AGENDA
IRVINE RANCH WATER DISTRICT
SUPPLY RELIABILITY PROGRAMS COMMITTEE
THURSDAY, APRIL 20, 2023

This meeting will be held in-person at the District's headquarters located at 15600 Sand Canyon Avenue, Irvine, California. The meeting will also be broadcasted via Webex for those wanting to observe the meeting virtually.

To observe this meeting virtually, please join online using the link and information below:

Via Web: https://irwd.webex.com/irwd/j.php?MTID=mbba8c62df820b4264a862a0d7b1c64cc
Meeting Number (Access Code): 2495 626 6661
Meeting Password: 7XBrUyye8J2

As courtesy to the other participants, please mute your phone when you are not speaking.

PLEASE NOTE: Participants joining the meeting will be placed into the Webex lobby when the Committee enters closed session. Participants who remain in the "lobby" will automatically be returned to the open session of the Committee once the closed session has concluded. Participants who join the meeting while the Committee is in closed session will receive a notice that the meeting has been locked. They will be able to join the meeting once the closed session has concluded.

CALL TO ORDER 1:30 p.m.

ATTENDANCE
Committee Chair: Douglas Reinhart ______
Member: Peer Swan ______

Note: Director Swan will be calling in via Webex for this meeting from 7 Terraza Drive, Newport Coast, CA 92657

ALSO PRESENT

Paul Cook	______	Paul Weghorst	______
Kellie Welch	______	Fiona Sanchez	______
Kent Morris	______	Christine Compton	______
Natalie Palacio	______	Marina Lindsay	______
Robert Huang	______	Cheryl Clary	______
______________	______	______________	______

PUBLIC COMMENT NOTICE

If you wish to address the Committee on any item, please submit a request to speak via the "chat" feature available when joining the meeting virtually. Remarks are limited to three minutes per speaker on each subject. Public comments are limited to three minutes per speaker on each subject. You may also submit a public comment in advance of the meeting by emailing comments@irwd.com before 5:00 p.m. on Wednesday, April 19, 2023.

COMMUNICATIONS

1. Notes: Weghorst
2. Public Comments
3. Determine the need to discuss and/or take action on item(s) introduced that came to the attention of the District subsequent to the agenda being posted.
4. Determine which items may be approved without discussion.

INFORMATION

5. DRAFT RECHARGE ENHANCEMENT STUDY AND PRELIMINARY DESIGN REPORT – WELCH / SANCHEZ / WEGHORST

   Recommendation: Receive and file.

6. WATER SUPPLY CONDITIONS AND WATER BANKING CONSIDERATIONS UPDATE – LINDSAY / WELCH / SANCHEZ / WEGHORST

   Recommendation: Receive and file.

7. WATER BANKING PROJECT FACILITIES, CAPACITIES, OPERATIONS AND PROGRAMS – LINDSAY / WELCH / SANCHEZ / WEGHORST

   Recommendation: Receive and file.

OTHER BUSINESS

8. Directors' Comments

9. Adjourn

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Availability of agenda materials: Agenda exhibits and other writings that are disclosable public records distributed to all or a majority of the members of the above-named Committee in connection with a matter subject to discussion or consideration at an open meeting of the Committee are available for public inspection in the District's office, 15600 Sand Canyon Avenue, Irvine, California ("District Office"). If such writings are distributed to members of the Committee less than 72 hours prior to the meeting, they will be available from the District Secretary of the District Office at the same time as they are distributed to Committee Members, except that if such writings are distributed one hour prior to, or during, the meeting, they will be available electronically via the Webex meeting noted. Upon request, the District will provide for written agenda materials in appropriate alternative formats, and reasonable disability-related modification or accommodation to enable individuals with disabilities to participate in and provide comments at public meetings. Please submit a request, including your name, phone number and/or email address, and a description of the modification, accommodation, or alternative format requested at least two days before the meeting. Requests should be emailed to comments@irwd.com. Requests made by mail must be received at least two days before the meeting. Requests will be granted whenever possible and resolved in favor of accessibility.

April 20, 2023
Prepared by: K. Welch
Submitted by: F. Sanchez / P. Weghorst
Approved by: Paul A. Cook

SUPPLY RELIABILITY PROGRAMS COMMITTEE

DRAFT RECHARGE ENHANCEMENT STUDY AND PRELIMINARY DESIGN REPORT

SUMMARY:

The IRWD Water Bank consists of multiple elements for the conveyance, recharge, and recovery of groundwater. Historically, the IRWD Water Bank's recharge basins have exhibited high initial infiltration rates which tend to decline after the first few months of recharge. At IRWD's request, consultants at Thomas Harder & Co. prepared a draft Recharge Enhancement Study and Preliminary Design Report, which provides an assessment of potential technologies to enhance recharge at the IRWD Water Bank. The report also includes preliminary designs and cost estimates to pilot test two approaches. At the Committee meeting, Thomas Harder will present an overview of the study and associated findings.

BACKGROUND:

The IRWD Water Bank includes recharge basins that are formed by small earthen embankments, with each basin having a different size, shape, and depth. During past recharge events, the basins have exhibited high initial infiltration rates, which decline over time. Infiltration rates can be impacted by factors including surface soil conditions, subsurface geology, soil saturation, suspended sediment concentrations, and nutrient loading in the source water. Of these factors, subsurface geology has the greatest impact on infiltration rates.

In August 2022, Thomas Harder and his staff began an investigation into available techniques and technologies that could enhance infiltration rates at the IRWD Water Bank. This work included reviewing past studies of managed aquifer recharge, analyzing actual recharge data from the historic operation of IRWD's Water Bank and other recharge areas, as well as evaluating recent advances in recharge techniques and technologies. Additionally, the work included an evaluation of sediment loads suspended in the water being delivered to the IRWD Water Bank and identifying concepts to remove sediment prior to delivery to the recharge basins. Based on the information compiled and evaluated, Thomas Harder identified two recharge technologies for pilot testing.

Draft Study and Preliminary Design Report:

In January 2023, Thomas Harder submitted the draft Recharge Enhancement Study Preliminary Design Report that is provided as Exhibit "A". This report documents his investigation, findings, and recommendations to consider for enhancing infiltration rates at the IRWD Water Bank. The draft report includes preliminary designs for pilot testing of dry wells and over excavation techniques. The report also includes a description of testing methodologies and data collection. The preliminary cost estimate for pilot testing the two concepts is approximately $1.9 million. At the Committee meeting, Thomas Harder will present an overview of the study and associated findings.

FISCAL IMPACTS:

Given site conditions, it is expected that a pilot test involving dry wells offers the best opportunity to enhance recharge at the IRWD Water Bank. Funding for such a pilot test will be included in the proposed FY 2024-25 Capital Budget.

ENVIRONMENTAL COMPLIANCE:

The implementation of a pilot project to enhance recharge at the IRWD Water Bank would be subject to environmental review under the California Environmental Quality Act. The appropriate type of environmental review would be identified once additional information is available.

RECOMMENDATION:

Receive and file.

LIST OF EXHIBITS:

Exhibit “A” – Thomas Harder & Co. Draft Recharge Enhancement Study and Preliminary Design Report dated April 2023

EXHIBIT "A"

Draft-Final Recharge Enhancement Study Preliminary Design Report - Bakersfield, California

April 2023

Thomas Harder & Co.
Groundwater Consulting

Irvine Ranch
WATER DISTRICT

Draft-Final Recharge Enhancement Study Preliminary Design Report – Bakersfield, California

April 2023

Prepared by

Thomas Harder, PG, CHG
Principal Hydrogeologist

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Tables

Figures

1 Introduction

This report presents a summary of potential methodologies and technologies that may have applicability for enhancing recharge rates at the Irvine Ranch Water District (IRWD) recharge facilities in the Kern Fan area near Bakersfield, California (see Figure 1). While historical infiltration rates at IRWD's Strand Ranch and Stockdale West facilities have generally been consistent with rates measured in other basins in the area, Strand Ranch basins south of the Cross Valley Canal (CVC) and at the Stockdale West basins have shown lower infiltration rates than Strand Ranch basins north of the canal. As water for recharge is often available in large quantities over short periods of time, increasing the infiltration rates would potentially allow IRWD to recharge more water in a shorter time, thus maximizing IRWD's stored water account.

This report evaluates historical infiltration rates, potential causes of slow infiltration rates, previous studies to assess technologies to maximize recharge rates, evaluates other methods for enhancing recharge rates based on data collected since the IRWD facilities were constructed, and recommends recharge enhancement methods for further testing. The last three sections present a pilot testing preliminary design to test the effectiveness of the recommended recharge enhancement methods at improving infiltration rates. While the pilot testing is proposed for the Strand Ranch South basins, where infiltration rates are generally lower than adjacent basins, the technologies tested, if successful, could be applied to other IRWD facilities, such as Strand North and Stockdale West.

1.1 Study Area

The Study Area for this report generally applies to IRWD's Strand Ranch and Stockdale West banking facilities abutting and to the south of Stockdale Highway approximately five miles west of Bakersfield, California (see Figures 1 and 2). In the interest of time, more focused attention was given to the South Strand Ranch recharge basins where recharge rates have historically been lower than the other basins. However, with site specific investigation, the concepts explored herein would apply to any of the recharge basins in the Study Area and throughout other parts of the Kern Fan.

1.2 Strand Ranch and Stockdale West Facilities

The Strand Ranch recovery facilities were completed in 2009 with the construction of eleven North Basins (7 through 17) and nine South Basins (1 through 6 and 18 through 20). The total area available for recharge is 490 acres. Groundwater recovery from Strand Ranch occurs via six production wells (SREX-1 through SREX-5 and SREX-7). Well SREX-6 was a pre-existing agricultural well that has also been utilized for groundwater recovery. Groundwater levels are monitored via three nested observation wells (SROW-1, SROW-3 and SROW-4) and 16 shallow piezometers (SR-1 through SR-12 and SW-1 through SW-4; see Figure 2). Water is delivered to the North and South Basins from the Cross Valley Canal (CVC) via two unlined feeder canals, one to the north of the CVC and one to the south, each located on the east side of the basins (see Figure 3).

Stockdale West consists of approximately 265 acres of additional basins and three additional extraction wells located adjacent and west of the Strand Ranch North basins. Water was first delivered to this facility for recharge in 2011 (see Figure 2).

1.3 Potential Causes of Slow Infiltration Rates

Infiltration rates in managed recharge basins can decline over time. Typical causes of infiltration rate declines over time include:

- Accumulation of fine sediment on the basin floors from source water suspended sediment, wind-blown dust, and erosion of the basin slopes. Fines accumulating on the surface of basin floors can form a low permeability clogging layer that impedes infiltration.
- Algae growth and accumulation within the basins.
- Geochemical reactions between surface water and sediments in the basins.

In addition to, or instead of basin clogging mechanisms, hydrogeologic conditions at the basins can impede recharge rates. These conditions include subsurface fine-grained silt and/or clay between the land surface and the regional aquifer that impede and, in the worst case, perch percolating water in the vadose zone. The ultimate recharge rate will be dictated by the lowest permeability layer in the unsaturated zone between the land surface and regional groundwater table. If groundwater rises too close to the land surface during managed recharge, infiltration rates will slow as well. Finally, during initial managed recharge activities after a long hiatus, air can become trapped beneath the infiltration wetting front and temporarily slow infiltration rates. This effect is temporary and typically occurs in the first few weeks of an initial recharge event. After the air is displaced, recharge rates increase again.

1.4 Purpose and Scope

The purpose of this report is to assess the relative effectiveness of potential technologies and options to enhance recharge rates at the IRWD recharge facilities in the Kern Fan Area near Bakersfield, California. The scope of work included:

1. Describing the hydrogeologic setting of the groundwater system at the basins.

2. Documenting historical recharge rates at the Strand Ranch and Stockdale West basins.

3. Reevaluating previous studies to assess various technologies to improve or maximize recharge rates.

4. Evaluating additional technologies or methodologies to improve recharge rates, not previously considered.

5. Developing a planning-level pilot test program to test two of the recharge enhancement technologies.

6. Planning-level costs to conduct the pilot testing program.

7. Preparing this report.

2 Kern Fan Area Physical Setting

2.1 Hydrogeological Setting

The Study Area is in the Tulare Basin, which is the southernmost extension of the San Joaquin Valley Groundwater Basin, a geographically significant structural depression of the Central Valley of California that extends from the City of Stockton on the north to the Tehachapi Mountains on the south (Faunt, 2009). The Tulare Basin is bounded by crystalline rocks of the Sierra Nevada to the east, crystalline rocks of the Tehachapi Mountains to the south and southeast, and Tertiary marine rocks of the Coast Ranges to the southwest (see Figure 4).

The Study Area is located on the flat distal portions of the alluvial fan deposited by the Kern River as it flows out of the Sierra Nevada Mountains on the east side of the Tulare Basin. Land surface elevation ranges from approximately 400 ft above mean sea level (amsl) on the east to approximately 300 ft amsl on the west (except for the Elk Hills). In general, the proportion of fine-grained sediments increases toward the terminus of the river and southwest of the Study Area where the depositional environment is dominated by lacustrine, marsh, and flood-basin deposits.

The groundwater system in the vicinity of the Study Area can generally be divided into four aquifer zones based on a previous analysis of the geology and hydrogeology of the area (TH&Co, 2011). The shallow aquifer zone generally extends from the groundwater table to approximately 100 feet below ground surface (ft bgs) (see Figure 5). This aquifer zone is unconfined to semi-confined and is periodically dewatered during low groundwater conditions. The intermediate aquifer zone generally extends from approximately 100 ft bgs to 350 ft bgs. Groundwater level differences between wells perforated in the upper part of this aquifer and wells perforated in the upper aquifer suggest that the intermediate aquifer zone is confined during periods of high groundwater levels but becomes unconfined to semi-confined when groundwater levels drop below the top of the zone. Many of the production wells associated with other area banking projects are perforated, at least partially, in the intermediate aquifer. The deep aquifer zone generally occurs from a depth of approximately 350 ft bgs to 950 ft bgs and is confined. Most of the area production wells, including the Strand Ranch wells, are perforated in the deep aquifer zone. A very deep aquifer has been characterized below 950 ft bgs. Few wells in the Kern Fan Area are perforated into this aquifer due to high arsenic concentrations and locally low permeability.

2.2 Soil Stratigraphy

An east-west cross section across the Stockdale West and Strand North Basins, that is depicted on Figure 2, shows that the upper 1,000 ft of alluvial sediments in the Study Area consists of a highly stratified sequence of more permeable sand and gravel interbedded with silt and clay (see Figure 6). No significant laterally extensive subsurface fine-grained units (i.e. silt and clay) are observed. Similarly, no distinct permeable units (aquifers) could be correlated across the area.

A more focused cross section of the upper 300 feet beneath the South Strand Basins (Section B-B') is shown on Figure 7 (see Figure 2 for cross section location). This cross section was developed based on detailed borehole lithologic logs from SR-9, SREX-5, SROW-3, SROW-1, SREX-7 and surface geophysical surveys (towed transient electromagnetics or "tTEM" of basins 1, 4, 6, 8 and 9). The tTEM geophysical results are shown on Figure 7 as subsurface profiles of varying electrical resistivity at locations along the section where measurements were taken. Electrical resistivity variation is shown as different colors, with the lowest resistivities in the blue to green color spectrum representing relatively low permeability. Electrical resistivity becomes increasingly higher from red to purple. While red colors are expected to be associated with more permeable sand sediments, the highest resistivities (purple colors) may represent either permeable sand and gravel or saturated sediments (the presence of groundwater can skew the electrical resistivity). It is noted that the tTEM surveys were conducted shortly after water was delivered to the basins and some basins to the west of the survey still contained surface water at the time of the surveys.

While comparison of the lithologic descriptions from the detailed borehole logs with the subsurface characteristics indicated by the tTEM survey do not always match exactly, they reveal general characteristics that allow grouping of three general layers:

1. A generally consistent layer of silt and silty sand (expected to be low permeability material) in the shallowest 10 to 50 ft bgs.
2. A predominantly sandy layer that extends below the shallow low permeability silt/silty sand to depths ranging from approximately 80 to 130 ft bgs (bottom of the shallow aquifer).
3. A layer of silty sand and sandy clay below the overlying sand that is expected to be lower in permeability.

The upper 80 to 130 feet of sediments (Nos. 1 and 2 above) represent the shallow aquifer system when saturated. The sediments below No. 3 above represent the intermediate aquifer. The purple areas from the tTEM survey likely represent saturated conditions at the time the survey was conducted as it was conducted in late September 2019 when water had recently been delivered to the basins.

2.3 Groundwater Occurrence

The term groundwater, as used herein, refers to underground water in the pore spaces of unconsolidated sediments to the point of saturation. It is distinguished from underground pore water adhered to sediment grains in the unsaturated, or vadose zone (i.e. soil moisture).

The occurrence of saturated groundwater conditions in the shallow aquifer beneath the Study Area (upper 80 to 120 feet below land surface) is almost completely controlled by managed recharge and recovery operations at the site and in the area. Periods of managed recharge result in rising groundwater levels and saturation of sediments. Subsurface percolation of water from managed recharge at the land surface will move by gravity drainage at rates dictated by the permeability of the sediments through which they infiltrate. The lowest permeability sediments in the vadose zone will dictate the overall percolation rate between the land surface and groundwater table.

Differences in groundwater levels measured in wells with varying perforation depths show that the levels become progressively lower with increasing perforation depth (see Figures 7 and 8), even during periods of recharge and relatively high groundwater levels. For example, groundwater levels in the shallowest wells (SR-1 through SR-8; perforated 10 to 25 ft bgs in the shallow aquifer) are approximately 30 feet higher than the next shallowest monitoring well SROW-3/1 perforated from 220 to 270 ft bgs in the intermediate aquifer. These data indicate a downward vertical gradient and movement of water from the shallow aquifer zone into the intermediate aquifer. The rate of vertical percolation of water from the shallow aquifer into deeper aquifers is dictated by the permeability of the sediments separating them, in this case the silty sand and sandy clay sediments occurring from approximately 100 to 200 ft bgs beneath South Strand (see Figure 7).

2.4 Groundwater Level Trends Over Time

Groundwater level changes over time can be observed from hydrographs developed from data collected from monitoring wells in the Study Area (see Figures 8 and 9). Changes in groundwater levels over time at Strand Ranch are correlated with recharge and recovery cycles (see Figure 8). During periods when project operations were predominantly recharge (e.g. between October 2011 and January 2012), groundwater levels rose in response to the addition of water to aquifer storage. During periods of groundwater recovery (e.g. May 2013 through December 2015) groundwater levels dropped in response to groundwater pumping.

Groundwater levels in the Study Area aquifers not only respond to recharge and recovery operations at the Strand Ranch and Stockdale West but also recharge and recovery operations at the other surrounding banking projects (e.g. Kern Water Bank and Pioneer Project; see Figure 9). Typically, when water is available to recharge at Strand Ranch, it is also available at the other banking projects. Similarly, groundwater pumping generally occurs at the same time. These coincident groundwater utilization activities have a compounded impact on groundwater levels beneath Strand Ranch. As a result, groundwater levels in the upper aquifer can fluctuate from within 10 ft of the land surface to below the bottom of the aquifer. Groundwater levels in the intermediate aquifer can fluctuate from within 80 feet of the land surface to greater than 300 ft bgs.

It is not clear the impact of neighboring recharge operations on groundwater levels in the shallow aquifer beneath the Strand Ranch. However, given their proximity, it is likely that there is at least some horizontal flow of water into the shallow aquifer beneath the Strand Ranch from neighboring areas. As recharge in the Strand Ranch and Stockdale West must stop if groundwater levels rise within 10 feet of the land surface along the CVC, contribution of water from neighboring areas may have a limiting effect on the recharge capacity of the Study Area.

2.5 Groundwater Chemical Characteristics

The groundwater chemistry in the shallowest portion of the aquifer system beneath the Study Area for which data are available (the intermediate aquifer) is relatively enriched in calcium and chloride relative to other cations and anions (see Figure 10). These findings are based on groundwater chemistry data from samples collected from the shallowest perforated completion of the Strand Ranch nested monitoring wells (SROW-1, SROW-3, and SROW-4). In contrast to shallow groundwater chemistry, groundwater from nested monitoring wells perforated in the deeper part of the intermediate aquifer and the deep aquifer is generally enriched in sodium/potassium relative to other cations and bicarbonate relative to other anions (see Figure 11).

Total dissolved solids (TDS) concentrations in groundwater generally decrease with depth (see Figure 6; Table 1). The TDS concentrations in the shallowest portion of the aquifer system ranges from approximately 380 to 680 milligrams per liter (mg/L). By contrast, the TDS of the deep aquifer at Strand Ranch ranges from approximately 100 to 320 mg/L. TDS concentrations measured in samples from pre-existing Strand Ranch agricultural wells with upper perforations as shallow as 90 to 250 feet below ground surface (ft bgs) ranged from 560 to 850 mg/L (Wildermuth, 2010). The high TDS concentrations in the shallow zones are likely associated with evaporative concentration of salts in the vadose zone and subsequent flushing from return flow of applied irrigation water.

2.6 California Aqueduct Water Chemical and Physical Characteristics

Water quality data for imported California Aqueduct water was relatively limited. The most complete data set available for plotting on the trilinear diagram on Figure 10 was from Check 28 collected on June 7, 2007 (CDWR, 2022). These data indicate the imported water is a sodium chloride type water, like that observed in the samples collected from the shallowest Strand Ranch observation wells. The data suggest that the groundwater chemistry of the shallowest portions of the aquifer system beneath the Study Area are influenced by the water chemistry of imported California Aqueduct water that has been recharged in the area since 1995. The TDS of imported water ranges from approximately 230 to 300 mg/L, based on the same dataset as obtained above.

Total suspended sediments (TSS) in California Aqueduct water were evaluated to assess the potential for their contribution to sediment buildup in the Study Area basins. Based on the datasets referenced above (CDWR, 2022), the TSS values in California Aqueduct water range from 3 to 8 mg/L (see Table 1). Turbidity generally ranges from 3 to 5 Nephelometric Turbidity Units (NTUs).

3 Historical Strand Ranch Operations and Infiltration Rates

Water was initially delivered to the Strand Ranch basins in September 2010. After a 4-yr hiatus, water was again delivered to the Strand Ranch Basins beginning in January 2017. Since that time, water has been delivered to the basins in 2018, 2019 and 2020. Water is delivered to the basins through releases from the CVC, which separates the North Strand basins from the South Strand basins (see Figure 2). The water is released to two unlined feeder canals, one to the north of the CVC and one to the south (feeder canal for South Strand is shown on Figure 3). The maximum rate of water released to either individual canal is 100 cubic feet per second (cfs) (44,883 gallons per minute).

3.1 North Strand Basins Infiltration Rates

Infiltration rates were measured in the individual North Strand basins during pond drop tests in January 2012. Based on that test, they ranged from 0.02 ft/day to 0.18 ft/day (see Table 2).

Although formal infiltration tests (i.e. "pond drops") have not been conducted since 2012, the infiltration rates can be estimated for the North Strand basins as a whole from time periods when all the basins were full and the inflow rate was relatively constant. TH&Co identified four time periods for analysis of North Basin infiltration rates based on data provided by RRBWSD (see Table 3). The time periods and their average infiltration rates are summarized as follows:

1. 21-May-17 through 25-Jul-17 0.33 ft/day
2. 3-Sep-17 through 3-Nov-17 0.41 ft/day
3. 13-Dec-17 through 4-Feb-18 0.45 ft/day
4. 22-Mar-18 through 25-Jun-18 0.38 ft/day
5. 2-Aug-18 through 15-Oct-18 0.41 ft/day

The average infiltration rate for the time periods analyzed for the North Basins was 0.4 ft/day. These infiltration rates are higher than those previously observed in the North Basins during the January 2012 pond drop testing (average of 0.11 ft/day) although they are more consistent with qualitative field observations of recharge rates (personal communication with Zach Smith, 2022).

3.2 South Strand Basins Infiltration Rates

Infiltration rates measured in the individual South Strand basins during the pond drop tests in January 2012 ranged from 0.08 ft/day to 0.31 ft/day in the South Basins (see Figure 3; Table 4). Using the same methodology described in Section 3.1, TH&Co also estimated the recharge rates in the South Strand basins for the following time periods:

1. 1-Mar-17 through 31-Mar-17 0.16 ft/day

2. 1-Apr-17 through 30-Apr-17 0.18 ft/day
3. 1-May-17 through 16-Jul-17 0.15 ft/day
4. 13-Sept-17 through 31-Oct-17 0.15 ft/day
5. 1-Jan-18 through 1-Feb-18 0.19 ft/day

The average infiltration rate over this time was 0.17 ft/day, as compared to an average of 0.16 ft/day during the 2012 pond drop test. These data do not show any declines in infiltration rate over the six-year period between 2012 and 2018 nor do they indicate any deterioration of infiltration rate between March 2017 and February 2018. However, they are lower than estimated for the North Strand basins.

3.3 Stockdale West Basins Infiltration Rates

Infiltration rates were measured in the individual Stockdale West basins during pond drop tests in January 2012. Based on that test, they ranged from 0.11 ft/day to 0.17 ft/day (see Table 2). Daily inflow rates after 2012 were not available for Stockdale West for this study. However, reviewing the monthly inflow rates to the facility between May 2017 and August 2017 when the basins were relatively full showed an average inflow rate of approximately 80 acre-ft/day. Given the 265-acre area of the basins, this equates to an average infiltration rate of approximately 0.3 ft/day. This infiltration rate is lower than Strand North but higher than Strand South.

3.4 Kern Fan Area Infiltration Rates

Comparison of the infiltration rates measured at the Strand Ranch between 2012 and 2018 are comparable with infiltration rates previously measured in other recharge basins in the Kern Water Bank (see Figure 12). In general, infiltration rates measured through controlled pond drop tests by the Kern County Water Authority between 1995 and 2005 have ranged from 0.1 to 0.24 ft/day in the basins immediately adjacent and to the west, south, and east of the Strand Ranch. These values are in line with those measured at the Strand Ranch. Infiltration rates as high as 1.2 ft/day have been measured in other areas of the Kern Fan. However, these infiltration rates are likely related to more permeable shallow subsurface conditions than have been observed in the Study Area.

4 Evaluation of Potential Causes of Low Recharge Rates in the Study Area

4.1 Accumulation of Fine Sediment on the Basin Floors

4.1.1 Suspended Sediments in Source Water

The source water for Strand Ranch and Stockdale West basins is mostly State Project water from the California Aqueduct. As described in Section 2.6 herein, the available data indicate the TSS concentration of this water is very low; typically below 10 mg/L. The turbidity is typically below 10 NTU, which is comparable to drinking water (see Photo 1). For comparison, during testing of surface water in the Santa Ana River in the Orange County Forebay between 2014 and 2016, TSS concentrations in the water, which is a source of managed recharge for nearby spreading basins, can exceed 200 mg/L and had a median of approximately 23 mg/L over the reporting period (Hutchinson, 2017).

Photo 1: Cross Valley Canal outlet to South Strand feeder canal.

Given the low suspended sediment and turbidity of the imported water used for recharge in the Strand Ranch and Stockdale West basins, it does not appear to be contributing suspended sediment to the basins at levels that would result in significant clogging.

4.1.2 Suspended Sediments Mobilized in Transit to the Basins

The Strand Ranch basins receive water from two largely unlined canals on the east side of the basins; one on the north and the other on the south. A fine-grained sediment layer was observed on the surface of the dry floor of these canals during a site visit on August 31, 2022 (see Photo 2). Fine-grained sediment buildup was also observed at the discharge points from the CVC and at the inlets to Basin 11 (North Strand) and Basin 4 (South Strand) (see Photos 3 and 4). As water can be released from the CVC to the unlined transit canals at rates as high as 100 cfs (44,883 gallons per minute), the force of water into the canals can suspend a significant amount of sediment prior to entry into the recharge basins.

Photo 2: Fine-grained buildup on the bottom of the South Strand feeder canal. The fines become cracked and breakup during dry periods but likely go into solution when water is released from the CVC.

Photo 3: View looking south at the CVC outlet to the South Strand feeder canal. Silt buildup can be seen on either side of the outlet pipe.

Photo 4: View of South Strand Basin 4 inlet pipelines showing buildup of silt near the pipes.

Settling of suspended sediment in water introduced to the recharge basins has the potential to clog surface and shallow subsurface pore spaces and reduce infiltration rates. To date, there is no evidence that this has taken place. However, based on observation of the fine-grained sediment buildup on the surface of the feeder canals and near the inlet pipes, the suspension of sediment from the walls and floor of the feeder canals when water is released from the CVC is a likely source of fines to the basins.

4.1.3 Suspended Sediments Mobilized from Wave-Induced Erosion of Basin Sides

During windy conditions, wave action against the basin sides can suspend fine sediments from the berms that are later deposited on the basin bottoms. The Kern Fan Area has periodic strong winds, and this is a possibility. Strand Ranch and Stockdale West basin berms have been designed with relatively gentle (3:1) side slopes to prevent erosion of basin sides from wave action. While this suspended sediment from wave erosion of basin sides may be depositing some fines on the basin bottoms, there is no evidence from infiltration rate decay that this is a significant issue.

4.2 Algae Growth

Algae growth is a common issue in recharge basins and has been observed throughout the Kern Fan Area banking projects (see Photo 5). The shallow water conditions, warm water, and nutrients in the soil combine to make optimum conditions for algae growth. When the basins dry, algae dries as well creating an algal mat on the basin bottom that can clog the near-surface sediments when the basins are re-wetted. Rosedale-Rio Bravo Water Storage District periodically treats the algal growth when the basins have water in them (personal communication with Zach Smith, 2022) to keep it from accumulating. To date, algal accumulation does not appear to have affected infiltration rates in the Strand Ranch basins.

4.3 Geochemical Reactions

Mixing water from two different sources can have the potential to supersaturate the mixture with respect to certain minerals depending on the concentrations of those minerals, the pH, and the temperature in the end member waters. The result can be precipitation of the mineral, which can clog the soil matrix and reduce the infiltration rate. Calcium carbonate is a common precipitant.

Based on analysis of the imported water from the California Aqueduct and groundwater beneath the Study Area, it is unlikely that mixing these sources will result in geochemical reactions that could cause precipitation of minerals. Both waters are very similar (see Figure 10) with relatively low TDS concentrations. As such, significant geochemical reactions that result in precipitants that could cement the soil matrix and reduce infiltration rates are not likely.

Photo 5: Strand Ranch basin during full condition showing algae buildup in surface water. (Photo from HDR, 2009).

4.4 Shallow Low Permeability Layers

Shallow low permeability sediments beneath the recharge basins are likely a limiting factor to recharge rates in the Study Area. A generally consistent layer of silt and silty sand (expected to be low permeability material) was observed in the shallowest 10 to 50 ft bgs at Strand Ranch South (see Figure 7). Fine sediments in the upper 10 to 20 ft bgs have also been observed beneath the Strand Ranch North (see Figure 6) and Stockdale West (Ramboll, 2020). As infiltration rates are constrained by the lowest permeability sediments between the land surface and groundwater table, these low permeability subsurface fine-grained sediments are a limiting factor to recharge rates.

4.5 Shallow Groundwater Levels

Shallow groundwater levels can also limit recharge rates in the Project Area. When groundwater levels in the shallowest SROW monitoring well completions rise above 50 ft bgs, RRBWSD is required to monitor groundwater levels in the Strand Ranch monitoring wells located along the CVC canal (see Figure 2). If groundwater levels in the Strand Ranch monitoring wells rise to within 10 feet of the land surface, delivery of water to the basins must stop to avoid damaging the CVC canal structure. It is noted that recharge rates at these shallow groundwater levels will decrease and eventually stop if groundwater rises to the land surface. Thus, shallow groundwater is a limiting factor for recharge rate and maintaining it at a depth at which delivery of water to the basins can continue will increase the volume of water IRWD can recharge in the area.

It is possible that some subsurface fine-grained sediment layers in the upper 50 ft bgs are constraining recharge rates or perching groundwater. Penetrating this fine-grained zone may help keep groundwater levels lower to facilitate more recharge. The fine-grained zone observed beneath the South Strand basins at a depth of approximately 100 to 120 ft bgs (bottom of the shallow aquifer) may also be limiting downward percolation to deeper zones and thus contribute to shallow groundwater.

Another factor contributing to shallow groundwater levels beneath the IRWD recharge facilities is recharge in other adjacent banking projects. Typically, when water is available for recharge in the IRWD facilities, it is also available for the Kern Water Bank and Pioneer Project, which are adjacent to Stockdale West and Strand Ranch. Subsurface groundwater mounding in the area is additive, such that nearby recharge raises

4.6 Factors Reducing Infiltration Rates in the Study Area

Based on a review of the various factors that can limit recharge rates in the basins of the Study Area in the context of the hydrogeological data reviewed to date, it is concluded that shallow low permeability layers in the upper 50 ft bgs and shallow groundwater levels are the two most likely limiting factors to recharge. While the feeder canals are a likely source of fine sediments that settle onto the surface of the basins, the buildup of these fines appears to be minor and has not reduced infiltration rates between 2012 and 2018.

5 Previous Studies to Evaluate Methods to Enhance Recharge in the Study Area

Near the time that the Strand Ranch recharge facilities were constructed, IRWD commissioned a study to evaluate options to improve the cost effectiveness of water banking in the Study Area (HDR, 2009; see Appendix A). As part of this study, HDR evaluated five recharge concepts and six sediment removal strategies. One of the recharge concepts evaluated, surface recharge ponds, has already been implemented and is not further evaluated herein. The other four concepts are revisited to discuss their potential applicability to Study Area banking activities. Potential for application of the sediment removal concepts previously evaluated are also discussed below.

5.1 General Recharge Concepts Evaluated in the HDR Report

5.1.1 Subsurface Recharge Galleries

This recharge concept is essentially a leach field, whereby rows of 5-foot deep trenches are excavated in the recharge area and lined with filter fabric, gravel backfill, and perforated PVC laterals. The PVC laterals are connected to a trunk line that receives water from the source, in this case the CVC.

Subsurface recharge galleries are suited to areas with limited to no space for recharge basins. For example, Santa Margarita Water District is incorporating a subsurface recharge gallery along San Juan Creek in the San Juan Basin of Orange County, California (personal communication with Michael Blazevic, 2022) in an urban developed area along the creek. For areas with available land to construct basins, this concept adds unnecessary capital cost for additional piping, logistics challenges as well as potential added operations and maintenance cost to replace clogged filter fabric (if the filter fabric can be replaced at all), and reduced recharge rates using the filter fabric. While the filter fabric could be removed from the design to improve recharge rates, the concept does not address the hydrogeological issues that are dictating infiltration rates in the Study Area; namely low permeability subsurface sediment layers in the upper 50 feet bgs and high groundwater levels. For this reason, the subsurface recharge gallery concept is not recommended for the banking projects in the Study Area.

5.1.2 Shallow Radial Injection Wells

The shallow radial injection wells concept is similar to Ranney Collector Wells except that water is injected into the formation instead of pumping it out. This concept consists of installing multiple horizontal wells in trenches trending in different directions from a central concrete caisson. The radial horizontal casings were conceptualized by HDR (2009) to be 250-foot long and could be installed at different depths up to approximately 12 feet below land surface. The trenches for the PVC laterals would be lined with filter fabric and backfilled with gravel around the PVC pipes although, as described in Section 5.1.1, the filter fabric could be removed from the design. HDR estimated that 454 individual centralized modules, each with 12 laterals, would be necessary to recharge 10,000 acre-ft in four months across 250 acres. This is a comparable recharge rate to a 250-acre recharge basin with a 0.33 ft/day infiltration rate.

