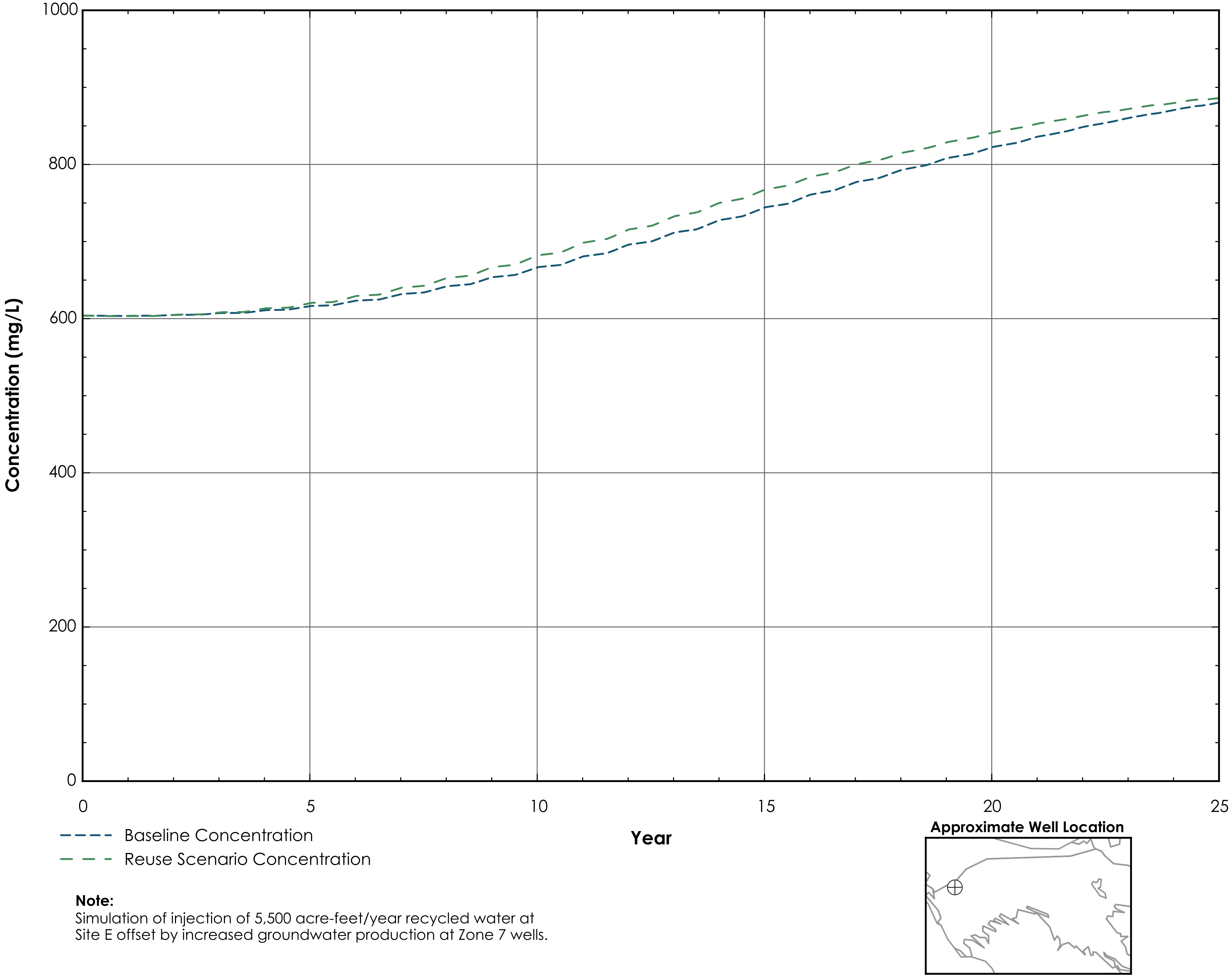
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well COL 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



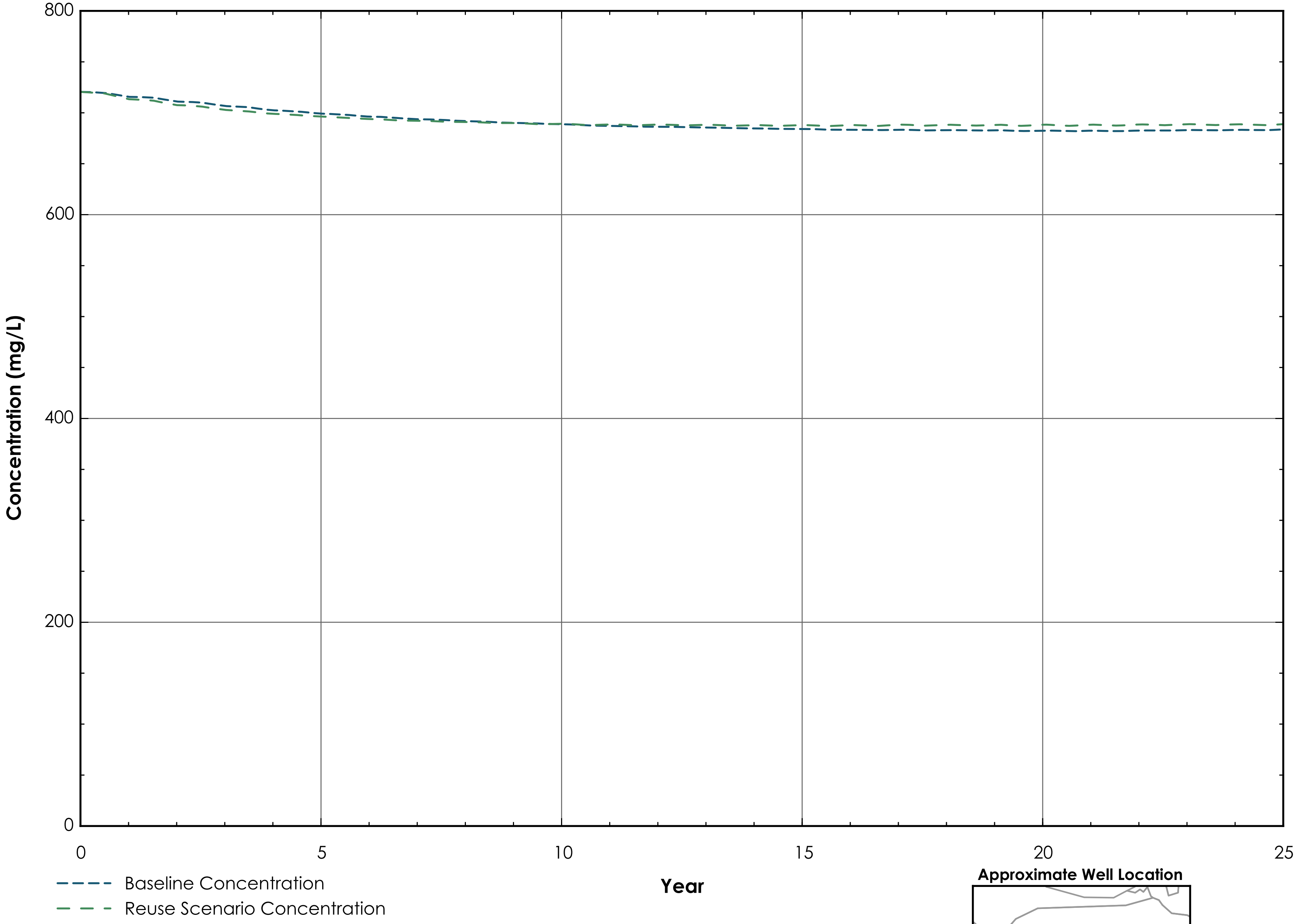
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well HOP 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



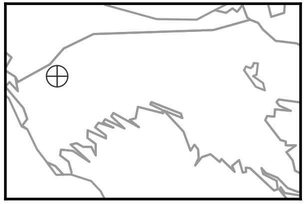
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well HOP 9 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

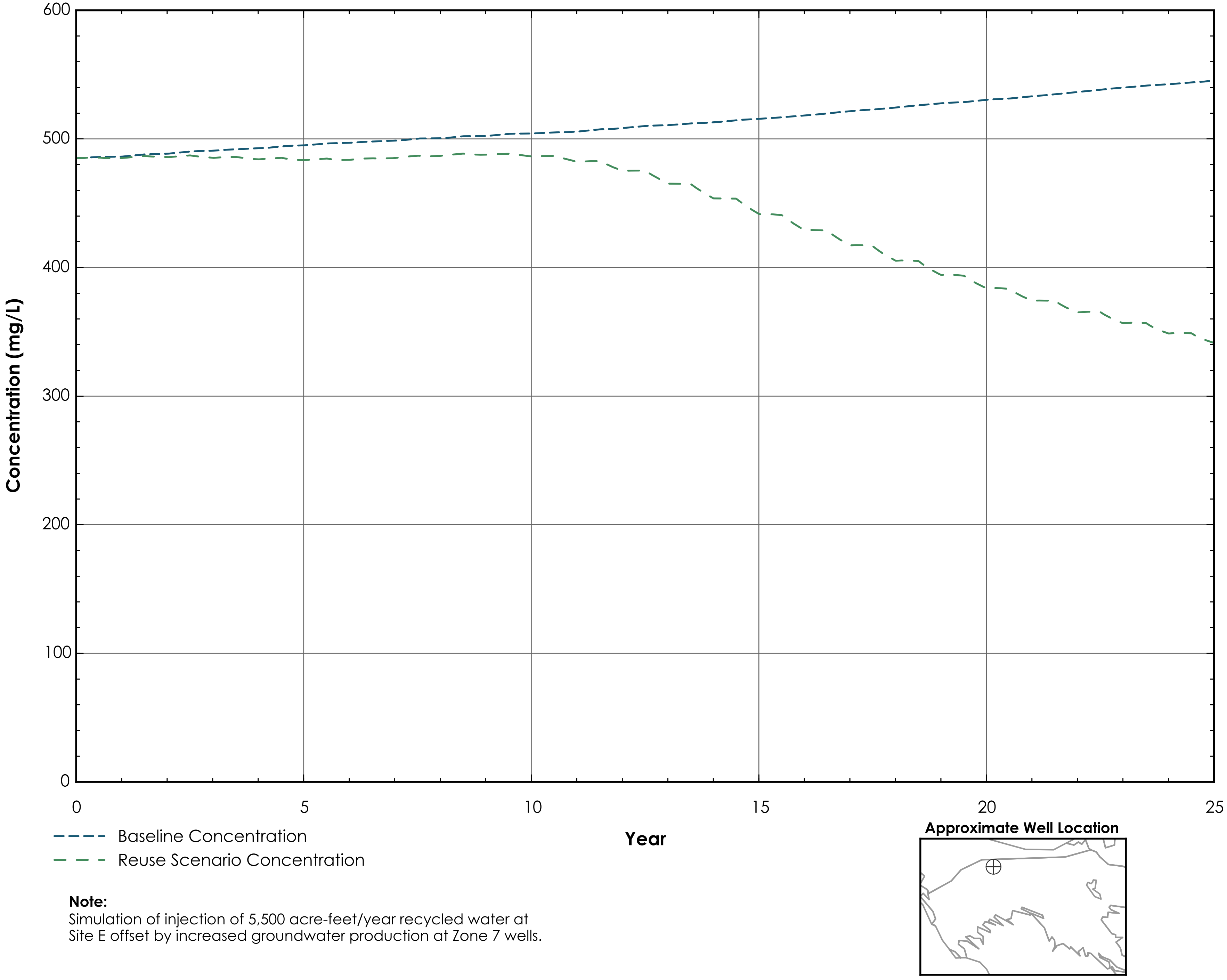


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

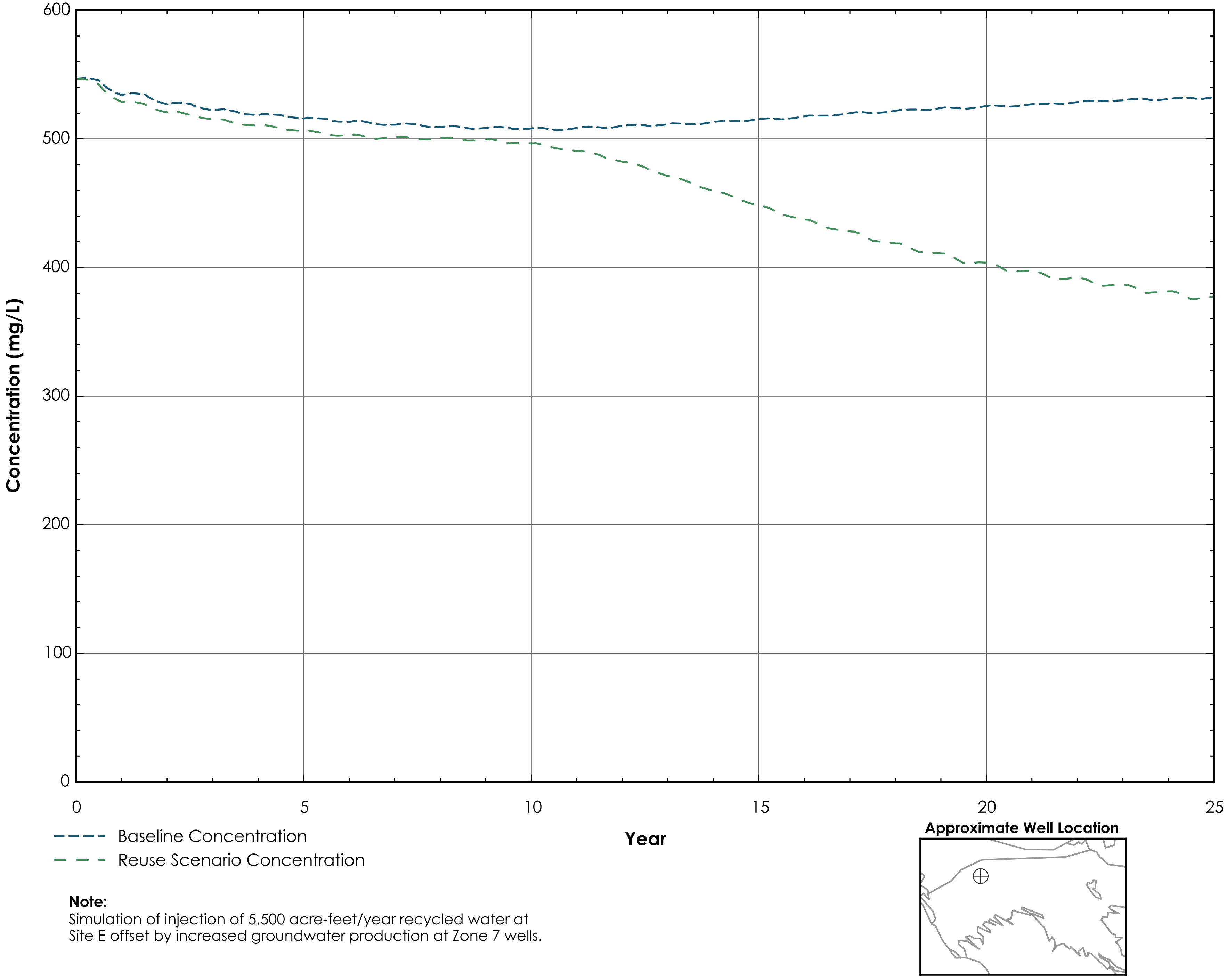


Well STONERIDGE 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



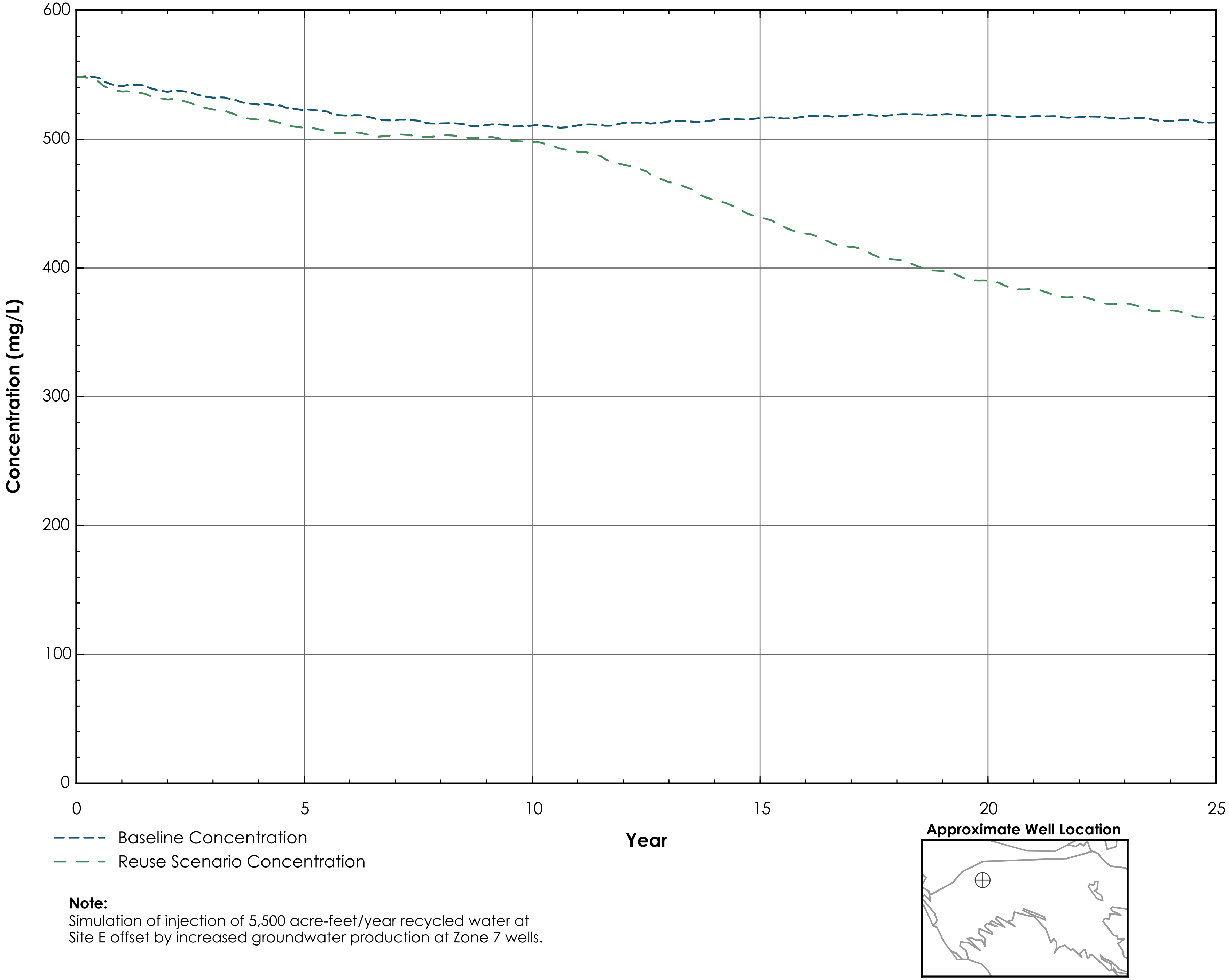
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



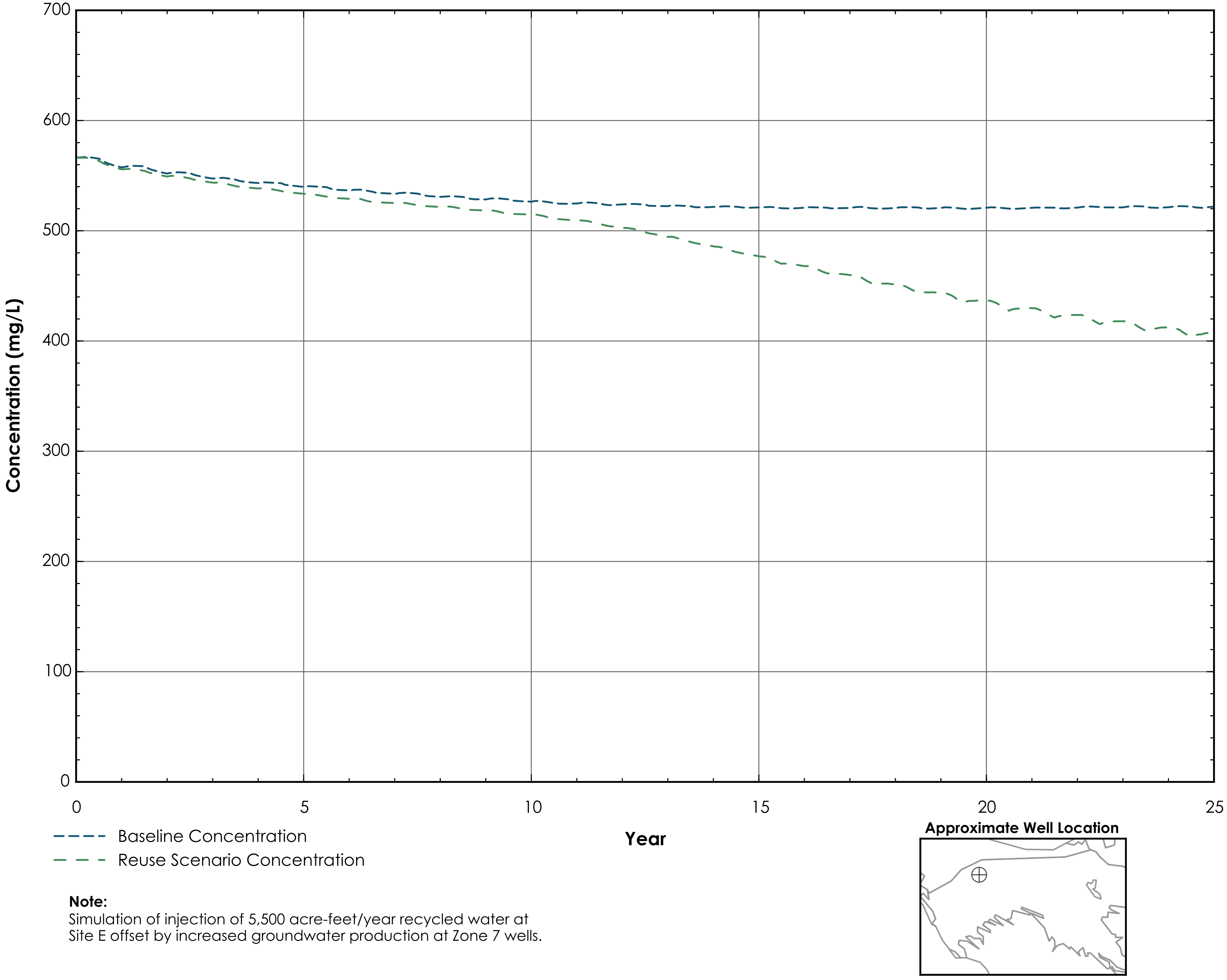
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



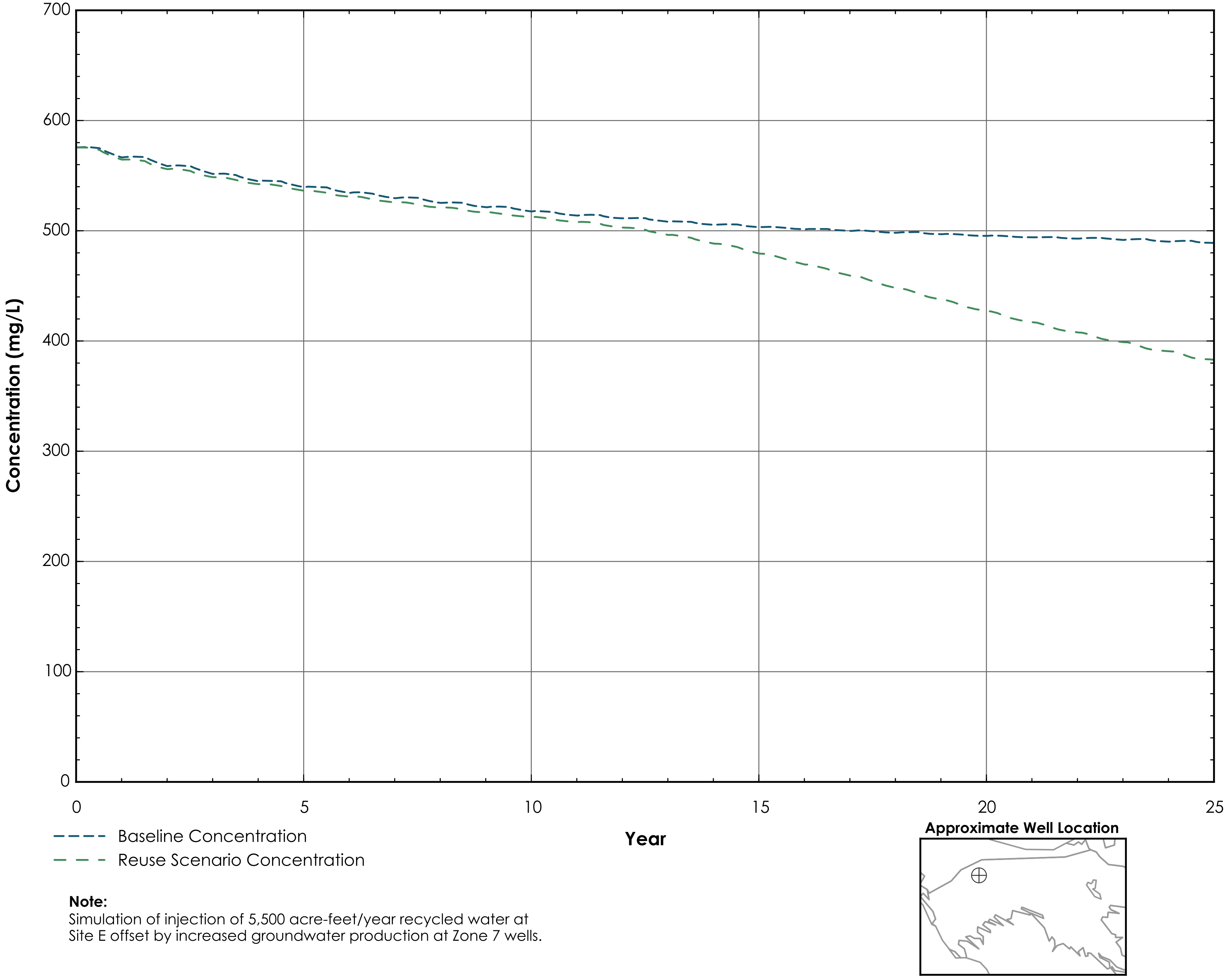
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 3 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



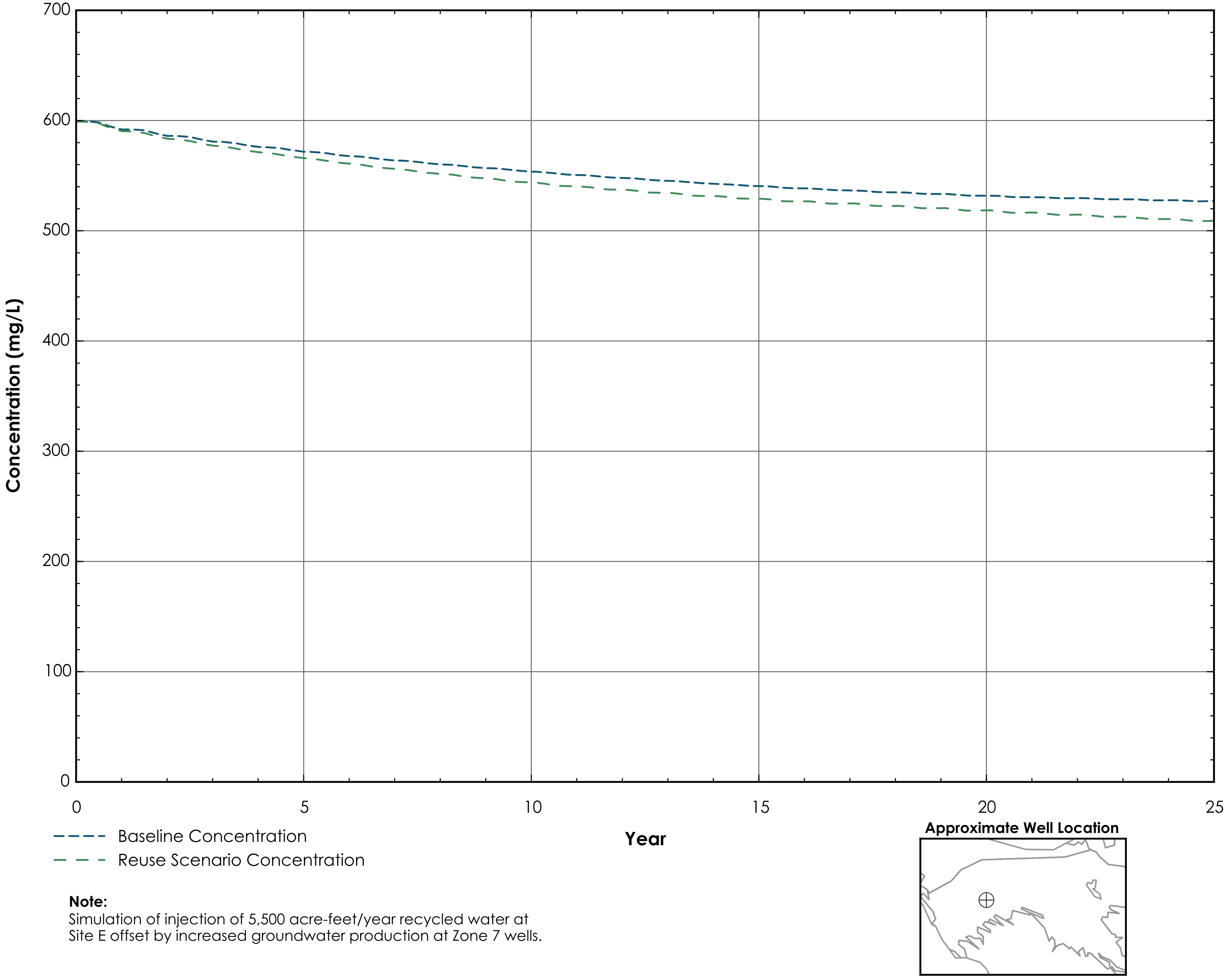
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Well MOCHO 4 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



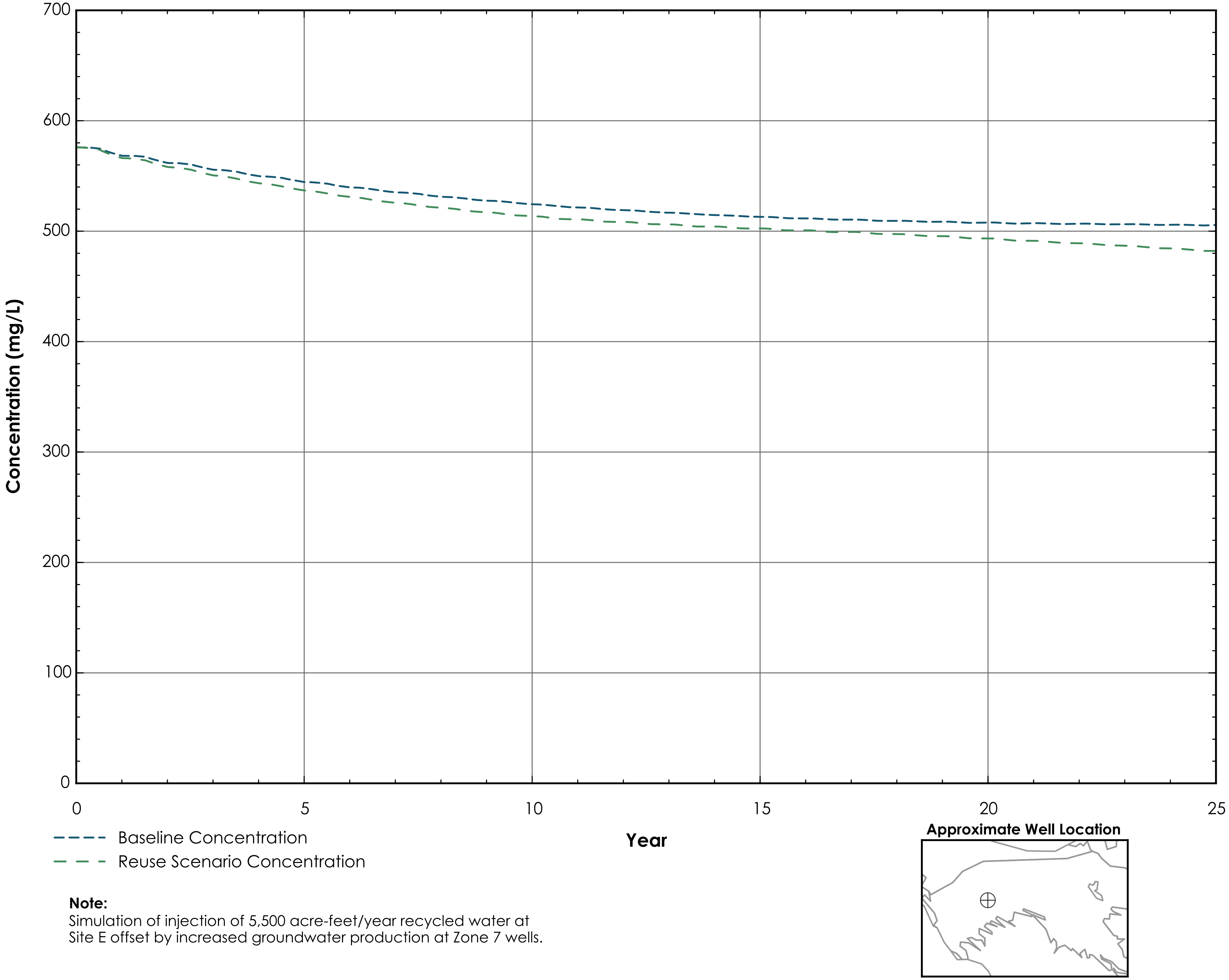
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



