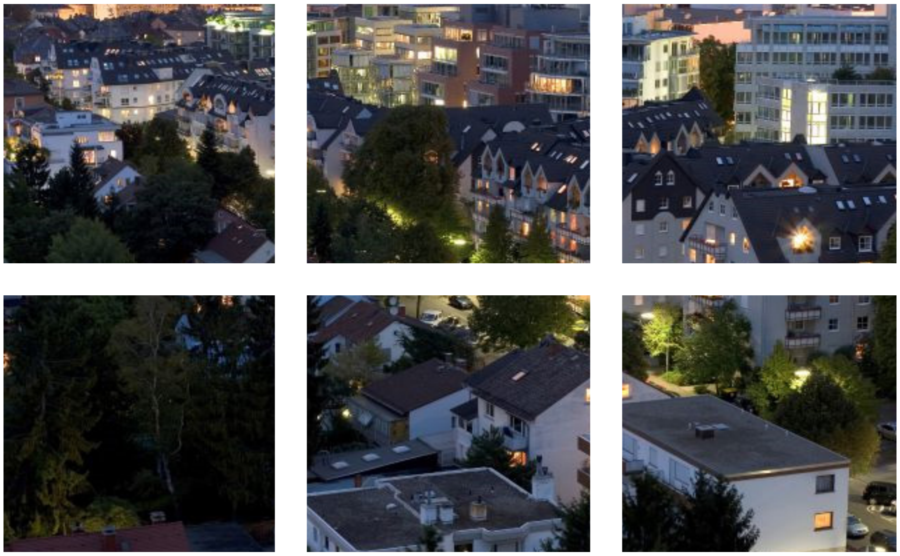

CALIFORNIA EMBEDDED WATER ENERGY SAVINGS – A COMPARATIVE BILLING REVIEW

Submitted to:
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1 EXECUTIVE SUMMARY

Water-related energy use in California is responsible for a significant portion of the state's overall electricity consumption.[1] Approximately 7% of the state's overall electricity use is consumed in the supply, conveyance, treatment and distribution of water upstream of end users.[2] When water is conserved, energy inputs are avoided that would have otherwise been required for the production, treatment and distribution of the conserved water. Estimating changes in this embedded energy use has been the focus of efforts by the California Energy Commission and the California Public Utilities Commission.[3] The CPUC Water Energy Calculator captures much of the work done to date on this topic and allows users to estimate embedded energy savings associated with a given volume of conserved water.[4]

The purpose of the current study is to contribute to the body of work that informs calculations of outdoor embedded energy reductions associated with water conservation. The study centers on calculating changes in water utilities' electricity consumption coincident with the 2015 statewide urban water reduction mandate based on billing data review. The study is organized around three objectives:

- Investigate and replicate statewide 2015 Q3 (July-September) energy use reduction calculations using average hydrologic region energy intensities
- Use billing data review to calculate outdoor embedded energy use changes 2013-2015
- Provide preliminary observations on patterns of change in energy intensity (EI) during the study period 2013-2015

The first study objective includes a re-calculation of embedded energy savings using the methods and data sources that underlie the CPUC Water Energy Calculator for the third quarter (Q3) of 2015, as applied in a web-based water-energy tool published by UC Davis.[5] The second component of the study focuses on the aggregation of monthly electricity bills upstream of end users for approximately 30 water agencies to directly calculate electricity use in 2014 and 2015 relative to 2013 as the baseline year. Finally, the study team investigates changes in the amount of energy required to extract and transport a parcel of water from its source to end-users, also known as energy intensity (EI), over the study period (2013-2015). Preliminary observations regarding changes in energy intensity over the study period are placed in comparison to the EI of water from the State Water Project (SWP), a long-distance conveyance system

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[1] See http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf

[2] California Public Utilities Commission, Embedded Energy in Water Studies. Study 1: Statewide and Regional Water-Energy Relationship (prepared by GEI Consultants/Navigant Consulting, Inc., 2010).

[3] See e.g. Executive Order B-29-15, https://www.gov.ca.gov/docs/4.1.15_Executive_Order.pdf

[4] http://www.cpuc.ca.gov/nexus_calculator/

[5] See https://cwee.shinyapps.io/greengov/

that transports water from the Sacramento River delta to end users across California. The findings from this study offer perspective on the accuracy of the data sources and methods underlying the CPUC Water Energy Calculator, as well as an initial foray into using a billing data review approach for directly measuring outdoor energy use changes coincident with changes in water use.

Investigating and replicating statewide 2015Q3 energy use reduction calculations using average energy intensities

A 2015 study by Navigant Consulting developed average outdoor energy intensities for each of California's ten hydrologic regions as defined by the California Department of Water Resources (DWR).[6] The average energy intensity values for each hydrologic region are the sum of the average energy intensities for water extraction, transport, potable water treatment, and distribution to end users. These average hydrologic region EIs underlie the embedded energy calculations in California's water-energy savings calculator and are applied in the 2016 UC Davis water-energy tool.[7] The study team re-calculated statewide energy savings from the 2015 mandate by investigating and replicating the calculation methods that underlie the CPUC water-energy calculator as applied in UC Davis water-energy tool. This effort began with an intensive review of existing literature and data sources. The evaluation team then recreated the 2015Q3 savings calculations and incorporated recommended changes relative to the UC Davis approach that emerged from the literature review.

Using billing data review to calculate outdoor embedded energy use changes 2013-2015

The second study objective was to use billing data to directly calculate changes in water-related electricity consumption at the water utility for a selection of 32 water agencies throughout the state. To be clear, the relevant set of billing accounts for a given water agency were those electric accounts associated with groundwater pumping, water transport, and potable water treatment, all upstream of end users and therefore exclusive of energy inputs directly from end users or wastewater treatment. While these water agencies were selected for broad representativeness across all 10 hydrologic regions and across a range of degrees of reliance on groundwater pumping versus surface water resources, it was not a random sample. The team relied on selecting water agencies where these accounts could be reasonably distinguished from other civic electric accounts using key words in the customer account names (such as "water district"). The primary approach was to use customer information systems (CIS) and associated 2013-15 billing data to calculate changes in water agency electricity consumption between 2013, 2014, and 2015 associated with outdoor water production. Where possible, these calculations were corroborated with electricity consumption and water savings data solicited by the study team directly

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[6] *Water/Energy Cost-Effectiveness Analysis*, Navigant Consulting, CPUC, April, 2015. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5356

[7] See https://cwee.shinyapps.io/greengov/

from water agency managers. Measured changes in water agencies' electricity consumption were then compared against parallel estimates calculated using the CPUC water-energy calculator approach. The results from the comparative billing review provide perspective on the accuracy of the existing CPUC methods and aid in the development of a set of recommendations for future improvements.

Providing preliminary observations on patterns of change in energy intensity (EI) during the study period 2013-2015

The final objective of the study was to provide commentary on patterns of change regarding EI between 2013 and 2015. The existing CPUC water energy calculator implies a default that energy intensities are stable and broadly representative of an average year. To better inform recommendations for improvements to the calculator, the evaluation team focused on two areas of year-to-year change potentially affected by changing drought conditions. The first of these was documenting the relationship between the volume of conserved water in different years and corresponding reduction in energy consumption to see if this was a simple linear association. The second was the relative reliance on groundwater versus imported water at the hydrologic region level across the study period.

The study team calculated the average energy intensity of each water agency in the sample for 2013 and 2015 and then for individual system components, including water production, potable water treatment, and distribution to end users. The study team also provided a preliminary characterization at the hydrologic region level of shifting degrees of reliance on groundwater pumping versus surface water imports, such as the State Water Project (SWP) for 2013-2015. Looking at groundwater pumping energy intensity from the billing data review relative to surface water energy intensity from publicly available SWP data and other secondary data sources, the team developed data-driven recommendations for adjustments to the CPUC water-energy calculator.

Key Findings

Key findings from this research are as follows:

- The study team provided two significant downward adjustments to the UC Davis web-based tool calculation of 460 GWh energy savings for 2015Q3, yielding an estimate of 130 GWh for statewide outdoor embedded energy reductions. One key adjustment is the exclusion of wastewater treatment which had been included in the UC Davis calculation. Also, in the revised approach savings are calculated for 2015 overall and then divided by four to yield a savings estimate for 2015Q3. The adjustment to an average quarter is done because the EI inputs to the calculation are derived on an annual basis and therefore should be applied to a year's worth of conserved water to avoid a methodological mismatch between the derivation and application of the EI figures. Lastly, the calculation of IOU-only energy usage reductions (i.e. energy usage reductions associated with power supplied by IOUs) should incorporate volumetric water savings data only from those water agencies whose power is supplied by IOUs. The study team notes that water agencies whose power is not provided by IOUs (but is instead provided by publicly owned utilities, or POUs, for example) were included in the original estimate. However, the study team did not make a quantitative adjustment to the savings calculation for this consideration, due to difficulties in identifying the full list of water agencies whose power is provided by IOUs.

- For the water agencies included in this study, results from the billing review indicate that reductions in water agencies' energy consumption in 2015 relative to 2013 are lower than those estimated using the CPUC water-energy calculator by an average 25%.[8]
- Groundwater-reliant water agencies in the billing data review showed 30% lower embedded energy reductions on average than those estimated using the average hydrologic region EI values.
- Import-reliant water agencies and mixed-source water agencies in the study showed only modestly lower embedded energy use reductions in the billing data review compared with the average hydrologic region EI approach.
- Billing data review shows embedded energy use reductions taking a two-stage trajectory, from 2013 to 2014 and from 2014 to 2015, with an especially large proportional reduction 2013 to 2014 for groundwater-reliant water agencies.
- Across all water agency types, the billing data review shows distinctly higher variability from one water agency to the next in embedded energy use change relative to the average hydrologic region EI approach.
- Based on limited data, the energy intensity of groundwater production and distribution appear to have increased over the study period 2013-2015, coincident with increasing drought conditions.
- Embedded energy reductions do not appear to increase in a 1-to-1 fashion with volumetric water savings. Rather, embedded energy reductions exhibit a relationship with water savings whose shape may be affected by changing drought conditions, changing pump system efficiencies at different volumes, and/or other factors.
- Eight out of the ten hydrologic regions in the state saw increasing reliance on groundwater pumping as a proportion of total water supply over the course of the study period. Additionally, most hydrologic regions sourcing water from the State Water Project showed a decline in reliance

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[8] This is exclusive of Contra Costa Water District, a district included in the overall water agency selection but whose data was excluded from overall averages in reporting. This was due to data quality concerns on the part of the study team. In particular, the number of water-related accounts for this water agency was deemed to be abnormally and unexpectedly high based on the satellite imagery approach used in this study. This may be due to incorrect identification of pump infrastructure and associated electric billing accounts. Findings for Contra Costa Water District, with acknowledgement of these potential data issues, are addressed in a standalone subsection of the report.

on surface water imports. These supply shifts took place within the context of declining total urban water consumption 2013-2015.

Recommendations

While embedded energy in water has the potential to be a significant source of energy savings, there is a lack of consistent rigor at a granular level of detail for estimating these savings. The study team recommends that the CPUC and other relevant stakeholders consider the following actions to increase the accuracy of embedded energy estimates looking forward. These recommendations fall into three broad categories supported by more specific recommendations in some cases:

- Consider expanding the billing data review approach to all water agencies throughout the state. In support of this recommendation:
    - Due to the inherent increased accuracy of the approach, consider expanding the billing data review approach to all water agencies throughout the state. This approach is a direct means of measuring changes in electricity usage concurrent with changes in water usage. It makes use of electric billing data that is more comprehensive and longer-standing than available volumetric water consumption data. If conducted on a recurring basis, this approach could yield outdoor embedded energy savings calculations in a way that augments or replaces the average hydrologic region EI approach.
    - Incorporate data collection on changes that affect equipment efficiency into calculations of embedded energy use. These changes may include investment in new pumps or variable speed drives. It also may include other changes that affect electricity consumption per volume of water pumped, such as reductions in output per pump due to friction in the common discharge pipe when multiple pumps operate in a parallel arrangement.[9]
- Consider refinements to improve the accuracy of the average hydrologic region EI approach that underlies the existing CPUC water energy calculator. In support of this recommendation:
    - Consider developing a system of adjustments that can be made to the average hydrologic region EIs as a function of drought intensity to better match embedded energy savings with current water conditions. It may be possible to identify easily measured proxy indicators that have a generally predictable effect on some components of overall EI, such as groundwater pumping, which may be applied as adjustment factors.
    - Make frequent, scheduled updates to the existing CPUC water-energy calculator as up-to-date information is reported. The urban water management plans (UWMPs) published for each water agency and the regional water reports published by the department of water resources (DWR) are excellent resources for this purpose. Both are updated on a routine

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[9] Al Lutz, PE, Itron, personal communication.

basis and provide valuable information on total water production and other relevant statistics for calculating energy intensities.

  - Work with other state agencies to require that water agencies report water-related energy consumption and total water production at least annually, and preferably monthly, as part of the routine UWMP process. In the absence of this requirement, accurate information on water agency energy consumption and water production may only be available every five years.

- At a general level, prioritize investment in the accuracy of calculating and evaluating embedded energy savings commensurate with the magnitude of these savings relative to other energy savings opportunities and priorities.

2 INTRODUCTION

When water is conserved, energy use is avoided that would otherwise be associated with the production,[10] treatment for potable use, and distribution of that water upstream of end users. In California, these embedded energy savings, coincident with the 2015 statewide mandate for 25% reduction of urban water usage, were estimated to be of comparable magnitude to the total savings from all utility energy efficiency programming traditional energy saving portfolios for the July-September 2015 period.[11] While avoided energy inputs from conserved water have the potential to be a significant source of energy savings, there is a lack of an industry agreed upon evaluation framework for estimating these savings. Rigorous evaluation and standardized reporting for estimating energy savings from water conservation is an outstanding need that it is crucial for the full realization of potential energy savings and the development of effective policies. This report details the methods that the evaluation team used to directly observe changes in water utility electric bills for 2013-2015. This period captures the 2015 statewide water conservation mandate (Executive Order B-29-15)[12] and the relevant baseline period of 2013. This study is an empirical evaluation of energy savings during a period of mandated state-wide urban water conservation and is part of the CPUC's continuing effort to obtain accurate estimates for embedded water energy savings.

Estimation of embedded water energy savings requires knowledge of the amount of energy that is required to extract and transport a parcel of water from its source to end-users and is referred to as its energy intensity (EI). EIs are presently used to estimate embedded water energy savings from water-saving measures and state-wide water conservation programs. Existing frameworks for estimating embedded water energy savings center on average energy intensity values for each of California's ten hydrologic regions as defined by the California Department of Water Resources (DWR). These overall average energy intensity values for each hydrologic region are the sum of the average energy intensities for water extraction, transport, treatment, and distribution within each region. A 2015 study by Navigant Consulting yielded average EIs for overall energy use as well as for IOU-only energy use.[13] The study serves as the data source for California's water-energy savings calculator.[14] One such application that followed the 2015 Navigant study was the 2016 UC Davis water-energy tool, published as part of the 2016 CA Water

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[10] Production encompasses a mixture of groundwater pumping, surface water conveyance, water recycling, and desalination. This mix is different across varying regions of California.

[11] See https://cwee.shinyapps.io/greengov/

[12] https://www.gov.ca.gov/docs/4.1.15_Executive_Order.pdf

[13] Water/Energy Cost-Effectiveness Analysis, Navigant Consulting, CPUC, April, 2015. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5356

[14] See http://www.cpuc.ca.gov/nexus_calculator/

Board Data Innovation Challenge, which applied the 2015 Navigant derived average EIs at the hydrologic region level to estimate 2015 Q3 water energy savings.[15]

This report builds upon work that has been done to date on embedded energy savings in water. The primary approach is to make use of customer information systems (CIS) and associated billing data for water agency accounts from 2013-2015 for a selection of water agencies throughout the state. For each selected water agency, the billing accounts encompass groundwater pumping, transport, storage, potable water treatment, and distribution upstream of urban end users. Using these data sources, the evaluation team developed estimates for each water agency's embedded water energy savings in 2014 and 2015 relative to 2013. Estimates were then directly compared against parallel estimates representative of the CPUC water-energy calculator to provide perspective on the existing method's accuracy and to develop a set of recommendations for future improvements.

2.1 BACKGROUND AND OBJECTIVES

The production, conveyance, treatment, and delivery of water involves electricity inputs at multiple stages between the initial sources and the end users. This makes the calculation of associated electricity consumption a complex undertaking that requires careful consideration of the boundaries of the system and accurate identification of the system inputs. A water agency billing data review approach implicitly defines the analysis system as all water pumping activity directly taking place within a given water agency and upstream of end users. It offers the opportunity to empirically observe energy savings associated with water conservation and compare estimates of reduced energy use to estimates that apply the methods and inputs of the CPUC water-energy calculator.

The most recent related research includes the UC Davis Water Energy 2016 project that produced a graphical user interface that allows a user to select a tailored water energy savings profile by water agency and for the state overall. The primary supporting research contributing to the UC Davis water energy project was the study that developed the CPUC water energy calculator.[16] The water energy calculator is a flexible tool that policy makers can use to generate estimates of energy savings associated with a variety of water saving strategies, most recently updated following a 2015 errata.[17] The CPUC water energy

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[15] See https://cwee.shinyapps.io/greengov/

[16] *Water/Energy Cost-Effectiveness Analysis*, Navigant Consulting, CPUC, April, 2015.

[17] Water/Energy Cost-Effectiveness Analysis Errata, Navigant Consulting, CPUC, May, 2015.

calculator used energy estimates for specific water system components detailed in earlier CPUC commissioned reports by Navigant.[18], [19]

The three objectives of this study were:

1. Investigate and replicate statewide 2015Q3 energy use reduction calculations using average hydrologic region energy intensities
2. Use billing data review to calculate outdoor embedded energy use changes 2013-2015
3. Provide preliminary observations on patterns of change in energy intensity (EI) during the study period 2013-2015

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[18] Embedded Energy in Water Studies Study 2: Water Agency and Function Component Study and Embedded Energy-Water Load Profiles, Navigant Consulting, CPUC, August, 2010.

[19] Embedded Energy in Water Studies Study 1: Statewide and Regional Water-Energy Relationship, Navigant Consulting, CPUC, August, 2010.

3 METHODS

The methods described here are replicable and are designed to provide useful feedback to the CPUC on current methods for estimating embedded water energy savings. Each study objective has a unique set of methods that are described separately below.

3.1 RE-CREATING 2015Q3 SAVINGS CALCULATIONS USING AVERAGE HYDROLOGIC REGION ENERGY INTENSITIES

California is divided geographically into 10 hydrologic regions defined by the Department of Water Resources based on regional water drainage basins and typical water supply sources.[20] Previous embedded water energy estimates have incorporated data at varying levels of granularity to calculate embedded water energy savings for individual water system components, water agencies, and the state.

Objective 1 of this study was to re-create pre-existing calculations of water energy savings for 2015 using hydrologic region average EI values and State Water Board reported volumetric water savings. As part of fulfilling objective 1, the study team conducted an intensive literature review of existing methods for estimating embedded water energy savings in California. The study team focused on the studies that support the CPUC water-energy calculator[21] and the later UC Davis water-energy tool[22] that applied the values and methods of the CPUC calculator.

Estimating embedded water energy requires data on the amount of energy that has been required to extract, transport, and distribute a water volume. Previous studies have developed energy intensity (EI) values to represent the amount of embedded water energy carried by a volume of water within each aspect of California's water framework (Figure 3-1).

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[20] http://www.water.ca.gov/waterplan/cwpu2013/final/index.cfm

[21] *Water/Energy Cost-Effectiveness Analysis*, Navigant Consulting, CPUC, April, 2015.

[22] https://cwee.shinyapps.io/greengov/

FIGURE 3-1: SYMBOLIC REPRESENTATION OF CALIFORNIA'S EMBEDDED WATER ENERGY EVALUATION FRAMEWORK

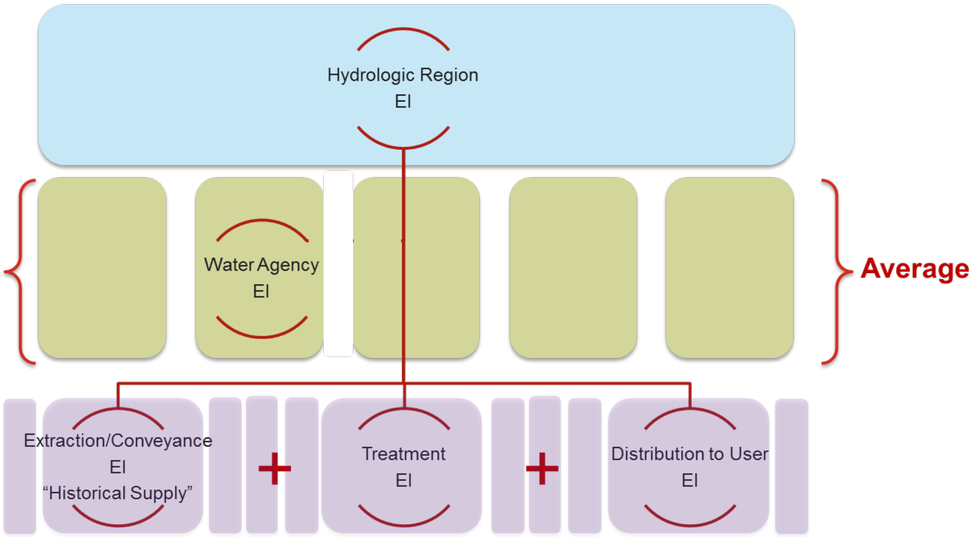

Figure 3-1 symbolically represents California's framework for estimating embedded water energy where each level of the framework has an EI. The most granular level is the water agency system component EIs of water extraction, treatment, distribution, and potable water treatment. Individual water agency EIs represent the next most granular level and are a sum of their individual system component EIs. Finally, averaging EIs across a set of geographically bound water agencies represents a hydrologic region EI. Note that these hydrologic region EI's can be expressed as either including or excluding any EI associated with the state's major water conveyance systems, such as the State Water Project (SWP), which may play a role in the overall extraction and transport of a parcel of water from its initial source to its end use. Power supply for these long-distance conveyance systems is independent of IOU power. The default EIs in the CPUC water energy calculator are "IOU-only" and exclude energy associated with these conveyance systems.

The CPUC water-energy calculator requires a user to input a conserved water volume that is then multiplied by the average IOU-only EI of the hydrologic region where the water conservation has taken place (average hydrologic region EI). The 2016 UC Davis water-energy web tool, developed as part of the 2016 CA Water Board Data Innovation Challenge, relies on the default methods and values of the CPUC water-energy tool. The web tool uses water savings supplied by water agencies to the State Water Board (SWB)[23] for Q3 2015 as its source for conserved water volume. These volumetric water savings are based on "water in use" within a given water agency, that is, groundwater and surface water that is treated for consumption and consumed within water agency boundaries. As such, this excludes any water that is

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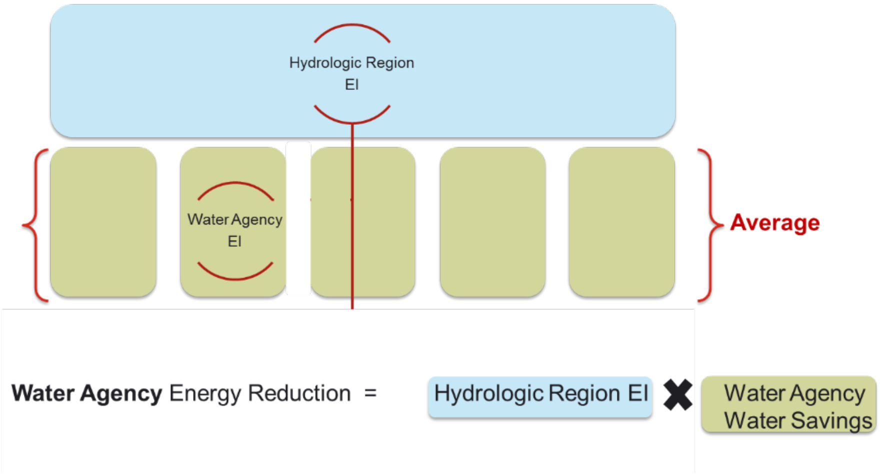
[23] http://www.waterboards.ca.gov/water_issues/programs/conservation_portal/conservation_reporting.shtml

recycled but not returned to potable use through treatment, any water produced locally but exported to another water agency for consumption, and raw water (local water such as lake water that is used without treatment). The inputs to the UC Davis water-energy web tool result in estimated Q3 2015 embedded water energy savings relative to a 2013 baseline for individual water agencies and for the state of California following the summer 2015 state-wide water conservation mandate.

FIGURE 3-2: UC DAVIS WATER-ENERGY WEB TOOL METHOD



The average hydrologic region EI values in the CPUC water-energy calculator can be modified to fulfill different goals. Importantly, the UC Davis water-energy tool applies a representative set of average hydrologic region IOU-only EI values that includes wastewater treatment in addition to water extraction, distribution, and treatment. This means that, unlike the billing data review conducted by Itron in this study, the embedded energy savings estimates from the UC Davis calculator include energy usage downstream of the user.

Part of objective 1 was to reproduce the UC Davis water-energy tool estimate for embedded water energy savings. The UC Davis water-energy tool estimate is relevant to this study as it applies to the same time interval and is also an example estimate where the values and methods of the CPUC water-energy calculator have been applied. In the recalculation of the UC Davis estimates the Itron team similarly applied IOU-only average hydrologic region EI values but with the exclusion of wastewater EI. The evaluation team excluded wastewater treatment to be consistent with the boundaries of the study being limited to only water system components upstream of the user. Additionally, in an effort to provide a more comparable metric of embedded water energy savings to California energy efficiency program savings, the Itron team calculated savings for an average quarter in 2015, rather than for 2015Q3 specifically. Additionally, through the process of recalculating UC Davis' estimate, the team identified several non-IOU serviced water utilities in the SWB water conservation data set that in future IOU-only estimates should be removed.

The CPUC average hydrologic region EI values were developed in a 2015 Navigant study focused on estimating embedded water energy savings for reporting water cost effectiveness. The average hydrologic region EI values calculated in the 2015 report are, in turn, derived from previous Navigant studies in which EI values were developed at the water agency and system component level. The 2015 Navigant study approximated hydrologic region EIs through a weighted average of the water system component level EIs by each hydrologic region's reported historical water supply mix published by the Department of Water Resources (DWR).[24] The result was a set of average hydrologic region EI values for each water system component: water extraction, treatment, distribution, and wastewater treatment. Reporting the average hydrologic region EIs in this way allows the user to modify estimates based off the boundary conditions of the desired embedded water energy reduction estimate. Following the 2015 final report, Navigant released an errata adjusting the previously published average hydrologic region EI.[25] In this study the evaluation team applied the errata outdoor AVG HR IOU-only EIs, unless otherwise noted.