The shallow radial injection well concept is not predicted to improve recharge rates in the Study Area. While the laterals, which are installed as deep as 12 feet, could penetrate shallow low permeability layers in some areas of the basins, they would not penetrate low permeability subsurface sediments in other areas that extend as deep as 50 ft bgs (see Figure 6). No advances in the concept have been identified since 2009. Given the relatively high cost of this concept and its predicted limited effectiveness, it is not recommended for implementation in the Project Area.

5.1.3 CULTEC Engineered Systems

The CULTEC Engineered Systems consist of plastic corrugated semi-circular domes that are buried within a trench or larger catchment basin. The domes are perforated and hollow to allow water in temporarily stored until it infiltrates into the subsurface through an open bottom. HDR described the base beneath the domes as being covered in filter fabric overlain by gravel. They are typically used in stormwater capture applications that allow for additional subsurface retained water capacity. The domes are approximately 36-inches high and are buried just beneath the land surface.

While the Cultec Engineered System would provide for more subsurface storage space for water, it is not predicted to improve recharge rates in the Study Area. The domed chambers would not be constructed deeper than approximately five to ten ft bgs such that they would not penetrate low permeability subsurface sediments in other areas that extend as deep as 50 ft bgs. Based on a review of the Cultec Engineered System web page (https://cultec.com/), the technology is essentially the same as it was in 2009. The additional storage space could just as easily be achieved through deepening of the existing recharge basins. Basin deepening would be simpler and more effective at removing shallow low permeability layers as the basins can be deepened more than 10 feet given their current footprint.

5.1.4 Subsurface Conveyance Concept

The subsurface conveyance concept incorporates both an underground water transmission trench as well as a recharge basin. The underground water transmission portion incorporates an inverted concrete trench box that is open on the bottom and similar to the Cultec Engineered System except that the water is recharged under dynamic (flowing) conditions rather than static conditions. Water not recharged within the conveyance trench is discharged to the recharge basin for infiltration. The HDR (2009) report suggests that 65 miles of trench and a 125-acre basin are necessary to recharge 10,000 acre-ft in four months.

Given the relatively high anticipated cost of this concept and relatively large footprint needed for the conveyance trench, it is not recommended for implementation in the Project Area.

5.2 Sediment Removal Concepts Evaluated in the HDR Report

The sediment removal concepts evaluated in the HDR (2009) report assumed that there was, or would be, entrained sediment in the source water to the basins that would collect on the basin bottoms and reduce infiltration rates. These sediment removal concepts included:

- **High-Rate Sedimentation** – The use of shallow gravitational settlers (tanks) to facilitate settling of suspended sediment prior to discharge to the basin. The tanks are designed with tubes or inclined plates to increase the settling efficiency, hence the term "high-rate."
- **Ballasted Sedimentation** – Introduction of fine sand, a coagulant and a polymer to turbid water inside a settling tank to facilitate the settling out of suspended sediment prior to discharge to the basin.
- **Dissolved Air Flotation** – The removal of suspended sediment by injecting dissolved air into the turbid water under pressure and then releasing the air under atmospheric pressure inside a flotation tank. The suspended sediment adheres to bubbles in the water and floats to the top of the water where it is skimmed off.
- **Cloth Media Filter** – A physical removal process that involves trapping sediment on cloth fabric in the influent stream of a tank. The cloth is periodically backwashed or vacuumed to remove sediment. Clarified water would be discharged to the basin.
- **Microfiltration** – Involves drawing water through a series of hollow fiber membranes to treat it to a high quality prior to discharge to the basin.
- **Passive Treatment** – Installing a Ranney Collector well, or wells (see Section 5.1.2), in the Kern River using the river sediments as a natural filter medium, transporting the water to the Project Area and discharging the clarified water to the basins.

The feasibility of these technologies was evaluated for recharge basin applications through a multi-phased large scale testing program, conducted for the Orange County Water District (OCWD) (HDR, 2010). The results of this testing showed that cloth filtration and riverbed filtration were the most effective at removing sediments and increasing recharge. Sediment removal technologies that involved adding chemicals to settle out solids (e.g. Ballasted Sedimentation) were effective at removing suspended sediment but resulted in elevated rates of basin clogging, presumably from residual flocculants or polymers in the water reacting with near-surface basin sediments. As a result of this testing, OCWD conducted a multi-year riverbed filtration test, which is described in this report in Section 5.3.

As noted in Sections 2.6 and 4.1.1 herein, the total suspended sediment and turbidity of the primary source water to Strand Ranch (imported State Project Water) is typically below 10 mg/L and 10 NTUs, respectively and is not expected to contribute sediment settling out on the basin bottoms at a rate that would cause significant clogging and reduced infiltration rates. Thus, these sediment removal concepts do not appear to be necessary, would be expensive to build and operate, and would not address IRWD's goal of increasing recharge rates at the Study Area facilities.

5.3 Subsurface Filtration System

As a result of the HDR (2010) Recharge Water Sediment Removal Feasibility Study described in Section 5.2, OCWD conducted field scale tests of the riverbed filtration concept (Hutchinson et al., 2017). The riverbed filtration concept consists of utilizing the native sediments of the river bottom to filter out suspended sediment in the surface water. The filtered water is captured through a gallery of shallow subsurface slotted PVC pipes and then conveyed to the recharge basin. OCWD tested two configurations of subsurface piping: one with pipeline parallel to the flow path in the river and one with pipeline perpendicular to the flow path. The pipelines were buried within trenches that were backfilled with gravel around the pipes and the covered with native riverbed sediments. The length of the filtration system was greater than 2,000 feet with a total infiltration area of approximately 10 acres.

During the OCWD subsurface filtration field test, the system could produce a maximum flow of 18 cfs, which was sustainable for weeks at a time. Source water pretreated TSS ranged from approximately 10 to 200 mg/L. Hutchinson et al., 2017 showed that the riverbed filtration system was effective at removing 97 percent of the suspended sediment from the source river water.

While it may be feasible to implement a riverbed-type filtration system in the CVC feeder canals for the Project Area recharge basins, the available data and operational parameters of the CVC system suggest that it is not likely the most cost-effective way to remove or limit TSS load to the basins. As noted previously in this report, the primary source of TSS in water delivered to the basins appears to be suspended sediment that is churned up in the unlined feeder canals during delivery of water from the CVC to the basins (see Section 4.1.2 herein). A riverbed filtration system in the feeder canal may help remove this TSS but it may not be as effective as the OCWD system for the following reasons:

- The inlet of the first basin is within 100 ft of CVC outlet. It's not possible to install a riverbed filtration system large enough to effectively remove suspended sediment between the CVC outlet and the Basin 4 inlet. This may be addressed through permanent removal of the inlet although this would need to be checked through analysis of land elevation slope.
- The feeder canal for the South Strand basins is approximately 900 feet long and 40 feet wide. A subsurface PVC collector gallery could be installed within the canal, resulting in approximately 36,000 square feet of collector piping (0.83 acres). Given that the OCWD field test apparatus was 10 acres and could produce a maximum of 18 cfs, it is not likely that a riverbed infiltration system in the feeder canal could accommodate

100 cfs, which is the maximum released from the CVC. A riverbed infiltration system in the feeder canal would accommodate approximately 1 to 2 cfs of flow. Thus, it would likely only address the TSS in some of the water released to the canal.

As per Hutchinson et al., 2017, the riverbed infiltration system they tested was constructed in 2013 at a cost of $1,900,000, of which $950,000 was for the pipeline connecting the system to the basin (this pipeline would not be necessary for the Project Area basins). Thus, in 2013 dollars, the OCWD system, which is approximately 10 times the size of that which the South Strand feeder canal could accommodate, was approximately $950,000. Assuming the cost is proportional to the size of the project, a riverbed infiltration system for the South Strand feeder canal would cost approximately $95,000 in 2013 dollars. Given inflation since that time, particularly in the last two years, this cost would be significantly higher.

For comparison, the South Strand feeder canal could be lined with concrete, which, given the apparent source of TSS in the water delivered to the basins, would address the issue. The cost to line the canal with concrete, in 2022 dollars, would be approximately $6 per square foot ($216,000) (personal communication with Curtis Skaggs, 2022). This option would address the potential for introducing TSS into the water after it is released from the CVC into the feeder canal at a cost that is comparable to the riverbed infiltration system and would be effective on the full 100 cfs capacity of the feeder canal.

Due to the limited available TSS data for CVC water, it is recommended to conduct further testing to confirm that the TSS of this water is always low. If the CVC water delivered to the Project Area basins is periodically much higher, then the riverbed filtration system may be revisited. However, based on the available data and observations in the field, concrete lining of the feeder canals appears to be a more effective solution to any TSS in the source water delivered to the basins.

6 Evaluation of Additional Recharge Enhancement Options

The recharge enhancement technologies previously evaluated assumed high TSS and turbidity in the source water delivered to the basins for recharge, which would cause clogging of the basin bottoms and reduced infiltration rates. Based on the available imported water quality data, observations of the lack of recharge rate decay in the Strand Ranch basins, analysis of subsurface lithology, and observations of groundwater levels (see Sections 2, 3 and 4), it is concluded that high TSS and high turbidity in the source water for recharge is not a limiting factor for recharge in the Study Area. While some sediments get churned up into suspension during delivery to the basins via the unlined feeder canals, this condition would be more effectively addressed through concrete lining of the canals (see Section 6.1). The additional recharge enhancement options discussed in this section address the role of subsurface lithology on recharge rate limitations.

6.1 Concrete Lining of Feeder Channels

One way to address surface fine-grained sediment suspended in the unlined feeder canal during inflow of water from the CVC is to line the canal floors and walls with concrete (see Section 4.1.2; Figure 3; Photos 2 through 4; see also Section 5.3). This would effectively address suspended sediment kicked up from the high energy inflow of water into the canals prior to delivery to the basins.

6.2 Over Excavation and Deepening of Basins

Over excavation involves excavating and removing shallow subsurface fine-grained sediments that cause reduced infiltration and recharge rates. Borehole data and tTEM show that the upper 10 to 50 feet of sediments in the South Strand Ranch basins consist of silt and silty sand, that would be expected to have lower permeability than the underlying sand sediments. Removal of these upper sediments through excavation to the depth that they intersect the sand would remove the shallow low permeability impediment to recharge. While deepening of the basins would not be feasible to 50 feet, there are areas where these fine sediments only extend between 10 to 20 ft bgs where removal through excavation is feasible.

The Buena Vista Water Storage District, located in the Kern Fan Area west of Strand Ranch, has deepened portions of recharge basins at their Palms, Corn Camp and Daly Ranch facilities to strategically remove shallow subsurface low permeability sediments (see Photos 6 and 7). As of August 2022, the only modified recharge facility that had received water for recharge was the Palms West and South basins. BVWSD reported that the infiltration rate in these basins during that year (2017) was approximately 0.6 ft/day. They had not conducted any infiltration testing prior to basin modification to determine what the infiltration rate was before deepening the basins. Further, they had not monitored groundwater levels during recharge to assess the impact that the managed recharge had on groundwater levels. Thus, how long they can recharge the groundwater at those rates is not known. However, the reported infiltration rate was significantly higher than that measured in many other basins in the western portion of the Kern Water Bank (see Figure 12).

Photo 6: View of Buena Vista Water Storage District Daly Ranch recharge facility showing deepened basins to expose sandy material (lighter colored sediments in the center right of the picture).

Photo 7: Deepening of basins at the Buena Vista Water Storage District Daly Ranch Facility.

Deepening of some and/or a portion of all the basins in the Study Area appears to be a viable option to increase recharge rates, at least in the short-term. While ultimately the limiting factor for recharge will be groundwater levels rising to within 10-ft of the land surface, this may allow IRWD to get more water into the ground quicker, thus increasing the volume of water stored when water is available for recharge.

6.3 Dry Wells

Dry wells consist of a large-diameter borehole either held open by a casing open at the bottom or filled with gravel (see Figure 13). In the Study Area, dry wells could be employed to facilitate recharge in areas where shallow subsurface fine-grained sediments extend to depths below that which excavation cannot feasibly remove. Dry wells can be constructed to maximum depths of approximately 120 feet. Thus, it is envisioned that they could be employed in areas of the Study Area basins where subsurface fine-grained sediments extend between approximately 20 and 50 ft bgs. The gravel-filled borehole would provide a conduit for surface water to percolate past the fine-grained layers to the sand below. Dry well boreholes would be approximately 48 to 52 inches in diameter and filled with ¼-inch to ½-inch gravel. The boreholes can be completed at the land surface with a gravel mound that can be easily scraped should basin maintenance be required.

These types of boreholes/wells have been used to facilitate recharge of captured stormwater as well as managed recharge in basins. In the Pinal Valley area of Arizona, dry wells were successfully employed to infiltrate recharge water past shallow subsurface caliche layers that were previously impeding recharge. Dry wells have also been employed in the Tejon Ranch area to facilitate stormwater capture (personal communication with Curtis Skaggs, 2022).

6.4 Deep Aquifer Injection Wells

Injection wells are another method of recharging deeper aquifers below shallower subsurface fine-grained layers. These wells are distinguished from a dry well in that they are completed similar to an extraction or production well with a well casing and perforated section in the target aquifer. They also are constructed with a gravel envelope around the perforations and a deep annular seal. Injection wells are more expensive than dry wells but can be drilled much deeper and allow for direct injection into any given aquifer, including either the intermediate, deep aquifer or both in the Project Area. As existing production wells can be converted to injection or dual "Aquifer Storage and Recovery" wells, the existing Strand Ranch wells may be modified to be utilized in this way. While this requires further investigation, conversion of Strand Ranch wells to enable injection would allow for recharging both the shallow aquifer via basins and deep aquifer via injection at the same time. Research would need to be performed to determine what type of pre-treatment would be needed to recharge water into the intermediate and deep aquifers using aquifer injections wells.

6.5 Regional Recharge Management Coordination

Currently, when water is available to the Kern Fan Area, most, if not all, water banking entities recharge at the same time. There have been periods of very high precipitation and available water when all of the basins in the area, including around the Project Area, have become full. However, it would be beneficial to coordinate with other banking entities, namely the Kern Water Bank Authority and the Kern County Water Agency, to strategically prioritize recharge in their basins that are further away from the Project Area to limit groundwater level rise beneath the Project Area. As stated earlier, when groundwater levels beneath the Strand Ranch rise to within 10 feet of the land surface, delivery of water to the basins must stop. By delaying the groundwater level rise in the Project Area associated with area banking, it may be possible for IRWD to recharge more water.

6.6 Recommended Recharge Enhancement Concepts for Further Testing

Given the conditions that are currently dictating recharge rates in the Project Area (shallow subsurface fine-grained layers and periodic high groundwater levels), we are recommending the following potential concepts for further testing to assess their feasibility for increasing recharge rates:

- Over Excavation
- Shallow Dry Wells

The following section presents a preliminary design to test the feasibility and effectiveness of each of the recommended recharge enhancement concepts.

7 Pilot Testing Preliminary Design – Over Excavation Concept

A pilot testing program has been developed to test the feasibility and effectiveness of increasing recharge rates by deepening a portion of one of the Strand Ranch basins. For this test, TH&Co selected a 2-acre area of South Strand Ranch Basin No. 1. This 2-acre area corresponds to an area where surface geophysics (tTEM) has shown that the upper approximately 20 feet of the subsurface consists of fine-grained sediments that are expected to result in low infiltration rates (see Figure 14). Pond drop data from 2012 indicates that the infiltration rate in this basin is approximately 0.1 ft/day. The purpose of this pilot test is to:

- Assess whether removal of the subsurface fine-grained sediments in the upper 20 ft bgs would improve infiltration rates and to what degree,
- Observe the paths and timing of recharge water migration in the shallow and intermediate aquifers, and
- Measure the magnitude and timing of groundwater level changes from recharge in the shallow and intermediate aquifers.

7.1 Pilot Over Excavated Recharge Basin

A 2-acre pilot recharge basin will be constructed in the southeast portion of South Strand Ranch Basin 1 (see Figure 14). The location of the basin corresponds to an area where tTEM surveys have indicated subsurface fine-grained sediments in the upper approximate 20 ft bgs. The pilot basin will initially be constructed without changing the existing basin bottom depth, which is approximately 5-feet below the top of berm. Recharge testing in this configuration of the basin will allow a more focused testing of infiltration rates without removing the shallow fine-grained sediments.

Upon completion of baseline pilot testing in the unimproved basin, the bottom will be deepened to a depth of approximately 20 feet below the existing basin bottom to remove subsurface fine-grained sediments indicated by the tTEM surveys. Excavation to this depth should expose underlying sand sediments, which are expected to be more permeable and will enable us to test the impact that removal of these upper fine-grained materials has on infiltration rates, through comparison with infiltration rates in the unimproved pilot basin.

Temporary berms will be constructed for the north, west and part of the south side of the pilot basin (see Figures 14 and 15). It is envisioned the berms will be constructed from basin bottom sediments outside the pilot basin berms. The inside and outside of each pilot basin berm will be constructed with 3:1 slopes to minimize erosion (see Figure 15). The basin will be supplied water via an 10-inch diameter PVC inlet pipeline connecting to the CVC feeder canal. The inlet pipeline will terminate inside the basin inside a small catchment lined with a 6-foot diameter plastic splash guard that is filled with riprap. This design prevents scouring of the basin bottom and excessive suspension of fine-grained material in the standing water in the basin.

7.2 Supply Water and Conveyance

There are two options for supplying water for pilot testing:

1. Imported water from the CVC, and
2. Groundwater pumped from Well SREX-7.

7.2.1 Option 1 – CVC/Off-Basin Supply Channel

If water is available from the CVC to supply the pilot test, then a conveyance pipeline will be connected to one of the corrugated pipelines making up the inlet structure to Basin 1 (see Figures 14 and 15). The remaining existing inlet pipelines to Basin 1 would be blocked off to focus water directly into the pilot testing conveyance pipeline. The conveyance pipeline would consist of above-ground 10-inch diameter PVC capable of supplying up to 500 gallons per minute. The pipeline alignment would be as shown on Figure 15. The inlet structure to each pilot basin would be constructed as shown on Figure 15 and described in Section 7.1 herein.

7.2.2 Option 2 – Groundwater from SREX-7

If water for pilot testing is not available from the CVC, then it could be alternatively supplied from groundwater pumped by Well SREX-7, located at the northwest corner of Basin 1 (see Figure 14). For this option, groundwater from SREX-7 would be discharged to the CVC as in a pump back condition. A like amount of water would be released from the CVC to the eastern feeder canal for conveyance to the pilot basin via the 10-inch diameter PVC pipeline. The pipeline alignment would be as shown on Figure 15.

7.3 Basin Instrumentation

7.3.1 Staff Gage

Surface water in the pilot basins will be monitored using a graduated staff gage. One gage will be placed in the basin as shown on Figure 16.

7.3.2 Monitoring Well

One nested monitoring well is proposed for the pilot basin, to be in the center of the basin on a raised earthen island (see Figure 16). It is planned to drill and construct the 280-ft deep monitoring wells prior to pilot basin construction such that the wellhead will be completed above the current basin floor. The island will have 3:1 slopes as with the basin walls.

The monitoring well will be completed as a nested well with two independent well casings in the same borehole, each with different perforation intervals (see Figure 17). The uppermost perforation interval will correspond to the shallow aquifer (conceptually approximately 50 to

100 ft bgs) and will enable monitoring of the timing and magnitude of changes in groundwater levels from recharge into this aquifer. The lowermost perforation interval will correspond to the intermediate aquifer (conceptually approximately 220 to 270 ft bgs) and will enable monitoring of the timing and magnitude of changes in groundwater levels in this aquifer during pilot recharge testing. The final depth and perforation interval of each casing will be determined from logging and analysis of data during the drilling of the borehole for the well.

The borehole for the monitoring well will be drilled using a direct mud rotary drilling method. Soil samples will be collected during drilling across 10-foot intervals and visually classified in the field in accordance with the USCS. All drilling, sample collection, and soil logging will be conducted under the supervision of a California Certified Hydrogeologist. Soil cuttings generated during drilling will be spread out on the ground in the western pilot basin. Drilling fluids will be transported offsite for disposal.

Upon completion of the monitoring well, the contractor will collect a suite of downhole geophysical logs including:

- Gamma Ray
- Sonic Velocity Variable Density
- Spontaneous Potential
- Short Normal Resistivity
- Long Normal Resistivity
- Laterolog Resistivity

The recommended preliminary design for the nested monitoring well is shown on Figure 17 and incorporates the following:

- 4-inch diameter PVC blank casing (+2 to 50 ft bgs and +2 to 220 ft bgs).
- 4-inch diameter PVC well screen (50 to 100 ft bgs and 220 to 270 ft bgs).
- Screen consisting of horizontal slots with 0.02-inch openings.
- A 20-ft deep mild steel conductor casing and seal.
- Annular cement/bentonite seals from 0 to 40 ft bgs and 110 to 210 ft bgs.

The preliminary design for the monitoring well is based on best available data and presented for planning purposes. However, the final design will be refined based on site-specific data to be collected during drilling of the borehole for the well.

The well will be completed at the surface inside a 12-inch diameter mild steel above-ground riser that extends three feet above the land surface. A dedicated reference point will be established and marked on the top of the well casing. The elevation of the reference point will be surveyed to an accuracy of 0.01 foot relative to mean sea level (NAVD88) by a California licensed land surveyor. All groundwater level measurements will be obtained relative to the reference point.

After installation, the monitoring well will be developed using a combination of swabbing and bailing. The well will be developed for approximately 8 to 16 hours, depending on the time required to produce clear water that is free of suspended sediment. During development, periodic measurements of electrical conductivity (EC), pH, temperature, and total dissolved solids will be recorded with a portable parameter kit and recorded on field daily summaries. The parameter kit will be calibrated in the field at the beginning of each day of development. Groundwater generated during the development process will be temporarily contained at the drilling site until suspended sediment has settled out. Clarified water will be discharged to the basins. Residual sediment will be transported offsite for disposal.

Upon completion, each completion in the nested monitoring well will be equipped with a continuous read pressure transducer for measuring groundwater levels. Transducers will be installed below the groundwater level with enough submergence to accommodate anticipated groundwater level fluctuations. Each pressure transducer will be programmed to collect data at 15-minute intervals.

7.3.3 Soil Moisture Neutron Probe Boreholes

Two boreholes will be drilled and completed with 2-inch diameter PVC casing for the purpose of enabling the periodic collection of neutron probe soil moisture data. The neutron probe is periodically run inside the casing during recharge testing where it emits neutrons through the casing and into the adjacent formation. The neutrons interact with water in the soil to provide a measurement of the degree of saturation. The probes will enable tracking the timing of vertical percolation of water introduced into the pilot recharge basin. The boreholes will be installed on each side of the central monitoring well island (see Figure 16). The casings will be constructed of blank Schedule 40 PVC installed to a total depth of 200 ft bgs inside a 6-inch diameter hollow-stem auger borehole.

7.3.4 Surface Electrical Resistivity Tomography

Electrical Resistivity Tomography (ERT) will be conducted in the pilot basin to track the vertical percolation of water in the subsurface. The ERT instrumentation is established in the basin bottom as an array of electrodes each connected by electrical wiring. Current is induced into the ground using two electrodes and the electrical potential drop is read using up to six other electrodes. In so doing it is possible to estimate lateral and vertical variations in electrical resistivity. As water changes the electrical resistivity, it can be used to measure variations and changes in soil saturation. This method is complimentary to the neutron probes, providing an independent method to track recharge water percolation.

The electrodes will be placed across the pilot basin bottoms with a spacing of approximately 5 feet. Line spacing will be approximately 10 feet. ERT data will be collected continuously throughout the pilot recharge testing.

7.4 Pre-Test Baseline Conditions

Pre-test observations and measurements will be conducted for a period of approximately 1 week prior to the start of the infiltration test to ensure that all monitoring equipment is working properly and to establish a baseline groundwater level condition for the project area. Baseline data to be collected will include:

- Soil moisture readings,
- Groundwater level measurements, and
- Groundwater quality data (one-time).

Soil moisture data and groundwater levels will be recorded automatically at regular intervals (15 minutes). Manual groundwater level measurements will be collected from the newly installed monitoring well prior to testing at least twice to compare and calibrate the transducer data.

Groundwater quality data will be obtained through analysis of samples collected from the newly installed monitoring well. One sample will be collected from each nest (if saturated) and analyzed for the constituents summarized in Table 5. This sample will be collected upon completion of monitoring well development (Section 7.3.2).

All groundwater samples will be collected in accordance with ASTM Standard Method D4448-85a. Prior to sampling, approximately three well volumes will be removed from each well using a submersible pump. Pumped groundwater will be monitored for temperature, pH, EC and TDS using field calibrated instrumentation. Measurements and observations will be recorded on daily field forms. Groundwater samples will be collected after three well volumes have been pumped, the water is relatively free and clear of suspended sediment, and the groundwater parameters have stabilized. Samples will be pumped directly into laboratory prepared sample containers. Each container will be labeled with the date and time sampled, the well name and number, the sampler's initials, and the preservative (if applicable). Samples will be placed in a field cooler with ice immediately upon collection. All groundwater samples will be submitted to a State-certified analytical laboratory under chain-of-custody protocol within 24 hours of collection. The submersible pump will be cleaned at the beginning of each sampling day and in between wells using a Liqui-Nox soap (or equivalent) solution wash and potable and distilled water rinses.

7.5 Infiltration Testing and Monitoring

A pilot infiltration test is proposed to assess the effectiveness of removing shallow low permeability layers at improving recharge rates in the project area. The test will be conducted in two phases:

1. Phase I will be to first introduce water into the unimproved pilot basin for a period of one month and measure infiltration rates, deep percolation of water, and effects on groundwater levels. Upon completion of Phase I, there will be a one-week period of ongoing monitoring

to assess soil moisture changes, deep percolation, and groundwater level change. The ERT and DTP instrumentation will then be temporarily removed and the basin bottom deepened to approximately 20 feet below current grade. The ERT and DTP instrumentation will then be reinstalled on the new basin floor.

2. Phase II will be to introduce water into the deepened pilot basin for a period of two months to measure infiltration rates, deep percolation of water, and effects on groundwater levels.

By comparing the infiltration rates between the two tests (Phase I and Phase II) and the corresponding deep percolation rates and response in groundwater levels, it will be possible to measure the relative benefit of removing shallow fine-grained layers on recharge rates.

Measurements to be gathered during each phase of recharge testing will include:

Basin Inflow – Basin inflow readings will be checked daily for the first week of each test. Inflow reading frequency may be decreased thereafter if recharge rates stabilize. At each reading, the instantaneous and total flow will be recorded. Inflow starting and stopping dates and times will also be recorded in a dedicated field manual by a TH&Co technician.

Surface Water Level Measurements - The depth of surface water in the pilot basins will be measured daily from the graduated staff gauges located in each pilot basin.

ERT Data – ERT data will be recorded continuously on a data logger and downloaded periodically during the pilot infiltration test.

Soil Neutron Probe Moisture Measurements – Downhole soil moisture measurements will be made using a neutron probe on a weekly basis.

Groundwater Level Measurements – Groundwater level measurements will be recorded at 15-minute intervals using downhole pressure transducers and downloaded periodically during the pilot infiltration test. Manual measurements of groundwater level will be made periodically during the pilot test using an electronic sounder to verify the accuracy of the transducer data.

Source Water Total Suspended Sediment Measurements – Surface water samples will be collected weekly from the unlined feeder canal prior to entry into the conveyance pipeline. Two samples will be collected during each sampling event: one from the discharge inlet from the CVC and one from immediately prior to the connection to the 8-inch conveyance pipeline.

Groundwater Quality Sampling/Analysis - Groundwater samples will be collected from the nested monitoring well upon completion of Phase I pilot infiltration testing and then again upon completion of Phase II pilot testing.

Observations of Basin Integrity – General observations of basin integrity, pipeline integrity, siltation, algal growth and any other factors that could affect the infiltration test will be make on a daily basis during the first week of each Phase of test and then as needed thereafter. Notes regarding pipeline leakage, basin side deterioration, siltation, algal growth and wildlife will be recorded on standard field forms.

7.6 Reporting

Throughout the pilot infiltration test project, monthly progress reports will be submitted to IRWD to summarize progress with the scope of work and communicate changes to the scope and/or schedule, as necessary. Preliminary results from the preliminary field testing phase will be summarized for IRWD via an interim report. In addition to reporting preliminary results of the project, the report will present pilot basin design drawings.

At the completion of the pilot infiltration testing, a draft report will be prepared and submitted to IRWD that summarizes the results of the pilot infiltration testing. Key elements of the report will include:

- The project background, purpose and scope;
- A description of the pilot testing approach and methodology;
- A description of the geology and aquifer systems, refined according to the results of the field drilling and testing program;
- A description of the pilot infiltration test set up and instrumentation;
- Analysis and findings of infiltration rates for the pilot test area;
- Analysis and findings of subsurface recharge water migration extent and paths;
- Analysis of groundwater level response and timing to artificial recharge of surface water;
- Conclusions regarding feasibility and potential effectiveness of large-scale over excavation/basin deepening as a means of improving recharge rates in the Project Area, and
- Recommendations for further analysis and/or regional implementation of this concept.

8 Pilot Testing Preliminary Design – Shallow Dry Wells

A separate pilot testing program has been developed to test the feasibility and effectiveness of dry wells at increasing recharge rates. For this test, TH&Co selected a 1-acre area of South Strand Ranch Basin No. 4 (see Figures 3 and 18). Surface geophysics (tTEM) and the borehole log for nearby Well SREX-7 has shown that the upper approximately 50 feet of the southwestern portion of this basin consists of fine-grained sediments that are expected to result in low infiltration rates (see Figure 7). Pond drop data from 2012 indicates that the infiltration rate in Basin 4 is approximately 0.31 ft/day. The purpose of this pilot test is to:

- Assess whether the dry wells are effective at improving infiltration rates in areas where fine-grain sediments extend deeper than excavation can remove;
- Test different gravel backfill sizes and surface completion configurations to assess effectiveness at improving and maintaining recharge rates;
- Observe the paths and timing of recharge water migration in the shallow and intermediate aquifers; and
- Measure the magnitude and timing of groundwater level changes from recharge in the shallow and intermediate aquifers.

8.1 Pilot Recharge Basin

One pilot recharge basin will be constructed in the southwest corner of South Strand Ranch Basin 4 (see Figures 18 and 19). The location of the pilot basin corresponds to an area where tTEM surveys and the borehole log from Well SREX-7 have indicated fine-grained sediments in the upper approximately 40 feet of sediments. The pilot basin will be approximately 1-acre, with 5-foot high berms constructed from sediments excavated from the areas of Basin 4 outside the pilot basin. The pilot basin will be constructed without changing the existing basin bottom depth, which is approximately 5-feet below the top of berm. This basin will allow for testing of the impacts that dry wells have on increasing infiltration rates in the area.

The inside and outside of the pilot basin berm will be constructed with 3:1 slopes to minimize erosion (see Figure 19). The basin will be supplied water via an 10-inch diameter PVC inlet pipeline connecting to the CVC feeder canal. The inlet pipeline will terminate inside the basin inside a small catchment lined with a 6-foot diameter plastic splash guard that is filled with riprap. This design prevents scouring of the basin bottom and excessive suspension of fine-grained material in the standing water in the basin.

8.2 Dry Well Construction

Six dry wells will be drilled and completed inside the pilot basin. Each dry well will be constructed as an uncased boreholes drilled to approximately 100 ft bgs using a 52-inch diameter bucket auger or solid stem auger drilling rig. Three of the boreholes will be backfilled with 1/4-inch "pea" gravel. The other three boreholes will be backfilled with ¾-inch gravel. The surface completion of each borehole will consist of a mound of ¼-inch gravel.

8.3 Supply Water and Conveyance

There are two options for supplying water for pilot testing:

3. Imported water from the CVC, and
4. Groundwater pumped from Well SREX-7.

8.3.1 Option 1 – CVC/Off-Basin Supply Channel

If water is available from the CVC to supply the pilot test, then a conveyance pipeline will be connected to one of the corrugated pipelines making up the inlet structure to Basin 4 (see Figures 18 and 19). The remaining existing inlet pipelines to Basin 4 would be blocked off to focus water directly into the pilot testing conveyance pipeline. The conveyance pipeline would consist of above-ground 10-inch diameter PVC capable of supplying up to 500 gallons per minute. The pipeline alignment would be as shown on Figure 19. The inlet structure to each pilot basin would be constructed as shown on Figure 19 and described in Section 8.1 herein.

8.3.2 Option 2 – Groundwater from SREX-7

If water for pilot testing is not available from the CVC, then it could be alternatively supplied from groundwater pumped by Well SREX-7, located at the southwest corner of Basin 4 (see Figure 18). For this option, groundwater from SREX-7 would be discharged to the CVC as in a pump back condition. A like amount of water would be released from the CVC to the eastern feeder canal for conveyance to the pilot basin via the 10-inch diameter PVC pipeline. The pipeline alignment would be as shown on Figure 19.

8.4 Basin Instrumentation

8.4.1 Staff Gages

Surface water in the pilot basins will be monitored using a graduated staff gage. One gage will be placed in the basin as shown on Figure 20.

8.4.2 Monitoring Wells

One nested monitoring well is proposed for the pilot basin, to be in the center of the basin on a raised earthen island (see Figure 20). It is planned to drill and construct the monitoring well prior to pilot basin construction such that the wellhead will be completed above the current basin floor. The island will have 3:1 slopes as with the basin walls.

The monitoring well will be completed as a nested well with two independent well casings in the same borehole, each with different perforation intervals (see Figure 17). The uppermost perforation interval will correspond to the shallow aquifer (conceptually approximately 50 to 100 ft bgs) and will enable monitoring of the timing and magnitude of changes in groundwater levels from recharge into this aquifer. The lowermost perforation interval will correspond to the intermediate aquifer (conceptually approximately 220 to 270 ft bgs) and will enable monitoring of the timing and magnitude of changes in groundwater levels in this aquifer during pilot recharge testing. The final depth and perforation interval of each casing will be determined from logging and analysis of data during the drilling of the borehole for the well.

The borehole for the monitoring well will be drilled using a direct mud rotary drilling method. Soil samples will be collected during drilling across 10-foot intervals and visually classified in the field in accordance with the USCS. All drilling, sample collection, and soil logging will be conducted under the supervision of a California Certified Hydrogeologist. Soil cuttings generated during drilling will be spread out on the ground in the western pilot basin. Drilling fluids will be transported offsite for disposal.

Upon completion of the monitoring well, the contractor will collect a suite of downhole geophysical logs including:

- Gamma Ray
- Sonic Velocity Variable Density
- Spontaneous Potential
- Short Normal Resistivity
- Long Normal Resistivity
- Laterolog Resistivity

The recommended preliminary design for the nested monitoring well is shown on Figure 17 and incorporates the following:

- 4-inch diameter PVC blank casing (+2 to 50 ft bgs and +2 to 220 ft bgs).
- 4-inch diameter PVC well screen (50 to 100 ft bgs and 220 to 270 ft bgs).
- Screen consisting of horizontal slots with 0.02-inch openings.
- A 20-ft deep mild steel conductor casing and seal.
- Annular cement/bentonite seals from 0 to 40 ft bgs and 110 to 210 ft bgs.

The preliminary design for the monitoring well is based on best available data and presented for planning purposes. However, the final design will be refined based on site-specific data to be collected during drilling of the borehole for the well.