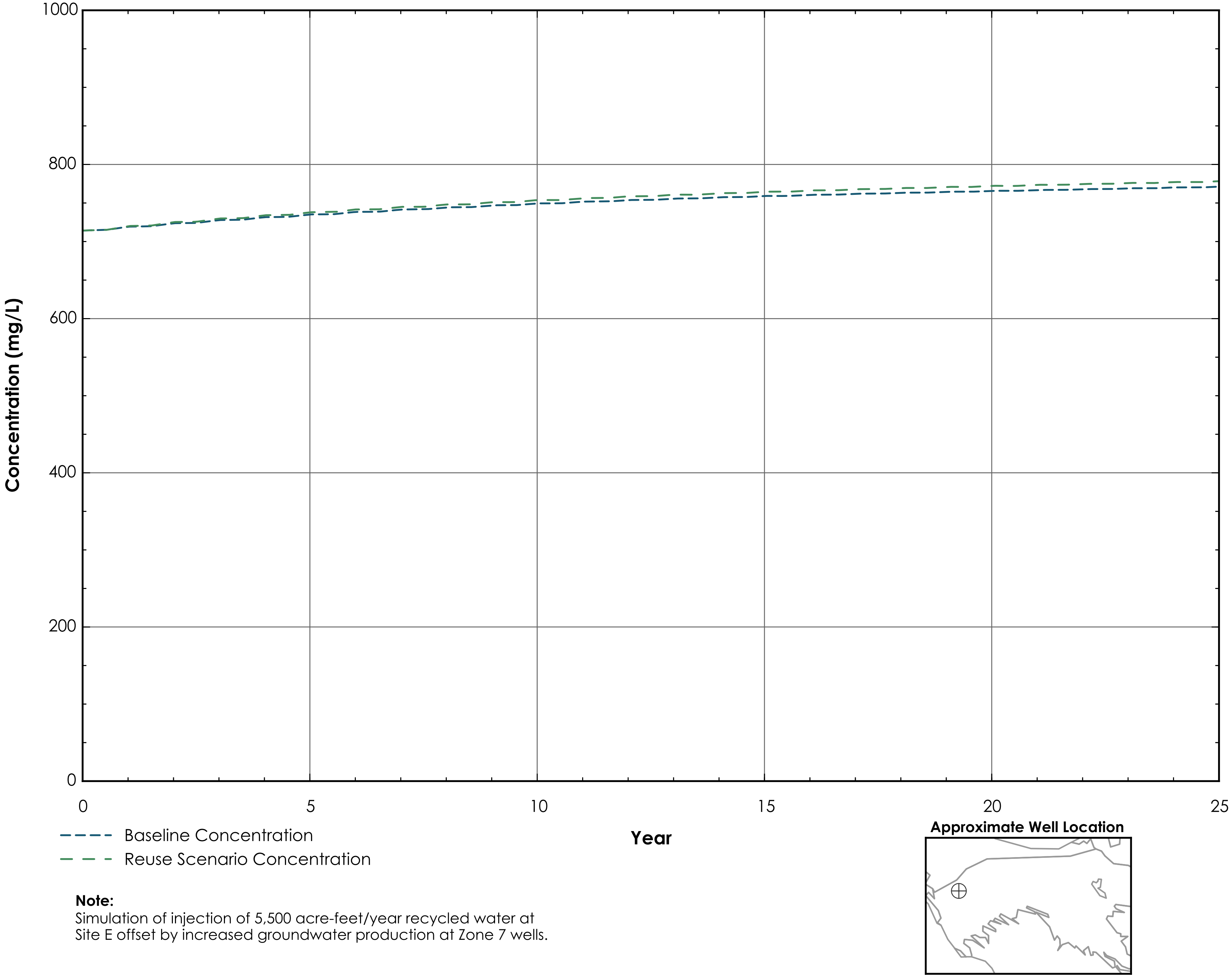
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



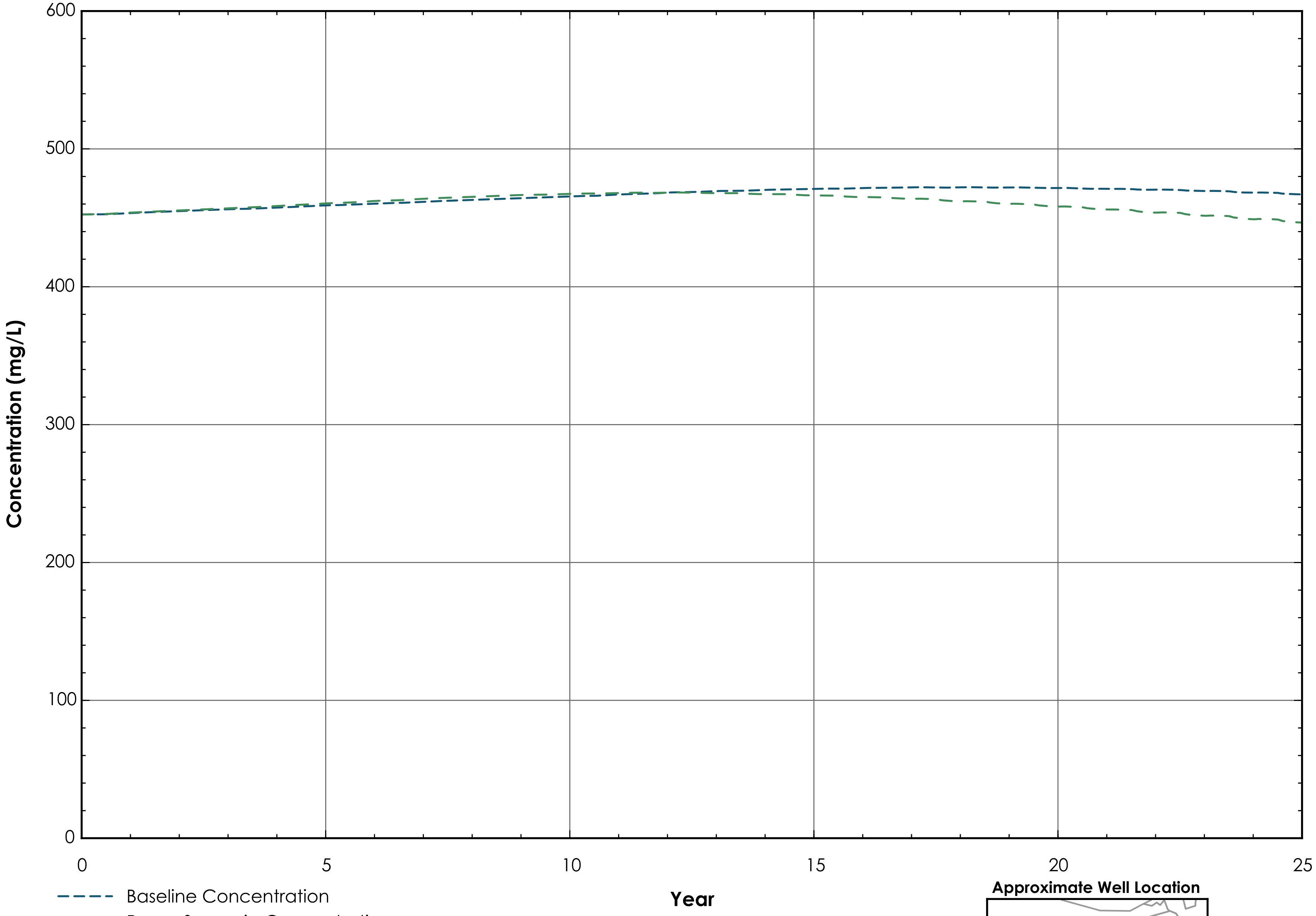
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 7 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E



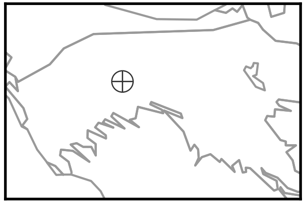
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Site E offset by increased groundwater production at Zone 7 wells.

Well PLEAS 8 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Well E

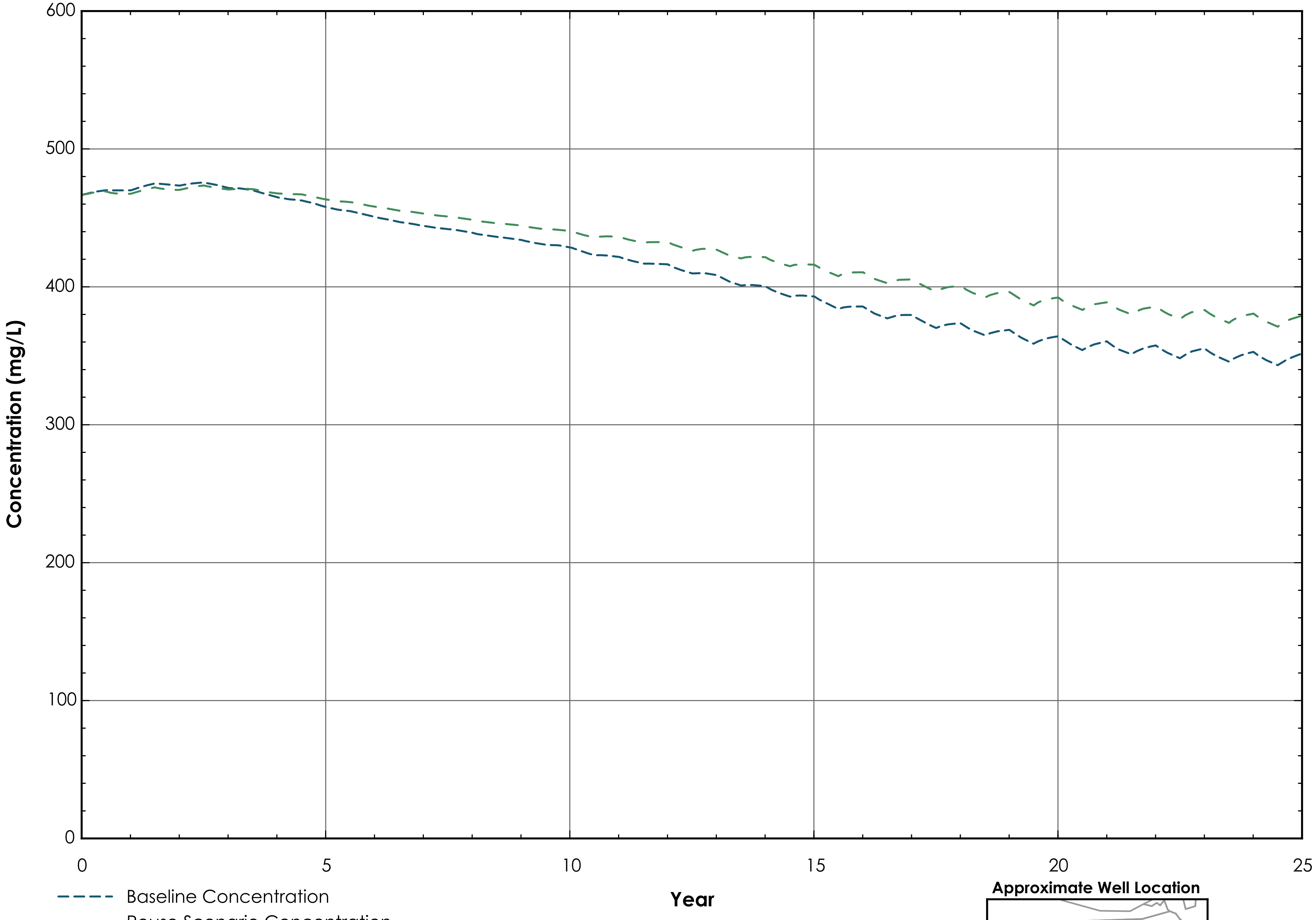


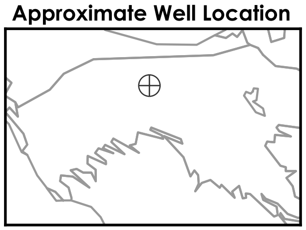
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Site E offset by increased groundwater production at Zone 7 wells.

Approximate Well Location



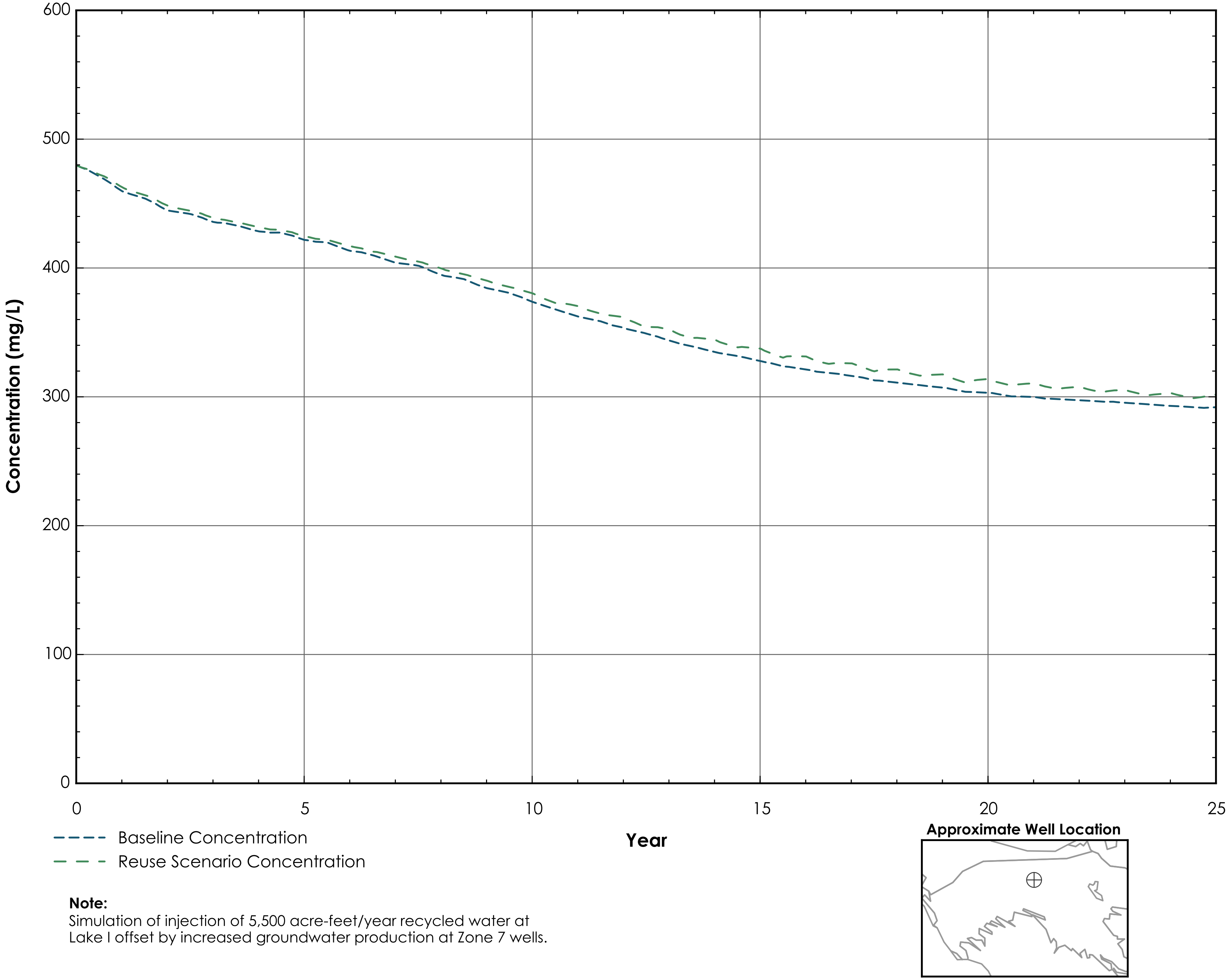
Well COL 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I





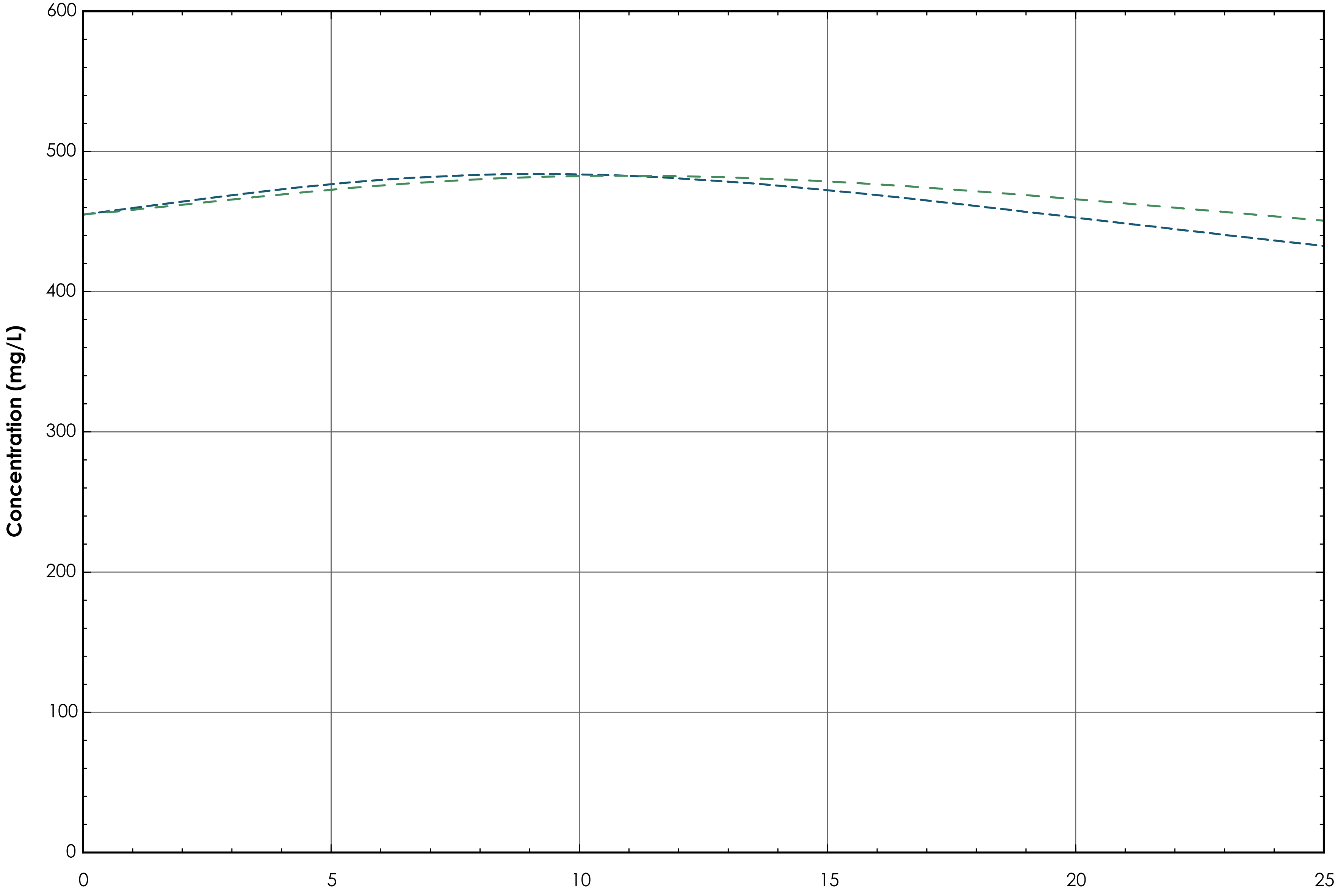
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

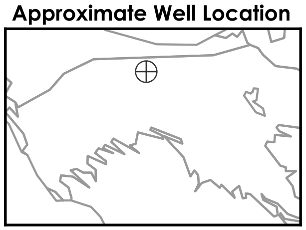
Well COL 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

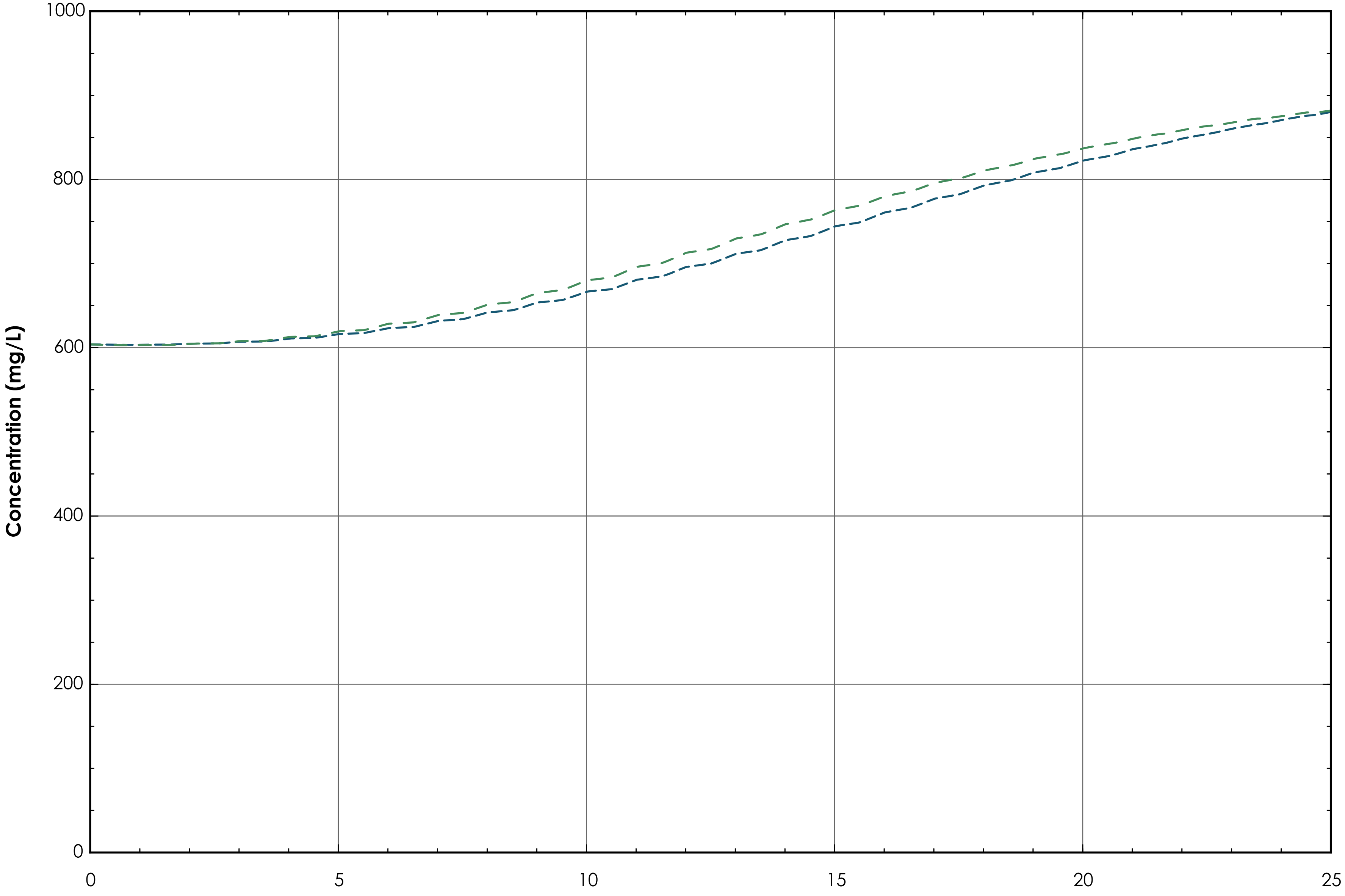
Well COL 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



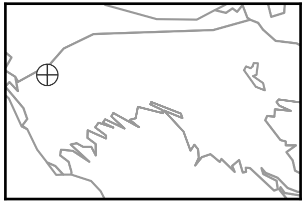


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

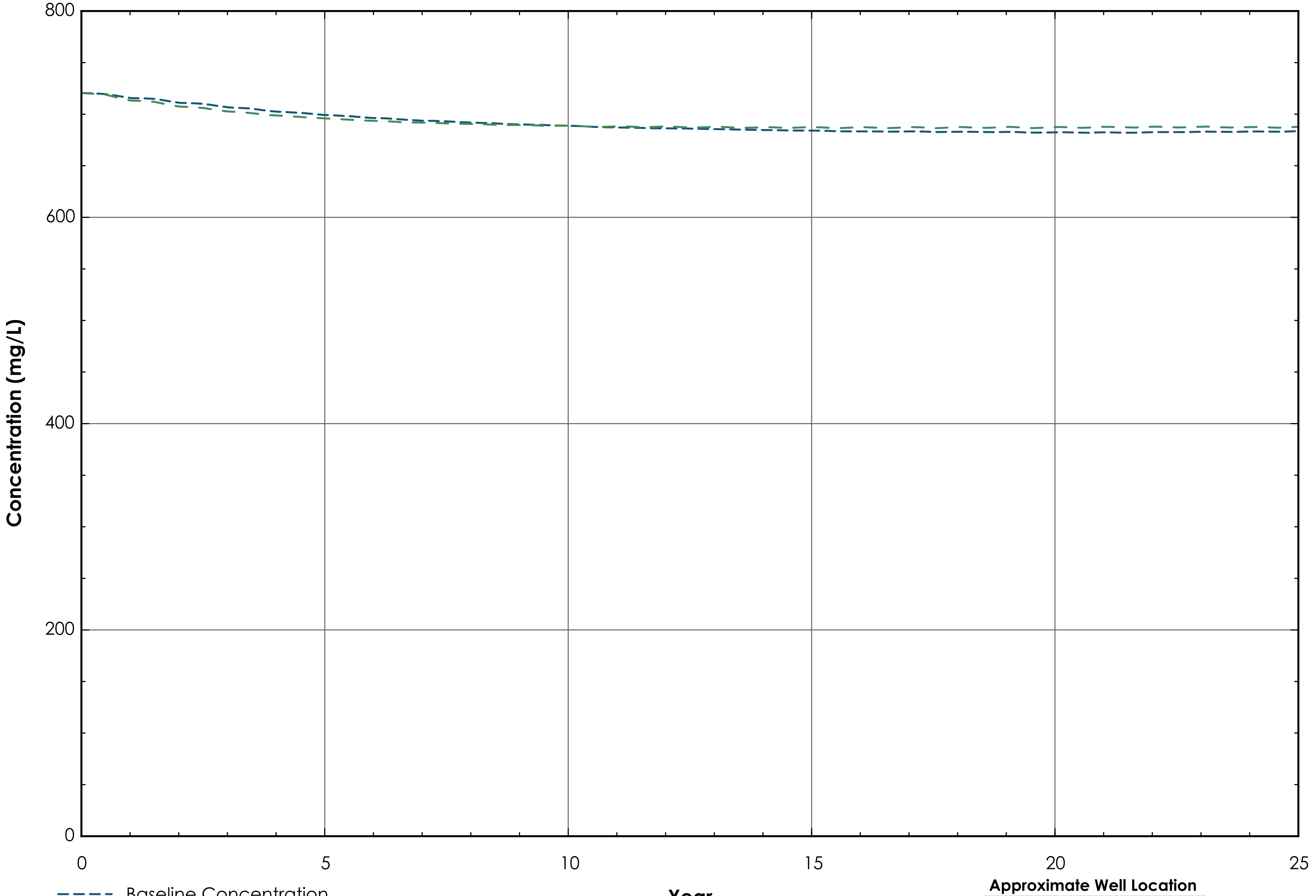
Well HOP 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



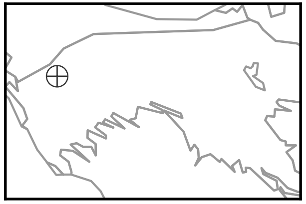
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.



Well HOP 9 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

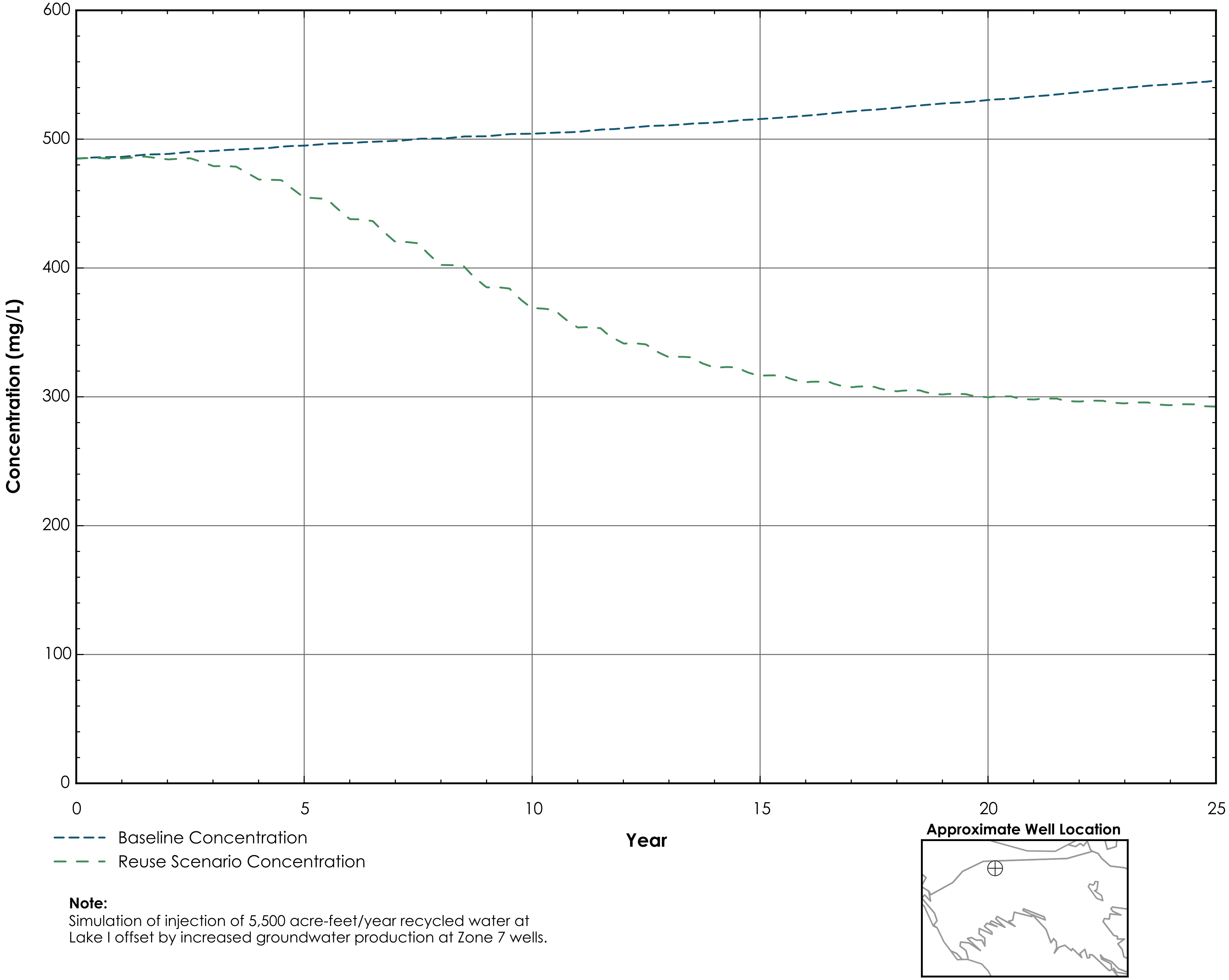


Approximate Well Location



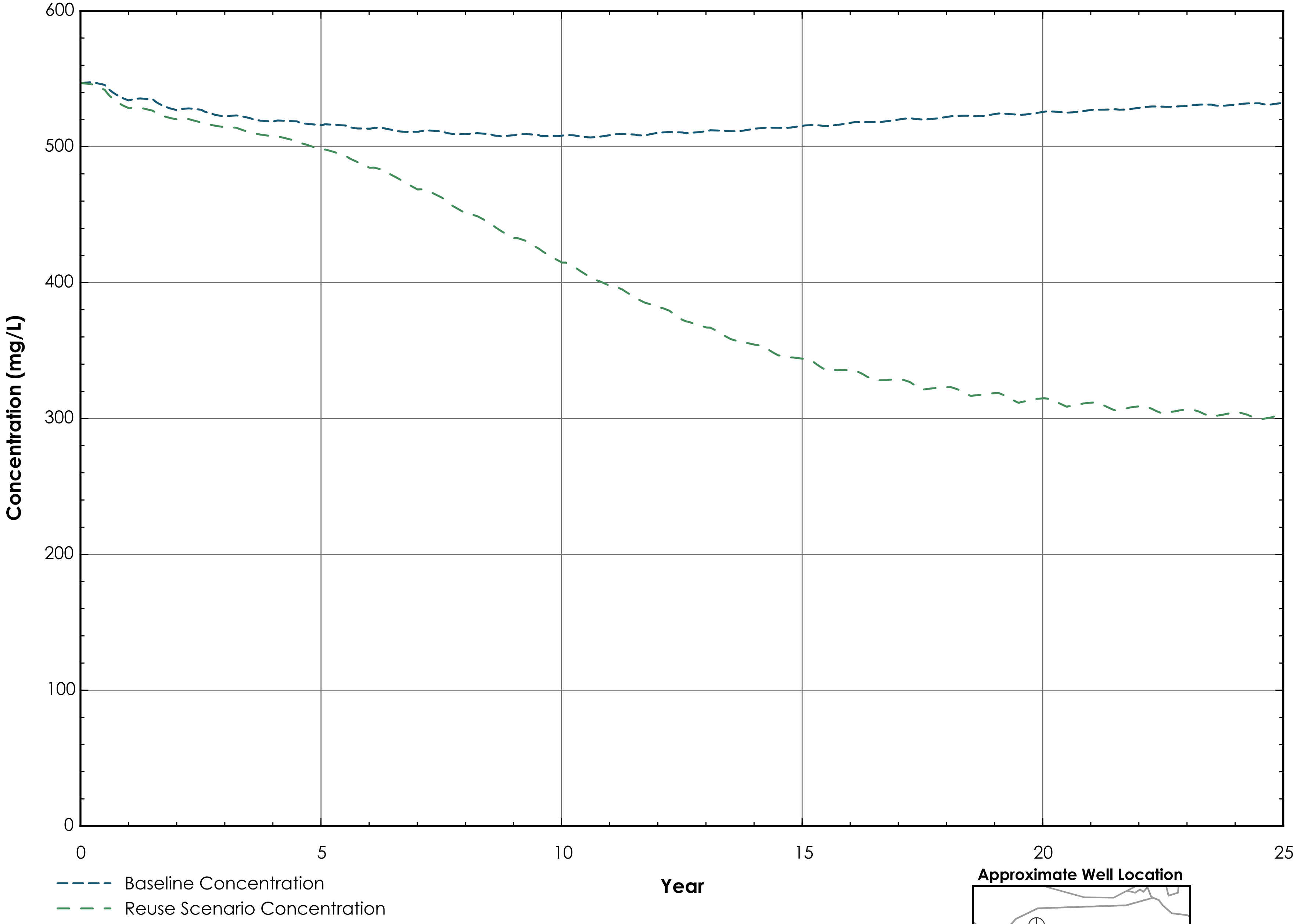
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well STONERIDGE 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



