Methodology for Evaluating Groundwater Zones of Benefit Santa Clara County, California

Prepared for:
Santa Clara Valley Water District

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EXECUTIVE SUMMARY

The Santa Clara Valley Water District (District) Act gives the District Board of Directors the authority to establish, amend, and revise groundwater charge zones and to levy and collect groundwater charges within a zone or zones that benefit from the recharge of underground water supplies or the distribution of imported water. The two primary existing charge zones, Zones W-2 and W-5, were established in 1963 and 1977, respectively. Zone W-2 generally covers the Santa Clara Plain in North County while Zone W-5 generally covers the Coyote Valley and Llagas Subbasin in South County

The purpose of the Groundwater Zone of Benefit Study (Study) is to complete a holistic review of the groundwater charge zones to ensure they reflect areas where current and future groundwater users receive similar benefit from current and planned District activities. Although the District is not aware of any specific problems with the existing Zone of Benefit designations, the District has received requests for exemption and recognizes that it is important for the District to periodically undertake an updated analysis of various factors upon which the zones are based and revise the boundaries if necessary. The Study will evaluate the ways in which the various District activities benefit groundwater users. These benefits are derived not only from the use of alternative water supplies for direct recharge, but also include the direct and indirect benefits of the District's holistic groundwater management, including in-lieu recharge, demand management, development of alternative water supplies and storage, conservation, and protection of water quality, amongst others.

An area within the District’s legal jurisdiction will be included in a groundwater zone of benefit if any of the following criteria are met:

- Water supply is provided by a District activity
- Groundwater supply reliability is improved due to District activities
- Land subsidence is prevented or limited due to District activities
- Saltwater intrusion is reversed or controlled due to District activities
- Groundwater quality is improved or maintained due to District activities
- Groundwater levels are improved due to District activities

Historical data and groundwater modeling will be used to assess the areas benefitting from District activities. If data and modeling are insufficient to assess whether an area benefits from District activities, the following assumptions will be made:

- Benefits from District activities extend to all areas that are hydrogeologically connected.
- Adjacent bedrock areas are not benefitting from District activities unless they are receiving District supply.

Evaluating groundwater zones of benefit is based on the hydrogeological characteristics that govern the movement of groundwater, District activities, and the benefits to groundwater users provided by the activities. The following methodology will be used to complete the study:

1. Map current and planned District activities that provide or will provide benefits to groundwater users in the District.
2. Map hydrogeologic features and groundwater occurrence and movement to define hydrogeologically connected areas.
3. Plot water balance over time in hydrogeologically connected areas to assess where the benefit of District activities can be demonstrated.
4. Use groundwater data and groundwater flow models to demonstrate the benefit of District activities.
5. Create recommended zones of benefit by grouping areas where users benefit from a similar set of District activities.

The evaluation of where groundwater users benefit from specific District activities will consider hydrogeologically connected areas and multiple lines of evidence. The lines of evidence can be grouped as follows:

1. Data demonstrating benefits derived from improved groundwater levels associated with District activities. In addition to groundwater level data, this includes the evaluation of land subsidence and saltwater intrusion data.
2. Groundwater model results demonstrating improved groundwater levels as a result of District activities have occurred or are projected to occur.
3. Data related to improved groundwater quality associated with District managed aquifer recharge.

All available information will be considered in identifying areas benefitting from specific District activities. Zones will be proposed for areas receiving benefits from similar sets of District activities.

INTRODUCTION

The Santa Clara Valley Water District (District) Act gives the District Board of Directors the authority to establish, amend, and revise groundwater charge zones and to levy and collect groundwater charges within a zone or zones that benefit from the recharge of underground water supplies or the distribution of imported water. The two primary existing charge zones, Zones W-2 and W-5, were established in 1963 and 1977, respectively. Zone W-2 generally covers the Santa Clara Plain in North County while Zone W-5 generally covers the Coyote Valley and Llagas Subbasin in South County (Figure 1). Figure 2 shows the three groundwater management areas of the District (Santa Clara Plain, Coyote Valley, and Llagas Subbasin) along with the California Department of Water Resources (DWR) subbasin definitions. Coyote Valley is part of southern zone W-5, but DWR includes Coyote Valley with the Santa Clara Subbasin in the north. While District water supply activities have changed considerably since the zones were established, the zones themselves have undergone only relatively minor, parcel-based revisions.

The purpose of the Groundwater Zone of Benefit Study (Study) is to complete a holistic review of the groundwater charge zones to ensure they reflect areas where current and future groundwater users receive similar benefit from current and planned District activities. The benefits to those who receive groundwater supplies are derived from the occurrence of groundwater and its movement through the sediments below ground surface. Therefore, the methodology will consist of hydrogeologic analyses consistent with existing understanding of the groundwater basins.

The Study will evaluate the ways in which the various District activities benefit groundwater users in different ways across the District. These benefits are derived not only from the use of alternative water supplies for direct recharge, but also include the direct and indirect benefits of the District's holistic groundwater management, including in-lieu recharge, demand management, development of alternative water supplies and storage, conservation, and protection of water quality, amongst others. Furthermore, due to the interconnected nature of the groundwater system, benefits are not limited to the immediate vicinity of particular District activities. Rather, benefits can extend from a project location throughout a surrounding basin or subbasin. Areas where groundwater users receive reasonably similar benefits or similar potential benefits from District activities, regardless of their surface proximity to District activities, will be grouped into zones. The purpose of this technical memorandum is to describe the approach and methodology for establishing the zones of benefit so that it can be reviewed and commented on by District partners and stakeholders.

As background for developing the methodology for this Study, HydroMetrics WRI conducted a cursory statewide review of other groundwater management agencies that have created multiple groundwater zones of benefit to determine the methodologies used to define the zones. A report summarizing the findings from that research is attached as Appendix A. The two significant findings are: 1) not many agencies who have the legal authorization to create groundwater zones of benefit have done so, meaning that the costs of groundwater management activities are spread throughout the agency's jurisdiction without making a distinction between benefits in different areas; 2) six agencies were identified that have developed a methodology for determining zone boundaries. Methods used by these six agencies to define zones of benefit vary between following DWR subbasin boundaries; identifying sub-areas based on hydrogeologic features; or creating a separate zone for areas benefitting from a singular beneficial activity such as delivered water. None of the agencies identified have undertaken the level of benefit analysis to justify the zone boundaries that will be performed in this Study.