The well will be completed at the surface inside a 12-inch diameter mild steel above-ground riser that extends three feet above the land surface. A dedicated reference point will be established and marked on the top of the well casing. The elevation of the reference point will be surveyed to an accuracy of 0.01 foot relative to mean sea level (NAVD88) by a California licensed land surveyor. All groundwater level measurements will be obtained relative to the reference point.

After installation, the monitoring well will be developed using a combination of swabbing and bailing. The well will be developed for approximately 8 to 16 hours, depending on the time required to produce clear water that is free of suspended sediment. During development, periodic measurements of electrical conductivity (EC), pH, temperature, and total dissolved solids will be recorded with a portable parameter kit and recorded on field daily summaries. The parameter kit will be calibrated in the field at the beginning of each day of development. Groundwater generated during the development process will be temporarily contained at the drilling site until suspended sediment has settled out. Clarified water will be discharged to the basins. Residual sediment will be transported offsite for disposal.

Upon completion, each completion in the nested monitoring well will be equipped with a continuous read pressure transducer for measuring groundwater levels. Transducers will be installed below the groundwater level with enough submergence to accommodate anticipated groundwater level fluctuations. Each pressure transducer will be programmed to collect data at 15-minute intervals.

8.4.3 Soil Moisture Neutron Probes

Eight boreholes will be drilled and completed with 2-inch diameter PVC casing for the purpose of enabling the periodic collection of neutron probe soil moisture data. The neutron probe is periodically run inside the casing during recharge testing where it emits neutrons through the casing and into the adjacent formation. The neutrons interact with water in the soil to provide a measurement of the degree of saturation. The probes will enable tracking the timing of vertical percolation of water introduced into the pilot recharge basin. Four boreholes will be constructed surrounding the northwesternmost dry well and four will be constructed surrounding the southeasternmost dry well (see Figure 20). The casings will be constructed of blank Schedule 40 PVC installed to a total depth of 200 ft bgs inside a 6-inch diameter hollow-stem auger borehole.

8.4.4 Surface Electrical Resistivity Tomography

ERT equipment will be installed both at the surface in the pilot basin and as depth-specific sensors attached to the outside of selected casings for neutron probe surveys. In the basin bottom, the ERT is established as an array of electrodes each connected by electrical wiring. Current is induced into the ground or formation using two electrodes and the electrical potential drop is read using up to six other electrodes. In so doing it is possible to estimate lateral and vertical variations in electrical resistivity. As water changes the electrical resistivity, it can be used to measure variations and changes in soil saturation. This method is complimentary to the neutron probes, providing an independent method to track recharge water percolation.

The electrodes will be placed across the pilot basin bottoms with a spacing of approximately 5 feet. Line spacing will be approximately 10 feet. In the boreholes, the ERT sensors will be attached at 10-ft intervals from the land surface to the bottom of the casings (200 ft bgs). ERT data will be collected continuously throughout the pilot recharge testing.

8.5 Pre-Test Baseline Conditions

Pre-test observations and measurements will be conducted for a period of approximately 1 week prior to the start of the infiltration test to ensure that all monitoring equipment is working properly and to establish a baseline groundwater level condition for the project area. Baseline data to be collected will include:

- Soil moisture readings,
- Groundwater level measurements, and
- Groundwater quality data (one-time).

Soil moisture data and groundwater levels will be recorded automatically at regular intervals (15 minutes). Manual groundwater level measurements will be collected from the newly installed monitoring well prior to testing at least twice to compare and calibrate the transducer data.

Groundwater quality data will be obtained through analysis of samples collected from the newly installed monitoring well. One sample will be collected from each nest (if saturated) and analyzed for the constituents summarized in Table 5. This sample will be collected upon completion of monitoring well development (Section 8.4.2).

8.6 Infiltration Testing and Monitoring

The pilot infiltration test to assess the effectiveness of dry wells at improving recharge rates in the project area will be conducted in two phases:

1. Phase I will be to first introduce water into the pilot basin for a period of one month prior to the construction of the dry wells. During this time, infiltration rates, deep percolation of water, and effects on groundwater levels will be observed and measured. Upon completion of Phase I, the dry wells will be constructed in the locations shown on Figures 18 and 20. During drilling, it may be necessary to remove some ERT and DTP instrumentation, which would be reestablished upon completion of the dry wells.
2. Phase II will be to introduce water into the pilot basin with the dry wells in place. This test would be for a period of two months to measure infiltration rates, deep percolation of water, and effects on groundwater levels.

By comparing the infiltration rates between the two tests (Phase I and Phase II) and the corresponding deep percolation rates and response in groundwater levels, it will be possible to measure the relative benefit of dry wells on recharge rates.

Measurements to be gathered during each phase of recharge testing will include:

Basin Inflow – Basin inflow readings will be checked daily for the first week of each test. Inflow reading frequency may be decreased thereafter if recharge rates stabilize. At each reading, the instantaneous and total flow will be recorded. Inflow starting and stopping dates and times will also be recorded in a dedicated field manual by a TH&Co technician.

Surface Water Level Measurements - The depth of surface water in the pilot basins will be measured daily from the graduated staff gauges located in each pilot basin.

ERT Data – ERT data will be recorded continuously on a data logger and downloaded periodically during the pilot infiltration test.

Soil Neutron Probe Moisture Measurements – Downhole soil moisture measurements will be made using a neutron probe on a weekly basis.

Groundwater Level Measurements – Groundwater level measurements will be recorded at 15-minute intervals using downhole pressure transducers and downloaded periodically during the pilot infiltration test. Manual measurements of groundwater level will be made periodically during the pilot test using an electronic sounder to verify the accuracy of the transducer data.

Source Water Total Suspended Sediment Measurements – Surface water samples will be collected weekly from the unlined feeder canal prior to entry into the conveyance pipeline. Two samples will be collected during each sampling event: one from the discharge inlet from the CVC and one from immediately prior to the connection to the 8-inch conveyance pipeline.

Groundwater Quality Sampling/Analysis - Groundwater samples will be collected from the nested monitoring well upon completion of Phase I pilot infiltration testing and then again upon completion of Phase II pilot testing.

Observations of Basin Integrity – General observations of basin integrity, pipeline integrity, siltation, algal growth and any other factors that could affect the infiltration test will be make on a daily basis during the first week of each Phase of test and then as needed thereafter. Notes regarding pipeline leakage, basin side deterioration, siltation, algal growth and wildlife will be recorded on standard field forms.

8.7 Reporting

Throughout the pilot infiltration test project, monthly progress reports will be submitted to IRWD to summarize progress with the scope of work and communicate changes to the scope and/or schedule, as necessary. Preliminary results from the preliminary field testing phase will be summarized for IRWD via an interim report. In addition to reporting preliminary results of the project, the report will present pilot basin design drawings.

At the completion of the pilot infiltration testing, a draft report will be prepared and submitted to IRWD that summarizes the results of the pilot infiltration testing. Key elements of the report will include:

- The project background, purpose and scope;
- A description of the pilot testing approach and methodology;
- A description of the geology and aquifer systems, refined according to the results of the field drilling and testing program;
- A description of the pilot infiltration test set up and instrumentation;
- Analysis and findings of infiltration rates for the pilot test area;
- Analysis and findings of subsurface recharge water migration extent and paths;
- Analysis of groundwater level response and timing to artificial recharge of surface water;
- Conclusions regarding feasibility and potential effectiveness of large-scale implementation of dry wells as a means of improving recharge rates in the Project Area, and
- Recommendations for further analysis and/or regional implementation of this concept.

9 Planning Level Cost Estimates

Planning-level cost estimates were developed for pilot testing both recommended recharge enhancement concepts described in Sections 7 and 8 (see Table 6). Key assumptions used in the development of the cost estimates are as follows:

- Water from either the CVC or Well SREX-7 will be available to conduct the testing and will be available without cost.
- Rosedale-Rio Bravo Water Storage District (RRBWSD) will provide access to Strand South to conduct the testing.
- All piping supplying water for pilot testing and basin berms will be temporary and will be removed following tesing.
- All conveyance piping will be temporary above-ground piping constructed of PVC.
- At Basin 1, the existing area outside the basin at the southeast corner will be available to stockpile soil from over excavation of the pilot basin. No over excavated soil will be hauled offsite.
- All field data collection work will be coordinated with Lawrence Berkeley Laboratories (LBL). Costs are included for LBL to coordinate instrumentation needs, help set up instrumentation, and process results. It is further assumed that LBL would be subcontracted to TH&Co.
- RRBWSD staff will be available periodically to check flow rates, inflow structures, and instrumentation periodically during pilot testing. Costs for this work are not included.
- Each pilot testing program would include a one-week pretesting period, an initial four-week monitoring phase to establish baseline infiltration rates, and a second four-week monitoring phase to measure infiltration rates with the concepts implemented. Total duration of each pilot testing program is estimated to be approximately 32 weeks (eight months). It may be possible to pilot test both concepts at the same time.
- Planning-level costs for monitoring well drilling are based on recent Contractor bids for drilling monitoring wells in alluvial aquifer systems in the Central Valley of California. The costs are for budget and planning purposes only and it is noted that recent well drilling costs have been unpredictable. Final costs would be obtained from a formal Contractor bid process.

The planning-level cost estimate for the Basin 1 over excavation pilot testing concept, as summarized in Table 6, is:

Base Estimate:	$757,500
Contingency of 15%:	$113,625
Total Planning Estimate:	$871,125

The planning-level contractor cost estimate for the Basin 4 dry well pilot testing concept, as summarized in Table 6, is:

Base Estimate:	$860,500
Contingency of 15%:	$129,075
Total Planning Estimate:	$989,575

The total planning level estimate to pilot test both concepts is $1,860,700.

10 References

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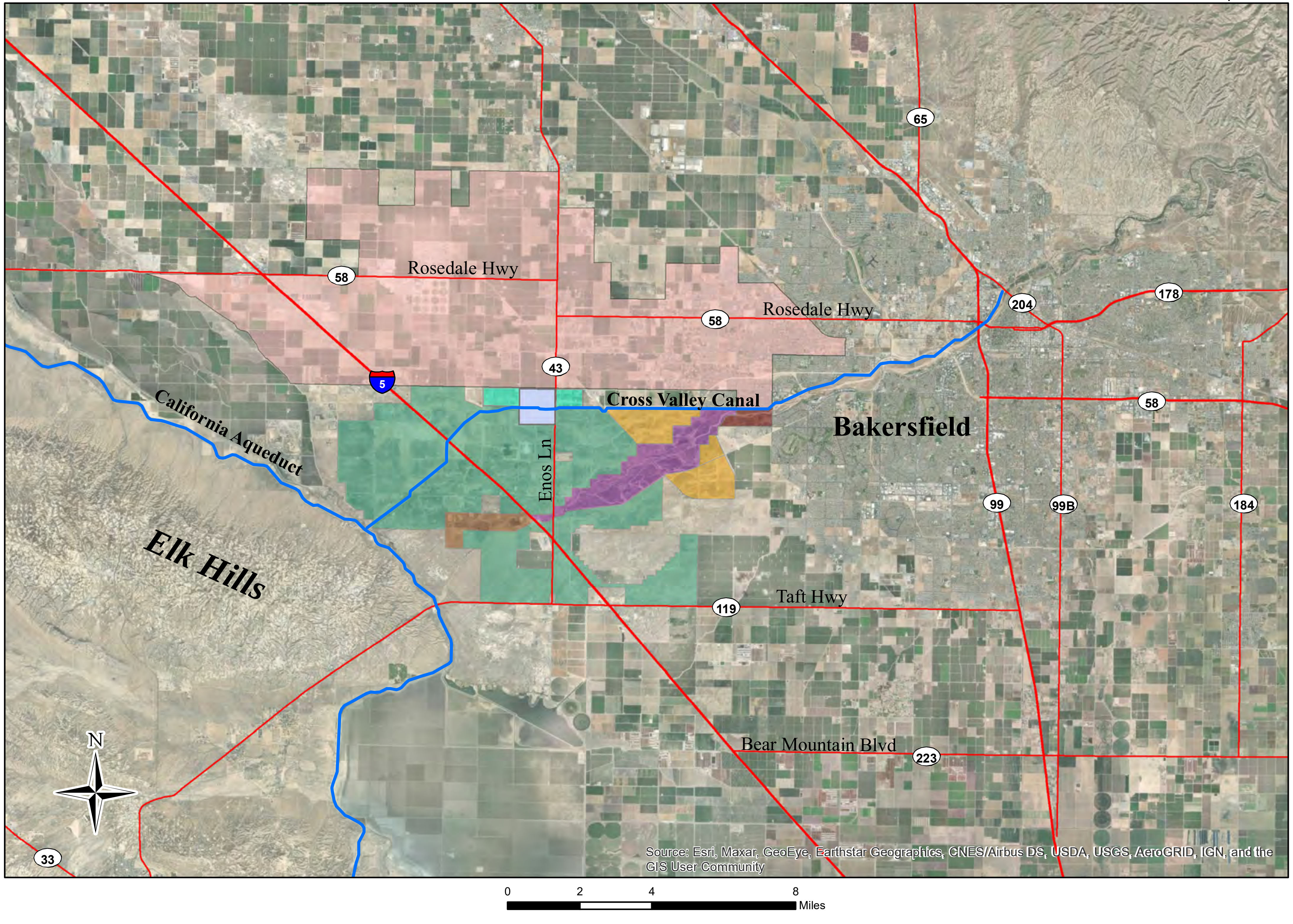
Wildermuth Environmental, 2010. Drilling, Construction, Development and Testing of Well SROW-1, Strand Ranch Water Banking Facility, Kern County, California. Prepared for Irvine Ranch Water District. Dated March 2010.

Figures

April 2023



Map Features

- California Aqueduct/Canal
- Highway/Freeway
- Strand Ranch
- Stockdale Project
- Berrenda Mesa
- Pioneer Project
- 2800 Acres (City of Bakersfield)
- Kern Water Bank
- West Kern/Buena Vista
- Rosedale-Rio Bravo Water Storage District

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Regional Setting

Figure 1

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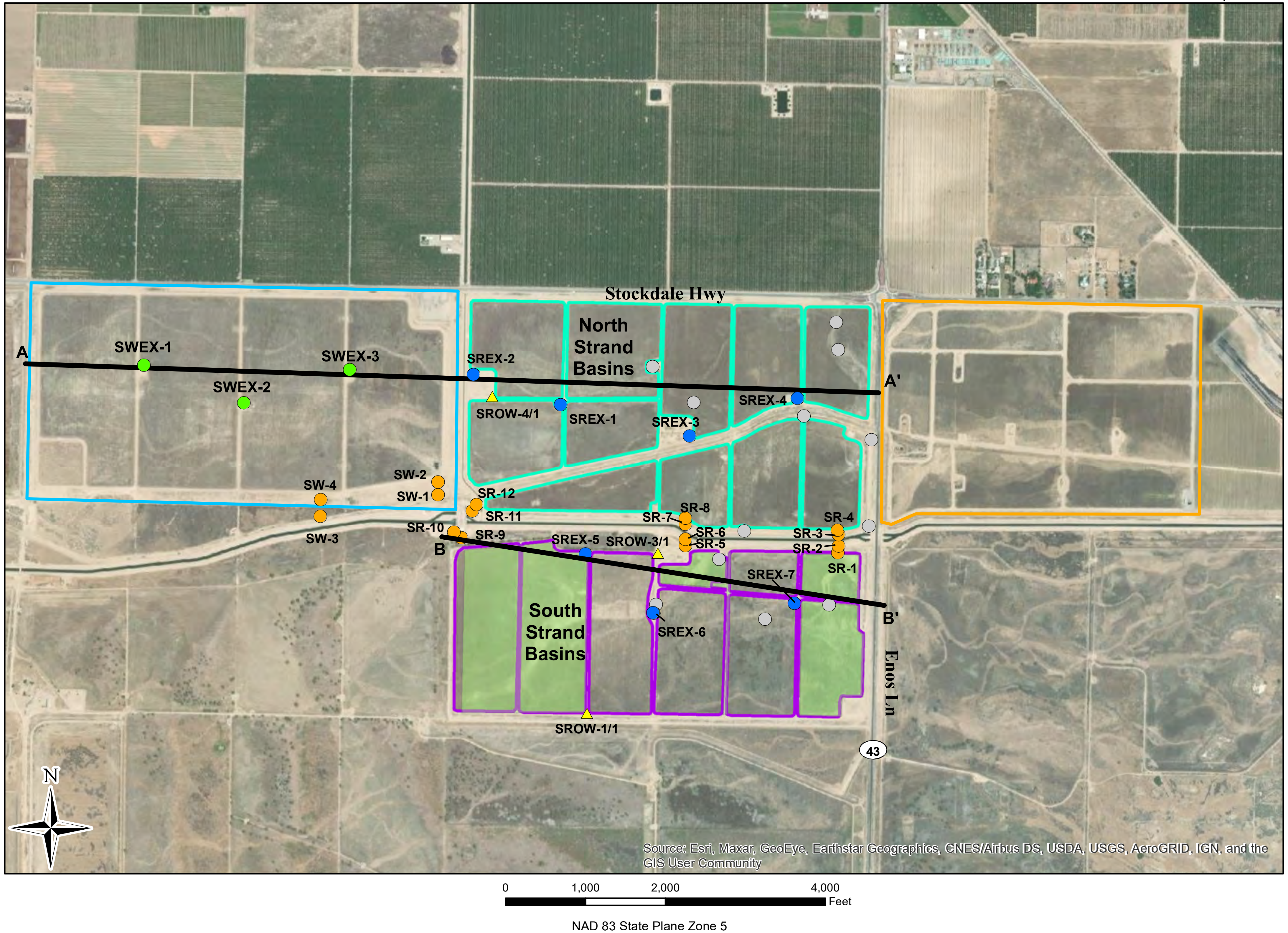

Map Features

- Stockdale West Well
- Strand Ranch Production Well
- Strand Ranch Observation Well
- Kern County Water Agency Monitoring Well
- Destroyed Well
- Cross Section
- Stockdale East
- Stockdale West
- Surveyed Zone
- North Strand Ranch
- South Strand Ranch

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Study Area

Figure 2

Recharge Enhancement Study
Preliminary Design Report -
Bakersfield, California

Irvine Ranch Water District

April 2023

0 250 500 1,000 Feet

NAD 83 State Plane Zone 5

Map Features

- Strand Ranch Production Well
- Strand Ranch Observation Well
- Destroyed Well
- Inlets
- Surveyed Zone
- South Strand Ranch

20 Basin Number

0.14 ft/day Infiltration Rate - 2012

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Strand Ranch South Basins and Conveyance Channels

Figure 3

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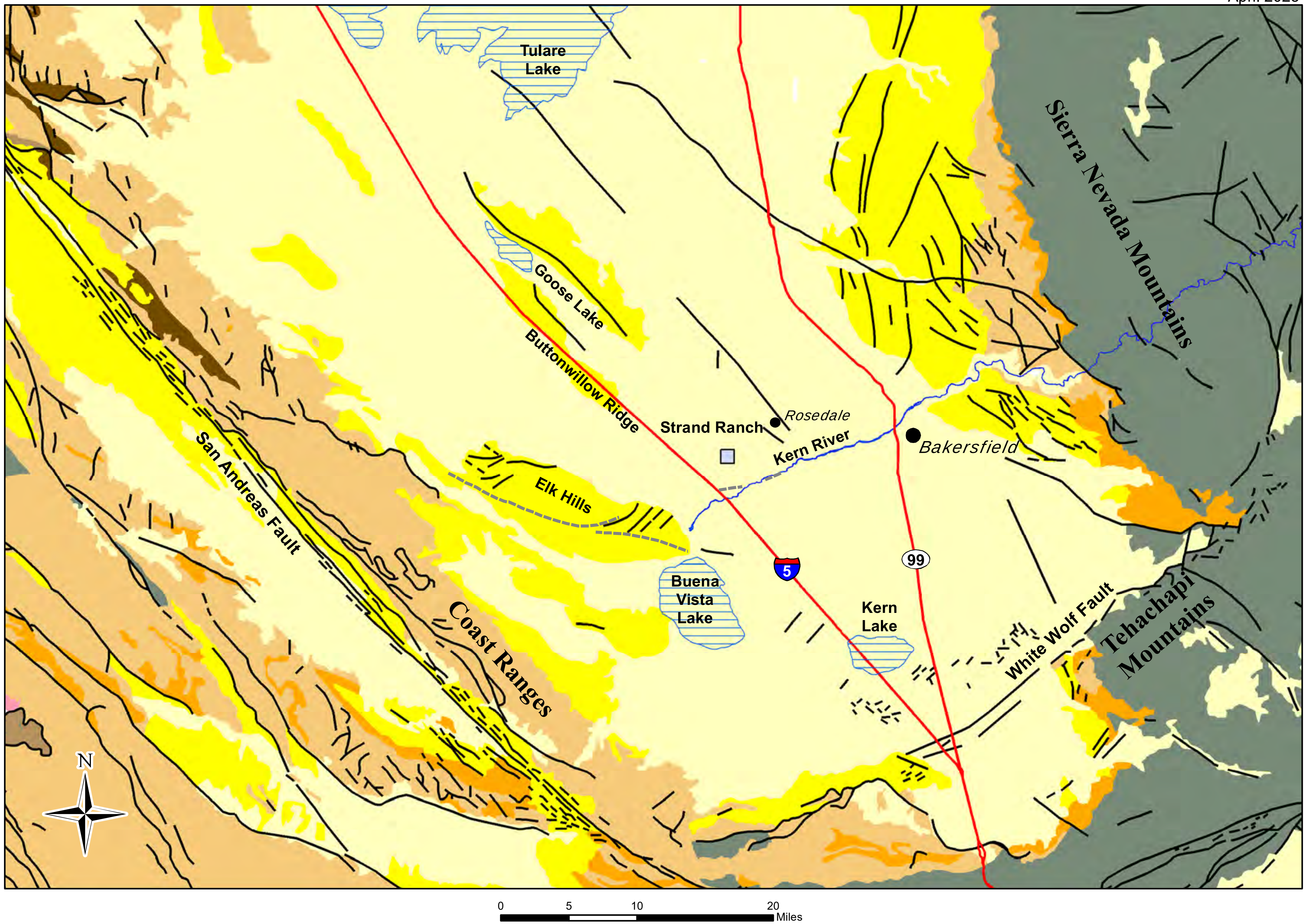

Map Features

- Strand Ranch
- Tulare Basin
- Lake Deposits
- Quarternary Alluvium
- Quarternary Loosely Consolidated Deposits
- Tertiary Non-Marine Sedimentary Rocks
- Tertiary Marine Sedimentary Rocks
- Cretaceous Marine Sedimentary Rocks
- Franciscan Complex
- Mesozoic Volcanic Rocks
- Paleozoic & Mesozoic Crystalline Rocks
- Anticline
- Faults
- Highways
- Kern River

Geologic units modified from USGS Open-File Report 2005-1305

Lake Deposits from California Geological Survey Geologic Atlas of California Map No. 002 1:250:000 scale, Compiled by Arthur R. Smith, 1964

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Geologic Map

Figure 4

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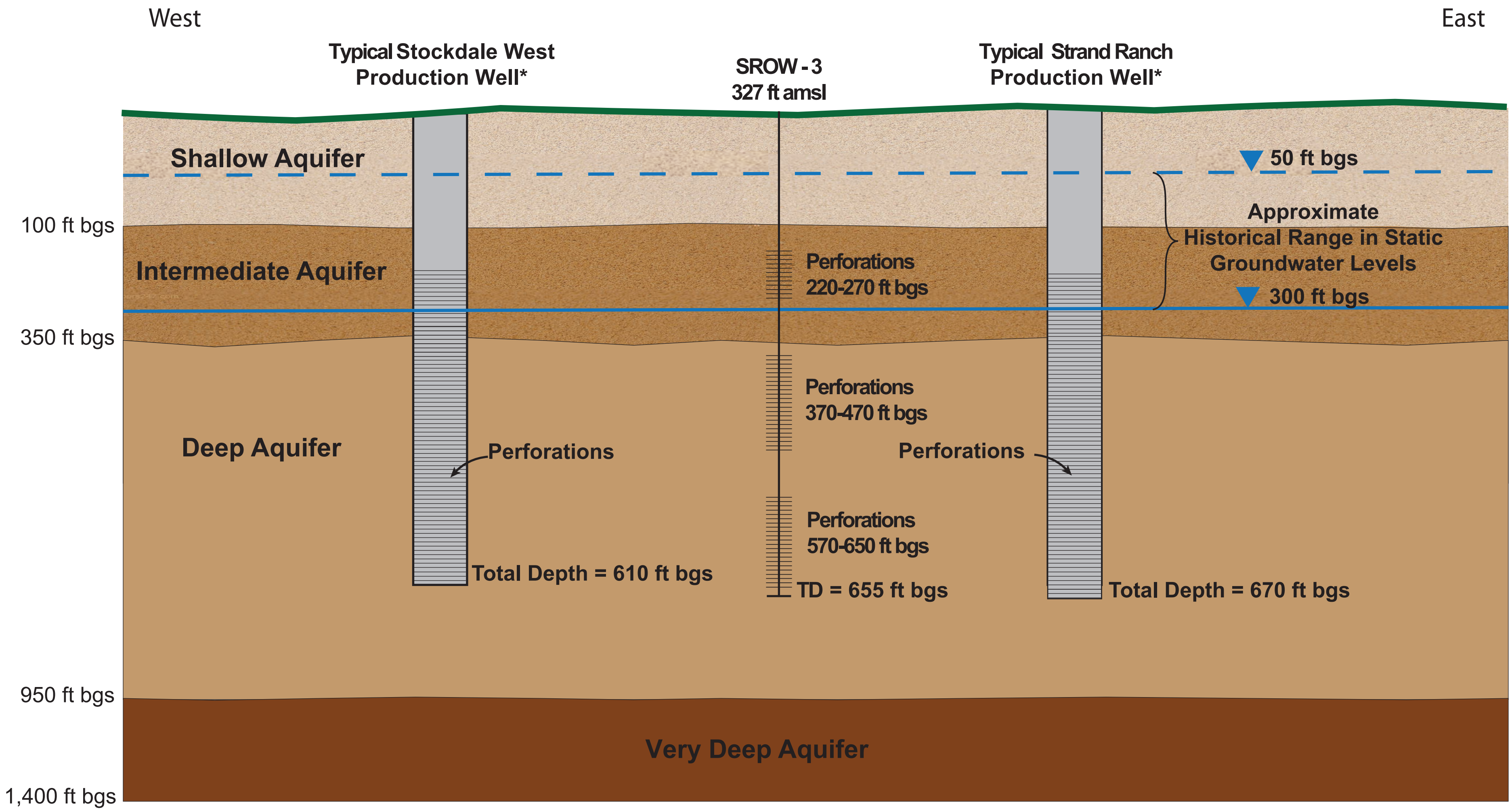

Note:

*Not to scale.
ft bgs = feet below ground surface.

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Conceptual Aquifer Diagram Stockdale West and Strand Ranch
Figure 5

Notes:

Data from Thomas Harder & Co., Irvine Ranch Water District, Rosedale Rio-Bravo Water Storage District, Kern County Water Agency, and Wildermuth Environmental, Inc.
*SREX-4 has been destroyed and replaced with SREX-4R.
gpm = gallons per minute
mg/L = milligrams per liter
µg/L = micrograms per liter

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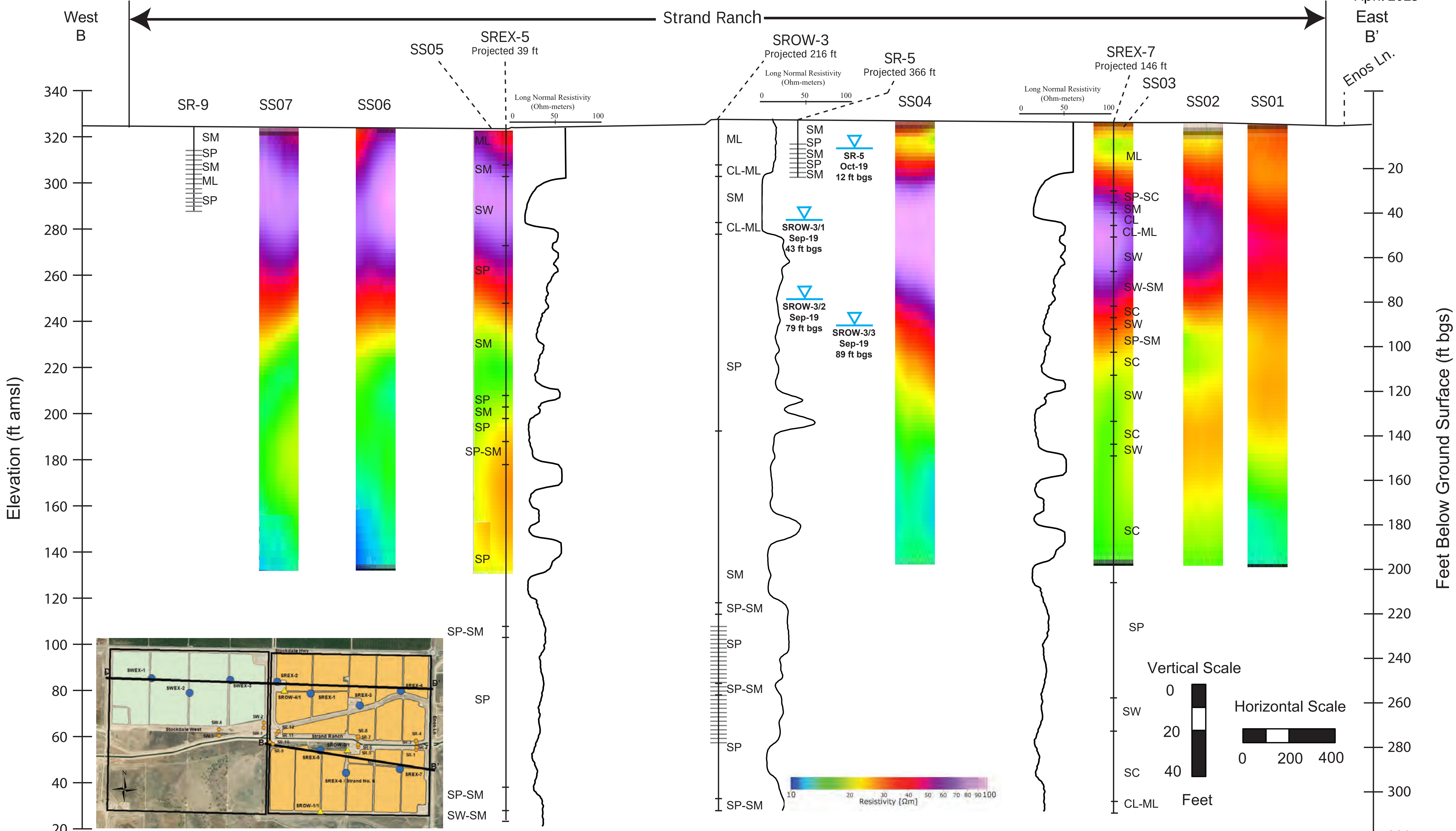
Figure 6

Hydrogeologic Cross Section A-A'
Stockdale West and Strand Ranch

Hydrogeologic Cross Section B-B' - South Strand Ranch



Notes:

Data from Wildermuth Environmental, Inc.,
Ramboll Kern Fan Shallow Hydrogeologic Assesment
tTEM - Geophysics, Google Earth

Figure 7
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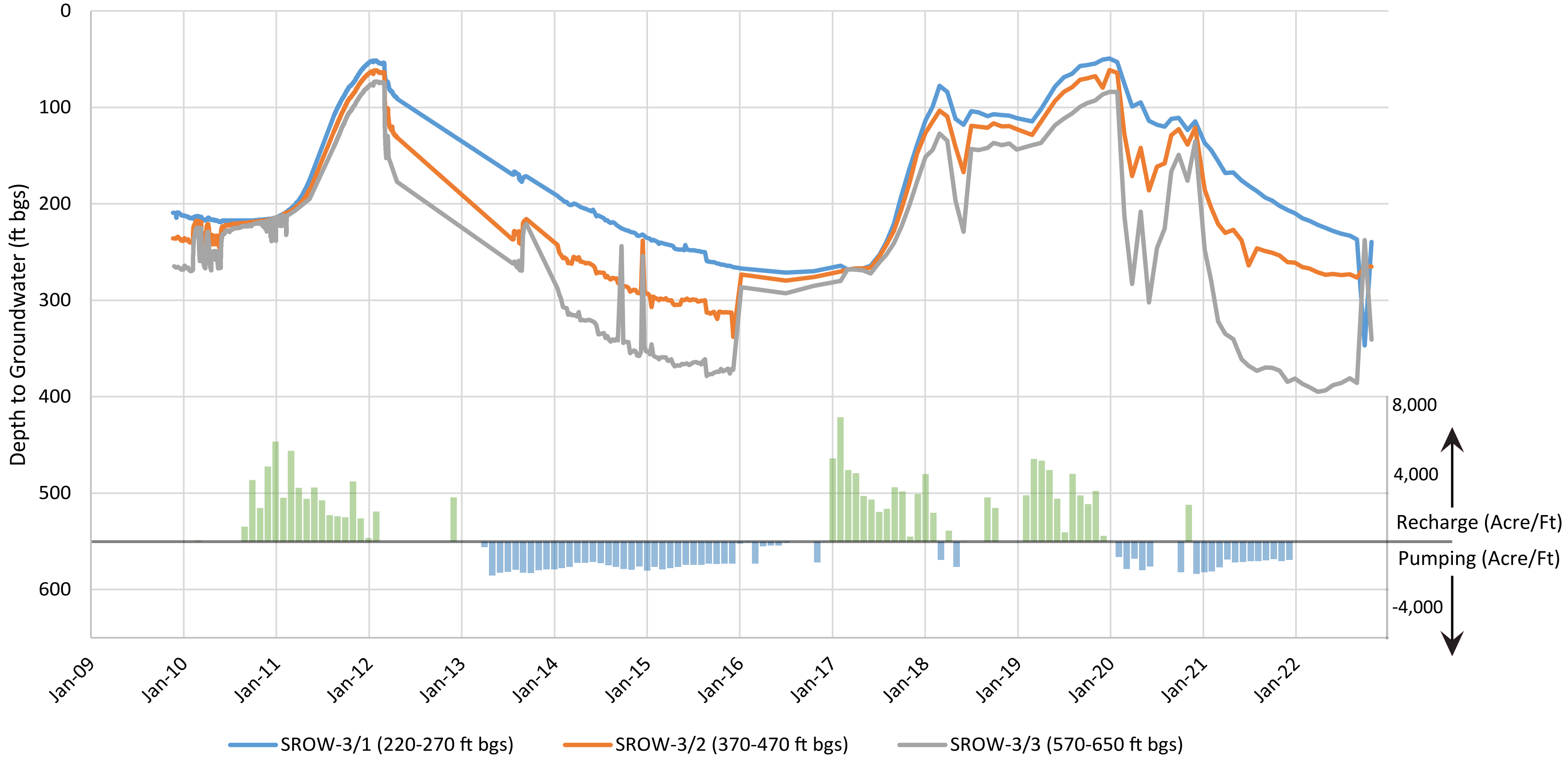
SROW-3 Hydrographs and Strand Ranch Recharge and Pumping