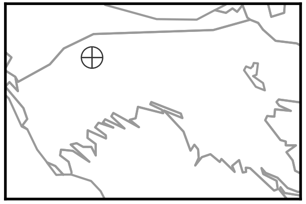
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 1 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I

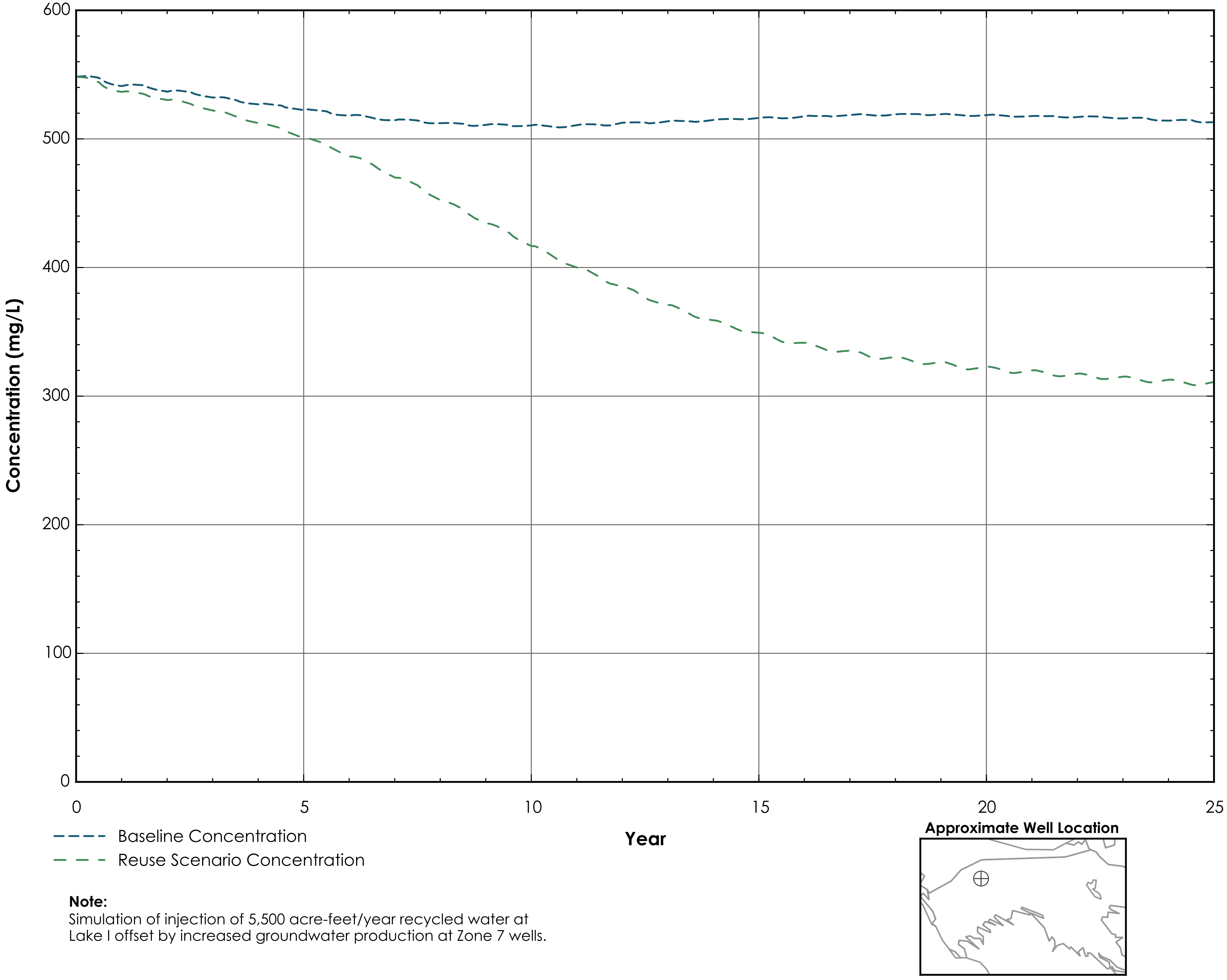


Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

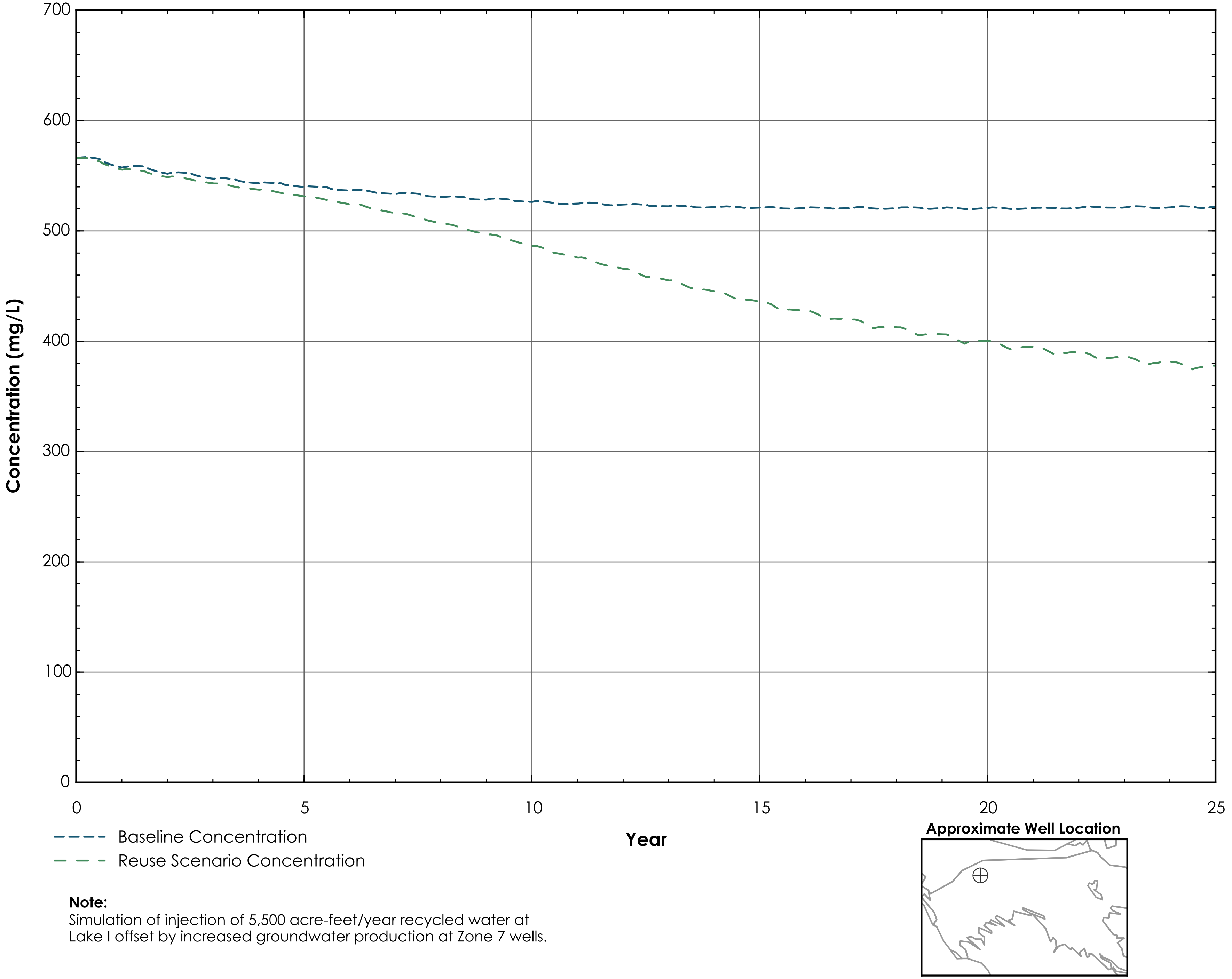


Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



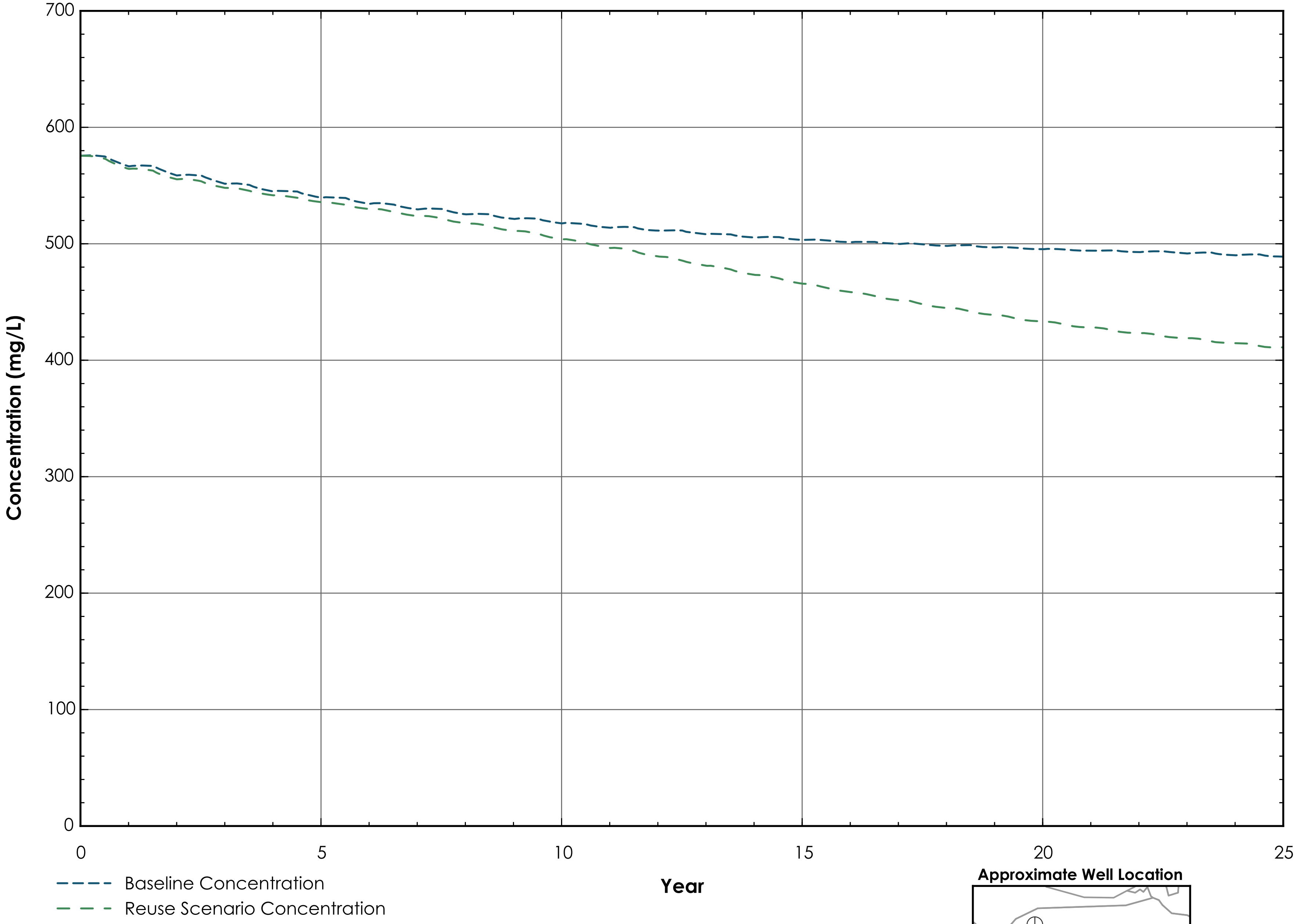
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

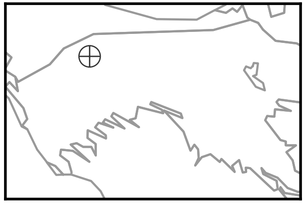
Well MOCHO 3 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

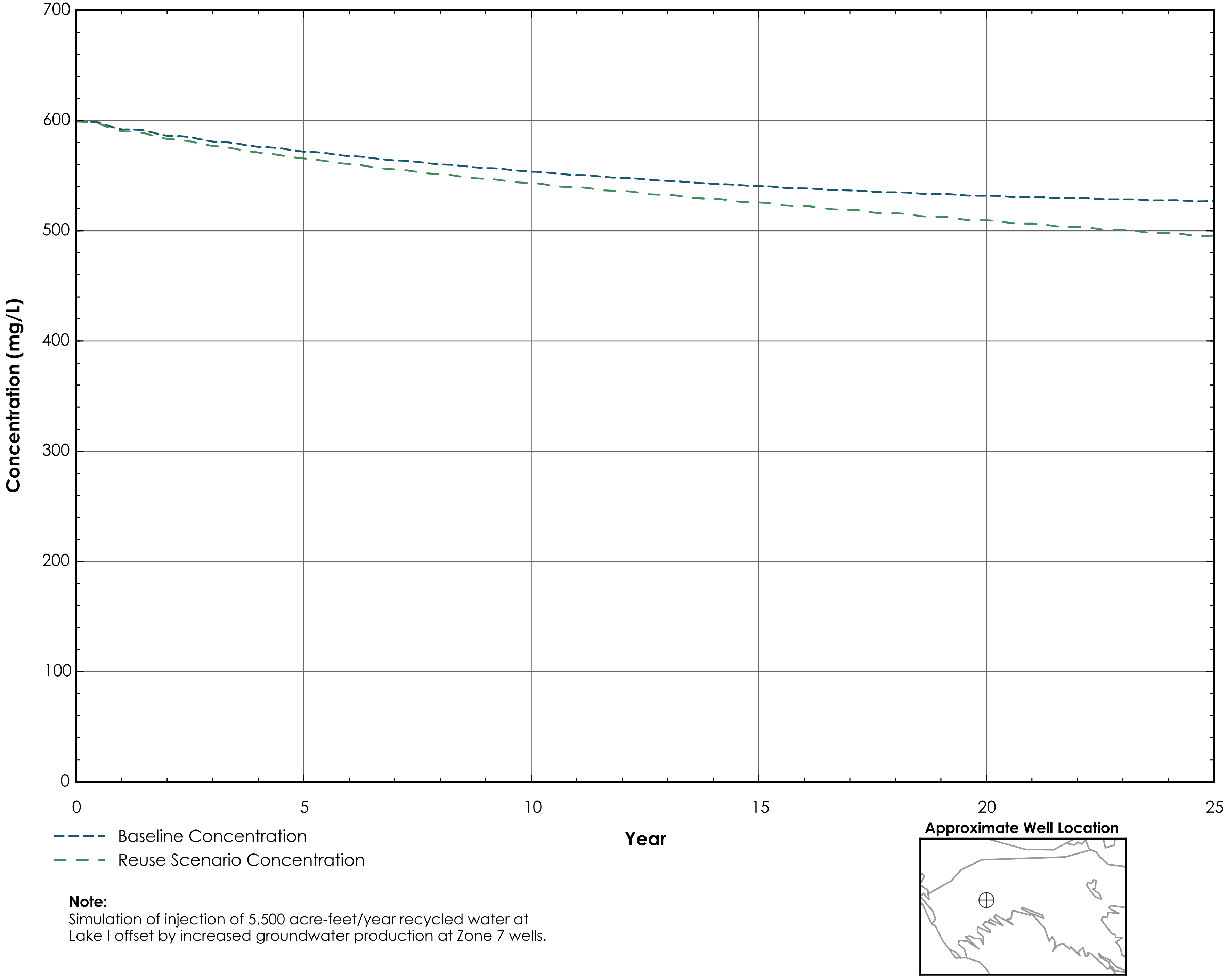
Well MOCHO 4 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I





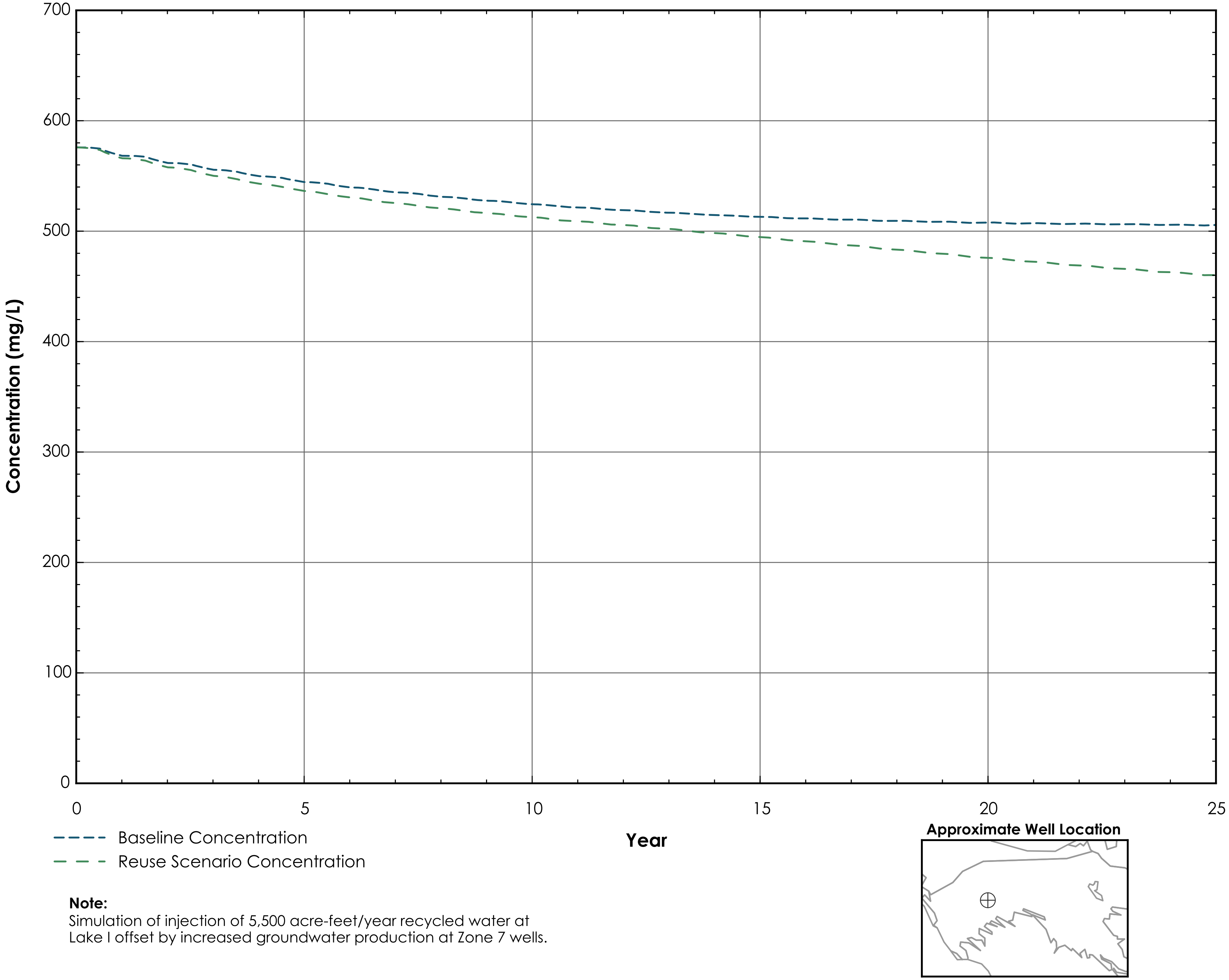
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 5 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



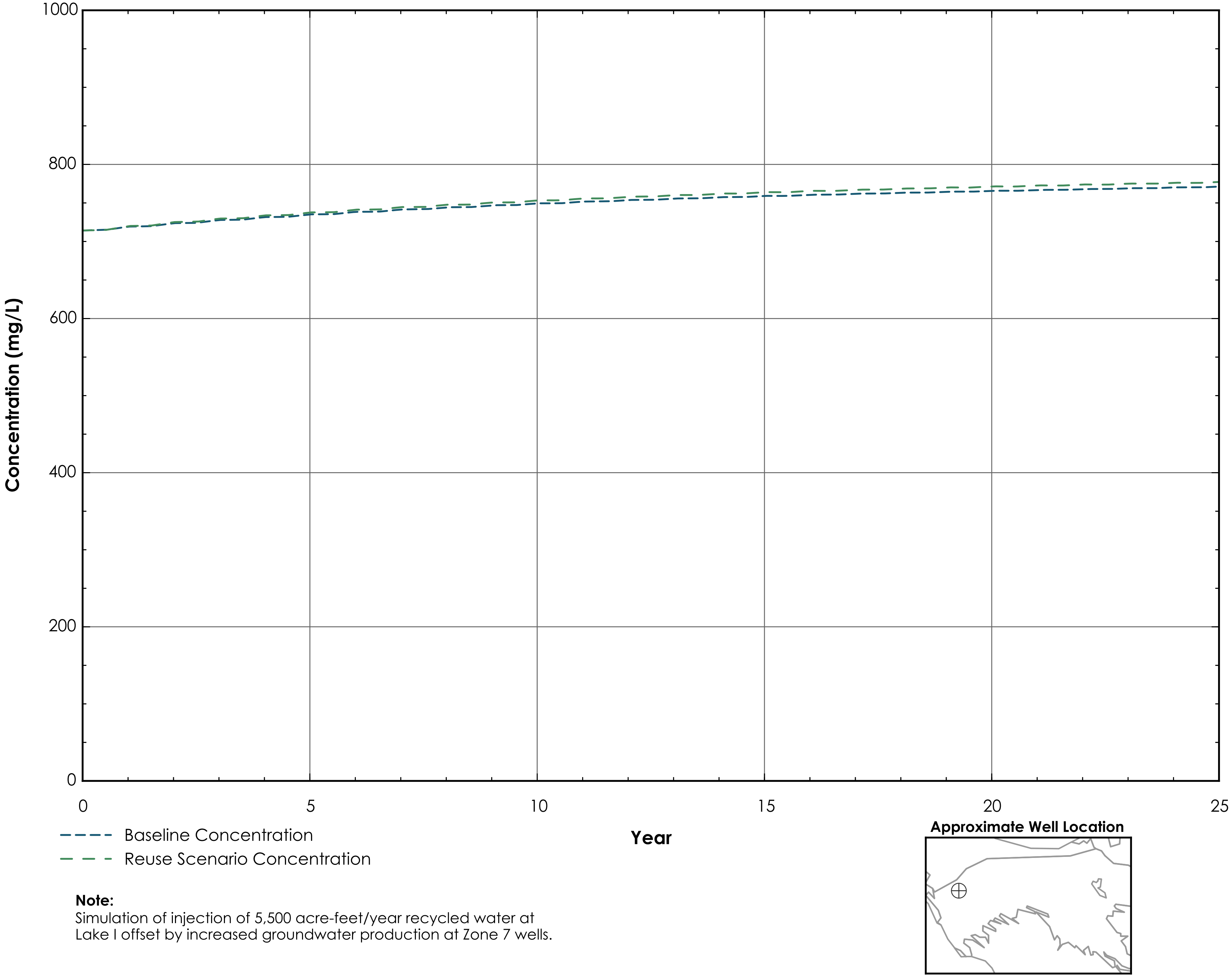
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 6 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



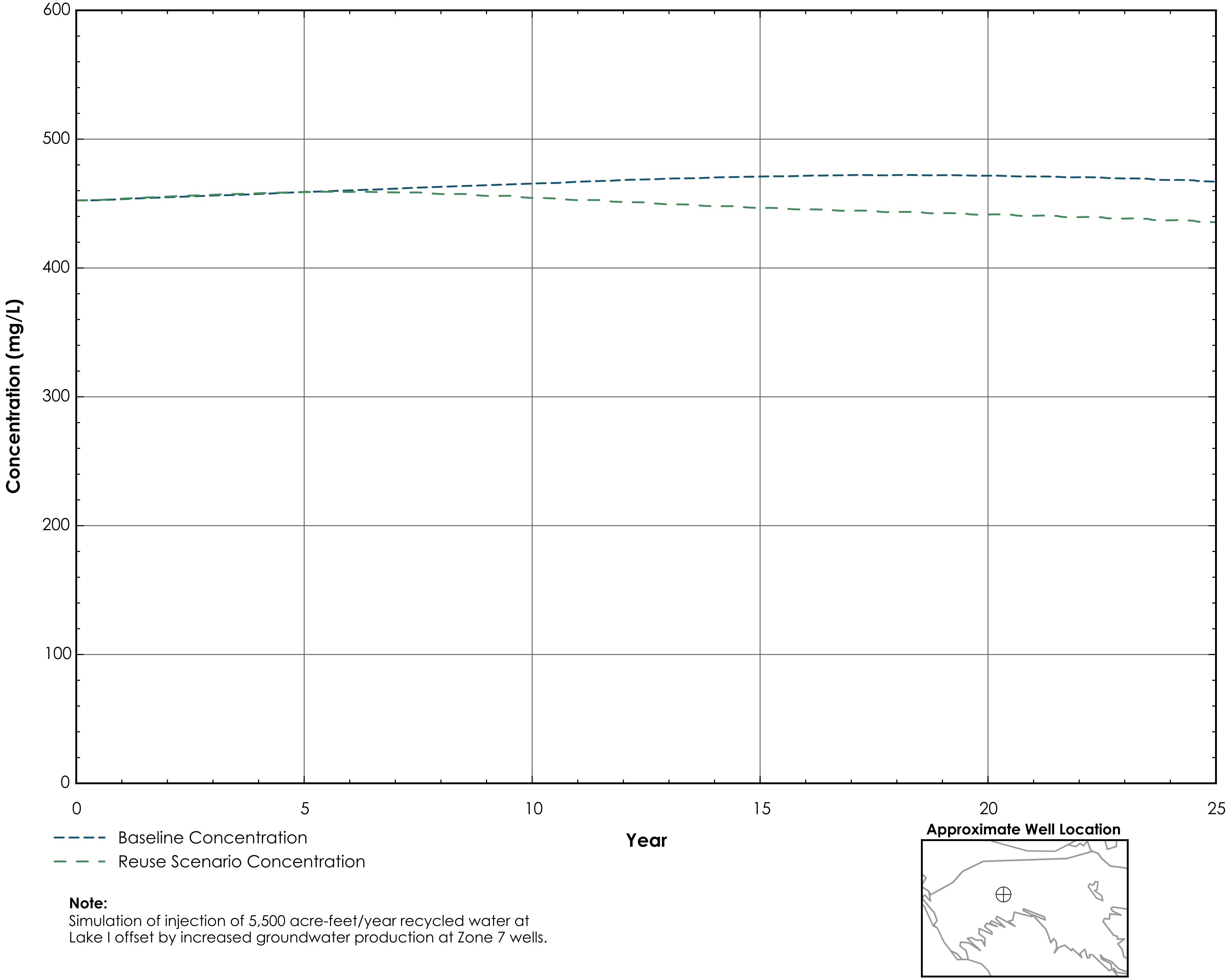
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 7 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



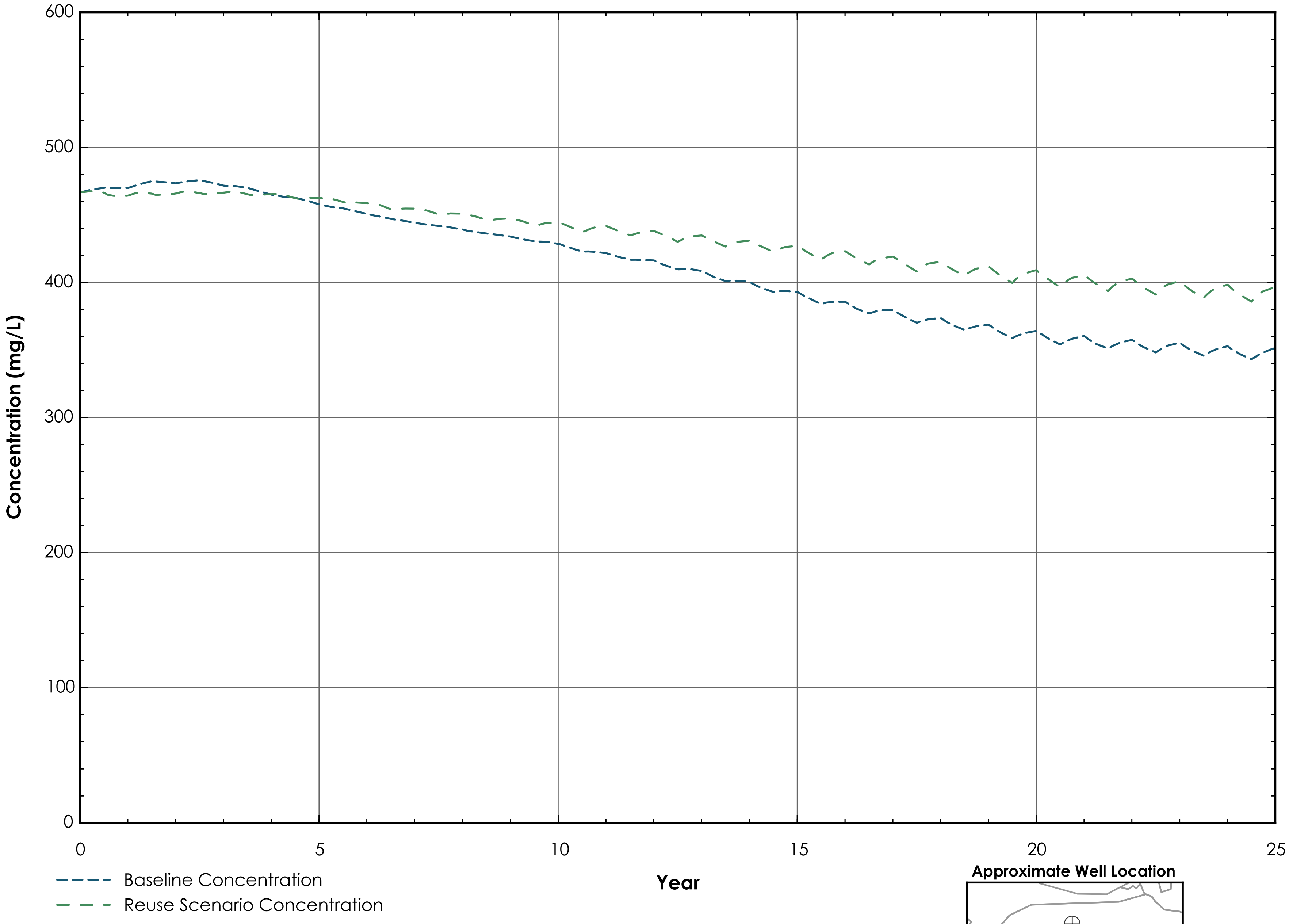
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 8 Simulated TDS Concentration in Lower Aquifer
5,500 AFY Recharge to Lake I



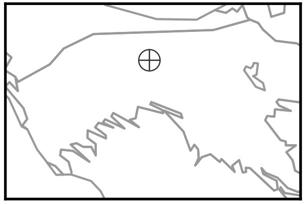
Note:
Simulation of injection of 5,500 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well COL 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