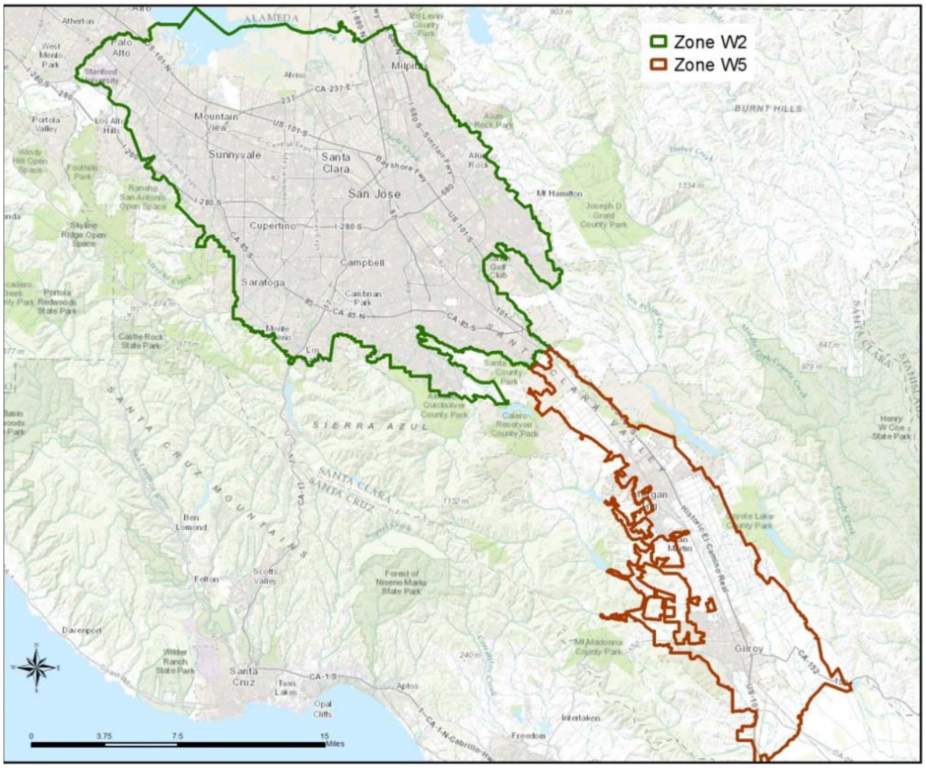

Figure 1: Existing Zones of Benefit

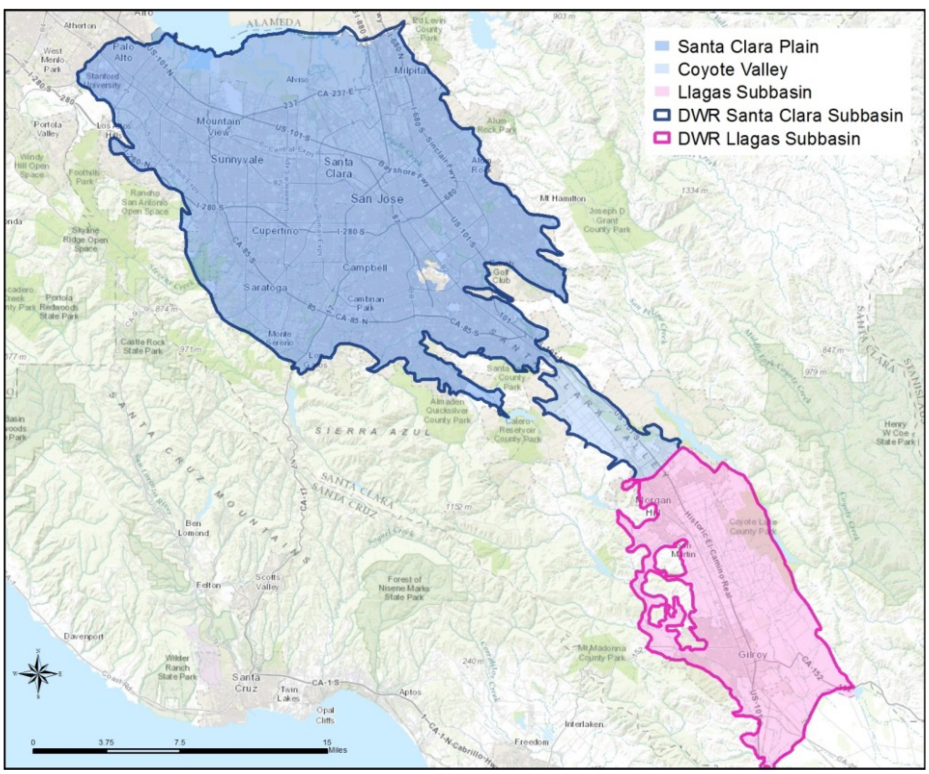

Figure 2: DWR Bulletin 118 Subbasins and District Groundwater Management Areas

CONCEPTS FOR EVALUATING GROUNDWATER ZONES OF BENEFIT

The proposed evaluation of groundwater zones of benefit is based on the hydrogeological characteristics that govern the movement of groundwater, District activities, and the benefits to groundwater users provided by the activities. First, we identify District activities that may provide benefits will be mapped. Second, we map hydrogeologically connected areas to the District activities. Third, we will map the areas where benefits to groundwater users from District activities are demonstrated. The recommended zones will be based on areas receiving benefit from similar District activities based on the analysis of hydrogeologically connected areas and observed and modeled groundwater data.

SUMMARY OF GROUNDWATER ZONE OF BENEFIT CRITERIA

An area within the District's legal jurisdiction will be included in a groundwater zone of benefit if any of the following criteria are met:

- Water supply is provided by a District activity
- Groundwater supply reliability is improved by District activities
- Land subsidence is prevented or limited due to District activities
- Saltwater intrusion is reversed or controlled due to District activities
- Groundwater quality is improved or maintained due to District activities
- Groundwater levels are improved due to District activities

Historical data and groundwater modeling will be used to assess the areas benefitting from District activities. If data and modeling are insufficient to assess whether an area benefits from District activities, the following assumptions will be made:

- Benefits from District activities extend to all areas that are hydrogeologically connected.
- Adjacent bedrock areas are not benefitting from District activities unless they are receiving District supply.

DISTRICT ACTIVITIES PROVIDING BENEFIT

District activities that provide a benefit to groundwater users include those covered under the District Act:

- Groundwater recharge,
- Importing water,
- Runoff capture,
- Water storage,
- Water treatment,

- Water distribution,
- Water recycling,
- Groundwater protection, and
- Water conservation.

The primary benefits to groundwater users are derived from District activities that support groundwater recharge. Managed aquifer recharge improves groundwater conditions by supplementing natural recharge of the underlying aquifers. Activities that support managed aquifer recharge are shown in. The District's direct delivery of water through various combinations of District activities, also shown in Figure 3, improves groundwater conditions by reducing groundwater extractions; this is referred to as in-lieu recharge. Demand management through water conservation programs also constitutes in-lieu recharge.

Additional benefits are derived from the District's groundwater protection programs, which improve groundwater conditions by maintaining or improving groundwater quality. Protecting groundwater quality is inextricably linked to water supply reliability as are District efforts to conserve and augment groundwater supplies.

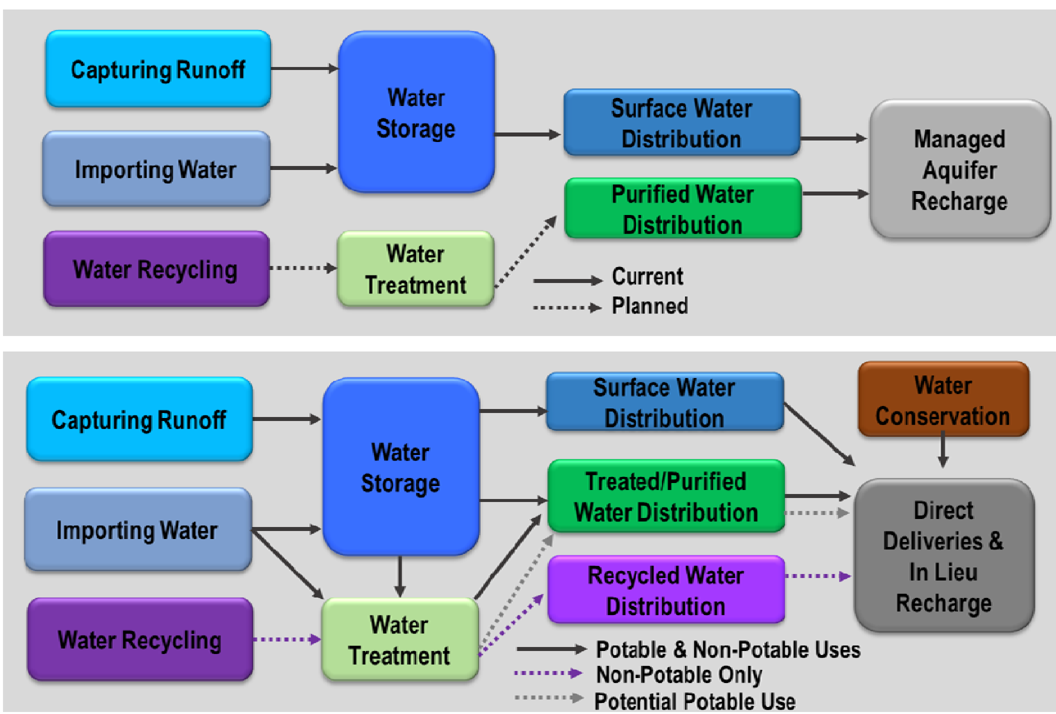

Figure 3: District Activities Supporting Groundwater Recharge For Benefit of Groundwater Users

BENEFITS OF DISTRICT GROUNDWATER MANAGEMENT ACTIVITIES

Groundwater is a shared resource that can be represented by a water budget, which includes estimates of groundwater inflows and outflows and conjunctive use of surface water supplies within a given area. Improved groundwater conditions resulting from District groundwater management activities can be summarized by an improved water budget, i.e. groundwater conditions would be worse in the absence of District activities. An improved water budget represents the overall benefit of District managed aquifer recharge and in-lieu recharge activities that sustain an area's groundwater supply. As an example, District activities in calendar year 2013 resulted in 96,000 acre-feet of managed aquifer recharge and 129,000 acre-feet of in-lieu recharge compared to 39,000 acre-feet of natural recharge (SCVWD, 2014). District activities that result in an improved water budget provide the following benefits to groundwater users:

Improved Groundwater Supply Reliability

On average, forty percent of the water used in Santa Clara County comes from wells pumping groundwater. Groundwater pumping (approximately 150,000 acre-feet in 2013) far exceeds natural recharge, and the District's managed and in-lieu recharge programs help replenish and sustain groundwater supplies. Figure 4 shows the rapidly growing population of Santa Clara County after World War II that was supported by a groundwater supply improved by District activities. This groundwater supply also supported high rates of business development and a viable agricultural economy. Community growth, quality of life and economic prosperity depend on a reliable and sustainable water supply that can be attributed to District groundwater management activities.

Reduced Risk of Land Subsidence

As shown in Figure 4, land in portions of the Santa Clara Valley subsided approximately 13 feet between 1915 and 1970 when groundwater pumping generally exceeded recharge. During that time, there was at least a 1-foot drop in the land surface over a 100-square mile area including portions of Palo Alto, Mountain View, Sunnyvale, Santa Clara, and San Jose. Since then, permanent subsidence has been halted due to an improved water budget resulting from District activities. Subsidence can result in adverse effects such as damaged infrastructure, increased flooding risk, increased sediment erosion or deposition, and, where relevant, impairment of leveled agricultural fields. Therefore, preventing subsidence is a benefit of the improved water budget resulting from District activities.