Navigant's previous studies that estimated the EIs of each water system component relied on a combination of primary water agency supplied data, interpolated and average data, publicly available data, and engineering models. Navigant's Study I: Statewide and Regional Water-Energy Relationships[26] was focused on estimating the EI of water sources such as groundwater extraction, whole-sale water imports, and state-wide water conveyance systems. This study resulted in EI estimates for each water source using DWR published hydrologic region historical supply mix data, publicly available water conveyance systems data, directly solicited wholesale water agencies' data, and well observation data. Data extracted from DWR observation wells was then interpolated and averaged across groundwater basins and inputted into a groundwater pumping model. The model was based off groundwater pumping engineering calculations and incorporated a set of numerical assumptions for well drawdown, pump efficiencies, column loss, etc. The groundwater pumping model was then used to approximate the EI of groundwater extraction for each hydrologic region. Navigant's Study II: Water Agency and Function Component Study on Embedded Energy-Water Load Profiles[27] elicited data from 22 water agencies across the state to derive estimates for the EI of water extraction, treatment, distribution, and wastewater treatment. The study attempted to survey water agencies representative of California's diversity in water agency structure, supply mix, climatology, and local topography. The results were presented as a representative range of EIs for each system component by IOU.

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[24] http://www.water.ca.gov/waterplan/cwpu2013/final/index.cfm

[25] Water/Energy Cost-Effectiveness Analysis Errata, Navigant Consulting, CPUC, May, 2015.

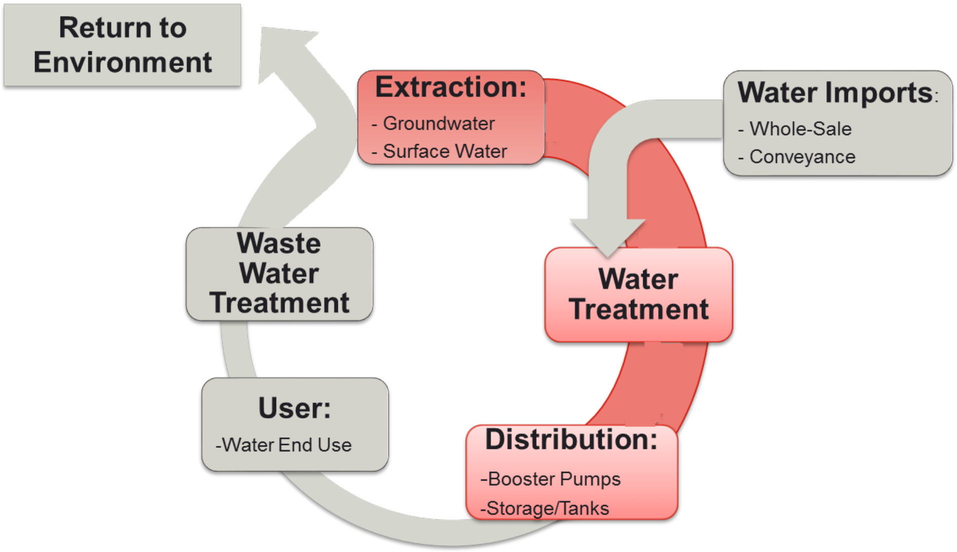
[26] Embedded Energy in Water Studies Study 1: Statewide and Regional Water-Energy Relationship, Navigant Consulting, CPUC, August, 2010.

[27] Embedded Energy in Water Studies Study 2: Water Agency and Function Component Study and Embedded Energy-Water Load Profiles, Navigant Consulting, CPUC, August, 2010.

3.2 BILLING DATA REVIEW

Objective 2 of this study was to use a billing data review to directly calculate changes in electricity use at the water agency level 2013-2015 for a selection of approximately 30 water agencies throughout the state and then compare savings calculations with estimates derived using average hydrologic region EI values. The methods described with respect to objective 2 detail the evaluation team's selection of water agencies and subsequent billing data review. Energy reductions are calculated for each water agency at the annual level for 2015 relative to a 2013 baseline. The annual energy consumption of each water agency is calculated from the aggregation of the relevant site accounts' monthly electric bills for 2013-2015. Annual 2015 energy reductions are reported both as an annual MWh difference and as a percentage difference relative to 2013. Each water agency's percent energy reductions are then compared against a parallel estimate calculated using average hydrologic region EI values and SWB water conservation data following the methods detailed in objective 1. The energy reductions calculated for water agencies using the billing review method include groundwater extraction, treatment, and distribution to water end users as highlighted in Figure 3-3.

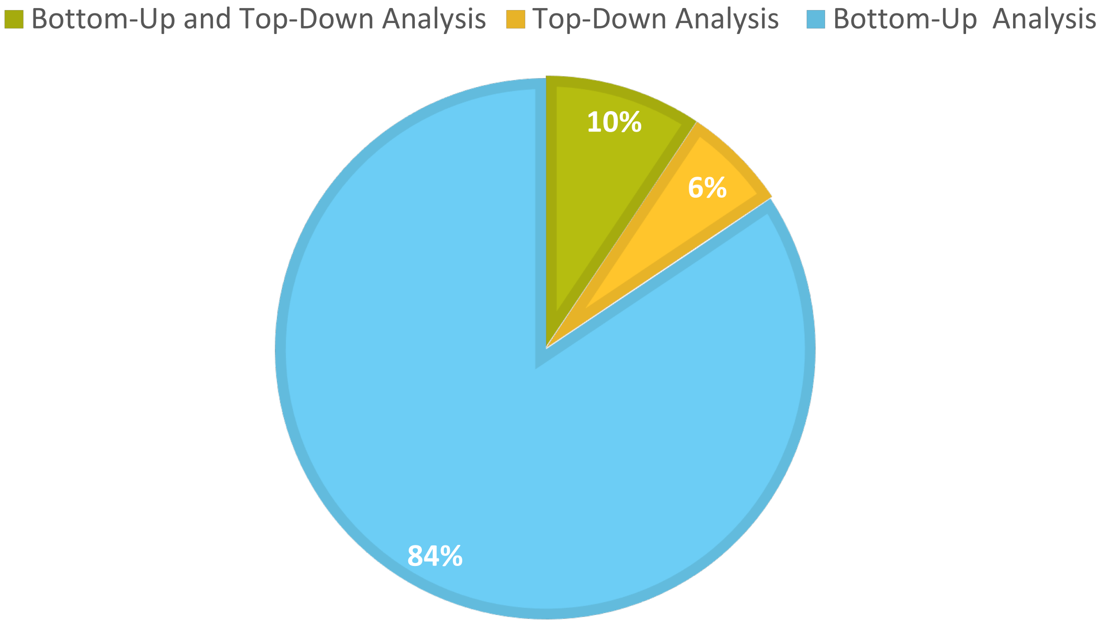
FIGURE 3-3: THE SCOPE OF THE BILLING REVIEW: EXTRACTION, WATER TREATMENT, DISTRIBUTION



The scope of the billing review is comparable to IOU-only outdoor embedded water energy reduction estimates as it excludes the energy consumption associated with imported water sources and wastewater treatment.

The study team used both a "bottom-up" and "top-down" strategy to collect water agencies' energy consumption data. The bottom-up approach consisted of using criteria within the Customer Information System (CIS) billing data such as customer name and address, combined with publicly available data on the precise location of wells and online mapping and satellite imagery tools, to identify the set of water pumping accounts for a given agency. The top-down approach consisted of seeking cooperation from water agency managers to identify the list of accounts associated with water-related electricity use upstream of end users as well as the total electricity consumption and water production associated with those accounts. In some cases, the team had the opportunity to compile data for a select water agency through both bottom-up and top-down methods. Figure 3-4 shows what percent of the Itron sample was completed by which method.

FIGURE 3-4: DISTRIBUTION OF ITRON SAMPLE SELECTION DATA SOURCE METHODS



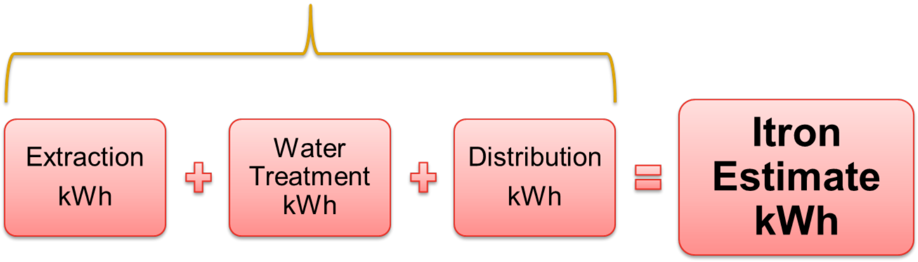
Itron's water agency selection was accomplished through a stratified sample of convenience. The evaluation team sought to include water agencies from each of California's hydrologic regions while capturing a representative range of the state's supply mix diversity. Given that the dominant method for data acquisition was achieved through bottom-up billing analysis, the sample selection was also biased towards small- to medium-sized water agencies whose customer names and other information in the CIS billing dataset facilitated distinguishing water pumping accounts from other civic electricity accounts (such as those that had 'water district' or similar in their name).

Water agency data collected through bottom-up methods required the identification of each water agency's relevant set of outdoor water system accounts in the CIS billing database. Each water agency's set of accounts was matched to monthly electric bills including each account's corresponding service address. Quality control was carried out for each water agency based on the number of monthly bills for each service address. If a service address did not have equivalent billing days for each month across the years 2013-2015, it was excluded from later analysis. The team did consider that a given address may have gone out of service between 2013-2015, but without explicit corroboration from water agency managers the evaluation team felt it was more accurate to disregard these addresses as incomplete.

Each water agency's addresses were then individually tagged as either production, storage/distribution, or treatment. If an address was associated with wastewater treatment or its association with the water agency was not identifiable by the evaluation team's methods, it was removed from later analysis. The identification of relevant accounts was made by searching for addresses on Google Earth and visually identifying the relevant infrastructure. Visual inspection on Google Earth was informed and corroborated wherever possible with the information supplied in each of the water agencies' 2015 Urban Water Management Plans (UWMP), which are publicly available online. The accuracy of each address identification was impacted by the search-ability of the given water agency's addresses in Google Earth. The ability to search for each address varied by the completeness of the CIS billing data record, the quality of available street views, and the presence of clouds or snow in Google Earth's aerial view. The applicability of each water agency's UWMP to the bottom-up effort also varied significantly among water agencies. For example, UWMPs from different water agencies varied in terms of the availability of detailed maps, specific descriptions for the quantity and location of water system components, such as the number of wells and pumps, and other relevant information on account activities 2013-2015. In the case of wastewater treatment, the UWMPs were explicit regarding the presence of wastewater treatment facilities, which allowed the Itron team to confidently exclude the associated accounts from analysis. However, the evaluation team was not able to disaggregate the energy consumption associated with the pumping of wastewater treatment from the end user to the wastewater facility. Further considerations that cannot be directly accounted for through the bottom-up method include changes in water agency technology, pump efficiencies, implementation of solar power and net metering, and any presence of gas powered water pumping accounts.

Both the top-down and bottom-up methods of objective 2 required acquisition of data at the most granular level of California's embedded water energy framework. Each water agency's energy consumption was calculated as an aggregation of its specific system components.

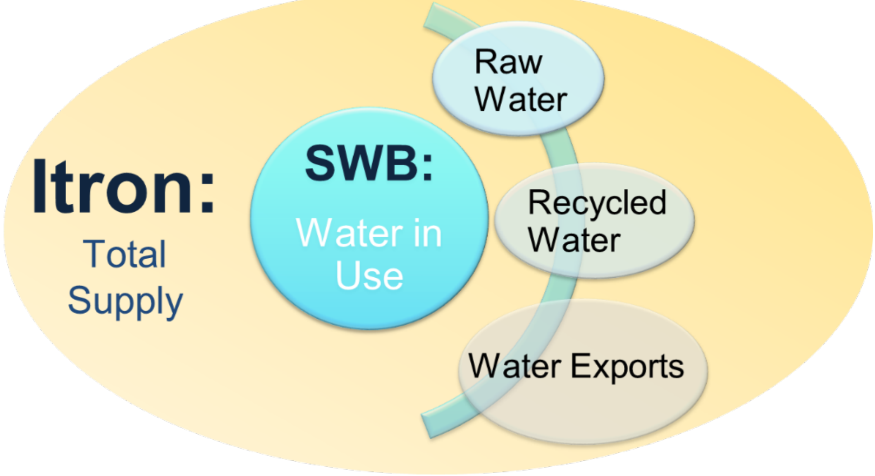
FIGURE 3-5: AGGREGATING BILLING ACCOUNTS ASSOCIATED WITH WATER AGENCY SYSTEM COMPONENTS



Comparing estimates from Itron’s billing review methods with the CPUC water-energy calculator served as an opportunity to reflect on and corroborate the accuracy of the existing average hydrologic region EI values. The evaluation team did not expect an exact match between the energy reduction estimates from the billing review and the estimate from the UC Davis web-based tool for each water agency, but rather a comparable magnitude when looking across multiple water agencies. The CPUC water-energy calculator values were intended to be broadly representative of a hydrologic region and would therefore be expected to mask the variability among water agencies within a hydrologic region.

The absolute comparability of the Itron billing review and average hydrologic region EI derived water energy reduction estimates requires some additional considerations. These pertain both to the volume of water included in the frame of analysis as well as the electricity consumption associated with that water for a given water agency. Regarding the volume of water considered, the average EI-derived approach uses water volumes as reported to the State Water Board by each water agency. Based on reporting requirements of the SWB, these volumes represent “water in use;” i.e., treated water consumed within water energy boundaries. These volumes therefore exclude raw water (any water that is produced and consumed without being treated, which may include rainwater, water from infiltration wells, and water from bodies like lakes and rivers), recycled water (wastewater this is re-used but is not treated back to potable water status), and water exports that are produced within the water agency but consumed elsewhere. The billing data review approach, by contrast, bypasses the direct consideration of water volume altogether in energy reduction calculations, in favor of directly measuring changes in water agency kWh consumption. As such, the volume of water associated with that consumption, from a boundary definition standpoint, is the total volume of water generated, consumed, or moved through a given water agency using power supplied by an IOU. As shown in Figure 3-6 below, the aggregated energy consumption from the Itron billing review for each water agency is associated with the total outdoor water supply.

FIGURE 3-6: CORRESPONDING ITRON WATER VOLUME TO AGGREGATED WATER AGENCY ENERGY CONSUMPTION



For each water agency the evaluation team calculated the percent difference between the reported SWB volume and the total supply reported in the 2015 UWMPs for each water agency where parallel data were available. Water agencies whose total supply differs significantly from that reported to the SWB are removed from calculations that incorporate energy consumption from multiple water agencies.

3.3 PATTERNS OF CHANGE IN ENERGY INTENSITY DURING THE STUDY PERIOD 2013-2015

Objective 3 of this study is to provide commentary on patterns of change regarding EI during the study period 2013-2015. This objective took the form of preliminary data-driven analyses focused on potential drivers of changes in EI over the study period. Given the increase in drought intensity over the study period, observed patterns of change in energy intensity may have been driven in large part by the intensifying drought conditions. However, correlation of EI trends with parallel physical phenomena and/or policy changes was outside the scope of this study.

Changes in overall EI for 2013 and 2015 for each water agency were calculated using the water agency energy consumption data collected for objective 2. The evaluation team used the SWB conservation data set for water agencies' historical monthly water production 2013-2015, incorporating where possible exact values supplied directly from water agencies. Annual EI values for each water agency were then calculated by dividing annual energy consumption by annual water production and comparing values for 2013 and 2015. The year of 2014 was not included, since the SWB conservation water data includes only the months of June-December for the year of 2014. For determining changes in EI for 2013 and 2015 at the water system component level (extraction, treatment, and distribution), the evaluation team determined that only water agencies whose energy consumption data was collected through top-down methods would be used. Top-down corroboration was assumed to be the only accurate means of assigning each electric account to a specific system component and therefore maximizing the accuracy of the component-level EI estimates.

Changes in water system component EIs and overall water agency EIs over the study period likely also incorporate changes in pump efficiency, sources of pump energy, depth of the local water table, and effects of water volume reduction on pressure in distribution and treatment systems. Additionally, water agencies' EI may be impacted by changes in their supply mix, especially shifts in the percent of their total supply being sourced from groundwater extraction versus water imports. Additional shifts in supply mix distribution may be a result of increased production of recycled water, desalination, adoption of storm water recycling methods, among other water use changes. Given the diversity of potential drivers of EI variability and the intentionally narrow scope of this study, the study team did not seek to attribute changes in EI over the study period to specific causes.

Finally, the team considered the potential significance of shifts in energy intensity at the overall hydrologic region level for 2013-2015. The evaluation team used a set of publicly available data sets to characterize shifts in this context and to identify further potential considerations for applying average hydrologic region EI. Analysis was particularly focused on changes in hydrologic region water supply mixes during the study period. Recall that the CPUC average hydrologic region EI values are determined as a weighted average of water system component EIs representative of each hydrologic region's historical supply mix. The evaluation team calculated for each hydrologic region in 2013 and 2015 the percent of total water production reported to the State Water Board relative to total retail groundwater production as reported in each water agency's Urban Water Management Plan (UWMP).[28] The percent reported is not wholly accurate and requires discussion of several considerations. Foremost, the evaluation team did not include whole-sale groundwater production. Additionally, the end use of retail groundwater production is not limited to urban water use and depending on the hydrologic region this may impact the accuracy of the reported percent. The evaluation team reviewed the 2013 DWR water planning reports released for each hydrologic region to qualitatively compare with 2013 and 2015 calculated groundwater percent. For most of California's hydrologic regions, the percent of urban water use met by groundwater was reasonable in terms of historical values, which makes sense given that the source of groundwater data was the 2015 UWMPs. However, following this report in 2018, more accurate hydrologic region supply mix statistics will be publicly available with the next planned DWR update.

As part of looking at shifts in supply mix at the hydrologic region level 2013-2015, the evaluation team calculated the percent of each hydrologic region's total water supply that came from the State Water

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[28] http://www.water.ca.gov/urbanwatermanagement/uwmp2015.cfm

Project[29] (SWP). The team compared these figures to the total water production reported to the State Water Board for each hydrologic region in 2013 and 2015 to characterize trends in SWP allocations relative to trends in total consumption. The SWP is selected for this comparison as it is both a primary water source for multiple California hydrologic regions, and it alone consumes 2-3% of the state's total electricity usage. Thus, there are potentially large energy implications associated with using locally sourced groundwater and surface water versus SWP water. Annual SWP deliveries were calculated using published water allocations by water agency to eliminate issues of inter-annual reservoir storage. The evaluation team also calculated State Water Project EIs for each hydrologic region to compare with groundwater extraction EIs using SWP provided monthly water production and energy consumption.[30] The primary end use of the SWP is environmental and agricultural thus the relative percentage to urban water production is not wholly accurate but still provides information on regional trends.[31] Following previous methodologies[32] for calculating SWP EIs by hydrologic region; Itron summed the EIs of each pumping station along the water's pathway in the SWP and calculated each pumping station EI as a 2013-2015 average.

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[29] http://www.water.ca.gov/swpao/deliveries.cfm

[30] http://www.water.ca.gov/swp/operationscontrol/monthly.cfm

[31] http://www.water.ca.gov/swp/watersupply.cfm

[32] Embedded Energy in Water Studies Study 1: Statewide and Regional Water-Energy Relationship, Navigant Consulting, CPUC, August, 2010.

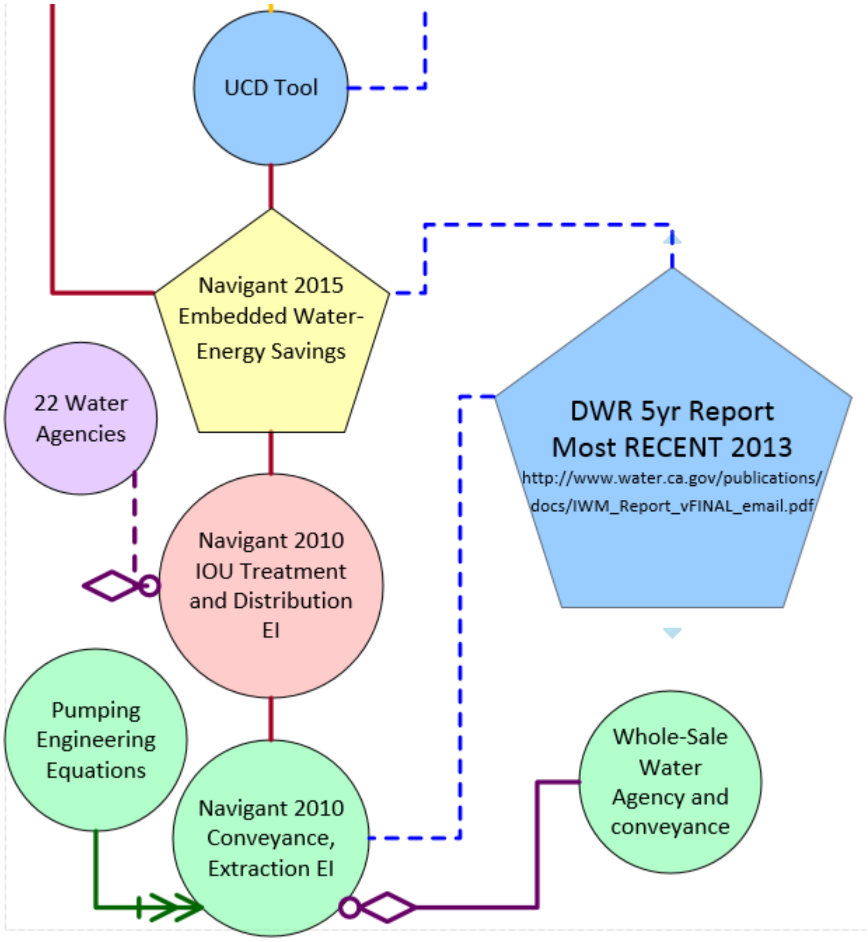
4 RESULTS

Results from this study are characterized by study objective below. First, findings are discussed from investigating and replicating statewide 2015 energy use reduction calculations using the approach that underlies the 2016 UC Davis water-energy tool and the CPUC water-energy savings calculator. We developed a modified calculation of energy use reductions for 2015Q3 based on the study team's recommended revisions to the scope of water volume and energy intensity used in the calculation. The next section walks through the results from the billing data review for all water agencies in the study broken out separately for groundwater-reliant, import-reliant, and mixed-source water agencies in the sample. Finally, the study team offers preliminary observations on patterns of change in EI during the study period, 2013-2015. These observations focus on trends in EI at the water system component level (production and distribution), at the water agency level, and at the hydrologic region level, with reference to changes in groundwater pumping EI and changing supply mix distributions during a period of increasing drought intensity.

4.1 OBJECTIVE 1: INVESTIGATING AND REPLICATING STATEWIDE 2015 ENERGY USE REDUCTION CALCULATIONS USING AVERAGE HYDROLOGIC REGION ENERGY INTENSITIES

Figure 4-1 below shows a schematic diagram of data sources and subsequent calculations that drive the savings estimates in the 2016 UC Davis water-energy tool. As is shown in the figure, the average hydrologic region EIs that underlie the UCD savings calculations are from the 2015 Navigant Embedded Water-Energy Savings report. The average hydrologic region EI values were developed from the Navigant 2010 IOU Treatment and Distribution EI study, which combined data from 22 water agencies, and EI values from the 2010 Navigant Conveyance and Extraction EI study. That conveyance and extraction study developed EIs based on wholesale water agency and conveyance data, as well as pumping engineering equations.

FIGURE 4-1: MAP OF DATA SOURCES AND PATHWAYS



Based on the literature review and the re-creation of savings calculations, the evaluation team found three areas where we felt changes to the average EI-derived energy reduction calculations for 2015Q3 are warranted:

- Exclude wastewater treatment EI from the energy intensity estimates
- Use the full year for water and energy savings calculations. If quarterly savings are desired, divide the full year calculation accordingly.
- Narrow the list of water agencies to include only those whose power is provided by IOUs

4.1.1 Exclude Wastewater Treatment EI from the Energy Intensity Estimates

The text on the UC Davis website describes the energy intensity values as based on average outdoor energy intensity estimates, excluding wastewater.[33] However, the study team verified in re-creating the UC Davis savings calculations that the EI values that were used included wastewater treatment EI. This was corroborated via personal communication.[34]

4.1.2 Use a Full Year of Water Savings Divided by 4

While 2015Q3 saw a spike in urban water conservation due to the mandate, it is noteworthy that the associated electricity reductions are subsequently compared with first year energy savings for energy efficiency program measures installed in the same period. Given this point of comparison, we believe a more accurate form of comparison between water energy reductions and energy efficiency program savings is taking the full year into account. Taking the entire year of water energy savings in 2015, one can then divide by four to yield quarterly energy savings.

4.1.3 Narrow the List of Water Agencies to Include Only Those Whose Power is Provided by IOUs

The UCD website notes that "The energy intensity estimate is specific energy procured from investor-owned energy utilities (IOUs)." However, the list of water agencies on the website appears to show all water agencies throughout the state, including those whose power is not provided by IOUs but is instead provided by publicly owned utilities or other sources. Hence an accurate accounting of relevant electricity reductions would come from multiplying the average EI estimates by the reduction in water volume only for those water agencies served by IOUs. Figure 4-2 below shows the quantitative effect of each of these adjustments.

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[33] See https://cwee.shinyapps.io/greengov/: "We consolidated estimates for average outdoor (excludes wastewater) energy intensity estimates (Table ES-3, p. xvi) for all ten hydrologic region in California from the Navigant Consulting report entitled, "Water-Energy Cost-Effectiveness Analysis: Final Report".[33] The energy intensity estimate is specific energy procured from investor-owned energy utilities (IOUs)."

[34] Frank Loge, personal communication, 11/9/2016.