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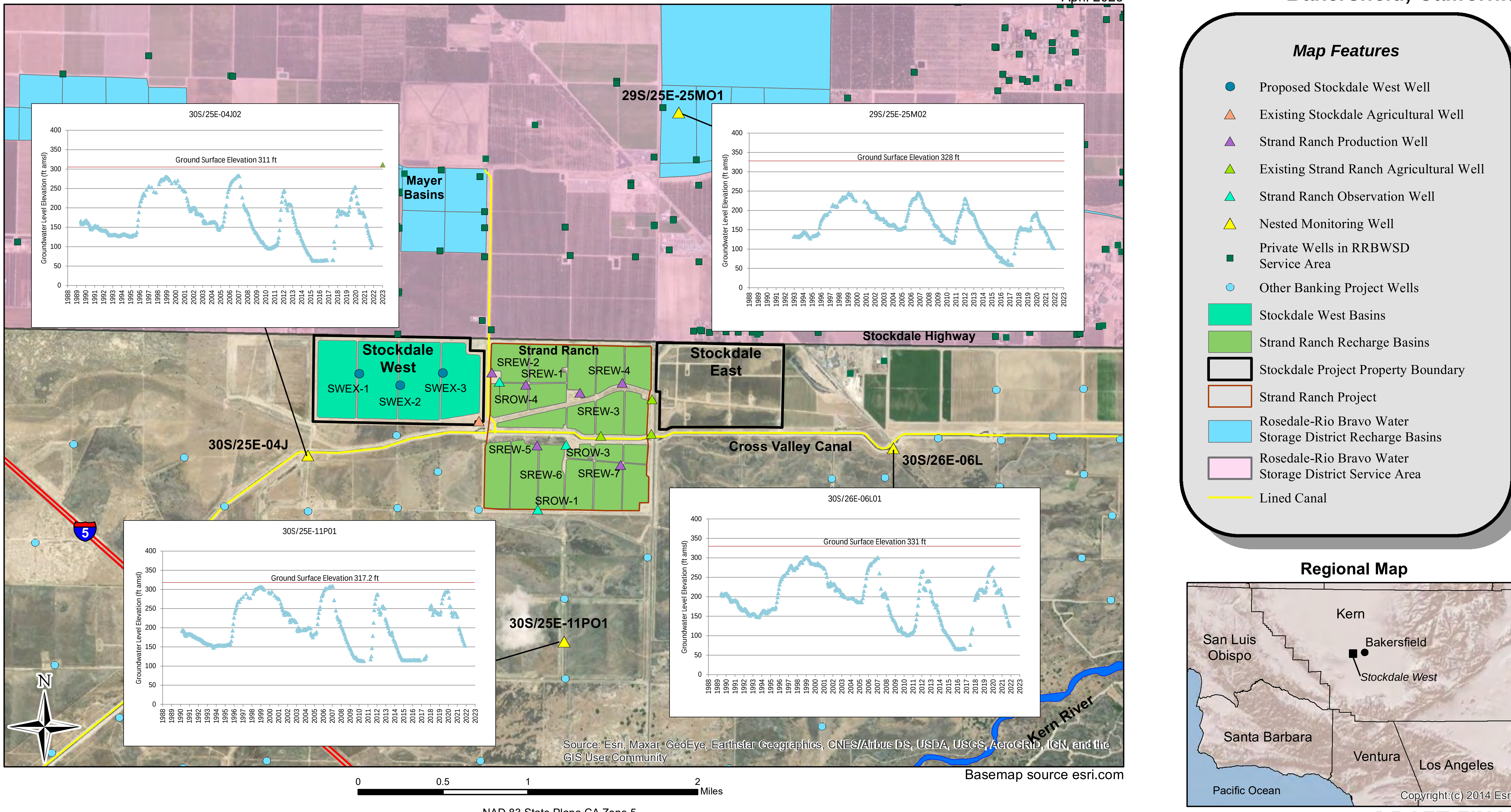
April 2023

Recharge Enhancement Study
Preliminary Design Report -
Bakersfield, California

April 2023



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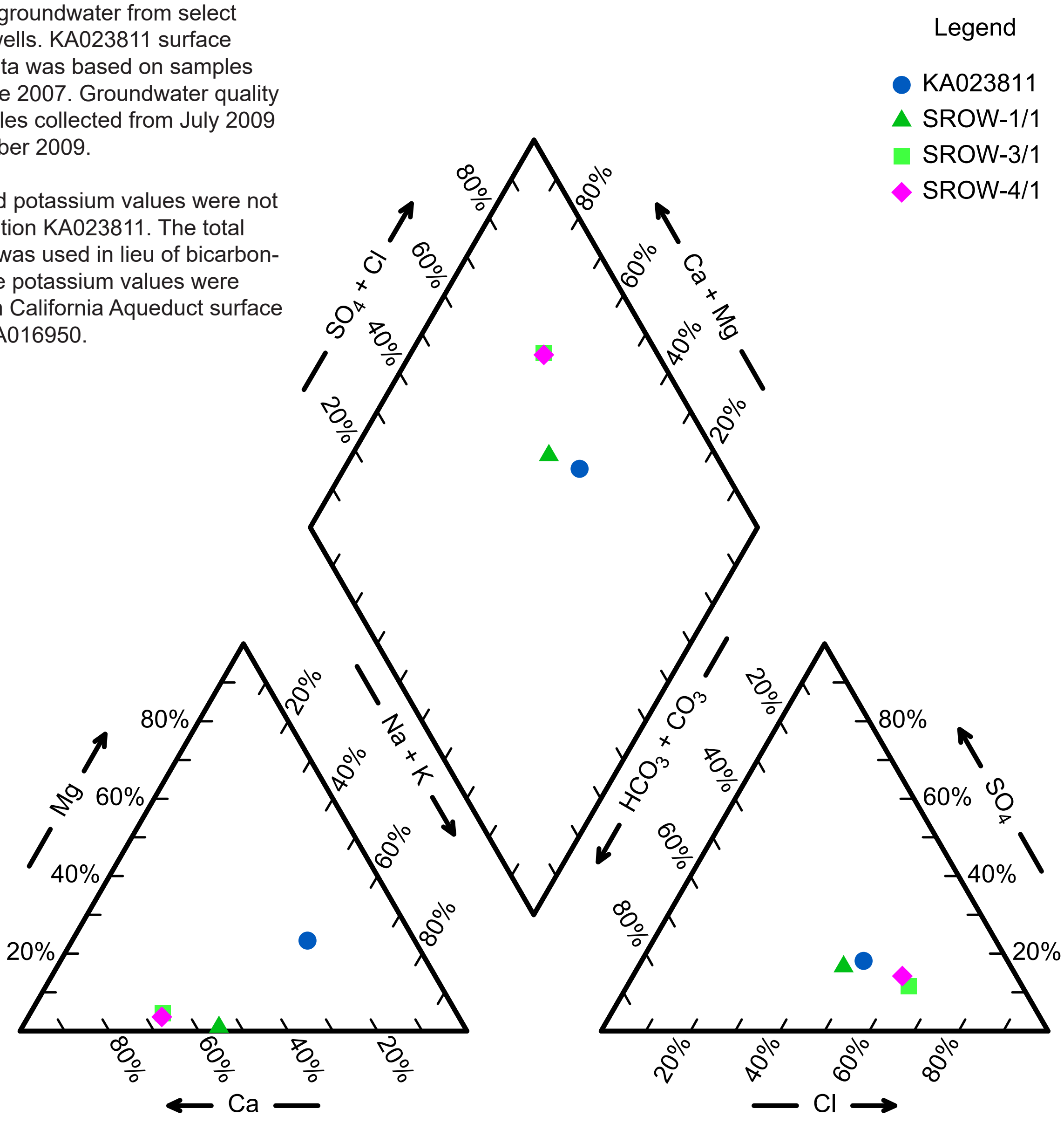
Study Area Hydrographs
Figure 9

Water Quality Trilinear Diagram
California Aqueduct Water Quality Station and Intermediate Aquifer Groundwater

This figure shows the general chemical characteristics of surface water from California Aqueduct water quality station KA023811 and groundwater from select Strand Ranch wells. KA023811 surface water quality data was based on samples collected in June 2007. Groundwater quality data from samples collected from July 2009 through November 2009.

Bicarbonate and potassium values were not available for station KA023811. The total alkalinity value was used in lieu of bicarbonate data and the potassium values were substituted from California Aqueduct surface water station KA016950.



Notes:
Data from California Department of Water Resources (2022) and from Strand Ranch Well Completion Reports (2010).

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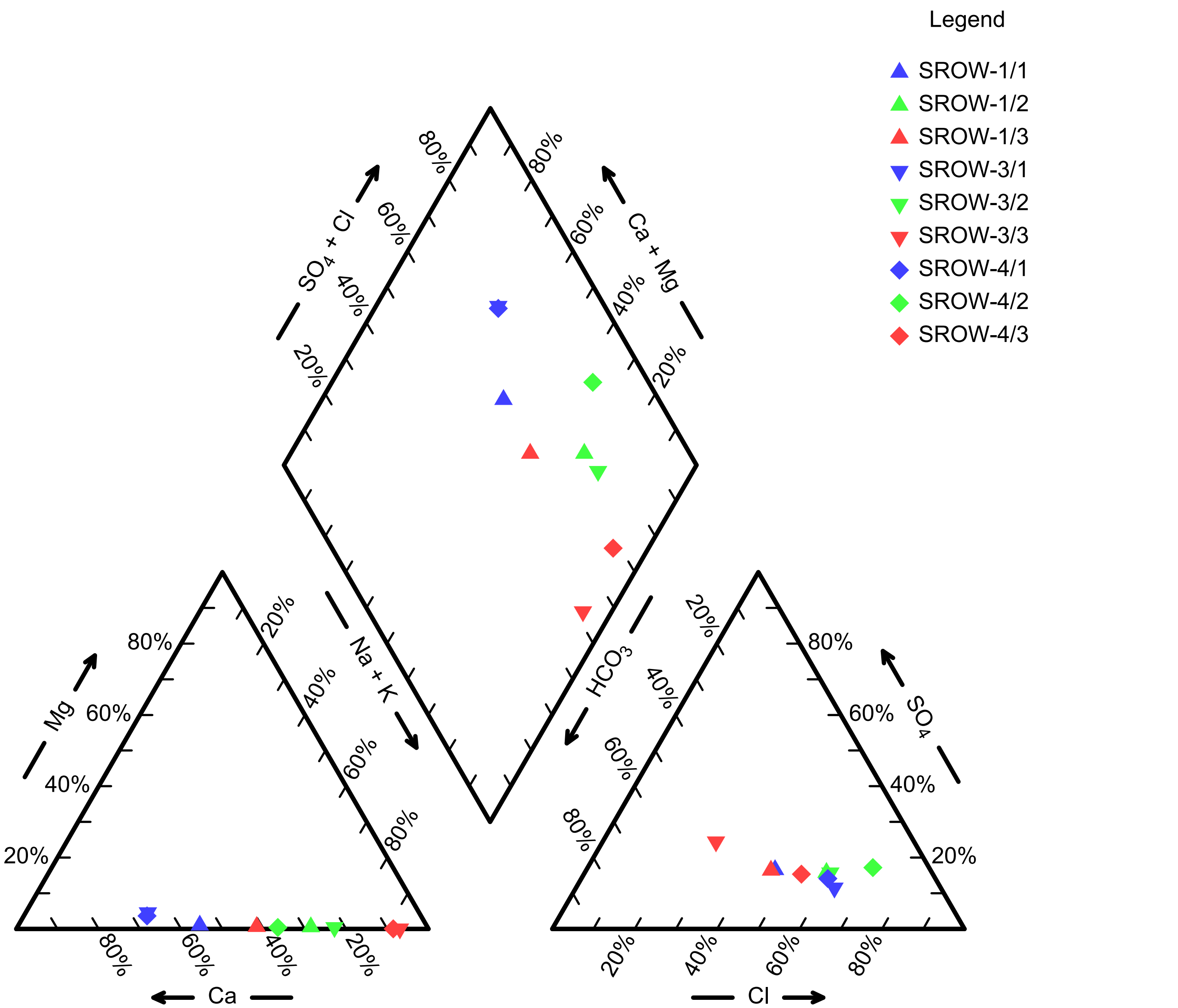
Water Quality Trilinear Diagram
Intermediate and Deep Aquifer Groundwater



Notes:
Data from California Department of Water Resources (2022) and from Strand Ranch Well Completion Reports (2010).

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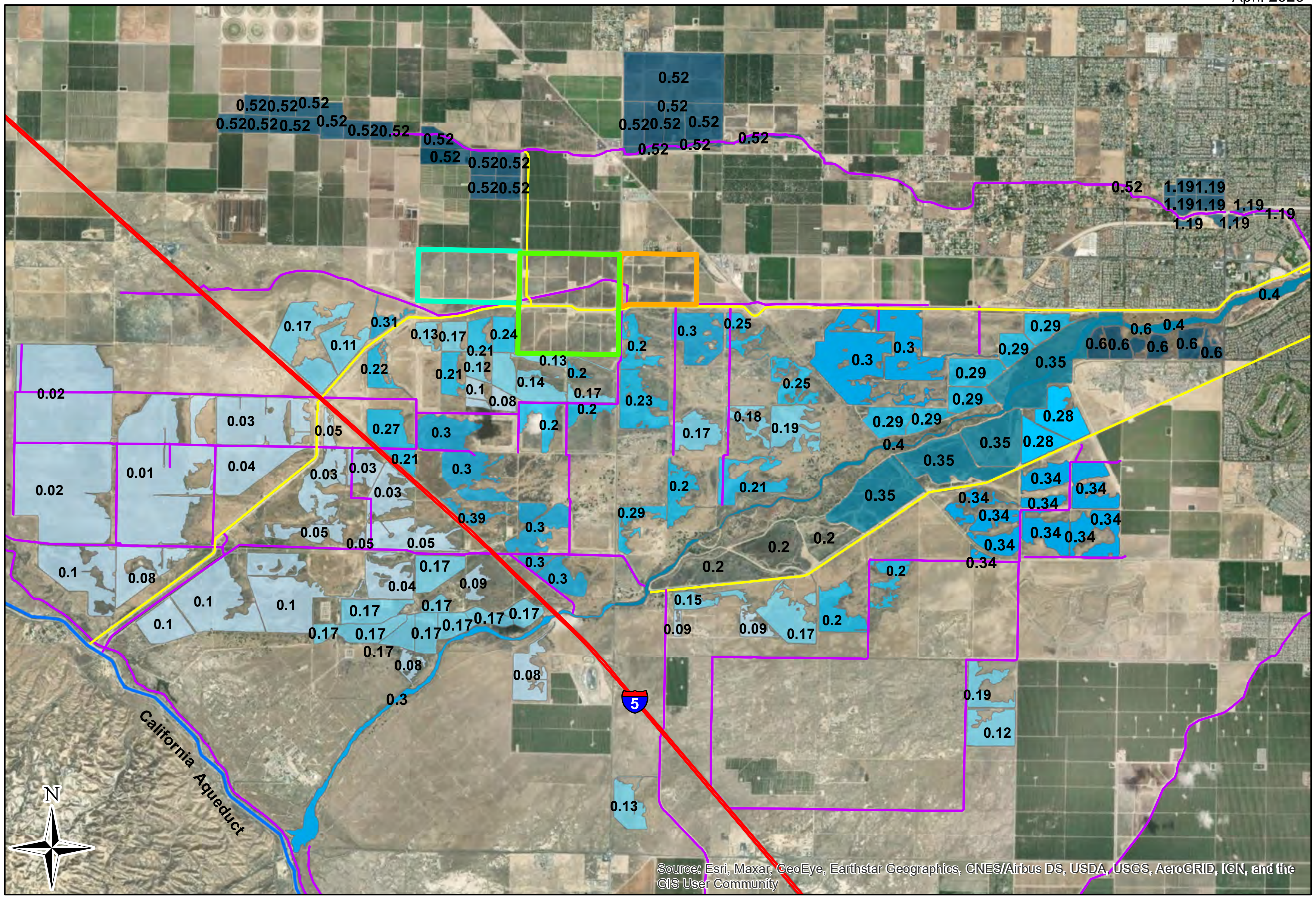
April 2023



Map Features

Infiltration Rate (ft/day)

- < 0.10
- 0.11 - 0.20
- 0.21 - 0.30
- 0.31 - 0.40
- 0.41 - 0.50
- > 0.51
- Strand Ranch
- Stockdale East
- Stockdale West
- Unlined Canal
- Lined Canal
- Aqueduct
- Interstate

Notes: Data from1995-2005 and provided by KCWA infiltration test or pond drops, from Pioneer & 2800 Acres Recharge Rates, KCWA 1/20/06, and provided by RRBWSD.

0 0.5 1 2 Miles

NAD 83 State Plane CA Zone 5
Central Meridian: -118

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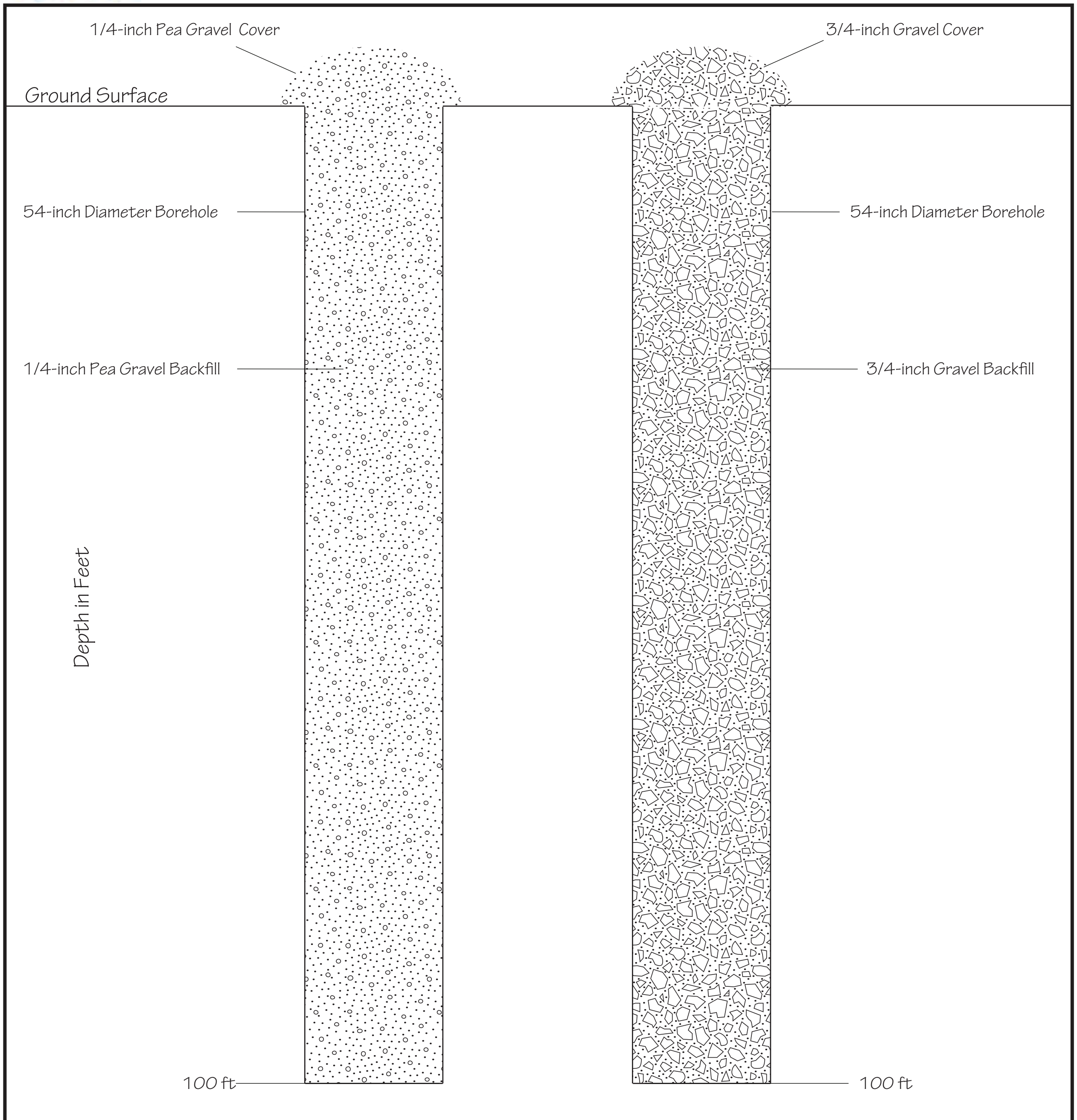
Kern Fan Area Infiltration Rates

Figure 12



Note:
1. Not to Scale.
2. Centralizers to be placed every 50 ft in screened sections and every 100 ft in blank sections.
3. Four protective cement-filled mild steel bollards.

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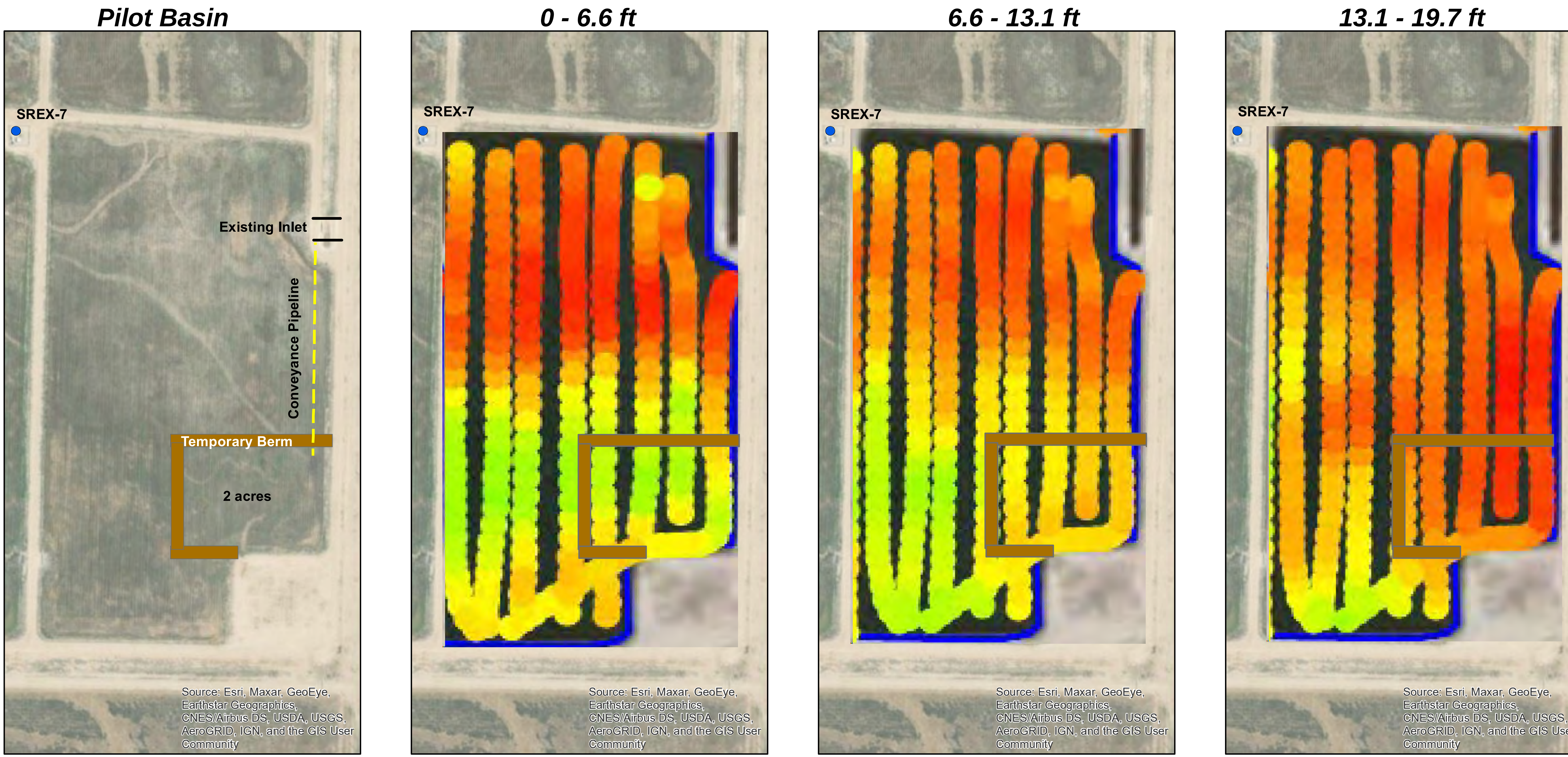
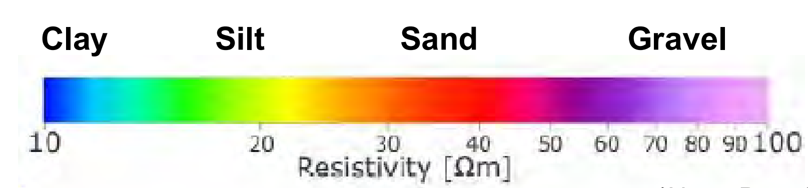
Dry Well Conceptual Diagram Figure 13





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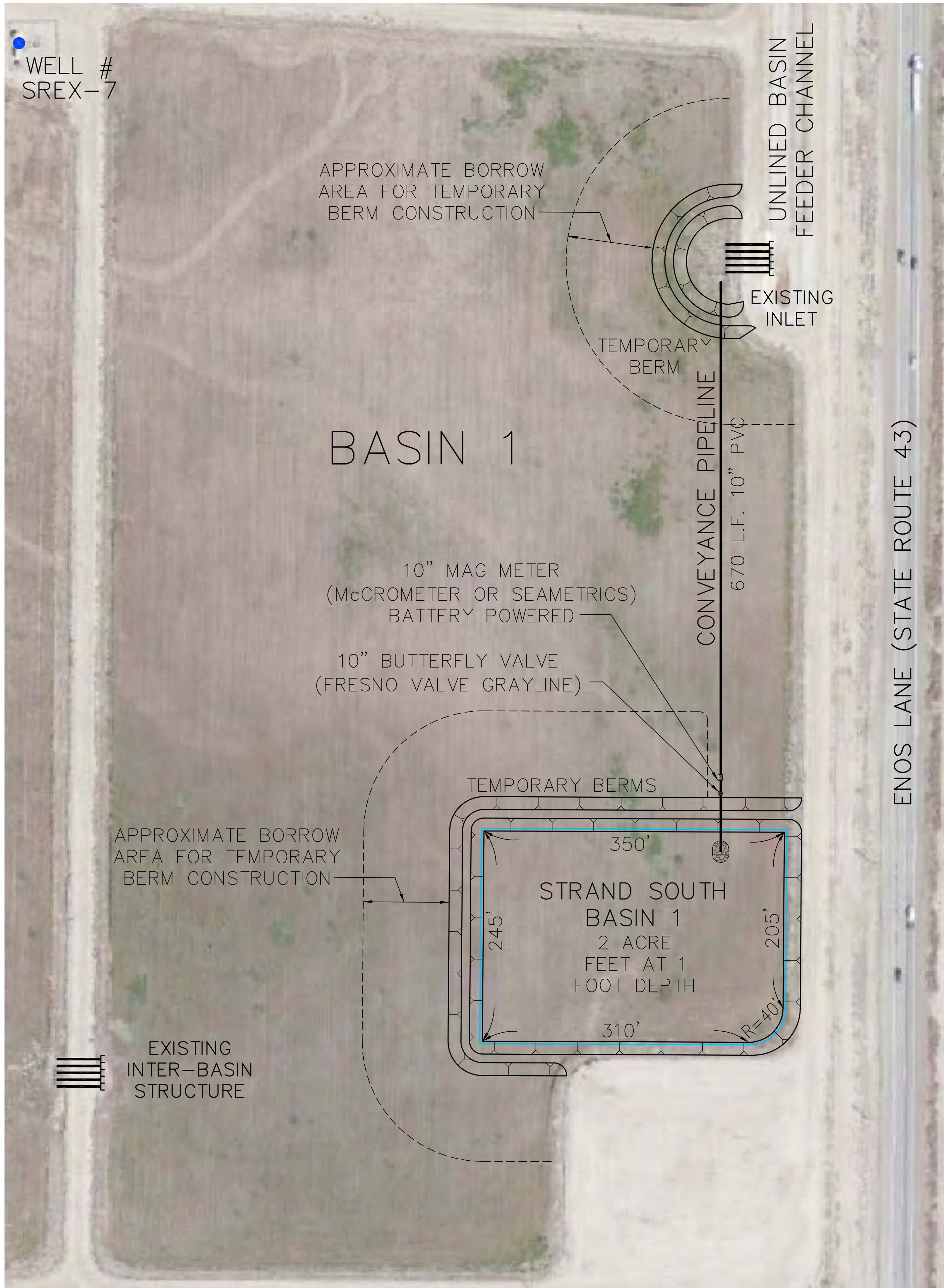
South Strand Basin 1 Over Excavation Pilot Test Concept

Figure 14
DRAFT-FINAL

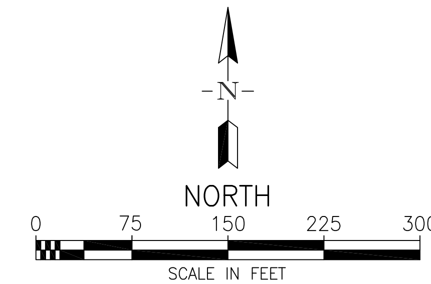
*Note: Data from Report titled:
'Kern Fan Shallow Hydrogeologic Assessment'
- Appendix 3 ' Resistiviy in Depth Intervals'
tTEM - GEOPHYSICS
Published: February 2020

DRAFT-FINAL

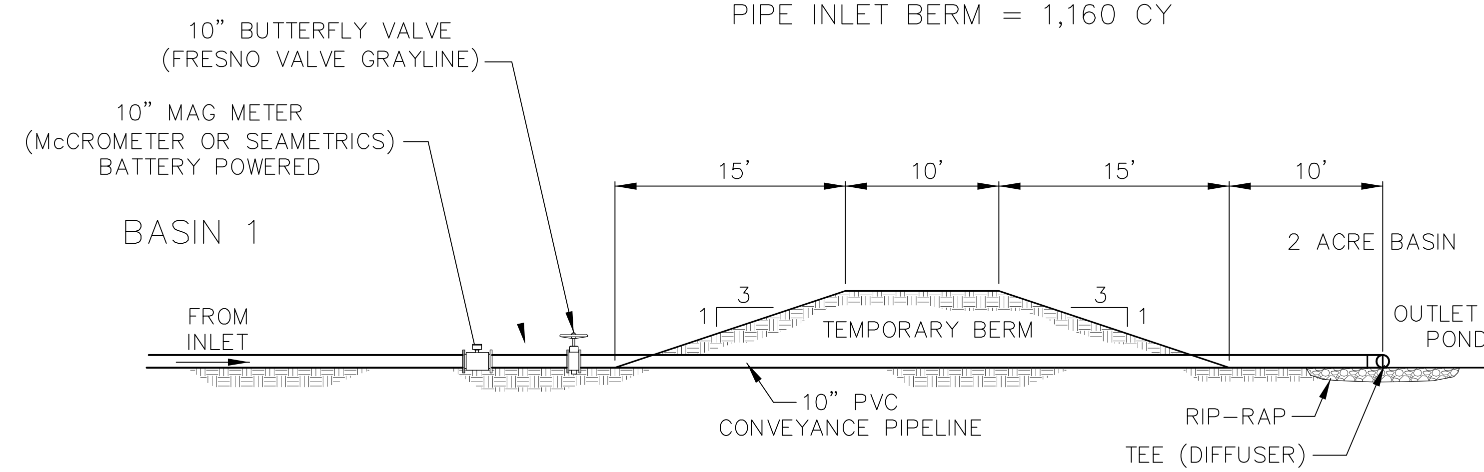
Over Excavation Concept
Strand South Basin 1



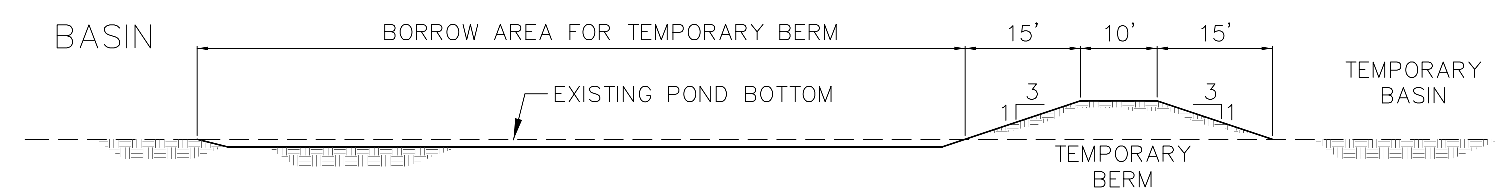
NOTE:
BORROW AREA FOR PONDS SHALL NOT BE UNDERNEATH CONVEYANCE PIPELINE



EARTHWORK VOLUMES:
(TEMPORARY BERM CONSTRUCTION)
BASIN 1 BERM = 3,680 CY
PIPE INLET BERM = 1,160 CY



PIPELINE THROUGH TEMPORARY BERM INTO 2 ACRE BASIN
NOT TO SCALE



TEMPORARY BORROW AREA SECTION FOR TEMPORARY BERM CONSTRUCTION
NOT TO SCALE

Thomas Harder & Co.
Groundwater Consulting

ZEIDERS CONSULTING
WATER ENGINEERS
"SERVING KERN COUNTY SINCE 1988"

Irvine Ranch Water District

Figure 15

Recharge Enhancement Study
Preliminary Design Report - Bakersfield, California

April 2023

Map Features

- Distributed Temperature Probe
- Soil Moisture Neurtron Probe
- Monitoring Well
- Staff Gage
- ERT
- Conveyance Pipeline
- Temporary Berm

DRAFT-FINAL

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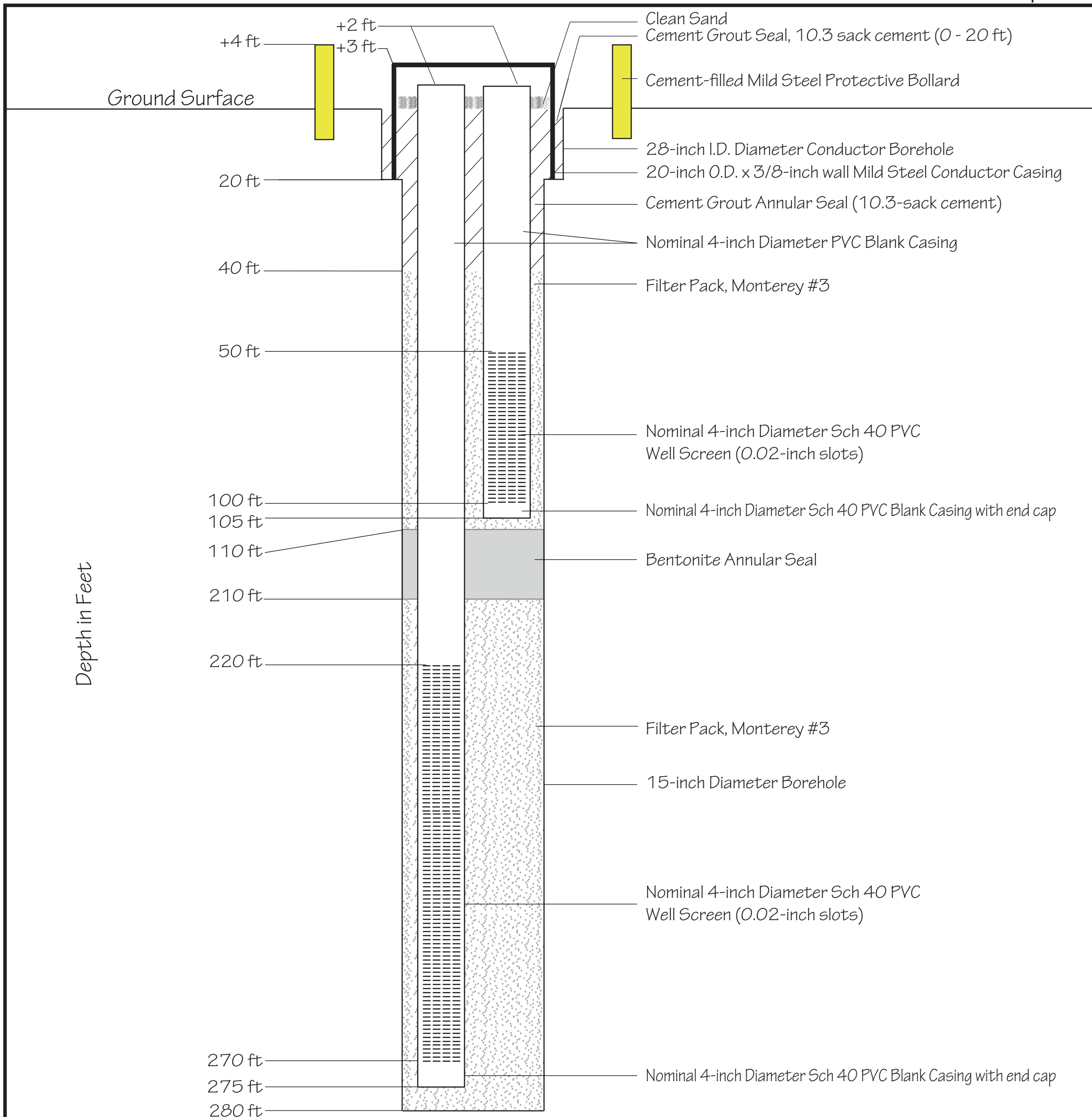
Strand Ranch Pilot Basin Instrumentation Plan Over Excavation

Figure 16

DRAFT-FINAL



Note:
1. Not to Scale.
2. Centralizers to be placed every 50 ft in screened sections and every 100 ft in blank sections.
3. Four protective cement-filled mild steel bollards.