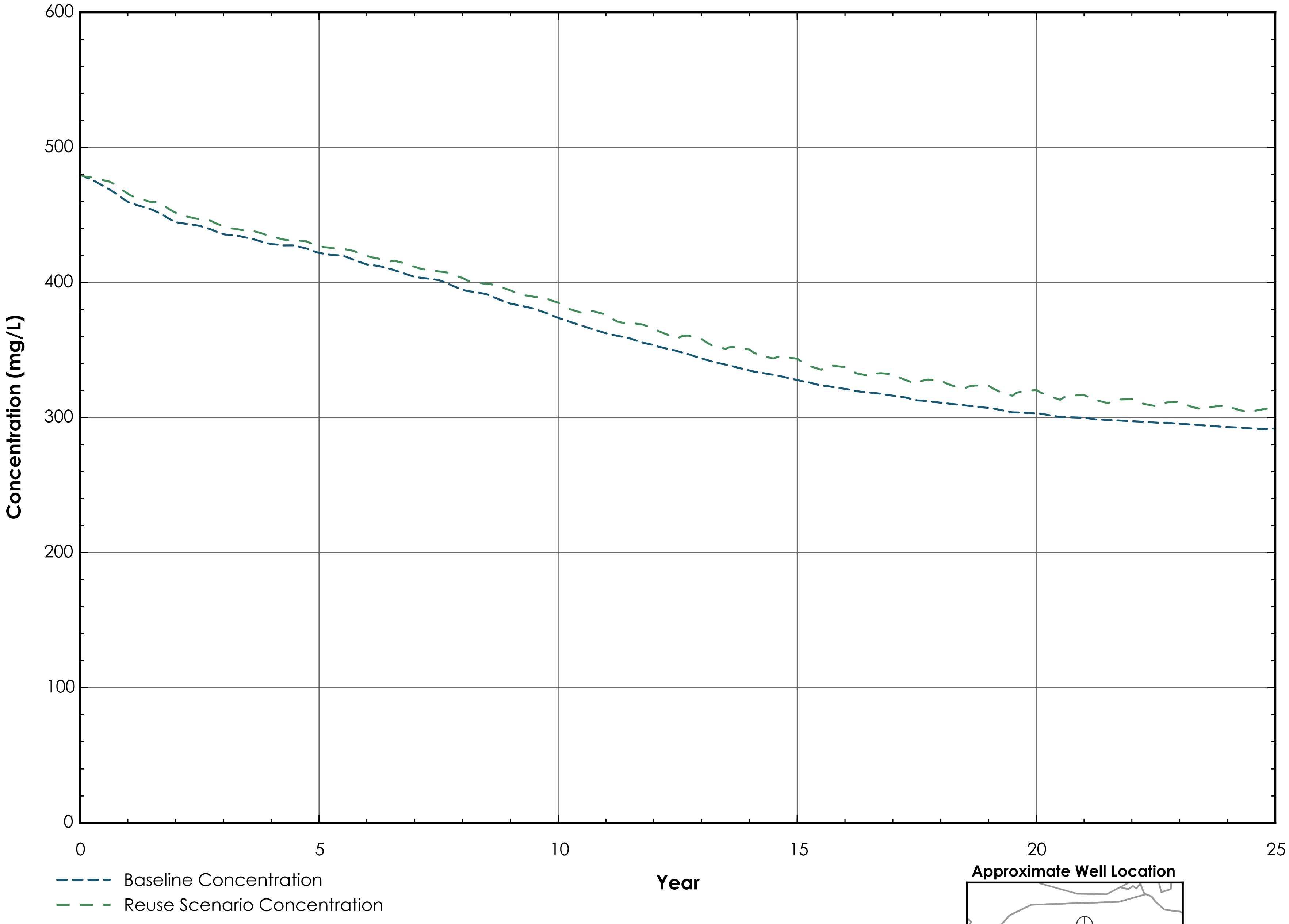


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

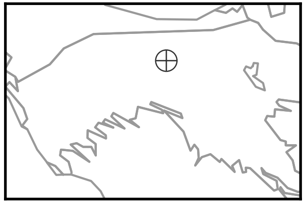
Approximate Well Location



Well COL 2 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

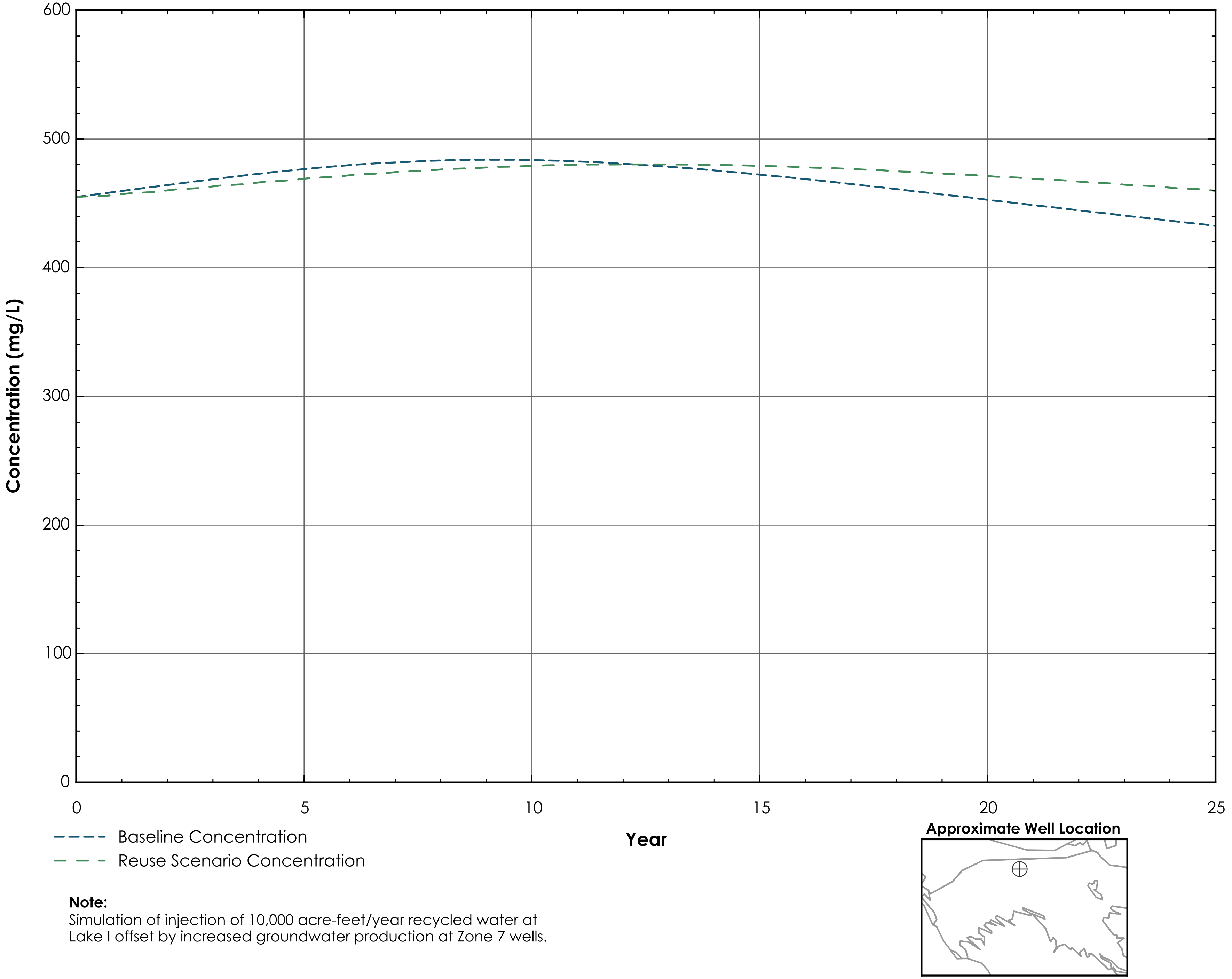


Approximate Well Location



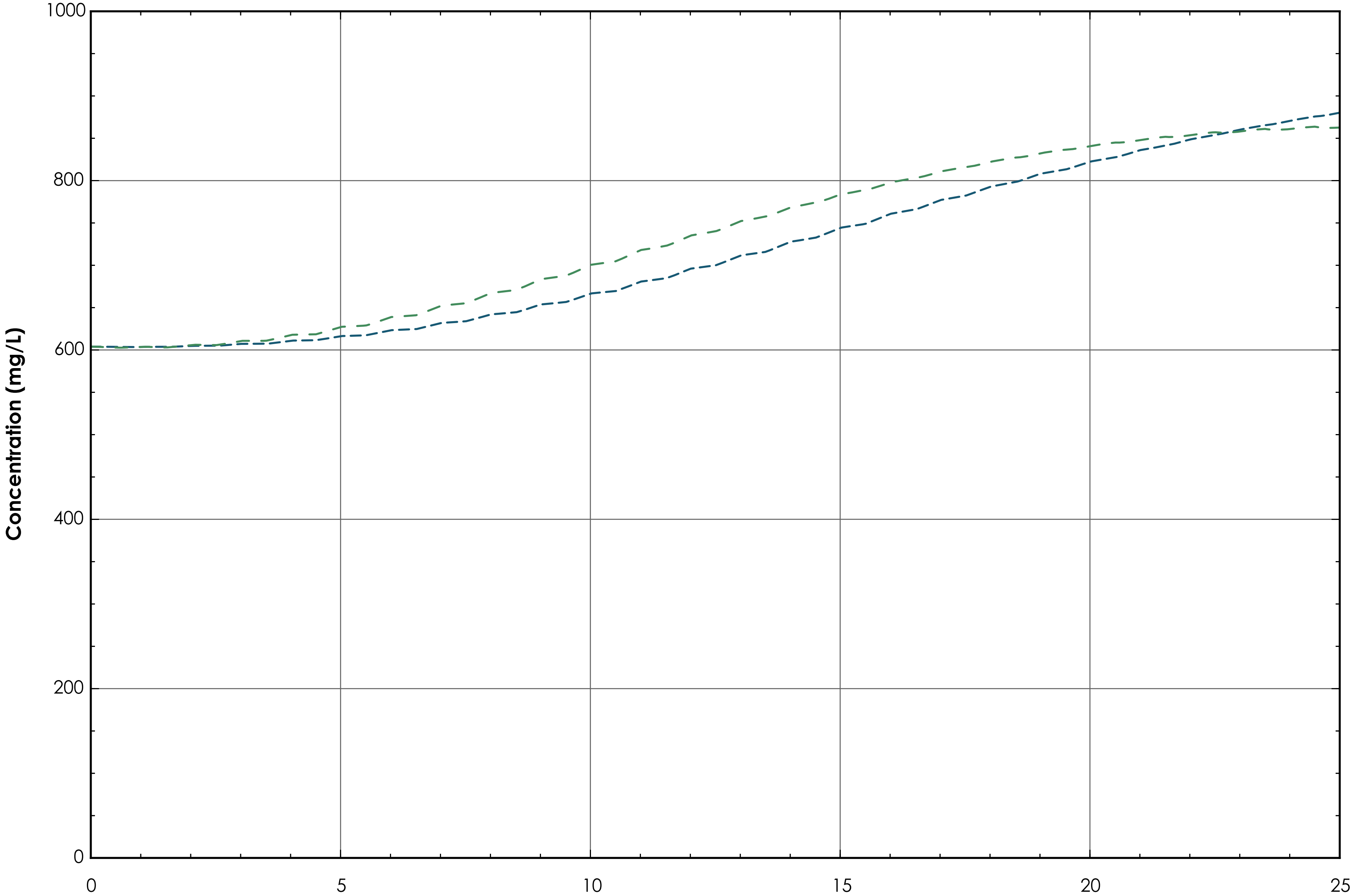
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well COL 5 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



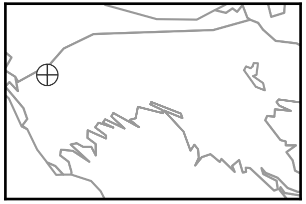
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well HOP 6 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

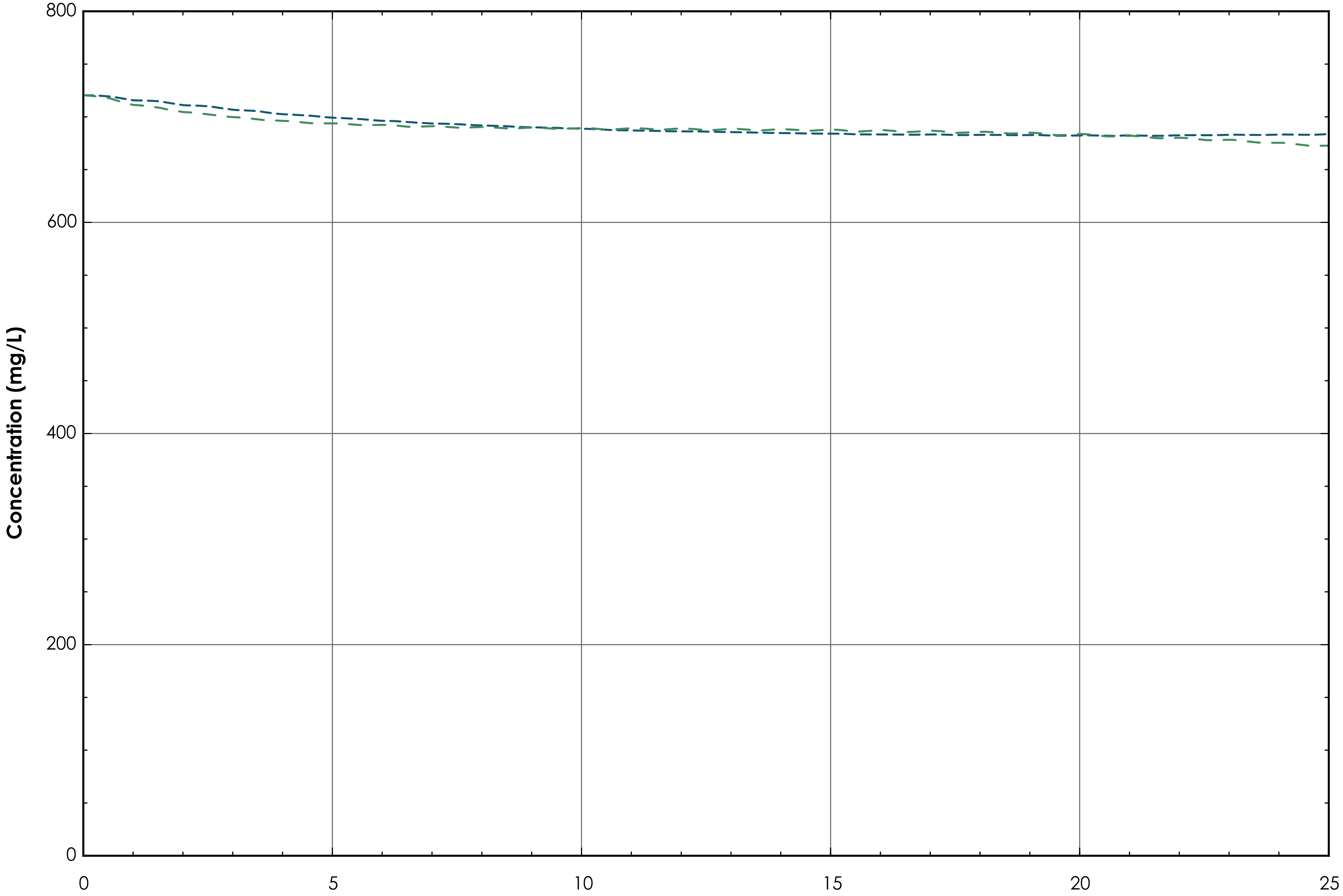


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location

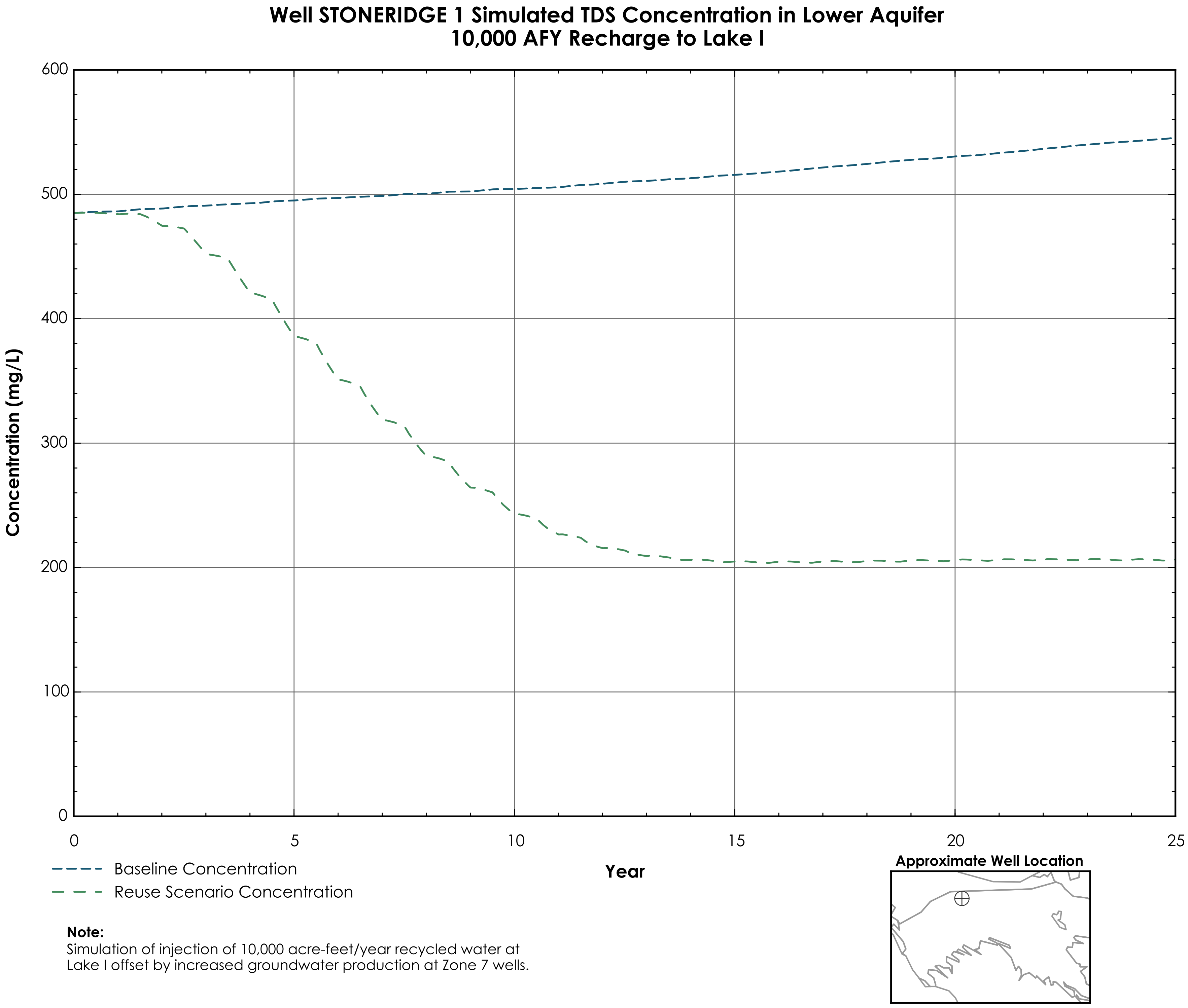


Well HOP 9 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

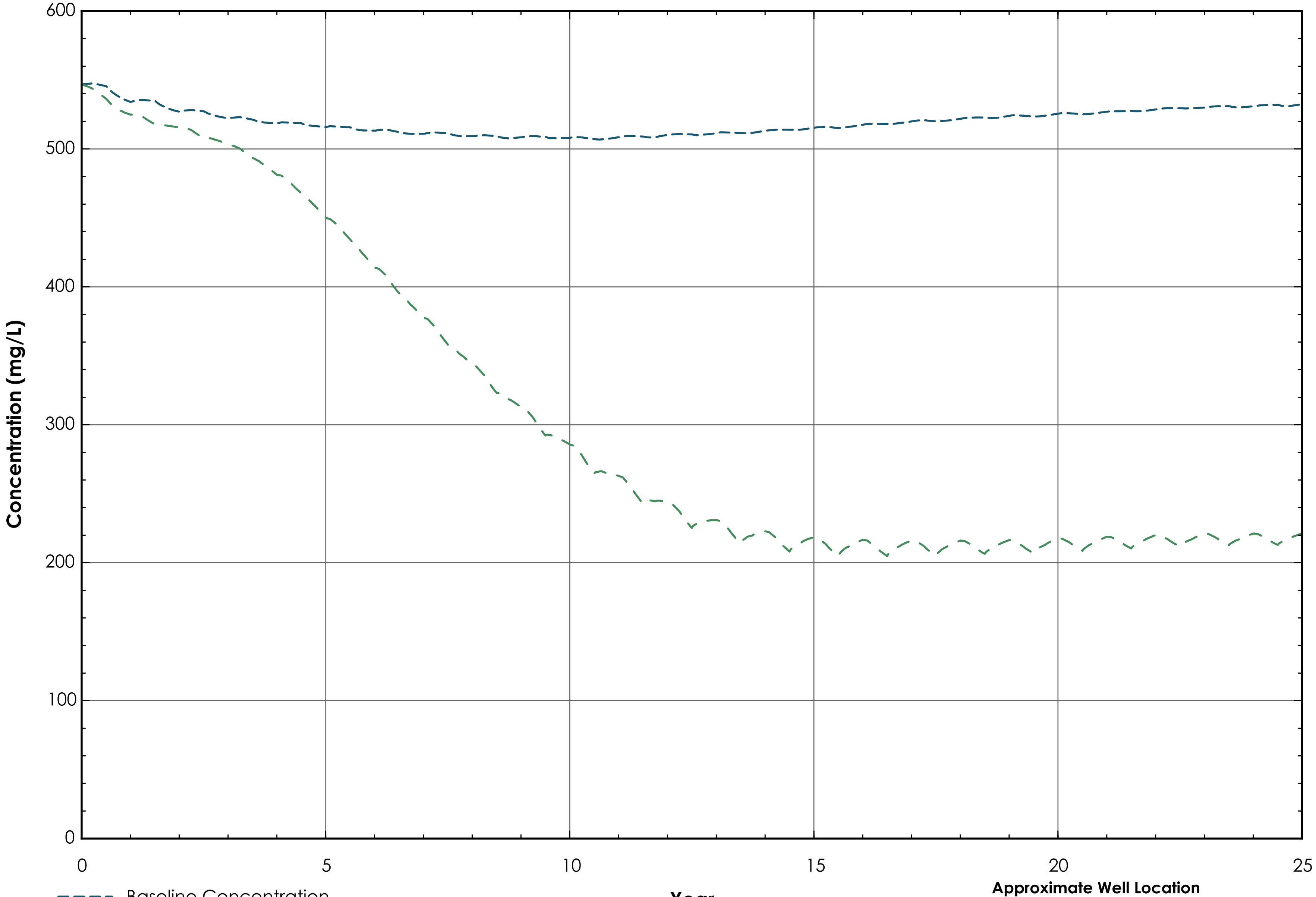
Approximate Well Location



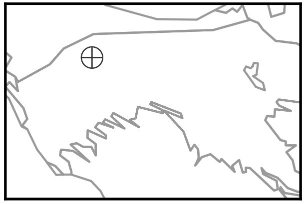
Well STONERIDGE 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 1 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

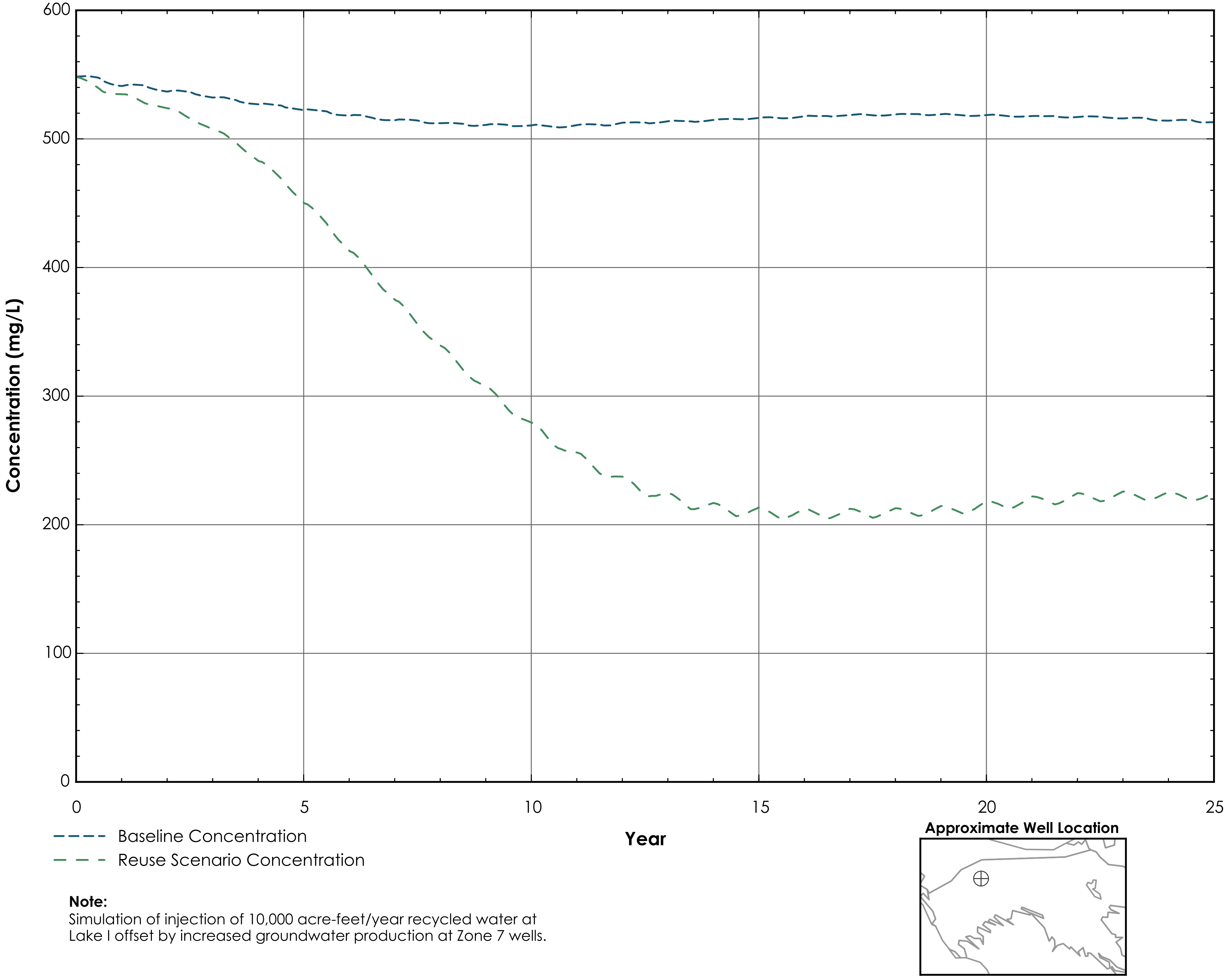


Approximate Well Location



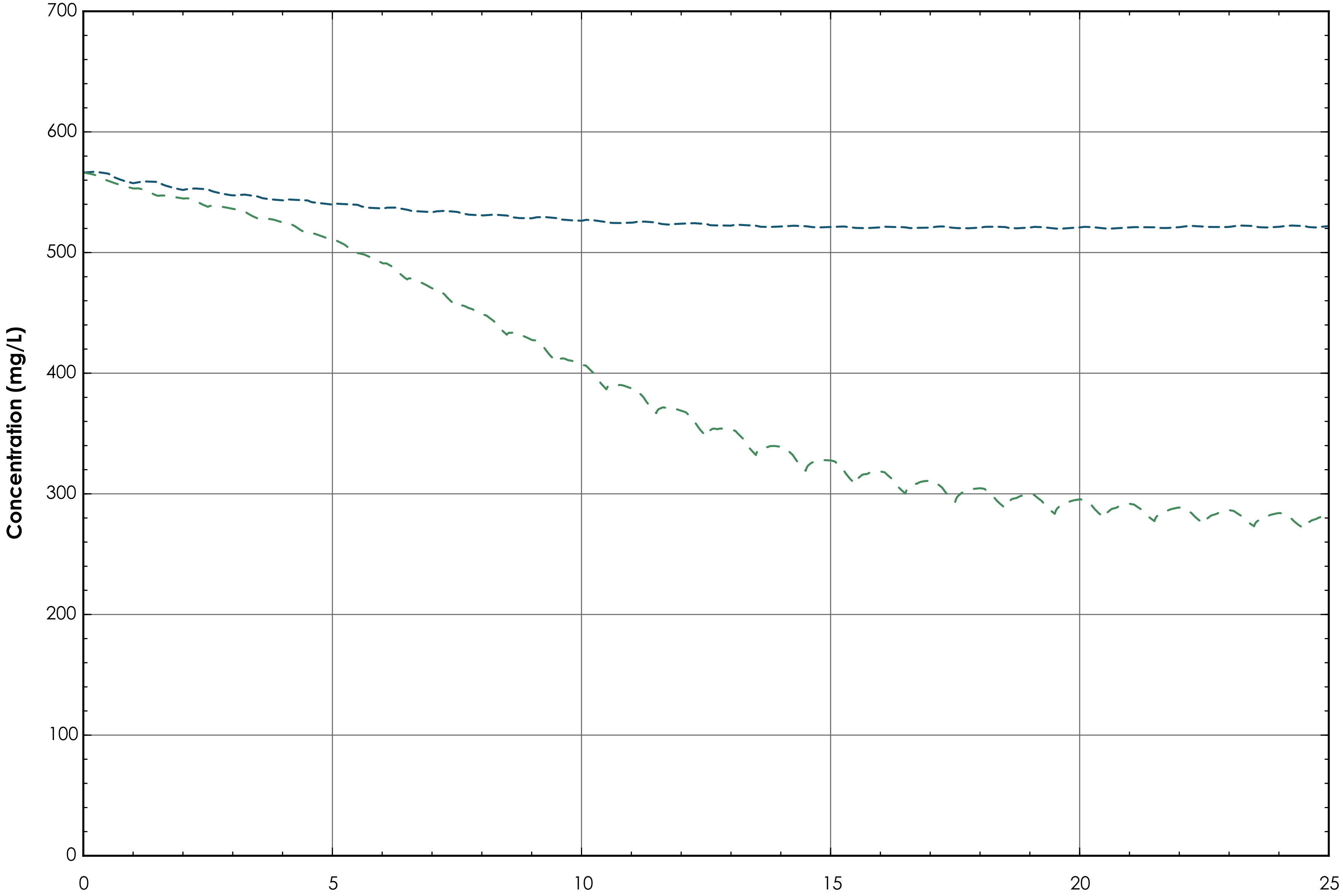
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 2 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



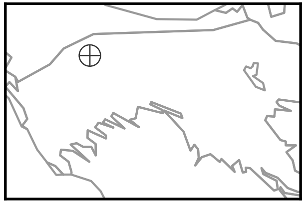
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well MOCHO 3 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

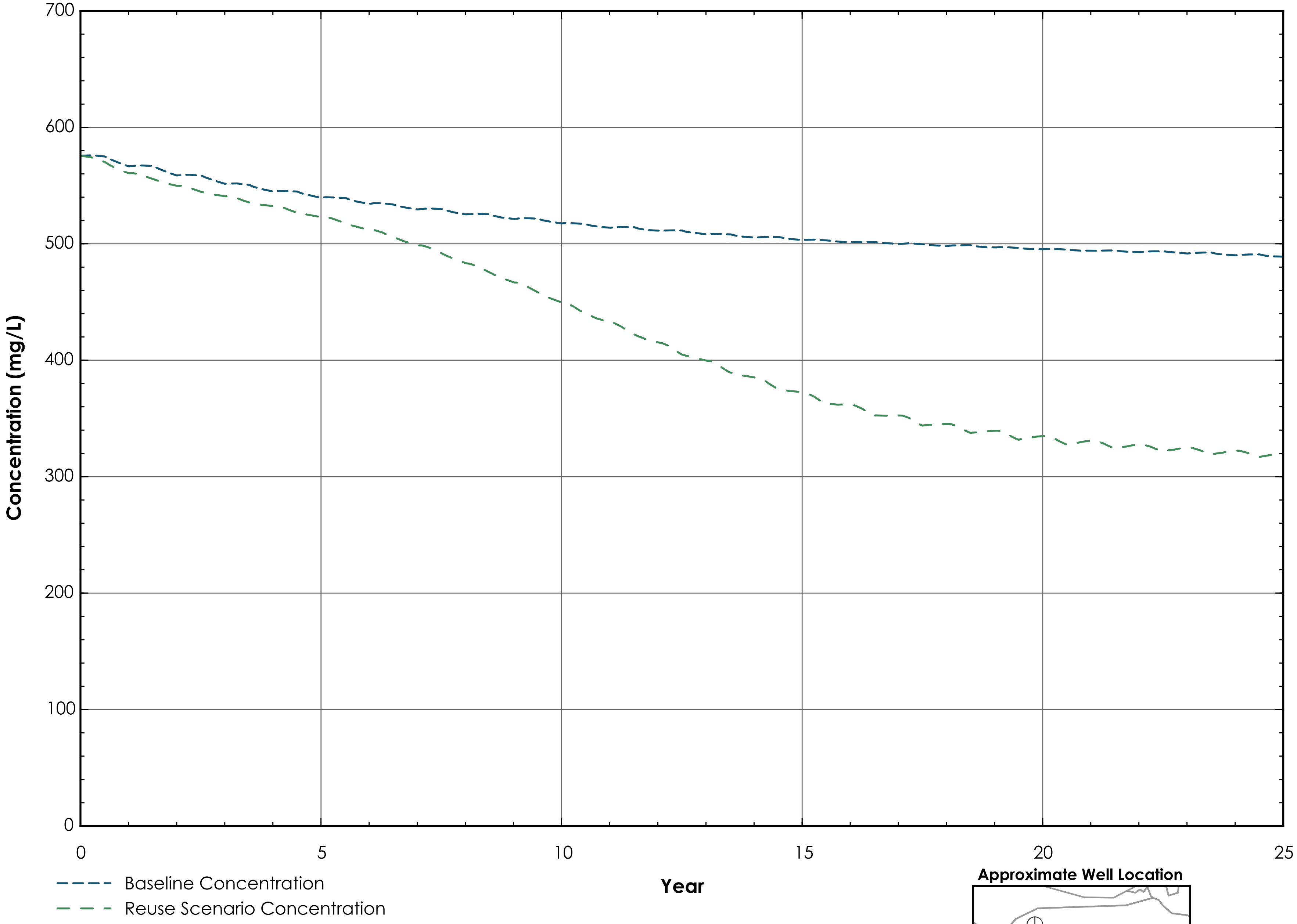


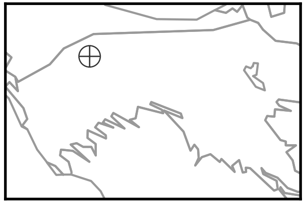
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Approximate Well Location