FIGURE 4-2: RECALCULATING Q3 2015 LITERATURE ESTIMATES

UC Davis Q3 2015	Itron Q3 2015	Itron AVG 2015 Quarter
460 GWh	223 GWh	**130 GWh ***
Includes wastewater treatment	Excludes wastewater treatment	Excludes wastewater treatment
IOU-ONLY	IOU-ONLY	IOU-ONLY

Water Agency Energy Reduction = Hydrologic Region EI ✖ Water Agency Water Savings

* Still requires filtering for non-IOU powered WAs

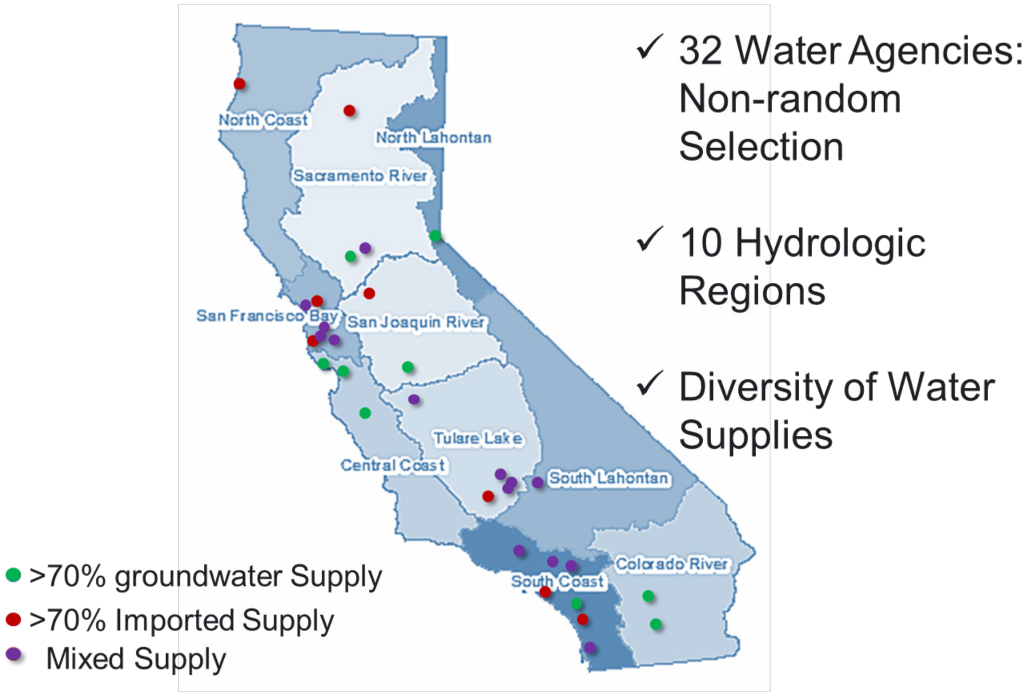
4.2 OBJECTIVE 2: USING A BILLING DATA REVIEW TO CALCULATE ENERGY USE CHANGES 2013-2015 FOR 32 WATER AGENCIES AND COMPARING THESE TO THE AVERAGE HYDROLOGIC REGION EI APPROACH

The billing data review enabled detailed, bottom-up calculation of changes in water agency electricity consumption from 2013-2015 for all selected water agencies. Results from that review are detailed in the sections that follow, with water agencies organized into three distinct groups:

- Groundwater-reliant: Water agencies that obtain more than 70 percent of their [urban potable] water from groundwater pumping within the water agency [boundaries]
- Import-reliant: Water agencies that obtain more than 70 percent of their [urban potable] water by importing it from other regions
- Mixed-source: Water agencies whose overall supply mix is not reliant on more than 70% groundwater or imported water but is more of an even mix among sources.

Figure 4-3 below shows how the selected water agencies were distributed throughout California and the 10 hydrologic regions into which the state is divided.

FIGURE 4-3: ITRON WATER AGENCY SAMPLE SELECTION



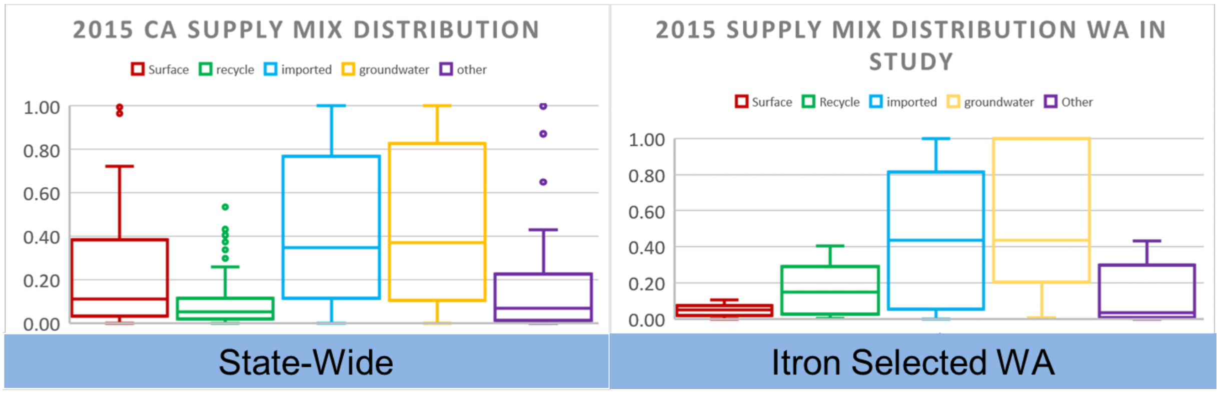
4.2.1 Contra Costa Water District

Due to challenges disaggregating water pumping activity from other potential pumping activity for the Contra Costa Water District, the study team made the analytic decision to report energy reductions separately for this water district from the other 31 water agencies in the study sample. For this water agency, the bottom up approach using satellite imagery to identify water pumping accounts and distinguish them from other municipal electricity accounts proved especially challenging, and the team had low confidence in the accuracy of the results as of report writing. Because Contra Costa is one of the largest water agencies in the study from a water volume standpoint, the team decided that reporting results for this water agency separate from the others would reduce the risk of skewing overall results with potentially inaccurate data.

4.2.2 Comparison Between Study Sample and Overall State

The overall water supply mix distribution of the 32 selected water agencies broadly matches the supply mix distribution for the state overall, as shown in Figure 4-4. Notably, imported water and groundwater make up approximately 80% of the total source mix, both for the state overall and for the set of water agencies selected in this study. While water agencies in the study showed a somewhat higher proportion of recycled water and correspondingly lower proportions of surface water and other water sources (such as desalinization) relative to the state overall, the Itron sample mean is within 10% of the California mean for each supply mix source.

FIGURE 4-4: DISTRIBUTION OF WATER AGENCY SUPPLY TYPES TO WATER AGENCY TOTAL SUPPLY AGGREGATED ACROSS ALL WATER AGENCIES IN 2015 UWMP (LEFT) AND ITRON WATER AGENCY SELECTION (RIGHT)



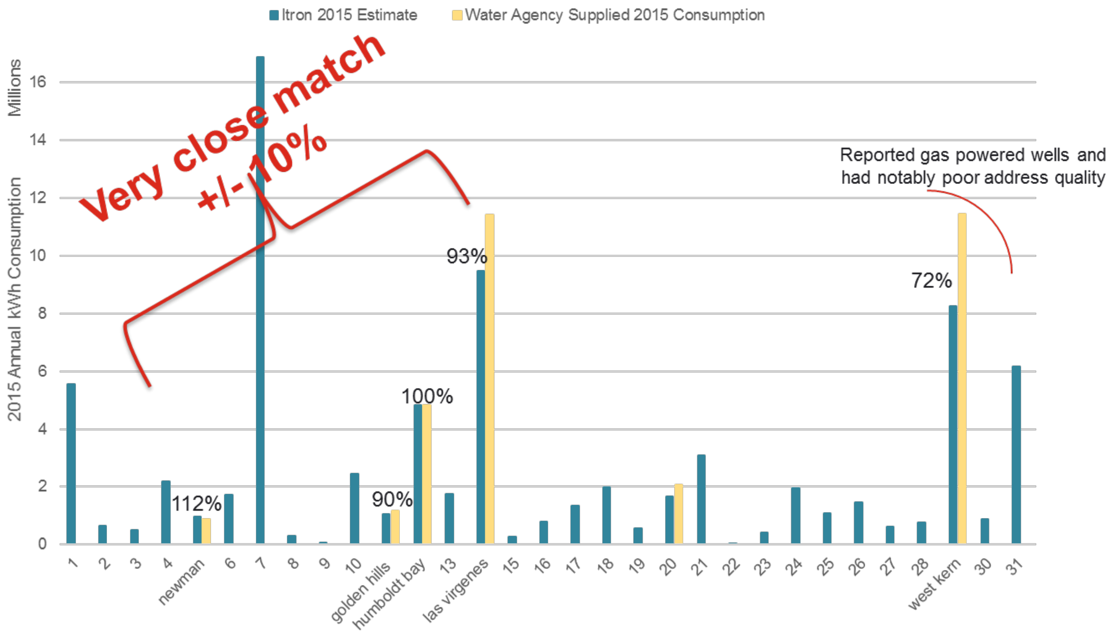
4.2.3 Top Down QC of Bottom Up Billing Data Review Approach and Findings

For a subset of 4 water agencies within the overall selection, the study team gained the direct cooperation of water agency managers to help verify the accuracy of the billing data review approach. These water agency managers supplied electricity consumption data that could be compared against the specific set of accounts and the resulting electricity consumption figures derived from the billing data review. The water agency managers also supplied water production data that could be compared against figures reported to the SWB. Information requested and received from the cooperating water agency managers included the following:

- Total annual kWh usage associated with the pumping, storage, and treatment of water, 2013-2015
- Account numbers (or street addresses) associated with the water utility billing accounts (not customer data)
- Flags associating each account with groundwater pumping, storage/transport, or treatment of potable water
- Water production at monthly granularity for each relevant account, 2013-present

Figure 4-5 below shows a comparison of total water agency electricity consumption in 2015 for each water agency in the study based on the billing data review, matched with primary data from the 4 water agencies where the study team gained the direct cooperation of water agency managers. As shown in the figure, total kWh consumption from the billing data review generally showed a close match with the data provided by water agency managers, with the billing data review total ranging from 90% to 112% of the total supplied by the water agency managers. This serves as reasonably strong corroboration for the validity and accuracy of the billing data review approach. This top-down corroboration suggests that Itron estimates are generally within 10%-15% of water agency's actual kWh consumption.

FIGURE 4-5: 2015 ANNUAL ENERGY CONSUMPTION TOP-DOWN CORROBORATION OF BOTTOM-UP RESULTS



4.2.4 Comparison of Overall Energy Use Reductions Across the Two Methods

Across the 31 water agencies in the study, billing data review yields an energy consumption reduction of 18%. For the same set of water agencies, the average hydrologic region EI approach yields an energy consumption reduction of 24%. Overall, this finding generally corroborates the magnitude of energy use reductions estimated using the average hydrologic region EI approach across the state but does suggest that reductions are somewhat lower than previously estimated. Percent energy reductions relative to each water agency and water agency supply type are explored below.

In addition to differences in overall percent energy use reductions, the billing data review shows much higher variability in energy use changes [2013-2015] across water agencies relative to the average hydrologic region EI approach. Some specifics are noted in the sections by water agency type below. This finding is to be expected, since the average hydrologic region EI approach was derived as an average value that smooths over the differences among water agencies within a hydrologic region. Another consideration of the average hydrologic region EI approach is the assumption that there is a linear relationship between the volume of water conserved and the magnitude of the embedded energy use reduction. The billing data review approach, by contrast, bypasses the relationship with volumetric water savings and directly measures the change in energy consumption. The outcome is a more granular and less smooth set of findings by water agency that in some cases produces findings such as an increase in water-related energy use despite a decrease in total water pumped.

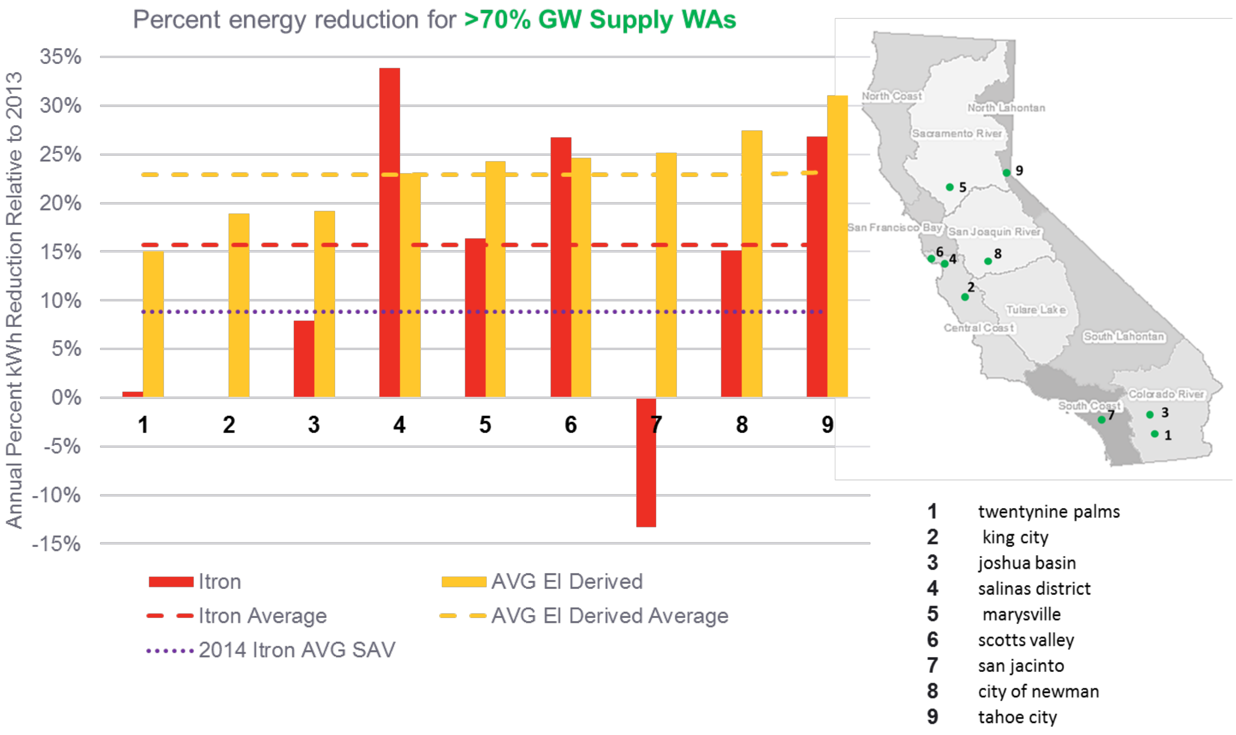
In addition to 2015 energy reductions the billing data review yields calculations of energy use reductions for 2014. The average energy intensity EI approach does not provide an energy reduction figure for 2014 due to the lack of complete volumetric water savings data reporting to the State Water Board that year. Average energy use reduction in 2014 calculated from the billing review is shown by water agency supply type below. As such, 2015 energy use reductions can be interpreted as the result of two years of change. Interestingly, this two-step view shows differing results among the water agency supply types.

4.2.5 Energy Savings for Groundwater-Reliant Water Agencies

Of the [32] water agencies in the study, nine [9] rely on groundwater pumping within the water agency boundary for at least 70 percent of their total water supply. Percent energy use reductions from the billing data review and from the average hydrologic region EI approach are shown for each water agency in Figure 4-6 below.

Across these nine water agencies, the billing data review yields an average 16% reduction in 2015 electricity use relative to 2013. The average EI-derived approach yields an average 23% reduction. The highest percent reduction in electricity use from the billing review is observed for Salinas Water District of 34%. The lowest is a negative percent reduction, or an overall increase in water agency electricity consumption for the City of San Jacinto of approximately 13% over the study period. In general, the billing data review does not show the consistent linear relationship between volume of water conserved and energy use reductions 2013-2015 at the individual water agency level that is a basic feature of the average hydrologic region EI approach.

FIGURE 4-6: 2015 ANNUAL PERCENT ENERGY SAVINGS RELATIVE TO 2013 FROM ITRON BILLING REVIEW AND APPLICATION OF AVERAGE EI VALUES FOR WATER AGENCIES THAT SOURCE > 70% GROUNDWATER FOR SUPPLIES

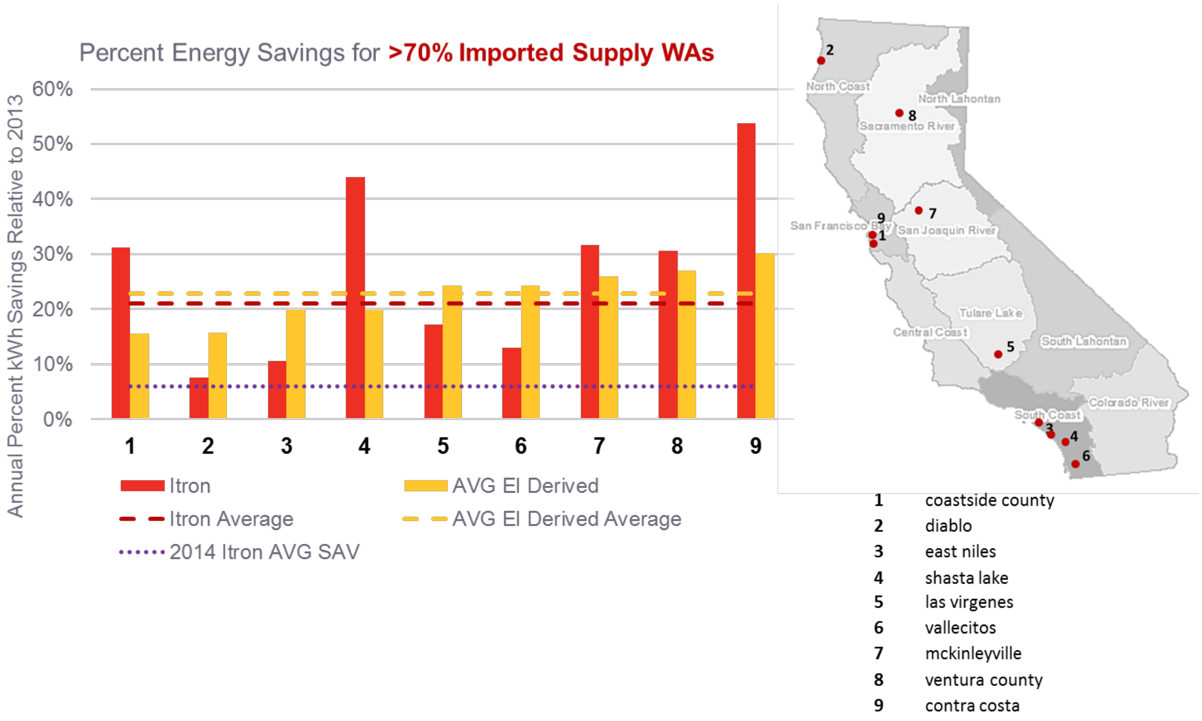


In addition to water agency electricity reductions in 2015 relative to 2013, the figure also captures the average electricity reduction in 2014 of 9% relative to 2013 for the set of groundwater-reliant water agencies. This provides an indication of year-to-year electricity savings from water conservation likely related to groundwater management coincident with 2014 being a drought cycle year. The 2015 reductions can be seen as building on the 2014 reductions, with a 9% reduction occurring in 2014 and an additional 7% reduction occurring in 2015. This is consistent with multi-year groundwater management plans that incrementally reduce groundwater pumping in response to multi-year drought conditions.

4.2.6 Energy Savings for Import-Reliant Water Agencies

Of the 32 water agencies in the study, 9 water agencies rely on imported water for more than 70% of their total water supply. Percent electricity reductions from 2013 to 2015, are shown in Figure 4-7 below. Notably, and in contrast to the groundwater-reliant water agencies, there is close agreement between the billing data review and the average EI-derived method for the average percent reduction in water agency kWh consumption. The billing data review yields an average 22% electricity reduction and the average EI-derived approach yields an average 24% reduction. While the degree of variability in energy reduction estimates among water agencies appears less dramatic than for groundwater reliant water agencies, 3 water agencies reliant on imported water differ by upwards of 50% from EI derived estimates.

FIGURE 4-7: 2015 ANNUAL PERCENT ENERGY SAVINGS RELATIVE TO 2013 FROM ITRON BILLING REVIEW AND APPLICATION OF AVERAGE EI VALUES FOR WATER AGENCIES THAT SOURCE > 70% IMPORT SUPPLIES



1	coastside county
2	diablo
3	east niles
4	shasta lake
5	las virgenes
6	vallecitos
7	mckinleyville
8	ventura county
9	contra costa

As with the groundwater-reliant water agencies, Figure 4-7 above also captures the average percent reduction in water agency electricity usage in 2014 relative to the 2013 baseline. In the case of import-reliant water agencies, the average water agency kWh reduction was approximately 6% in 2014 relative to 2013. The average 22% reduction in 2015 relative to 2013 therefore represents a significantly larger year-to-year change compared to that seen for groundwater reliant water agencies for 2014 to 2015.

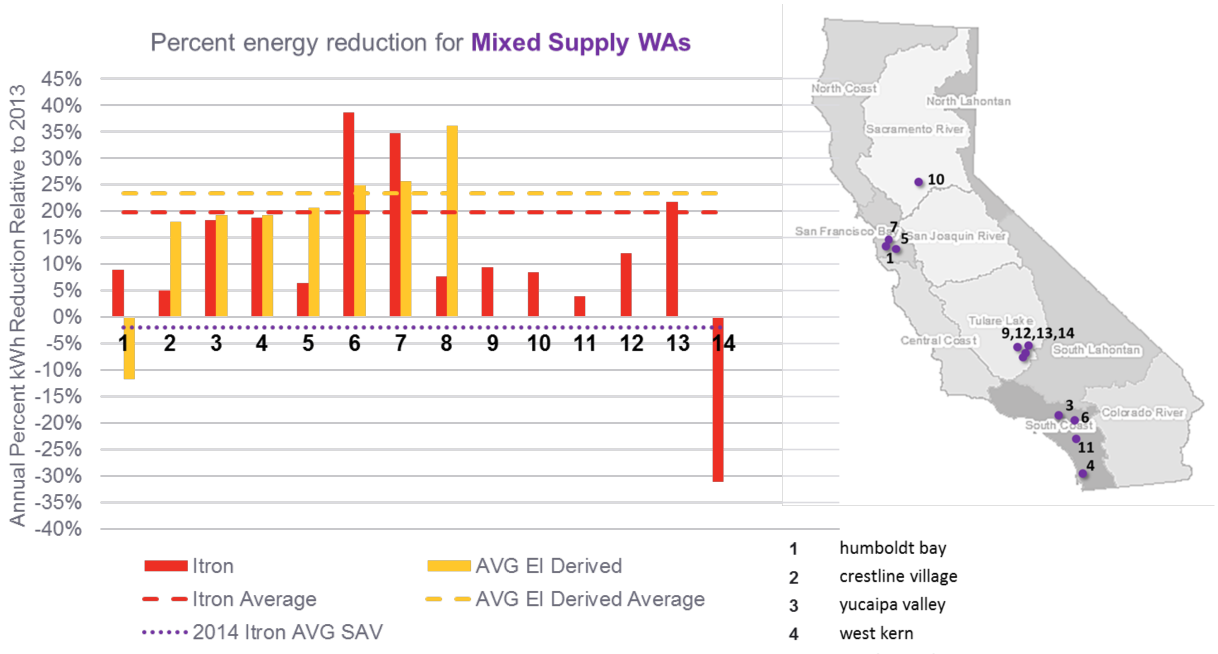
4.2.7 Energy Savings for Mixed Supply Water Agencies

Thirteen water agencies in the study rely on a mix of groundwater, imported, and surface water for their total water supply, along with smaller contributions from other water sources such as raw and recycled water. The average percent kWh reduction from 2013 to 2015 for mixed supply water agencies are similar to import-reliant water agencies with a billing review average of 22% and the EI derived approach yielding 24%.

Similar to the groundwater-reliant water agencies, billing review calculated percent energy reductions show a high degree of variability among water agencies compared to the EI derived estimates. Among the mixed supplied water agencies there are two cases where the methods yield opposing signs and three other cases where the billing data review estimates are less than half of those from the average EI-derived approach.

For six of the water agencies in this group, average EI-derived energy reduction estimates were not available. This is because volumetric water savings in 2015 were not reported to the State Water Board (SWB) for these water agencies. When the study team was selecting water agencies for the billing data review, we used criteria regarding broad representativeness across hydrologic regions and water supply mix. We were not aware at that time that some water agencies in the state did not report their 2015 volumetric water savings to the SWB. The billing review average percent reduction in water agency kWh shown in Figure 4-8 does not include those agencies where parallel figures using the average EI-derived approach are not available. If those water agencies are included the average billing data review value is 19%.

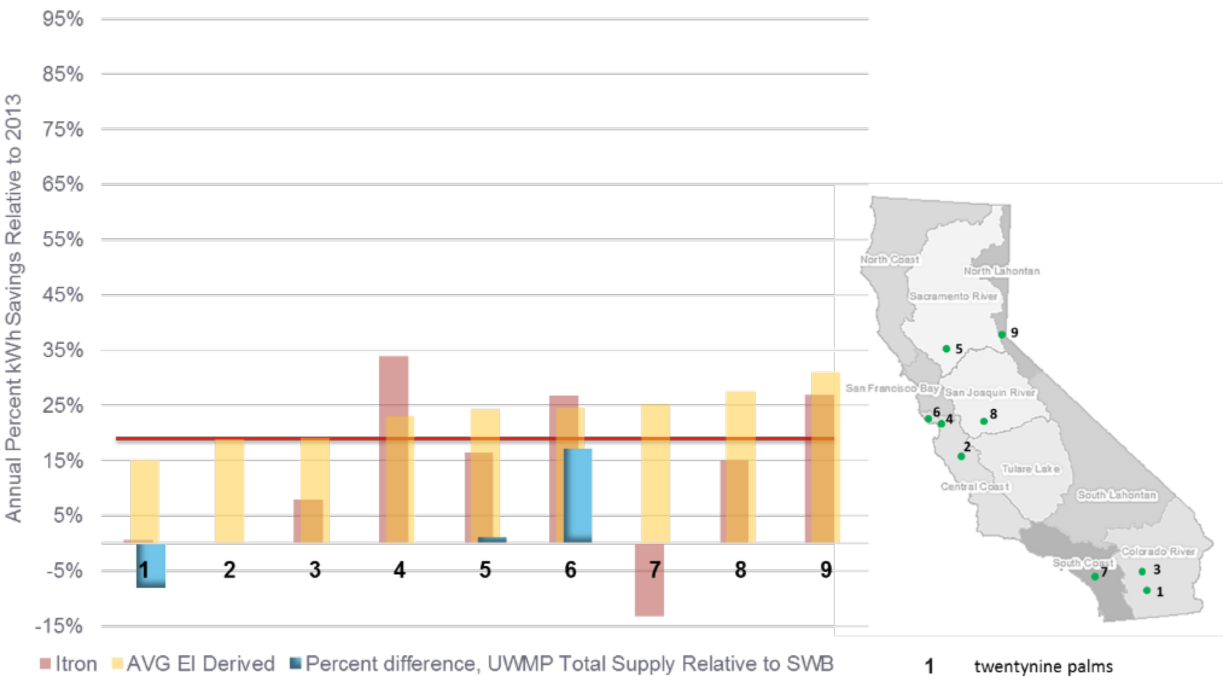
FIGURE 4-8: 2015 ANNUAL PERCENT ENERGY SAVINGS RELATIVE TO 2013 FROM ITRON BILLING REVIEW AND APPLICATION OF AVERAGE EI VALUES FOR WATER AGENCIES THAT HAVE MIXED SUPPLIES



1	humboldt bay
2	crestline village
3	yucaipa valley
4	west kern
5	westborough
6	rosamond
7	alameda county

The inherent difference in system boundary definitions between the billing data review and the average hydrologic region EI with respect to the volume of water considered in the analysis requires additional discussion. Recall that the billing review captures the energy associated with total water supply production versus the CPUC water-energy calculator approach that relies on only on urban water in use reported to the State Water Board (SWB). For water agencies reliant on groundwater this distinction is found to be negligible.