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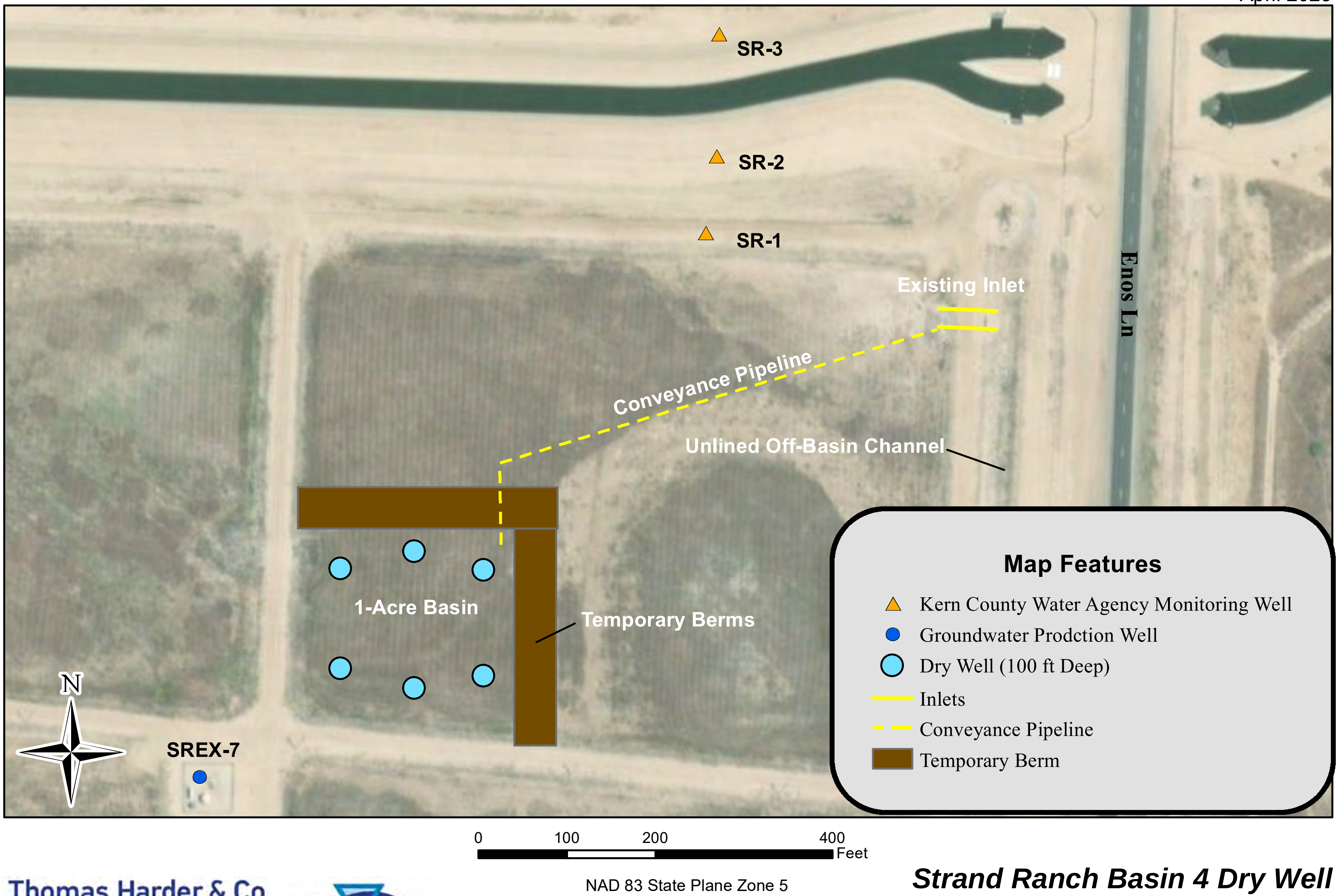
**Strand Ranch Pilot Basin
Nested Monitoring Well
Conceptual Design
Figure 17**

DRAFT-FINAL



Thomas Harder & Co.
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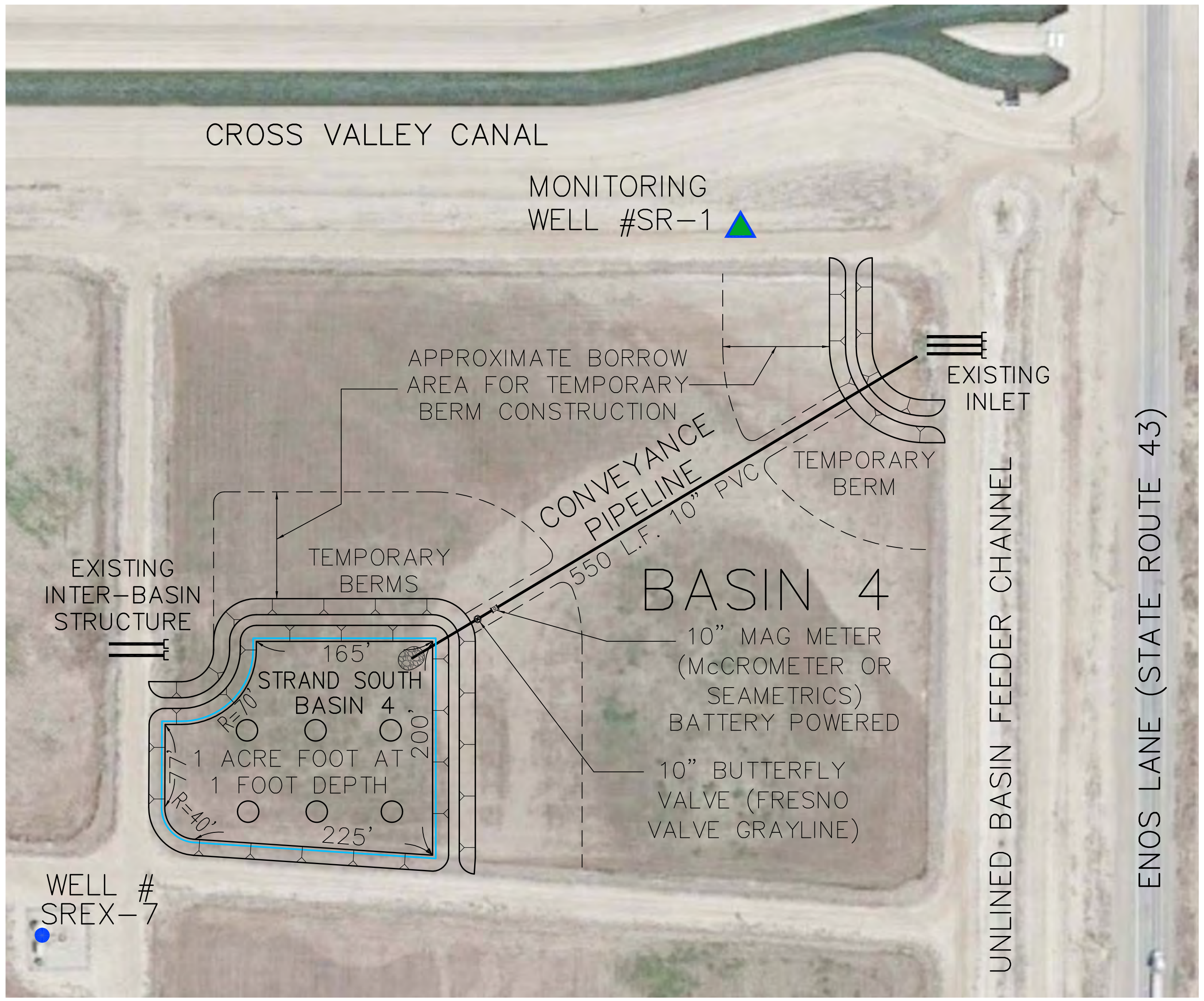
Strand Ranch Basin 4 Dry Well Pilot Test Concept
Figure 18

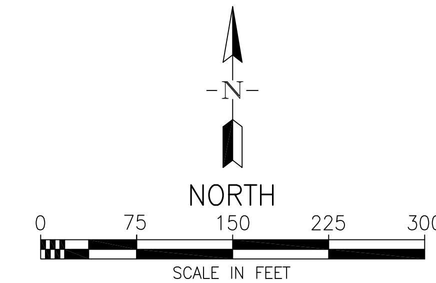
DRAFT-FINAL

Dry Well Concept
Strand South Basin 4

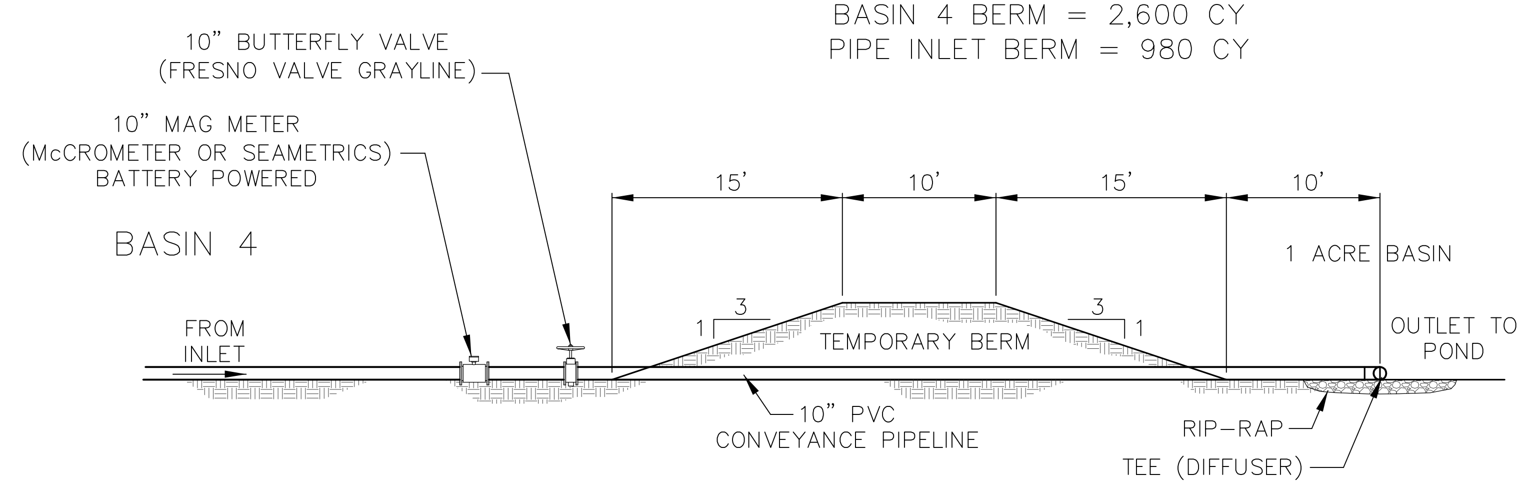


NOTE:
BORROW AREA FOR PONDS SHALL NOT BE UNDERNEATH CONVEYANCE PIPELINE

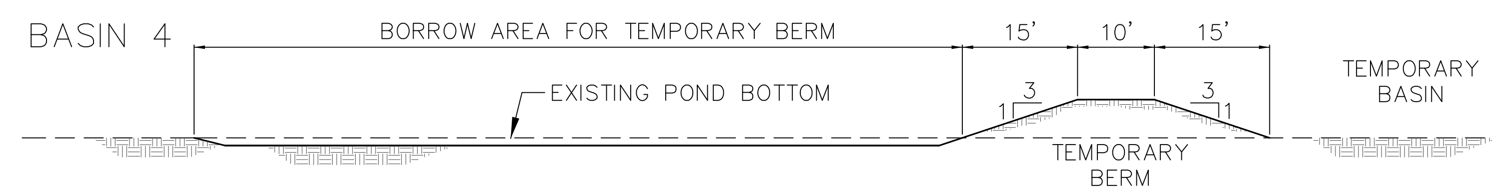
○ = CONCEPTUAL DRY WELL



EARTHWORK VOLUMES:
(TEMPORARY BERM CONSTRUCTION)
BASIN 4 BERM = 2,600 CY
PIPE INLET BERM = 980 CY



PIPELINE THROUGH TEMPORARY BERM INTO 1 ACRE BASIN
NOT TO SCALE



TEMPORARY BORROW AREA SECTION FOR TEMPORARY BERM CONSTRUCTION
NOT TO SCALE

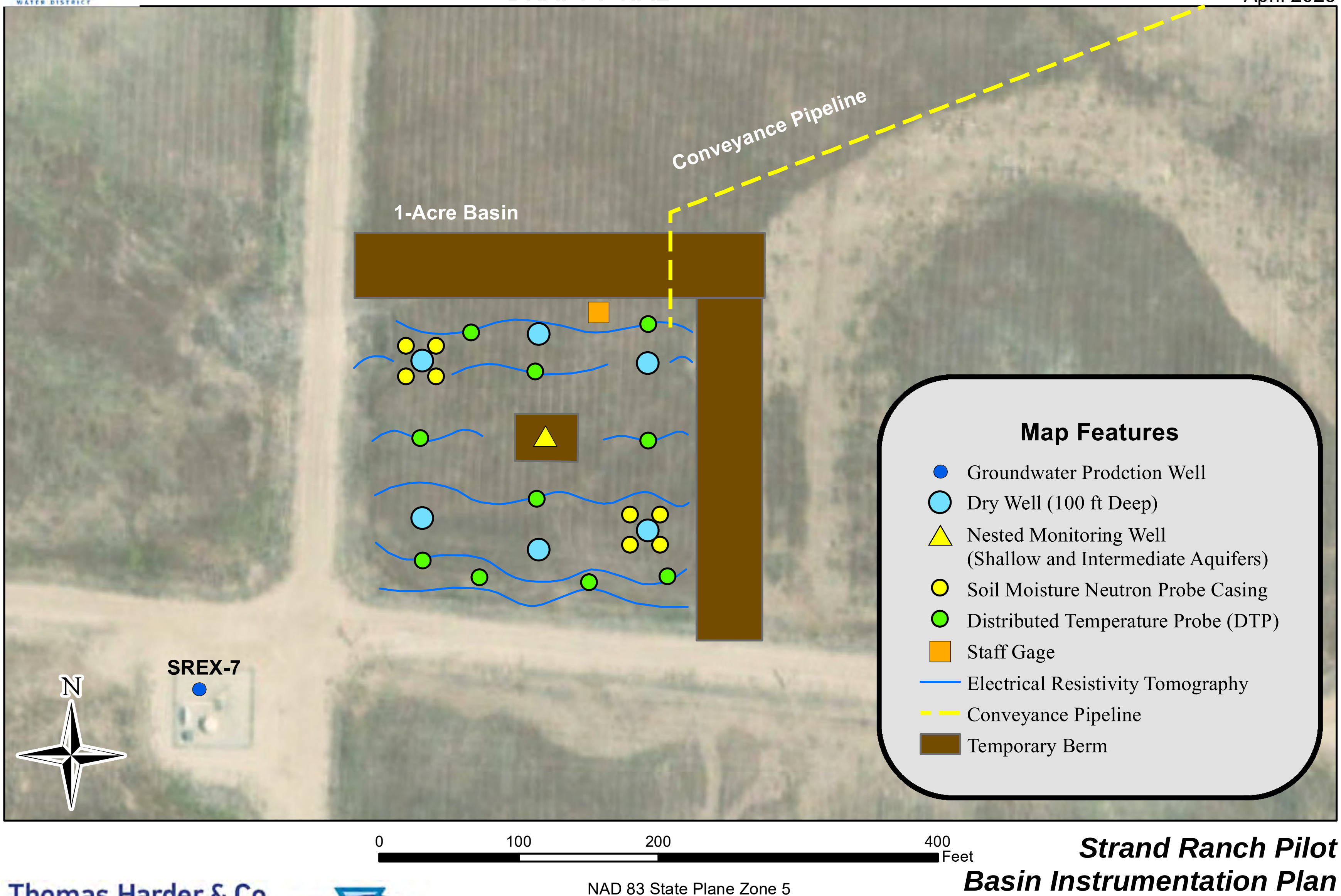
Thomas Harder & Co. Groundwater Consulting

ZEIDERS CONSULTING WATER ENGINEERS "SERVING KERN COUNTY SINCE 1988"

Irvine Ranch Water District

Figure 19

DRAFT-FINAL



Thomas Harder & Co.
Groundwater Consulting

Strand Ranch Pilot Basin Instrumentation Plan Dry Wells
Figure 20

Tables

Summary of Imported Surface Water and Groundwater Quality Data from the Study Area

Location	Source	Perforation Interval	Sample Date	Turbidity (NTU)[1]	Total Suspended Solids (mg/L)[2]	Total Dissolved Solids (mg/L)[2]	Sulfate (mg/L)	Chloride (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Alkalinity (as CaCo3) (mg/L)	Bicarbonate (as CaCo3) (mg/L)	Carbonate (as CaCo3) (mg/L)
KA016950	Surface Water	-	12/3/1990	-	-	-	-	-	-	-	-	4.2	-	-	-
KA023811	Surface Water	-	3/6/2001	3	3	299	54	78	26	15	60	-	85	-	-
KA023811	Surface Water	-	5/1/2007	4	-	233	35	63	19	11	45	-	73	-	-
KA023811	Surface Water	-	5/15/2007	5	-	246	35	69	20	12	51	-	77	-	-
KA023811	Surface Water	-	6/7/2007	4	-	261	34	69	22	13	53	-	79	-	-
SROW-1/1	Groundwater	250 - 290	7/30/2009	0.39	-	380	45	92	63	0.71	58	<2	130	130	<1
SROW-1/2	Groundwater	430 - 470	7/30/2009	<0.1[3]	-	320	35	96	28	0.32	81	<2	72	72	<1
SROW-1/3	Groundwater	550 - 590	7/29/2009	0.15	-	320	40	81	44	0.39	71	<2	120	120	<1
SROW-3/1	Groundwater	220 - 270	11/19/2009	0.12	-	680	42	170	110	4.60	57	<2	120	120	<1
SROW-3/2	Groundwater	370 - 470	11/6/2009	<0.1	-	180	21	59	13	0.14	51	<2	43	42	1.5
SROW-3/3	Groundwater	570 - 650	11/10/2009	<0.1	-	100	12	10	2.2	<0.1	34	<2	59	30	29
SROW-4/1	Groundwater	220 - 260	9/21/2009	0.18	-	590	51	160	110	3.60	57	<2	120	120	<1
SROW-4/2	Groundwater	350 - 450	9/24/2009	0.12	-	340	35	104	40	0.26	80	<2	35	35	<1
SROW-4/3	Groundwater	605 - 665	10/1/2009	<0.1	-	110	11	28	3.4	<0.1	42	<2	48	29	20

Notes:

[1] NTU - nephelometric turbidity unit

[2] mg/L - milligrams per liter

[3] <X - Analyte not detected above the detection limit

Surface water data used on the trilinar diamgram is highlighted yellow.

Staff Gauge Readings for January 2012 Pond Drop Test

Area	Basin Number	Acres	Jan-5 (ft)	Jan-6 (ft)	Jan-7 (ft)	Jan-8 (ft)	Jan-9 (ft)	Jan-10 (ft)	Jan-11 (ft)	Jan-12 (ft)	Jan-13 (ft)	Jan-14 (ft)	Infiltration Rate[1] (ft/day)
South Strand	1	25.46	3.00	2.80	2.66	2.56	2.42	2.30	2.20	2.06	1.92	1.78	0.14
South Strand	2	31.44	-[2]	2.10	2.00	1.96	1.86	1.80	1.70	1.60	1.50	1.40	0.09
South Strand	3	32.21	-	1.68	1.58	1.52	1.42	1.32	1.24	1.14	1.06	0.96	0.09
South Strand	4	9.94	3.08	2.48	2.00	1.66	1.30	0.96	0.64	-	0.38	0.30	0.31
South Strand	5	10.56	2.38	2.04	1.66	1.40	1.12	0.84	0.58	0.32	0.00	-	0.30
South Strand	6	7.54	2.30	1.96	1.62	1.34	1.06	0.78	0.50	0.26	0.00	-	0.29
South Strand	18	37.00	1.72	1.68	1.60	1.50	1.42	1.34	1.24	1.16	1.06	0.96	0.08
South Strand	19	40.00	1.40	1.34	1.24	1.16	1.10	1.00	0.96	0.84	0.74	0.64	0.08
South Strand	20	38.00	0.32	0.22	0.12	0.00	-	-	-	-	-	-	0.11
North Strand	7	21.35	2.78	2.46	2.20	2.04	1.90	1.80	1.70	1.60	1.52	1.44	0.15
North Strand	8	25.44	2.30	2.24	2.16	2.10	2.04	1.96	1.90	1.84	1.76	1.68	0.07
North Strand	9	17.66	2.26	2.22	2.22	2.18	2.14	2.12	2.12	2.12	2.12	2.10	0.02
North Strand	10	19.80	1.84	1.80	1.76	1.70	1.66	1.60	1.56	1.52	1.46	1.40	0.05
North Strand	11	24.29	2.50	2.10	1.98	1.90	1.80	1.70	1.60	1.48	1.36	1.12	0.15
North Strand	12	26.56	2.52	2.10	2.00	1.96	1.90	1.74	1.70	-	1.76	1.62	0.10
North Strand	13	30.60	2.44	2.08	1.84	1.76	1.72	1.66	1.64	1.62	1.56	1.56	0.10
North Strand	14	19.16	2.58	2.36	2.16	2.04	1.84	1.64	1.46	1.26	1.10	0.96	0.18
North Strand	15	25.89	2.26	2.08	1.98	1.72	1.56	1.36	1.14	0.98	0.80	0.62	0.18
North Strand	16	32.05	-	-	2.04	1.94	1.86	1.80	-	1.66	1.64	1.60	0.06
North Strand	17	30.88	-	-	2.40	2.30	2.20	2.02	1.88	1.74	1.60	1.42	0.14
Stockdale West	1	57.80	2.58	2.50	2.26	2.12	1.98	1.80	1.66	1.50	1.34	1.18	0.16
Stockdale West	2	69.00	2.70	2.60	2.40	2.24	2.02	1.86	1.68	1.50	1.30	1.14	0.17
Stockdale West	3	67.10	2.46	2.40	2.24	2.16	2.04	1.94	1.82	1.70	1.60	1.44	0.11
Stockdale West	4	56.50	1.86	1.66	1.50	1.32	1.06	1.00	0.84	0.68	0.54	0.40	0.16

Notes:

[1]Infiltration rate is equal to the first measurement minus the last measurement, divided by the number of days.

[2]Indicates measurements not used in the analysis.

Analysis of Strand Ranch Basin Infiltration Rates
North Basins

Recharge Period	Date	Average Inflow (cfs)	Average Inflow (acre-ft/day)	Estimated Infiltration Rate[1] (ft/day)
	1-Jan-12			**0.11**
1	5/21/17 - 7/25/17	43.60	86	0.33
2	9/3/2017 - 11/3/2017	54.40	108	0.41
3	12/13/2017 - 2/4/2018	60.90	121	0.45
4	3/22/2019 - 6/25/2019	51.60	102	0.38
5	8/2/2019 - 10/15/2019	54.40	108	0.41
			Average:	0.40

Notes:

[1]Based on a total area of the North Basins of approximately 266 acres.

Analysis of Strand Ranch Basin Infiltration Rates
South Basins

Recharge Period	Date	Average Inflow (cfs)	Average Inflow (acre-ft/day)	Estimated Infiltration Rate[1] (ft/day)
	1-Jan-12			**0.16**
1	3/1/2017 - 3/31/2017	18.19	36	0.16
2	4/1/2017 - 4/30/2017	20.77	41	0.18
3	5/1/17 - 7/16/17	17.43	35	0.15
5	9/13/2017 - 10/31/2017	16.90	34	0.15
6	1/5/2018 - 2/1/2018	21.00	42	0.19
			Average:	0.17

Notes:

[1]Total area of the South Basins is approximately 224 acres.

Laboratory Water Quality Testing Suite

Constituent	Units	Detection Limit	Method
General Physical Properties			
Color	Color Unit	3.0	SM-2120B
Odor	Odor Unit	1.0	SM-2150B
Turbidity*	NTU	0.2	SM-2130B
General Minerals			
Ammonia as N	mg/L	0.1	EPA-350.1
Ortho Phosphate as P	mg/L	0.1	EPA-365.1
Total Phosphate	mg/L	0.2	EPA-365.4
Total Phosphorus as P	mg/L	0.1	EPA-365.4
Total Hardness	mg/L	3.1	SM 2340B/EPA
Calcium	mg/L	1.0	EPA-200.7
Magnesium	mg/L	1.0	EPA-200.7
Sodium	mg/L	1.0	EPA-200.7
Potassium	mg/L	1.0	EPA-200.7
Total Alkalinity, as $CaCO_3$	mg/L	3.0	SM 2320B
Hydroxide	mg/L	3.0	SM-2320B
Carbonate	mg/L	3.0	SM-2320B
Bicarbonate	mg/L	3.0	SM-2320B
Sulfate	mg/L	0.5	EPA-300.0
Chloride	mg/L	1.0	EPA-300.0
Nitrate, as N	mg/L	0.2	EPA-300.0
Fluoride	mg/L	0.1	EPA-300.0
pH*	pH unit	1.0	EPA-150.1
Temperature*			
Electrical Conductance*	µmhos/cm	1.0	SM-2510B
Total Dissolved Solids (TDS)	mg/L	20.0	SM-2540C

Explanation of Units
NTU - nephelometric turbidity units
mg/L - milligrams per liter
µmhos/cm - micromhos per centimeter
µg/L - micrograms per liter

*Temperature, pH, electrical conductivity and turbidity will also be measured in the field.

Strand Ranch Recharge Enhancement Pilot Tests
Planning Level Cost Estimates

Description	Planning Cost
Basin 1 Basin Over Excavation and Pilot Testing	
Labor (TH&Co and LBL)	$271,000
TH&Co Direct Costs	$21,000
Monitoring Well Drilling Contractor	$222,000
Neutron Probe Drilling Contractor	$58,000
Laboratory Costs	$5,000
Instrumentation Costs	$28,000
Excavation/Pipeline Costs	$152,500
Total Basin 1 Deepening and Testing	**$757,500**
15% Contingency	**$113,625**
Total Basin 1 with Contingency	**$871,125**

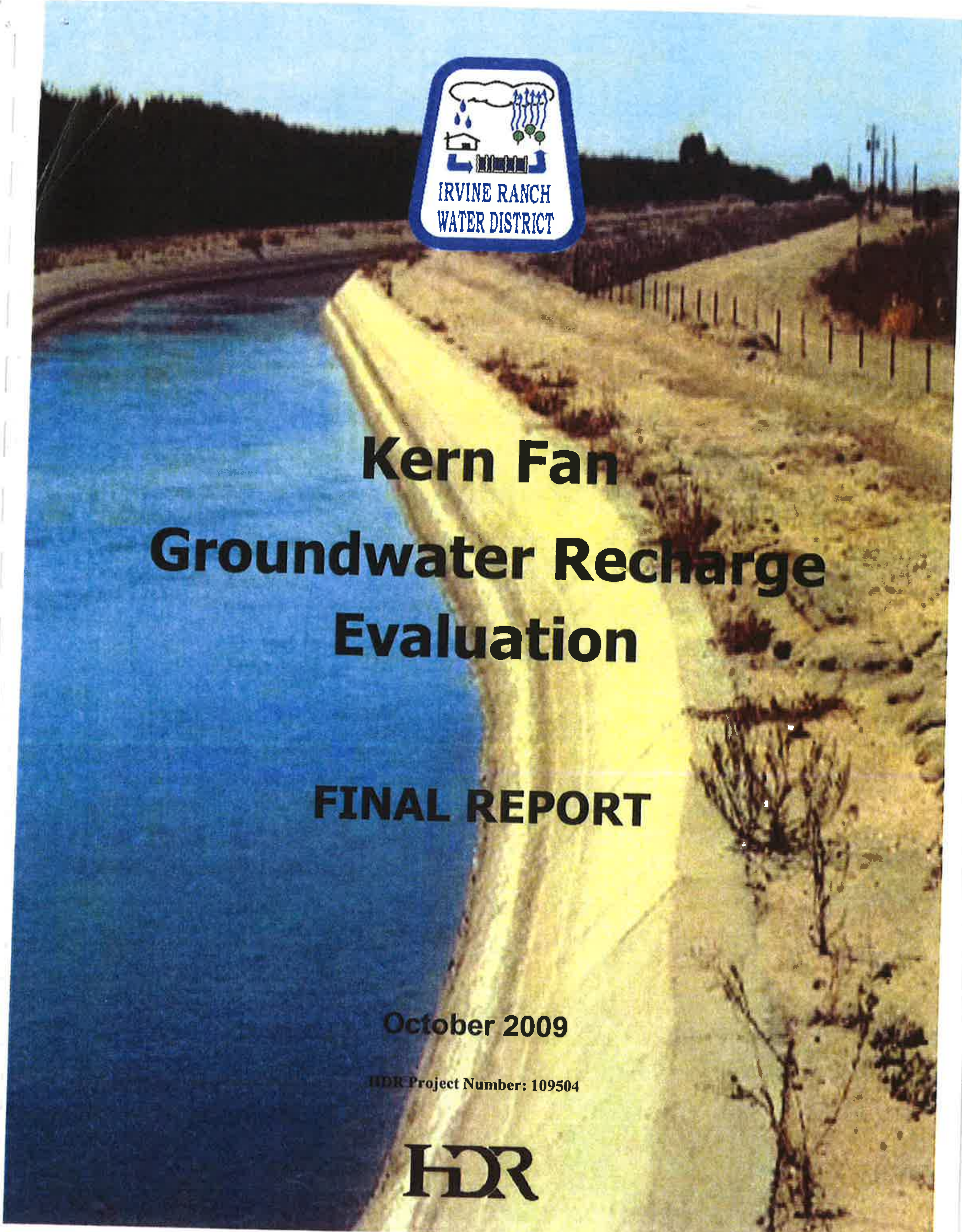
Strand Ranch Recharge Enhancement Pilot Tests
Planning Level Cost Estimates

Description	Planning Cost
Basin 4 Dry Well Pilot Testing	
Labor (TH&Co and LBL)	$305,000
TH&Co Direct Costs	$36,000
Monitoring Well Drilling Contractor	$222,000
Neutron Probe Drilling Contractor	$202,000
Laboratory Costs	$5,000
Instrumentation Costs	$13,000
Excavation/Pipeline Costs	$77,500
Total Basin 4 Dry Well Testing	**$860,500**
15% Contingency	**$129,075**
Total Basin 4 with Contingency	**$989,575**

Appendix A

Kern Fan Groundwater Recharge Evaluation

HDR, 2009



IRVINE RANCH WATER DISTRICT

Kern Fan Groundwater Recharge Evaluation

FINAL REPORT

October 2009

HDR Project Number: 109504

HDR

Irvine Ranch Water District

Kern Fan Groundwater Recharge Evaluation

Final Report

October 2009

HDR

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1.0 Introduction and Study Objectives

This report seeks to identify and evaluate options to improve the cost effectiveness of the Irvine Ranch Water District's (IRWD, District) water banking program at the Kern Fan project area. With the ever increasing demand on local water resources, and the continuing cutbacks in State Project Water (SPW) and Colorado River Water (CRW) supplies, it is of vast importance for water agencies to identify new and innovative opportunities for water banking and maintaining reliable sources of water. Water banking in its simplest form, is a method of temporarily transferring water entitlement based on a user's needs without a permanent change in water rights. For example, in drought years when Metropolitan Water District (MET) allotments are restricted, the water banking approach would provide IRWD with an additional resource to meet consumer demand. IRWD is currently expanding their Kern Fan recharge basins with an initial goal of recharging over 17,500 acre-feet per year. This study presents a comparative analysis of potential methods of recharging water for the purpose of expanding the water banking program and improving the reliability during drought years to provide IRWD customers with increased water supply through redundancy and diversification.

The objectives of this study as included and summarized within this report are as follows:

- Identify the methods currently used to recharge water in the Kern River Fan area.
- Evaluate five potential water recharge/infiltration concepts including the following:
  - Surface Recharge Ponds
  - Subsurface Recharge Galleries
  - Shallow Injection Wells
  - CULTEC Engineered Systems
  - Subsurface Conveyance System
- Evaluate five sediment removal strategies that could be utilized as means of optimizing recharge/infiltration potential.
- Summarize and evaluate findings from the Orange County Water District (OCWD) Recharge Water Sediment Removal (RWSR) feasibility study.
- Develop an appraisal-level, order of magnitude economic evaluation of potential recharge systems and sediment removal strategies including a determination of capital costs, O&M costs and cost per acre-foot of water recharged based on a 40-year project life cycle.
- Establish generalized conclusions and recommendations based on the findings of the comparative analysis study.

The remainder of this report is divided into the following chapters:

- Chapter 2 – Summary of Kern Fan Recharge Systems
- Chapter 3 – Identification of Recharge/Infiltration Systems
- Chapter 4 – Characteristics of Clogging During Artificial Recharge
- Chapter 5 – Sediment Removal Strategies
- Chapter 6 – Summary of OCWD Study/Results
- Chapter 7 – Non-Economic Evaluation
- Chapter 8 – Economic Evaluation
- Chapter 9 – Conclusions and Recommendations

2.0 Summary of Kern Fan Recharge Systems

The Kern Fan area is located within Kern County, which is in the southern central valley of California. Some regions of the county are characterized by hydrogeologic conditions that are well-suited for groundwater recharge operations. Additionally, because of its proximity to federal, state and local water supply conveyance facilities, Kern County is also strategically located *geographically* for groundwater recharge operations.