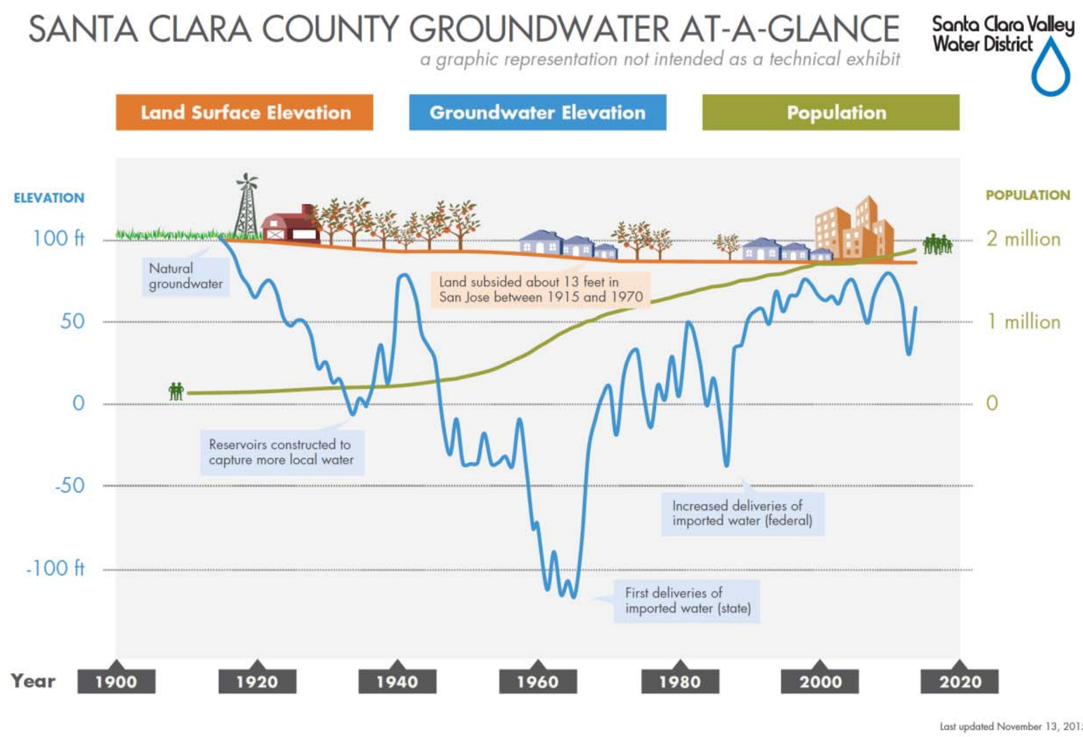

Figure 4: Graphic Representation of Groundwater Levels, Population and Land Subsidence (Courtesy SCVWD)

Saltwater Intrusion Prevention

Historically, denser saltwater moved inland from brackish channels connected to the San Francisco Bay when groundwater pumping exceeded natural recharge and subsidence resulted in greater tidal influence on the creeks connected to the bay. Figure 5 shows the inland migration of saltwater intrusion in the shallow aquifer zone from 1945 to 1980. Figure 5 additionally illustrates the reversal of saltwater intrusion in the shallow zone from 1980 to 2012. Saltwater intrusion adversely affects groundwater quality and can consequently have an adverse effect on groundwater use. Therefore, preventing saltwater intrusion is a benefit of the improved water budget from District activities.

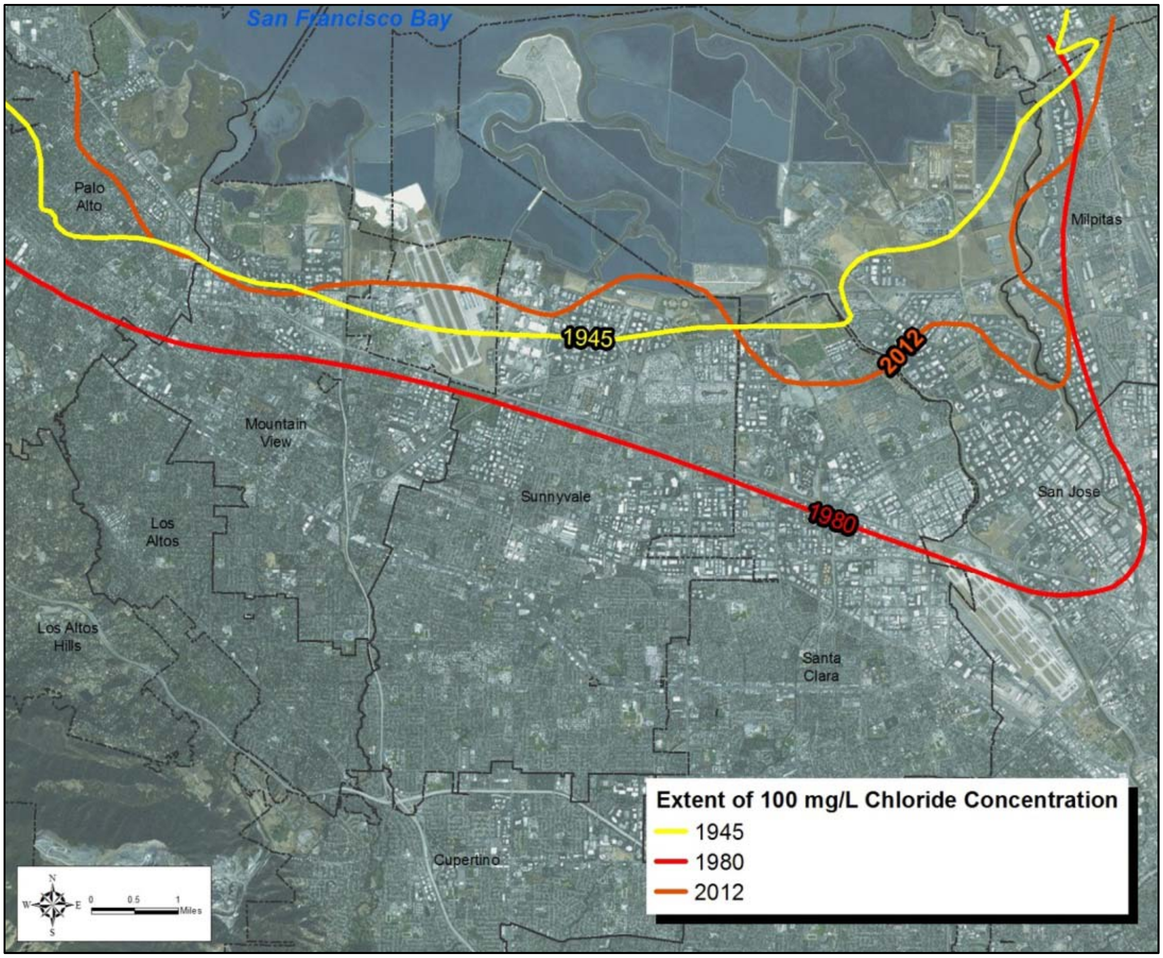

Figure 5. Extent of Shallow Zone Saltwater Intrusion

Improved Groundwater Quality

Recharge water can be higher quality than the ambient groundwater so an improved water budget from District activities can also improve groundwater quality. For example, nitrate concentrations are high in ambient groundwater in portions of the Llagas Subbasin, but imported water used for managed aquifer recharge has a dilution benefit by adding water with low nitrate concentrations to the water budget (MACTEC, 2009). Groundwater protection activities also conserve and improve groundwater quality. This prevents depletion of groundwater supply due to groundwater quality concerns and helps maintain an improved water budget.

MAPPING EXTENT OF BENEFITS BASED ON HYDROGEOLOGIC FEATURES

The initial evaluation of the areal extent of benefits from District activities will be based on defining hydrogeologically connected areas. District activities that improve the water budget are assumed to benefit all groundwater users within the hydrogeologically connected area subject to further evaluation with data and models described below. The areal extent of benefit beyond the District activity will be initially defined by mapping hydrogeologic features that control groundwater flow, such as the contact between water-bearing sediments and bedrock, the thickness of the water-bearing sediments, and the location of groundwater divides and faults. Mapping these features will form the boundaries of hydrogeologically connected areas that will be the first step for defining zones.

EVALUATING EXTENT OF BENEFITS WITH DATA AND MODELS

Field data, including groundwater levels, land subsidence, saltwater intrusion, and groundwater quality, will be evaluated to map the extent of benefits associated with District activities. Comparison of model simulations with and without District activities will also be used to map the extent of benefits. These maps will show areas where users receive benefits from a similar set of District activities. A defined zone of benefit will be created for each of these areas. There may be spatial data gaps, particularly along the subbasin margins, so areas demonstrated to be receiving benefit will be extended based on hydrogeologically connected areas as discussed above.

METHODOLOGY FOR EVALUATION OF GROUNDWATER ZONES OF BENEFIT

Groundwater zones of benefit will be defined initially based on areas of hydrogeologic connection and refined, if necessary, based on where benefits are demonstrated from a specific set of District activities. Groundwater flow extends benefits beyond the immediate location of activities to hydrogeologically connected areas. Benefits from current and planned District activities within initially defined hydrogeologic areas will be evaluated based on historical data and groundwater model results. The methodology to evaluate the zones of benefit will rely on a four-step process:

1. Map current and planned District activities that provide or will provide benefits to groundwater users in the District.
2. Map hydrogeologic features and groundwater occurrence and movement to define hydrogeologically connected areas.
3. Plot water balance over time in hydrogeologically connected areas to demonstrate overall benefit of District activities.

4. Use groundwater flow models and groundwater data to demonstrate the benefit of District activities.
5. Create recommended zones of benefit by grouping areas where users benefit from a similar set of District activities.

IDENTIFY AND MAP DISTRICT ACTIVITIES

As shown on Figure 3, the two main categories of District activities that provide groundwater benefits are managed aquifer recharge and in-lieu recharge. The managed aquifer recharge facilities and end-point uses of deliveries that result in in-lieu recharge will be identified and mapped. The mapping of activities is illustrated on Figure 6 which contains a series of hypothetical maps for demonstrating the methodology.

Managed Aquifer Recharge Activities

Managed aquifer recharge occurs in District recharge ponds (off-stream recharge) and within streambeds (in-stream recharge). Geographic Information System (GIS) data of pond and stream features mapped by the District will be used to define these locations (Figure 6A). Benefits from managed aquifer recharge extend beyond the immediate area of recharge.

In order to evaluate the areal extent where groundwater users receive benefit from District managed aquifer recharge activities, recharge volumes will be plotted over time at each recharge system using data from the District. Recharge volumes over time represent changes in District activity that can be associated with groundwater benefits. When data or estimates for recharge volumes are not available for historical periods, periods when recharge volumes increased or decreased can be identified based on qualitative information such as commencement of recharge at any location.