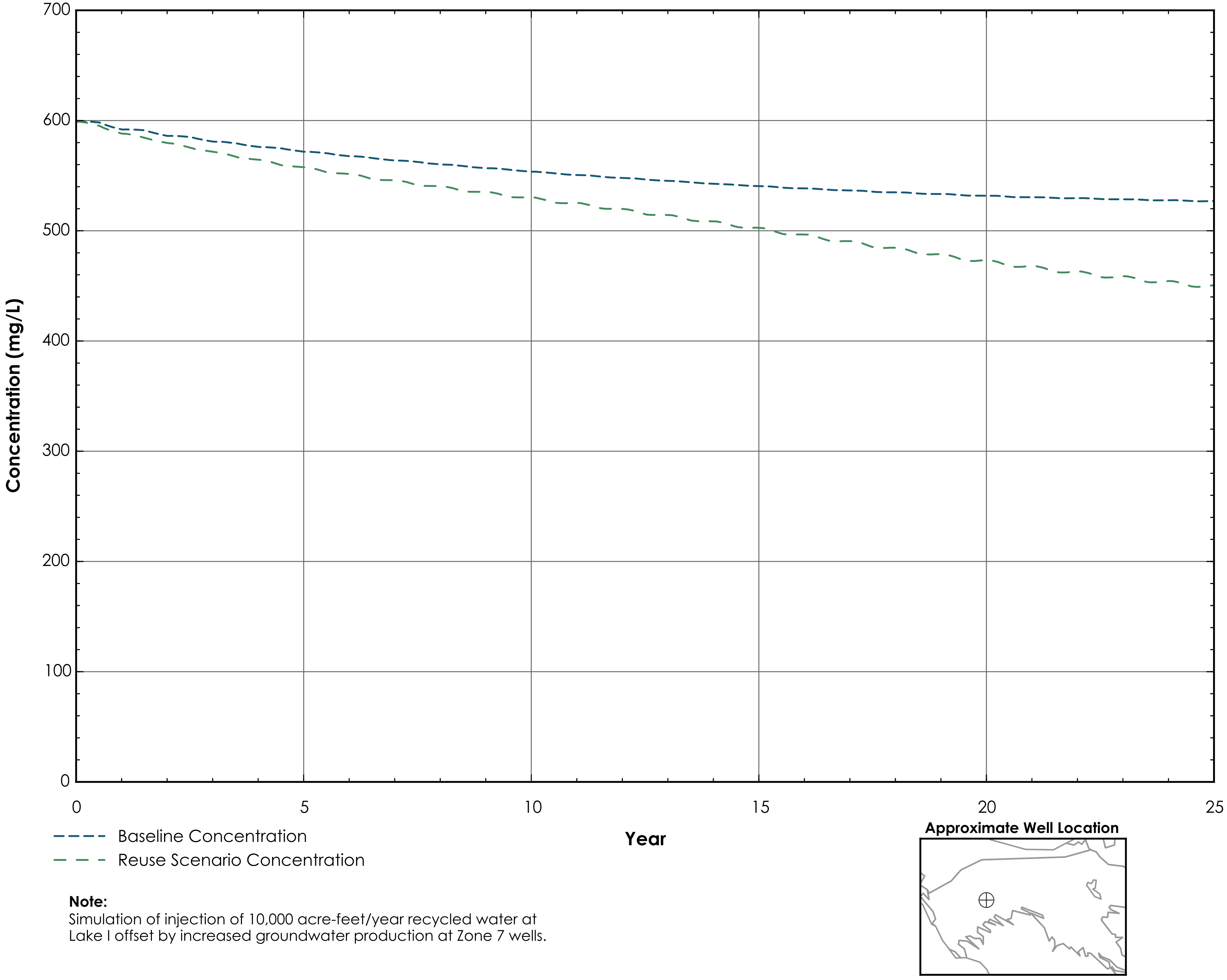
Well MOCHO 4 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I




Approximate Well Location

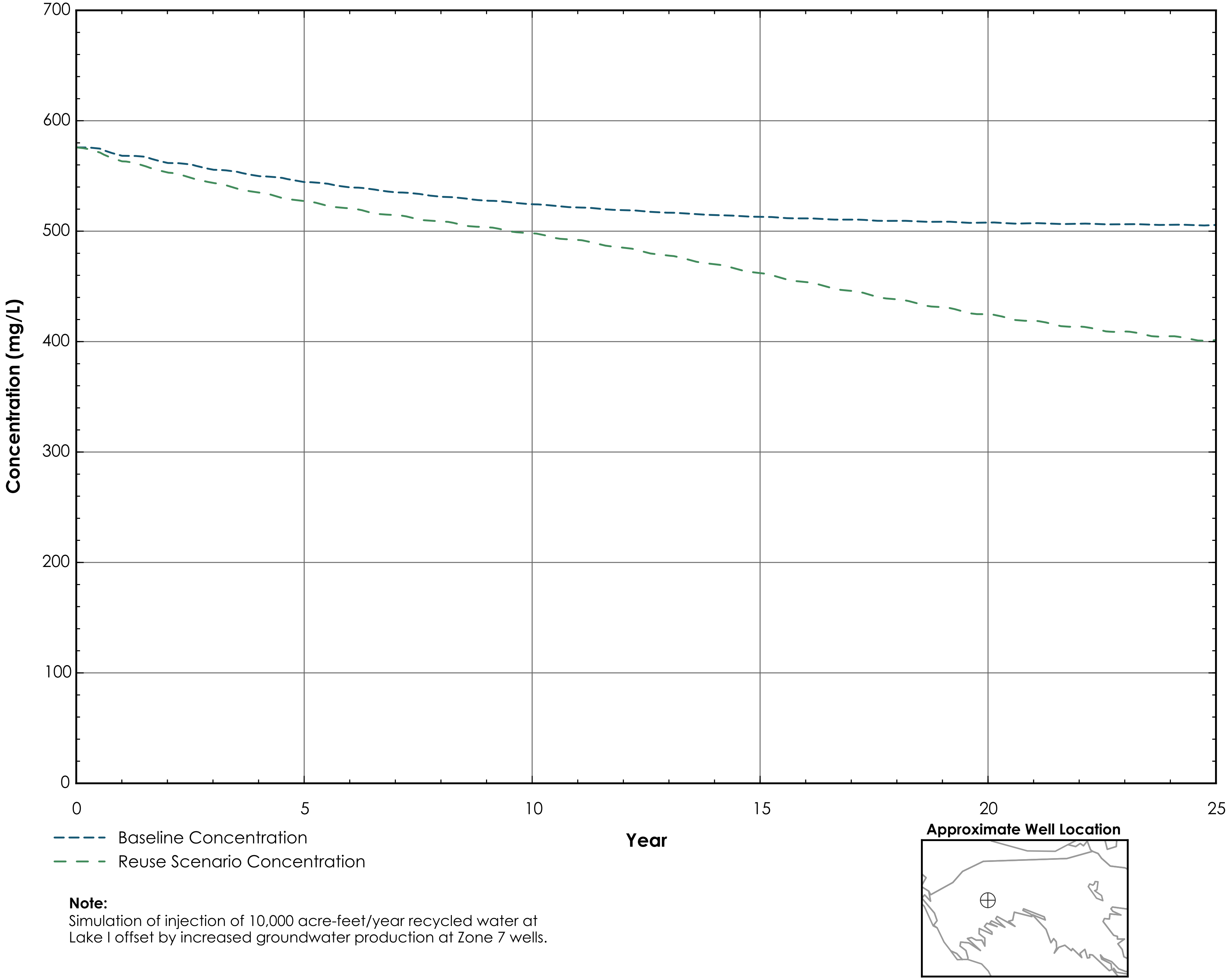
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at
Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 5 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



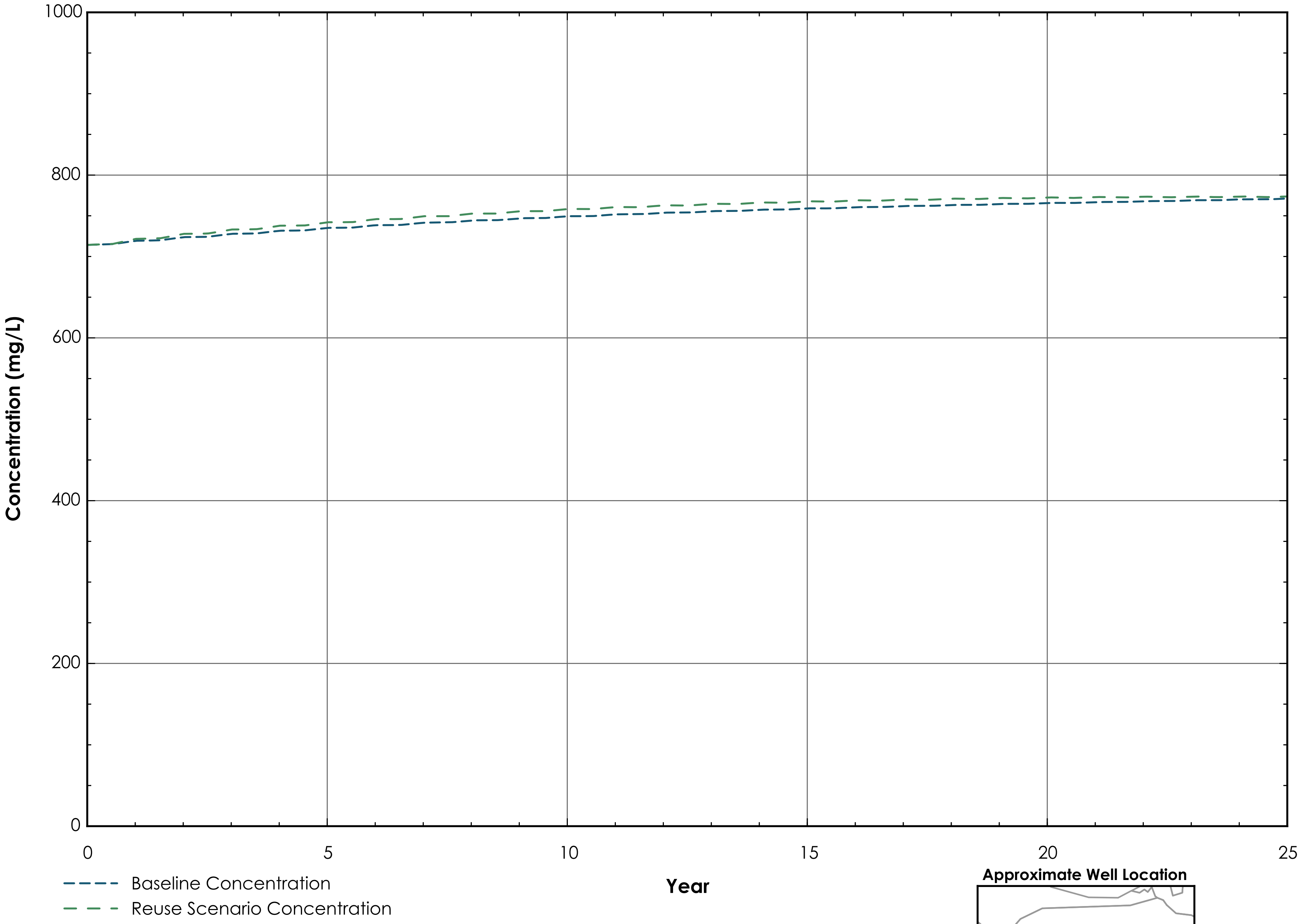
Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 6 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

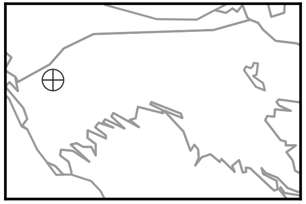


Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 7 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I

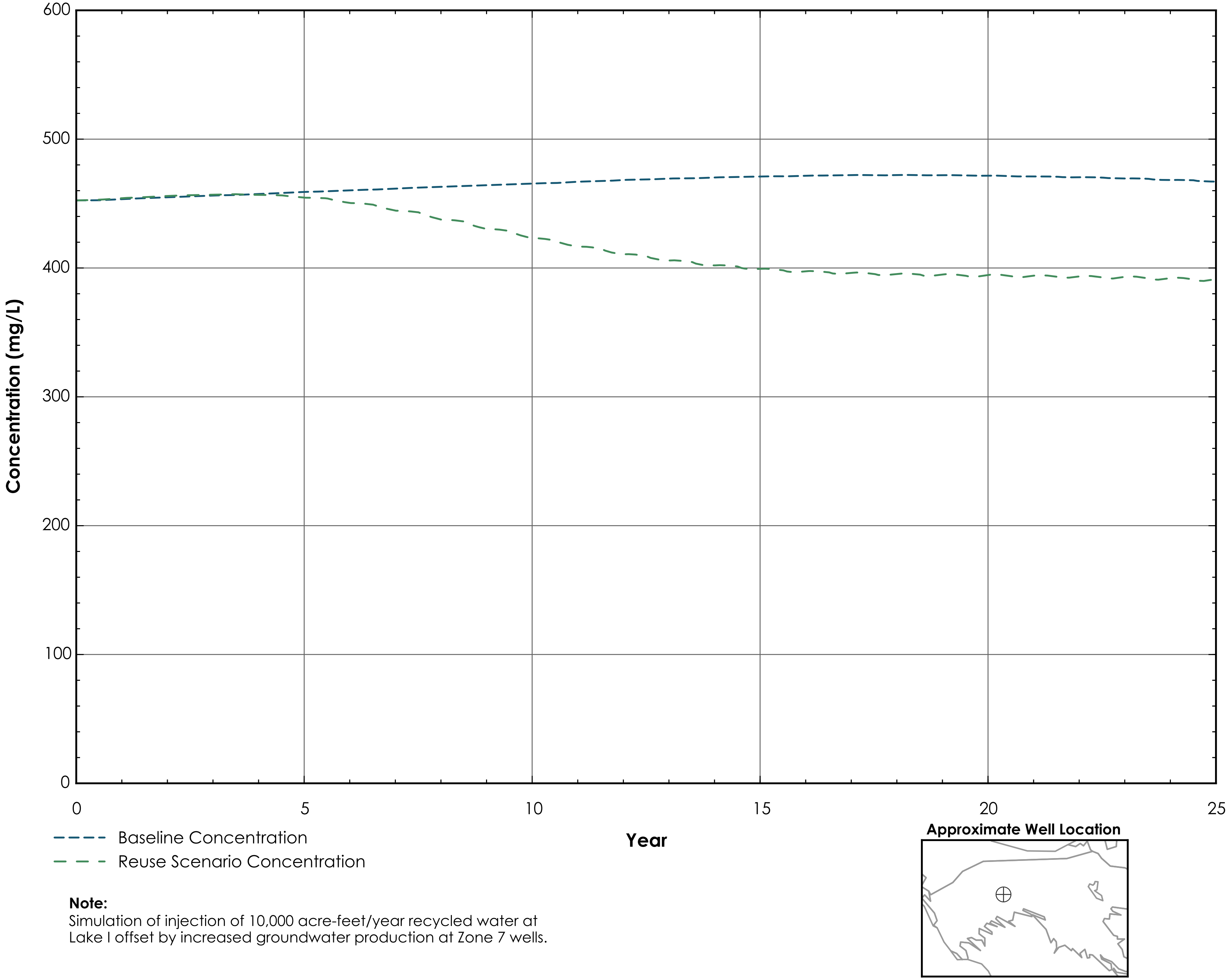


Approximate Well Location



Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Well PLEAS 8 Simulated TDS Concentration in Lower Aquifer
10,000 AFY Recharge to Lake I



Note:
Simulation of injection of 10,000 acre-feet/year recycled water at Lake I offset by increased groundwater production at Zone 7 wells.

Appendix D

ASR SYSTEMS TECHNICAL MEMORANDUM

540 NE 5th Avenue, Gainesville, Florida 32601
Phone 352-336-3820
Fax 352-373-2381
www.asrsystems.ws

The Pioneer of ASR Technology

TECHNICAL MEMORANDUM

To: Jeff Stovall, PhD/ Carollo
From: David Pyne and Richard Glanzman, PhD
Re: Review of a Technical Memorandum for Zone 7 dated October 23, 2000, by Dan Wendell/CH2M HILL, entitled “ASR Test Results for the Hopyard-6 Well”
Date: 11 August 2017

As a subconsultant to Carollo Engineers, ASR Systems LLC is investigating the viability of Aquifer Storage Recovery (ASR) and Recharge Wells for subsurface storage and conveyance of highly purified wastewater to augment water supply reliability and reduce salinity for Zone 7 and its customers. ASR Systems was asked to review the referenced report by CH2M HILL regarding prior ASR testing at the Hopyard-6 well, and to render an opinion as to 1) why we think ASR today would turn out differently than what they did before, and 2) to come up with the next steps to move forward.

Two subsurface water storage approaches are under consideration for meeting Zone 7 goals for storage and recovery of purified water that meets all drinking water standards. The first is an “ASR Approach,” under which low salinity recharge water would be stored within one or more sand intervals of the Lower Aquifer System and recovered from the same, or adjacent, wells after storage for at least 60 to 120 days. Recovered water would then be blended with water produced from other sources to immediately achieve drinking water salinity goals.

Under the second, “Recharge well” approach, recharge water would be injected into the same sand intervals of the Lower Aquifer System. It would then flow to down-gradient production wells located at a sufficient distance so that a travel time of at least 60 to 120 days is ensured. Actual travel time may be months to years. The stored water, blended with native water in the aquifer, would be eventually pumped from production wells for potable water supply. A reduction in salinity of the produced water is reasonably expected, but may or may not actually occur since there remains uncertainty regarding the source of the saline water that is currently causing a steadily increasing salinity from the Lower Aquifer System. This is presumed to be due to leakage from the more saline Upper Aquifer System, however it could also be partly due to upward leakage from below the Lower Aquifer System. This is a common issue for ASR wells storing water in saline aquifers or in fresh aquifers underlain by more saline aquifers. Resolution of this uncertainty would require further investigations.

Well B Site Information and Basis of Recommendations

This Technical Memorandum is based upon information from the previous 3-layer simulation model of the Zone 7 aquifer system, and the recently-updated 10-layer model, indicating the following pertinent characteristics at the Well B site that has been tentatively selected for subsurface storage:
Even numbered layers in the updated, 10-layer model represent coarse-grained water-bearing deposits. Layer 5 represents the main aquitard that separates the Lower Aquifer System (LAS) and the Upper Aquifer System (UAS) in the main basin. For the original, three-layer simulation model, the UAS, Aquitard and LAS were the three layers.

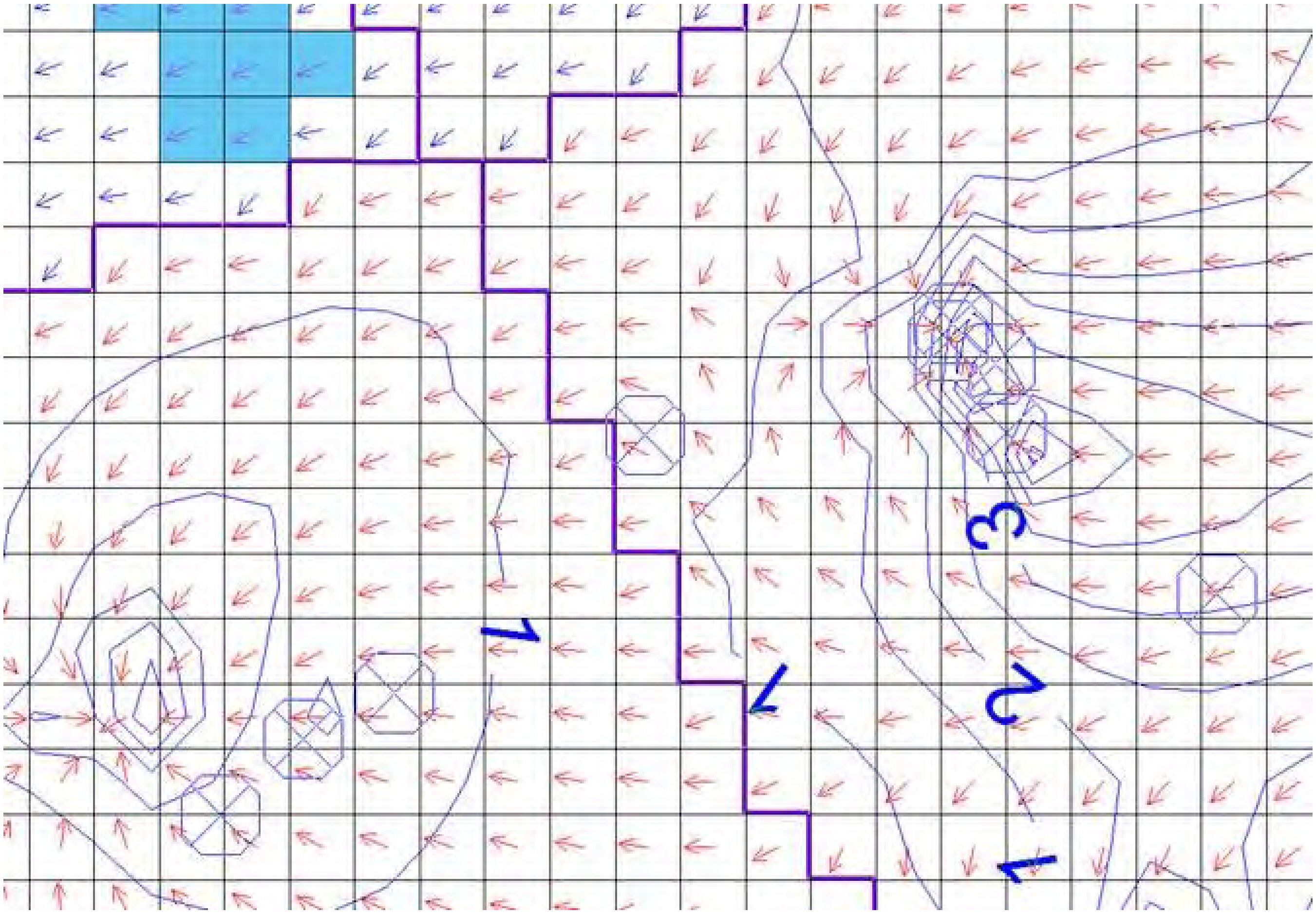
Well B is tentatively located at 6,160,635E, 2,074,810N, or (66,51) in the updated model. The following data from the updated model is for that location, as delineated in the table below.

Layers 6, 8 and 10 are the sand and gravel layers of interest for ASR or Recharge well operations. The “Top of Layer” and “Bottom of Layer” columns are land surface elevations, indicating that these three layers are, respectively, 104, 174 and 161 feet thick. Confining or semi-confining layers overlying or underlying these sand intervals are 26, 45 and 104 ft thick. Thickness of the confining layer beneath Layer 10 is unknown. The very thick sand layers each provide excellent potential storage reservoirs for purified water, laterally displacing the native groundwater around each well. ASR wells in these three sand intervals could possibly be stacked one on top of the other, achieving substantial storage volume within a relatively small radius. Kx and Kz are estimates of horizontal and vertical hydraulic conductivity. Ss and Sy are estimates of specific storage, while “n” is an estimate of effective porosity, probably based on geophysical log interpretation. It is anticipated that core analysis will indicate a higher porosity estimate such as double this amount.

Near Well B, velocities in the aquifer are in the range of 0.4 to 0.7 ft/day. The velocity through cell (66,51) is 0.43 ft/day. Flow through the aquitard between the upper and lower aquifers is downward at 0.00654 ft/day at this location in this simulation. These are very preliminary estimates pending further model development and verification. It is likely that lateral velocities will be slower in deeper sand intervals of the LAS, and higher in the UAS.

Layer	Top of Layer	Bottom of Layer	Kx	Kz	Ss	Sy	n
1	333.7	293.4	0.155	0.00276	1.03E-06	0.095	0.129
2	293.4	267.6	20.6	2.25	1.11E-06	0.133	0.171
3	267.6	262.6	0.884	0.00275	1.00E-06	0.183	0.212
4	262.6	252.6	20.6	2.25	1.11E-06	0.133	0.171
5	252.6	226.8	1.00	0.0992	1.10E-06	0.245	0.275
6	226.8	122.9	7.40	0.809	2.66E-06	0.117	0.140
7	122.9	78.1	0.992	0.03	2.42E-06	0.150	0.174
8	78.1	-95.9	7.40	0.809	2.66E-06	0.117	0.140
9	-95.9	-199.5	1.70	0.0514	2.42E-06	0.150	0.174
10	-199.5	-360.9	7.40	0.809	2.66E-06	0.117	0.140

A screenshot of the velocity vectors in layer 3 (deep aquifer, Lower Aquifer System) of the previous 3-layer model is shown below. The Well B location is the blue marker in the center.



Next Steps To Move Forward

If Zone 7 elects to move forward with either an ASR approach or a Recharge Well approach for purified water storage to provide water supply security while meeting regulatory requirements, the recommended sequence of steps is as follows:

1. Select a preferred area for construction and testing of wellfield facilities. Currently this is assumed to be the site of Well B and surrounding area. Site selection criteria would include hydrogeologic evaluation of expected aquifer and confining layer characteristics, and expected travel time to adjacent production wells; infrastructure proximity and availability (treatment facilities, transmission pipelines, drainage facilities for disposal of well backflush water; site access; power supply, etc); and land area to support construction and operation of wellfield and related facilities. Other criteria will undoubtedly impact the site selection process.

2. Construct a continuous wireline core hole from the land surface to a sufficient depth below the base of the Lower Aquifer System (LAS) (Model Layer 10) so that underlying vertical confinement can be evaluated. Tentatively this would be to a depth of about 800 ft, or about 100 ft below the estimated base of the LAS. During coring operations, provide full-time resident observation services by an experienced hydrogeologist familiar with coring and core handling, including field lithologic analysis; marking, recording, photographing, preservation and storage of the cores; geophysical logging of the core hole; shipping of selected frozen cores to a core lab for detailed geochemical and geotechnical analysis; preparation of a detailed lithologic analysis of the cores, and preparation of a coring summary report, including the results from the core lab and

associated core lab report. Grout back the core hole to land surface. Alternatively, consider completing the core hole as a monitor well for Layer 10, or possibly another potential storage interval. Also consider obtaining depth-specific water quality samples in the core hole. These are less likely to be representative of native water quality at each sample depth, as compared to samples pumped from a monitor well, however comparison of the values will be of interest.

Cores were not collected for the Hopyard-6 ASR test, resulting in the lack of sufficient information to interpret the recovered water geochemistry and understand what caused the continuous decline in the aquifer transmissivity during the five cycles of ASR testing.

3. Construct individual monitor wells completed in Layers 6, 8 and 10 at the selected site. If the core hole has been completed as a monitor well in Layer 10, a second monitor well in Layer 10 may not be needed. The primary initial purpose of these monitor wells would be to obtain reliable data on the water quality for each of the interval(s) that are potentially being screened. Water samples from a properly designed monitor well are more reliable than water quality samples from a continuous wireline core hole.

   Recovered water from the Hopyard-6 ASR cycle testing indicates that there are differences in the native groundwater chemistry of the screened depth intervals. Mixing of these native groundwaters from the screened depth intervals when the well was idled may be responsible for at least part of the continuous increase in well clogging. Mixing of the recharge water with the native groundwater did result in the precipitation of calcium carbonate. The resulting precipitation could be considerably different for depth intervals with differing native groundwater chemistry. Therefore, it is important to know the baseline chemistry of native groundwater from the three layers. Monitoring wells in the three layers would not only monitor the water level but also document the arrival and transport of the recharge water through each layer.

4. Prepare a representative estimate of recharge water chemistry and variability for each of approximately 50 constituents of interest for geochemical analysis. If more than one source may be utilized for aquifer recharge, prepare such a list for each constituent for each source. For the same water quality constituents, determine the native groundwater quality in each storage aquifer interval.

   As with the Hopyard-6 ASR tests, there may be more than one recharge water source making up the recharge water chemistry. If so, it is important to have a representative water chemistry of each source if the relative amount of each is not a constant to understand the chemical reactions occurring between the recharge water and the mineralogy of each layer affecting the recovered water chemistry and potential plugging of the individual layers.

5. Use Geochemist's Workbench software to conduct a geochemical model analysis of mixing between the recharge water quality, the native groundwater quality, and the potential short term and long term impact of chemical reactions occurring between the mixture and the mineralogy of each layer. The purpose of this analysis is to predict subsurface geochemical reactions, estimate the recovered water chemistry and provide recommendations regarding pretreatment geochemical conditioning of the aquifer and/or of the recharge water that may be necessary to provide for aquifer storage without well clogging or potential problems in the recovered water chemistry. For example, this might include pH adjustment of the recharge water to prevent chronic well clogging due to calcium carbonate precipitation.

   There was insufficient data to perform this geochemical modeling on the Hopyard-6 ASR project and help understand the chronic well clogging that occurred during the five cycles at the site. Prior geochemical modeling may have controlled or prevented well clogging during ASR cycle testing.

6. Prepare a Preliminary Design Technical Memorandum (PDTM), constituting a 30% design deliverable, providing the Basis of Design for subsequent wells and wellhead facilities, and equipping of the wells. A draft document would be reviewed and approved by Zone 7 to determine that it is consistent with evolving program goals, current understanding of the area hydrogeology, risk management, needs, constraints and opportunities. To the extent that such topics have not already been addressed in prior investigations, the PDTM would address the following issues:
   a. Project objectives, listed and prioritized
   b. Recharge water quality and variability
   c. Water demand, trends and seasonal/drought variability
   d. Recharge water supply, trends and variability
   e. Selection of an ASR approach or a Recharge well approach
   f. Target Storage Volume, including Buffer Zone Volume (for an ASR approach)
   g. Hydrogeology of the Selected Site, including geochemical considerations
   h. Conceptual design of wells, equipping of wells, and wellhead facilities
   i. Pretreatment, post-treatment and well conditioning
   j. Preliminary estimate of construction and capital costs for wellfield and related facilities
   k. Regulatory considerations and requirements
   l. Legal, environmental and institutional issues

7. Design, permit, construct and test a demonstration ASR or Recharge Well, or perhaps both. The well design may be different, but both would be equipped with a pump to provide for periodic backflushing. Backflushing frequency might range from once or twice a week to as much as once every two months, to be determined during demonstration well startup testing and during the first year of operations. Initial testing of each well would include a step drawdown test and a constant rate pumping test to establish well efficiency and aquifer hydraulic characteristics. This would be followed by a step injection test to establish recharge hydraulic characteristics. Injection testing could be accomplished with potable water if the purification treatment plant is not yet operational. Design and analysis of pump test results would be conducted to establish leakance characteristics of overlying and underlying confining layers, supplementing conclusions based upon prior analysis of the continuous wireline cores. Equipping of the well(s) would be conducted after hydraulic performance has been confirmed through initial testing. The wellhead design would provide for maintaining a small pressure at the wellhead during aquifer recharge, such as up to about 10 psi.

   For an ASR well, the well design would likely be in one or more of the three, thick sand intervals comprising Layers 6, 8 or 10 of the hydrogeologic simulation model of the selected site. Alternatively, consideration should be given to constructing a cluster of three ASR demonstration wells, one screened in each major sand interval, instead of a single ASR well in one or more sand intervals. Water stored in an ASR well would be recovered after 60 or 120 days of storage, as approved by regulatory agencies. Stored water may be recovered from the same ASR well or, depending on confining layer hydraulic characteristics, could be recovered from an adjacent layer, providing supplemental soil aquifer treatment. Water would be recovered locally at the Well B site and would be blended as needed to meet Zone 7 needs for peak water supplies and/or for reducing salinity.

   For a Recharge Well, the well design would likely be open to all three sand intervals. Other than periodic backflushing to maintain hydraulic performance, no water would be recovered from a Recharge Well. Instead it would be recovered months to years later at a down-gradient production well. At that time it may or may not reduce salinity of the produced drinking water, depending upon the source of the currently, steadily increasing salinity. Baseline TDS at the Hopyard-6 well prior to 1997 to 2000 ASR testing was in the range of 480 to 550 m/gl. Recovered water during ASR cycle testing showed a reduction in salinity. The well has been in a production mode of operation since then, and salinity has most recently been 675 mg/l.

8. Monitor performance of the demonstration wellfield facilities. This will include regular water chemistry sampling of the recharge water and, for ASR wells, the recovered water. For Recharge wells, sampling would also occur at downgradient monitor wells and downgradient production wells. Tracer testing would be needed for the Recharge well so that arrival of the leading edge of the recharge bubble may be detected when it reaches each successive monitor well or production well. Tracer testing may also be advisable for the ASR well, establishing recovery efficiency after the water has been stored for 60 days or 120 days. Further investigation would be appropriate to determine whether an intrinsic or extrinsic tracer would be needed to differentiate between the recharge water and the native groundwater. Most ASR tracer testing to date has been conducted with intrinsic tracers such as conductivity and chloride.

   Monitoring during the first year would also include hydraulic performance, including Specific Capacity during Production (SCp) and Specific Capacity during Injection (SCi); recharge and recovery flow rates and cumulative volumes; backflushing frequency, procedures, volumes discharged to waste, and overall performance. Periodic review of monitor program results will provide a basis for adjustment of operating procedures to enhance well performance, and also an improved Basis of Design for wellfield expansion.

9. Expand wellfield facilities at the “Well B” site, whether ASR or Recharge Wells, sufficient to provide for 10,000 AFY of recovery capacity, or whatever updated goal may have been determined at that time. Expansion would include one or more monitor wells in each interval of the LAS, or possibly a multi-zone well monitoring all three sand intervals.

   If Zone 7 elects to proceed with ASR wells, construct one or more clusters of three ASR wells, each well screened in one of the three, thick, sand and gravel intervals of the LAS. Operate each well in each cluster to achieve at least 60 days of subsurface storage, then recover the stored water from the same well or possibly from an adjacent well, and blend with other water supply sources. Any water that is not recovered from the ASR wells, such as due to lateral movement of the stored water, will not be lost. It will be eventually recovered from the downgradient production wells. It is anticipated that lateral velocity of groundwater movement in deeper sand intervals of the LAS will tend to be slower than in shallower intervals, and also slower than in the UAS.