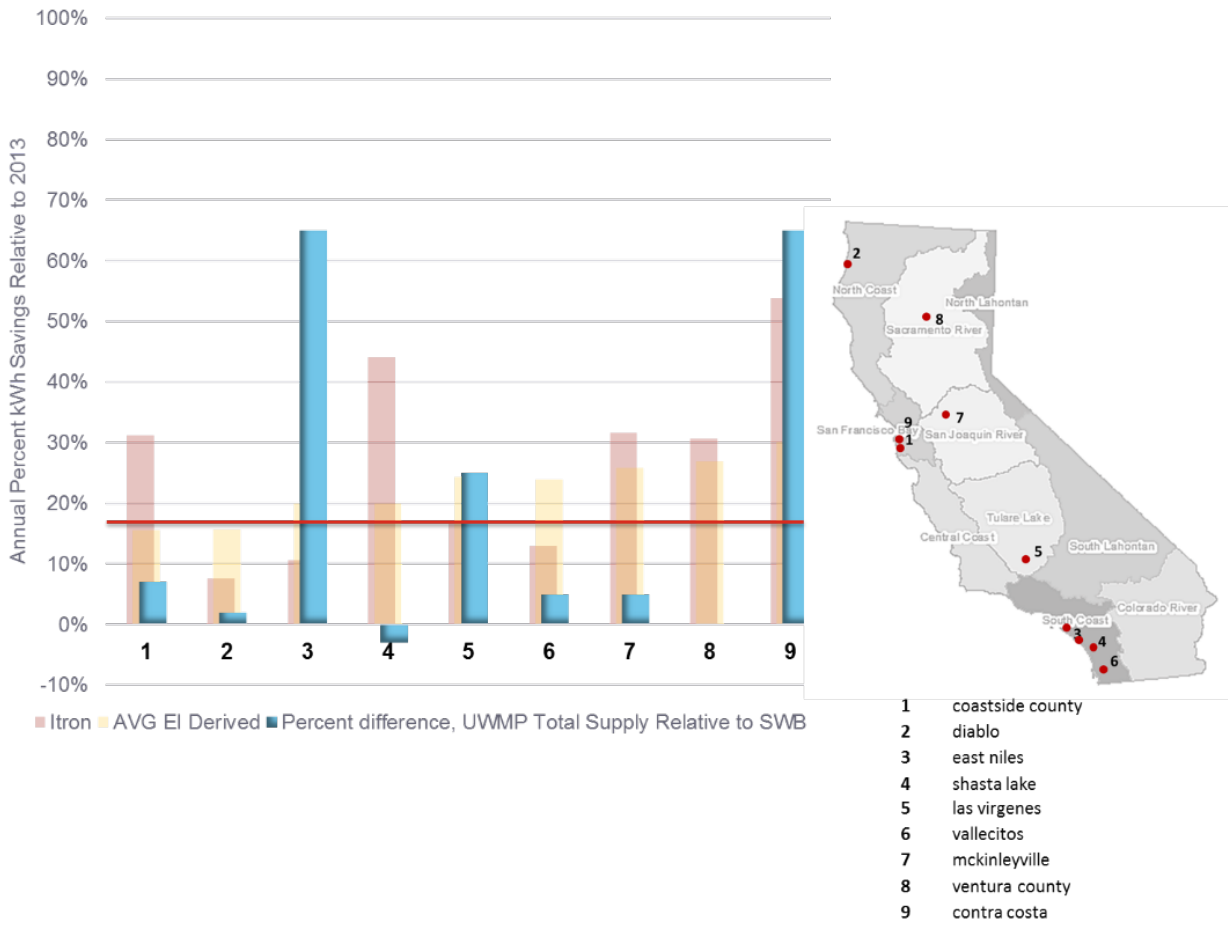
FIGURE 4-9: COMPARABILITY OF 2015 UWMP TOTAL WATER SUPPLY TO 2015 SWB VOLUME FOR WATER AGENCIES RELIANT ON GROUNDWATER



1	twentynine palms
2	king city
3	joshua basin
4	salinas district
5	marysville
6	scotts valley
7	san jacinto
8	city of newman
9	tahoe city

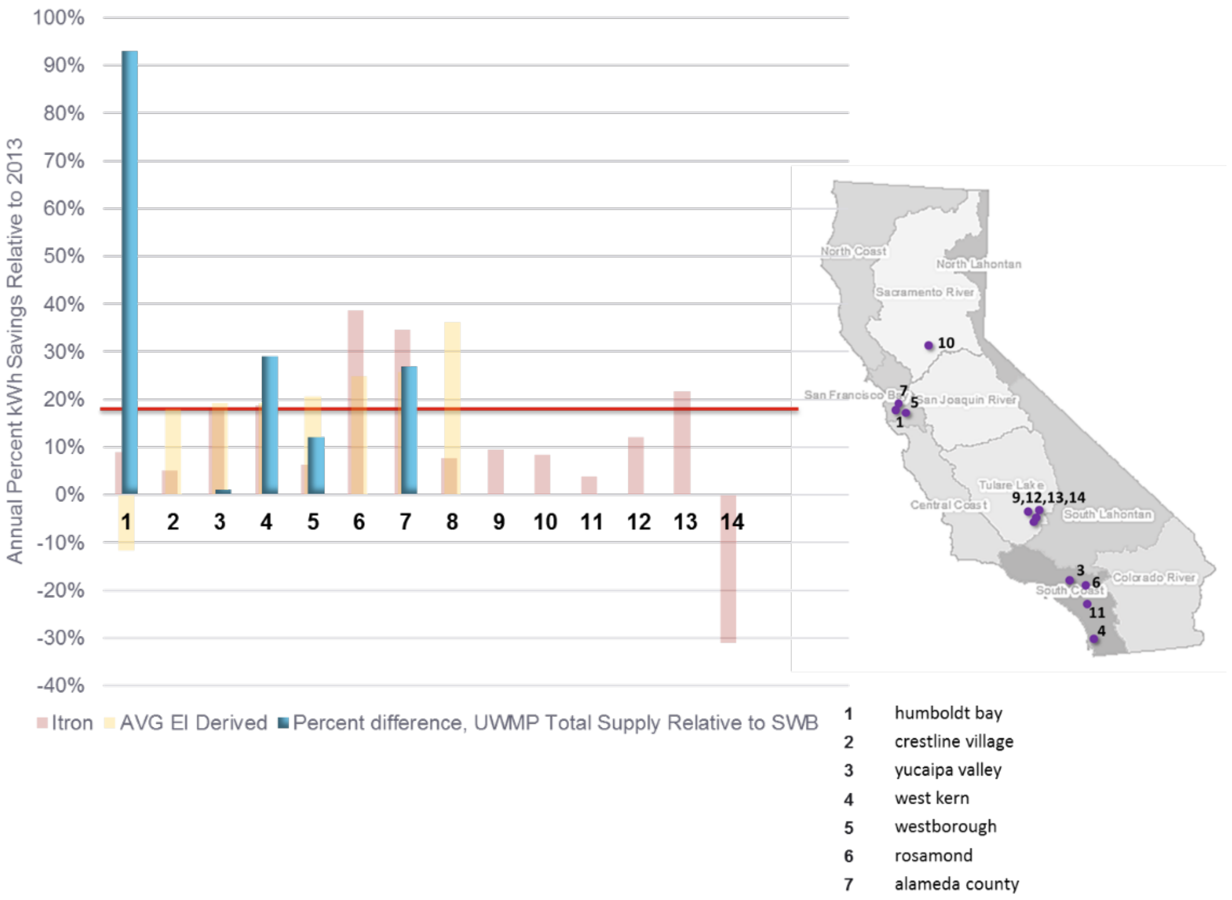
For all groundwater reliant agencies the percent difference between the total water supply in the UWMPs and that reported in the SWB conservation dataset are less than 20%. This finding signifies that the comparability between the Itron billing review and EI derived estimates, based off the equivalency of associated water volumes is quite good. For the other water agency supply types the percent difference between the UWMP reported total water supply and the SWB dataset are much larger on average than for groundwater reliant agencies. Among the water agencies reliant on imported supplies, three show percent differences greater than 20% shown in Figure 4-10.

FIGURE 4-10: COMPARABILITY OF 2015 UWMP TOTAL WATER SUPPLY TO 2015 SWB VOLUME FOR WATER AGENCIES RELIANT ON IMPORTED SUPPLIES



For water agencies reliant on mixed supplies, 3 water agencies show percent differences greater than 20%. In particular, Humboldt Bay is characterized by a 92% difference due to the majority of its total water production being exported outside of the water agencies boundaries.

FIGURE 4-11: COMPARABILITY OF 2015 UWMP TOTAL WATER SUPPLY TO 2015 SWB VOLUME FOR WATER AGENCIES RELIANT ON MIXED SUPPLIES



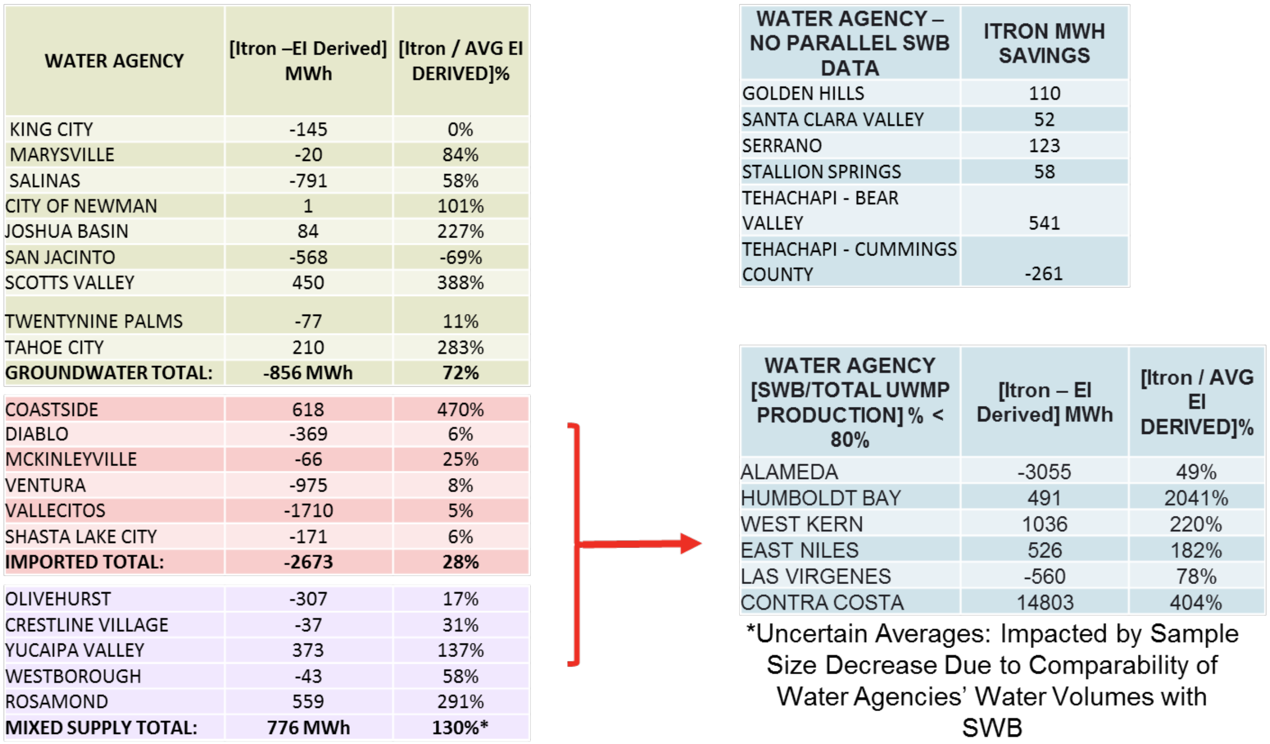
The impact of the larger percent differences between associated water volumes particularly for water agencies reliant on imported and mixed supplies is important to highlight for all comparative results presented in this report.

Overall Comparison Across the Three Water Agency Types

Across all 32 water agencies in this study the results of the billing review indicate that actual percent energy reductions associated with water conservation are lower than estimates derived from the application of the CPUC water-energy calculator EI values. Specifically, energy reductions for groundwater reliant water agencies are significantly lower than estimates derived using average EI values. For water agencies reliant on imported and mixed supplies the billing review percent energy reductions were only slightly lower. Since the selection of water agencies for this study was a sample of convenience rather than a random sample, these results cannot robustly discredit the accuracy of the average hydrologic region EI approach applied at the state level. However, findings clearly show wide differences between estimated embedded water energy savings and empirically measured energy usage reductions for many of the water agencies in the study.

Figure 4-12 below shows the differences in actual MWh reductions for all water agencies in the study calculated using the billing data review and the average hydrologic region EI approach. Results are expressed as actual MWh differences between the two methods and as a percent calculated as the ratio between the billing data review and the average EI derived MWh reduction. As is done elsewhere, water agencies are grouped into those that are groundwater-reliant, those that are import-reliant, and those that are mixed source. Note that the findings below do not capture or account for equipment efficiency changes that may have taken place across the study period.

FIGURE 4-12: COMPARISON OF ACTUAL 2015 MWH SAVINGS RELATIVE TO 2013 FROM ITRON BILLING REVIEW AND APPLICATION OF AVG EI VALUES



WATER AGENCY	[Itron –EI Derived] MWh	[Itron / AVG EI DERIVED]%
KING CITY	-145	0%
MARYSVILLE	-20	84%
SALINAS	-791	58%
CITY OF NEWMAN	1	101%
JOSHUA BASIN	84	227%
SAN JACINTO	-568	-69%
SCOTTS VALLEY	450	388%
TWENTYNINE PALMS	-77	11%
TAHOE CITY	210	283%
GROUNDWATER TOTAL:	**-856 MWh**	**72%**
COASTSIDE	618	470%
DIABLO	-369	6%
MCKINLEYVILLE	-66	25%
VENTURA	-975	8%
VALLECITOS	-1710	5%
SHASTA LAKE CITY	-171	6%
IMPORTED TOTAL:	**-2673**	**28%**
OLIVEHURST	-307	17%
CRESTLINE VILLAGE	-37	31%
YUCAIPA VALLEY	373	137%
WESTBOROUGH	-43	58%
ROSAMOND	559	291%
MIXED SUPPLY TOTAL:	**776 MWh**	**130%***

WATER AGENCY – NO PARALLEL SWB DATA	ITRON MWH SAVINGS
GOLDEN HILLS	110
SANTA CLARA VALLEY	52
SERRANO	123
STALLION SPRINGS	58
TEHACHAPI - BEAR VALLEY	541
TEHACHAPI - CUMMINGS COUNTY	-261

WATER AGENCY [SWB/TOTAL UWMP PRODUCTION] % < 80%	[Itron – EI Derived] MWh	[Itron / AVG EI DERIVED]%
ALAMEDA	-3055	49%
HUMBOLDT BAY	491	2041%
WEST KERN	1036	220%
EAST NILES	526	182%
LAS VIRGENES	-560	78%
CONTRA COSTA	14803	404%

*Uncertain Averages: Impacted by Sample Size Decrease Due to Comparability of Water Agencies' Water Volumes with SWB

Figure 4-13 below shows the differences in actual MWh reductions for all water agencies in the study as above but in addition to being grouped by water agency supply, they are also separated by the magnitude of water agencies' annual 2015 kWh consumption. Small water agencies are characterized by annual 2015 kWh consumption magnitudes of 10^6 versus large water agencies having magnitudes of 10^7. Contra Costa is separated individually as its 2015 kWh magnitude exceeds all other water agencies in the sample at 10^8.

FIGURE 4-13: COMPARISON OF ACTUAL 2015 MWH SAVINGS RELATIVE TO 2013 FROM ITRON BILLING REVIEW AND APPLICATION OF AVG EI VALUES SEPARATED BY WATER AGENCY SIZE

SMALL (10^6 ANNUAL KWH) WATER AGENCY	[Itron –EI Derived] MWh	[Itron / AVG EI DERIVED]%
KING CITY	-145	0%
MARYSVILLE	-20	84%
CITY OF NEWMAN	1	101%
TAHOE CITY	210	283%
GROUNDWATER TOTAL:	**46**	**108%**
DIABLO	-369	6%
SHASTA LAKE CITY	-171	6%
IMPORT TOTAL:	**-541**	**6%**
OLIVEHURST	-307	17%
CRESTLINE VILLAGE	-37	31%
WESTBOROUGH	-43	58%
MIXED SUPPLY TOTAL:	**-387**	**27%**

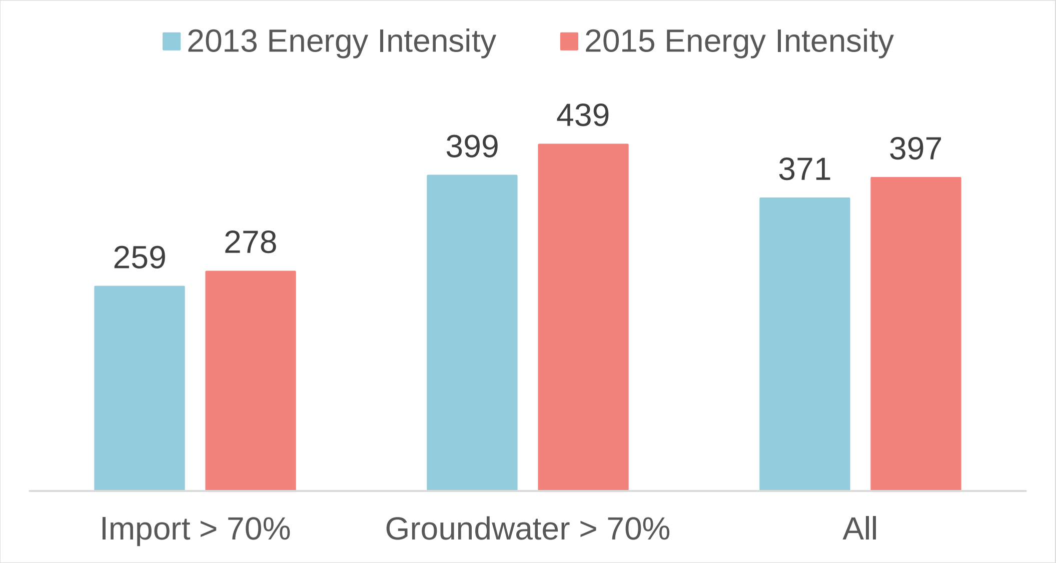
LARGE (10^7 ANNUAL KWH) WATER AGENCY	[Itron –EI Derived] MWh	[Itron / AVG EI DERIVED]%
SALINAS	-791	58%
JOSHUA BASIN	84	227%
SAN JACINTO	-568	-69%
SCOTTS VALLEY	450	388%
TWENTYNINE PALMS	-77	11%
GROUNDWATER TOTAL:	**-902**	**65%**
COASTSIDE	618	470%
VENTURA	-975	8%
EAST NILES	526	182%
LAS VIRGENES	-560	78%
MCKINLEYVILLE	-66	25%
VALLECITOS	-1710	5%
IMPORT TOTAL:	**-2166**	**66%**
CONTRA COSTA (10^8)	14803	404%
YUCAIPA VALLEY	373	137%
ROSAMOND	559	291%
ALAMEDA	-3055	49%
HUMBOLDT BAY	491	2041%
WEST KERN	1036	220%
MIXED SUPPLY TOTAL:	**-596**	**93%**

While the billing data review yielded lower and more variable energy usage reductions than the average hydrologic region EI approach, this empirical study nevertheless corroborated the finding of very substantial electricity reductions associated with water conservation. Total energy reduction in 2015 relative to 2013, coincident with the urban water conservation mandate, was 34 GWh for the 32 water agencies in the study. As a back-of-the-envelope exercise, if one assumed these were average sized water agencies, this would translate to 431 GWh reduced energy use for the state overall coincident with the water conservation mandate relative to the 2013 baseline. The study team sees this as a significant finding and as support for investing energy efficiency resources in water conservation, as well as ongoing accurate measurement of the water and energy conserved, commensurate with the scale of savings.

4.3 OBJECTIVE 3: PROVIDING PRELIMINARY OBSERVATIONS ON PATTERNS OF CHANGE IN EI DURING THE STUDY PERIOD 2013-2015

Based on the billing data review, overall water agency IOU-only EI increased for all water agencies during the study period 2013-2015, whether they received their water primarily from imports, from local groundwater pumping, or from mixed supplies. The overall average EI across all 32 water agencies in the study increased by 7%, from 371 kWh/acre-ft to 397 kWh/acre-ft. The overall EI for water agencies relying on groundwater was approximately 50% higher than the overall EI for water agencies reliant on imported water. EI for these groundwater-reliant water agencies rose an average of 10% over the study period, while EI for import-reliant water agencies rose approximately 7%.

FIGURE 4-14: AVERAGE ANNUAL WATER AGENCY ENERGY INTENSITIES BY SUPPLY MIX FOR 2013 AND 2015

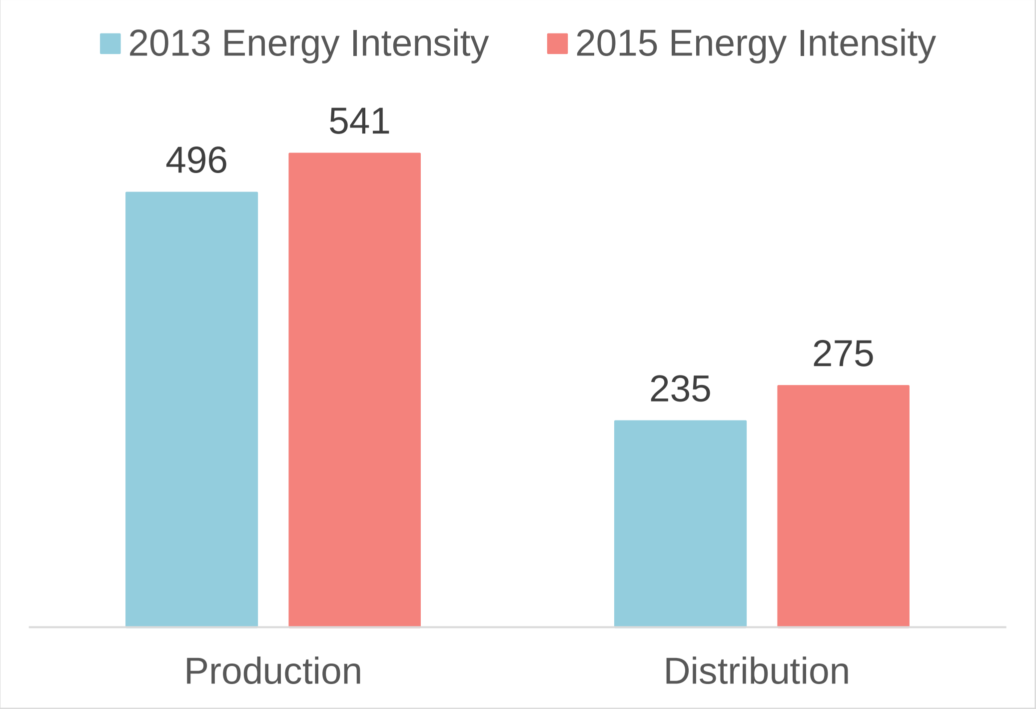


Looking at the water system component level (extraction, treatment, and distribution), the study team found that assigning specific pumping accounts to a particular water system component was not reliable enough to serve as the basis for deriving component-level EI estimates. For the bottom-up approach used with most water agencies, the single available data source in most cases for assigning a component label to a given account was the google earth data that gave visual information about the physical infrastructure associated with a given pump. A comparison between these bottom-up water system component assignments and the top down information for those water agencies that provided it showed a match of only 60% for these component element assignments. Misidentifications of account types can lead to significant error in component level EI calculations. Hence the evaluation team decided to use only top-down data for these calculations.

FIGURE 4-15: AVERAGE NUMBER OF SYSTEM COMPONENT ACCOUNTS ACROSS WATER AGENCIES IN SAMPLE

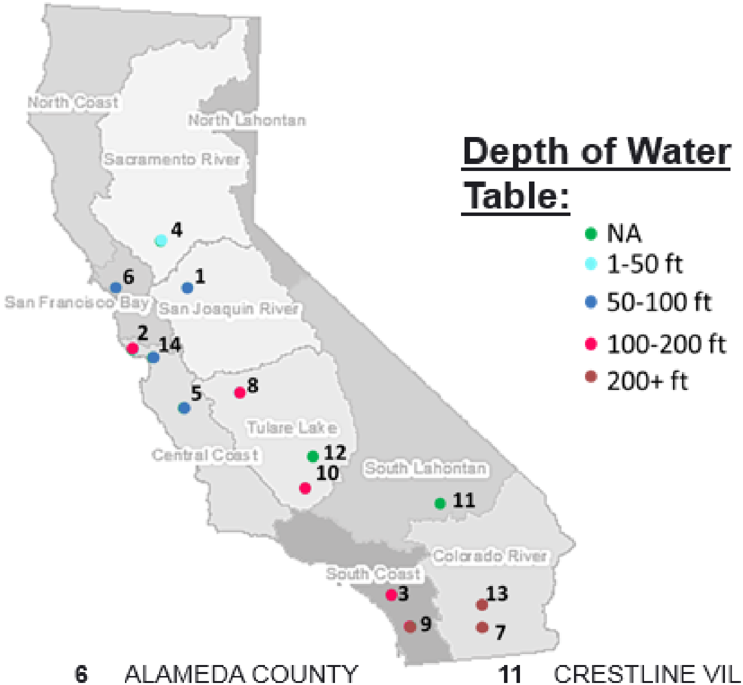
As shown in Figure 4-16 below, data from the four water agencies whose managers supplied information on reliably labeled water system components (extraction, treatment, and distribution) shows that the EI of both water production and distribution increased over the study period. Based on this data, EI of water production rose 9%, and EI of water distribution rose 17% during the study period.

FIGURE 4-16: AVERAGE ANNUAL WATER AGENCY ENERGY INTENSITIES BY SYSTEM COMPONENT FOR 2013 AND 2015



Not surprisingly, increased water table depth, generally exacerbated by increasing drought conditions, means that the water must be raised a greater distance to reach the surface. The total equivalent height that a fluid is to be pumped (taking into account friction losses in the pipe) is known as the Total Dynamic Head, and this value is used directly in the numerator of some industrial and agricultural energy efficiency programs to calculate energy savings when pumped water is conserved. The study team initially sought to characterize changes in water table depth over the study period using publicly available data from the U.S. Geological Survey test wells as proxy indicators of water table depth for groundwater wells in the study frame. The intent was to note changes in water table depth coincident with observations of changing groundwater EI in the billing data over the study period. However, brief exploration showed that water table depth can vary dramatically over very small geographic distances, depending on underground hydrology, geology, and other factors, and the study team retreated from this effort. Figure 4-17 below nevertheless provides context in terms of general patterns in water table depth for water agencies in the study frame, with a general pattern of a deeper water table found further south in the state.