Water banking and recharge activities have been operated extensively within Kern County for over 10 years in an effort to manage and offset overdraft conditions in the Kern County aquifer. Water recharge is currently implemented by a number of agencies who have partnered under the Rosedale Conjunctive Use Program, including; Kern-Tulare Water District, Rag Gulch Water District, Arvin-Edison Water Storage District, Castaic Lake Water Agency, Buena Vista Water Storage District, GLC (Coachella Valley Water District), and most recently IRWD (ESA EIR, 2008). Currently, these agencies jointly have the ability to recharge over 150,000 acre-ft per year. The Conjunctive Use Program manages approximately 210,000 acre-feet of stored groundwater in the underlying aquifer and includes 1,000 to 1,200 acres of recharge basins and seven recovery wells. Water supplies for this program are supplied by participating water agencies and include source water from the Kern River as well as water from the Central Valley Project (CVP) and the State Water Project (SWP). The Rosedale-Rio Bravo Water Storage District (RRBWSD or Rosedale) currently manages and operates the Conjunctive Use Program.

In 2004, IRWD purchased the 611-acre Strand Ranch property in western Kern County to develop a water banking program to improve water supply reliability during drought years. The Strand Ranch property is comprised of agricultural land located in an unincorporated portion of Kern County in the northern Kern River Fan area south of Stockdale Highway. Two existing water conveyance facilities bisect Strand Ranch including the Pioneer Canal and the Cross Valley Canal (CVC).

In 2006, IRWD and Rosedale constructed an interim recharge project on the Strand Ranch property including 125 acres of recharge basins in the southwest corner of the property (see Figure 2-1). The purpose of this interim recharge project was to test soil percolation rates, correct overdraft conditions from the on site agricultural wells, and ensure that adequate recharge capabilities existed before launching a larger project. During the interim program in 2006, 5,552 acre-ft of water was stored.

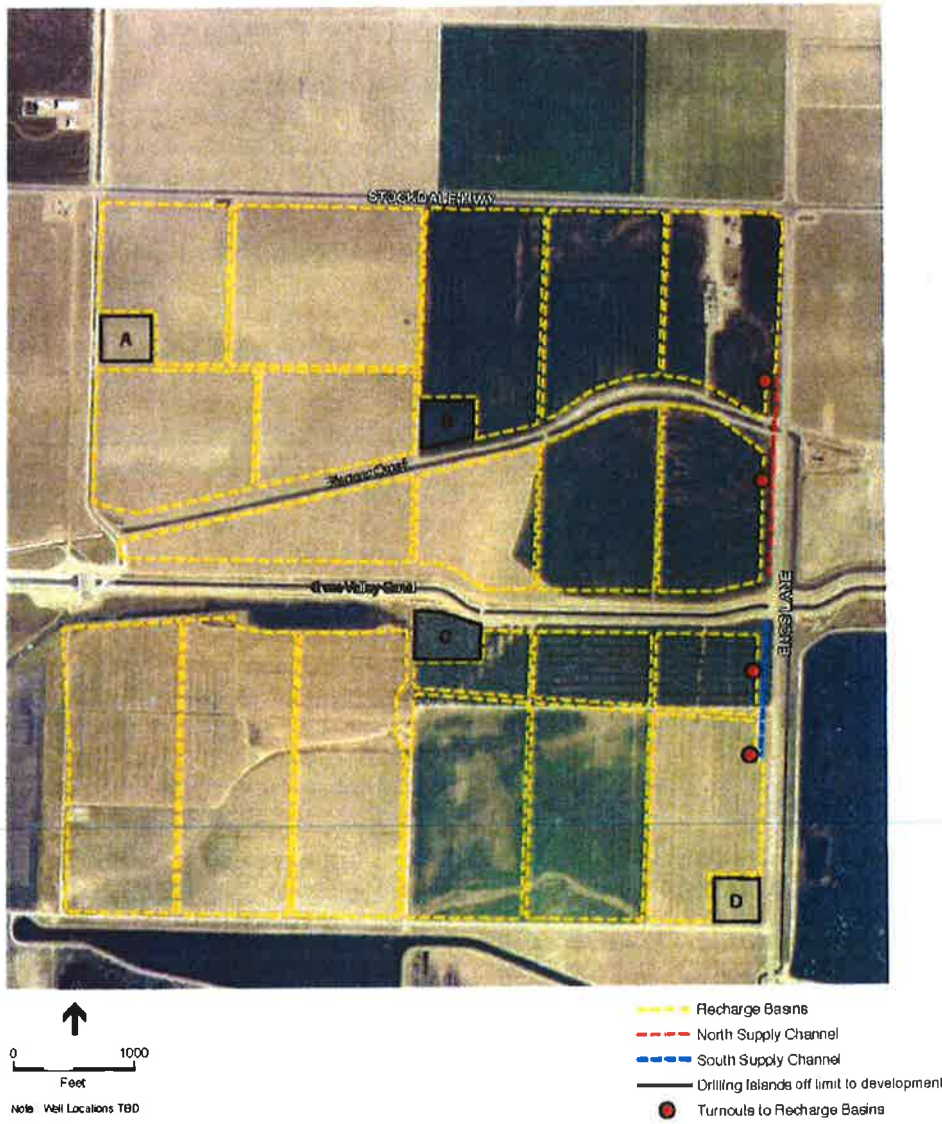

Figure 2-1: Strand Ranch Property Recharge Ponds

In 2009, IRWD entered into an agreement with Rosedale to expand the interim recharge project for enhanced capture, storage and recovery facilities based on favorable results from the interim recharge project. Since that time, IRWD has constructed approximately 502 acres of the recharge ponds on the Strand Ranch and is currently constructing the recovery facilities. The existing IRWD recharge ponds consist of excavated and contoured on-site soils to form earthen berm walls. The maximum water depth in each of the basins is approximately three feet with a minimum of one foot freeboard space. The CVC conveys water from the Kern River and SWP which is diverted through a turnout structure and transfer structures in order to supply the IRWD recharge basins. When fully operational, the Strand Ranch property is expected to recharge and recover up to 17,500 acre-feet per year for IRWD.

The Strand Ranch recharge project and future IRWD recharge projects in the Kern Fan region will integrate IRWD's participation in Rosedale's Conjunctive Use Program by providing additional groundwater recharge, storage and recovery capacity, and enhance water supply reliability for IRWD's customers by providing contingency storage to augment supplies during periods when other supply sources may be limited or unavailable.

3.0 Identification of Recharge/Infiltration Systems

Water recharge is currently implemented by a number of agencies throughout California to augment surface water supplies. The most common mechanism employed by these agencies to recharge surface water or reuse supplies has historically been through the use of recharge ponds or basins. In some areas, development and land cost have motivated agencies to consider other subsurface approaches to groundwater augmentation such as shallow infiltration galleries, injection wells, and engineered subsurface systems. A handful of agencies, such as the West Basin Municipal Water District and OCWD, have implemented more advanced indirect water reuse programs utilizing reverse osmosis membranes in order to further treat tertiary treated water for direct injection as a salt water intrusion barrier or as an advanced treatment to surface recharge. This study focuses on the evaluation of surface and subsurface recharge systems that would be appropriate for meeting the IRWD goals and objectives for water banking in the Kern Fan area.

Prior to the start of this study, IRWD completed a review of alternative groundwater recharge methods for increasing groundwater supplies. These methods included surface recharge basins and four types of subsurface recharge systems. At the first project workshop for this study held May 4, 2009, the project team reviewed the various methods and decided to evaluate the following five recharge concepts for this project:

- Surface Recharge Ponds
- Subsurface Recharge Galleries
- Shallow Injection Wells
- CULTEC Engineered Systems
- Subsurface Conveyance System

To evaluate each recharge concept on a common basis, the criteria below were mutually developed by HDR and IRWD at the first workshop. These criteria were used to size and evaluate each recharge concept.

Sizing Criteria	
Recharge Yield	10,000 AF
Recharge Duration	4 months
Infiltration Rate	4 inches per square foot per day
Distance from Cross Valley Canal (CVC)	0.5 miles

Each recharge concept is described in the sections below. The detailed evaluation and comparison between recharge concepts is presented in the non-economic evaluation in Section 7.0. The detailed economic comparison of each of the recharge concepts based on the sizing criteria described herein is included in Section 8.0.

3.1 Surface Recharge Ponds

Surface recharge ponds are constructed ponds or bodies of water where recharge water is applied to the surface and allowed to infiltrate into the soils and aquifer below. Recharge ponds are created through the excavation of native soils and construction of earthen embankments and berms designed to percolate water. Multiple recharge ponds can be constructed and operated in parallel or in series depending on operational objectives. The ponds are relatively easy to construct due to their shallow nature, are readily accessible for maintenance, and easy to operate. Management of flows to multiple ponds can either be controlled by manually actuating gates or valves, or simple automation can be incorporated to control flow from a remote location. IRWD currently utilizes surface recharge ponds as part of the recharge project at the Strand Ranch property (Figure 3-1).

Figure 3-1: Concept 1 - Strand Ranch Property Recharge Pond

Taking into account a uniform infiltration rate of 4 inches per square foot per day, approximately 250 acres of surface recharge ponds are required to recharge 10,000 acre-feet over a 4-month period.

For purposes of this evaluation, it was considered that two 125-acre recharge ponds are utilized to provide operational flexibility and the opportunity to conduct maintenance on part of the system, while maintain flows to the other half. The depth of each pond is assumed to be 3 feet based on the existing recharge ponds at the Strand Ranch property. Since the exact location or placement of the future recharge facilities is not yet known, it is assumed that the recharge ponds are approximately one-half mile from the diversion at the CVC (refer to Figure 3-2).

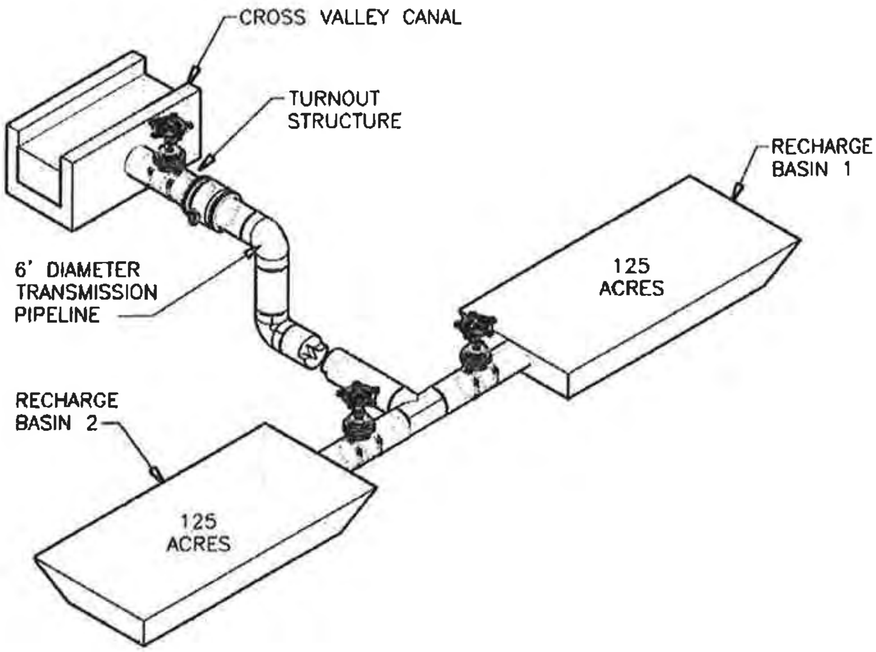

Figure 3-2: Concept 1 – Surface Recharge Ponds Concept

3.2 Subsurface Recharge Galleries

A subsurface recharge gallery is similar to a leach field, but intended to recharge water to the aquifer below. Utilities would typically consider this alternative in areas where land is unavailable or at a premium. This system is made up of smaller-diameter perforated lateral pipes that sit within shallow gravel and native soil trenches lined with filter fabric, along with headers that feed the system water from a large-diameter transmission pipeline. The filter fabric is installed in between the gravel and native soil to prevent sediment and fine particles from penetrating and clogging the native soil, thus reducing the hydraulic conductivity (i.e., movement of water into the soil). The mechanism and impacts of clogging are described in greater detail in Section 4.0.

The large-diameter transmission pipeline conveys water that is gravity-fed from a canal turn-out structure to various header pipes that feed the recharge galleries. Since the exact location or placement of the future subsurface recharge system is not yet known, this study assumes that the recharge galleries are approximately one-half mile from the diversion at the CVC (see Figure 3-3).

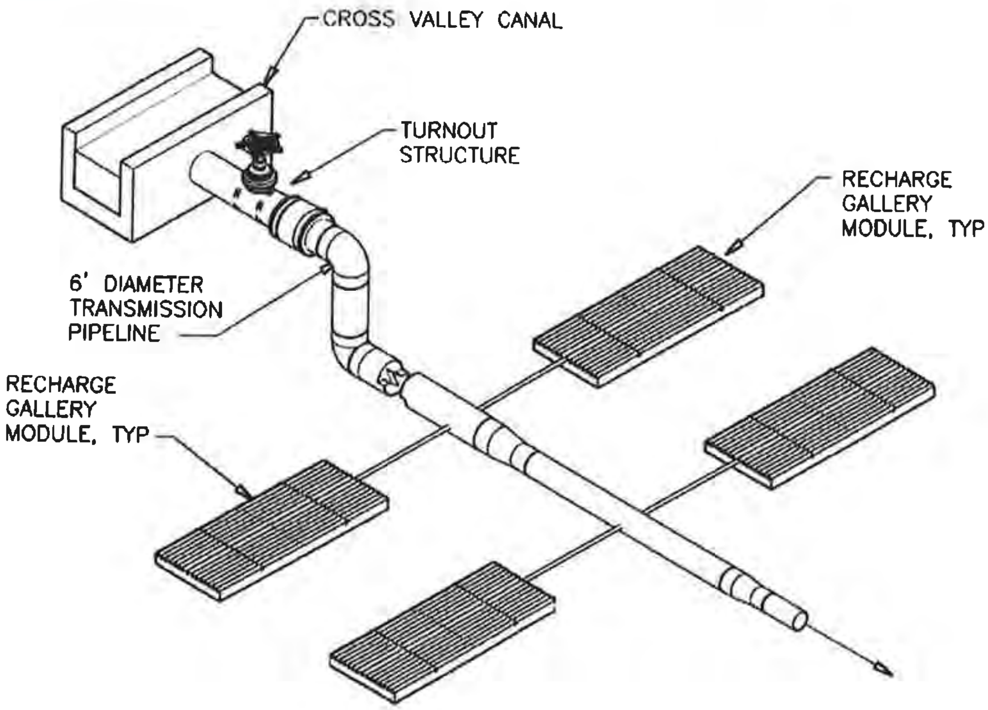

Figure 3-3: Concept 2 - Subsurface Recharge Gallery Concept

Management of flows to modular recharge galleries can either be controlled manually through valves, or automation can be readily implemented. Each module could be further modified with additional valves in an effort to isolate specific legs of the installation for maintenance while keeping the rest of the system in service. Accessibility for maintenance activities is more challenging due to the subsurface nature and configuration of this system, when compared to other alternatives.

Sizing the subsurface recharge gallery based on a uniform infiltration rate of 4 inches per square foot per day, requires approximately 250 acres of wetted area to recharge 10,000 acre-feet over a 4-month period. The spacing between lateral rows depends on the hydraulic conductivity of the soil, which may vary with location. For purposes of this study, it is assumed that the soils are such that the wetted area includes 5 feet on either side of the center of the lateral pipeline. Therefore, laterals are installed 10 feet on-center from each other.

This preliminary concept includes multiple 'modules' that each contain 80, 100-foot, 6-inch diameter perforated lateral pipelines connected by 8 or 10-inch diameter headers that can be connected to other modules or to the large-diameter transmission pipeline. One module is depicted in Figure 3-4. In order to encompass the required 250 acres of wetted area, approximately 137 modules need to be installed. The laterals are installed in trenches that are excavated approximately 5 feet deep. The lower one foot of the trench is back-filled with gravel while the rest of the depth is back-filled with compacted lifts of native soils.

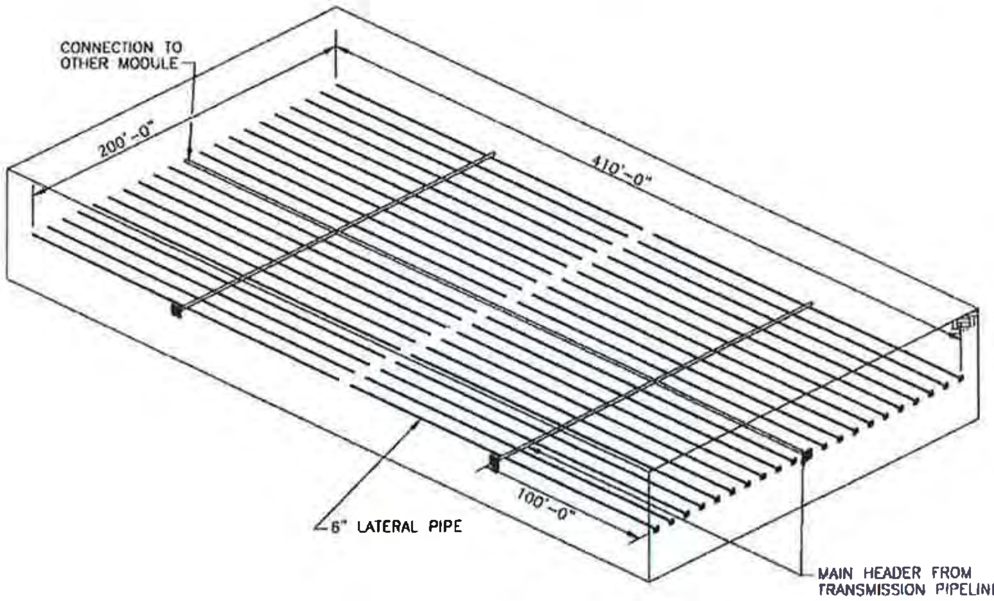

Figure 3-4: Concept 2 – Subsurface Recharge Gallery Module

The configuration assumed in this report is based on a previous study conducted by HDR that included a simulation model of river bed hydraulics in order to size a pilot scale underdrain collection system. The model accounted for site-specific soil characteristics such as saturated hydraulic conductivity, soil porosity, saturated water content, shape parameters of the soil water retention function and foulant accumulation layers. It should be noted that these soil characteristics are site-dependent and should be evaluated on their own merit under a more detailed evaluation. For purposes of this conceptual study, it is assumed that the subsurface recharge gallery concept would exhibit similar hydraulic characteristics as the underdrain collection system.

3.3 Shallow Injection Wells

The shallow injection well concept is similar to the subsurface recharge gallery concept, but instead of distribution of source water through a header, distribution occurs through a vertical shaft, stabilized by a concrete caisson, that in turn distributes water to radial laterals that extend from the shaft. Typically, these types of systems have been used in reverse, as radial wells or Ranney wells to intercept and collect groundwater derived principally from surface water infiltration. They can also be used for deeper recharge applications where confining soil layers are present, preventing recharge by shallow galleries as previously described. For this concept, a large-diameter transmission pipeline conveys gravity-fed water from a canal turn-out structure to multiple vertical shafts that feed the radial laterals. Since the exact location or placement of the shallow injection wells is not yet known, it is assumed that the injection wells are approximately one-half mile from the diversion at the CVC (see Figure 3-5).

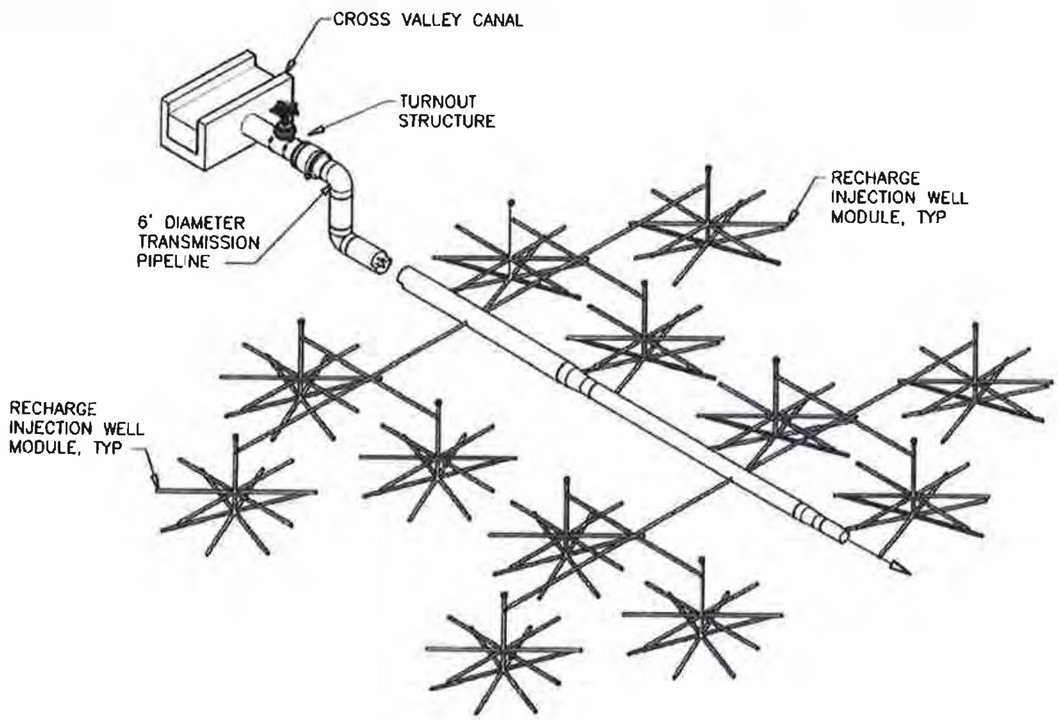

Figure 3-5: Concept 3 – Shallow Injection Wells Concept

Management of flows can either be controlled manually through valves, or easily automated. Similar to Concept 2, accessibility for maintenance activities is more challenging due to the subsurface nature and configuration of this system, when compared to other alternatives.

Sizing of the shallow injection wells based on a uniform infiltration rate of 4 inches per square foot per day requires approximately 250 acres of wetted area to recharge 10,000 acre-feet over a 4-month period. The spacing between laterals depends on the hydraulic conductivity of the soil, which may vary with location. For purposes of this study, it is assumed that the hydraulic conductivity is uniform throughout. Additionally the analysis assumes that soils are such that the wetted area includes 5 feet on either side of the center of the lateral pipeline. However, because the laterals move further apart as they extend out, more total land is required for easement purposes than is actually required for the 250 acres of wetted area.

This preliminary concept includes multiple 'modules' that each contain 12, 200-foot, 12-inch diameter screened or perforated lateral pipelines connected to a 24-inch diameter vertical shaft and caisson that can be connected to other modules and to the large-diameter transmission pipeline. The vertical shaft is installed to a depth approximately 12 feet below the surface. It should be noted that because of the circumference of the vertical shaft and limited space to connect in the 12-inch diameter laterals, 6 laterals are installed approximately 6 feet above the other 6 laterals, and rotated to maximize the wetted area. The deepest 6 laterals are installed 12 feet deep in trenches backfilled with one foot of gravel and 11 feet of compacted native soils. The shallowest 6 laterals are installed approximately 6 feet deep in trenches backfilled with one foot of gravel and the other 5 feet of compacted native soils. All of the lateral trenches utilize a filter fabric layer in between the gravel and native soils to prevent sediment and fine particles from penetrating and clogging the native soil, thus reducing the hydraulic conductivity. This concept is depicted in Figure 3-6. In order to encompass the required 250 acres of wetted area, approximately 454 modules need to be installed.

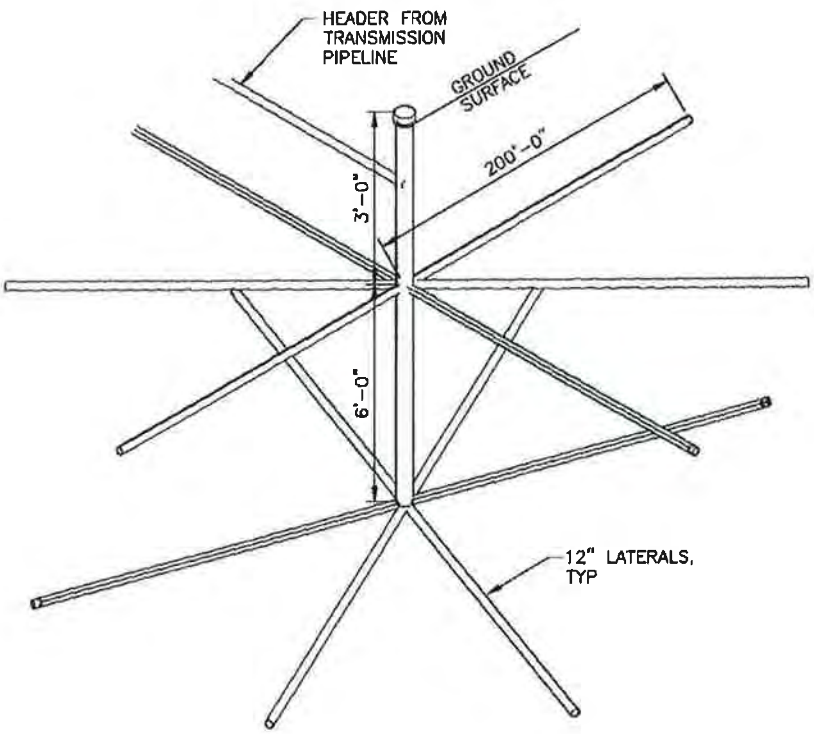

Figure 3-6: Concept 3 – Shallow Injection Wells Module

3.4 CULTEC Engineered Systems

CULTEC Engineered Systems are commercially-available units that are typically used to collect and recharge storm water flows, however may also be used for subsurface infiltration and retention/detention systems. The CULTEC Recharger® system consists of a dome-shaped, fully open bottom corrugated chamber with perforated sidewalls. This chamber stores water until it can infiltrate into the ground to the aquifer below. The bottom of the unit consists of a gravel pack and filter fabric in order to allow percolation while preventing sediment from clogging the native soils. The dome chambers may be installed in trench or bed configurations. Manholes can be installed to allow for maintenance access for periodic cleaning and replacement of the filter fabric.

Sizing of the CULTEC system is based on the recommendations provided by the manufacturer. For a project of this size, the CULTEC Recharger® V8™ is recommended. The V8™ is approximately 34 inches tall, 54 inches wide and 7.5 feet long and is manufactured of high molecular weight high-density polyethylene. Each chamber provides approximately 100 cubic feet of storage. Multiple chambers can be joined using an interlocking rib method. The manufacturer recommends that for the 10,000 AFY system (based on recharge over 4 months), only two-thirds of the wetted area needs to be provided based on the unit storage volume. Note that this storage volume credit is not included for any of the other concepts evaluated herein. Based on the information received from the manufacturer, and consideration of the infiltration criteria established in Section 3.0, it is anticipated that 322,667 V8™ units are required. It should also be noted that CULTEC is currently designing a larger unit that may be available in the future if this concept is utilized. This concept is depicted in Figures 3-7 and 3-8. Note that Figure 3-8 depicts a "cut-away" view of the asphalt surface above in order to more clearly show the subsurface installation of the system. Since the exact location or placement of the CULTEC Engineered System is not yet known, it is assumed that they are installed approximately one-half mile from the diversion at the CVC.

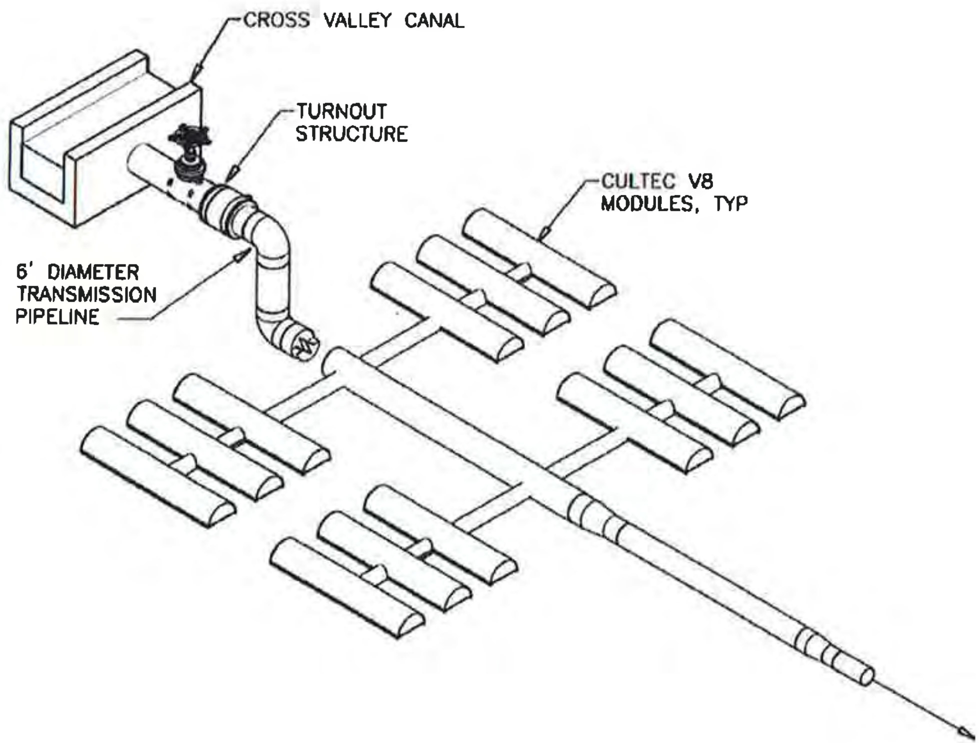

Figure 3-7: Concept 4 – CULTEC Engineered Systems

Figure 3-8: Concept 4 – CULTEC Engineered Systems Photo

3.5 Subsurface Conveyance Concept

The subsurface conveyance system concept consists of a large inverted trench box with gravel bottom in order to convey the source water while percolating a portion of the water into the ground as the water and associated sediments continue to flow through the length of the system. This concept is similar to the CULTEC system described in Concept 4 with the intent of conveying and infiltrating the source water in large underground structures. The primary difference between concepts is that the CULTEC system tends to capture and percolate the water under near-static conditions (i.e., vertical percolation in large, underground storage tanks), while Concept 5 maintains a horizontal flow through the system. Source water is diverted from the canal turn-out structure and transported through the inverted trench box at sufficient velocity to keep the sediment suspended and carried through the underground conveyance system, while recharging a portion of the source water through the bottom of the trench. The remaining portion of the source water that does not recharge in the inverted trench box is recharged via a smaller surface recharge basin similar to those described in Section 3.1.

Sizing of the subsurface conveyance concept based on a uniform infiltration rate of 4 inches per square foot per day, requires approximately 250 acres of combined wetted area to recharge 10,000 acre-feet over a 4-month period. More detailed hydraulic modeling will refine the length and diameter of the inverted trench box necessary to maintain the velocity at the speed needed to keep a large percentage of the sediment suspended while allowing the source water recharge. However, for purposes of this study, this concept is evaluated such that the inverted trench box provides half of the required wetted area (125 acres). The other half of the required wetted area is provided by a surface recharge pond. This approach assumes that the soils are such that the wetted area includes 5 feet on either side of the sides of the inverted trench box (see Figure 3-9).

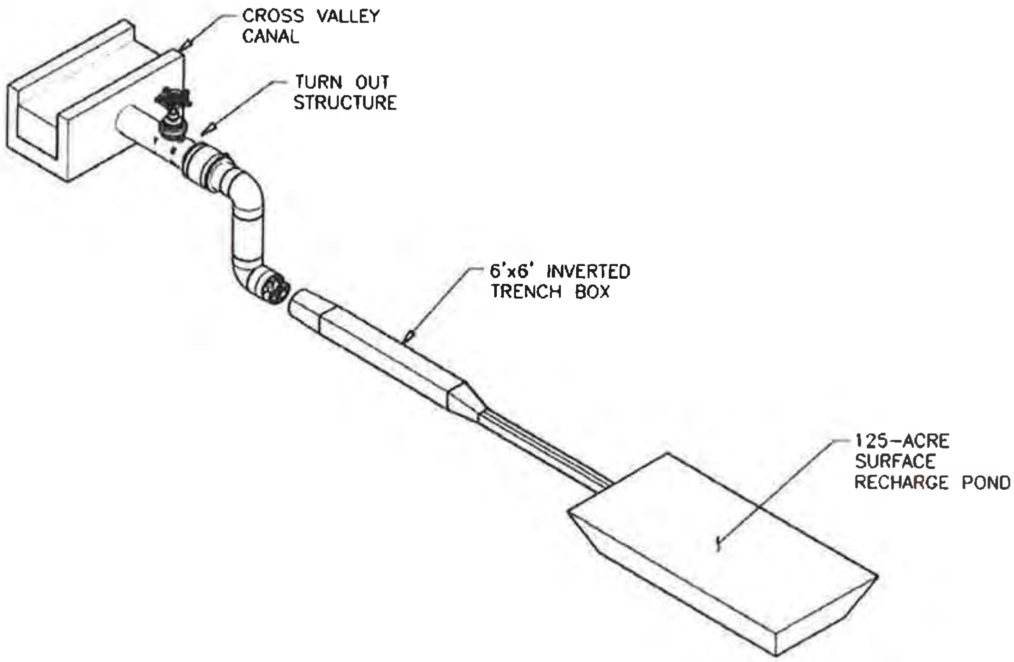

Figure 3-9: Concept 5 – Subsurface Conveyance System

A preliminary hydraulic analysis assumes a 65-mile, 6-foot by 6-foot inverted trench box will convey the source water to an approximately 125-acre surface recharge pond. For purposes of this study, it is assumed that the trench box is installed in a 10-foot deep trench, allowing 3 feet of cover over the top of the conveyance system. The bottom foot of the trench is filled with gravel and covered with a layer of filter fabric to help filter out fine particles and prevent these sediments from filling and clogging the native soils. Native soils are used to backfill the remaining trench (refer to Figure 3-10). The concept will include manholes spaced at appropriate intervals in order to facilitate accessibility for periodic cleaning and filter fabric replacement.

Representative section of the proposed 65-mile conveyance system

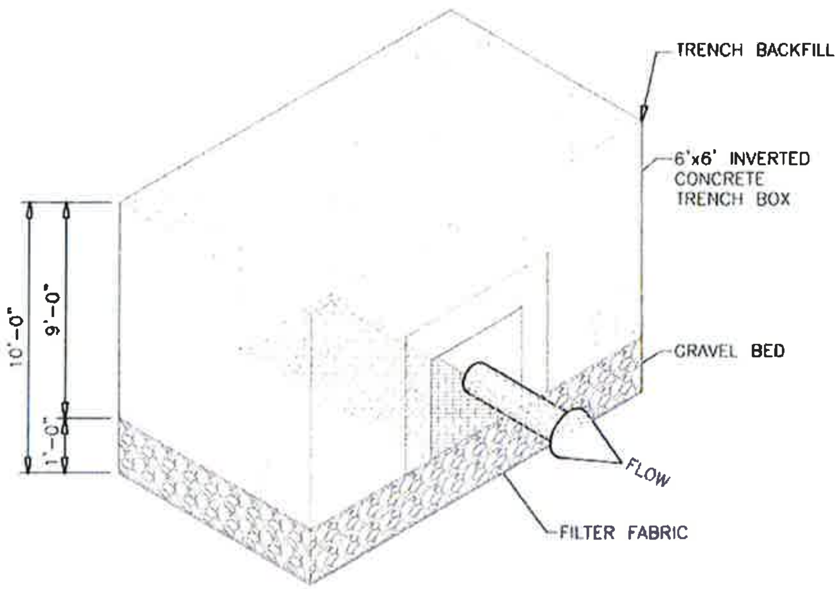

Figure 3-10: Concept 5 – Subsurface Conveyance System – Trench Cut View

4.0 Characteristics of Clogging During Artificial Recharge of Groundwater

Both surface and subsurface recharge concepts may be subject to clogging depending on the quality of the source water, changing environmental factors, or recharge facility mode of operation. Clogging occurs when sediments or biological material (such as algae or plankton) collect over time within the small pore spaces of the sand or gravel interface between the recharge concept (i.e., recharge pond, subsurface recharge gallery, etc.) and the aquifer below, thus restricting the amount of water able to be recharged. Organic and inorganic silts and clays that may be native to the source waters (or within the rivers and canals that convey the water) are typically the primary contributors to clogging. These silts and clays have a tendency to accumulate over time and establish a confining layer that reduces the rate of percolation.