   If Zone 7 elects to proceed with Recharge Wells, recharge whenever purified water is available and recover from downgradient production wells when needed to meet drought or seasonal peak demand needs. It may be possible to interconnect all three sand intervals of the LAS in a single LAS well instead of three separate wells, depending upon the ability to manage well clogging by periodic backflushing. If more intensive well redevelopment methods are needed to maintain recharge performance, such as bringing in a well driller; removing the backflush pump; setting packers downhole and pumping each screened interval separately, then operating costs will increase, perhaps justifying the same design approach as for the ASR wells. Recovery of the stored water may occur months to years later, and may or may not reduce salinity of the drinking water provided to consumers from the production wells, depending upon the source of the currently steadily increasing salinity. The source of the increasing salinity is generally assumed to be downward movement of more saline water from the UAS, through the semi-confining layer separating the UAS from the LAS. Based upon experience at other ASR sites, it may also be partly due to upward movement of more saline water from sedimentary layers beneath the LAS.

10. Operating permits will have been issued. Monitor performance of the expanded wellfield facilities. The frequency and intensity of monitoring should be significantly reduced compared to the comparable level of effort during the demonstration period. The number of water quality constituents being monitored would be scaled back, as would the sample collection frequency.

Hydraulic performance (water levels, flows, daily and cumulative volumes) would continue to be monitored through a SCADA system with data stored on a Hiistorian, providing the opportunity for an annual performance review that should be conducted. An annual report should be prepared, including recommendations for operational enhancements that would improve overall performance.

The ten steps listed above for moving forward with an ASR or Recharge well program at Zone 7 are consistent with project development procedures developed and implemented during the past thirty years at many ASR and recharge wellfield sites, particularly at those where there has been no prior well recharge experience. At locations where ASR wells or wellfields have been in successful operation for many years, some of these steps can be scaled back or perhaps eliminated since the risk of an adverse outcome is greatly reduced. The underlying principal is to develop such a project in phases, learning as you go along, and with "go, no-go" decision points along the way. Such an approach is an effective way to manage risk.

Some water utilities and agencies make a conscious decision to bypass these recommended steps, thereby saving time and money, but accepting the higher risk associated with such a decision. Usually this is in the form of putting some water down an existing production well, often an old, abandoned one; waiting a few days, and then pumping it out to see what happens. This is similar to what Zone 7 did in 1999. With insufficient data, it is not possible to interpret the results. Well clogging occurred, but the reasons for that are unclear, whether physical, microbial or geochemical clogging occurred, or some combination of these three clogging mechanisms. As indicated elsewhere in this Technical Memorandum, physical clogging due to air entrainment is likely to have been a significant factor contributing to both the acute clogging incident that occurred during September 2000, and also the chronic clogging that occurred during the cycle testing program from 1997 to 2000. Air entrainment may have had a secondary effect of contributing to geochemical clogging that probably also occurred. Regardless of the reasons for this perceived failure, the results effectively dampened local enthusiasm for ASR as a potential water management tool for achieving water supply reliability. It has taken 16 years, and ASR success at many other locations nationwide and overseas, for Zone 7 to revisit the potential application of this subsurface water storage technology to meet evolving local needs.

ASR wells and Recharge wells have several unique design features that differentiate them from production wells. Equipping of ASR wells and Recharge wells is also different when compared to production wells. For example, downhole flow control valves are typically recommended for ASR wells where cascading of recharge water may otherwise occur, ensuring a small pressure at the wellhead, regardless of the recharge flow rate, so that air entrainment does not occur. Unlike the Hopyard-6 well, ASR wellheads are typically designed to hold pressure.

Pumping a well prior to recharge, and purging any stagnant water in wellhead piping prior to recharge, is still recommended. However, we typically do not rely on this to initiate recharge through a siphon down the pump column. If air vacuum relief valves in the wellhead piping are inadvertently left open, or are leaky, or if the well is inadvertently not pumped to waste prior to initiating recharge, air will be siphoned into the water column under the partial vacuum that often occurs at the wellhead. This can clog a well in a few minutes and is probably what happened during the acute clogging event that occurred in November 1999.

A review of the hydraulic data for the five cycles conducted in 1997 to 2000 (Figure 5) indicates that static water levels typically varied between 35 and 45 ft below ground surface (BGS). Recharge water levels were generally in a range of 5 to 25 ft BGS, with extremes ranging from 35 ft to 0 ft BGS (overflowing at the wellhead). Some head loss would have occurred during flow down the approximately 350 ft of pump column and through the pump bowls. Assuming a 14-inch pump column diameter inside the 18-inch casing, the head loss was probably less than 5 ft at a recharge flow rate of 2,000 GPM. This suggests that the wellhead was under a partial vacuum virtually all of the time during recharge periods. Any opportunity for air entry, such as through a leaky or open air relief valve or a pump shaft seal, would cause air entrainment. At 2,000 GPM, downhole velocities in the pump column and in the well casing below the pump intake would have significantly exceeded the approximately 1 ft/sec rise rate for entrained air bubbles. Entrained air would then enter the well screens, filter pack and surrounding aquifer, causing air binding and chronic well clogging. The additional oxygen added to the water would contribute to geochemical and microbial well clogging, such as by increasing the pH and causing increased precipitation of calcium carbonate.

The acute clogging that occurred in November 1999 was probably caused by starting recharge without prior pumping to waste to purge air and particulates from the well and pump column. Perhaps closing of air/vacuum relief valves may also not have been implemented at that time. That would have pulled probably a full vacuum at the wellhead at startup, entraining a lot of air and carrying it downhole, causing the observed rapid well clogging. At other ASR sites where this has occurred, clogging has occurred in minutes from startup. Once clogged with air, it sometimes takes weeks for the air to go into solution under the increased downhole pressure. As indicated above, a recommended, better approach for equipping ASR wells is to provide a downhole flow control valve so that a small, positive pressure is maintained at the wellhead, regardless of the recharge flow rate.

Inner casing materials of construction avoid the use of mild steel since corrosion products are swept downhole during aquifer recharge, contributing to well clogging by both physical and microbial processes.

ASR well design, equipping and operation includes several unique features that are different than for production wells or injection wells. Understanding these differences is important for ensuring ASR success.

Why ASR Today Would Turn Out Differently

With phased implementation of the recommended sequence of steps outlined above, data would be available to guide the ASR or Recharge well program along a proven, logical path, with facilities designed for project purposes and a commitment to obtaining necessary, reliable data. Any project working hundreds of feet below ground has inherent risks and uncertainties, but these can be managed and minimized.

Wells would be designed based upon extensive, site-specific data to guide storage interval selection, screen design, filter pack design to maximize well efficiency, and operational procedures to efficiently achieve program goals. Wellfield design and operations, such as well spacing, would be based upon a well-informed local model, based on site-specific data regarding groundwater velocities, leakance of confining layers, and pressures in different sand intervals. Wellhead facilities would be designed to maximize flow rates and thereby minimize unit operating costs. Pretreatment would be implemented if necessary to control well clogging. Unique backflushing and well development procedures would be implemented to maximize well recharge and recovery rates. All of these key elements contribute toward ultimate project success.

Air entrainment would be eliminated as a potential cause of chronic and acute well clogging, through appropriate equipping of the well(s) with use of downhole control valves. This would also further reduce the potential for geochemical clogging due to calcium carbonate precipitation.

Well casing and column pipe would avoid the use of mild steel, thereby eliminating a potential source of corrosion products that can clog a well screen while stimulating microbial activity downhole. Corrosion products from mild steel also tend to increase the duration and frequency of backflushing required to maintain well performance, and the volume of backflush water that requires disposal.

A disinfectant residual would be maintained downhole at all times, not only during recharge periods but also during extended periods of no recharge and no recovery, exceeding about one week. This would be achieved through a trickle flow of disinfected water during extended storage periods. Disinfection byproduct attenuation would occur during the 60-day to 120-day storage periods underground.

If needed, pretreatment of the recharge water could be implemented to reduce well clogging. This might be through pH adjustment to eliminate calcium carbonate precipitation or to avoid destabilization of clays.

If bypass filter testing indicates occasional slugs of poor quality water reaching the wellhead, such as may occur due to flow reversal in a long transmission pipeline, a simple wellhead filtration system could be installed as a supplemental pretreatment device.

ASR wells or Recharge wells would be designed and equipped to provide for efficient backflushing and redevelopment procedures, maximizing the energy available to periodically purge particulates from around the well screens and to stabilize the filter pack material for both recharge and recovery.

Most importantly, Zone 7 would be guided by a consultant team that has worked together for decades, successfully implementing ASR programs for clients nationwide and in other countries. Such proven performance is the best indicator of likely success of an ASR or Recharge well program for Zone 7. Carollo and ASR Systems have worked together on numerous ASR projects nationwide since 2001, when David Pyne formed ASR Systems after leaving CH2M HILL. Prior to 2001, David Pyne and Richard Glanzman worked together at CH2M Hill on numerous ASR projects nationwide, from the initial ASR project in 1980. That teaming relationship has continued since 2001. Other team members at Carollo and at ASR Systems bring unmatched ASR experience to Zone 7.

Summary

If implemented today, an ASR or Recharge well program for Zone 7 would most likely be successful, providing water supply reliability during droughts; meeting peak demands, and reducing salinity. The best guarantee of success would be to follow a proven procedure for successful ASR or Recharge wellfield development, as described in this Technical Memorandum, working with a team of engineers, hydrogeologists, geochemists and others who have a substantial depth of ASR and Recharge well experience. At least 500 ASR wells and about 130 ASR wellfields are currently operational in at least 20 states, plus many more in other countries. Many Recharge well projects are operational or in development nationwide. California has about 18 ASR wellfields and about 63 ASR wells. Zone 7 can benefit from this experience.

Appendix E

DETAILED DESIGN CRITERIA

TableE.1 Design Criteria for AWPFs

DESIGN CRITERIA	5 mgd AWPF	12 mgd AWPF
Effluent Feed Flow, gpm	4233	10277
Interstage Boost Pump Flow, gpm	2117	5139
Total Permeate Flow, gpm	3386	8222
Total Concentrate Flow, gpm	847	2055
Finished Water Flow, gpm	3386	8222
Finished Water Average Day Flow, gpm	3386	8222
MF Feed Pump Vertical Lift, ft H2O	10	10
MF Feed Pump Discharge Pressure, psi	35	35
RO Lift Station Vertical Lift, ft H2O	10	10
RO Lift Station Discharge Pressure, psi	30	30

Table E.2 Design Criteria for AWPFs

DESIGN CRITERIA	5 mgd AWPF	12 mgd AWPF
Raw Water TDS, mg/L	1400	1400
RO Permeate Water TDS, mg/L	85	85
Temperature, deg. C	30	30
Raw Water pH	7.50	7.50
Finished Water pH	8.65	8.65
Raw Water Chloride, mg/L	500	500
Permeate Water Chloride, mg/L	30	30
Blended Water Chloride, mg/L	30	30
Raw Water Sulfate, mg/L	85	85
Permeate Water Sulfate, mg/L	2	2
Blended Water Sulfate, mg/L	2	85
Raw Water Calcium, mg/L as $CaCO_3$	53	53
Permeate Calcium, mg/L as $CaCO_3$	0.65	0.65
Blended Water Calcium, mg/L as $CaCO_3$	0.7	53.0
Finished Water Calcium, mg/L as $CaCO_3$	24	24
Raw Water Alkalinity, mg/L as $CaCO_3$	120	120
Permeate Water Alkalinity, mg/L as $CaCO_3$	10	10
Blended Water Alkalinity, mg/L as $CaCO_3$	10	120
Finished Water Alkalinity, mg/L as $CaCO_3$	37	37
Finished Water CCPP, mg/L as $CaCO_3$	9	9
Finished Water LSI	0.9	0.9
% Calcium Rejection	99%	99%
% TDS Rejection	95%	95%

Table E.3 Chemical Concentrations

DESIGN CRITERIA	5 mgd AWPF	12 mgd AWPF
RO Recovery	80%	80%
MF Recovery	100%	100%
Membrane Feed Chemicals		
Sulfuric Acid, mg/L	184	184
Scale Inhibitor, mg/L	2	2
Aqua Ammonia	1.3	1.3
Sodium Hypochlorite, mg/L	5	5
Blended Permeate Chemicals		
Caustic Soda, mg/L	0	0
Calcium Chloride, mg/L	0	0
Lime, mg/L	24	24
Carbon Dioxide, mg/L	19	19
Chlorine Gas, mg/L	0.0	0.0
Sodium Hypochlorite, mg/L	6	4.8
Hydrogen Peroxide, mg/L	0	0

Table E.4 Microfiltration Design Criteria

DESIGN CRITERIA	5 mgd AWPF	12 mgd AWPF
MF Membrane Flux, gfd	25	25
Production Cycle Duration, min	30	30
Backwash Duration, min	3	3
Filtrate Recovery, %	98	98
Feed Water Recovery, %	94	94
Square feet of MF Membrane Per Module, ft^2	800	800
Number of MF Modules, No.	335	814
Number of Modules/Rack	100	100
Number of Racks (1 Redundant)	6	11
Membrane Life, years	5	5
Hydraulic Configuration	Outside to Inside Flow	Outside to Inside Flow
MF Maintenance Clean Frequency		
Sodium Hypochlorite Solution, gallons per day	10,000	24,000
Sodium Bisulfite Solution (Neutralization), gallons per day	10,000	24,000
MF Maintenance Clean Chemical Dose		
Sodium Hypochlorite, ppm	500	500
Sodium Bisulfite (Neutralization), ppm	735	735
MF Maintenance Clean Chemical Use		

Table E.4 Microfiltration Design Criteria (continued)

DESIGN CRITERIA	5 mgd AWPF	12 mgd AWPF
Sodium Hypochlorite, lbs per year	15,197	36,472
Sodium Bisulfite (Neutralization), lbs per year	22,339	53,614
MF Clean-in-Place Frequency		
Sodium Hypochlorite Solution, gallons per month	10,000	24,000
Sodium Bisulfite Solution (Neutralization), gallons per month	10,000	24,000
Sulfuric Acid Solution, gallons per month	10,000	24,000
Citric Acid Solution, gallons per month	10,000	24,000
Sodium Hydroxide Solution (Neutralization), gallons per month	10,000	24,000
MF Clean-in-Place Dose		
Sodium Hypochlorite, ppm	500	500
Sodium Bisulfite, ppm	735	735
Sulfuric Acid, ppm	5,000	5,000
Citric Acid, ppm	5,000	5,000
Sodium Hydroxide, ppm	10,000	10,000
MF Clean-in-Place Chemical Use		
Sodium Hypochlorite, lbs per year	500	1,199
Sodium Bisulfite, lbs per year	734	1,763
Sulfuric Acid, lbs per year	4,996	11,991
Citric Acid, lbs per year	4,996	11,991
Sodium Hydroxide, lbs per year	9,992	23,982

Table E.5 Reverse Osmosis Design Criteria

DESIGN CRITERIA	5 mgd AWPF	12 mgd AWPF
RO Recovery		80%
RO Flux, gfd	12.0	12.0
RO Feed Pump Suction Pressure, psi	20	20
RO Feed Pump Discharge Pressure (ave), psi	150	150
RO Feed Pump Discharge Pressure (max), psi	165	165
Interstage Booster Pump TDH, psi	45	45
Pump Efficiency	70%	70%
Motor Efficiency	90%	90%
Maximum RO Process Power	2.41	2.41
Square Feet of RO Membrane Per Element, ft^2	400	400
Number of RO Membrane Elements, No.	1016	2466
Number of Elements per Pressure Vessel	7	7
Number of Pressure Vessels Per Train	54	54
Number of Pressure Vessels (Total)	145	352
Number of Trains (total)	3	7
Membrane Life, years	5	5
Membrane Cleaning Frequency, days	90	90
Cleaning Chemicals Consumption		
Low pH, lbs/cleaning	2660	6458
High pH, lbs/cleaning	2660	6458
Cartridge Filter Loading Rate, gpm/10-inch	2.5	2.5
Cartridge Filter Length, inches	40	40
Replacement Frequency, days	30	30
Number of Cartridge Filters, No.	420	1020

Table E.6 GAC Design Criteria

DESIGN CRITERIA	5 mgd AWPF	12 mgd AWPF
GAC Design Criteria		
Total Flow (gpm)	3386	8222
Loading Rate (gpm/ft2)	6.5	6.5
Adsorber Surface Area (SF)	56.5	56.5
Number of adsorbers	5	12
Flow per adsorber	677	685
Lbs of Carbon per Adsorber	20,000	20,000

Table E.7 UV AOP Design Criteria

DESIGN CRITERIA	5 mgd AWPF	12 mgd AWPF
UV Power Required, kW	245	583
UV Lamp Replacement Frequency years	1.60	1.60
UV Lamps (Duty), No.	408	972
UV Lamps replaced per year	255	608
UV Ballast Replacement Frequency, years	5	5
UV Ballasts, No.	204	486
UV Ballasts Replaced per year	41	97
UV Wiper Replacement Frequency, years	1	1
UV Wipers, No.	0	0
UV Wipers Replaced per Year	0	0
UV Sleeve Replacement Frequency, years	20	20
UV Sleeves, No.	408	972
UV Sleeves Replaced per year	20	49
UV Chemical Cleaning Interval, times per year	24	24
UV Chemical Cleaning, lbs/clean	300	545
UV Chemicals per year, lbs	7200	13078
Number of Reactors, (1 redundant)	3	8

Table E.8 ESB Design Criteria

DESIGN CRITERIA	5 mgd AWPF	12 mgd AWPF
Hold Time	30 min	30 min
Volume (each)	110,000 gal	250,000 gal
Diameter	35 ft	50 ft
Height	17 ft	19 ft
Freeboard	2 ft	2 ft

Appendix F

STAFFING MEMO

PROJECT MEMORANDUM

TRI-VALLEY POTABLE REUSE FEASIBILITY STUDY

Tri-Valley Agencies

To:	Rhodora Biagtan (DSRSD), Helen Ling (Livermore), Amparo Flores (Zone 7)		
Copies to:	Lydia Holmes, Elisa Garvey, Brian Graham, Andrew Salveson, Wes Mercado		
From:	Christina Casler		
Date:	8/31/2017	**Project No.:**	10414A.00
Subject:	Advanced Treatment Plant Staffing		

Purpose

The purpose of this memo is to determine the staffing requirement for a potential future advanced treatment potable water reuse facility. This need is precipitated by the ongoing Tri-Valley Potable Reuse Feasibility conducted by the Tri-Valley Agencies [California Water Service Company- Livermore District, City of Livermore, City of Pleasanton, Dublin San Ramon Services District (DSRSD), and Zone 7 Water Agency (Zone 7)].

The results of a preliminary screening revealed six optimum potable water reuse project alternatives for the Tri-Valley Area. In these alternatives, four different advanced water purification facilities (AWPFs) were identified, as described below. Each would treat secondary effluent from either Livermore Water Reclamation Plant (LWRP) or the DSRSD Wastewater Treatment Plant (WWTP). These alternatives, described in more detail in Technical Memorandum 5 - Detailed Alternatives Development, are listed below.

- A 5 million gallons per day (mgd) facility for raw water augmentation (RWA) consisting of microfiltration (MF), reverse osmosis (RO), granular activated carbon (GAC), ultraviolet advanced oxidation process (UV AOP) and an engineered storage buffer (ESB). This AWPF would be located on existing LWRP property.
- A 12 mgd facility for RWA consisting of MF, RO, GAC, UV AOP, and an ESB. This AWPF would be located on existing DSRSD WWTP property.
- A 12 mgd facility for groundwater augmentation (GWA) consisting of MF, RO, and UV AOP. This AWPF would be located at a location owned by DSRSD but not collocated with the WWTP.
- A 12 mgd facility for RWA consisting of MF, RO, GAC, UV AOP, and an ESB. This AWPF would be located on City of Pleasanton property.

For full cost accounting of each option, it is necessary to determine the staffing requirements. This memo provides a general schema and assumptions for determine staff numbers. The recommendations within this memo were based upon detailed discussions with Brian Graham (Carollo). Prior to joining Carollo as an employee of Suez, Brian was responsible for managing the operations and maintenance staff at the West Basin Municipal Water District's Edward C. Little Water Recycling Facility in El Segunda CA. That facility produces 40 mgd of new water using five different treatment trains for five different water reuse applications, including potable water reuse.

Definitions

Operations, Maintenance, Laboratory, and Maintenance staff are all necessary. The job description for each position is defined below. For small facilities, often staff will have responsibilities in more than one of the four listed areas.

- Operations Staff - The Operations Staff is responsible for the basic running of the plant, monitoring of effluent, and maintaining compliance. They are not responsible for major repairs. Many operators work 12 hour shifts (meaning they receive overtime in California). In DSRSD/Livermore, operators work 10-hour shifts, with overlapping start and end times. While this can be arranged, it would require 50 percent more staffing than is presented within this document.
  - Grade V Operator - Chief primary operator. A Grade V operator is required for permit compliance for the AWPF, but is not required on site at all times for an AWPF.
  - Grade III Operator - A lead Grade III operator is required on site at all times of AWPF plant operations.
  - Grade II Operator - The Grade II operators are support staff for the lead operators and would assist with the running of the plant.
- Maintenance Staff - Maintenance staff is at the plant about 8 hours a day, but can be on call for nights and weekends. They are responsible for keeping equipment in running shape. However, major repairs may be contracted out. Three specific types of staff are needed. Again, for a small plant, one person may be trained in multiple areas.
  - Electrician.
  - Mechanic.
  - Instrument Technologist - An instrument technologist is essential in AWPFs due to the high level of monitoring and instrumentation required.
- Lab Staff - The AWPF will require stringent testing procedures to maintain compliance. Many of these tests, at least initially, will be daily tests. It is recommended to have a fully staffed lab at the plant to prevent delays that could result from outsourcing lab testing. It may also be a long term cost saving to have in house lab versus contract work. Lab staff typically works 8 hour days.
  - Lab Supervisor.
  - Lab Technician.
- Management Staff - In addition to the working staff, a minimum layer of management is needed to provide overall direction and reporting to the Utility's General Manager.
  - Plant Manager.
  - Maintenance Supervisor.
  - Lab Manager (same as Lab Supervisor).
  - Admin.

Staffing Requirements & Assumptions

Two staffing scenarios were investigated for the future AWPFs - a fully sufficient staff, and a lean staff.

Fully Staff

The fully sufficient staff would not require significant amounts of emergency contract work and would not require as much automation. The plant would be able to be run comfortably. The estimated staff requirements are summarized in Table 1 below.

Table 1 Full Staff Requirements

Staff Title	Number
Grade V	2
Grade III	5
Grade II	6
Maintenance Supervisor	1
Mechanics	2
Electrician	1
Instrument Tech	1
Lab Supervisor	1
Lab Tech	4
Plant Manager	1
Ops Manager	1
Admin	1
Total	**26**

Lean Staff Requirements

The lean staff would require a heavily automated facility with much of the maintenance work outsourced, especially as the plant ages. The majority of the cut down in staff is in the lab. This means that much of the lab samples will have to be sent out to a contract lab for permitting. The lean staff requirement also assumes that much of the management would be handled by the existing Tri-Valley Agencies. Table 2 summarizes staffing requirements for a lean staff.

Table 2 Lean Staff Requirements

Staff Title	Number
Grade V	1
Grade III	5
Grade II	5
Mechanics	1
Electrician	1
Instrument Tech	1
Lab Tech	1
Admin	1
Total	16

Work Hours and Shifts

Operators typically will work a 12 hour shift and will work in a 3-day on, 2 day off, 2 day on rotation. All other staff are assumed to be full time 8-hour employees. Figures 1 and 2 show example two week operational shifts for the full and lean staff, respectively.

Shift teams for the full staff are shown in Table 3. Table 4 shows the lean staff shift teams. Floats are additional Grade III or V operators who can fill in for the full-time employee in case of vacation or sick-day.

Table 3 Full Staff Work Shifts

Shift Team	Number per team
Full time 8-hr staff	14
Day shift team 1	3
Day shift team 2	3
Night shift team 1	2
Night shift team 2	2
Float	2
Total	**26**

Table 4 Lean Staff Work Shifts

Shift Team	Number per team
Full time 8-hr staff	7
Day shift team 1	2
Day shift team 2	3
Night shift team 1	2
Night shift team 2	2
Float	2
Total	**18**

Certification Requirements

The State of California Division of Drinking Water (DDW) recognizes that many of the treatment systems used for potable water purification are not part of conventional water or wastewater operator training programs. To that end, DDW has pushed the CA/NV AWWA to develop a new operator certification program for "Advanced Water Treatment" (AWT) operators. DDW has requested (but not yet required) that new potable water reuse programs have one of more of their operators certified under the new AWT program, once it is in place.

The final AWT program is not solidified, but several CA/NV AWWA Expert Panels have met over the last year to develop and detail the job requirements and skill needs for the AWT operator. The same group of experts expects the program to be voluntary at first, but transition to mandatory for potable water reuse projects. Eligibility to take the AWT test is expected to be simple, requiring a minimum Grade III water or wastewater operator's license.

Appendix G

SITE VISIT MEMOS

PROJECT MEMORANDUM

TRI-VALLEY POTABLE REUSE FEASIBILITY STUDY

Date:	May 20, 2017
Project No.:	10414A.00

Tri-Valley Agencies

Prepared By:	Christina Casler and Andrea F. Corral
Reviewed By:	Lydia Holmes, Paul Friedlander and Andrew Salveson
Subject:	DSRSD Regional Wastewater Treatment Plant and Mocho Site Visit

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Purpose

The purpose of the May 11, 2017, site visits to DSRSD's Regional Wastewater Treatment Plant (WWTP) and Mocho site was to identify site specific conditions that related to locating an Advanced Water Treatment Facility (AWTF) at the plant site. These conditions include existing layout, electrical, piping, access, deliveries, and public impact, among others.

Advanced Water Purification Facility Location

DSRSD WWTP

The Carollo Team met with Levi Fuller (Operations Supervisor at the DSRSD's WWTP) and Rhodora Biagtan to tour possible locations at the DSRSD's WWTP and the Mocho Site.

The first option proposed for the location of the AWTF (12 mgd, 2.9 Acres area required) was the area located southwest of the existing facultative sludge lagoons (FSLs) (Site 1, Figure 1). However, this site had already been identified as a location for a potential mechanical dewatering facility. An alternative location is south of the LAVWMA diversion structure in the dedicated land disposal (DLD) (Site 2, Figure 1). The following advantages/challenges were identified for Site 2:

- Advantages:
  - Near LAVWMA facilities for ease of source water access and concentrate disposal.
  - Potential for easier staffing with proximity to future mechanical dewatering facility.
  - An electrical power sharing agreement may potentially be arranged with LAVWMA.

- Challenges:
  - Proximity of a solids handling facility close to an advanced treatment facility may pose issues from public perception and health perspectives.
  - While there may be the potential to arrange an electricity sharing deal with LAVWMA, this location will likely require to bring all utilities to the site, including electrical.
  - The site may be designated for a future SCFI solids handling project.
  - For construction, the lot will need additional site work to ensure that stormwater runoff stays on the DLDs. This could be construction of a berm around the AWPF, raising the site to a certain, or creatively grading the site. Future efforts will determine the most cost effective method of runoff management.

The best location for the AWTF identified during the visit was the southwestern corner of the DLD (Site 3, Figure 1). This location presents several advantages and challenges, listed below:

- Advantages:
  - The site provides great visibility of the project for public education and outreach.
  - Good access to the facility and for delivery of chemicals. Johnson Drive will be widened in the near future to accommodate planned development projects.
- Challenges:
  - For construction, the lot will need to be leveled and filled up to 10 feet.
  - This location will require extension all utilities to the site.
  - To bring source water to the site, a new pipeline will need to be extended from the LAVWMA pump station site. Alternatively, a new pipeline will need to be tapped off the Livermore 27" pipeline and the DSRSD 42" pipeline. A Other outcomes and considerations for the DSRSD site are as follows:
- During the site visit, the existing membrane building (both the MF and RO sections) was visited (Figure 3). This building, approximately 200 feet long and 50 feet wide, was identified as a potential housing for the new microfiltration (MF) membranes. Some of the piping could be reused and the building would be repurposed. This could potentially save up to $4 million in building costs. However, the cost savings come with extra complexity/inconvenience for the operators; they would have to drive between the MF units and other processes (crossing a road) potentially multiple times a day. This option can be investigated further in preliminary design should a project move forward.
- Use of any of the sites identified at DSRSD (sites 1, 2, 3) requires decommissioning a portion of their existing solids handling process.
  - The current solids percentage is 3 percent. At this rate, the DLDs are limited by liquids loading. If the solids percentage were raised to 6 percent (like through mechanical dewatering), the DLDs would have enough capacity even with reduced acreage to make room for an AWTF.
  - Mechanical dewatering will result in higher rates for the customer without some cost sharing with other agencies. This needs to be considered before pursuit of a project at the DLDs.
- The existing DLDs are required to have raised edges to keep rain runoff from escaping and impacting other locations. To use a portion of the DLD, berms would have to be constructed to prevent runoff from the DLDs getting into the project site. Alternatively, the entire project site could be raised to keep rain runoff contained within the DLDs. If the DLDs are be deepened, that soil could be used to raise the project site. DSRSD sent the groundwater surface elevation underneath the DLD and DLD topography information on June 14, 2017.

Mocho Well Site

An alternate location for the AWTF is at the Mocho site (Figure 4) property of DSRSD and the City of Pleasanton (Figure 5), south of the Zone 7 Mocho Groundwater Demineralization Facility. The site currently has multiple easements on it (Figure 6), including several easements to Zone 7 for a production well and pipelines. A high pressure petroleum pipeline also crosses the site. The available space is approximately 74,000 square feet (1.7 acres). The advantages and challenges of this location are presented below.

- Advantages:
  - Provides great visibility of the project.
  - Existing site appears to have all relevant utilities. It should be determined if these utilities can be expanded to meet the AWTF needs.

  - An electrical power sharing agreement may potentially be arranged with DSRSD.
- Challenges:
  - The site has public access and leads to a walking trail as shown in Figure 7.
  - There is an existing extraction well within the building onsite (Figure 8) that cannot be moved, which makes constructing in the tight site even more complex. A more detailed site layout will help determine the need to relocate the building.
  - The geometry of the site is narrow and not uniform.
  - The available area is not enough to accommodate the estimated AWTF footprint of 2.9 acres. An alternative would be a two story-building to reduce the footprint. Carollo will study the feasibility of this alternative

Action Items

- Carollo will include annual operating cost for solids disposal.
- Carollo will determine the cost to fill and level the site for construction (sites 2 and 3).
- Carollo will study the feasibility of a two story-building to reduce the footprint to accommodate the AWTF at the Mocho Site.

Figure 1 DSRSD WWTP Potential Locations

Figure 2 View of Access Road from Southwest Corner of DLD

Figure 3 DSRSD MF

Figure 4 Mocho Wells Site Potential Location

Figure 5 Mocho Site Parcel Lines

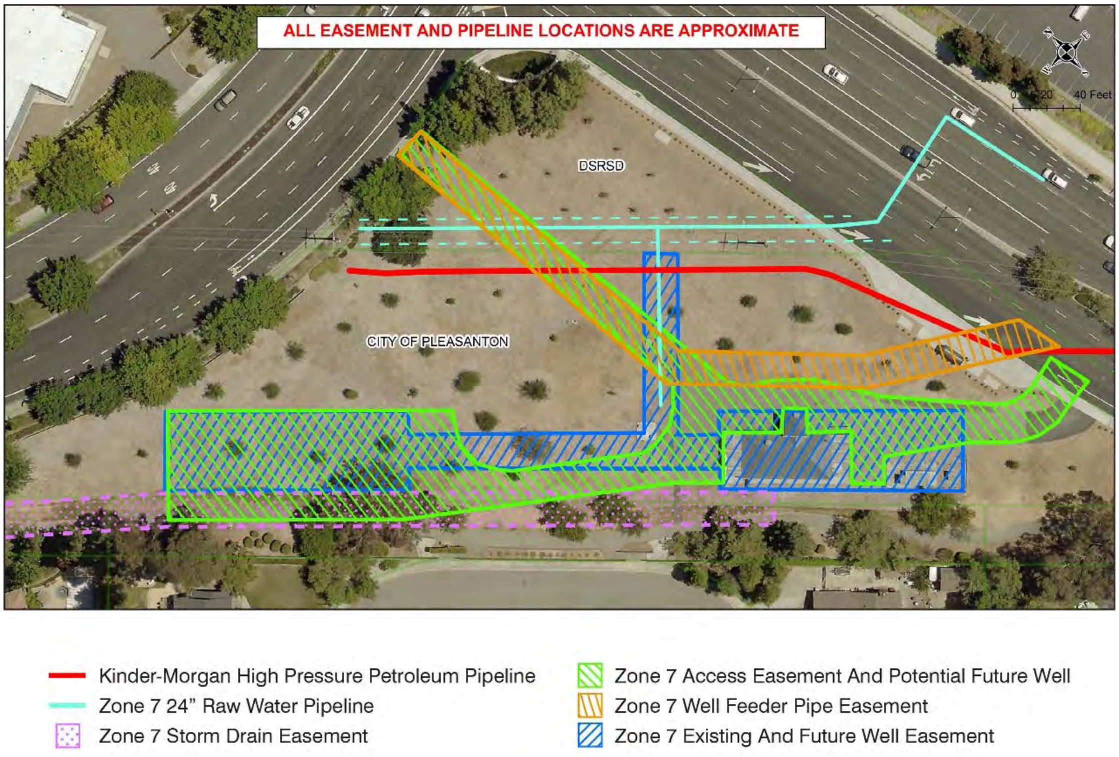

Figure 6 Existing Easements on Mocho Site

Figure 7 Public Access to the Mocho Wells Site

Figure 8 View of Zone 7 Chemical Building from West Side of Site

PROJECT MEMORANDUM

TRI-VALLEY POTABLE REUSE FEASIBILITY STUDY

Date:	May 23. 2017
Project No.:	10414A.00

Tri-Valley Agencies

Prepared By:	Christina Casler and Andrea F. Corral
Reviewed By:	Lydia Holmes and Zaheer Shaikh
Subject:	Livermore Water Reclamation Plant

Purpose

The purpose of the May 23, 2017, site visit to the Livermore Water Reclamation Plant (WRP) was to identify site specific conditions that need to be considered when locating an Advanced Water Treatment Facility (AWTF) at the plant site. These conditions include existing layout, electrical, piping, access, deliveries, and public impact, among others.