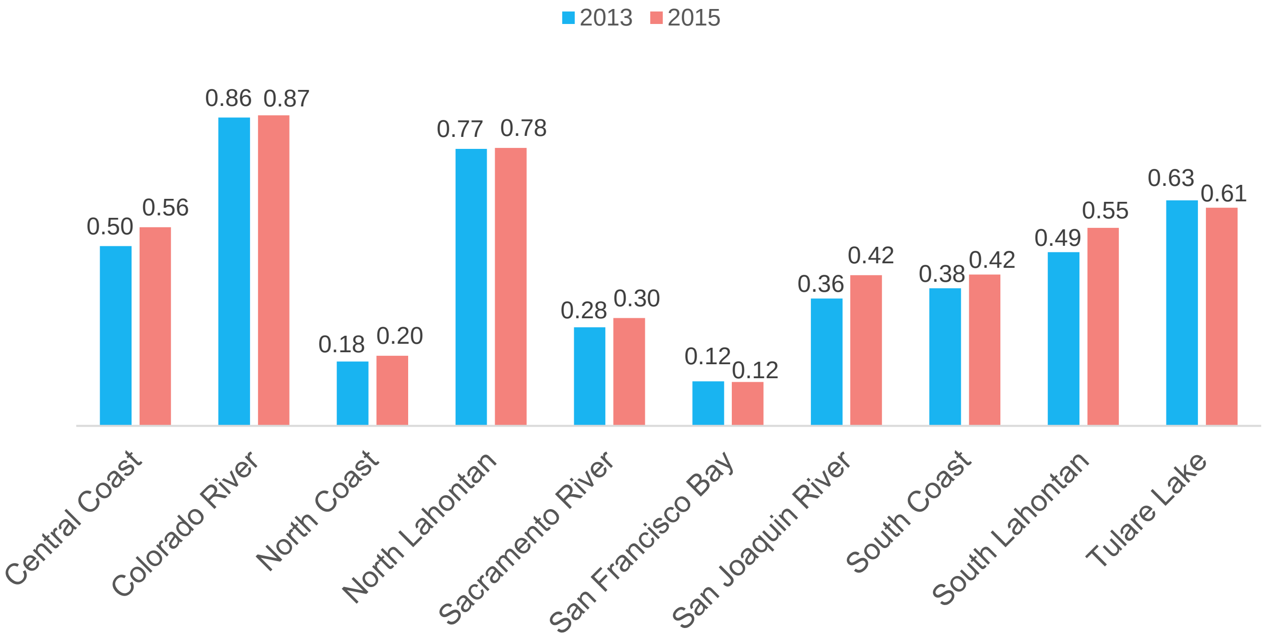
FIGURE 4-17: RANGE OF WATER TABLE DEPTHS FOR A SELECTION OF WATER AGENCIES IN ITRON SAMPLE



1 DIABLO
2 SALINAS
3 VENTURA COUNTY
4 MARYSVILLE
5 KING CITY
6 ALAMEDA COUNTY
7 TWENTYNINE PALMS
8 WEST KERN
9 SAN JACINTO
10 EAST NILES
11 CRESTLINE VILLAGE
12 GOLDEN HILLS
13 JOSHUA BASIN
14 SCOTTS VALLEY

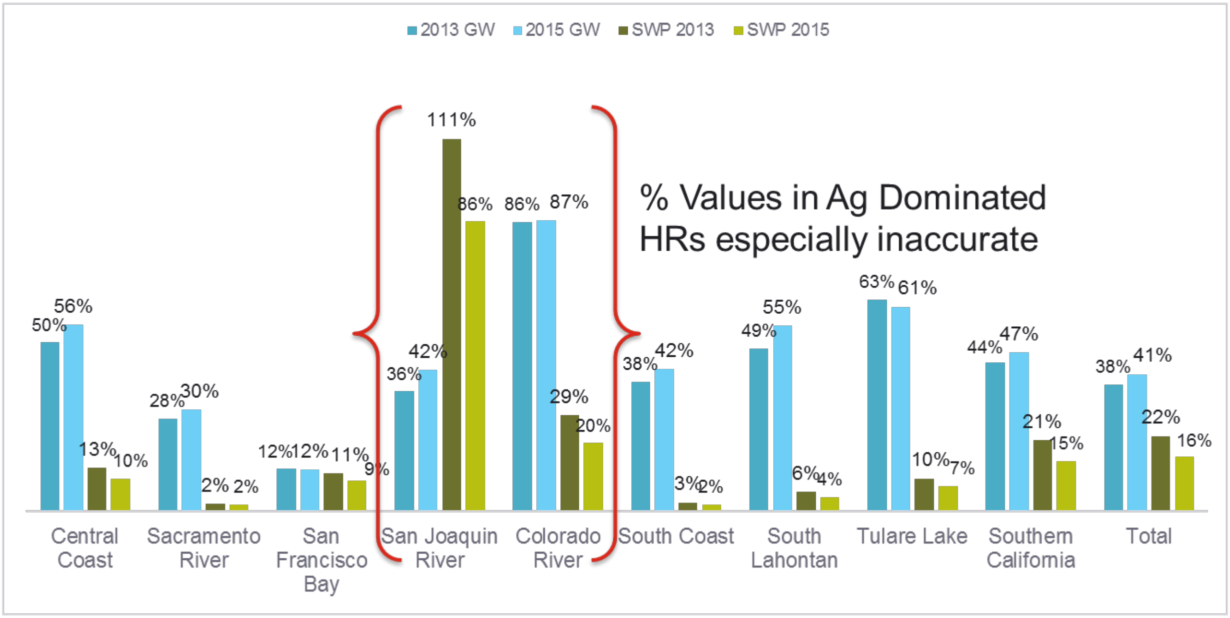
The 2015 urban water conservation mandate resulted successfully in a statewide reduction in urban water use of 25% relative to 2013. In the context of increasing drought conditions and declining overall urban water usage during that period, shifts also took place in water supply mix throughout the state. This was especially true in terms of the relative balance of groundwater pumping and imports from the state's long distance conveyance systems. As shown in Figure 4-18 below, all but 2 of California's 10 hydrologic regions saw groundwater production grow as a proportion of total water supply, even as the total pumped volume was declining in an absolute sense. The largest proportional increases were seen for the Central Coast, San Joaquin River, and South Lahontan hydrologic regions.

FIGURE 4-18: ANNUAL AVERAGE RATIO OF RETAIL GROUNDWATER PRODUCTION TO SWB PRODUCTION BY HYDROLOGIC REGION



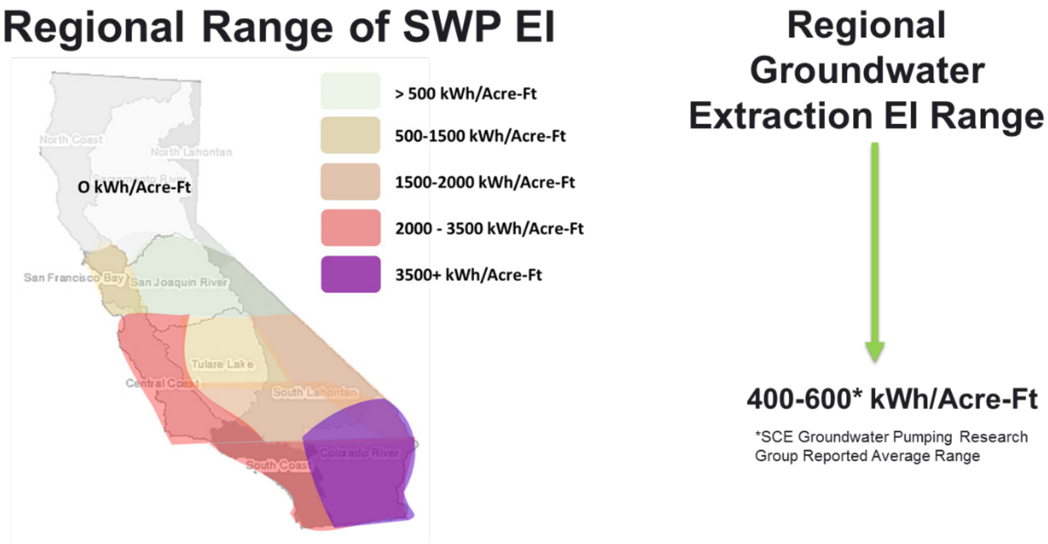
In this same context of declining total consumption, the proportion of total water supplied by the State Water Project also decreased for 8 out of 10 hydrologic regions. As shown in Figure 4-19 below, the most dramatic proportional reductions in overall SWP water use were for the San Joaquin River and the Colorado River hydrologic regions. However, from an urban water standpoint, these are somewhat distorted figures, since much of the SWP water in those regions and captured in the figure below is used for agriculture.

FIGURE 4-19: ANNUAL AVERAGE RATIO OF STATE WATER PROJECT DELIVERIES AND RETAIL GROUNDWATER PRODUCTION TO SWB PRODUCTION BY HYDROLOGIC REGION



As shown in Figure 4-20 below, there is a large range in the energy intensity of SWP water, depending sensitively on how far the water is transported (in particular, how many vertical feet the water must be raised) to get from its source in the Sacramento River Delta to its destination. Notably, SWP deliveries to the far southeastern corner of California, which include the largest amount of embedded energy from pumping stations along the route, have energy intensities exceeding 4,000 kWh/acre-ft. This is at least 7 to 10 times higher than typical groundwater EIs. This comparison suggests that, at least when taking non-IOU energy into account in the case of the State Water Project, a parcel of water saved in the southern half of the state may yield significantly higher embedded energy savings than an equivalent parcel saved in the northern half of the state. This dramatic difference in EI may justify an investment in granular, methodical data collection and analysis to fully characterize this dynamic for the incorporation into water and energy conservation policies.

FIGURE 4-20: APPROXIMATE 2013-2015 STATE WATER PROJECT EI RANGE BY HYDROLOGIC REGION (LEFT) AVERAGE GROUNDWATER EXTRACTION EI IN SCE SERVICE TERRITORY (RIGHT)



5 CONCLUSIONS

The primary objective of this research was to directly observe water agency electric reductions parallel with the 2015 California statewide urban water conservation mandate. Empirical reduction estimates derived from the billing review were informed by several publicly available resources and the direct solicitation of data from water agency managers. The billing review was developed as a highly granular approach to corroborate the existing CPUC water-energy calculator methods and default values. Outcomes from the comparative billing analysis primarily show that embedded water energy savings are highly variable across all water agencies and yield lower energy savings than estimated using the average hydrologic region EI values that underlie the CPUC water-energy calculator. In addition, trends in EI at each level of granularity for 2013-2015 form the basis for a set of improvements regarding the CPUC water-energy calculator. The conclusions following the completion of each objective are summarized below.

5.1 CONCLUSIONS FROM RE-CREATING 2015Q3 SAVINGS CALCULATIONS USING AVERAGE HYDROLOGIC REGION ENERGY INTENSITIES

Objective 1 was focused on the recalculation of the UC Davis Q3 2015 embedded water energy savings published as a water-energy web tool that applied the methods and values of the CPUC water-energy calculator. The boundary conditions of the water-energy web tool were not directly comparable to those taken in this research and required adjustment. The first adjustment was to recalculate Q3 2015 embedded water energy savings without the inclusion of wastewater treatment. The UC Davis estimate of 460 GWh recalculated without the added EI of wastewater treatment yielded 223 GWh. The 223 GWh is representative of IOU-only outdoor water energy savings in Q3 2015 following the water conservation mandate. Additionally, following the literature review conducted in parallel to the recalculation of the UC Davis estimate, the evaluation team determined that the average EI values were derived from multi-year data sources and that accurate application of these values would be limited to annual savings estimates. The evaluation team then recalculated Q3 2015 savings as an average 2015 quarter yielding an energy savings estimate of 130 GWh.

5.2 CONCLUSIONS FROM THE BILLING DATA REVIEW

The empirical investigation of embedded water energy reductions from water agency electric bills for 2013-2015 was carried out on a selection of 32 water agencies. The selected water agencies represented each of California’s 10 hydrologic regions and were selected to broadly reflect the state’s relative reliance on differing supply sources. Each water agency’s 2015 energy savings were calculated relative to 2013 and were presented both as a percent reduction and as a total MWh reduction. Water agency energy reductions were then compared to parallel estimates representing the methods and values from the CPUC water-energy calculator.

Percent energy reductions for each water agency from the billing review analysis are compared to estimates derived using average EI values by water agency type (groundwater-reliant, import-reliant, mixed). Percent energy savings calculated from the billing review are found to be lower and more variable than parallel average EI estimates across all water agency types. For water agencies that source greater than 70% of their supplies from groundwater, the Itron billing review 2015 percent energy reductions relative to 2013 were 16% relative to 23% estimated following CPUC water energy calculator methods. For water agencies that source greater than 70% of their water supplies from imported water sources the billing review predicted 22% reductions versus average EI derived yielding 24%. For water agencies of mixed supply, the billing review showed a percent energy reduction of 20% versus 24%. In summary, the methods of the CPUC water energy calculator may overestimate energy reductions relative to the billing review particularly for water agencies who are reliant on groundwater pumping. These results indicate that reduced energy savings are not directly proportional to changes in volumetric water consumption and that individual water agencies deviate even farther from this assumption.

Comparing actual MWh reductions between the Itron billing review and savings estimates representative of the CPUC water-energy calculator are presented by supply type and relative water agency size. Actual MWh reductions extracted from the water agency billing review analysis are largely less than reduction estimates derived from AVG hydrologic region EI values with a few notable exceptions. Interpretation of MWh reduction comparisons require the additional consideration of the comparability of the corresponding water volume to the calculated energy consumption. As previously noted, the aggregated energy consumption for each water agency in the billing review is associated with the water agency's total water supply rather than only the urban water in use reported in the SWB conservation dataset; impacting the comparability of estimates. For all the water agencies that are reliant on groundwater actual MWh reductions are 72% of those estimated using average EI values. For water agencies reliant on mixed and imported water supplies, after removing water agencies of non-comparable water volumes, actual MWH reductions are respectively, 130% and 49% of estimates derived using AVG hydrologic region EI values. The analysis was then divided by water agency size and supply type to minimize the effect of large water agencies. For the 9 water agencies grouped in the small water agency category the billing review versus AVG hydrologic region EI derived estimates ranged from 6% for importing to 108% for groundwater sourced water agencies. For the 15 water agencies that fell in the large water agency category the billing review versus AVG hydrologic region EI derived estimates ranged from 65% for groundwater to 93% for mixed supply sourced water agencies. Results largely indicate that actual AVG hydrologic region EI values overestimate embedded water-energy reductions but to what degree cannot be determined exactly given the high degree of variability among water agency savings and size. The results specific to groundwater reliant water agencies most robustly suggests that average EI values overestimate embedded energy reductions by upwards of 28%.

The water-in-use figures from the State Water Board offer an advantage in that they are focused on the particular volume of water over which urban users in a given water agency have direct control and choice in terms of their water use and water conservation behaviors. This is a reasonable volume of water to consider when calculating the energy impacts of conservation efforts. However, this approach makes the embedded energy reduction calculation completely dependent on the accuracy of these reported water consumption figures assembled by the water agencies and for a different purpose than embedded energy reduction calculations. A consequence of this, discussed elsewhere, is that these figures exclude raw and recycled water altogether from the savings calculations, while exported water is ostensibly accounted for at the water agencies importing that water. In addition, this approach is exposed to the fact that imported volumes of water to which average hydrologic region EIs are applied in embedded energy reduction calculations may in fact originate in water agencies from a different hydrologic region.

The total water supply volume accounted for in the billing data review approach addresses all water that is directly pumped by water agency accounts. This creates a clearer boundary regarding the water volume that corresponds with the water agency level EI. Total water production figures from the Urban Water Management Plans enables water agency level EI calculations that are very likely more accurate than the average hydrologic region EI calculations. One observation that flows from this is that the comparison between the billing data review and average hydrologic region EI approach is not an apples-to-apples comparison except for water agencies with 100% groundwater reliance where the State Water Board data also represents the total water supply. Another observation is that both of these approaches, when pursued for all of the approximately 400 water agencies in the state, yield internally consistent overall results where the water exported from one water agency and imported into another is ultimately accounted for in the overall EI figures.

5.3 CONCLUSIONS REGARDING CHANGING ENERGY INTENSITY OVER THE STUDY PERIOD

Results from the review of water agency electric bills support the conclusion that the relationship between volumetric water and energy reductions are not directly proportional. This study concluded analysis with an investigation on patterns of change in EI at each level of the embedded water energy framework, starting with average water agency EIs. The average water agency energy intensity across all water agencies in the study increased from 371 kWh/Acre-Ft to 397 KWh/Acre-Ft. For groundwater and imported water reliant water agencies, EIs increased from 399 to 439 and 259 to 278 KWh/Acre-Ft respectively. While there are a number of considerations that are left to be accounted for in the interpretation of increasing EIs across all water agencies, it is unlikely that these would contribute to raising the EI of a water agency. These considerations would include such changes as increased pump efficiencies, technology upgrades, incorporation of distributed energy resources, changeover to gas energy sources, expansion of service territory, etc. Increases in water agency EIs are therefore likely attributed to either changes in water agency supply mix or increases in the energy intensity of the agency's system components.

Changes in EI at the water agency system component level were found to be increasing for both groundwater production and distribution processes by approximately 40 kWh/Acre-Ft. This phase of analysis only included results from water agencies where top-down supplied data were available, drastically limiting the sample size and scalability of results. The evaluation team interpreted these results as preliminary but strong support for directional recommendations for CPUC water-energy calculator improvements.

As noted previously, changes in water agency supplies may result in an increased reliance on more energy intensive methods for procurement of water resources such as groundwater pumping versus surface water imports. Specific knowledge on the supply trends for the 32 water agencies in this study were not available. In order to provide some exploratory analysis on this aspect, historical groundwater production and SWP deliveries were compared to total urban water production for each hydrologic region. Results show an increase in the percent supply sourced from groundwater pumping in 2015 versus 2013 for eight of the state's hydrologic regions. For all hydrologic regions served by the SWP; SWP deliveries decreased in 2015 versus 2013 (SR stayed the same). These preliminary analyses demonstrate shifting in regional water supply mixes in 2015 relative to 2013. For the majority of California's hydrologic regions, the EI of water sourced from the SWP far exceeds the average groundwater production EI. The relative EIs of each hydrologic region's supply mix source are significant both for the accuracy of estimating embedded water energy savings but for the development of policies leveraging the reduction of energy from water conservation.

6 RECOMMENDATIONS

While avoided energy inputs from conserved water have the potential to be a significant source of energy savings, there is a lack of an industry agreed upon evaluation framework for estimating these savings. Rigorous evaluation and standardized reporting for estimating energy reductions from water conservation is an outstanding need that it is crucial for the full realization of potential energy savings and the development of effective policies. Recommendations from this study are in service of an increasingly accurate estimate of these outdoor embedded water energy savings to help promote effective savings estimation as well as informed decision making and prioritization around water conservation efforts.

The study team recommends that the CPUC and other relevant stakeholders consider the following actions to increase the accuracy of embedded water energy estimates looking forward. These recommendations fall into three broad categories supported by more specific recommendations in some cases:

- Consider expanding the billing data review approach to all water agencies throughout the state. In support of this recommendation:
  - Due to the inherent increased accuracy of the approach, consider expanding the billing data review approach to all water agencies throughout the state. This approach is a direct means of measuring changes in electricity usage concurrent with changes in water usage. It makes use of electric billing data that is more comprehensive and longer-standing than available volumetric water consumption data. If conducted on a recurring basis, this approach could yield outdoor embedded energy savings calculations in a way that augments or replaces the average hydrologic region EI approach.
  - Incorporate data collection on changes that affect equipment efficiency into calculations of embedded energy use. These changes may include investment in new pumps or variable speed drives. It also may include other changes that affect electricity consumption per volume of water pumped, such as reductions in output per pump due to friction in the common discharge pipe when multiple pumps operate in a parallel arrangement.[35]
- Consider refinements to improve the accuracy of the average hydrologic region EI approach that underlies the existing CPUC water energy calculator. In support of this recommendation:
  - Consider developing a system of adjustments that can be made to the average hydrologic region EIs as a function of drought intensity to better match embedded energy savings with current water conditions. It may be possible to identify easily measured proxy indicators that have a generally predictable effect on some components of overall EI, such as groundwater pumping, which may be applied as adjustment factors.

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[35] Al Lutz, PE, Itron, personal communication.

  - Make frequent, scheduled updates to the existing CPUC water-energy calculator as up-to-date information is reported. The urban water management plans (UWMPs) published for each water agency and the regional water reports published by the department of water resources (DWR) are excellent resources for this purpose. Both are updated on a routine basis and provide valuable information on total water production and other relevant statistics for calculating energy intensities.
  - Work with other state agencies to require that water agencies report water-related energy consumption and total water production at least annually, and preferably monthly, as part of the routine UWMP process. In the absence of this requirement, accurate information on water agency energy consumption and water production may only be available every five years.
- At a general level, prioritize investment in the accuracy of calculating and evaluating embedded energy savings commensurate with the magnitude of these savings relative to other energy savings opportunities and priorities.

APPENDIX A ACRONYMS AND GLOSSARY

A.1 ACRONYMS

AVG	average
CC	Central Coast hydrologic region
CIS	customer information system
CPUC	California Public Utilities Commission
CR	Colorado River hydrologic region
DWR	Department of Water Resources
EI	energy intensity
GHG	greenhouse gas
GWh	gigawatt-hour
IOU	investor-owned utility
KWh	kilowatt-hour
MWh	megawatt-hour
NC	North Coast hydrologic region
SC	South Coast hydrologic region
SF	San Francisco Bar hydrologic region
SJ	San Joaquin River hydrologic region
SL	South Lahontan hydrologic region
SR	Sacramento River
SWB	State Water Board
SWP	State Water Project
TL	Tulare Lake hydrologic region
WA	Water Agency
UC Davis	University of California at Davis
UWMP	Urban Water Management Plan

APPENDIX B SUPPLIMENTARY FIGURES AND TABLES

FIGURE B-1: PROJECT WORK FLOW AND CONNECTIVITY TO RELEVANT LITERATURE

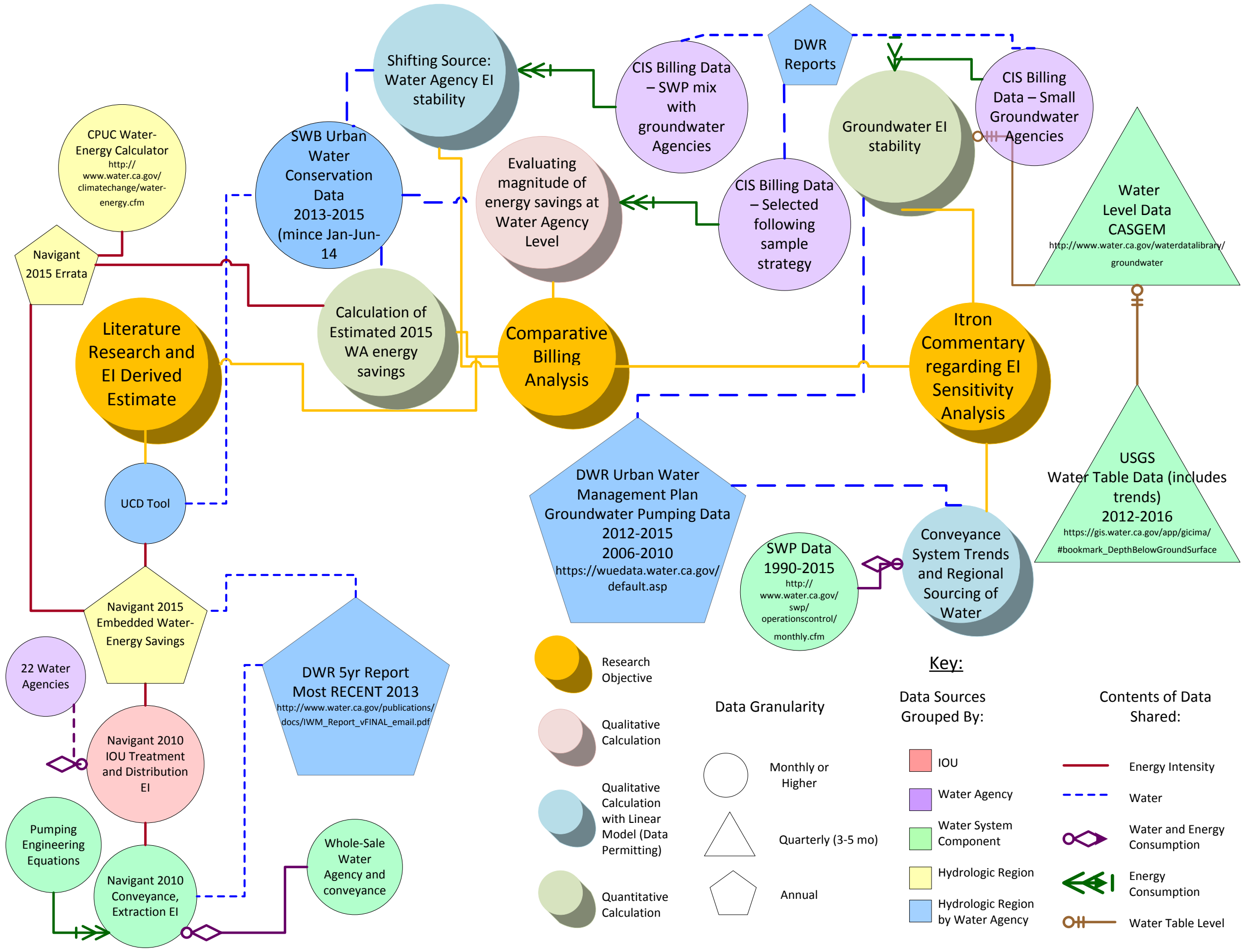

FIGURE B-2: BOTTOM-UP WATER AGENCY ANNUAL CIS BILLING DATA

Water Agency	IOU	HR	Navigant EI KWh/Acre-Ft	SWB Water '15 Acre-Ft	SWB Water '14 Acre-Ft	SWB Water '13 Acre-Ft	Itron kWh '15	Itron kWh '14	Itron kWh '15	EI Derived '15 kWh	EI Derived '14 kWh	EI Derived '13 kWh	Percent Change Itron 15-13	Percent Change EI Derived 15-13	MWh EI Derived	MWh Itron Derived	MWH Difference
ALAMEDA COUNTY	PGE	SF	478	36383	20884	48920	5541484	6915066	8478936	17391290	9982433	23383977	35%	26%	5993	2937	3055
KING CITY	PGE	CC	433	1441	1042	1777	655780	688661	656460	624169	451186	769398	0%	19%	145	1	145
MARYSVILLE	PGE	SR	221	1742	1326	2300	500866	578947	572988	384894	293046	508410	13%	24%	124	72	51
SALINAS DISTRICT	PGE	CC	433	14659	10510	19060	2178293	2578571	3286681	6347390	4550830	8252980	34%	23%	1906	1108	797
NEWMAN	PGE	SJ	239	1890	1199	2605	968013	996907	1141309	451601	286488	622690	15%	27%	171	173	-2
COASTSIDE COUNTY	PGE	SF	478	1895	1290	2245	1735468	2391957	2521204	905622	616578	1072939	31%	16%	167	786	-618
CRESTLINE VILLAGE	SCE	SL	396	611	421	745	310207	269284	326694	241761	166686	294948	5%	18%	53	16	37
DIABLO	PGE	SJ	239	4466	3587	6114	55172	68671	79540	1067330	857233	1461197	31%	27%	394	24	369
EAST NILES	PGE	TL	245	7504	6012	10125	2460443	3153522	3385051	1838480	1472940	2480625	27%	26%	642	925	-282
GOLDEN HILLS	SCE	SL					1055489	1368407	1165331				9%		0	110	-110
HUMBOLDT BAY	PGE	NC	354	619	344	554	4818938	4990715	5287024	219211	121795	196274	9%	-12%	-23	468	-491
JOSHUA BASIN	SCE	CC	204	1359	997	1682	1751588	1960682	1901170	277209	203295	343044	8%	19%	66	150	-84
LAS VIRGENES	SCE	SC	440	17931	14850	23690	9460822	10725915	11435218	7889640	6534000	10423600	17%	24%	2534	1974	560
MCKINLEYVILLE	PGE	NC	354	1332	724	1579	264453	279260	286130	471456	256368	559102	8%	16%	88	22	66
OLIVEHURST	PGE	SR	221	2972	2684	4656	779962	789425	844834	656724	593194	1029068	8%	36%	372	65	307
ROSAMOND	SCE	SL	396	2233	1924	2972	1352395	2085557	2204474	884236	761979	1176997	39%	25%	293	852	-559
SAN JACINTO	SCE	SC	440	2270	1678	3035	1975438	2053703	1744153	998933	738239	1335370	-13%	25%	336	-231	568
SANTA CLARA VALLEY	PGE	SR					572108	475031	624433				8%		0	52	-52