In addition to identifying locations of current recharge from captured local runoff and imported surface water, potential locations of recharge from purified recycled water (Indirect Potable Reuse or IPR) will also be mapped. IPR is in the planning stage and is expected to be implemented by the District within the next 5 years.

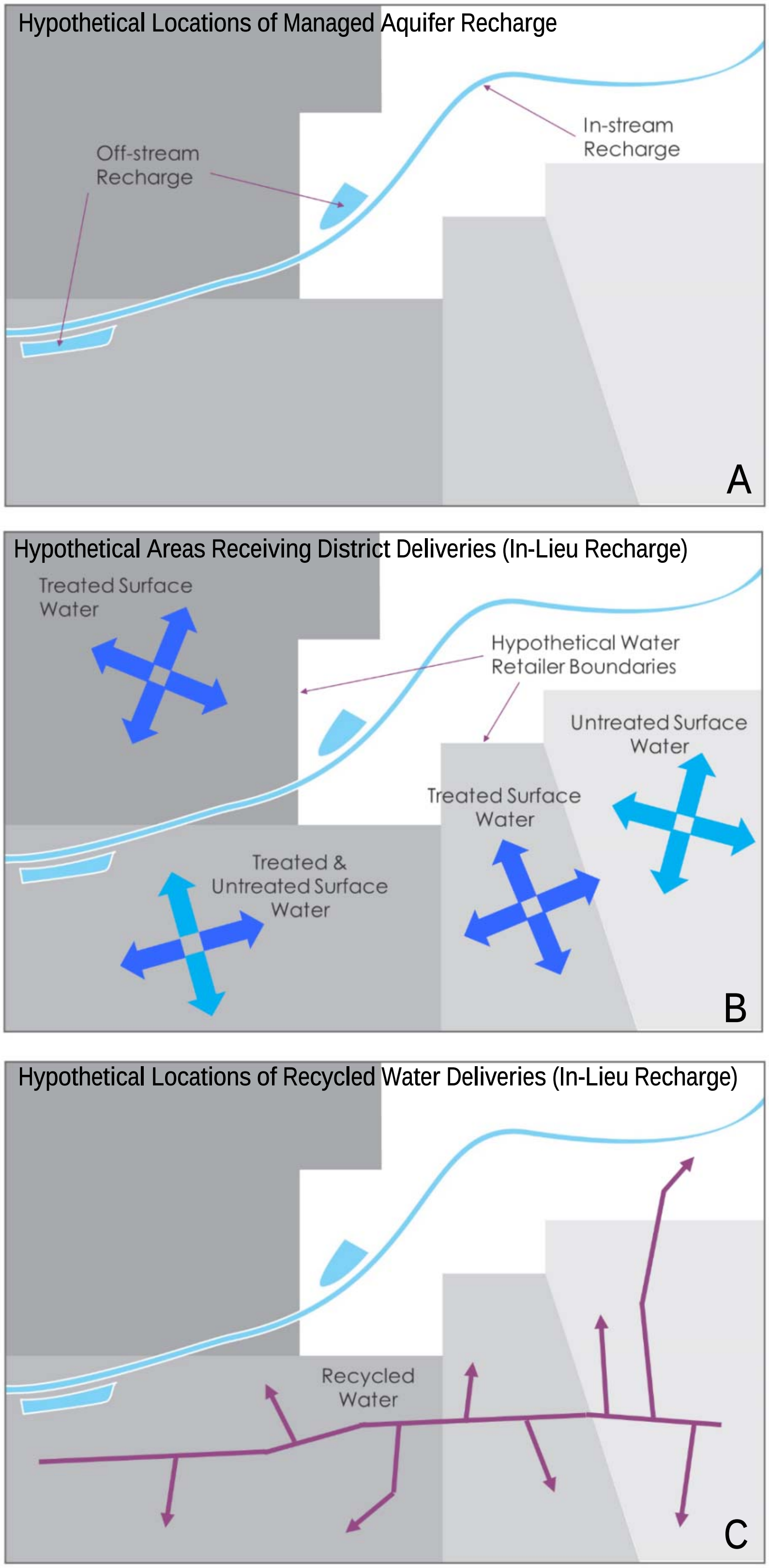

Figure 6: District Activities Mapping Methodology

In-Lieu Recharge Activities

Deliveries of treated water that provide in-lieu recharge benefits to groundwater users will be mapped to correspond to the service area boundaries of the retailers that receive District water supplies (Figure 6B). If a retailer delivers specific District supplies to distinct areas, those distinct areas will be mapped. Deliveries of surface water to non-retailer users will also be mapped. More detailed mapping than retailer service areas will be required to distinguish areas within a retailer boundary that receive different water sources. For example, an area receiving raw surface water from the District would be distinguished from an area receiving treated surface water from the District. GIS data provided by the District, retailers, and California Public Utilities Commission (PUC) will be used to provide these boundaries. Groundwater users in the areas receiving deliveries of District treated, raw, and recycled water are benefitting from in-lieu recharge provided by the District supplies. In addition, benefits from in-lieu recharge also extend beyond the delivery area.

In order to identify areas where groundwater users benefit from District delivery of raw and treated surface water, the volumes of District water supplies over time to each area will be charted using data from the District. These volumes over time represent changes in District supplies that can be associated with groundwater benefits. When data or estimates for recharge volumes are not available for deliveries, periods when deliveries increased or decreased can be identified based on qualitative information such as the availability of imported water to deliver.

Areas receiving recycled water will also be mapped based on GIS data provided by the District (Figure 6C). As with surface water benefits, recycled water benefits extend beyond the areas of direct delivery. To evaluate the extent of the area receiving in-lieu benefits, as discussed below, deliveries of recycled water to various areas will be charted over time using data from the District.

Based on the availability of data, these charts may be limited to indicating when deliveries increased or decreased based on qualitative information about the recycled water program. Historically, the areas receiving recycled water have been smaller than areas receiving raw or treated surface water and the volumes of water were smaller, which may make it difficult to distinguish between in-lieu benefits from recycled water and raw and treated surface water. Therefore, areas receiving recycled water located within areas receiving raw or treated surface water will be grouped within the larger area receiving in-lieu benefits from raw or treated surface water deliveries. Areas receiving recycled water that are outside of areas receiving raw or treated surface water may provide in-lieu benefits that do not overlap areas with in-lieu benefits from raw or treated surface water deliveries.

Water conservation provides benefits to groundwater users resulting from in-lieu recharge facilitated by the reduced demand. These are broad benefits throughout the groundwater basins. Areas that benefit from managed aquifer recharge and other in-lieu recharge activities are also assumed to benefit from water conservation activities. However, to assist in identifying zones of benefit, areas where conservation activities occur will be mapped based on information from the District.

Groundwater Protection Activities

Groundwater protection activities provide broad benefits to groundwater quality throughout the groundwater basins. Areas that benefit from managed aquifer recharge and in-lieu recharge activities are also assumed to benefit from the groundwater protection activities. Similar to the approach to be used for water conservation activities, groundwater protection activities will be summarized and mapped based on information from the District to assist with identifying zones of benefit.

DEFINE HYDROGEOLOGICALLY CONNECTED AREAS BASED ON HYDROGEOLOGIC FEATURES

As discussed previously, District activities provide groundwater benefits beyond the immediate location of an activity. Groundwater flow patterns control how benefits extend beyond the activity locations. Several hydrogeologic features affect groundwater flow and will be mapped to define areas hydrogeologically connected to District activities. The planned features to be mapped are the contact between water-bearing sediments and bedrock and the location of groundwater divides and faults. These features will provide the boundaries for the hydrogeologically connected areas.

Mapping Water-Bearing Sediments

Quaternary deposits are mostly alluvium that provide the highest permeability for groundwater flow and therefore the greatest potential for connecting areas with groundwater users to benefits from District activities. Quaternary deposits mapped at the surface that are not specifically labeled alluvium are included because they are relatively young deposits and are relatively permeable compared to the older bedrock that bounds the basin. Bedrock has much lower overall permeability for groundwater flow and groundwater flow typically occurs in fractures that have not been mapped. Therefore, the Quaternary deposit/bedrock contact (Figure 7A) will define the hydrogeologically connected areas used to define the extent of potential benefit.