Advanced Water Purification Facility Location

The Carollo Team met with Helen Ling (Water Resources Division Manager), Todd Yamello and Jimmie Truesdell to tour possible locations for the AWTF at the Livermore WRP.

The first option for the location of the AWTF was the area currently occupied by the abandoned trickling filters (Figure 1, #32). However, this area was identified in the Wastewater Master Plan as an aeration basin expansion area for future nutrient removal. The initial idea of repurposing the reverse osmosis (RO) building (Figure 1, #29) was discarded - the building is too small, it does not have enough security, and it is already being used for office space. Similarly, the vehicle/material storage building (Figure 1, #31) was also discarded because the building is still in use and, in its current condition, it would not be beneficial to repurpose it.

The preferred location for the AWTF is the abandoned facultative sludge lagoons site located in the southwest edge of the Livermore WRP (Figure 1, #20 and Figure 2). The following advantages/challenges were identified for this site. A potential layout is shown in Figure 4.

- Advantages:
    - Interest in repurposing the area where the abandoned facultative sludge lagoons are located.
    - The site provides great potential for visibility of the project for public education and outreach.
    - The new facilities for purified water can be kept separated from the current wastewater processes for better public perception and outreach opportunities.
    - Voyager Road provides an easy access to the site for chemical deliveries or potentially tours. The turn onto Voyager from Jack London Blvd is governed by a traffic light. (Figure 3).
        - A contained loop for chemical delivery should be included in layout (Figure 4).
    - Available utilities line nearby the site.
        - Potable and fire water supply (southwest corner of property, Livermore to confirm).
        - Process water.
        - Fiber for SCADA system.

- Challenges:
  - The larger lagoon will need to be dredged and reclaimed. The smaller lagoons have already been dredged. The solids were dewatered and hauled off without any restrictions due to metals or contamination. Currently, all lagoons are filled with reclaimed water.
  - For construction, all ponds will need to be leveled. The current water depth is about 10-15 feet but the berms are raised above the ground so the fill requirement is unclear.
  - While the new switchgear has the capacity to support the projected electrical demand, there would be no redundant electrical system. Therefore, a new electrical connection will be assumed for this location.

Other outcomes and considerations for the Livermore site are as follows:

- Existing Tertiary treatment system operated during off peak times of day to save energy peaking costs. Filters sized for 8 mgd. New AWTF would be running all day. If Tertiary run all day then could probably feed both non-potable and potable reuse systems. Pull off before UV system for non-potable reuse. Could potentially use the alignment of the existing UV overflow pipe to LAVWMA (not used).
- A new SCADA loop will be required for the AWTF.
- It might be possible to build the influent pipeline to the AWTF in place of the UV overflow to feed the AWTF.
- Existing laboratory space is big enough to accommodate the additional analysis for an AWTF. However, more personnel will be required to meet the new needs.
- A new electrical connection would need to be installed. Consult with PG&E requirements and availability to install the new connection.
- The current operations building for Livermore does not have much room for expansion. A new operations building should be assumed. The current administrative building can be used by the AWTF staff if it is expanded. A new visitor center for outreach and education purposes will be assumed as well.
- Livermore also suggested to increase the number of maintenance personnel, from two to three, to meet the needs of the AWTF.
- For security reasons, a fence should be built around the facility, potentially encompassing all of the purification facilities, separating it from the wastewater facilities. A fully enclosed facility may make sharing staff inconvenient.
- Further discussion with the Steering Committee should include administrative, maintenance, and operations staffing, as well as project cost sharing.

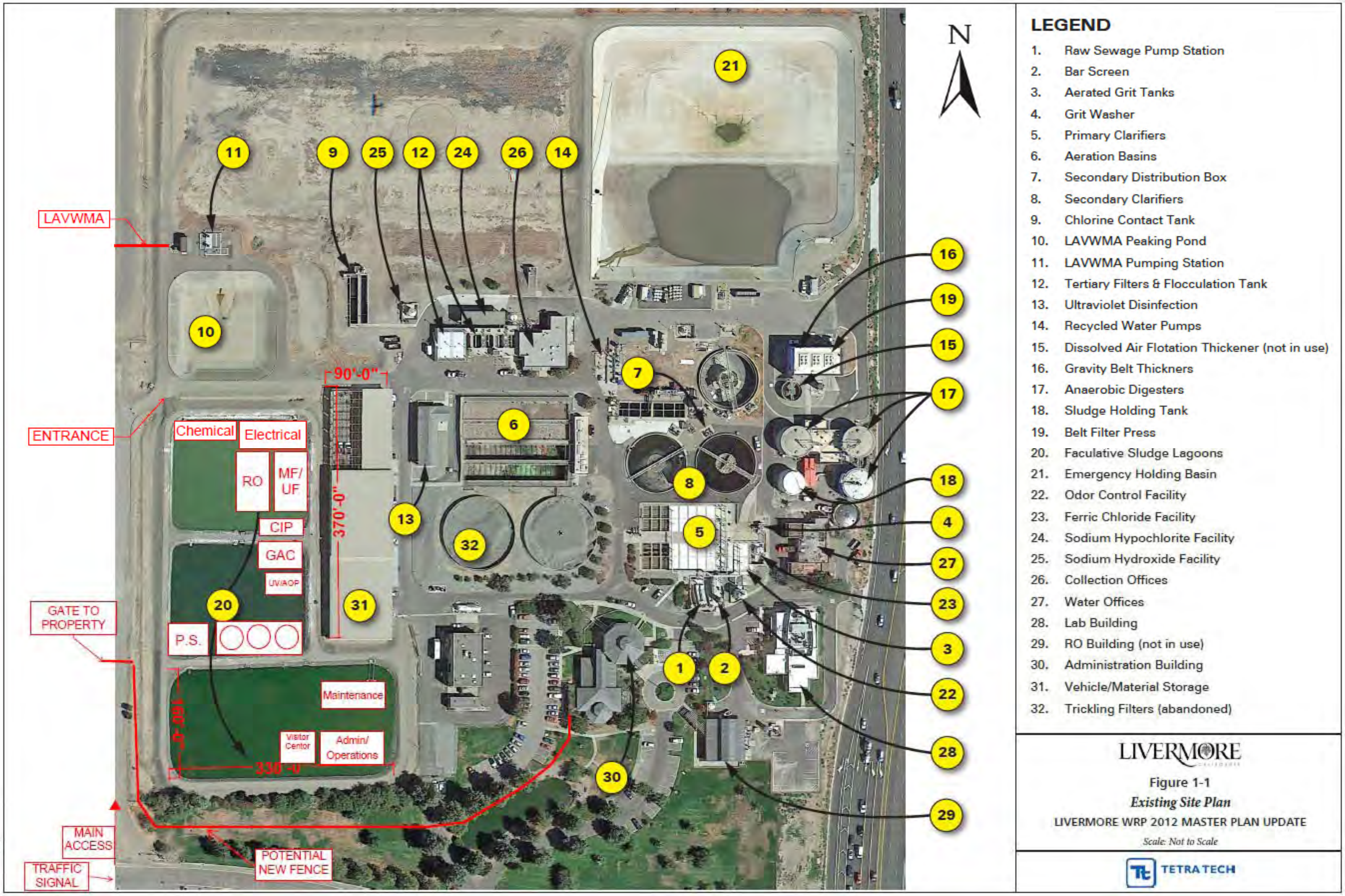

Figure 1 Livermore WRP Site Plan - Originally from 2012 Master Plan Update

Figure 2 Livermore WRP Existing Lagoons.

Figure 3 Livermore WRP Entrance Jack London Blvd. and Voyager St.

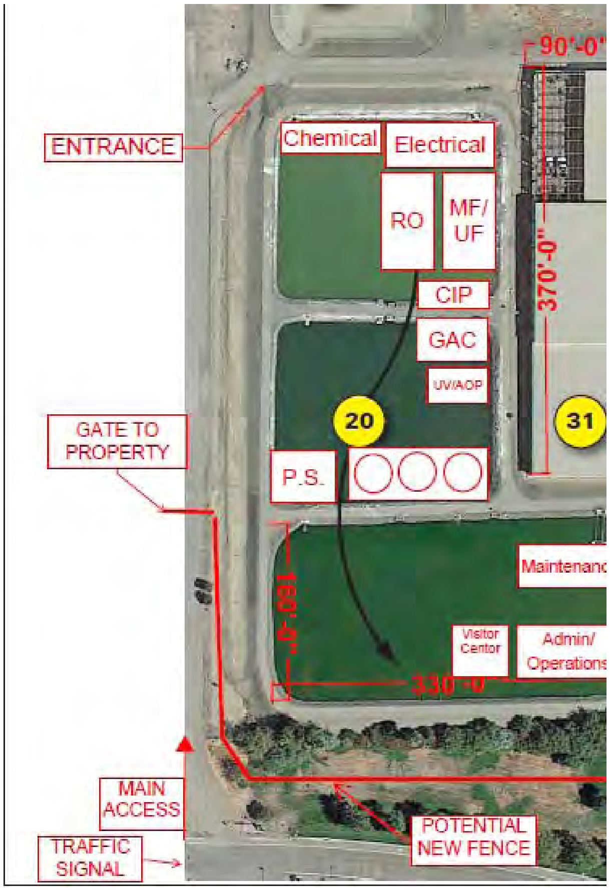

Figure 4 Example Layout of AWTF

Action Items

- Carollo will check the cost and footprint impact of using tertiary effluent as influent to the AWTF vs secondary effluent.
- Carollo will include online monitoring points and equipment in the previous TM.
- Carollo will determine the cost of cleaning the large facultative sludge lagoon.
- Carollo will determine the cost to fill and level the site for construction.
- Carollo will check on the staffing requirements for operations and maintenance
- Livermore will provide topological information of the facultative sludge lagoons.
- Livermore will provide the estimated sludge volume from the cleaning of the small facultative sludge lagoons.
- Livermore will check where the pipeline for the old RO is located. Carollo will determine if this pipeline can be used for the microfiltration backwash flow.
- Livermore will confirm location of utilities near the facultative sludge lagoons.

Appendix H

DETAILED COST ESTIMATES

PROJECT: Tri-Valley Potable Reuse Feasibility Study
JOB NO.: 10414A.00
DATE: 12/21/2017
BY: CYC
OPTION: Livermore AWPF to Lake I

CAPITAL COST ESTIMATE

Classification	**Quantity**	**Units**	**Unit Cost**	**Extended Cost**
Sludge Lagoon Dredging & Removal	1	LS	$900,000	$900,000
Building [1]	18,400	SF	$350	$6,440,000
Administrative Building	7,400	SF	$400	$2,960,000
MF Feed Equalization Basin [2]	130,000	Gallon	$2.0	$260,000
MF Equipment [3]	6.1	MGD	$861,000	$5,260,000
RO Feed Flow Equalization Basin [2]	130,000	Gallon	$2.0	$260,000
RO Equipment [4]	6.1	MGD	$800,000	$4,880,000
Chemical Storage/Feed System [5]				
Sodium Hypochlorite	1	LS	$200,000	$200,000
Aqua Ammonia	1	LS	$150,000	$150,000
Sulfuric Acid	1	LS	$100,000	$100,000
Scale Inhibitor	1	LS	$100,000	$100,000
Lime	1	LS	$200,000	$200,000
Sodium Bisulfite	1	LS	$70,000	$70,000
Caustic Soda	1	LS	$100,000	$100,000
Citric Acid	1	LS	$100,000	$100,000
Hydrogen Peroxide	0	LS	$150,000	$ -
Carbon Dioxide Post-Treatment System	1	EA	$650,000	$650,000
UV Equipment for UV/AOP	1	EA	$1,205,000	$1,205,000
GAC Contactor System	5.0	MGD	$270,000	$1,350,000
Engineered Storage Buffer	330,000	Gallon	$5.0	$1,650,000
Yard Piping	1	LS	$1,750,000	$1,750,000
Process Electrical [6]	1	LS	$7,000,000	$7,000,000
Process Instrumentation	1	LS	$4,500,000	$4,500,000
Site Work [7]	1	LS	$2,500,000	$2,500,000
Total Direct Cost				$42,590,000
Contingency (30%)				$12,780,000
Subtotal				$55,370,000
General Conditions (15%)				$8,310,000
Subtotal				$63,680,000
Contractor Overhead & Profit (10%)				$6,370,000
Subtotal				$70,050,000
Escalation to Midpoint (0%)				$ -
Subtotal				$70,050,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$2,570,000
TOTAL CONSTRUCTION COSTS [8]				**$72,620,000**
TOTAL TREATMENT PROJECT COST [9]				**$94,406,000**
Infrastructure				
Pipelines				
Pipeline to Cope Lake - 18 inch	16,000	LF	$269	$4,301,000
Waste Stream Pipeline	300	LS	$183	$50,000
Total				*$4,351,000*
Pumping				
Finished Water Pump Station	1	LS	$1,530,000	$1,530,000
Increase in Pump Station Size from Cope to DV WTP	1	LS	$2,000,000	$2,000,000
Total Direct Cost				$7,890,000
Contingency (30%)				$2,370,000

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	Livermore AWPF to Lake I

CAPITAL COST ESTIMATE

Classification	Quantity	Units	Unit Cost	Extended Cost
Subtotal				$10,260,000
General Conditions (15%)				$1,540,000
Subtotal				$11,800,000
Contractor Overhead & Profit (10%)				$1,180,000
Subtotal				$12,980,000
Escalation to Midpoint (0%)				$ -
Subtotal				$12,980,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$480,000
TOTAL CONSTRUCTION COSTS [8]				**$13,460,000**
Engineering and Contract Administration (30%)				**$4,038,000**
TOTAL INFRASTRUCTURE PROJECT COST [9]				**$17,498,000**
Cost to Bring Electrical				**$500,000**
TOTAL PROJECT COST				**$112,404,000**
Annual Yield		AF		5,500
Annual Yield		MG		1,800
Annual O&M Costs				
Treatment				$6,374,000
Infrastructure				$256,000
Total O&M				**$6,630,000**
Annualized Project Cost				$7,312,000
Total Annual Cost				**$13,942,000**
Unit Cost ($/AF)				$2,530

Notes:

(1) Includes general building HVAC, plumbing, and electrical. Unit price based on CMU block building type construction. Unit price based on usable square footage.

(2) Constructed below grade, under the building. Flow equalization is required before the MF/UF and RO feed pump stations so that MF/UF and RO trains maintain a constant flow. Sized to provide approximately 30 minutes of storage.

(3) Includes membrane trains, piping, membrane modules, CIP system, pre-strainers and on-skid instrumentation & control.

(4) Includes membrane trains, piping, RO pressure vessels, membranes, CIP system, cartridge filters and on-skid instrumentation & control.

(5) Tanks, feed pumps and piping included.

(6) Does not include stand-by power or off-site power improvements.

(7) Includes demolition, excavation, paving, sidewalks, landscaping and general site improvements.

(8) ENR Construction Cost Index (20-City average, March 2017): 10,288.

(9) This is a class 4 Budget Estimate as defined by the AACEI's Revised Classification (1999) with an expected accuracy range of + 30 percent or - 15 percent. This cost estimate is based upon the Engineer's perception of current conditions in the project area and is subject to change as variances in the cost of labor, materials, equipment, services provided by others or economic conditions occur. Since the Engineer has no control over these factors, he cannot warrant or guarantee that actual bids will not vary from the costs presented herein. This estimate does, however, reflect the Engineer's professional opinion of accurate costs at this time.

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	Livermore AWPF to Well E

CAPITAL COST ESTIMATE

Classification	Quantity	Units	Unit Cost	Extended Cost
Sludge Lagoon Dredging & Removal	1	LS	$900,000	$900,000
Building [1]	18,400	SF	$350	$6,440,000
Administrative Building	7,400	SF	$400	$2,960,000
MF Feed Equalization Basin [2]	130,000	Gallon	$2	$260,000
MF Equipment [3]	6.1	MGD	$861,000	$5,260,000
RO Feed Flow Equalization Basin [2]	130,000	Gallon	$2	$260,000
RO Equipment [4]	6.1	MGD	$800,000	$4,880,000
Chemical Storage/Feed System [5]				
Sodium Hypochlorite	1	LS	$200,000	$200,000
Aqua Ammonia	1	LS	$150,000	$150,000
Sulfuric Acid	1	LS	$100,000	$100,000
Scale Inhibitor	1	LS	$100,000	$100,000
Lime	1	LS	$200,000	$200,000
Sodium Bisulfite	1	LS	$70,000	$70,000
Caustic Soda	1	LS	$100,000	$100,000
Citric Acid	1	LS	$100,000	$100,000
Hydrogen Peroxide	0	LS	$150,000	$0
Carbon Dioxide Post-Treatment System	1	EA	$650,000	$650,000
UV Equipment for UV/AOP	1	EA	$1,205,000	$1,205,000
Yard Piping	1	LS	$1,750,000	$1,750,000
Process Electrical [6]	1	LS	$6,300,000	$6,300,000
Process Instrumentation	1	LS	$4,200,000	$4,200,000
Site Work [7]	1	LS	$2,200,000	$2,200,000
Total Direct Cost				$38,290,000
Contingency (30%)				$11,490,000
Subtotal				$49,780,000
General Conditions (15%)				$7,470,000
Subtotal				$57,250,000
Contractor Overhead & Profit (10%)				$5,730,000
Subtotal				$62,980,000
Escalation to Midpoint (0%)				$0
Subtotal				$62,980,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$2,310,000
TOTAL CONSTRUCTION COSTS [8]				**$65,290,000**
TOTAL TREATMENT PROJECT COST [9]				**$84,877,000**
Infrastructure				
Pipelines				
Pipeline to Cope Lake - 18 inch	6,500	LF	$269	$1,747,000
Waste Stream Pipeline	300	LS	$183	$50,000
Total				*$1,797,000*
Pumping				

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	Livermore AWPF to Well E

CAPITAL COST ESTIMATE

Classification	**Quantity**	**Units**	**Unit Cost**	**Extended Cost**
Finished Water Pump Station	1	LS	$1,040,000	$1,040,000
Injection Well	2	EA	$1,500,000	$3,000,000
Increase in Pump Station Size from Cope to DV WTP	1	LS	$2,000,000	$2,000,000
Total Direct Cost				$7,840,000
Contingency (30%)				$2,360,000
Subtotal				$10,200,000
General Conditions (15%)				$1,530,000
Subtotal				$11,730,000
Contractor Overhead & Profit (10%)				$1,180,000
Subtotal				$12,910,000
Escalation to Midpoint (0%)				$0
Subtotal				$12,910,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$480,000
TOTAL CONSTRUCTION COSTS [8]				**$13,390,000**
Engineering and Contract Administration (30%)				**$4,017,000**
TOTAL INFRASTRUCTURE PROJECT COST [9]				**$17,407,000**
Cost to Bring Electrical				**$500,000**
TOTAL PROJECT COST				**$102,784,000**
Annual Yield		AF		$5,500
Annual Yield		MG		$1,800
Annual O&M Costs				
Treatment				$6,374,000
Infrastructure				$256,000
Total O&M				**$6,630,000**
Annualized Project Cost				$6,686,000
Total Annual Cost				**$13,316,000**
Unit Cost ($/AF)				$2,420

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	Livermore AWPF to Well E

CAPITAL COST ESTIMATE

Classification	Quantity	Units	Unit Cost	Extended Cost

Notes:

(1) Includes general building HVAC, plumbing, and electrical. Unit price based on CMU block building type construction. Unit price based on usable square footage.
(2) Constructed below grade, under the building. Flow equalization is required before the MF/UF and RO feed pump stations so that MF/UF and RO trains maintain a constant flow. Sized to provide approximately 30 minutes of storage.
(3) Includes membrane trains, piping, membrane modules, CIP system, pre-strainers and on-skid instrumentation & control.
(4) Includes membrane trains, piping, RO pressure vessels, membranes, CIP system, cartridge filters and on-skid instrumentation & control.
(5) Tanks, feed pumps and piping included.
(6) Does not include stand-by power or off-site power improvements.
(7) Includes demolition, excavation, paving, sidewalks, landscaping and general site improvements.
(8) ENR Construction Cost Index (20-City average, March 2017): 10,288
(9) This is a class 4 Budget Estimate as defined by the AACEI's Revised Classification (1999) with an expected accuracy range of + 30 percent or - 15 percent. This cost estimate is based upon the Engineer's perception of current conditions in the project area and is subject to change as variances in the cost of labor, materials, equipment, services provided by others or economic conditions occur. Since the Engineer has no control over these factors, he cannot warrant or guarantee that actual bids will not vary from the costs presented herein. This estimate does, however, reflect the Engineer's professional opinion of accurate costs at this time.

PROJECT: Tri-Valley Potable Reuse Feasibility Study
JOB NO.: 10414A.00
DATE: 12/21/2017
BY: CYC
OPTION: DSRSD AWPF To Cope Lake

CAPITAL COST ESTIMATE

Classification	**Quantity**	**Units**	**Unit Cost**	**Extended Cost**
Building [1]	42,000	SF	$350	$14,700,000
Admin Building	7,200	SF	$400	$2,880,000
Cost to raise site	1	LS	$510,000	$510,000
MF Feed Equalization Basin [2]	0	Gallon	$2	$0
MF Equipment [3]	14.8	MGD	$639,000	$9,460,000
RO Feed Flow Equalization Basin [2]	310,000	Gallon	$2	$620,000
RO Equipment [4]	14.2	MGD	$775,000	$11,020,000
Chemical Storage/Feed System [5]				
Sodium Hypochlorite	1	LS	$272,000	$272,000
Aqua Ammonia	1	LS	$156,000	$156,000
Sulfuric Acid	1	LS	$156,000	$156,000
Scale Inhibitor	1	LS	$156,000	$156,000
Lime	1	LS	$311,000	$311,000
Sodium Bisulfite	1	LS	$109,000	$109,000
Caustic Soda	1	LS	$156,000	$156,000
Citric Acid	1	LS	$156,000	$156,000
Hydrogen Peroxide	0	LS	$233,000	$0
Carbon Dioxide Post-Treatment System	1	EA	$1,010,000	$1,010,000
UV Equipment for UV/AOP	1	EA	$2,723,000	$2,723,000
GAC Contactor System	12	MGD	$270,000	$3,240,000
Finished Water Pump Reservoir [5]	750,000	Gallon	$5	$3,750,000
Yard Piping	1	LS	$3,200,000	$3,200,000
Process Electrical [6]	1	LS	$13,500,000	$13,500,000
Process Instrumentation	1	LS	$9,000,000	$9,000,000
Site Work [7]	1	LS	$4,750,000	$4,750,000
Total Direct Cost				*$81,840,000*
Contingency (30%)				$24,560,000
Subtotal				$106,400,000
General Conditions (15%)				$15,960,000
Subtotal				$122,360,000
Contractor Overhead & Profit (10%)				$12,240,000
Subtotal				$134,600,000
Escalation to Midpoint (0%)				$0
Subtotal				$134,600,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$4,930,000
TOTAL CONSTRUCTION COSTS [8]				**$139,530,000**
Engineering and Contract Administration (30%)				**$41,859,000**
TOTAL PROJECT COST [9]				**$181,389,000**
Infrastructure				
Pipelines				
Source Water Pipeline - 30 inch	1,000	LF	$387	$387,000
Waste Conveyance - 16 inch	1,200	LF	$237	$284,000
Pipeline to Lake I - 30 inch	23,000	LF	$387	$8,902,000

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	DSRSD AWPF To Cope Lake

CAPITAL COST ESTIMATE

Classification	**Quantity**	**Units**	**Unit Cost**	**Extended Cost**
Total				$9,573,000
Pumping				
Source Water Pump Station	1	LS	$1,101,000	$1,101,000
Finished Water Pump Station	1	LS	$4,805,000	$4,805,000
Additional contingency to send to Cope Lake/DV WTP	1	LS	$2,000,000	$2,000,000
Total Direct Cost				*$17,480,000*
Contingency (30%)				$5,250,000
Subtotal				$22,730,000
General Conditions (15%)				$3,410,000
Subtotal				$26,140,000
Contractor Overhead & Profit (10%)				$2,620,000
Subtotal				$28,760,000
Escalation to Midpoint (0%)				$0
Subtotal				$28,760,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$1,060,000
TOTAL CONSTRUCTION COSTS [8]				**$29,820,000**
Engineering and Contract Administration (30%)				**$8,946,000**
TOTAL PROJECT COST [9]				**$38,766,000**
Costs to Bring Electricity				**$750,000**
Cost for Additional Solids Handling				**$1,460,000**
Total Project Cost				**$222,365,000**
Annual Yield		AF		$10,000
Annual Yield		MG		$3,300
Annual O&M Costs				
Treatment				$8,215,000
Infrastructure				$840,000
Total O&M				$9,055,000
Annualized Project Cost				$14,465,000
Total Annual Cost				**$23,520,000**
Unit Cost ($/AF)				$2,350

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	DSRSD AWPF To Cope Lake

CAPITAL COST ESTIMATE

Classification	Quantity	Units	Unit Cost	Extended Cost

Notes:

(1) Includes general building HVAC, plumbing, and electrical. Unit price based on CMU block building type construction. Unit price based on usable square footage.
(2) Constructed below grade, under the building. Flow equalization is required before the MF/UF and RO feed pump stations so that MF/UF and RO trains maintain a constant flow. Sized to provide approximately 30 minutes of storage.
(3) Includes membrane trains, piping, membrane modules, CIP system, pre-strainers and on-skid instrumentation & control.
(4) Includes membrane trains, piping, RO pressure vessels, membranes, CIP system, cartridge filters and on-skid instrumentation & control.
(5) Tanks, feed pumps and piping included.
(6) Does not include stand-by power or off-site power improvements.
(7) Includes demolition, excavation, paving, sidewalks, landscaping and general site improvements.
(8) ENR Construction Cost Index (20-City average, March 2017): 10,288.
(9) This is a class 4 Budget Estimate as defined by the AACEI's Revised Classification (1999) with an expected accuracy range of + 30 percent or - 15 percent. This cost estimate is based upon the Engineer's perception of current conditions in the project area and is subject to change as variances in the cost of labor, materials, equipment, services provided by others or economic conditions occur. Since the Engineer has no control over these factors, he cannot warrant or guarantee that actual bids will not vary from the costs presented herein. This estimate does, however, reflect the Engineer's professional opinion of accurate costs at this time.

PROJECT: Tri-Valley Potable Reuse Feasibility Study
JOB NO.: 10414A.00
DATE: 12/21/2017
BY: CYC
OPTION: DSRSD AWPF to Wells

CAPITAL COST ESTIMATE

Classification	**Quantity**	**Units**	**Unit Cost**	**Extended Cost**
Building [1]	42,000	SF	$350	$14,700,000
Admin Building	7,200	SF	$400	$2,880,000
Cost to raise site	1	LS	$510,000	$510,000
MF Feed Equalization Basin [2]	0	Gallon	$2	$0
MF Equipment [3]	14.8	MGD	$639,000	$9,460,000
RO Feed Flow Equalization Basin [2]	310,000	Gallon	$2	$620,000
RO Equipment [4]	14.2	MGD	$775,000	$11,020,000
Chemical Storage/Feed System [5]				
Sodium Hypochlorite	1	LS	$272,000	$272,000
Aqua Ammonia	1	LS	$156,000	$156,000
Sulfuric Acid	1	LS	$156,000	$156,000
Scale Inhibitor	1	LS	$156,000	$156,000
Lime	1	LS	$311,000	$311,000
Sodium Bisulfite	1	LS	$109,000	$109,000
Caustic Soda	1	LS	$156,000	$156,000
Citric Acid	1	LS	$156,000	$156,000
Hydrogen Peroxide	0	LS	$233,000	$0
Carbon Dioxide Post-Treatment System	1	EA	$1,010,000	$1,010,000
UV Equipment for UV/AOP	1	EA	$2,723,000	$2,723,000
Yard Piping	1	LS	$2,500,000	$2,500,000
Process Electrical [6]	1	LS	$11,500,000	$11,500,000
Process Instrumentation	1	LS	$8,000,000	$8,000,000
Site Work [7]	1	LS	$4,200,000	$4,200,000
Total Direct Cost				*$70,600,000*
Contingency (30%)				$21,180,000
Subtotal				$91,780,000
General Conditions (15%)				$13,770,000
Subtotal				$105,550,000
Contractor Overhead & Profit (10%)				$10,560,000
Subtotal				$116,110,000
Escalation to Midpoint (0%)				$0
Subtotal				$116,110,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$4,250,000
TOTAL CONSTRUCTION COSTS [8]				**$120,360,000**
Engineering and Contract Administration (30%)				**$36,108,000**
TOTAL PROJECT COST [9]				**$156,468,000**
Infrastructure				
Pipelines				
Source Water Pipeline - 30 inch	1,000	LF	$387	$387,000
Waste Conveyance - 16 inch	1,500	LF	$237	$355,000
Pipeline to Lake I - 30 inch	11,100	LF	$387	$4,296,000

PROJECT: Tri-Valley Potable Reuse Feasibility Study
JOB NO.: 10414A.00
DATE: 12/21/2017
BY: CYC
OPTION: DSRSD AWPF to Wells

CAPITAL COST ESTIMATE

Classification	Quantity	Units	Unit Cost	Extended Cost
Total				*$5,038,000*
Pumping				
Source Water Pump Station	1	LS	$1,101,000	$1,101,000
Finished Water Pump Station	1	LS	$3,181,000	$3,181,000
Total				*$3,181,000*
Injection Wells	4	EA	$1,500,000	$6,000,000
Additional contingency to send to Cope Lake/DV WTP	1	LS	$2,000,000	$2,000,000
Total Direct Cost				*$16,220,000*
Contingency (30%)				$4,870,000
Subtotal				$21,090,000
General Conditions (15%)				$3,170,000
Subtotal				$24,260,000
Contractor Overhead & Profit (10%)				$2,430,000
Subtotal				$26,690,000
Escalation to Midpoint (0%)				$0
Subtotal				$26,690,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$980,000
TOTAL CONSTRUCTION COSTS [8]				**$27,670,000**
Engineering and Contract Administration (30%)				**$8,301,000**
TOTAL PROJECT COST [9]				**$35,971,000**
Costs to Bring Electricity				**$750,000**
Cost for Additional Solids Handling				**$1,256,000**
Total Project Cost				**$194,445,000**
Annual Yield		AF		$10,000
Annual Yield		MG		$3,300
Annual O&M Costs				
Treatment				$8,124,000
Infrastructure				$693,000
Total O&M				$8,817,000
Annualized Project Cost				$12,649,000
Total Annual Cost				**$21,466,000**
Unit Cost ($/AF)				$2,150

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	DSRSD AWPF to Wells

CAPITAL COST ESTIMATE

Classification	Quantity	Units	Unit Cost	Extended Cost

Notes:

(1) Includes general building HVAC, plumbing, and electrical. Unit price based on CMU block building type construction. Unit price based on usable square footage.

(2) Constructed below grade, under the building. Flow equalization is required before the MF/UF and RO feed pump stations so that MF/UF and RO trains maintain a constant flow. Sized to provide approximately 30 minutes of storage.

(3) Includes membrane trains, piping, membrane modules, CIP system, pre-strainers and on-skid instrumentation & control.

(4) Includes membrane trains, piping, RO pressure vessels, membranes, CIP system, cartridge filters and on-skid instrumentation & control.

(5) Tanks, feed pumps and piping included.

(6) Does not include stand-by power or off-site power improvements.

(7) Includes demolition, excavation, paving, sidewalks, landscaping and general site improvements.

(8) ENR Construction Cost Index (20-City average, March 2017): 10,288.

(9) his is a class 4 Budget Estimate as defined by the AACEI's Revised Classification (1999) with an expected accuracy range of + 30 percent or - 15 percent. This cost estimate is based upon the Engineer's perception of current conditions in the project area and is subject to change as variances in the cost of labor, materials, equipment, services provided by others or economic conditions occur. Since the Engineer has no control over these factors, he cannot warrant or guarantee that actual bids will not vary from the costs presented herein. This estimate does, however, reflect the Engineer's professional opinion of accurate costs at this time.