SCOTTS VALLEY	PGE	CC	433	1102	628	1464	1661072	1642267	2161187	477376	271942	633729	23%	25%	156	500	-344
SERRANO	SCE	SC					3084766	3372940	3208260				4%		0	123	-123
SHASTA LAKE	PGE	SR	221	1679	563	2506	14963	22315	26744	370962	124448	553914	44%	33%	183	12	171
STALLION SPRINGS	SCE	SL					426463	498053	484740				12%		0	58	-58
TEHACHAPI - BEAR VALLEY	SCE	SL					1950964	2419600	2491935				22%		0	541	-541
TEHACHAPI - CUMMINGS COUNTY	SCE	SL					1098160	1853721	837464				-31%		0	-261	261
TWENTYNINE PALMS	SCE	CR	204	2396	1654	2820	1473406	1414086	1482506	488839	337370	575355	1%	15%	87	9	77
VALLECITOS	SDGE	SC	440	12689	10455	16777	605199	650823	693281	5583248	4600112	7381704	13%	24%	1798	88	1710
VENTURA COUNTY	SCE	SC	440	9730	6906	12150	752597	903250	842253	4281068	3038640	5345824	11%	20%	1065	90	975
WEST KERN	PGE	TL	245	14814	10593	18351	8261217	11771477	10163325	3629525	2595381	4495992	19%	19%	866	1902	-1036
WESTBOROUGH	PGE	SF	478	819	529	1032	874756	876223	934095	391295	253003	493140	6%	21%	102	59	43
YUCAIPA VALLEY	SCE	SC	440	9594	7614	11881	6162817	8671004	7542295	4221321	3350020	5227760	18%	19%	1006	1379	-373
TOTAL: (30 WA)				**152129**	**108413**	**199041**	**62803298**	**76466038**	**76809715**	**60093582**	**42457206**	**78618040**	**18%**	**24%**	**18524**	**14006**	**4518**
CONTRA COSTA	PGE	SF	478	23598	20029	33770	16866987	20285713	36532622	11279844	9573862	16142060	54%	30%	4862	19666	-14803

APPENDIX C BOTTOM-UP WATER AGENCY BILL SELECTION

FIGURE C-1: BOTTOM-UP WATER AGENCY FREQUENCY COUNTS REPORTED IN UWMPS AND EXTRACTED FROM GOOGLE EARTH

Water Agency	#Unique Addresses	#Number of Accounts	# UWMP Reported Groundwater Pumps	# UWMP Reported Distribution (Tanks and Booster)	#UWMP Reported Treatment	#UWMP Reported Wastewater Treatment	# Google Earth Groundwater Pumping	# Google Earth Distribution (Tanks and Booster)	#Google Earth Treatment	#Google Earth Wastewater Treatment
Bear Valley – Tehachapi (includes Cummings County)	69	74	28	43		1	28	36		1
Marysville	11	12	5	4	1	1	5	4	1	1
Salinas	17	37	Does Not Specify	Does Not Specify	Does Not Specify		9	9		
Coastside County	13	33	5	7			4	6		
Golden Hills - Tehachapi	25	31	15	7			12	7		
Humboldt Bay Municipal	8	14	Does Not Specify	Does Not Specify	Does Not Specify	0	3	3	2	
Joshua Basin	8	8	5	9			5	7		
King City	6	22	6	2		1	5	2		1
Las Virgenes	55	66	24	25	1	1	24	16	1	1
McKinleyville	7	16	4	6			2	6		
Newman	69	230	NO UWMP	NO UWMP						
Olivehurst	51	132	14	4	2	1	16	4	1	1
Rosamond	9	10	3	5	1	1	3	4	1	1
San Jacinto	24	24	4		2		4		1	
Scotts Valley	18	41	6	5	1	1	3	4	1	1
Serrano Water	5	8	3	9		1	3	2	1	1
Stallion Springs -Tehachapi	18	20	4	4	1		4	4		1

Water Agency	#Unique Addresses	#Number of Accounts	# UWMP Reported Groundwater Pumps	# UWMP Reported Distribution (Tanks and Booster)	#UWMP Reported Treatment	#UWMP Reported Wastewater Treatment	# Google Earth Groundwater Pumping	# Google Earth Distribution (Tanks and Booster)	#Google Earth Treatment	#Google Earth Wastewater Treatment
Twenty-nine Palms	16	16	9	6			9	6		
Vallecitos	22	27	9	19	2	1	5	13	2	1
Westborough	5	9		8				7		
Contra Costa	114	205	0	111	2	1	2	111		
Shasta	24	48		10	1	1		4		
West Kern	47	130	14	41		1	Did not use GE	Did not use GE	Did not use GE	Did not use GE
Santa Clara			Does Not Specify	Does Not Specify	3	4			3	
East Niles	26	73	7	22			4	15		
Diablo	11	21	7	Does Not Specify		1	5	0		1
Yucaipa Valley	51	65								
Alameda County	57	111	8	22			6	22	1	
Crestline Village	21	21	39	14			5	13		
Ventura River Water District	7	6	NO UWMP	NO UWMP			1	5		