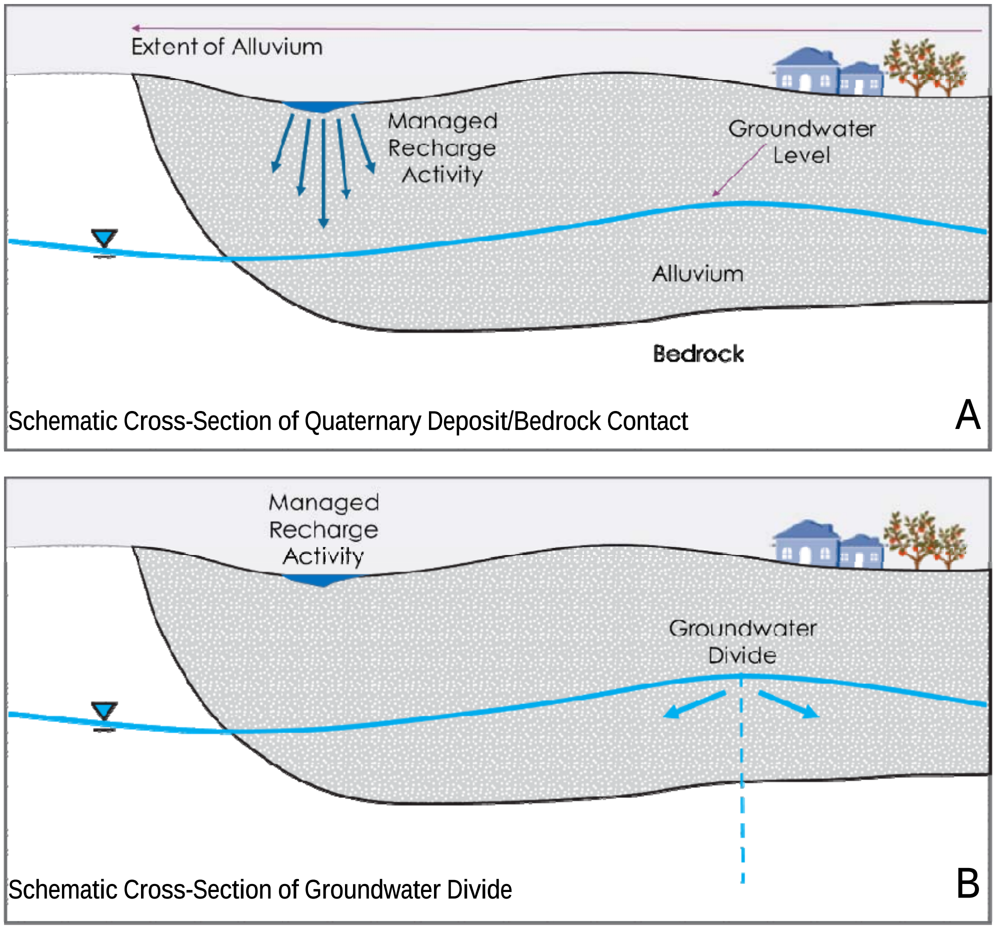

Figure 7: Schematic Cross-Sections

The Quaternary deposit/bedrock contact will be based on existing sources, such as mapping by the U.S. Geological Survey and California Geological Survey, including but not limited to *Maps of Quaternary Deposits and Liquefaction Susceptibility in the Central San Francisco Bay Region, California* (Witter et al., 2006) and *Preliminary Maps of Quaternary Deposits and Liquefaction Susceptibility, Nine County San Francisco Bay Region, California* (Knudsen et al., 2000). GIS formats of these maps are available for use in this study.

Available basin wide information on the thickness of the Quaternary deposits and stratigraphy of the deposits will also be mapped. Large changes in thickness or stratigraphy could be geologic features that affect how groundwater flows between areas. One source that will be considered is *Physical Subdivision and Water-Bearing Sediments of the Santa Clara Valley, California* (Wentworth et al., 2015). These maps only cover North County.

Groundwater Divides and Faults

A groundwater divide occurs where there is a regionally high groundwater level and groundwater flows in opposite directions on either side of the divide (Figure 7B). Groundwater benefits are unlikely to extend from a District activity on one side of the divide to the other side of the divide unless the activity provides a large enough change to groundwater levels or is close enough to the divide to actually alter the divide's location. Groundwater divides can change over time, so groundwater divides over different years will be mapped to the extent possible. Available District groundwater level contour maps will be evaluated to identify the groundwater level contours that represent a divide. One of the main groundwater divides of interest is expected to be in South County between the Coyote Valley and Llagas Subbasin. California Department of Water Resources defines the northern boundary of the Llagas Subbasin based on the groundwater divide near Cochrane Road in Morgan Hill (DWR, 2004).

Faults can be barriers to groundwater flow. However, faults are not expected to be significant barriers to flow that define the extent of benefits in the District. Nonetheless, faults will be mapped and groundwater flow in the vicinity of faults will be evaluated . The initial evaluation will compare mapped faults with the contour maps. Faults identified as barriers to groundwater flow will be considered when identifying areas with improved groundwater levels as discussed below. The U.S. Geological Survey and California Geological Survey (2010) have developed fault maps in GIS format, which will be used for this purpose.

PLOT WATER BUDGET OVER TIME IN HYDROGEOLOGICALLY CONNECTED AREAS

In order to summarize the benefit of District activities in hydrogeologically connected areas, the water budget in each area will be plotted over time. The plots will show the effect of District activities on the water budget for the hydrogeologically connected area. Estimated volumes for different categories of District activities shown in Figure 3 that result in managed aquifer and in-lieu recharge will be included along with estimates of outflows such as pumping. There may not be data or published estimates for volumes of groundwater inflows and outflows for historical periods, but the plots will represent and document the conceptual water budget for these periods given available information. These plots will provide background for how District activities improve conditions for the shared groundwater resource defined by each hydrogeologically connected area.

EVALUATE AREAS WHERE GROUNDWATER USERS BENEFIT FROM SPECIFIC DISTRICT ACTIVITIES

The evaluation of where groundwater users benefit from specific District activities will consider multiple lines of evidence. The lines of evidence can be grouped as follows:

1. Data demonstrating benefits derived from improved groundwater levels associated with District activities. In addition to groundwater level data, this includes the evaluation of land subsidence and saltwater intrusion data.
2. Groundwater model results demonstrating improved groundwater levels as a result of current or future District activities.
3. Data demonstrating improved groundwater quality associated with District managed aquifer recharge.

All available information from these lines of evidence will be considered in identifying areas benefitting from specific District activities. Figure 8 summarizes the use of the three lines of evidence. If any of the lines of evidence demonstrate that groundwater users in an area benefit from a set of District activities, then the area will be mapped as benefitting from that set of District activities. Additional lines of evidence and alternate methods of evaluating information may be considered as new information become available and data are compiled. Any changes to methodology will be fully documented.

Evaluation of Data Related to Improved Groundwater Levels

This line of evidence is based on an evaluation of groundwater levels, land subsidence, and saltwater intrusion data. If data show groundwater levels, land subsidence, and saltwater intrusion in an area have improved or stabilized as a result of a District activity, then groundwater users in the area are benefitting from that activity. Historically, the District has implemented its activities to mitigate chronic overdraft that was causing undesirable effects such as declining groundwater levels, subsidence and saltwater intrusion. Therefore, the analyses will find a beneficial improvement whenever District activities result in any rise or stabilization of groundwater levels or prevention of the undesirable effects associated with declining groundwater levels. These groundwater level analyses are summarized in Figure 8 and described in greater detail below. The analysis as applied to groundwater level data is described immediately below. Discussion of specific differences in the analyses of land subsidence and saltwater intrusion data from the evaluation of groundwater level data follows.

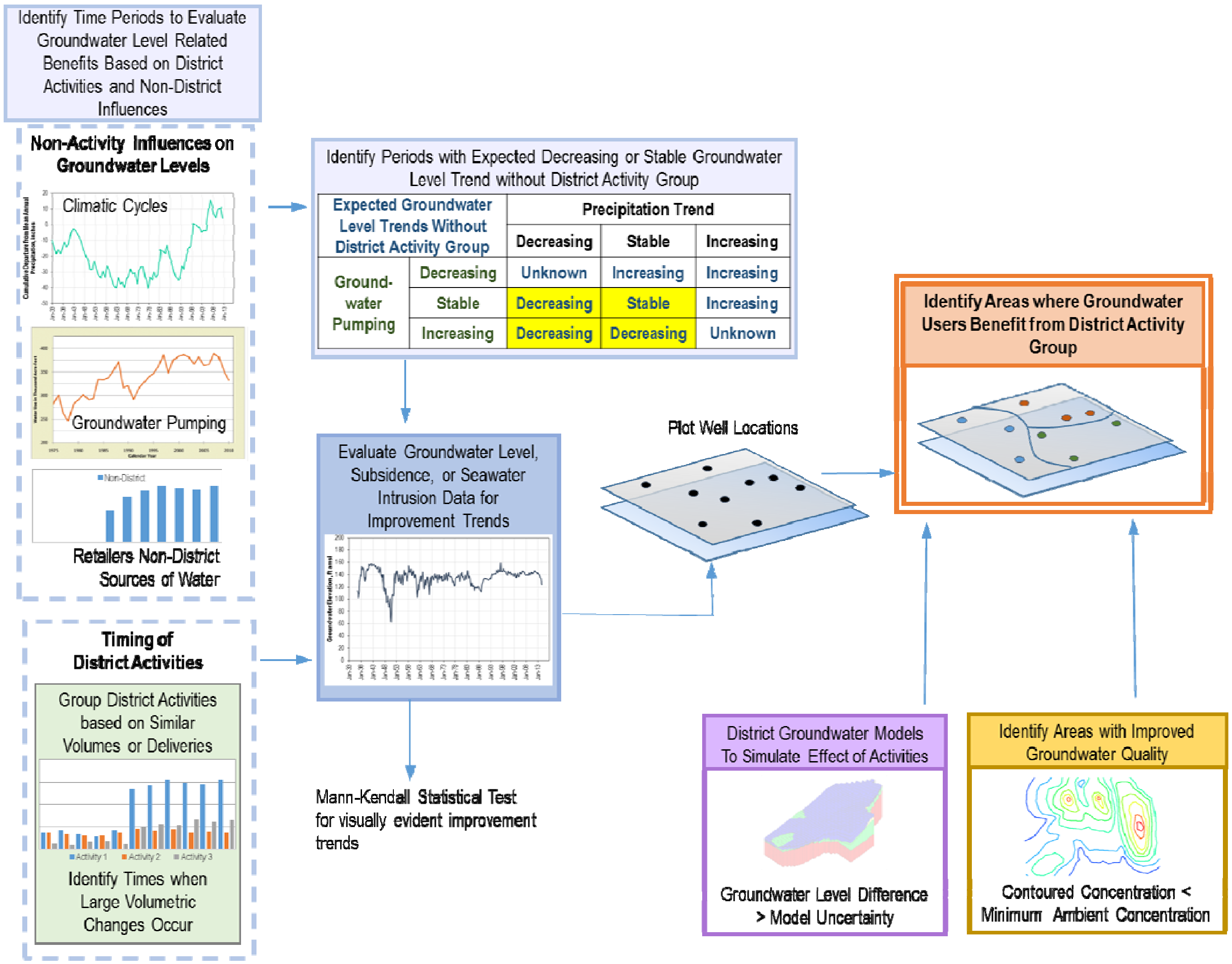

Figure 8. Flow Chart for Identifying Hydrogeologically Connected Areas where Groundwater Users Benefit from Improved Groundwater Conditions