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	Mocho AWPF to Wells

CAPITAL COST ESTIMATE

Classification	Quantity	Units	Unit Cost	Extended Cost
AWPF Costs				
Building [1]	36,000	SF	$400	$14,400,000
Chemical Building	10,500	SF	$350	$3,680,000
MF Feed Equalization Basin [2]	310,000	Gallon	$2	$620,000
MF Equipment [3]	14.8	MGD	$639,000	$9,460,000
RO Feed Flow Equalization Basin [2]	310,000	Gallon	$2	$620,000
RO Equipment [4]	14.2	MGD	$775,000	$11,020,000
Chemical Storage/Feed System [5]				
Sodium Hypochlorite	1	LS	$272,000	$272,000
Aqua Ammonia	1	LS	$156,000	$156,000
Sulfuric Acid	1	LS	$156,000	$156,000
Scale Inhibitor	1	LS	$156,000	$156,000
Lime	1	LS	$311,000	$311,000
Sodium Bisulfite	1	LS	$109,000	$109,000
Caustic Soda	1	LS	$156,000	$156,000
Citric Acid	1	LS	$156,000	$156,000
Hydrogen Peroxide	0	LS	$233,000	$0
Carbon Dioxide Post-Treatment System	1	EA	$1,010,000	$1,010,000
UV Equipment for UV/AOP	1	EA	$2,723,000	$2,723,000
Yard Piping	1	LS	$2,600,000	$2,600,000
Process Electrical [6]	1	LS	$11,500,000	$11,500,000
Process Instrumentation	1	LS	$8,000,000	$8,000,000
Site Work [7]	1	LS	$4,000,000	$4,000,000
Relocation of existing monitoring well	1	EA	$110,000	$110,000
Total Direct Costs				$71,220,000
Contingency (30%)				$21,370,000
Subtotal				$92,590,000
General Conditions (15%)				$13,890,000
Subtotal				$106,480,000
Contractor Overhead & Profit (10%)				$10,650,000
Subtotal				$117,130,000
Escalation to Midpoint (0%)				$0
Subtotal				$117,130,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$4,290,000
TOTAL CONSTRUCTION COSTS [8]				**$121,420,000**
Engineering and Contract Administration (30%)				**$36,426,000**
TOTAL PROJECT COST [9]				**$157,846,000**
Infrastructure				

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	Mocho AWPF to Wells

CAPITAL COST ESTIMATE

Classification	**Quantity**	**Units**	**Unit Cost**	**Extended Cost**
Pipelines				
Source Water Pipeline - 24 inch	13,000	LF	$323	$4,193,000
Waste Conveyance - 16 inch	500	LF	$237	$118,000
Pipeline to Well - 30 inch	6,300	LF	$387	$2,438,000
Total				*$6,749,000*
Pumping				
Source Water Pump Station	1	LS	$3,095,000	$3,095,000
Concentrate Pump Station	1	LS	$735,000	$735,000
Finished Water Pump Station	1	LS	$4,805,000	$4,805,000
Total				*$8,635,000*
Injection Wells	4	EA	$1,500,000	$6,000,000
Additional contingency to send to Cope Lake/DV WTP	1	LS	$2,000,000	$2,000,000
Subtotal				$23,390,000
Contingency (30%)				$7,020,000
Subtotal				$30,410,000
General Conditions (15%)				$4,570,000
Subtotal				$34,980,000
Contractor Overhead & Profit (10%)				$3,500,000
Subtotal				$38,480,000
Escalation to Midpoint (0%)				$0
Subtotal				$38,480,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$1,410,000
TOTAL CONSTRUCTION COSTS [8]				**$39,890,000**
Engineering and Contract Administration (30%)				**$11,967,000**
TOTAL INFRASTRUCTURE PROJECT COST [9]				**$51,857,000**
Cost to Bring Electrical				**$750,000**
Total Project Cost				**$210,453,000**
Annual Yield		AF		$10,000
Annual Yield		MG		$3,300
Annual O&M Costs				
Treatment				$8,026,000
Infrastructure				$764,000
Total O&M				**$8,790,000**
Annualized Project Cost				$13,690,000
Total Annual Cost				**$22,480,000**
Unit Cost ($/AF)				$2,250

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	Mocho AWPF to Wells

CAPITAL COST ESTIMATE

Classification	Quantity	Units	Unit Cost	Extended Cost

Notes:

(1) Includes general building HVAC, plumbing, and electrical. Unit price based on CMU block building type construction. Unit price based on usable square footage.
(2) Flow equalization is required before the MF/UF and RO feed pump stations so that MF/UF and RO trains maintain a constant flow. Sized to provide approximately 30 minutes of storage.
(3) Includes membrane trains, piping, membrane modules, CIP system, pre-strainers and on-skid instrumentation & control.
(4) Includes membrane trains, piping, RO pressure vessels, membranes, CIP system, cartridge filters and on-skid instrumentation & control.
(5) Tanks, feed pumps and piping included.
(6) Does not include stand-by power or off-site power improvements.
(7) Includes demolition, excavation, paving, sidewalks, landscaping and general site improvements.
(8) ENR Construction Cost Index (20-City average, March 2017): 10,288.
(9) This is a class 4 Budget Estimate as defined by the AACEI's Revised Classification (1999) with an expected accuracy range of + 30 percent or - 15 percent. This cost estimate is based upon the Engineer's perception of current conditions in the project area and is subject to change as variances in the cost of labor, materials, equipment, services provided by others or economic conditions occur. Since the Engineer has no control over these factors, he cannot warrant or guarantee that actual bids will not vary from the costs presented herein. This estimate does, however, reflect the Engineer's professional opinion of accurate costs at this time.

PROJECT: Tri-Valley Potable Reuse Feasibility Study
JOB NO.: 10414A.00
DATE: 12/21/2017
BY: CYC
OPTION: Pleasanton AWPF to Cope Lake

CAPITAL COST ESTIMATE

Classification	Quantity	Units	Unit Cost	Extended Cost
AWPF Costs				
Building [1]	36,000	SF	$350	$12,600,000
Administration Building	7,200	SF	$400	$2,880,000
MF Feed Equalization Basin [2]	310,000	Gallon	$2.0	$620,000
MF Equipment [3]	14.8	MGD	$639,000	$9,460,000
RO Feed Flow Equalization Basin [2]	310,000	Gallon	$2.0	$620,000
RO Equipment [4]	14.2	MGD	$775,000	$11,020,000
Chemical Storage/Feed System [5]				
Sodium Hypochlorite	1	LS	$272,000	$272,000
Aqua Ammonia	1	LS	$156,000	$156,000
Sulfuric Acid	1	LS	$156,000	$156,000
Scale Inhibitor	1	LS	$156,000	$156,000
Lime	1	LS	$311,000	$311,000
Sodium Bisulfite	1	LS	$109,000	$109,000
Caustic Soda	1	LS	$156,000	$156,000
Citric Acid	1	LS	$156,000	$156,000
Hydrogen Peroxide	0	LS	$233,000	$ -
Carbon Dioxide Post-Treatment System	1	EA	$1,010,000	$1,010,000
UV Equipment for UV/AOP	1	EA	$2,723,000	$2,723,000
GAC Contactor System	12	MGD	$270,000	$3,240,000
Finished Water Pump Reservoir [5]	750,000	Gallon	$5.0	$3,750,000
Yard Piping	1	LS	$2,700,000	$2,700,000
Process Electrical [6]	1	LS	$12,000,000	$12,000,000
Process Instrumentation	1	LS	$8,500,000	$8,500,000
Site Work [7]	1	LS	$4,200,000	$4,200,000
Total Direct Costs				$76,800,000
Contingency (30%)				$23,040,000
Subtotal				$99,840,000
General Conditions (15%)				$14,980,000
Subtotal				$114,820,000
Contractor Overhead & Profit (10%)				$11,490,000
Subtotal				$126,310,000
Escalation to Midpoint (0%)				$ -
Subtotal				$126,310,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$4,620,000
TOTAL CONSTRUCTION COSTS [8]				**$130,930,000**
Engineering and Contract Administration (30%)				**$39,279,000**
TOTAL PROJECT COST [9]				**$170,209,000**
Infrastructure				
Pipelines				

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	Pleasanton AWPF to Cope Lake

CAPITAL COST ESTIMATE

Classification	**Quantity**	**Units**	**Unit Cost**	**Extended Cost**
Source Water Pipeline - 24 inch	13,000	LF	$323	$4,193,000
Source Water Pipeline - 30 inch	7,000	LF	$387	$2,709,000
Waste Conveyance - 16 inch	8,900	LF	$237	$2,105,000
Pipeline to Lake I - 30 inch	6,150	LF	$387	$2,380,000
Total				*$7,194,000*
Pumping				
Source Water Pump Station	1	LS	$3,633,000	$3,633,000
Concentrate Pump Station	1	LS	$997,000	$997,000
Finished Water Pump Station	1	LS	$2,637,000	$2,637,000
Total				*$7,267,000*
Additional contingency to send to Cope Lake/DV WTP	1	LS	$2,000,000	$2,000,000
Subtotal				$16,470,000
Contingency (30%)				$4,950,000
Subtotal				$21,420,000
General Conditions (15%)				$3,220,000
Subtotal				$24,640,000
Contractor Overhead & Profit (10%)				$2,470,000
Subtotal				$27,110,000
Escalation to Midpoint (0%)				$ -
Subtotal				$27,110,000
Sales Tax (9.25%) on 50% of Direct Costs Plus Contingency				$1,000,000
TOTAL CONSTRUCTION COSTS [8]				**$28,110,000**
Engineering and Contract Administration (30%)				**$8,433,000**
TOTAL INFRASTRUCTURE PROJECT COST [9]				**$36,543,000**
Cost to Bring Electrical				**$750,000**
Total Project Cost				**$207,502,000**
Annual Yield		AF		10,000
Annual Yield		MG		3,300
Annual O&M Costs				
Treatment				$8,079,000
Infrastructure				$851,000
Total O&M				**$8,930,000**
Annualized Project Cost				$13,498,000
Total Annual Cost				**$22,428,000**
Unit Cost ($/AF)				$2,240

PROJECT:	Tri-Valley Potable Reuse Feasibility Study
JOB NO.:	10414A.00
DATE:	12/21/2017
BY:	CYC
OPTION:	Pleasanton AWPF to Cope Lake

CAPITAL COST ESTIMATE

Classification	Quantity	Units	Unit Cost	Extended Cost

Notes:

(1) Includes general building HVAC, plumbing, and electrical. Unit price based on CMU block building type construction. Unit price based on usable square footage.
(2) Constructed below grade, under the building. Flow equalization is required before the MF/UF and RO feed pump stations so that MF/UF and RO trains maintain a constant flow. Sized to provide approximately 30 minutes of storage.
(3) Includes membrane trains, piping, membrane modules, CIP system, pre-strainers and on-skid instrumentation & control.
(4) Includes membrane trains, piping, RO pressure vessels, membranes, CIP system, cartridge filters and on-skid instrumentation & control.
(5) Tanks, feed pumps and piping included.
(6) Does not include stand-by power or off-site power improvements.
(7) Includes demolition, excavation, paving, sidewalks, landscaping and general site improvements.
(8) ENR Construction Cost Index (20-City average, March 2017): 10,288.
(9) his is a class 4 Budget Estimate as defined by the AACEI's Revised Classification (1999) with an expected accuracy range of + 30 percent or - 15 percent. This cost estimate is based upon the Engineer's perception of current conditions in the project area and is subject to change as variances in the cost of labor, materials, equipment, services provided by others or economic conditions occur. Since the Engineer has no control over these factors, he cannot warrant or guarantee that actual bids will not vary from the costs presented herein. This estimate does, however, reflect the engineer's professional opinion of accurate costs at this time.

Appendix I

ZONE 7 RISK MODEL

Joint Tri-Valley Potable Reuse Feasibility Study

Water Supply Risk Model Evaluation of Project Options

The potable reuse project options considered in Chapter 7 were analyzed using Zone 7's Water Supply Risk Model, in order to evaluate potential impacts to system-wide water supply reliability and water shortage risk. The methods used for evaluation were consistent with the 2016 Water Supply Evaluation Update (WSE Update) to allow for direct comparison with the results from that document. A total of 48 separate scenarios were evaluated, a combination of:

- 6 potable reuse project options, with the available potable reuse supply increasing with time until 2035 buildout conditions are reached,
- 2 potential trends for future State Water Project reliability (static/declining),
- 2 alternative years for the beginning of California WaterFix operations (2028 and 2040), and
- 2 potential trends in future water demand (baseline growth/faster growth).

Each scenario was modeled using a Monte Carlo simulation that provided measures of water supply reliability and risk. Each Monte Carlo simulation ran 1,000 trials. In total, 48,000 separate forecasts were made to achieve the comparative results. This analysis updates the assumptions used in the WSE Update's Portfolio B, which included portable reuse.

The results were as one would expect: when more water supplies were available, there was a lower probability of water shortages. A summary of each project option and its model results is presented in Table 1. Every option performed better than the baseline portfolio from the WSE Update (i.e., the "Current Plan" portfolio). The WSE Update also featured a portfolio that included potable reuse supply, Portfolio B, and a summary of its risk model results is also included in Table 1 for comparison (note that Portfolio B made the assumption of producing a full 7,700 AFY starting in 2022, which the options in this analysis made a more conservative assumption of increasing production with time until expected buildout in 2035. This difference in timing drove the result that no single option outperformed Portfolio B in all categories. Both the current analysis and the WSE Update used the years 2022 through 2040 for the statistics describing the overall results.

Options 2b and 3 had the best results in terms of improving overall reliability, raising the 2022-2040 average to 99.7%, up from the baseline 98.0%. In addition, these options maintained the highest average groundwater level at 84% of total capacity, where the baseline was 75%. Option 2a had the highest water supply during a worst-case scenario: 75 gpcd, or 55% of typical demand, where the worst-case scenario in the baseline was 39 gpcd or 35%. Options 1a, 1b, and 5 had the least beneficial results, which was largely driven by the smaller buildout yield of 5,500 AFY instead of the 10,000 AFY supplied by the other options.

The gradual phasing-in of the potable reuse supply to buildout made any patterns in the results less noticeable than if the buildout yield were available from the outset. For example, the 10,000 AFY option for raw water augmentation (Option 2a) provided a base supply of surface water to the water treatment plants, and during simulated State Water Project shortages, the plants had capacity to treat the available raw water augmentation supply. Alternatively, the high-yield options for groundwater augmentation (Options 2b, 3, and 4) provided a base supply to groundwater, and while the wells increased production during simulated SWP shortages, they lacked the capacity to take full advantage of the potable reuse supply in addition to the existing groundwater supply. On a related note, groundwater pumping in the Risk Model is based on the amount required for peaking and to make up for any deficits in surface water supply. If instead the average groundwater pumping is increased to match the purified water injection, as it was in the Zone 7 Groundwater Model, then the long-term change in average basin levels might be less pronounced between the various options. If needed, additional modeling might help evaluate the difference. These patterns were more apparent during initial analyses which omitted supply growth and phasing over time; with phasing included as the more conservative approach, these differences have less of an impact on final results.

It should be noted that the choice of location for the advanced water purification plant is not a factor in the model simulations; therefore, the project options that differed only by plant location produced identical results in the risk model. Specifically, Option 2b and Option 3 had identical results, because both yielded 10,000 AFY of purified water used for groundwater injection. Summaries of the modeled project option results are presented in Table 1.

Table 1: Water Supply Risk Model results for Chapter 7 project options are compared along with results from the 2016 Water Supply Evaluation Update. The best results in each metric are highlighted in green. Options 2b and 3 achieve the best outcomes in terms of increasing reliability and maintaining high groundwater storage levels, Option 2a achieved the best results for mitigating the effects of a worst-case water shortage.

Potable Reuse Option	**Yield (AFY)**	**Yield (MGD)**	**End Use**	**Average Reliability**, % of Demand	**Worst-Case Supply**, gpcd	**Worst-Case Supply**, % of Demand	**Average Groundwater Storage**, % of Basin Capacity
1a	5,500	5	Groundwater Augmentation via COL Recharge	99.2%	60	47%	79%
1b	5,500	5	Groundwater Augmentation via Well Injection	99.4%	61	47%	82%
2a	10,000	12 (winter) 5 (summer) 9 (average)	Raw Water Augmentation to DVWTP	99.6%	75	55%	81%
2b, 3	10,000	12 (winter) 5 (summer) 9 (average)	Groundwater Augmentation via Well Injection	99.7%	66	50%	84%
4	10,000	12 (winter) 5 (summer) 9 (average)	Groundwater Augmentation via COL Recharge	99.5%	71	53%	81%
5	5,500	5	Raw Water Augmentation to DVWTP	99.3%	60	47%	77%
WSE Update "Current Plan"	0	0		98.0%	39	35%	75%
WSE Update "Portfolio B" (Potable Reuse)	7,700	7	Raw Water Augmentation to DVWTP	99.5%	72	54%	84%

Appendix J

INSTITUTIONAL, OUTREACH, AND FUNDING NEXT STEPS AND OPPORTUNITIES

The Joint Tri-Valley Potable Reuse Technical Feasibility Study focused only on the technical aspects of implementing a potable reuse project. Chapter 8 enumerated some key next steps to proceed with the technical and permitting portion of the projects. However, projects are rarely that one-dimensional. For true project success, a multi-pronged approach, including institutional, outreach, and funding projects, should be implemented. Potential recommendations in each of these areas are described below.

Potential Institutional Next Steps

Any project within the Tri-Valley area will require coordination between multiple agencies. Depending on the type of project, end use, and location of treatment, various entities may be involved.

Institutional agreements and additional studies could include:

- Developing cost sharing agreements for future work:
    - Contracting a third-party mediator for developing cost sharing agreements may be helpful.
- Identify location for future Advanced Water Purification Facility (AWPF):
    - All potential treatment locations are owned by at least one of the partner agencies in the Tri-Valley area. The location selection process would include lease/ownership/operation discussions.
- Develop operational and ownership agreements:
    - Determination of how decisions are made (e.g., democratic decisions by a collective board or a lead agency with supporting advisors).
    - Clear determination of cost sharing.
    - Clear determination of capacity allocation/rights to expanded supply.
    - Agreements to document system operations and maintenance responsibilities by agency, hiring and training of staff, and legal responsibilities for new water production, distribution, and use. All such costs, including salaries for staff, would be discussed in the cost sharing agreement.
- Conduct a comprehensive rate study to determine impacts on rates for each agency
    - The split of funding for the project would be determined by the ownership and cost sharing agreement.
- Seek and apply for funding opportunities to offset rate payer impacts.
    - Funding opportunities for potable reuse are discussed in Section 8.5.

Potential Outreach and Education Next Steps

A comprehensive outreach and education program is critical for implementation of a successful potable reuse program. The last potable reuse project attempted in the Tri-Valley area (1990s) was not implemented, largely due to public resistance. It is therefore recommended to begin outreach efforts as soon as possible, explaining the concept of potable reuse even before a project is selected. These outreach efforts could include speaking engagements, surveys, educational tours, school outreach, and assemblies with community leaders.

An important component of other successful outreach programs has been treatment demonstrations. While not required for permitting or for design, a demonstration facility helps educate the public and elected officials by being able to actually see and taste the purified water that is produced. A demonstration facility also allows for site specific water quality testing and data collection to address questions about water quality and how it compares to the existing drinking water supply.

Funding Source Identification

Costs of the Tri-Valley Potable Reuse Project consist of two components – (1) capital cost for construction of the facilities and associated components, and (2) O&M costs of the project, including the treatment and distribution systems.

The funding sources available range from traditional funding options such as pay-as-you-go funding, bond funding, grants, and State assisted loans to non-traditional funding sources such as market-based programs.

The main instruments available for funding the capital costs include:

- Pay-as-you-go financing or upfront collection of project costs from existing and/or new users for future capital improvement projects.
- Debt financing or the acquisition of funds through borrowing mechanisms.
- Grants and loans or alternate source of funds at no or minimal interest cost. Examples include federal, state, and local grant programs that provide funding at zero interest for projects that meet select criteria or loan programs that provide funding at a lower rate (estimated currently around 2.5 percent).
- Market-based programs that refer to financing through funds obtained from tax credits, purchase agreements, voluntary programs, trading and offset programs, and public-private partnerships.
- Public/Private Partnerships where the financing is by a private party whereby design, construction and operation is all by a private entity and the utilities would purchase the water at an agreed upon price for a set term. This is the model currently being considered by Santa Clara Valley Water District to expand their AWPF and develop their potable reuse program.

The Tri-Valley agencies would develop a specific financial and funding plan should a project move forward. Only grant and loan opportunities are discussed herein.

Grants and Loans

Table J.1 provides a summary of some of the available state and federal funding sources available for potable reuse projects. Please refer to the contact or website for the most up to date information for each of these grants and loans.

There are numerous factors that should be considered in the pursuance of grant funding. Several factors that should be noted in pursuance of grant funding include:

- Grant applications require demonstration of the ability to construct, operate, and maintain the project without grant funding.
- Grant award or funding authorization is not a promise of grant reimbursement.
- Most grants are reimbursements and not cash up front. This requires that a source of funding be available for the construction of the project.
- Grant reimbursements are subject to annual budget and appropriations process and thus disbursement of grant funds on schedule is not guaranteed.

  - It may take several years after project completion to receive reimbursements, especially in difficult economic times.
  - Most grants require a minimum cost share by project sponsor.
- Federal grants typically require investment of additional resources to obtain lobbying support.

Despite the competitive nature of alternative funding, available funding sources should be considered to maximize ratepayer financial benefits. The following sections summarize available state and federal funding options.

State Funding

Several state funding sources are applicable to potable reuse projects. These grants and loans require environmental documents such as CEQA or CEQA-Plus. Note that grant programs may change over time depending on fund availability; grant programs should be reviewed as a project moves toward construction.

Water Recycling Funding Program

One option for financing a potable reuse project is the Water Recycling Funding Program administered by the State Water Resources Control Board. The program offers funding for research, feasibility studies, planning, and construction. The program is financed through Propositions 1, 13, 50, and the State Revolving Fund (SRF):

Recycling projects are categorized by their potential benefits to state and local communities, which in turn determine which funding sources are applicable.

- Category I projects will offset state water supplies and increase water to the Delta.
- Category II projects will offset state water use, but do not provide benefits to the Delta.
- Category III projects use recycled water to supplement local water supplies but have no impact on the state water supply or the Delta.
- Category IV projects will treat and reuse groundwater contaminated by human activity.
- Category V projects will treat and dispose wastewater to meet waste discharge regulations.
- Category VI captures miscellaneous projects that do not fall into other categories and have no benefits to state or local water supplies.

The recycled water projects fall into Category III although a potable reuse project in the Tri-Valley could be used as a Category I project to offset state water use. The source of available funding varies with the category in which the project is classified. The maximum award for construction grants for Category I through IV projects is the lesser value of $5 million per project or 25 percent of construction costs.

Category V and VI projects are only eligible for SRF loans. Loans are capped at $50 million per agency per year. The SRF interest rate is set at one-half of the state General Obligation bond rate and has historically averaged around 2.5 percent.

Table J.1 Grant and Loan Funding Summary

Program	Agency	Type	Description
State			
Water Recycling Funding Program	State Water Resources Control Board	Loan/ Grant	Funding is available for projects in the following categories: 1. Category I projects will offset state water supplies and increase water to the Delta. 2. Category II projects will offset state water use, but do not provide benefits to the Delta. 3. Category III projects use recycled water to supplement local water supplies but have no impact on the state water supply or the Delta. 4. Category IV projects will treat and reuse groundwater contaminated by human activity. 5. Category V projects will treat and dispose wastewater to meet waste discharge regulations. 6. Category VI captures miscellaneous projects that do not fall into other categories and have no benefits to state or local water supplies. The maximum award for construction grants for Category I through IV projects is the lesser value of $5 million per project or 25 percent of construction costs. Category V and VI projects are only eligible for SRF loans. Loans are capped at $50 million/agency/year.
Clean Water State Revolving Fund (CWSRF)	State Water Resources Control Board	Loan	Low interest loan for a 30-year payment period (same as Water Recycling Funding Program). Rolling application period. No limit to funding amounts, but depends on available funding.
Green Project Reserve (GPR)	State Water Resources Control Board	Grant	Grant program to fund water efficient components of a project in the form of loan forgiveness for the principal amount, up to 50 percent of GPR eligible construction and 75 percent of GPR eligible planning costs. The maximum amount of funding for recycled water projects is $2.5 million. Applications are on a rolling basis with a business case along with the CWSRF application.
Integrated Regional Water Management Grants Program (Prop 84 and Prop 1)	Department of Water Resources	Grant	Grants are available for projects that support integrated water resources management (IWRM) plans and are related to water supply reliability, groundwater recharge, water quality enhancement, etc.
Proposition 1	State Water Resources Control Board	Grant	Funding is available for recycled water projects as well as groundwater sustainability projects. The recycled water grants are being run through the SRF program (application is the same as an SRF application). Grant award is up to 35 percent of construction costs or a maximum of $15 million (for recycled water projects). The Proposition 1 Groundwater Sustainability Grants funds up to 50 percent of the construction costs with a maximum cap of $50 million. Funds are available on a first-come, first-served basis. Projects must have a groundwater sustainability focus, either through prevention or cleanup of contaminated groundwater.

Table J.1 Grant and Loan Funding Summary (Continued)

Program	Agency	Type	Description
Federal			
Title XVI	U.S. Bureau of Reclamation	Grants	Eligible projects include recycled water feasibility study, demonstration, and construction projects. The program provides as much as 25 percent of construction costs with a maximum of $20 million. To meet eligibility requirements a project must have a Bureau of Reclamation approved feasibility study, comply with federal environmental regulations (NEPA), and demonstrate the ability to pay the remainder of the construction costs. Once the project feasibility study is approved, the project must be authorized by Congress to be eligible for a Title XVI grant. This process has been streamlined through Water Infrastructure Improvements for the Nation (WIIN) Act.
WIFIA	EPA	Loan	Minimum project cost is $20 million for communities over 25,000 people. Total federal assistance may not exceed 80% of the project's eligible costs. Low interest rate loan.

The SWRCB provides one application package for both construction grants and SRF recycled water loans. The application package consists of:

- Financial Assistance Application.
- Facilities Plan composed of:
  - Project report.
  - Environmental documents including CEQA documents.
  - Construction Financing Plan.
  - Recycled Water Market Assurances documenting user participation in the project.
  - Authorized Representative Resolution (Legal Authority).
- Water Conservation Plan demonstrating that the applicant has a water conservation program in effect.

The SWRCB will review the application package and assess eligibility. Once the SWRCB receives and reviews the final plans and specs, it will issue project performance standards. Once performance standards are agreed to and the applicant chooses a contractor, the parties sign a funding agreement. The applicant must also have an Urban Water Management Plan filed with the Department of Water Resources to receive funds. Passed in 2014, Proposition 1 allocated $625 million for funding of recycled water projects through the Water Recycling Funding Program. At this time, these funds have been largely depleted. In January 2016, the SWRCB added $1.2 billion to the funds available for SRF. Unlike the Prop 1 funds that included grant funding, the program has returned to primarily issuing water recycling loan applications. Due to the long drought from 2012 to 2016, many recycled water projects have been submitted for funding. The SWRCB has indicated that in the future there may be competitive criteria for funding as opposed to first-come, first-served.

Clean Water State Revolving Fund

The Clean Water State Revolving Fund (CWSRF) is the umbrella funding program for the Water Recycling Fund. The benefits and application process are the same. The allocated money differs depending on the project. CWSRF is more focused on wastewater projects - for example lift station rehabilitation, wastewater treatment plant upgrades, and infrastructure. From July 2016 to April 2017, the CWSRF program applicants received $1.016 billion while the Water Recycling Funding Program projects received $89 million.

The application for both SRF programs is the same and therefore it is possible to apply for both programs with the same application.

Green Project Reserve

Within the Clean Water SRF program, there is an additional funding source called the Green Project Reserve (GPR). Projects with greater than 10 percent of GPR eligible components are prioritized above others without a GPR component. This program allows up to 50 percent of GPR eligible components of loan forgiveness for projects which have received CWSRF funding. In order to qualify, projects must fit into one of the following four categories:

- Green infrastructure.
- Water efficiency.
- Energy efficiency.

- Environmentally innovative activities.

All projects must also qualify for the CWSRF program in order to receive loan forgiveness. The maximum award amount for the GPR is 50 percent of GPR eligible costs and 75 percent of GPR eligible planning costs, with a cap of $2.5 million for recycled water projects. A business case must be presented within the CWSRF application explaining the GPR components of the program and note on the CWSRF application the portion of the project that is GPR eligible.

Integrated Regional Water Management Implementation Grant Program

Grants are available for projects that support Integrated Regional Water Management (IRWM) Plans and are related to water supply reliability, groundwater recharge, water quality enhancement etc.

In transitioning from Prop 50 funding to Prop 84 funding, the Department of Water Resources (DWR) altered several of the standards it uses to evaluate regions including governance requirements, acknowledgement of water conflicts, and potential climate change requirements. To facilitate this change, DWR has allowed regions with standing IRWM plans to also receive funds under Prop 84 to comply with the new standards and to develop new projects. Projects seeking funding through this grant process generally submit a project summary to the respective local IRWM management group to review and assess the merits of a project and its ability to fulfill the intent of the IRWM plan. Once approved through this process, a project may be included in the region's implementation grant application.

The IRWM program was also allocated an additional $510 million of funds from Proposition 1. The initial release of funds from this program has been focused on providing assistance to disadvantaged communities. However, grant money is expected to be available and advertised for all other qualified projects that are included in their own regional IRWM Plans is expected in 2018. Therefore, any potable reuse project must be a part of the Bay Area IRWMP to qualify for this grant.

Proposition 1

Proposition 1 was approved by California voters in November, 2014 and allocates a total of $7.5 billion to water projects and programs as part of a statewide water plan for California. There are six main funding areas defined:

- Regional Water Reliability.
- Water Storage Capacity.
- Water Recycling.
- Groundwater Sustainability.
- Safe Drinking Water.
- Watersheds and Flood Management.

Proposition 1 allocated $625 million for funding of recycled water projects. As discussed above these funds were routed through the SWRCB Water Recycling Funding Program. At this time, these funds have been largely depleted.

Proposition 1 also allocated funds for preventing groundwater contamination or cleaning up groundwater that serves as a source for drinking water. The SWRCB will administer $800 million of these funds. In March 2017 the SWRCB awarded $20 million in an initial round of grant funds. There is a minimum grant amount of $100,000 and a maximum grant amount of $2 million for planning projects that are designed to lead to implementation projects that prevent or clean up contamination of an aquifer. There is a minimum grant amount of $500,000 and a maximum grant amount of $50 million for implementation projects that prevent or clean up contamination of an aquifer.

The Budget Act of 2015 appropriates Proposition 1 funds and makes the funding available for expenditure (i.e., encumbered in a funding agreement) until June 30, 2018, and available for liquidation (i.e., funds encumbered in funding agreements have been invoiced and paid) until June 30, 2021. The applicant is required to provide a minimum local cost share of fifty (50) percent of the total project cost. Other state funds (regardless of the issuing state agencies) cannot be used for the required match funds. Match funds may include, but are not limited to: federal grants and loans; or "in-kind" services provided by the applicant. The projects help achieve the goals of California's Water Action Plan, which serves as California's road map toward sustainable water management and calls for accelerating the cleanup of contaminated groundwater and preventing future contamination.

Federal Funding

In addition to local and State grants and loans, there are several highly competitive Federal grant and loan programs that provide financial resources to purified recycled water projects.

Title XVI

The U.S. Bureau of Reclamation administers funds for recycled water feasibility, demonstration, and construction projects through the Water Reclamation and Reuse Program authorized by the Reclamation Wastewater and Groundwater Study and Facilities Act of 1992 (Title XVI) and its amendments. The program provides as much as 25 percent of construction costs with a maximum of $20 million. To meet eligibility requirements a project must have a feasibility study meeting federal standards through compliance with USBR feasibility study guidelines, comply with environmental regulations, and demonstrate the ability to pay the remainder of the construction costs. Projects are authorized by Congress and recommended in the President's annual budget request by the Bureau of Reclamation. Congress then appropriates funds and the Bureau ranks and prioritizes projects and disburses the money on a competitive grant basis each year. Prioritized projects are those that postpone the development of new water supplies, reduce diversions from natural watercourses, and reduce demand on federal water supply facilities, or that have a regional or watershed perspective.

Water Infrastructure Improvements for the Nation (WIIN) Act

In July 2017, the Bureau of Reclamation released a new funding opportunity for the Title XVI water recycling projects under the Water Infrastructure Improvement for the Nation (WIIN) Act. This funding opportunity is for sponsors of water recycling projects that have completed a Title XVI Feasibility Study that has been reviewed by Reclamation, found to meet all the requirements of Reclamation Manual Release WTR 11-01 and been transmitted to Congress by Reclamation. For this first funding opportunity under the WIIN Act, only $10 million was allocated and the Bureau accepted applications during a one month window (July 17-August 17, 2017) to fund up to 25 percent of the total cost of planning, design and /or construction that would be conducted before September 30, 2019. No other restriction on funding is explicitly stated. It is anticipated that future Title XVI funding opportunities will include allocations under WIIN.

Water Infrastructure Finance and Innovation Act (WIFIA) Program

The EPA's Water Infrastructure Finance and Innovation Act (WIFIA) establishes a new financing mechanism for water and wastewater infrastructure projects. WIFIA provides low interest rate financing for large dollar-value water and wastewater projects. The interest rate will be equal to or greater than the U.S. Treasury rate of a similar maturity at the date of execution of the Financial Agreement. Projects must cost no less than $20 million (large communities) or $5 million (small communities <25,000 people), however projects can be combined and submitted as a group of projects with the maximum amount of the loan not exceeding 49 percent of the total eligible project costs. Total federal assistance may not exceed 80% of the project's eligible costs. The WIFIA loan term is 35 years, with a 5 year maximum repayment deferment after substantial completion of the project. Project selection is competitive.

Eligible projects include:

- CWSRF eligible projects.
- Drinking Water State Revolving Fund (DWSRF) eligible projects.
- Projects for enhanced energy efficiency at drinking water and wastewater facilities.
- Brackish or seawater desalination project, an aquifer recharge project, water recycling project.
- Acquisition of property if it is integral to the project or will mitigate the environmental impact of a project.
- Bundled State Revolving Fund (SRF) projects submitted under one application by an SRF program.
- A combination of projects secured by a common security pledge.

The WIFIA application process includes a two-step application process with the first step including the submittal of a Letter of Interest (LOI). Based upon a review of the LOI, Agencies may be Invited to Apply, upon which a more comprehensive WIFIA Application will need to be developed and submitted within 6 months of notification. The WIFIA application process can take 1 to 1.5 years to complete. The WIFIA program charges an application fee for the submittal of the WIFIA Application ($25,000 for small agencies and $100,000 for large agencies) and upon closing of the Financial Agreement, the EPA will provide an invoice to the applicant reconciling all application costs (anticipated to range from $250,000-$700,000 pending the size of the loan and agency negotiations).

The next round of WIFIA funding is anticipated in early 2018.

Summary of Funding Options

Costs of the Tri-Valley Potable Reuse Project consist of two components – (1) capital cost for construction of the facilities and associated components, and (2) O&M costs of the project, including the treatment and distribution systems.

The funding sources available range from traditional funding options such as pay-as-you-go funding, bond funding, grants, and State assisted loans to non-traditional funding sources such as market-based programs. These funding options are detailed in Appendix J. The following list summarizes a sample of other California utilities that are currently working on their potable reuse programs and how they are planning to fund them:

- Soquel Creek Water District - Prop 1 Groundwater grant (for preventing seawater intrusion), Title XVI grants, and SRF loans.
- Morro Bay - WIFIA loans and SRF loans
- Santa Clara Valley Water District - Public/Private partnership

The State of California is working on another water bond, so additional grant funding may be made available should that water bond pass in the future.