FIGURE C-2: BEAR VALLEY

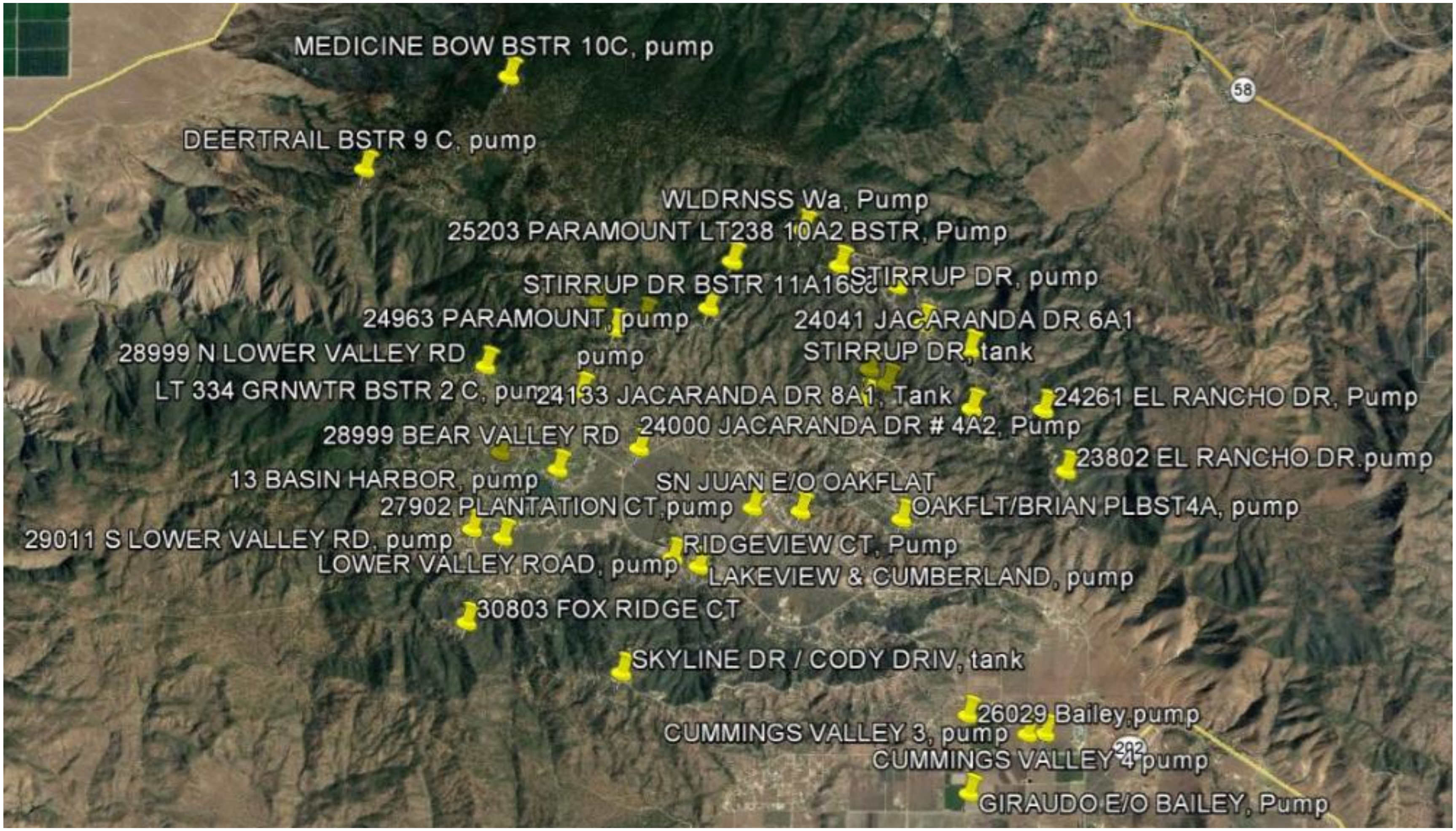

FIGURE C-3: MARYSVILLE

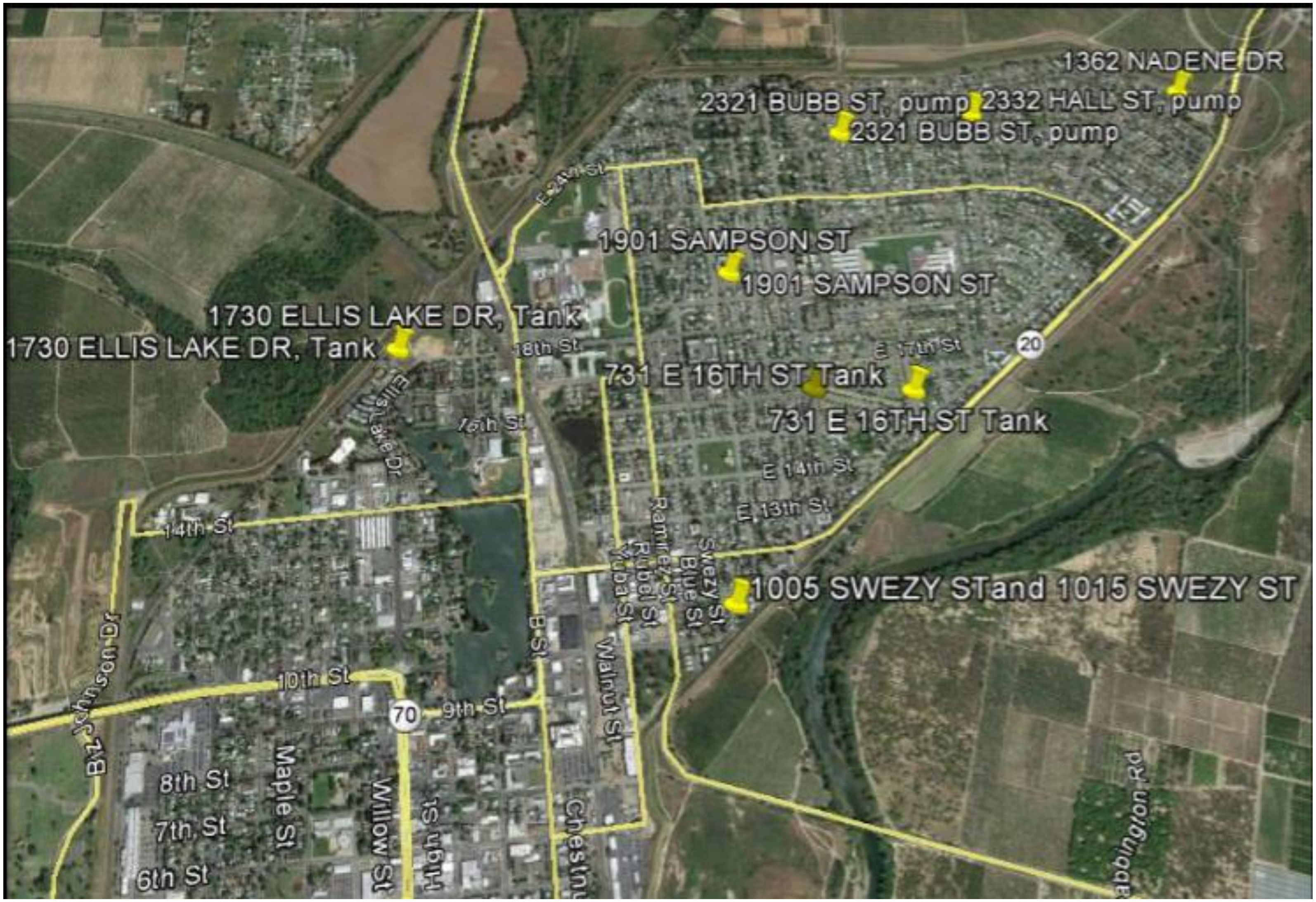

FIGURE C-4: SALINAS

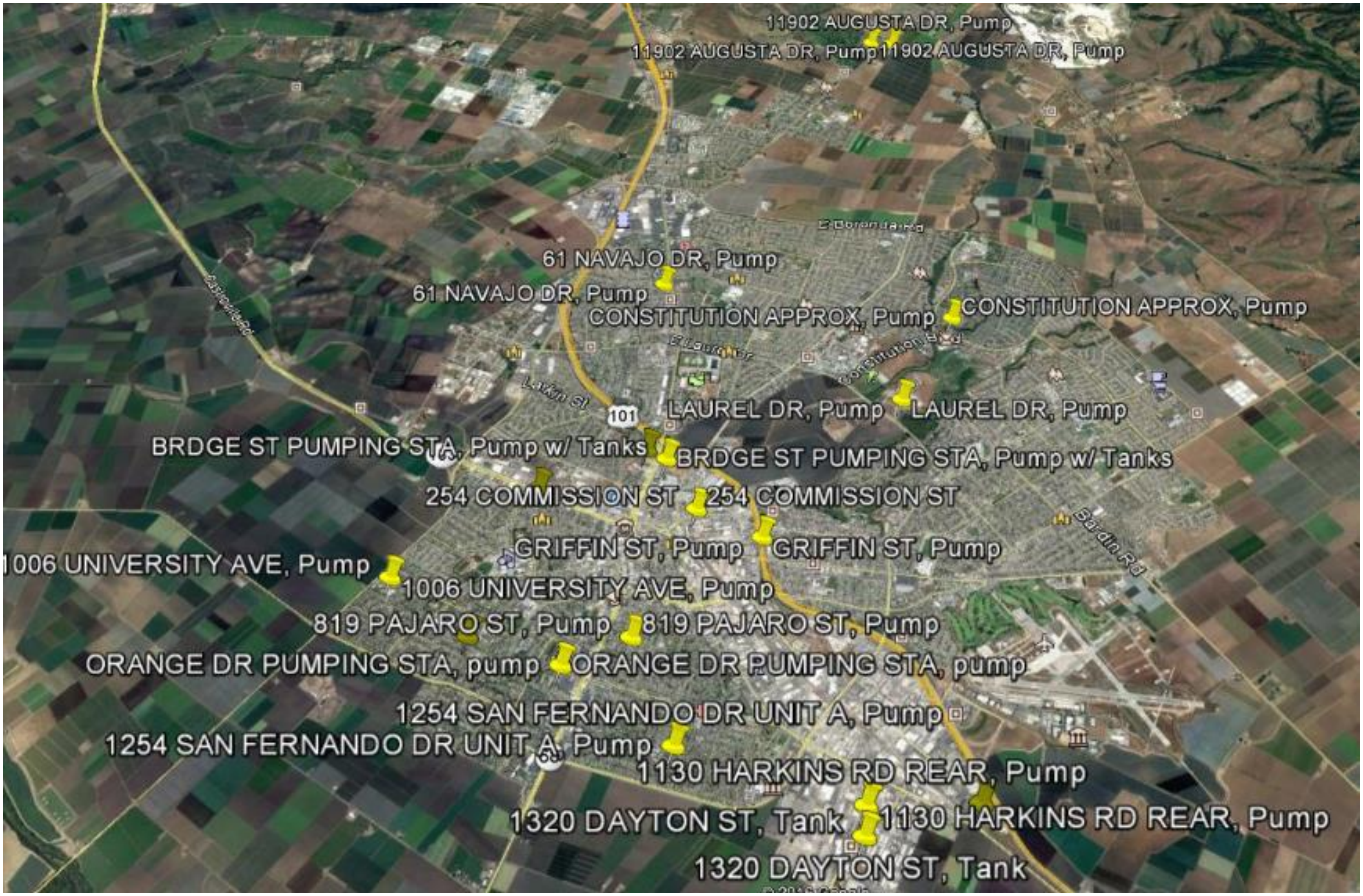

FIGURE C-5: COASTSIDE COUNTY

FIGURE C-6: GOLDEN HILLS

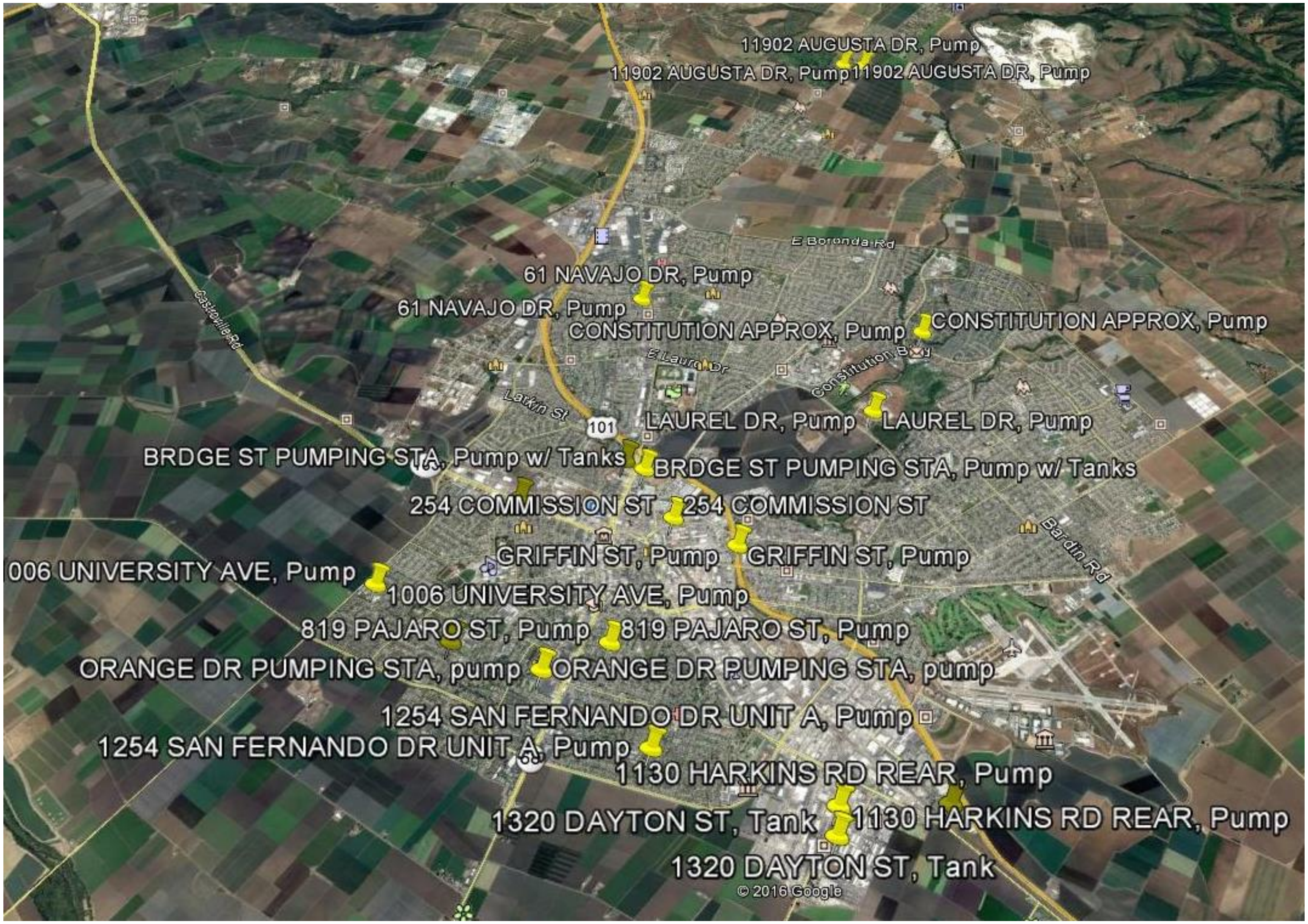

FIGURE C-7: HUMBOLDT BAY

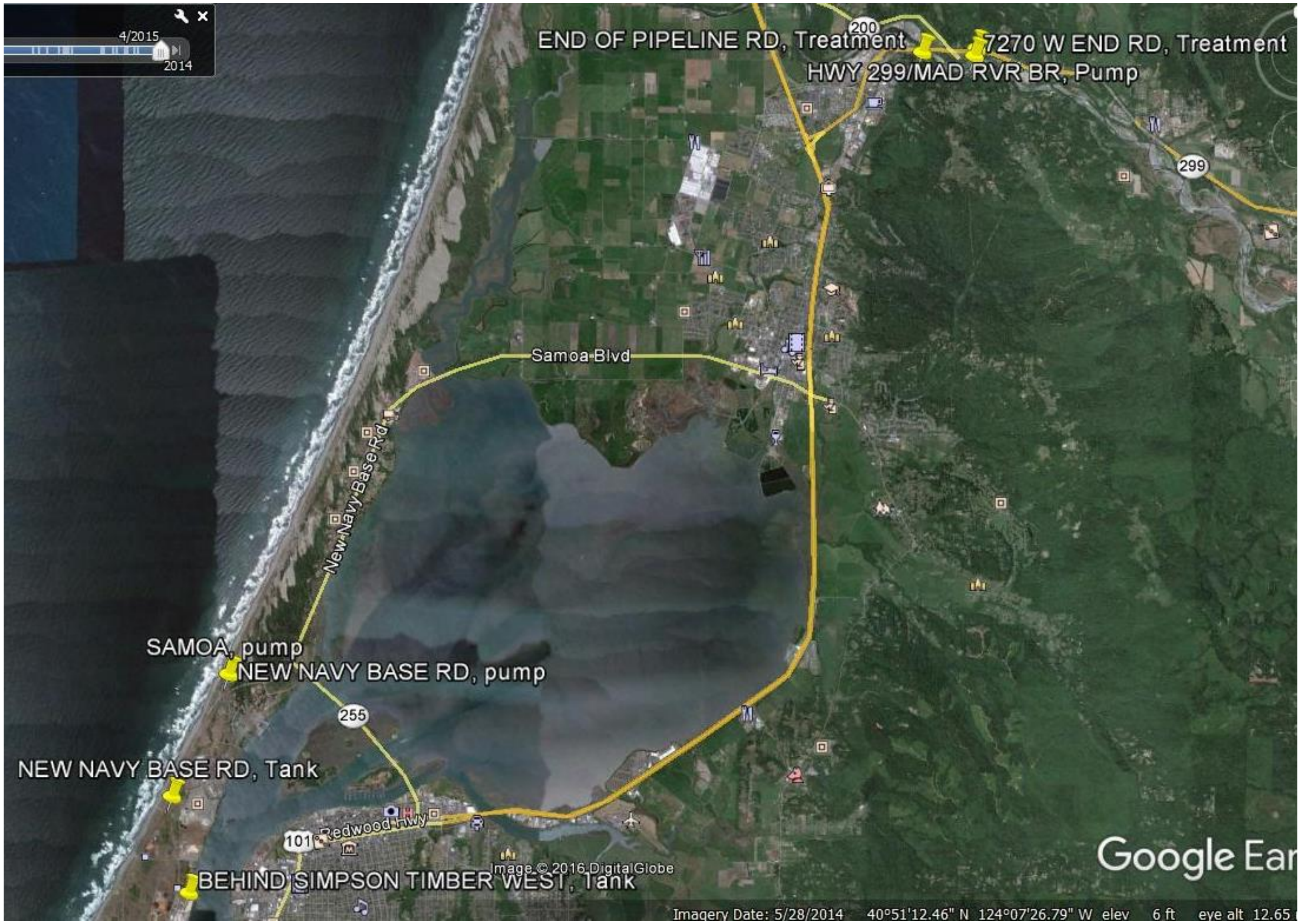

FIGURE C-8: JOSHUA BASIN

FIGURE C-9: KING CITY

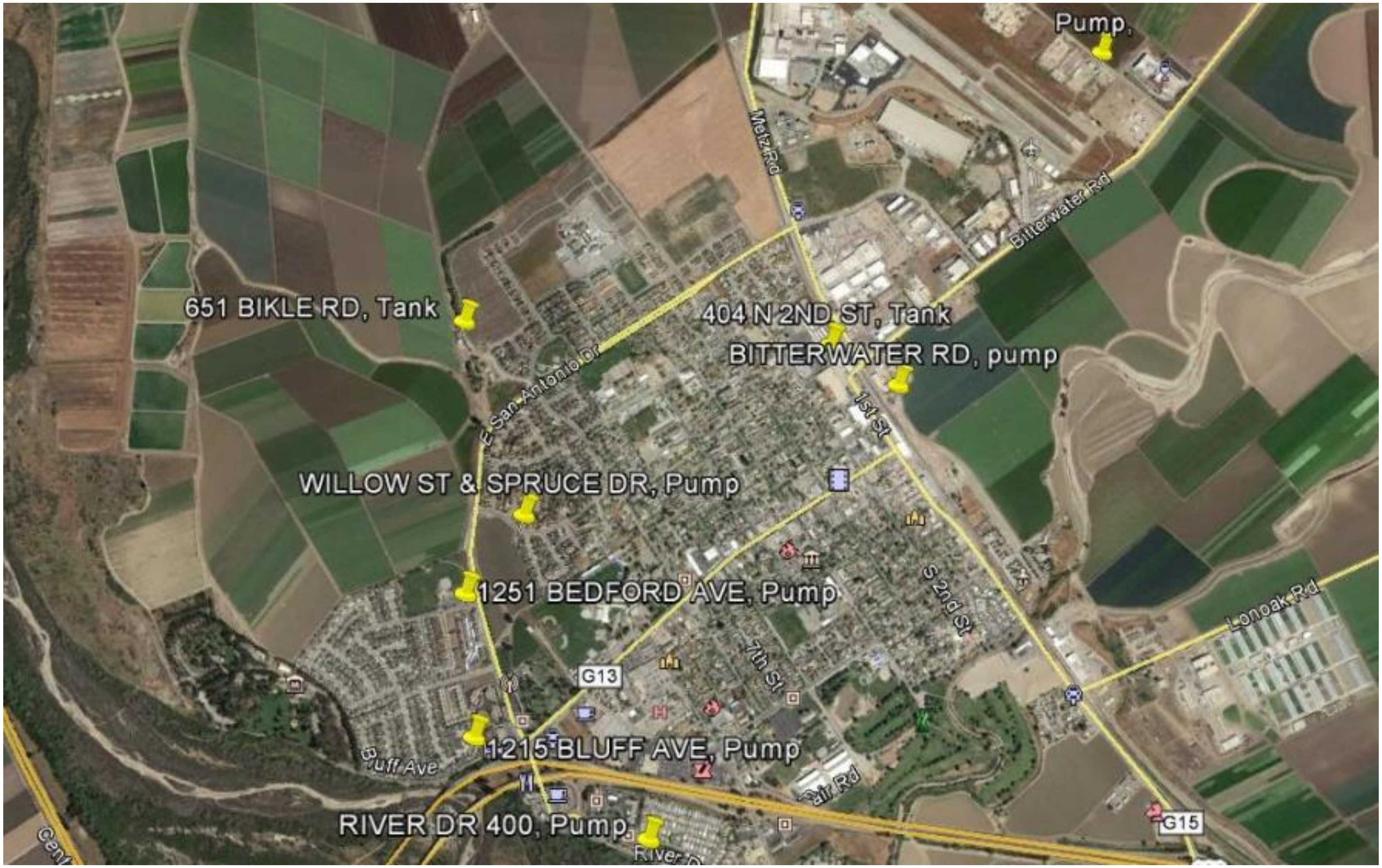

FIGURE C-10: LAS VIRGENES

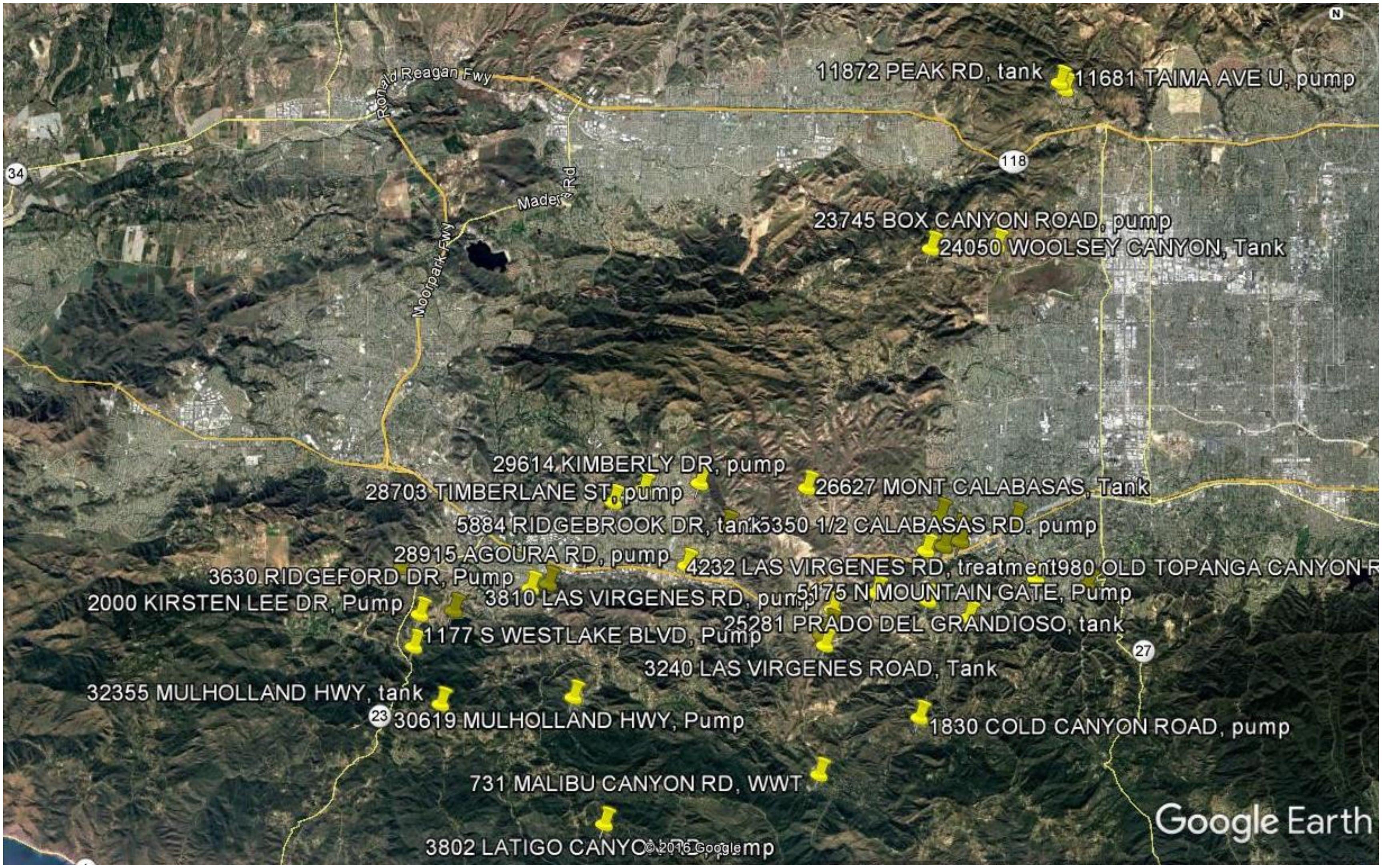

FIGURE C-11: MCKINELYVILLE

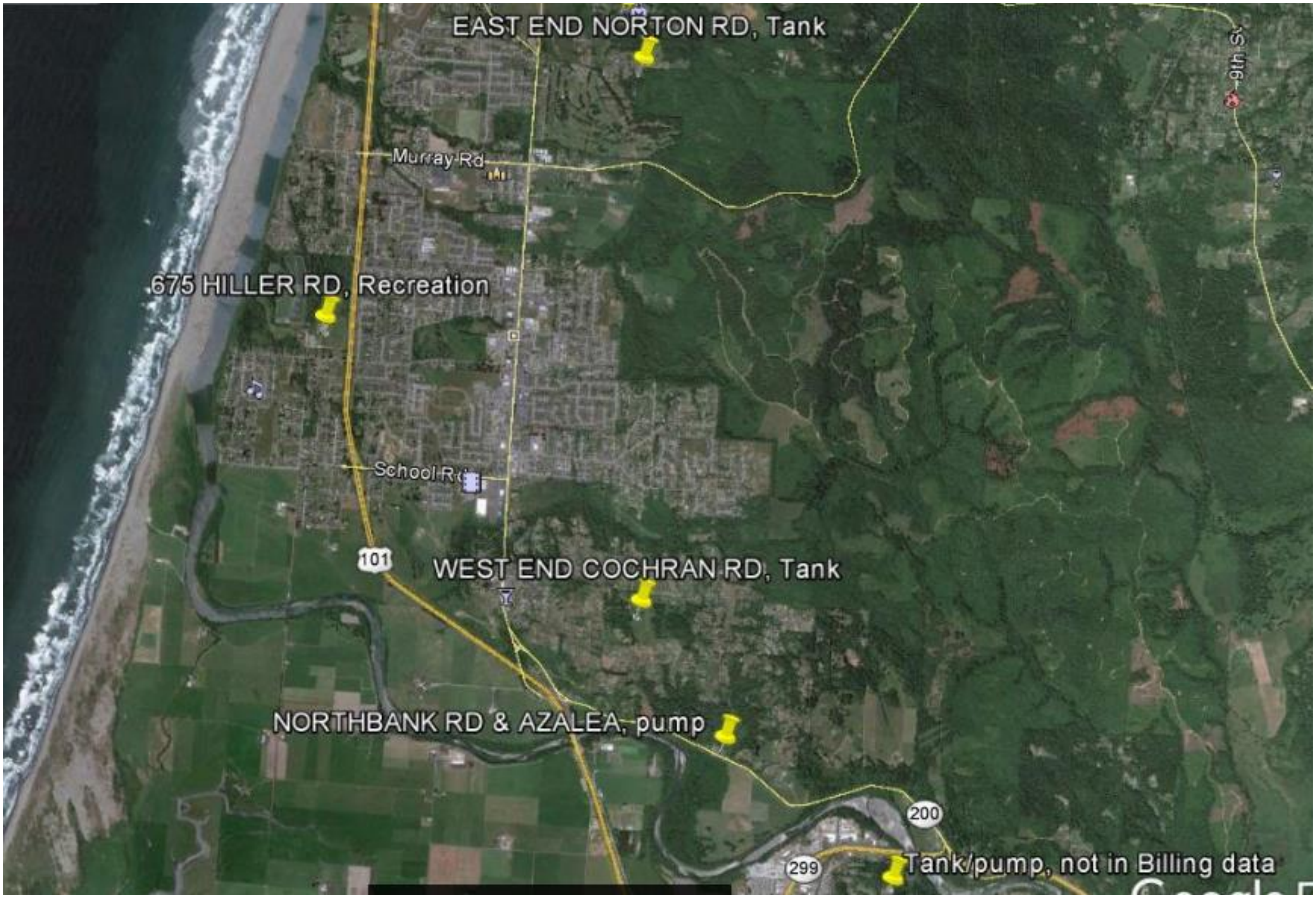

FIGURE C-12: NEWMAN

FIGURE C-13: OLIVEHURST

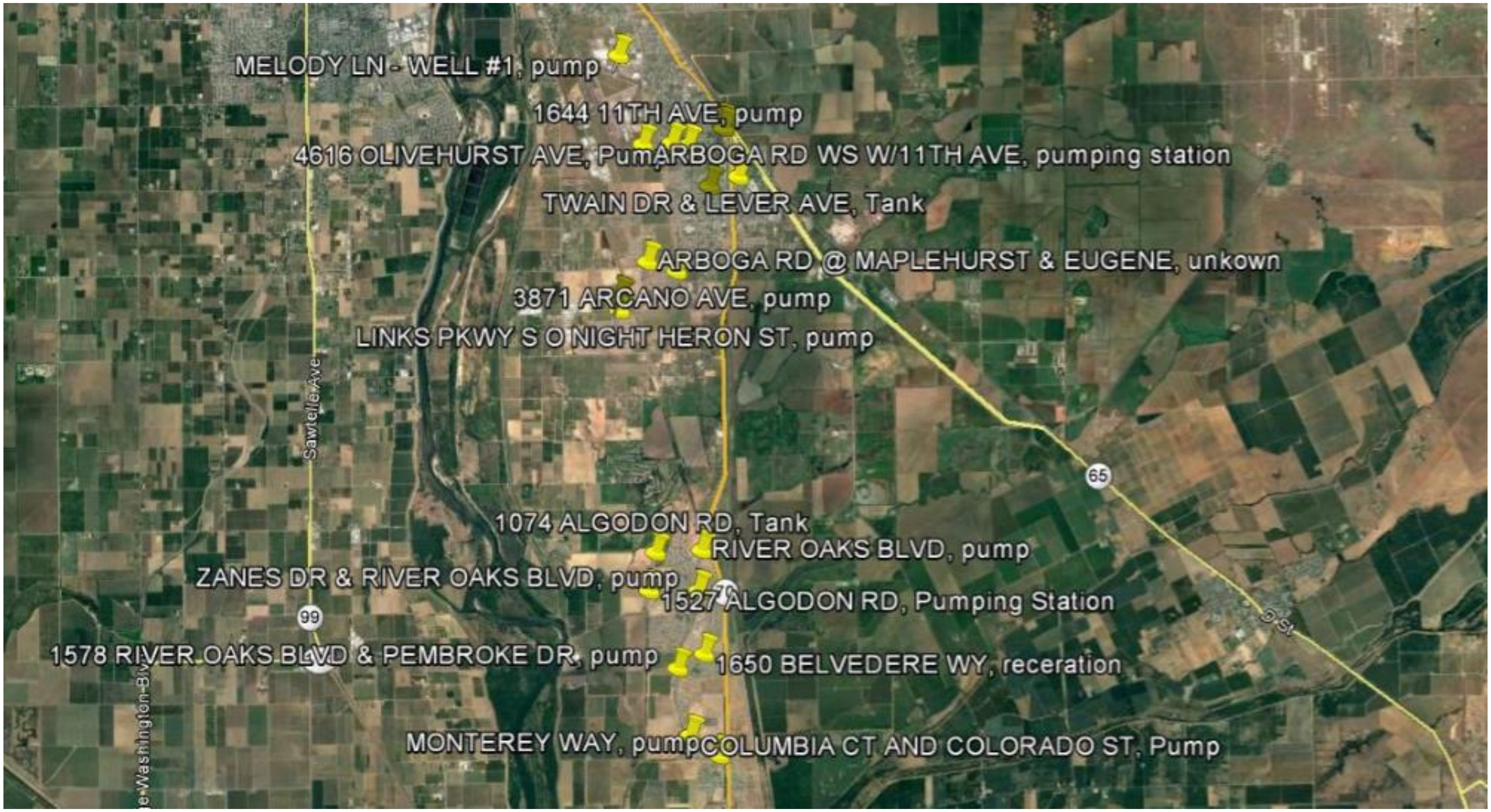

FIGURE C-14: ROSAMOND

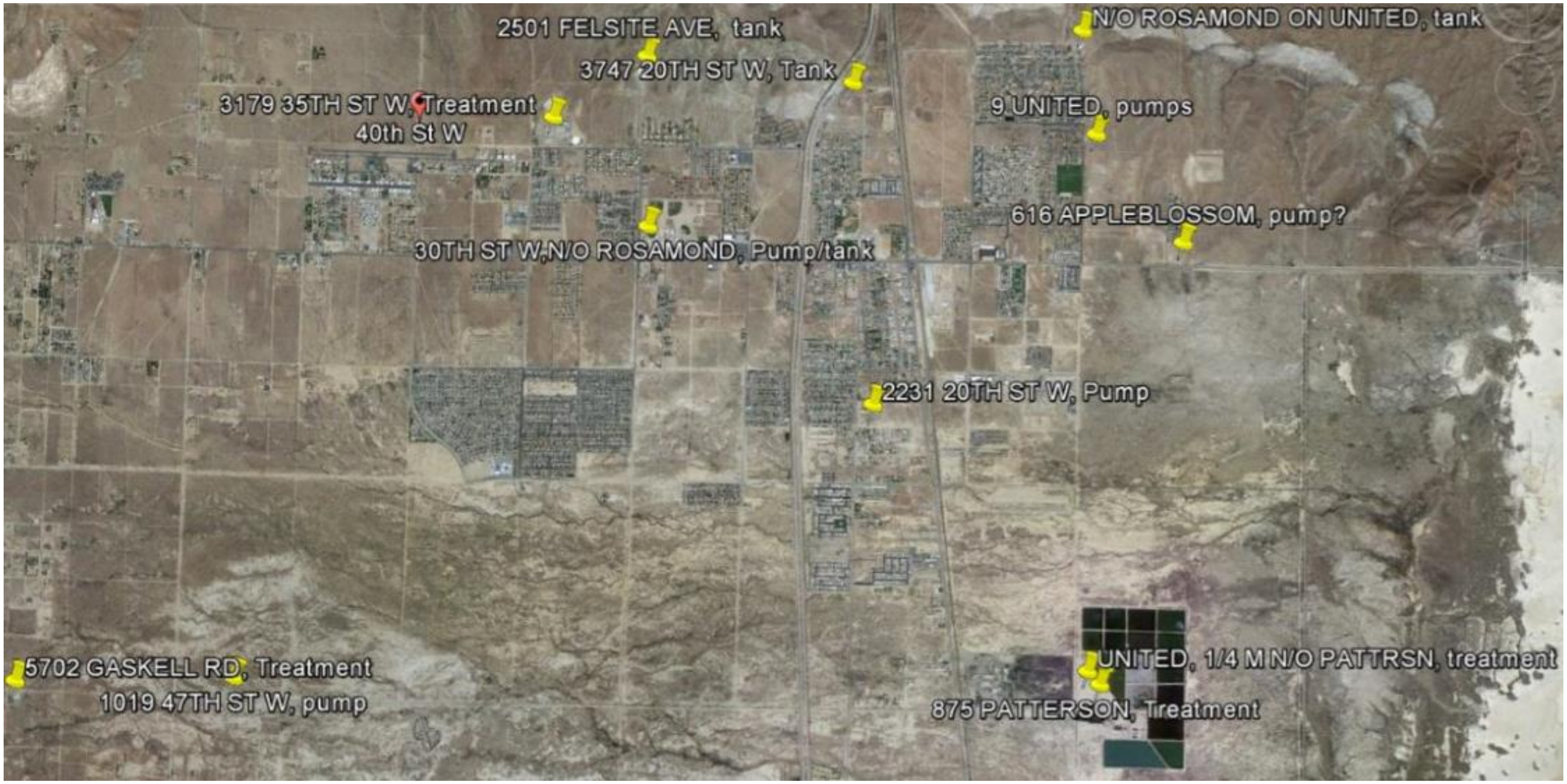

FIGURE C-15: SAN JACINTO

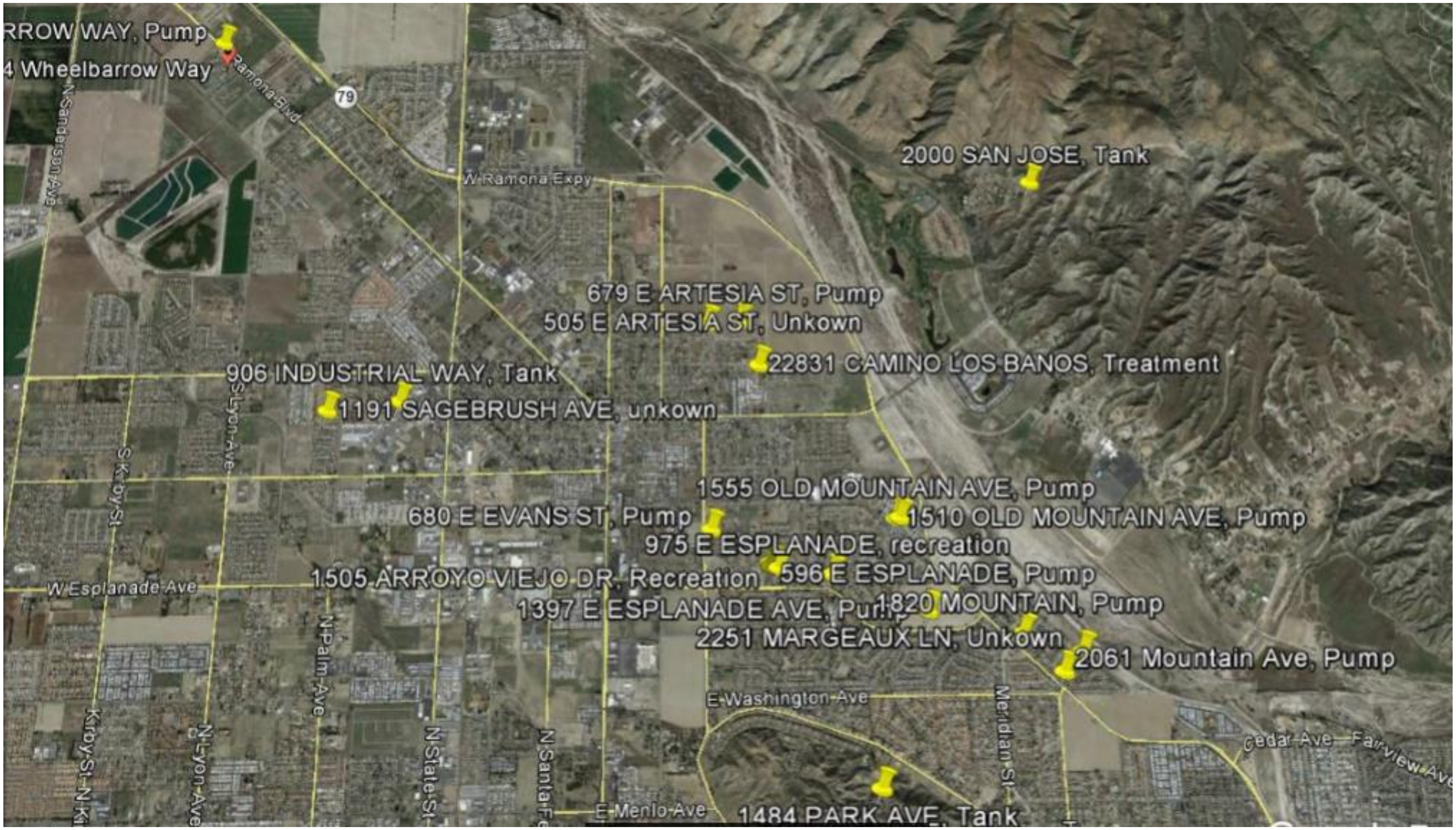

FIGURE C-16: SCOTTS VALLEY