Analysis Applied to Groundwater Level Data

Groundwater level improvements associated with District activities will first be evaluated based on trends in groundwater level observation data at wells throughout the District. As described above, there are two main categories of District activities providing groundwater level improvement benefits: managed recharge and in-lieu recharge. In-lieu recharge encompasses a number of types of activities providing in-lieu recharge: treated water delivery, untreated surface water delivery, recycled water delivery, and conservation. The purpose of this analysis is to identify groundwater level improvements associated with specific groups of District activities. The steps for this analysis will be as follows:

1. Group District activities based on category, type, location and similar volumetric recharge or deliveries over time. This grouping will be based on the most reliable information available.
2. Identify time periods when volumetric recharge or deliveries increase for each group of activities from step #1. As in step #1, time periods will be identified based on the most reliable information available.
3. In order to evaluate the influence of each group of District activities on groundwater levels, evaluate influences on groundwater levels (as described below) that are unrelated to the group of District activities being evaluated (hereafter also referred to as "the District activity group") over each time period identified for the District activity group in step #2. These influences may be hydrologic conditions, non-District activities, or other District activities[1] not in the District activity group. Based on the evaluation of these influences, identify whether the expected groundwater level trend without the District activity group would be decreasing, stable, or increasing over each time period.
4. If the expected groundwater level trend without the District activity group , as defined in step #3, is decreasing or stable, evaluate whether the groundwater level trend in wells throughout the District show an improvement compared to the expected trend over the identified time period. Although periods will not be evaluated when there is an expected increasing groundwater level trend even

[1] Evaluating influences from other District activities has been added to the methodology since draft methodology was shared with stakeholders. This will facilitate evaluating benefits from District managed recharge in areas that receive District in-lieu recharge supplies. As a result, we are evaluating groundwater pumping for an area instead of non-District net demand as described in draft methodology.

without the District activity group , any demonstrated benefit from District activities for the area would still occur during those periods.

When volumetric recharge or deliveries increase over time from a District activity group (steps #1 and #2), groundwater levels should improve or stabilize in the areas with groundwater users receiving a benefit from the District activity. Time periods of increasing volumes will typically be associated with a new source of water coming online. The groundwater level trend at wells will be evaluated over each time period with increased volumes to assess whether an area's groundwater users are receiving a benefit from the District activity.

The evaluation of hydrographs will also consider other influences on groundwater levels over the time periods identified in steps #1 and #2 that are unrelated to the District activity group, such as changing climatic cycles, water demand, and water suppliers' sources of water. The effect of these other influences on the water balance will be evaluated to identify the expected groundwater level trend without the District activity (step #3).

Changing climatic cycles will be represented by charting the departure of mean annual precipitation from the mean precipitation measured at the nearest gauge with valid data. Historic long-term precipitation data from the ALERT hydrologic data collection system within or close to the groundwater basins will be used. The data from the most-representative station or stations for an area will be used for evaluating the climatic cycle. Figure 9 shows an example mean annual precipitation departure curve with periods of different precipitation trends. If groundwater levels responded only to climatic change, the expected groundwater level trend would be decreasing between 1942 and 1955 based on the decreasing precipitation trend. The expected groundwater level trend would be increasing between 1992 and 2005 based on the increasing precipitation trend. Although any benefit from a District activity would still be occurring, we will not be able to distinguish a groundwater benefit from District activities based on increasing groundwater levels during a period of increasing precipitation.

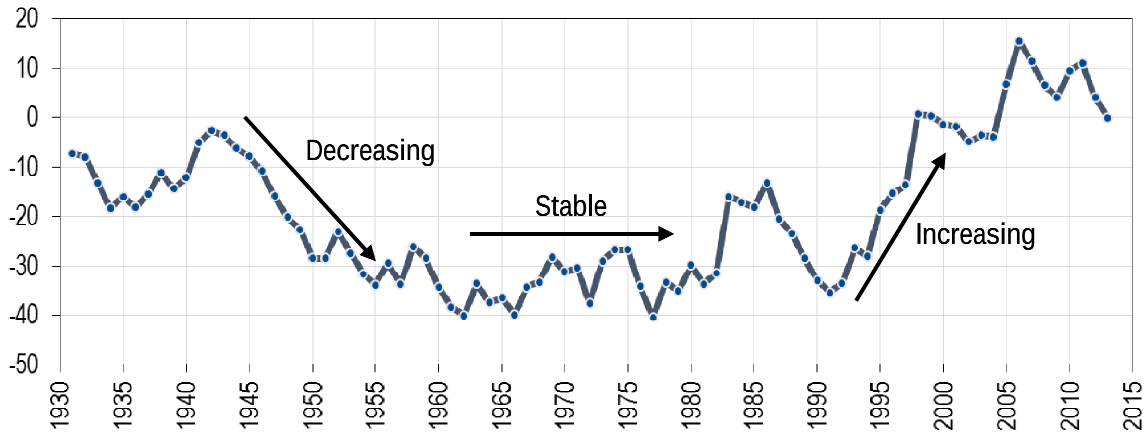

Figure 9: Example of Cumulative Departure from Mean Annual Precipitation

There are instances where water suppliers provide water sources other than groundwater, which for this study is referred to as in-lieu water supply. Groundwater pumping represents the expected influence of each water supplier's in-lieu water supplies on groundwater levels. In-lieu water supplies reduce groundwater pumping, and groundwater pumping has an inverse relationship to expected groundwater trends. Groundwater pumping will be evaluated for each water supplier's service area receiving a specific set of in-lieu water supplies. We expect a trend of decreasing groundwater levels when groundwater pumping increases within a water supplier's service area. We expect a trend of increasing groundwater levels when groundwater pumping decreases within a water supplier's service area.[2] This evaluation identifies periods when benefits from either a managed recharge or in-lieu District activity group cannot be identified due to non-District in-lieu water supplies. This evaluation also identifies periods when benefits from a managed recharge District activity group cannot be distinguished from District in-lieu recharge activities. In either of these cases, those periods will not be evaluated.

During periods of decreasing groundwater pumping, water budget information will be evaluated to assess whether the District's conservation activities may have resulted in decreasing groundwater pumping. If so, increasing groundwater levels during such a period would further demonstrate benefit from District conservation activities, but would be unable to demonstrate benefit from the District's other recharge activities.

[2] In order to account for non-District in-lieu recharge activities, groundwater pumping is equivalent to non-District net demand concept discussed in draft methodology shared with stakeholders.

Land use changes can also alter water demand. The study will include a high level description of land use changes that have impacted demand, and such changes will not be attributed to District activities.

Table 1 shows the nine potential combinations of precipitation trends and groundwater pumping trends and the expected groundwater level trends without the District activity group based on those combinations. In order to identify groundwater benefits from District activities other than conservation, groundwater level trends will be evaluated when the expected trend is stable or decreasing. The four expected scenarios that result in stable or decreasing groundwater level trends are shown in grey boxes on Table 1. These expected groundwater level trends can be compared to observed groundwater level trends to identify benefits from District activities.

Based on this analysis, a benefit from the District activity group will be demonstrated when:

- the expected groundwater level trend without the District activity group is decreasing and observed groundwater level trends are stable or increasing
- the expected groundwater level trend without the District activity group is stable and the observed groundwater level trend is increasing

If the expected groundwater level trend without the District activity group is unknown or increasing, there will not be enough information to determine the benefits from District activities. However, a benefit from the District activity group as demonstrated during other periods would still occur during these periods.

Expected Groundwater Level Trend Without the District Activity Group		**Precipitation Trend**		
		Decreasing	**Stable**	**Increasing**
Groundwater Pumping	**Decreasing**	Unknown	Increasing	Increasing
	Stable	Decreasing	Stable	Increasing
	Increasing	Decreasing	Decreasing	Unknown

Table 1: Expected Groundwater Level Trend Based on Precipitation and Groundwater Pumping (Without the District Activity Group)

Groundwater level hydrographs will be evaluated for a trend that demonstrates a groundwater level improvement compared to the expected trend and therefore a benefit to groundwater users in the area from the District activity (step #4). The groundwater level trend demonstrating improvement will need to be visually evident in the hydrograph over the period of increased volumes by the District activity as identified in step #2. A single period that shows groundwater level improvement from the District activity demonstrates benefit to groundwater users in the area because the benefits may be masked for periods where other influences evaluated in step #3 prevent identification of improvements from District activities. Figure 10 shows an example hydrograph with periods of increased volumes by District activities annotated based on new water sources being secured by the District. Note that the increasing trend in the late 1930s would likely not be used to demonstrate benefit based on groundwater level data because precipitation increased during that time (Figure 9) while the stable trend in the 1950s would be used to demonstrate benefit because precipitation was stable and demand increased.