Biological elements can also contribute to the clogging depending on the environmental conditions and availability of nutrients to sustain or proliferate biological activity. Biological growth can occur in both autotrophic (growth within direct sunlight) and heterotrophic (growth in the absence of light) conditions. Biological fouling can further decrease percolation rates due to additional plating or plugging of the interstitial spaces between the pores. A conceptual model of clogging is further described within this section. It should be noted that currently, the groundwater recharge projects in Kern County have not experienced significant percolation impacts as a result of clogging, based on Rosedale Conjunctive Use Partnership operational experience to date. This may be due, in part, to the current mode of operation which limits recharge activities to approximately 4 months. The seasonal loading and drainage of the basins may help control clogging potential as the accumulated silts dry and contract (i.e., crack), however the impacts may be realized in the future as the foulants continue to accumulate within the recharge basins.

4.1 Causes of Clogging

The formation of a clogging layer within groundwater recharge basins has been observed by other area agencies such as the Orange County Water District (OCWD). Clogging causes a decrease in recharge or infiltration (percolation rates) by reducing the hydraulic conductivity of the soil materials. Hydraulic conductivity is a quantitative measure of the soil's ability to transmit water when subjected to a given hydraulic gradient and essentially describes how easily water can move through the soil pores under a given driving force. Sometimes the reduction of hydraulic conductivity due to clogging can be as high as five orders of magnitude.

The clogging layer is often very thin, ranging from just a few millimeters up to approximately 4 centimeters. Clogging layers may consist of suspended solids, algae, microbes, dust and salts, and may be caused by different physical, chemical and biological factors. The causes of the development and extent of clogging are complex, but are influenced by recharge water quality, basin (or recharge concept) soil texture, mounding depth, hydraulic loading rate and cycle and vegetation.

Determination of the clogging layer can be challenging because the three different types of processes (physical, biological, and chemical) can work collectively or independently to reduce infiltration. Physical factors include the deposition and accumulation of organic and inorganic solids (such as clay and silt particles, algae cells and microorganisms) at the soil surface. If the suspended particles are smaller than the pore size of the media, and/or if the suspended solids are colloidal in size and if flocculating conditions exist, they can clog larger pores and form thick deposits on the pore walls. Biological factors include microbial cells and their metabolic byproducts (gas entrapped in pores or exopolymers that clog pores) that can alter soil properties (i.e., pore size, pore volume, flow path interconnectedness), and in turn affect the hydraulic conductivity of the media. Chemical factors include chemical precipitation and deposition in the pores. Chemical properties of soil particles and the infiltrating water, such as electrolyte concentration, pH, redox potential, and mineralogical composition of the soil, may influence the geometry of the pore space and may affect the shape and stability of the pores, which in turn determines the hydraulic conductivity of the media.

Research suggests that total suspended solids (TSS) and biological oxygen demand are the most important water quality components that influence the formation of a clogging layer. Additionally, extended mounding periods enhance soil clogging, whereas wetting and drying cycles tend to degrade the clogging layer. Prior to the start and during water recharge operations, IRWD may find it beneficial to monitor TSS levels in the source water, to help trend water quality constituent data with clogging rates.

4.2 Description of Phases of the Clogging Process

There are a number of effects which occur during artificial recharge that result in "clogging" and the accompanying decrease in percolation rates. A conceptual model is presented in Figures 4-1 and 4-2 to assist in understanding the clogging process. The model divides the clogging process into 6 phases and steps through the clogging process by starting with a clean recharge basin initially filled with recharge water and ending with a clogged recharge basin. Each phase corresponds to distinct physical phenomena which are characteristic of that phase of the recharge process. Conceptually, these phases occur in the sequence listed below and illustrated in Figure 4-2. In reality, not all phases may be present or important, and the phases are not as distinct as the model implies. It should also be noted that although Figure 4-1 illustrates a surface recharge basin, the concepts described below can also be applied to subsurface recharge alternatives.

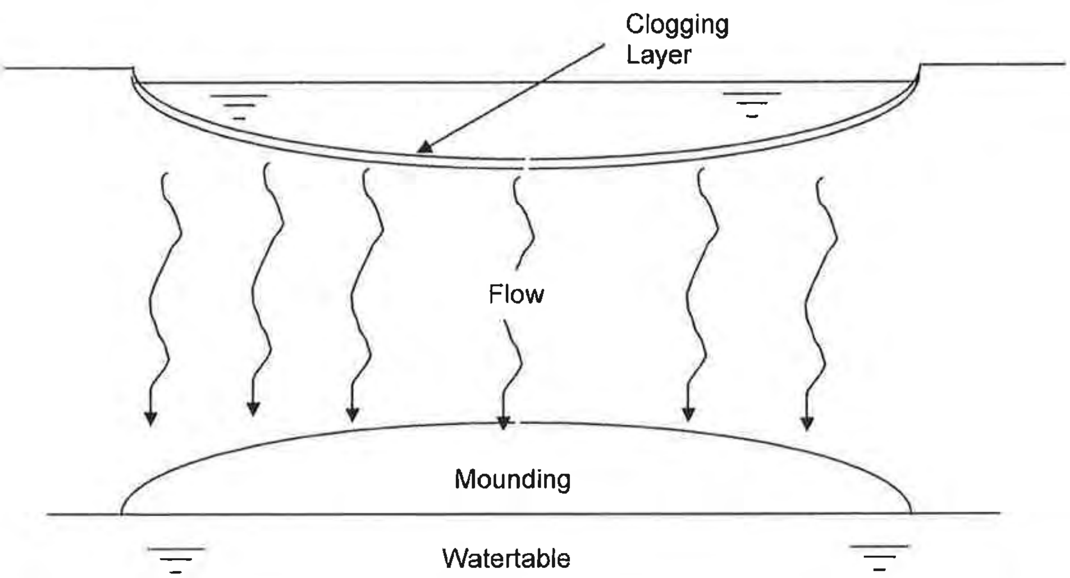

Figure 4-1: General Context of Clogging

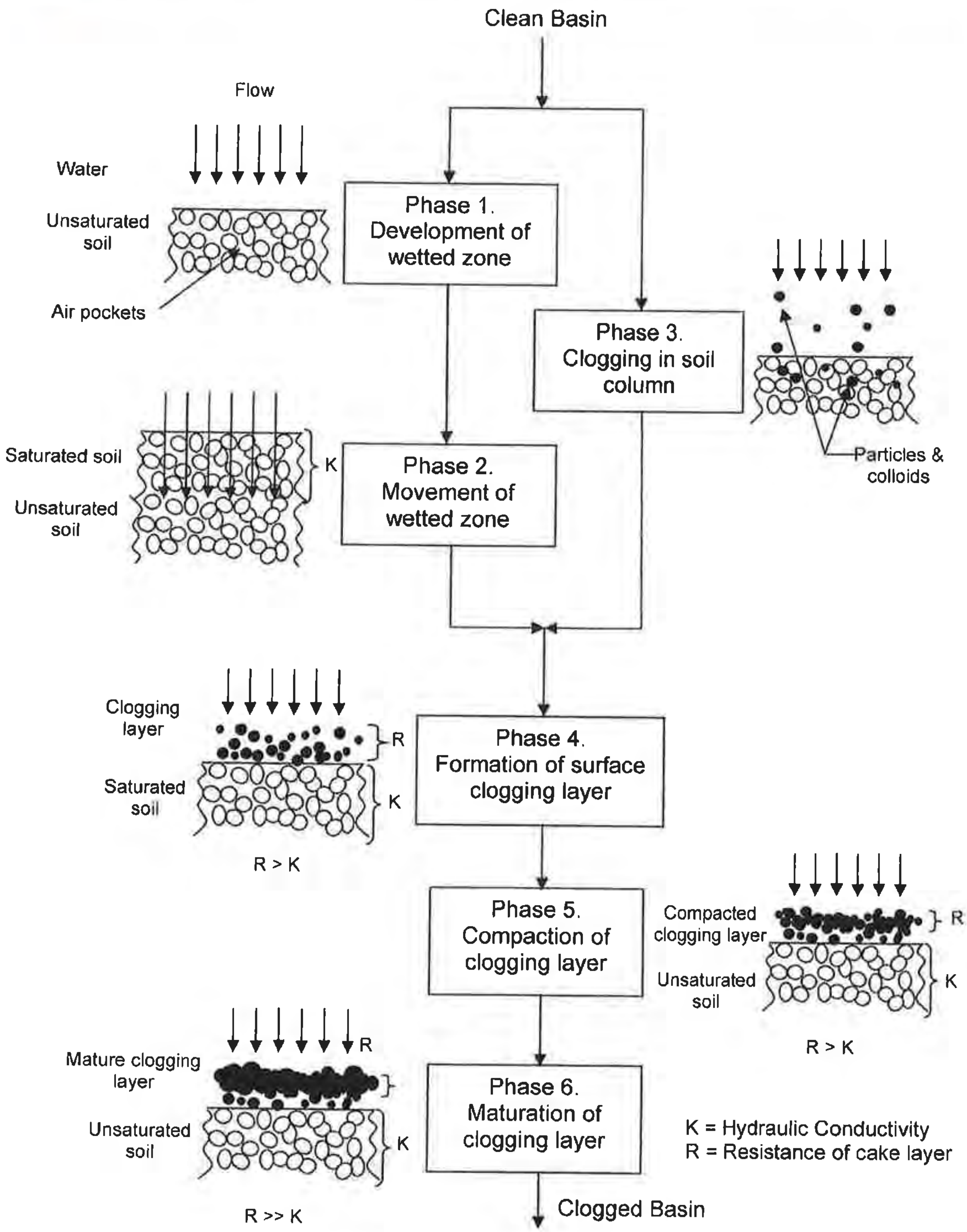

Figure 4-2: Phases of Clogging During Artificial Recharge

4.2.1 Phase 1 - Development of Wetted Zone in Soil

During Phase 1, water enters the soil from the recharge basin (or subsurface recharge concept), developing a wetted zone. The movement of the water results in the creation of flow paths in the soil matrix, but saturation of the soil is limited by entrapped air. Characteristics of Phase 1 include an increase or decrease in the percolation rate as entrapped air is released from the soil matrix.

4.2.2 Phase 2 - Movement of Wetted Zone in Soil

During Phase 2, the top portion of the soil becomes fully wetted and flow paths are developed. Flows respond to Darcy's law (flow proportional to head and inversely proportional to flow distance, the proportionality constant is the hydraulic conductivity (*K*)). Characteristics of Phase 2 include an initial high percolation rate, followed by a decrease in percolation rate as the length of the flow path in the wetted zone increases, and an eventual equal percolation rate and hydraulic conductivity. The hydraulic conductivity of the soil sets the maximum sustainable percolation rate for the system without clogging.

4.2.3 Phase 3 - Initial Clogging in Soil

Phase 3 is distinguished by the beginning of the entrance of colloids and particulates into the soil blocking pores in the soil. Characteristics of Phase 3 include an initial decrease in soil hydraulic conductivity near the surface of the soil while the lower soil is not impacted by clogging. This effect becomes less important as the clogging layer develops on the surface of the soil.

4.2.4 Phase 4 - Formation of Surface Clogging Layer

During Phase 4, particulates accumulate on the surface of the soil forming a cake clogging layer. Colloids penetrate into cake layer increasing hydraulic resistance. Characteristics of Phase 4 include formation of a thin, low hydraulic conductivity layer at the surface of soil, resulting in particulates and colloids that become trapped by the cake layer, and can no longer penetrate into the soil. Additionally, the system percolation rate is now controlled by the cake layer resistance (R) rather than the hydraulic conductivity of the soil and the wetted zone in the soil becomes unsaturated since flow is now controlled by cake layer resistance.

4.2.5 Phase 5 - Compaction of clogging layer

Phase 5 occurs when the clogging layer is compressed under hydraulic head. Characteristics of Phase 5 include an increase in intergranular pressure as unsaturated flow below the cake layer increases, causing compaction of the cake layer and thus increasing the hydraulic resistance of the cake layer. This becomes the dominant effect controlling the percolation rate.

4.2.6 Phase 6 - Maturation of Compacted Clogging Layer

During the final phase, Phase 6, biological and chemical interaction occurs in the clogging layer further increasing resistance and decreasing permeability. Characteristics of Phase 6 include further reduction of percolation rates by biological activity, through clogging, changes in pH, oxidation reduction reactions, or respiration. Additionally, chemical precipitation of carbonates, sulfates, phosphates may occur, increasing hydraulic resistance. Inter-particle effects related to surface charge may also occur, increasing hydraulic resistance. Phase 6 is a long-term development, typically developing after one or more months of recharge operation.

5.0 Sediment Removal Strategies

Previous sections of this report described various surface and subsurface recharge concepts without consideration of the impacts of clogging. Although clogging has not been identified as a problem on existing IRWD recharge projects, long-term accumulation of sediments and biological activity can reduce percolation rates over time and adversely impact the annual recharge and storage potential. The impacts due to clogging can be actively managed within recharge concepts that allow for easy access for cleaning, handling and removal of the associated foulants; however recharge concepts that are not readily accessible will exhibit diminished percolation rates over prolonged usage. As mentioned in Section 4.1, the causes of clogging are complex, but are often related to TSS or sediment load of the source water quality, and to a lesser extent, the nutrients within the source water that may lead to biological activity. For this reason, potential sediment removal strategies capable of removing these constituents are evaluated in this section as potential pretreatment options. Pretreatment is recommended for those recharge concepts where accessibility for maintenance is limited. Specific to this study, it is recommend that Concepts 2, 3 and 4 include pretreatment due to inaccessible or limited access to these recharge alternatives. Concept 1 – Surface Recharge Ponds are readily accessible for maintenance and cleaning activities, thus the IRWD recharge goals can reasonable be achieved without additional pretreatment. Concept 5 – Subsurface Conveyance System also provides the ability of access via manholes, which facilitate cleaning opportunities, albeit a more complex maintenance approach, allowing for a means of managing clogging potential while achieving the recharge goals.

The primary functional objectives for the sediment removal strategies are to remove sediment from the source water to be used in IRWD's potential recharge projects as a means to assist IRWD in optimizing the performance of its recharge facilities and in reaching long-term water banking goals.

Sediment removal alternatives were identified by HDR based on previous project experience and categorized as follows:

- Chemical/Physical Removal:
  - High Rate Sedimentation (HRS)
  - Ballasted Sedimentation (HRC)
  - Dissolved Air Flotation (DAF)
- Mechanical Removal
  - Cloth Filter
  - Membrane Technology
- Passive Treatment Systems

It should be noted that all of the chemical/physical sediment removal strategies stated above require the addition of a chemical coagulant. Mechanical sediment removal strategies typically do not require coagulant addition. The more chemical coagulant that is added to a process, the more precipitants are formed and must be dealt with during the residuals handling process. Typical chemical coagulants contain metals, which could add challenges to disposal options.

Each of the potential sediment removal strategies identified above are described in greater detail throughout this chapter.

5.1 Chemical/Physical Removal Strategies

Chemical/Physical removal technologies utilize a chemical or physical process to reduce the amount of sediments carried in the source water. The strategies described below are distinguished by several different criteria including:

- Surface Loading Rate (SLR) – Flow of water applied to a square foot of surface area
- Detention Time – Amount of time a fluid element remains within a particular basin
- Side Water Depth – Height of water required for process
- Anticipated Percent Solids – Percent of solid residuals within process waste stream
- Anticipated Footprint – Total land area required for entire sediment removal strategy (including all structures, equipment pads, pumping stations, etc.)

The typical design criteria indicated in the following sections are based on a combination of manufacturer input, literature searches and previous project experience. The design criteria included are for a potential IRWD system of 27 mgd or 10,000 AFY (over four months) and are based on scaled values from a recent project that HDR has performed for OCWD (refer to Section 6.0). Each of the potential chemical/physical removal strategies (High Rate Sedimentation, Ballasted Sedimentation, and Dissolved Air Flotation) is described in the sections below.

5.1.1 High Rate Sedimentation

High Rate Sedimentation is a modified version of the conventional sedimentation process that involves the installation of tubes or plates in the settling basin to increase the settling surface area, while reducing the footprint. Tube settlers are installed in the sedimentation zone at an angle (typically 60°), thus providing a larger surface area for the settled floc to accumulate. Flow enters through the bottom of the tubes and moves up to an effluent collection device such as a launder or submerged pipe lateral orifice. As the water moves up the pipe, floc settle on the inclined surface and gradually gain mass until sliding down the angled tube wall to the sludge zone. Figure 5-1 provides an example of typical flocculation-sedimentation basins and Figure 5-2 illustrate the tube settlers associated with the high rate sedimentation process.

Plate settlers are similar to tube settlers in that they are installed in the sedimentation zone at an angle (typically 55°), allowing the solids to slide down the angled plate into the sludge zone below. Flow typically enters the plates from the side near the bottom and moves up to an effluent collection device.

Figure 5-1: Typical Flocculation-Sedimentation Basins

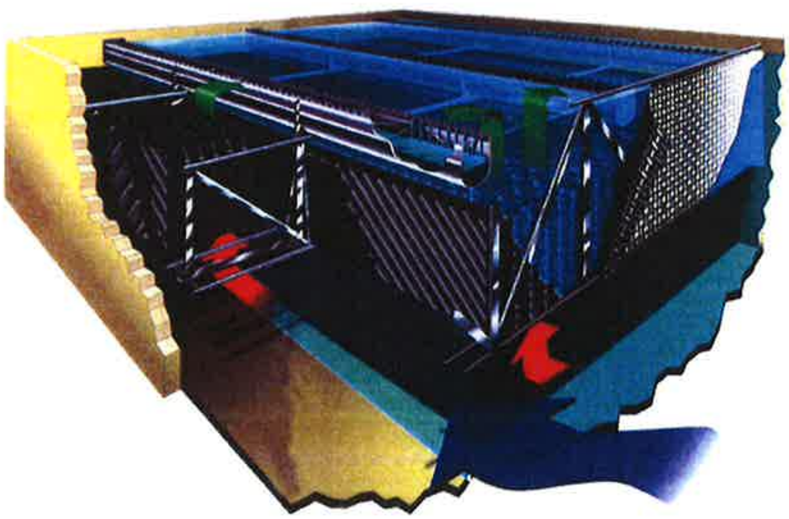

Figure 5-2: High Rate Sedimentation

Table 5-1 provides a summary of the typical design criteria associated with High Rate Sedimentation:

Table 5-1: High Rate Sedimentation Typical Design Criteria

Description	Criteria	Units
Surface Loading Rate	2.0- 3.5	gpm/ft^2
Detention Time		
Flocculation Zone	30 – 45	min
Sedimentation Zone	45-60	min
Side Water Depth	13 - 15	ft
Anticipated Percent Solids	0.8 – 1.5	%
Anticipated Footprint (27 mgd)	13,000-16,000	ft^2

5.1.2 Ballasted Sedimentation

Ballasted sedimentation, also referred to as high rate clarification (HRC) is a treatment process that utilizes microsand as a ballast or nucleus to form a dense floc that readily settles. The process uses a coagulant and polymer to assist the removal efficiency. A hydrocylone is used to separate the microsand from the sludge for reuse. Lamella plate settlers are installed in the clarifier, allowing high surface loading rates.

Table 5-2 provides a summary of the typical design criteria associated with Ballasted Sedimentation:

Table 5-2: Ballasted Sedimentation Typical Design Criteria

Description	Criteria	Units
Surface Loading Rate	20-40[a]	gpm/ft^2
Side Water Depth	26-28	ft
Anticipated Percent Solids	0.1-0.5	%
Anticipated Footprint (27 mgd)	3,000-4,500	ft^2

Figure 5-3 illustrates the HRC process. This proprietary process, known as Actiflo®, is manufactured by Krüger.

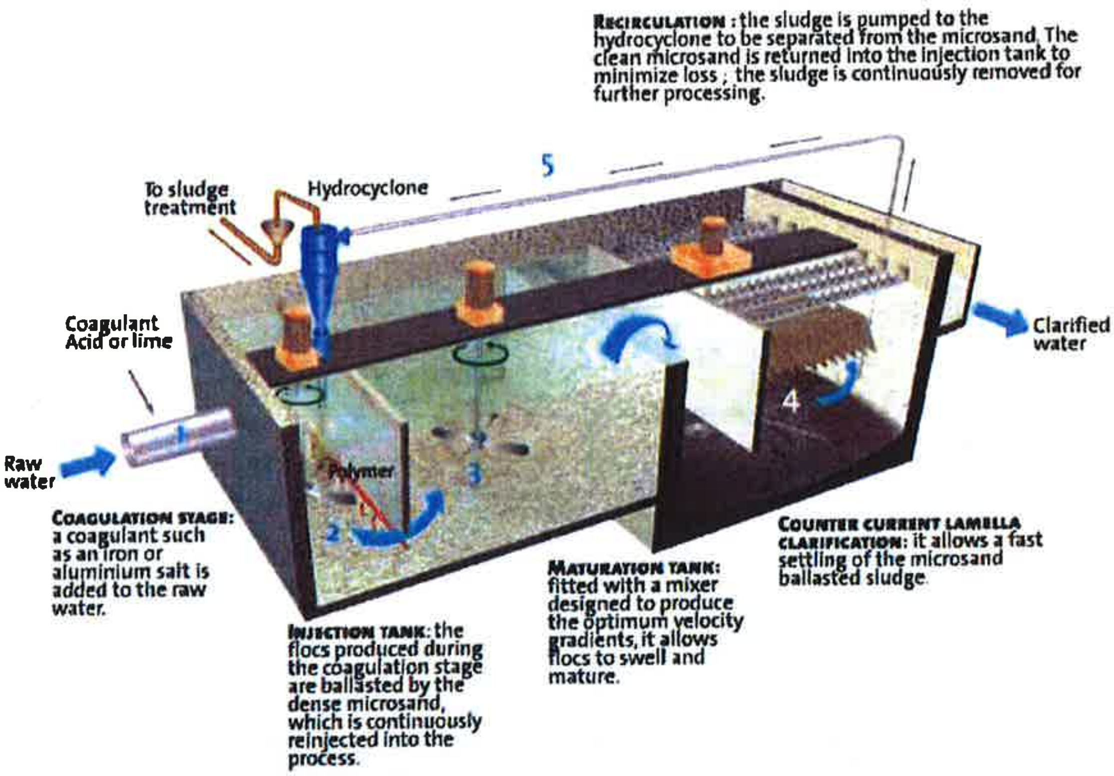

Figure 5-3: Krüger Actiflo® Ballasted Sedimentation Process

5.1.3 Dissolved Air Flotation (DAF)

Dissolved Air Flotation (DAF) is an alternative to conventional clarification that achieves removal by creating smaller floc particles that can be floated to the surface. This is accomplished by dissolving air in the water under pressure and then releasing the air at atmospheric pressure in a flotation tank or basin. The released air forms tiny bubbles with a size range of 10 to 100 µm that adhere to the suspended matter causing the floc to float to the surface of the water where they may then be removed by a skimming device. If left at the surface, the floating floc layer can thicken to approximately 3% to 6% dry solids.

Table 5-3 provides a summary of the typical design criteria associated with DAF:

Table 5-3: Dissolved Air Flotation Typical Design Criteria

Description	Criteria	Units
Surface Loading Rate	12[a]	gpm/ft^2
Side Water Depth	12-16	ft
Anticipated Percent Solids	3.0-6.0	%
Anticipated Footprint (27 mgd)	6,800	ft^2

Figure 5-4 illustrates the DAF process. Manufacturers of proprietary DAF units include Leopold and Siemens.

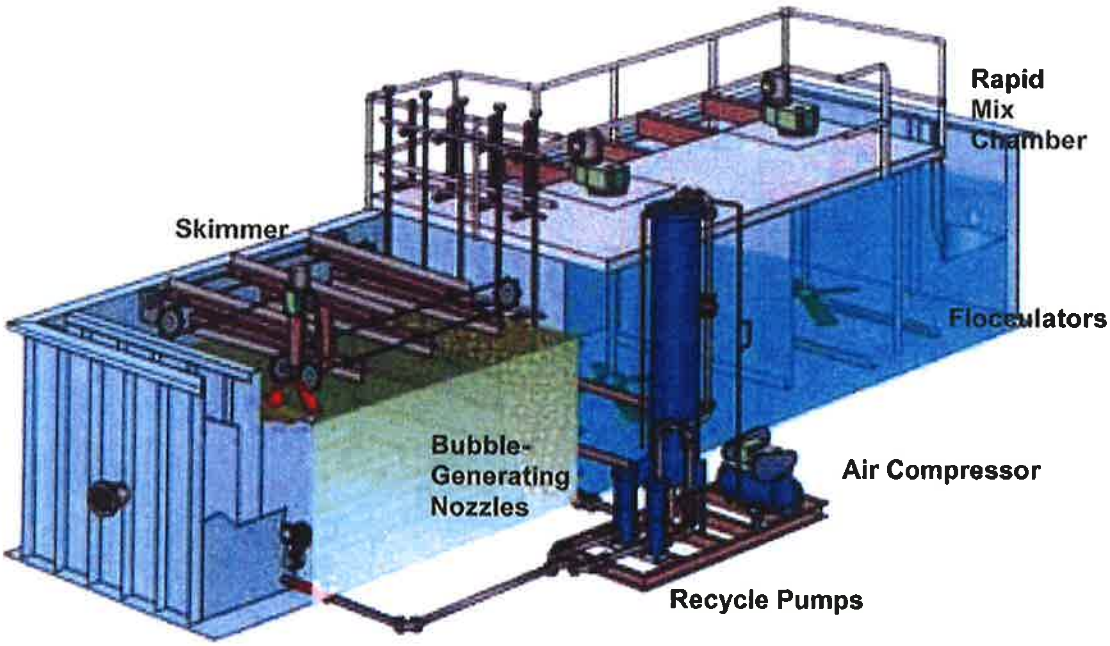

Figure 5-4: Leopold Clari-DAF® Process

5.2 Mechanical Removal Strategies

Mechanical removal strategies utilize a mechanical process to reduce the amount of sediments carried in source water. The strategies described below are distinguished by several different criteria including:

- Filter Loading Rate – Flow of water applied to a square foot of filter
- Flux Rate – Flow of permeate or filtrate through an MF membrane
- Side Water Depth – Height of water required for process
- Anticipated Percent Solids – Percent of solid residuals within process waste stream
- Anticipated Footprint – Total land area required for entire sediment removal strategy (including all structures, equipment pads, pumping stations etc.)

The typical design criteria indicated in the following tables are based on a combination of manufacturer input, literature searches and previous project experience. The design criteria included are for a potential IRWD system of 27 mgd or 10,000 AFY (over four months) and are based on scaled values from the OCWD project. Each of the potential mechanical removal strategies (Cloth Filter, Membrane Technology) is described in the sections below.

5.2.1 Cloth Media Filters

Cloth filters utilize a cloth fabric media to trap sediments as water is pushed through the fabric. The cloth media is completely submerged in the influent stream, while sediment is deposited on the outside of the cloth as the influent stream flows through the media. Effluent flows are collected via laterals inside the media and discharged by gravity. Backwash occurs periodically and involves vacuuming of the solids off the outside of the cloth media. Cloth Filters are low head systems, and typically do not require additional pump stations. Several configurations of cloth media filters exist including disk and diamond formation.

Table 5-4 provides a summary of the typical design criteria associated with Cloth Filters:

Table 5-4: Cloth Filters Typical Design Criteria

Description	Criteria	Units
Filter Loading Rate	2.0-4.0	gpm/ft^2
Side Water Depth	8.0	ft
Anticipated Percent Solids	0.5-1.0	%
Anticipated Footprint (27 mgd)	5,800	ft^2

Manufacturers of these filters include Aqua-Aerobics (AquaDisk®, AquaDiamond®) Parkson (Dynadisc®), and Krüger (Hydrotech Discfilter®). The AquaDiamond® is shown in Figures 5-5 and 5-6.

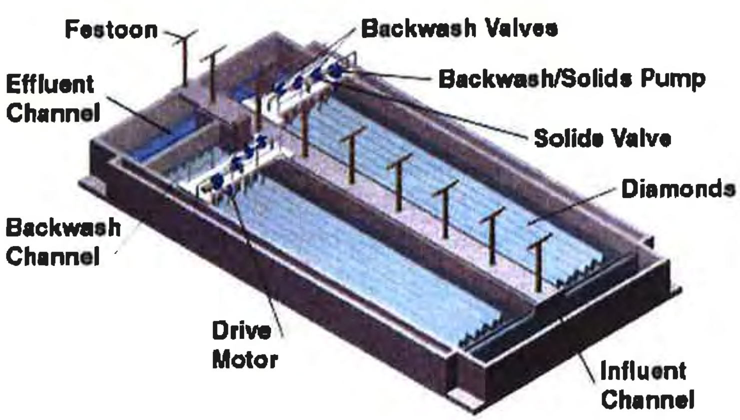

Figure 5-5: AquaDiamond Cloth Filter Process

Figure 5-6: AquaDiamond Cloth Filter Installation

5.2.2 Microfiltration (MF)

Immersed membranes can produce effluent with virtually no suspended solids and can remove some microorganisms such as bacteria and cysts. In some situations, this process can be effective for removing certain organic species. This process will produce high quality finished water.

Immersed membranes use hollow fibers bundled into a cassette arrangement. The cassettes are then immersed in the effluent and operate under a vacuum created within the hollow membrane fibers by a permeate pump. Water is drawn through the membrane pores and enters the inside of the hollow fibers. Filtered material is kept on the exterior surface of the fibers. Air is introduced at the bottom of the membrane cassettes to create turbulence, scour and clean the outside surface of the membrane fibers. The filter cell is periodically backwashed to remove filtered material from the membrane surface. Periodic chemical cleaning is required to remove deposits of materials entrained on the membrane surface that is not removed by backwashing.

It is anticipated that this process will not require chemical pretreatment due to the tighter membrane pore size, thus simplifying residuals handling associated with this alternative.

Table 5-5 provides a summary of the typical design criteria associated with Microfiltration:

Table 5-5: Microfiltration Typical Design Criteria

Description	Criteria	Units
Flux Rate	37	$g/d/ft^2$
Side Water Depth	11-12	ft
Anticipated Percent Solids	0.5	%
Anticipated Footprint (27 mgd)	8,800	ft^2

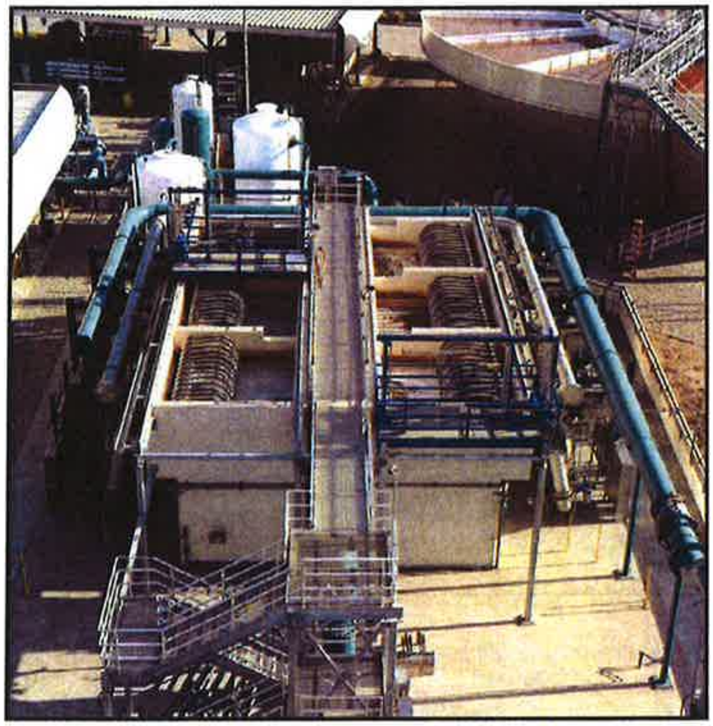

Figure 5-7: Immersed Microfiltration Membranes at West Basin MWD

5.3 Passive Treatment Systems

Passive treatment systems (i.e., river-bed filtration systems) can be installed within the river itself, or within close proximity to the river, utilizing the natural sand as a means of filtering sediment from the source waters in order to optimize recharge. Shallow Ranney wells (wells drilled vertically to a particular depth with horizontal perforated pipes or laterals extending radially outward) are employed to naturally filter water in the river bed, collect the filtered water via perforated pipes, and transport to recharge facilities. In-channel bank filtration systems with dedicated conveyance ditches or top-slotted pipelines (basically, reverse French drains) are used in a similar manner, with the potential advantage of conveying water by gravity in lieu of pumping, provided that there is sufficient grade difference from the location of the passive underdrain system and the receiving recharge basin or facility.

Passive treatment for sediment removal may not be a viable option for IRWD's Kern Fan project where the recharge facilities are a considerable distance from the source water. Additionally, stringent permitting requirements may deter construction within the river.

6.0 Summary of OCWD Study/Results

IRWD's Kern Fan area recharge objectives and goals are similar to other agencies that are actively pursuing recharge projects, such as the Orange County Water District (OCWD). Both agencies are currently focused on mitigating the increasing demands on California's water resources, in part, by implementing methods to capture and store (via underground aquifers) surplus storm waters that would otherwise be lost to other watersheds or the ocean. Also, both agencies are actively investigating available methods and technologies to enhance or optimize their recharge potential. This section provides a brief insight into OCWD's recent evaluation of optimizing their recharge spreading basins, and identifies the relevance to IRWD's current recharge program.

OCWD has been involved with groundwater recharge since the 1930's. Since inception, OCWD has built over 1,000 acres of recharge spreading facilities located in and adjacent to the Santa Ana River. OCWD has operated recharge basins to augment its groundwater supply to provide water for more than 2.3 million people served by more than 20 water providers that pump water for domestic purposes. One of the most plentiful supplies for groundwater replenishment is the Santa Ana River, the base flow of which has increased over time as the upper river basin has been urbanized and yields more runoff. However, recharge of the aquifer with available water supplies is limited by a number of factors, including clogging of the recharge facilities by a combination of organic and inorganic sediments in the Santa Ana River. Currently, the operable storage of the aquifer is not being fully utilized and increasing quantities of available renewable water supplies cannot be recharged because of the limitations caused, in part, by clogging due to the sediment carried in the Santa Ana River and local runoff.