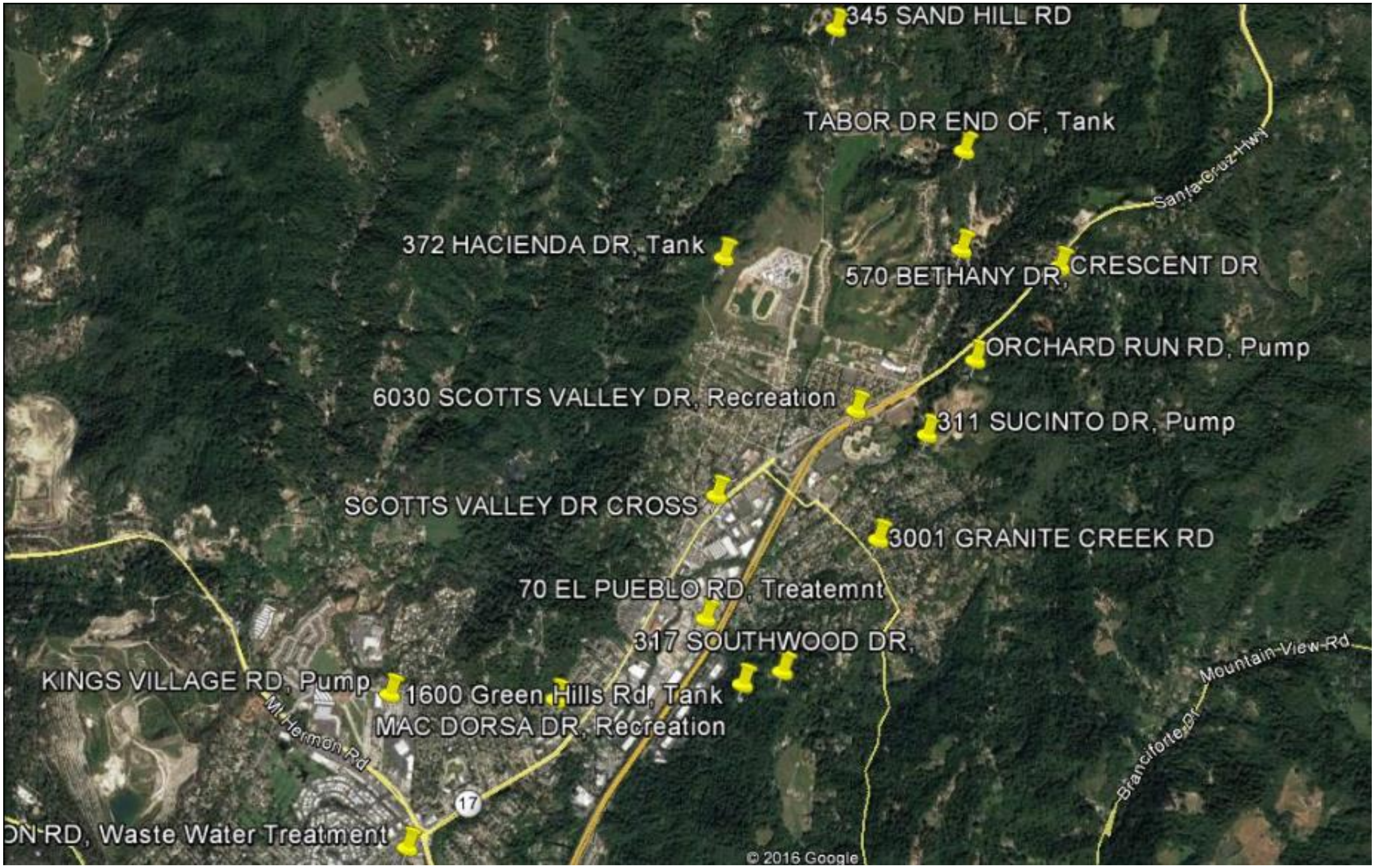

FIGURE C-17: SERRANO

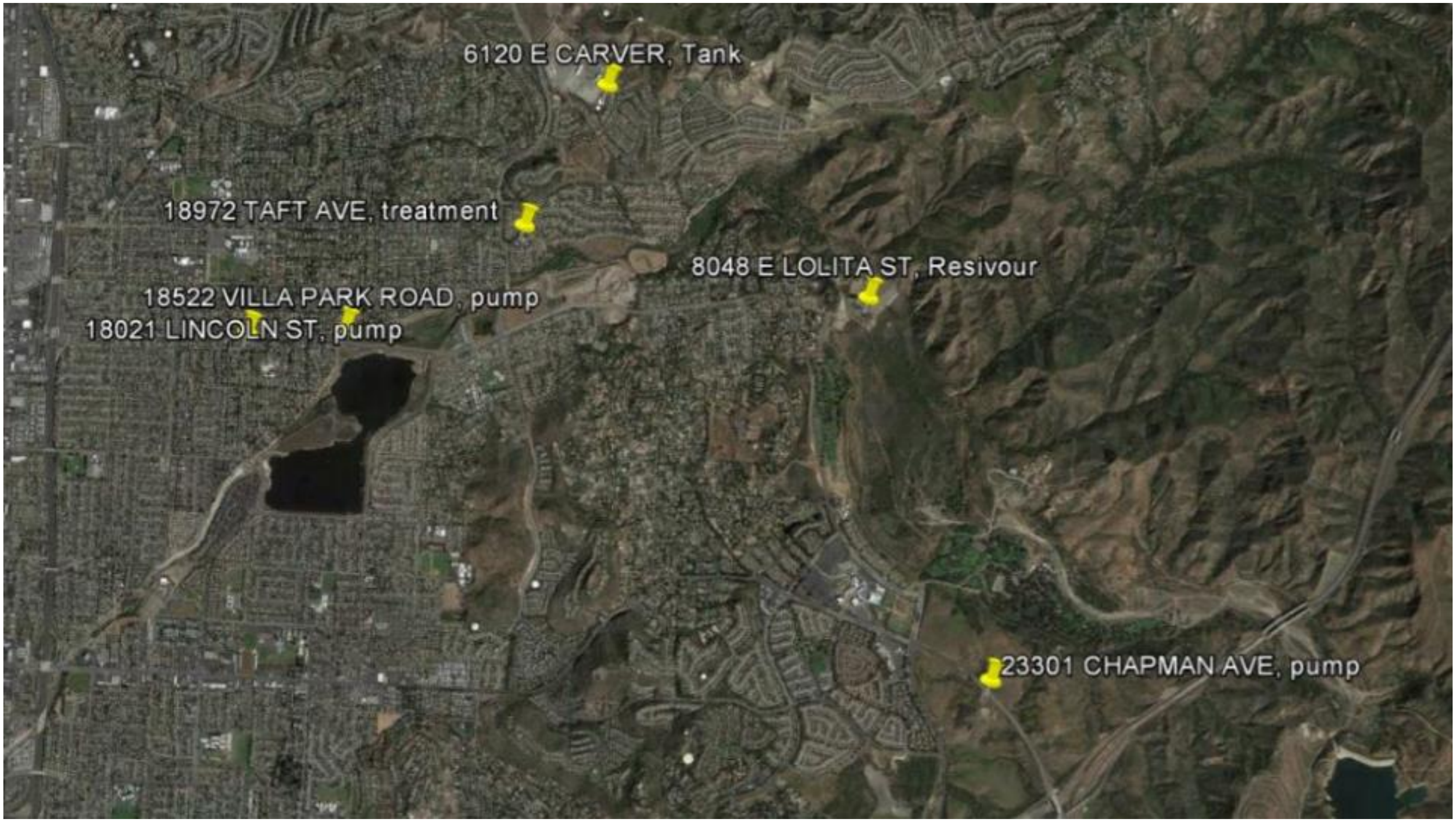

FIGURE C-18: STALLION SPRINGS

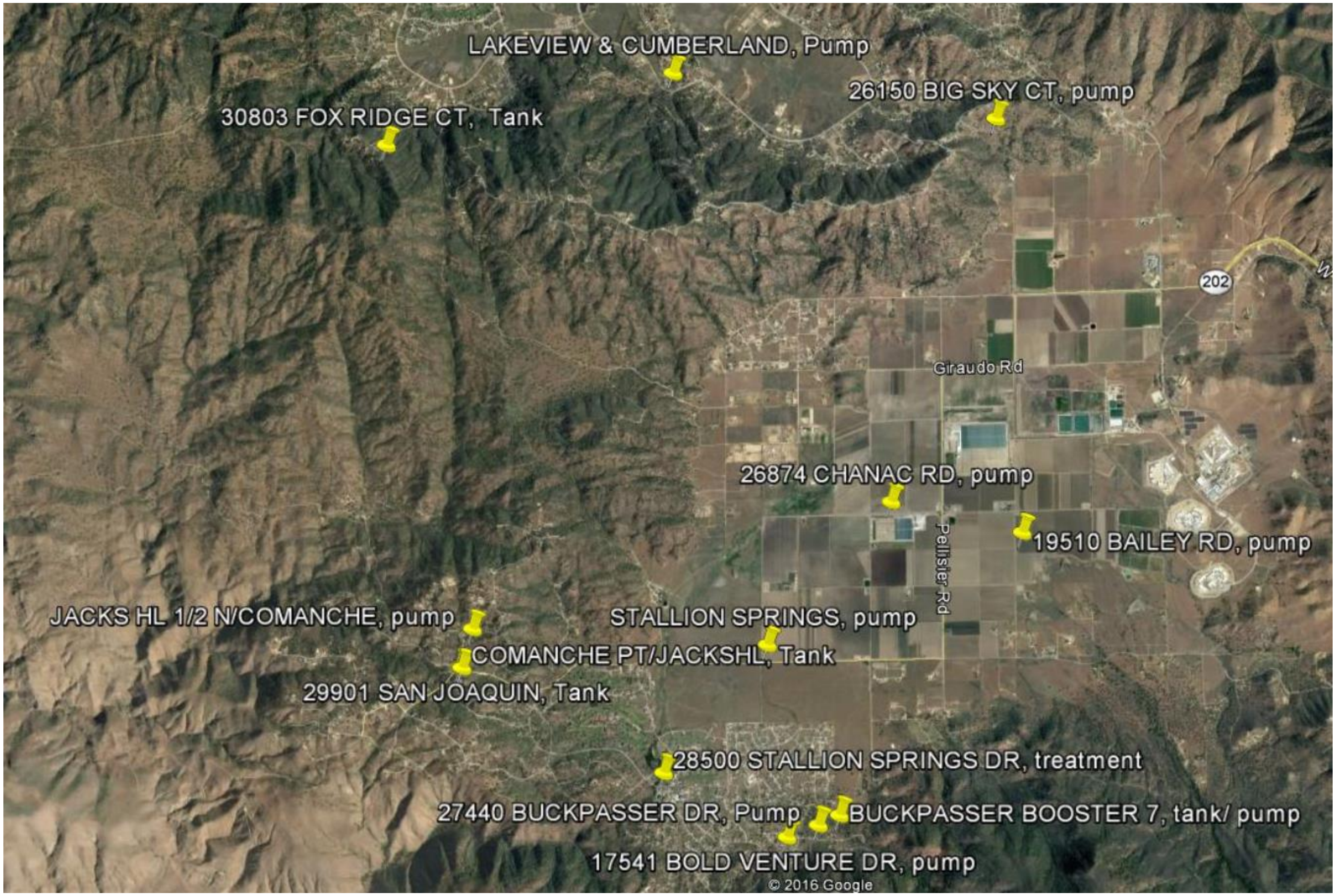

FIGURE C-19: TWENTYNINE PALMS

FIGURE C-20: VALLECITOS

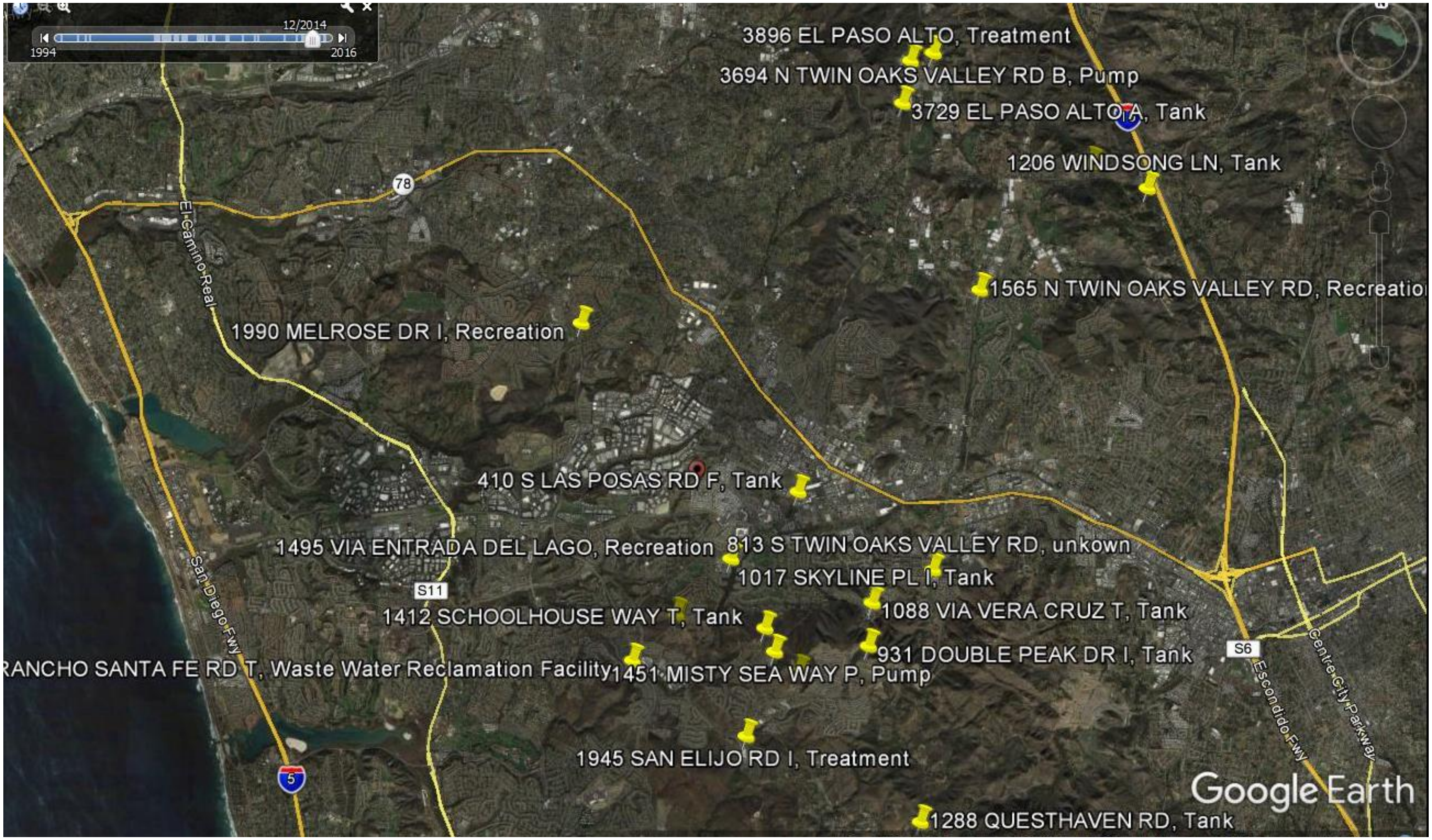

FIGURE C-21: WESTBOROUGH

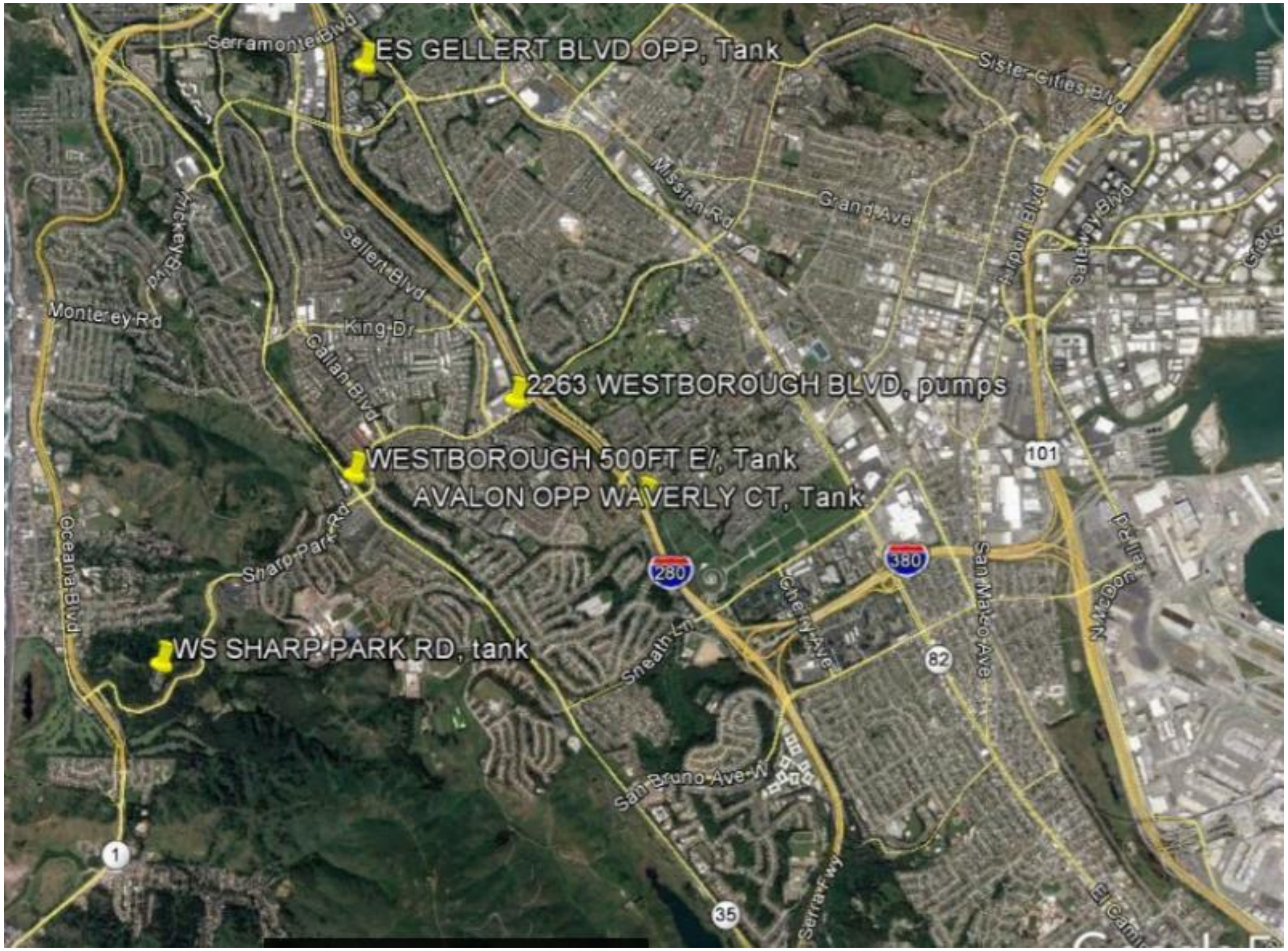

FIGURE C-22: CONTRA COSTA

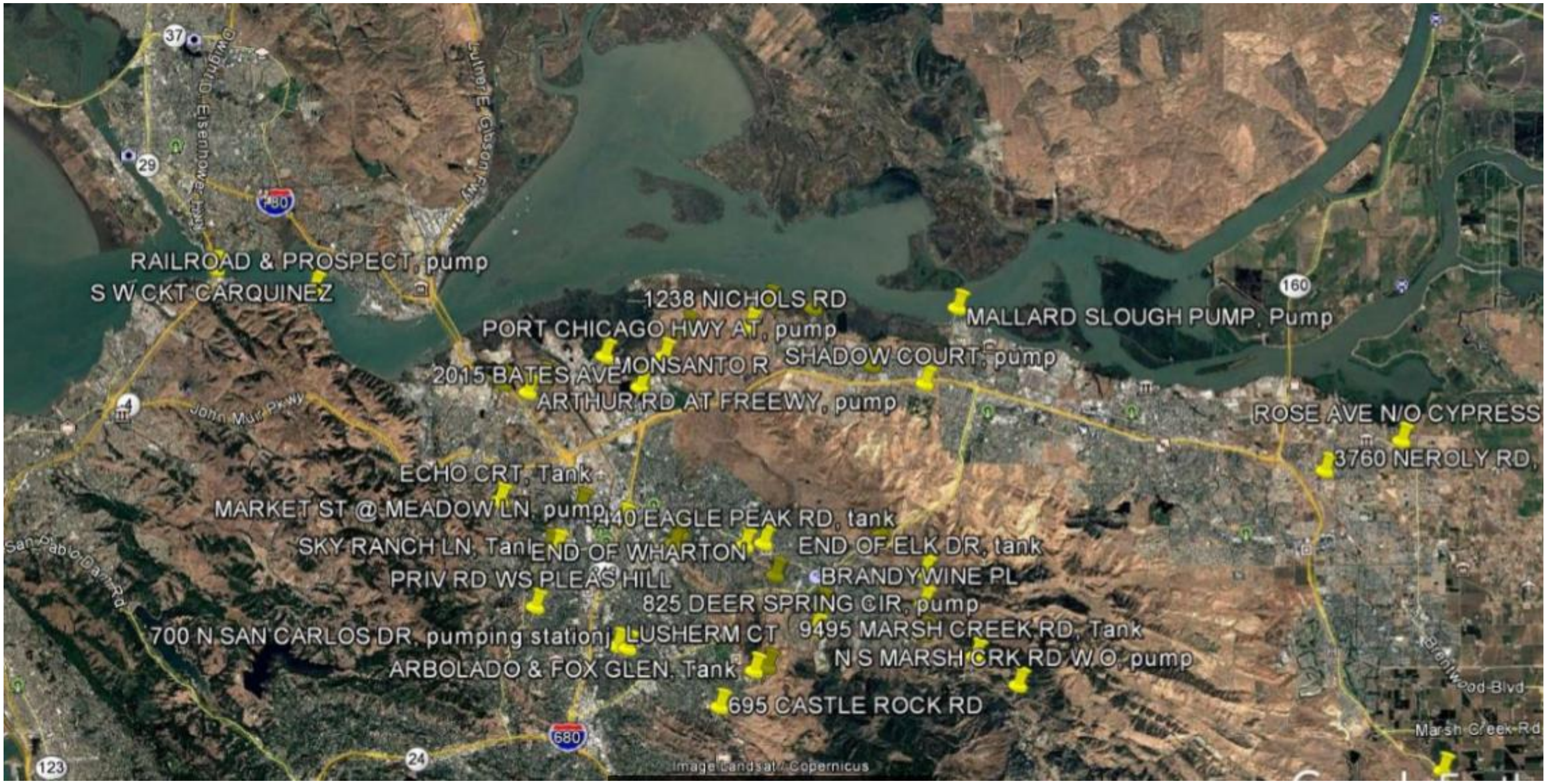

FIGURE C-23: SHASTA

FIGURE C-24: WEST KERN

Addresses in CIS billing data did not contain enough information to be searchable using Google Earth.

FIGURE C-25: SANTA CLARA VALLEY

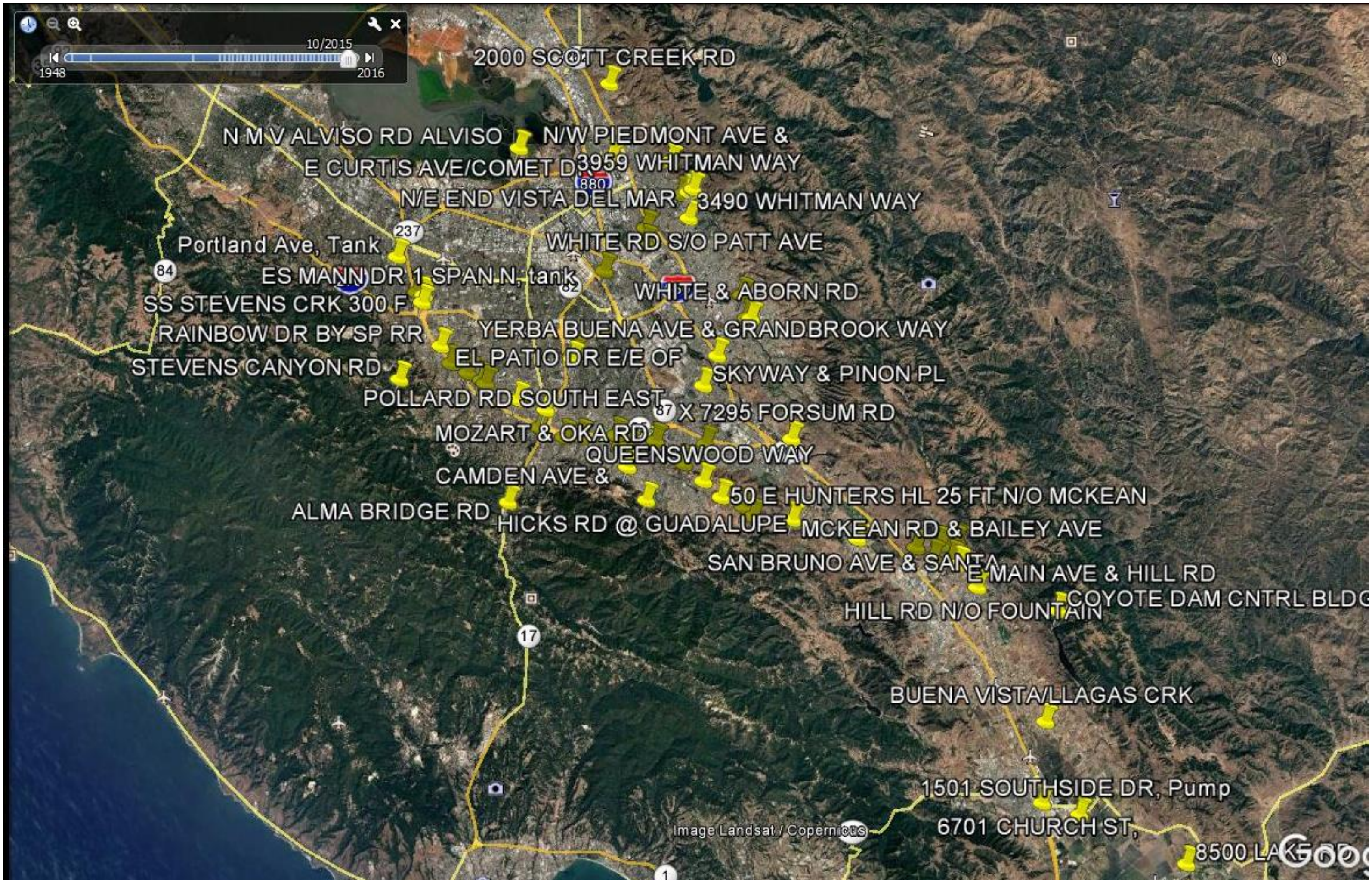

FIGURE C-26: EAST NILES

FIGURE C-27: DIABLO

FIGURE C-28: YUCAIPA VALLEY

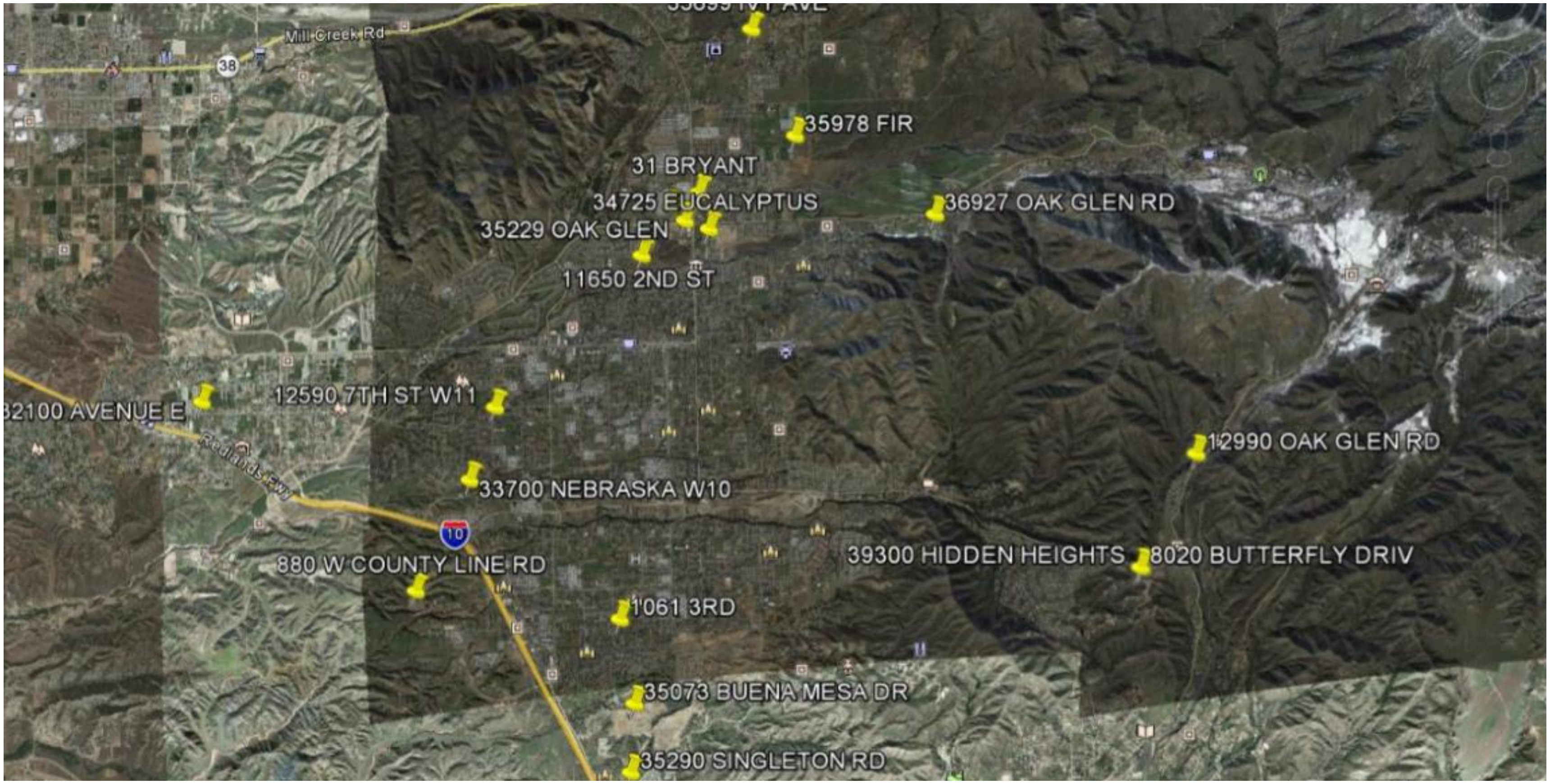

FIGURE C-29: ALAMEDA

FIGURE C-30: CRESTLINE

APPENDIX D REFERENCES

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