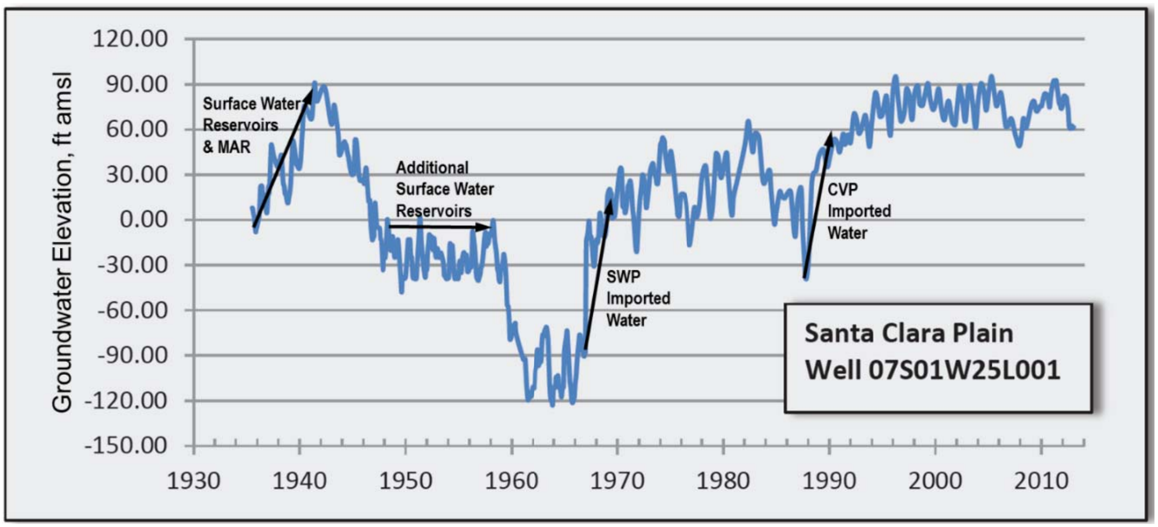

Figure 10: Groundwater Level Responses to District Activities

In order to quantify the statistical significance of the visually evident groundwater level trend demonstrating improvement, a Mann-Kendall test will be performed for data over the time period when a trend demonstrates improvement. The Mann-Kendall test is appropriate because it is non-parametric and does not rely on the distribution of the data set (Heisel and Hirsch, 2002). If data show regular seasonal variation, the seasonal Kendall test will be performed to calculate the probability that the visually evident trend is false.

If groundwater level data from a well demonstrates a benefit from a set of District activities for any time period, the map of benefits to groundwater users from that set of District activities will extend to the hydrogeologically connected area around the well.

Data used for the hydrograph analyses will be from the District's monitoring well network, and from water suppliers and stakeholders, as available. Data being considered for use will be evaluated to verify adequate measurement protocol and ensure there are sufficient regularly measured static groundwater levels to evaluate trends during times of increased volumes from District activity (step #2). Stakeholders should submit all information about the well such as a well log and construction information.

Available data for individual wells will be evaluated to ensure the wells are representative of aquifer conditions. Criteria that will be used to evaluate which individual wells will be used in the analysis include, but are not limited to:

- Well construction information, such as well depth, screened intervals, and lithology
- Period/frequency of water level measurements
- Completeness of water level records

Stakeholders are also encouraged to provide any other information, including data related to the calculation of groundwater pumping and non-District recharge activities, that they wish the study to consider. For example, information about non-District recharge activities would be evaluated using a similar procedure to District managed recharge activities. Hydrographs for wells near a non-District recharge activity would be compared to the non-District recharge quantities over time as well as District activity quantities over time to assess whether groundwater level improvements at those wells can be associated with District activities and are not solely a result of the non-District recharge activity.

Analysis of Land Subsidence Data

Improved groundwater levels are the mechanism by which land subsidence has been halted and prevented. However, land subsidence data will also be useful for evaluating benefit from District activities to groundwater users. Subsidence data will be evaluated from locations where land subsidence has occurred since 1915. Data to be evaluated includes key benchmark ground surface elevations and extensometer measurements. The expected trend without District activities given the historical subsidence at the location is continued lowering of the ground surface. If data show subsidence stops occurring after groundwater volumes increase from a set of District activities, a benefit to groundwater users in the area is demonstrated.

Analysis of Saltwater Intrusion Data

Similar to land subsidence, improved groundwater levels are the mechanism by which saltwater intrusion has been halted or reversed. Likewise, saltwater intrusion data will also be useful for evaluating benefit from District activities to groundwater users. Saltwater intrusion data represented by chloride concentrations will be evaluated from wells along the San Francisco Bay where concentrations increased above 100 mg/L after 1945. The trend in chloride concentrations over and after periods of increased water volumes from District activities will be evaluated using similar methodology to trends in groundwater levels. Trends at monitoring locations may not follow the same time periods because the effect of improved groundwater levels on saltwater intrusion may be delayed. The expected trend without District activities given the historical saltwater intrusion at the location is continued saltwater intrusion or increasing chloride concentrations. If chloride concentration data show a trend of stable or decreasing concentrations after groundwater volumes increase from a set of District activities, a benefit to groundwater users in the area is demonstrated.

Groundwater Model Simulations

Results from groundwater model simulations will be a second and equivalent line of evidence evaluated for the effect of District activities in different areas. The simulated data will be generated using calibrated District groundwater flow models for the Santa Clara Plain, Coyote Valley, and Llagas Subbasin.

Evaluating whether groundwater levels improve from District activities will be performed by comparing simulations of conditions with and without District activities. Therefore, the modeling will evaluate the same sets of District activities evaluated in the groundwater level analysis.

District activities for managed aquifer recharge are simulated in various ways in the models and reduced recharge volumes will simulated accordingly. Reduced volumes of deliveries for in-lieu recharge will be simulated as increased pumping in the models. Complete removal of managed aquifer recharge and/or delivered water for any set of District activities may alter the water balance so drastically that the basin completely dries out in the model so alternatives such as partial reductions in recharge volumes may be used for the model to provide meaningful results that can be used to evaluate the effect of District activities.

Groundwater levels simulated with District activities removed or reduced will be subtracted from groundwater levels simulated with actual historical conditions. The average difference in groundwater levels will be calculated over the modeled time period of the set of District activities. The map of the average differences will show where groundwater levels improve and benefits occur. All models have some uncertainty, and we will ensure that the benefits we identify in the model are the result of District activities, and not model uncertainty.

If results from model simulations using the Santa Clara model evaluating indirect potable reuse are available, results showing benefit from the planned recharge of purified water will be used in the evaluation.

Identifying Areas with Improved Groundwater Quality

The first step in identifying areas with improved groundwater quality as a result of District activities is identifying key constituents that differentiate ambient groundwater from recharge water. Possible constituents include total dissolved solids and nitrates. For each of these constituents, the expected range of concentrations will be estimated for ambient groundwater and recharge water. Contours of current groundwater quality will be developed around recharge streams and ponds for identified constituents using data from monitoring wells sampled by the District. Contours of concentrations below the low end of concentrations expected for ambient groundwater will define the area with improved groundwater quality and therefore benefits from the managed aquifer recharge. Isotopic analysis that differentiate ambient groundwater from recharge water will also be considered. These data were collected by the GAMA program (Ray, 2009) and as part of the Olin remediation project (MACTEC, 2009).

PROPOSING ZONES OF BENEFIT

Zones of benefit will be proposed based on the analyses described above that provides maps illustrating where groundwater users are benefiting from District activities. Zones will be proposed for areas receiving benefits from similar sets of District activities.

SUMMARY

District activities provide benefits to groundwater users through managed aquifer recharge, in-lieu recharge, and groundwater protection. A methodology has been outlined that defines the areas hydrogeologically connected to District activities. Then, available data and groundwater model simulations will be evaluated to identify the benefits from all District activities in the area. Zones of benefit will be defined based on areas receiving benefits from similar sets of District activities.

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APPENDIX A: EVALUATION OF METHODOLOGIES USED TO ESTABLISH GROUNDWATER ZONES OF BENEFIT IN CALIFORNIA

Historically, California water agencies have been limited in their ability to establish groundwater zones of benefit as a means for funding projects and programs. Statutes creating agencies to manage groundwater (such as the Santa Clara Valley Water District Act) as well as other special act districts providing water related services (e.g. Coachella Valley Water District, Monterey County Water Resources Agency, and San Benito County Water District) have various provisions related to creating charge zones. Water conservation districts formed under Water Code Division 21, and agencies providing groundwater management under AB3030 (Water Code Sections 10754 *et. seq.)* are legislatively authorized to form zones of benefit and assess charges to groundwater users to recover the cost of district activities that benefit the groundwater resource. At the request of Santa Clara Valley Water District, HydroMetrics WRI has researched current groundwater zones of benefit and the methodologies used to establish multiple zones within a single agency's jurisdiction.

The initial agencies to review for methodologies establishing groundwater zones of benefit were identified from a paper on funding sustainable groundwater management in California posted by the UC Davis Center for Watershed Sciences (Hanak et al., 2014). The UC Davis paper includes a chart prepared by the Public Policy Institute of California listing groundwater pumping charges in special act districts as of 2013/2014. Of the 15 agencies created by statute to manage groundwater, the authors found evidence that only five of those agencies charge pumping fees, including Santa Clara Valley Water District[3]. Of the remaining four, only Pajaro Valley Water Management Agency assesses charges depending on pumping location, thereby establishing different charge zones. The paper also notes that, according to the DWR Bulletin 118 2003 update, none of the AB 3030 agencies was known to have exercised its authority to enact groundwater pumping charges through the creation of groundwater replenishment districts. Five additional agencies with multiple charge zones were identified through personal knowledge and research. These are the special act districts of Coachella Valley Water District, Monterey County Water Resources Agency (Salinas Valley Basin), and San Benito County Water District, and the water conservation districts of Santa Ynez

[3] It is worth noting that the activities performed by these agencies to manage groundwater range considerably. In previous research, HydroMetrics WRI could not find any evidence that four of the listed agencies are functioning and three others do not appear to have active groundwater restoration programs.

River Water Conservation District and United Water Conservation District. The methodologies used by the six identified agencies to establish multiple zones of benefit are summarized below.

COACHELLA VALLEY WATER DISTRICT (CVWD)

The CVWD has three zones of benefit. Initially, there were two zones with boundaries corresponding to DWR subbasins. A USGS study indicated a clay aquitard within the Whitewater River subbasin, which resulted in CVWD sub-dividing that zone of benefit into two. No further analysis of the zone boundaries has been conducted, although CVWD is reconsidering restoring the Whitewater River subbasin as a single zone. The CVWD District Act limits zone charges to benefits from imported water used for direct groundwater recharge and in-lieu recharge from use of recycled water (Reyburn, 2015).

PAJARO VALLEY WATER MANAGEMENT AGENCY (PVWMA)

The PVWMA Agency Act provides for creating zones of benefit for areas within PVWMA's jurisdiction that will benefit from planning, studies, or any management program undertaken by PVWMA in a manner different from other areas within the agency's jurisdiction. Zones of benefit are established by a resolution of the board that describes the boundaries of the zones and may only be adopted following a noticed public hearing.

Two zones were established in 2010 based on delivered water (Carollo, 2010). Parcels along the coast with access to water delivered through PVWMA's coastal distribution system are in the Delivered Water Zone. All other parcels within PVWMA's boundaries are in the Outside Delivered Water Zone. In arriving at the current zone determination, several options were considered including geographic segmentation using 1/2 mile contours, hydrogeologic segmentation based on seawater intrusion, and zone of service segmentation based on availability of delivered water. The adopted variation in zone definition was intended to recognize that the water users closer to the coast benefit more (receive greater service) from PVWMA's system than inland water users.

MONTEREY COUNTY WATER RESOURCES AGENCY (SALINAS VALLEY BASIN) (MCWRA)

The Salinas Valley Basin zone of benefit has been defined based on geological conditions and hydrologic factors, which define and limit the benefits derived from MCWRA's reservoir operations. Historic work showed there to be five distinct sub-areas within the Salinas Valley Basin. Those sub-areas were first identified in DWR Bulletin 52, which established the division in accordance with sources of replenishment of groundwater for the respective areas served as indicated by direction of groundwater flow after the close of the 1944 irrigation season. Bulletin 52 emphasizes that these areas are not in any way to be confused with subbasins. This analysis resulted in the five original zones.

Historic work showed that each of the sub-areas within the Salinas Valley is hydraulically connected, but due to their varying geology and geography, they receive varying levels of benefits from the operation of the two existing reservoirs. Many of those same bodies of work have shown that the benefits that could be derived from proposed Salinas Valley Water Project facilities would also vary by geographic location within the Salinas Valley.

In 2001, a Technical Committee reviewed the sub-area delineations established in DWR Bulletin 52, and determined that there is information supporting those delineations and there is no known contradictory information. However, a review of the geology of the Salinas Valley indicates water-bearing alluvium extends south of the Upper Valley area, as delineated in DWR Bulletin 52, to beyond the Monterey/San Luis Obispo County line. This alluvium also extends west from the Salinas River area to the area surrounding San Antonio Reservoir. The original five sub-areas were, therefore, expanded to seven.

Prior to 2003, special benefit zones covering the Salinas Valley were known as: Zone 2 and 2A, which funded standby and availability charges associated with the operation and maintenance of existing facilities; and Zone 2B, which included approximately 12,800 acres of irrigated agricultural lands within the Castroville Seawater Intrusion Project (CSIP) distribution system. In 2003, Zone 2C was created and includes the lands that receive benefits from the Salinas Valley Water Project. Zone 2C overlays the previous Salinas Valley zones and was defined based on geological conditions and hydrologic factors, which define and limit the benefits derived from the reservoirs and the proposed changes to the operations, storage, and release of water from the reservoirs. Zone 2C is separated into the seven major hydrologic sub-areas described above.

The basis for inclusion within the Zone 2C zone of benefit consists of the following eight criteria reviewed and approved by the Technical Committee in 2001:

(a) There must be a hydro-geologic or flood protection basis for establishing benefit;

(b) The zone of hydrologic benefits is defined as land overlying water bearing alluvium that has hydraulic continuity with the Salinas River;

(c) The zone of benefit excludes narrow, likely shallow, channels off the main basin where pumping cannot induce an up-gradient recharge;

(d) Existing annexations that are non-hydraulically connected have been included since they are receiving benefits through physically installed pumping and piping equipment;

(e) The southern boundary of the zone of benefit is defined by the Monterey/San Luis Obispo County line;

(f) Lands immediately adjacent to San Antonio reservoir receive hydrologic benefits due to recharge of the underlying aquifer and receive recreational benefits afforded by their proximity to San Antonio reservoir;

(g) The boundary in the Fort Ord area is defined by the existing boundary of zone 2A. ;

(h) Any contiguous parcel that overlies a portion of the alluvial material that is in hydrologic continuity with the Salinas River has been included in a zone of benefit since the overlying portion of the parcel provides access to all hydrologic benefits (RMC, 2003).

Section 3.2.1 of the Salinas Valley Water Project Engineer's Report (RMC, 2003) describes the benefits and weighting factors assigned to each benefit in developing the Zone 2C charges. The benefits are identified as: (1) control of seawater intrusion; (2) flood control; (3) increased groundwater recharge; (4) groundwater quality; (5) timing and location of the recharge; (6) drought protection; (7) preservation of aquifer storage; and (8) recreation.

SAN BENITO COUNTY WATER DISTRICT (SBCWD)

SBCWD was formed by a special legislative Act in 1953. The original jurisdiction was valley-wide instead of county-wide. An early amendment to the Act, redefined the boundaries to be county-wide; however, taxing powers were limited to areas within zones of benefit. Five zones were created between 1953 and 1967 to fund specific projects. Only Zone 3 of those original five zones remains active. Zone 3 was formed in 1957 to finance construction and operation of the Hernandez and Paicines reservoirs and related groundwater recharge and management activities. The original Zone 1 practically overlapped with Zone 3 exactly and was dissolved. The other original zones were dissolved for the following reasons: the Zone 2 function was assumed by the Tri-County Water Authority; the Zone 4 function was turned over to the City of Hollister; and Zone 5 was temporary to finance engineering and hydrological studies to prepare development of facilities to distribute San Felipe water and was succeeded by the permanent operating Zone 6 (Creegan & D'Angelo-McCandless, 1977, pages I-2 – I-3).

The current Zone 1 encompasses the entire county and provides the funding base for specific SBCWD administrative expenses. The methodology used to define the Zone 3 boundaries could not be located. A master plan report prepared in 1977 by Creegan & D'Angelo-McCandless, Consulting Engineers, documents the formation of Zone 6, which establishes the assessment area for financing the capital and operating expenses of the San Felipe project (CVP). Zone 3 and Zone 6 overlap in areas that receive benefits from projects funded by the both zones.

The Zone 6 boundaries were determined primarily by land classifications within the area to receive CVP water. The foundation document for establishing the project benefit area was the U.S. Bureau of Reclamation's March, 1973, "Land Classification Appendix" for the Hollister Subarea, San Felipe Division, Central Valley Project. The Zone 6 area encompasses acreage referred to in the Land Classification Appendix as the Hollister Basin and San Juan Valley. Zone 6 boundary modifications were made in the above referenced master plan to eliminate non-irrigable lands in adjacent hills, for political considerations, and to observe parcel boundaries to simplify taxation.

SANTA YNEZ RIVER WATER CONSERVATION DISTRICT (SYRWCD)

SYRWCD was formed in 1939 for the primary purpose of protecting water rights on the lower Santa Ynez River following construction of two upstream reservoirs. Additional projects or exportation of water were also being studied, and the Cachuma Project was administratively authorized in the same year. For these reasons, the people of the Santa Ynez and Lompoc Valleys joined together to form a water conservation district. The purpose of SYRWCD is to protect, and if necessary, augment the water supplies of the SYRWCD. (Stetson Engineers, 2015). SYRWCD's role is essentially that of an oversight authority and it operates on a budget of approximately $500,000/year. Groundwater charges are incurred by the owners of water production facilities and are charged at uniform rates (for each category of water) within SYRWCD or each Zone thereof, based on the amount of groundwater produced (Wales, 2015).

There were three zones prior to 1995: the Santa Ynez River alluvial channel; the Lompoc Plain; and all others. In the course of preparing an AB3030 plan, SYRWCD convened a committee of five geologists who determined boundaries for three additional zones based on hydrogeological distinctions and groundwater recharge from the Santa Ynez River. While SYRWCD continues to be segregated into six zones, there are only two groundwater rate schedules: Zone A (Santa Ynez River alluvial channel), which accounts for 27% of the total groundwater pumping, and Zone B (Lompoc Plain, Lompoc Upland and Lompoc Terrace sub-basins), which accounts for 50% of the total groundwater pumping, are charged at a higher rate; Zones C, D, E, and F are charged a lower rate (Wales, 2015). Zone C encompasses all portions of the SYRWCD not included in the other zones, and Zones D, E, and F cover the SYRWCD's portion of three distinct upland basins.

UNITED WATER CONSERVATION DISTRICT

United Water Conservation District (UCWD) has established two zones. Zone A includes all lands lying within the boundaries of UWCD. Zone B was formed to pay for operation and maintenance of, and any improvements to, the Freeman Diversion project facilities. Zone B is a sub-area of Zone A that encompasses the portions within the UWCD boundaries of all DWR defined basins or subbasins down gradient of the diversion project. Since 2012, two of these basins have been re-labeled (Montalvo is now referred to as Oxnard Forebay; and North Las Posas is now referred to as West Los Posas), but the zone boundaries have not been re-evaluated (Morgan, 2015).

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