It is OCWD's goal to capture and recharge as much Santa Ana River water as possible on an annual basis through its facilities, with long-term goals of achieving 700 cfs winter/spring and 500 cfs summer/fall recharge capacities. In an effort meet these goals without adding additional recharge facilities, OCWD recently embarked on a study in cooperation with HDR, Inc. to evaluate and determine effective alternatives to remove sediment from the Santa Ana River, in order to optimize and sustain "clean bed" percolation rates for extended durations and minimize the impacts due to clogging.

6.1 Pilot Testing of Sediment Removal Technologies

The OCWD study began with a preliminary investigation and pre-screening of potential sediment removal technologies. Technologies evaluated and piloted tested include; chemical/physical removal, mechanical removal and passive treatment strategies. Sediment removal strategies were evaluated at a base flow rate of 40 million gallons per day (mgd), or 62 cfs. Depending on the amount of water deemed necessary to meet OCWD's recharge goals, the base flow rate/sediment removal strategies could be scaled up to a larger system for further evaluation.

Based on the results of the preliminary evaluation of the sediment removal strategies, the project team determined that pilot testing of pre-screened technologies was necessary in order to observe the performance of each technology on treating varying water quality of the Santa Ana River and the resulting impacts to percolation. The primary objective of the pilot testing study was to demonstrate the ability of the processes to reliably remove sediment from the Santa Ana River water in an effort to reduce the clogging potential and to sustain the percolation rates within OCWD's recharge basins for longer periods of time. This primary objective would assist OCWD in optimizing the performance of the existing recharge facilities as one of the approaches to reaching their long-term recharge capacity goals.

Other objectives associated with the pilot testing included collection of data for each sediment removal process in order to develop specific design criteria to meet the production goals of the selected treatment technologies.

The pre-screened technologies selected for pilot testing included; ballasted sedimentation, dissolved air flotation, conventional flocculation-sedimentation, cloth filters, and passive (in-river) underdrain systems, similar to the technologies described in Section 5.0. The project team decided to pilot test conventional flocculation-sedimentation rather than high rate sedimentation since the two processes are essentially the same and differ only in footprint and settling tubes. Microfiltration was removed as a candidate for pilot testing due to budget constraints.

Pilot testing began in January 2009 and continued for approximately eight weeks. Water quality data was collected on raw source water as well as treated water from each technology throughout the duration of the pilot testing. Each sediment removal technology was compared to the others based on pre-determined evaluation methods which included; lab column percolation tests, larger percolation test cells, membrane fouling index (MFI), reduction in particle size distribution, and reduction of TSS and turbidity. Data from the study was reduced and evaluated. Section 6.2 summarizes the primary conclusions and recommendations.

6.2 OCWD Study Conclusions and Recommendations

Results from the pilot testing phase generally indicated that sediment removal technologies which did not rely on chemicals to induce coagulation, such as the cloth filter and passive system, performed the best. It was determined that chemical addition to the OCWD source water resulted in faster percolation decay than the untreated source water. Although the scope of the study did not include a thorough investigation into the mechanism causing the chemical fouling, it was theorized that the clogging could be attributed to destabilization and agglomeration of particles within the recharge basin media as a result of chemical carry-over.

The passive system performed the best in all of the evaluation methods, followed by cloth filters. Percolation testing results indicated that both the passive system and the cloth filter technologies have the potential to improve overall recharge performance by reducing the percolation decay rates currently exhibited by untreated Santa Ana River water.

From an operational viewpoint, both the passive and cloth filter systems were determined to be relatively simple to operate and, as stated above, did not involve the use of chemicals. Based on the results of the pilot test, the following recommendations were made for the OCWD recharge project:

1) The cloth filter and passive systems should be considered for additional evaluation.
2) Treatment systems that involve the use of chemical systems to aid in coagulation/flocculation of the water should not be further investigated.
3) Demonstration level testing is needed to address performance issues over time periods representative of clogging, rather than on an accelerated time scale. To the extent possible, the demonstration test should be performed under hydraulic conditions in a basin whose hydraulic residence time is similar to OCWD recharge basins, and under similar environmental conditions as the current OCWD recharge facilities.

6.3 Relevance of OCWD Study to IRWD Kern Fan Project

The Irvine Ranch and Orange County Water Districts both currently own and operate existing recharge facilities, and both agencies are actively investigating innovative and economical means of optimizing recharge potential and maximizing effective land use. Although IRWD does not currently experience clogging problems within their surface recharge ponds, OCWD's study evaluates strategies to reduce clogging in their own surface recharge ponds in order to optimize recharge performance. These same sediment removal strategies may also be considered useful for IRWD's Kern Fan project in order to enhance recharge within the concepts considered in this report. Additionally, results from the OCWD study and associated pilot testing offer additional insight related to expected treatment performance and operational parameters that may also be considered by IRWD as the District continues to pursue recharge opportunities.

7.0 Non-Economic Evaluation of Recharge/Infiltration Concepts and Sediment Removal Strategies

Sections 3.0 and 5.0 of this report have identified and described potential recharge alternatives and sediment removal technologies, respectively, that could be considered for future implementation for IRWD's Kern Fan water banking program. The following section provides a qualitative, non-economic evaluation of the identified recharge alternatives and sediment removal technologies by establishing comparative criteria from which each concept or technology can be weighed against the other.

7.1 Non-Economic Evaluation of Recharge/Infiltration Concepts

A qualitative evaluation of the recharge/infiltration concepts using the non-economic criteria presented below are summarized in this section.

- Performance – A recharge concept's ability to infiltrate water into the soils and aquifer below. Also considers proven performance and extent of use within the industry in the field of recharge or similar application.
- Constructability – Considers the complexity of construction and level of difficulty associated with the permitting process for each of the recharge concept.
- Operations and Maintenance – Considers the level of operational attention required by each concept, frequency and difficulty of maintenance activities, accessibility to the working parts of the system, and complexity of operation.

7.1.1 Evaluation of Concept 1 – Surface Recharge Ponds

Benefits or advantages associated with Surface Recharge Ponds include proven performance, simple construction, and accessibility for operations and maintenance, including periodic scraping to manage sediment accumulation within the basin. Surface recharge is widely used throughout the arid southwest for the purpose of reclamation and aquifer storage. These systems have a proven track record for recharge performance and are simple to operate. Construction activities have a relatively low complexity since most of the construction is dedicated to shallow earthwork to construct the berms of the ponds.

Disadvantages of this type of recharge system include the potential of biological fouling in shallow basins due to the daily exposure to the sun. There is potential for a faster rate of fouling caused by phytoplankton or algal blooms. The daily exposure to higher temperatures also results in additional evaporation losses, when compared to the other subsurface alternatives. Another disadvantage of this concept is use of land. Because the ponds are constructed at grade, beneficial use of the land is limited when compared to the other alternatives.

7.1.2 Evaluation of Concept 2 – Subsurface Recharge Galleries

The primary benefit of utilizing the subsurface recharge gallery concept is that it can be constructed beneath parks, greenbelt areas or areas with existing improvements in which a less expensive lease or easement for the site could replace ownership, as well as facilitate beneficial use of the land. Additional advantages of this concept include a reduction (or potential elimination) of evaporation losses attributed to sun exposure, and a potential reduction of biological fouling (i.e., reduction of autotrophic biological activity as described in Section 4.0).

Disadvantages include less proven performance, more difficult construction, limited accessibility for maintenance and more difficult O&M because of the size and complexity of the system. Based on literature searches, this type of recharge system is not widely utilized for systems of the magnitude considered for the IRWD Kern Fan water banking project. The most common use of this type of infiltration system is with respect to leach fields associated with septic systems. Construction is anticipated to be somewhat more difficult when compared to the surface ponds, due to the installation and placement of the multiple laterals and header piping. Although algal growth is not expected to be an issue due to the absence of sunlight, other biological growth (heterotrophic activity) is expected to occur in the benthic zone (soil near the soil/water interface) which could contribute to fouling. However, since the anticipated system usage in the Kern Fan area is limited to four months out of the year, drainage of the system during the off-season may help to mitigate biological fouling. Due to the inaccessibility of this option, the potential for irreversible sediment clogging over time presents significant challenges.

7.1.3 Evaluation of Concept 3 – Shallow Injection Wells

Concept 3 shares the same benefits as described for Concept 2, with respect to easements, beneficial use of the land, reduced evaporation, and potential reduction in biological fouling impacts due to intermittent use. Additionally, if a confining layer exists in selected recharge location, this alternative has the ability to develop the point of recharge below the confining layer.

Disadvantages include less proven performance, more difficult construction, limited accessibility for maintenance and more difficult O&M because of the size and complexity of the system. Similar to Concept 2, this infiltration concept is not widely used for large recharge systems, and is more commonly utilized for deep injection. Due to the depth of the laterals and central caisson associated with this concept, the construction will be more difficult and include the need for shoring and potential dewatering activities. The system, once installed, is also inaccessible for maintenance and cleaning which will present clogging challenges as sediment accumulates within the laterals over time.

7.1.4 Evaluation of Concept 4 – CULTEC Engineered Systems

Concept 4 shares the same benefits as described for Concepts 2 and 3, regarding easements, beneficial use of the land, reduced evaporation and potential reduction in biological fouling due to intermittent use. Additionally, the systems have proven performance, specific to storm water management, and are of a modular construction for relatively easy expansion. The CULTEC systems can be accessed for periodic maintenance, however it would be considered a confined space and the manufacturer recommends limiting access.

Disadvantages include more difficult construction, requiring shoring and anticipated dewatering activities due to the depth of the system. Clogging as a result of accumulated sediment and heterotrophic biological activity is anticipated. Although access is provided with this system, it is more challenging for cleaning and maintenance operations when compared to some of the other systems considered in this section.

7.1.5 Evaluation of Concept 5 – Subsurface Conveyance Concept

Similar to Concepts 2, 3, and 4, benefits associated with the Subsurface Conveyance concept include easements, beneficial use, reduced evaporation and potential reduction in biological fouling due to intermittent use. The subsurface conveyance system also poses the added benefit of potentially flushing much of the suspended sediment through the system, provided that the system is hydraulically modeled and designed to keep the velocities at appropriate speeds to prevent settling. Additionally, the large size of the inverted trench box will allow for accessibility via manholes located at reasonable distances along the conveyance system. Accessibility can also allow for periodic cleaning of portions of the system.

The primary disadvantage of this concept is that it is a unique approach to recharge and the performance and suitability of this concept is currently unknown. Detailed hydraulic modeling should be considered, as well as further studies such as pilot and/or demonstration testing in order to gain a better understanding of the anticipated performance and detailed design criteria associated with this concept.

The construction of Concept 5 will include some challenges due to the anticipated 65-mile length of pipeline needed to provide 50% of the overall percolation, with a smaller surface recharge basin providing for the remaining recharge as described in Section 3.0. The large width and depth of trench required may result in significant impacts to the public right of way, including prolonged traffic disruptions during construction. Due to the depth of the large trench box system, shoring and dewatering activities are anticipated. Depending on the actual alignment location, the construction may pose some environmental and/or public impacts. Because of the large length of conveyance required, the system is expected to require multiple bends in an effort to follow existing roadways and accessible right-of-ways. These bends may create eddies and "dead zones" in the flow stream, causing the sediment to drop out and accumulate at these locations. Additionally, because the system will utilize non-conventional conveyance methods (i.e., inverted trench box or half-pipe), availability of segments for bends, etc, will be limited. Most likely these segments need to be specially precast or cast in place.

Although this concept assumes that much of the sediment will be carried through the system, it is unlikely that all silts and sediment will pass through without some impacts to clogging. As a percentage of the flow percolates into the soils, the flow vectors will tend to carry some quantity of fine silts into the pours of the filter fabric, contributing to clogging. Additionally, heterotrophic biological activity, similar to Concepts 2, 3 and 4, may also contribute to clogging over time. Periodic cleaning through access manholes will help mitigate the impacts of clogging.

7.1.6 Comparison of the Non-Economic Criteria

The advantages and disadvantages of each concept, as identified above, are consolidated into a comparative format in Table 7-1. Each of the three non-economic criteria established earlier (i.e., Performance, Constructability, and O&M) are independently considered in this table, from which an overall comparison and scoring can be derived as established in Table 7-2.

Table 7-1: Recharge Conce

Concept	Performance	Const
Concept 1 – Surface Recharge Ponds	• Proven performance for large scale recharge projects	• Sim req • Lea cor • Sim • Re
Concept 2 – Subsurface Recharge Galleries	• Not as common for large scale recharge projects • Pretreatment is recommended to optimize performance	• Mo per • Mo • Ca
Concept 3 – Shallow Injection Wells	• Proven track record for deep bed injection • Pretreatment is recommended to optimize performance	• Mo witl • Lar late • Mo • Ca
Concept 4 – CULTEC Engineered Systems	• Unproven performance for large-scale recharge projects (Typically used for storm water storage and infiltration.) • Pretreatment is recommended to optimize performance	• Mo (sh • Mo • Ca
Concept 5 – Subsurface Conveyance	• Unproven performance for large scale recharge projects • Long term performance is unknown	• Tra • Mo witl • No • Lim • Ca

Considering the information in the previous sections, the recharge concepts were numerically rated from 1 to 5 for each of the non-economic evaluation criteria. Results of this ranking are shown in Table 7-2.

Table 7-2: Non-Economic Recharge Concept Evaluation

Concept	Performance	Constructability	Operations & Maintenance	Overall Ranking
Concept 1 – Surface Recharge Ponds	5	5	5	5.0
Concept 2 – Subsurface Recharge Galleries	4	3	2	3.0
Concept 3 – Shallow Injection Wells	3	1	1	1.7
Concept 4 – CULTEC Engineered Systems	3	3	4	3.3
Concept 5 – Subsurface Conveyance	2	2	4	2.7

1 = Least favorable
5 = Most favorable

Taking into account only this preliminary non-economic evaluation, Surface Recharge Ponds appear to be the most favorable choice, followed by CULTEC Engineered Systems and then Subsurface Recharge Galleries. The Surface Recharge Ponds received the highest comparative ranking due to their proven performance in the industry, simple construction, and ease of operation. The Subsurface Conveyance Concept and Shallow Injection Wells appear to be least favorable choices when evaluated by these non-economic criteria.

7.2 Non-Economic Evaluation of Sediment Removal Strategies

A qualitative evaluation of the sediment removal strategies identified in Section 5.0 is summarized in this section based on the following non-economic criteria.

- Performance – A sediment removal system's ability to remove sediment from a source water to effectively increase recharge into the soils and aquifer below. Also considers proven performance and use within the industry.
- Constructability – Considers the complexity of construction and level of difficulty associated with the permitting process for each of the treatment concepts.
- Operations and Maintenance – Considers the level of operational attention required by each concept, frequency and difficulty of maintenance activities, accessibility to the working parts of the system, and complexity of operation.

As discussed in Section 5.0, pretreatment is recommended for those recharge concepts that are not accessible, or provide limited access for maintenance and cleaning; specifically Concepts 2, 3 and 4.

7.2.1 Evaluation of Concept 1 – High Rate Sedimentation

The primary benefit of high rate sedimentation is that it is a robust process with a proven track record for performance, and is widely used in water treatment. The system is capable of providing reliable treatment during variations in flow rate or water quality. The process is also relatively simple to operate, has minimal equipment to control, and is fairly simple to maintain.

Disadvantages of high rate sedimentation include larger land requirements than some of the other treatment technologies, more challenging construction due to the larger footprint and the reliance on chemicals for coagulation. The use of chemicals will require additional storage and feed facilities, and require an additional level of training of personnel for proper handling and safety.

7.2.2 Evaluation of Concept 2 – Ballasted Sedimentation

The advantages of ballasted sedimentation are that it is a compact process requiring a much smaller footprint than high rate sedimentation and is capable of producing high quality treated water, even during variation in flow rates and water qualities. The system has a proven track record and is frequently used in water treatment. Additionally, the system is modular, which allows for ease of expansion in the future.

The primary disadvantage associated with ballasted sedimentation when compared to the other technologies is that it is a more complex system to operate. As described earlier in the report, the system includes the use of a coagulant (typically ferric chloride or alum), polymer, and microsand as the ballast, of which doses and quantities need to be monitored and maintained. The system requires a higher level of operator attention and associated maintenance when compared to some of the other technologies.

7.2.3 Evaluation of Concept 3 – DAF

The primary benefit of utilizing the DAF concept is that it is also a compact process requiring a much smaller footprint than high rate sedimentation and is capable of producing high quality treated water, even during variation in flow rates and water qualities. Additionally, the system is modular, which allows for easier expansion in the future.

Disadvantages include its complexity, with more operator attention and maintenance required similar to ballasted sedimentation. Also, this system relies on a chemical coagulant as part of the process, of which dose and quantities need to be monitored and maintained.

7.2.4 Evaluation of Concept 4 – Cloth Filtration

The cloth filtration technology provides for a relatively small, modular footprint similar to Concepts 2 & 3, above. In addition, the cloth filter system is a simple process, easy to operate and maintain with simply automation. An additional benefit of the cloth filter system is that it does not rely on chemicals to facilitate the process as the other technologies evaluated above.

Some disadvantages of the cloth filtration technology are that it may be limited to wide variations in flow rate and solids loading. Although the system is automated to initiate backwashes as the solids build up on the filter, excessive solids loading or flow rates may result in some breakthrough or carry-over of material into the downstream side of the process. The cloth filter process also does not currently possess the proven track record in water treatment, as do the other technologies, primarily as a result of being a fairly new technology. However, it should be noted that during the OCWD pilot testing, the data indicated that this process performed better than the other technologies (except passive) when comparing the percolation test results.

7.2.5 Evaluation of Concept 5 – Passive Treatment

The primary benefit of utilizing the passive treatment concept is that it can be used within the river itself and requires no moving mechanical components or chemicals. Once installed, the passive treatment system needs minimal maintenance, except for potential routine scraping or tilling of the riverbed, if solids tend to accumulate and impact performance over time. Additionally, this system also performed well during the OCWD pilot testing previously discussed.

Disadvantages include difficult construction in the river bed, such as shoring and potentially significant dewatering activities in order to install the laterals and collection pipeline to the depths necessary for proper performance. Environmental issues and the permitting process may also prove to be difficult. It is unknown if the system could potential clog over time due to accumulation of sediment. It may be necessary to excavate and replace laterals over many years of prolonged use. Also, with respect to the IRWD Kern Fan area, this concept may not be suitable, since it requires installation in the river, or directly next to the river.

7.2.6 Comparison of the Non-Economic Criteria for Sediment Removal

The advantages and disadvantages of each sediment removal concept, as identified above, are consolidated into a comparative format in Table 7-3. A comparative scoring of the alternatives is established in Table 7-4.

Table 7-3: Sediment Removal S

Concept	Performance	Constru
Concept 1 – High Rate Sedimentation	• Produces high quality treated water; Large reductions in TSS typical • Capable of handling variation in flow rates; Robust process • Capable of treating varying influent water qualities; Slow start up time	• Som • Not ı
Concept 2 – Ballasted Sedimentation	• Produces high quality treated water; Large reductions in TSS and algae typical • Capable of handling variation in flow rates; Robust process • Capable of treating varying influent water qualities; Quick start up time	• Com • Mod
Concept 3 – DAF	• Produces high quality treated water; Large reductions in TSS and algae typical • Capable of handling variation in flow rates; Robust process • Capable of treating varying influent water qualities; Somewhat quick start up time	• Som • Som addil
Concept 4 – Cloth Filtration	• Produces high quality treated water; Large reductions in TSS and algae typical • Capable of handling variation in flow rates; Robust process • Capable of treating varying influent water qualities; Quick start up time	• Som • Mod
Concept 5 – Passive Treatment	• Produces high quality treated water; Large reductions in TSS typical	• Som river • Not l

Considering the information in the previous sections, the sediment removal strategies were numerically rated from 1 to 5 for each of the non-economic evaluation criteria. Results of this ranking are shown in 7-4.

Table 7-4: Non-Economic Sediment Removal Strategy Evaluation

Concept	Performance	Constructability	Operations & Maintenance	Overall Ranking
Concept 1 – High Rate Sedimentation	2	1	3	2.0
Concept 2 – Ballasted Sedimentation	3	5	3	3.7
Concept 3 – DAF	3	4	3	3.3
Concept 4 – Cloth Filtration	4	5	4	4.3
Concept 5 – Passive Treatment[a]	5	1	4	3.3

1 = Least favorable
5 = Most favorable
a. Although passive treatment systems are evaluated in the table above, this strategy is not considered feasible for the IRWD Kern Fan project, unless IRWD were granted access to a portion of the river, or land immediately adjacent to the river.

Of the sediment removal strategies that were evaluated for this exercise, cloth media filters scored the highest, followed by ballasted sedimentation. High rate sedimentation scored the lowest. It should be noted that although passive systems were evaluated in this section, this strategy is not considered feasible for the IRWD Kern Valley project, unless IRWD owned a portion of the river or land immediately next to the river. This option could also raise questions as to the feasibility of conveying and recharging water that has already percolated below grade.

8.0 Economic Evaluation of Recharge/Infiltration Concepts and Sediment Removal Strategies

For purposes of this study, an appraisal-level, economic evaluation of each of the five recharge concepts and the sediment removal strategies identified is presented in this section. This cost analysis is based on the 10,000 AFY treatment volume (over 4 months) established by IRWD as the evaluation/comparison baseline.

The capital costs presented are comparative planning-level opinions of construction costs based on conceptual sizing, including preliminary layouts of major structures and rough sizing of critical equipment. Capital costs have been established in 2009 dollars, with escalation to 2012. Estimates of this type can be expected to vary from 50 percent less than to 30 percent more than actual final project costs.

The sources of construction cost data are:

- R.S. Means
- IRWD Strand Ranch Construction Cost Data
- Construction cost data for other similar facilities, adjusted to regional market conditions and 2009 dollars.
- Equipment pricing from manufacturers, with installation costs based on similar projects.

Additionally, capital costs for each of the five recharge concepts were developed based on the following assumptions developed collectively by HDR and IRWD:

- Cost of land purchase - $14,000/acre.
- Cost of easement - $1,400/acre.
- All excavated fill will be reused onsite, thus no hauling costs are included.
- All recharge concepts are assumed to be installed approximately 0.5 miles from the diversion of source water at the CVC.
- Each recharge cost includes a 35% project contingency.
- Unit costs are inclusive of prevailing wages.

8.1 Recharge Concepts – Capital Cost Analysis

Table 8-1 summarizes opinion of probable cost for the recharge concepts discussed within this report. The capital costs include a high and low range based on a 35% contingency. This table accounts for the cost of each recharge system only, and does not include cost of pretreatment. The pretreatment cost is established in subsequent tables within this section. Complete detailed capital cost estimates for each of the recharge concepts can be found in the Appendix.

Table 8-1: Opinion of Probable Cost – 27 mgd Recharge Concepts

Recharge Concept	Recharge Concept Capital Cost Range	
	Low Range	High Range
Concept 1 – Surface Recharge Ponds	$9,800,000	$11,600,000
Concept 2 – Subsurface Recharge Galleries	$16,700,000	$21,800,000
Concept 3 – Shallow Injection Wells	$61,700,000	$80,300,000
Concept 4 – CULTEC Engineered Systems	$105,300,000	$138,000,000
Concept 5 –Subsurface Conveyance System	$69,400,000	$89,200,000

Based on the information shown in Table 8-1, the following observations are made:

- Concept 4 – CULTEC Engineered Systems has the highest projected capital cost
- Concept 1 – Surface Recharge Ponds has the lowest projected capital cost.

8.2 Sediment Removal Concepts – Capital Cost Analysis

Table 8-2 summarizes the opinion of probable cost for the sediment removal technologies evaluated within this report. Costs for the passive system sediment removal technology have been excluded from this evaluation since the passive system is not recommended for the IRWD Kern Fan project.

Table 8-2: Opinion of Probable Cost – 27 mgd Sediment Removal Systems

Sediment Removal Strategy	Sediment Removal Strategy Estimated Capital Cost
Dissolved Air Flotation	$8,900,000
Sand Ballasted Sedimentation	$8,000,000
Cloth Filter	$9,500,000
High Rate Sedimentation	$10,800,000

Based on the information shown in Table 8-2, these cost estimates indicate that:

- High Rate Sedimentation has the highest projected capital cost.
- Sand Ballasted Sedimentation has the lowest projected capital cost.

8.3 Cost Analysis with Recommended Pretreatment

As mentioned in Section 4.0, pretreatment would help optimize the recharge potential by maintaining the "clean bed" percolation rates for extended periods of time before decay of the percolation rate begins to occur as solids accumulate at the water/soil interface. However, even with pretreatment, there will be a small percentage of particles that will pass through the treatment system (via break-through in mechanical separation such as filters or carry-over in the chemical/physical treatment alternatives). Over time, the particles that pass through the pretreatment system will accumulate within the recharge system, inducing clogging and a reduced percolation rate.

For purposes of this study, it is recommended that pretreatment be considered for all subsurface recharge concepts, with exception of Concept 5 – Subsurface Conveyance System. For Concept 5, one of the underlying assumptions is that much of the sediment will be carried through the system, provided the velocities are maintained throughout. As previously stated, this assumption will need to be validated via additional hydraulic modeling and pilot testing. Additionally, the subsurface conveyance concept will be accessible for periodic maintenance and removal of sediment without the need for pretreatment. It is anticipated that some portion of the sediment will accumulate within the system over time, and that the filter fabric will need to be replaced after prolonged usage of the system.

Sediment removal pretreatment is not anticipated for the surface recharge alternative established under Concept 1. The anticipated recharge operation of four months out of the year will allow for periodic management of residuals in the basins without the need for pretreatment. The basins will experience a faster decay of the "clean bed" percolation rate than will be experienced with pretreatment; nevertheless, it is assumed that this mode of operation is acceptable as a result of current operating experience of other recharge operations within the Kern Fan area. Additional data from IRWD's current Strand Ranch operations will help determine the average basin recharge capacity over the typical operating duration, which can then be applied to future studies.

Table 8-3 provides a summary of the opinion of probable cost for each of the recharge concepts, including the cost for sediment removal treatment as recommended for Concepts 2, 3 and 4. For purposes of this study, the cloth filter system is considered as the preferred method of pretreatment. Although the cloth filter system is not the most economical alternative as indicated in Table 8-2, it appears to be the best choice when considering the benefits identified in the non-economic evaluation, as well as its positive performance during the OCWD pilot testing compared to the other treatment alternatives.

Table 8-3: Opinion of Probable Capital and O&M Costs – 27 mgd Recharge Concept Including Recommended Pretreatment

Recharge Concept	Total Recharge and Pretreatment Cost Range		O&M Cost per year
	Low Range	High Range	
Concept 1 – Surface Recharge Ponds	$9,800,000	$11,600,000	$38,000
Concept 2 – Subsurface Recharge Galleries	$26,200,000	$31,300,000	$80,000
Concept 3 – Shallow Injection Wells	$71,200,000	$ 89,800,000	$80,000
Concept 4 – CULTEC Engineered Systems	$114,800,000	$147,500,000	$80,000
Concept 5 –Subsurface Conveyance System	$69,400,000	$89,200,000	$19,000

Table 8-3 also includes a column that establishes O&M costs. The values indicated in this column specifically pertain to the anticipated annual O&M cost associated with each of the recharge concepts and include:

- Annual pretreatment O&M costs for cloth filter including filter replacement, labor, power and equipment replacement.

- Periodic access and maintenance of the surface recharge ponds, including periodic tilling or mowing.
- Periodic access and maintenance of the subsurface conveyance system.

These O&M costs do not include residual management and hauling/disposal from either the pretreatment system or from scraping activities in the case of surface recharge ponds. As additional data is collected from the current Strand Ranch recharge basins, the extent of annual residual accumulation can be further assessed in order to determine the effort required for cleaning the recharge ponds and potential volumes of silt that will require hauling and disposal.

As previously mentioned, all of the evaluated recharge concepts are expected to experience some amount of clogging. Some of this clogging will be mitigated by use of a sediment removal pretreatment system, but surface and subsurface recharge systems that are accessible for periodic maintenance will require rehabilitation and subsurface recharge systems that are inaccessible for periodic maintenance will eventually need to be replaced. Table 8-4 includes recharge concept rehabilitation and replacement costs. This analysis assumes the following:

- In addition to the periodic maintenance stated above, the surface recharge ponds will require rehabilitation via thorough cleaning on a 20 year cycle by bulk removal and hauling of accumulated silt and sediments.
- Filter fabric will be replaced on a 20 year cycle for the CULTEC Engineered Systems and Subsurface Conveyance concepts.
- The perforated laterals and filter fabric associated with the subsurface recharge galleries and shallow injection wells will be completely replaced every 20 years. It is assumed that the new systems will be constructed on the same land and no new easements or land purchases will be required.

Table 8-4: Sediment Removal 20-Year Rehabilitation and Replacement Costs – 27 mgd

Recharge Concept	20 Year Rehabilitation and Replacement Costs
Concept 1 – Surface Recharge Ponds	$2,700,000
Concept 2 – Subsurface Recharge Galleries	$11,100,000
Concept 3 – Shallow Injection Wells	$48,500,000
Concept 4 – CULTEC Engineered Systems	$2,200,000
Concept 5 –Subsurface Conveyance System	$2,200,000

8.4 Cost Recovery Analysis

A capital recovery analysis was applied to each of the systems based on a 5% discount rate over a 40-year project life for the estimated recharge and pretreatment concept capital and O&M costs, including the 20-year rehabilitation and replacement costs. The annualized cost of each system is shown in Table 8-5. Costs per acre foot were calculated based on the 10,000 acre-feet of water recharged per year and are also shown in Table 8-5.

Table 8-5: Annualized Cost

Recharge Concept	Annualized Recharge and Treatment Cost	Annualized Cost per Acre Foot
Concept 1 – Surface Recharge Ponds	$800,000	$80
Concept 2 – Subsurface Recharge Galleries	$2,300,000	$230
Concept 3 – Shallow Injection Wells	$6,600,000	$660
Concept 4 – CULTEC Engineered Systems	$8,700,000	$870
Concept 5 –Subsurface Conveyance System	$5,300,000	$530

Based on the capital recovery analysis shown in Table 8-5, Concept 1 – Surface Recharge Ponds is the least expensive annualized recharge and treatment cost, and cost per acre-foot of water recharged, with each acre foot of water recharged costing approximately $80. Concept 4 – CULTEC Engineered Systems is the most expensive annualized recharge and treatment cost and cost per acre foot of water recharged, with each acre foot of water recharged costing approximately $870.

Each of the recharge concepts evaluated in this study involves the purchase or lease of additional land. The evaluation assumes that the surface recharge alternative requires the purchase of land to implement, while the subsurface recharge alternatives benefit by the lower cost of leased land. Presently, with the downturn of the economy, land purchase prices are low, but are expected to increase as the economy improves. The following tables present an evaluation of escalating land cost over time in an effort to determine the potential "break even" cost between concepts as a result of real estate escalation. The results of this analysis are included in Tables 8-6, 8-7, and 8-8. Table 8-6 establishes anticipated escalation of land on a per acre basis as well as for the 250 acre system, based on assumed escalation rates of 1%, 3% and 5%. Tables 8-7 and 8-8 indicate the low and high capital cost, respectively, for each of the Concepts evaluated in this report. These tables also establish the differential cost when compared to the lowest priced option (Concept 1), for which the years to "break even" cost can be extracted from Table 8-6.

Table 8-6: Land Escalation Analysis

Year	Land Escalation			Cost of 250 Acres		
	5%	3%	1%	5%	3%	1%
0	$ 14,000	$14,000	$14,000	$ 3,500,000	$ 3,500,000	$ 3,500,000
5	$ 17,868	$16,230	$14,714	$ 4,466,985	$ 4,057,459	$ 3,678,535
10	$ 22,805	$18,815	$15,465	$ 5,701,131	$ 4,703,707	$ 3,866,177
15	$ 29,105	$21,812	$16,254	$ 7,276,249	$ 5,452,886	$ 4,063,391
25	$ 47,409	$29,313	$17,954	$ 11,852,242	$ 7,328,223	$ 4,488,512
30	$ 60,507	$33,982	$18,870	$ 15,126,798	$ 8,495,419	$ 4,717,471
35	$ 77,224	$39,394	$19,832	$ 19,306,054	$ 9,848,519	$ 4,958,110
40	$ 98,560	$45,669	$20,844	$ 24,639,960	$ 11,417,132	$ 5,211,023
45	$ 125,790	$52,942	$21,907	$ 31,447,527	$ 13,235,585	$ 5,476,838
50	$ 160,544	$61,375	$23,025	$ 40,135,899	$ 15,343,671	$ 5,756,211
55	$ 204,899	$71,150	$24,199	$ 51,224,708	$ 17,787,520	$ 6,049,836
60	$ 261,509	$82,482	$25,434	$ 65,377,151	$ 20,620,611	$ 6,358,438
65	$ 333,759	$95,620	$26,731	$ 83,439,652	$ 23,904,940	$ 6,682,783
70	$ 425,970	$110,850	$28,095	$ 106,492,489	$ 27,712,377	$ 7,023,672
75	$ 543,658	$128,505	$29,528	$ 135,914,401	$ 32,126,240	$ 7,381,950
80	$ 693,860	$148,972	$31,034	$ 173,465,044	$ 37,243,117	$ 7,758,503
85	$ 885,561	$172,700	$32,617	$ 221,390,237	$ 43,174,980	$ 8,154,265
90	$1,130,225	$200,207	$34,281	$ 282,556,278	$ 50,051,635	$ 8,570,214
95	$1,442,485	$232,094	$36,030	$ 360,621,368	$ 58,023,563	$ 9,007,381
100	$1,841,018	$269,061	$37,867	$ 460,254,402	$ 67,265,212	$ 9,466,848

Table 8-7: Land Escalation Analysis – Comparison of Capital Cost (Low Range)

Concept	Concept Cost (low range)	Cost Difference to Concept 1	Estimated Years to Breakeven at Percent Land Escalation		
			5%	3%	1%
Concept 1	$9,767,227	$ -	-	-	-
Concept 2	$26,188,951	$16,421,724	31	51	>100
Concept 3	$71,155,970	$61,388,743	59	97	>100
Concept 4	$114,734,331	$104,967,104	70	>100	>100
Concept 5	$69,329,069	$59,561,842	58	95	>100

Table 8-8: Land Escalation Analysis – Comparison of Capital Cost (High Range)

Concept	Concept Cost (High range)	Cost Difference to Concept 1	Estimated Years to Breakeven at Percent Land Escalation		
			5%	3%	1%
Concept 1	$11,564,934	$ -	-	-	-
Concept 2	$31,277,982	$19,713,048	34	57	>100
Concept 3	$89,767,152	$78,202,218	64	>100	>100
Concept 4	$147,496,543	$135,931,609	75	>100	>100
Concept 5	$89,142,504	$77,577,570	63	>100	>100

Evaluating the low and high capital cost ranges between Concept 1 (Surface Recharge) and the next lowest priced alternative, Concept 2 (Subsurface Recharge Galleries), results in a perceived cost difference of $16.4 million to $19.7 million. Dividing these differences by the anticipated 250 acres to accommodate the 10,000 AFY recharge goal, indicates that the assumed cost of land ($14,000) would need to increase to $65,000-$79,000 before Concept 2 will be viable on an economic basis. The tables above suggest that if real estate escalates annually at 5%, it will take between 31 and 34 years before the cost of Concept 1 equals the cost of Concept 2. It should also be noted that the tables above do not account for future rehabilitation and replacement costs as discussed in Section 8.3. If these costs are included in the land escalation analysis, the time until Concept 1 equals Concept 2 is increased even more significantly. For example, considering rehabilitation costs for Concept 1 and replacement costs for Concept 2, with 5% land escalation, it will take between 41 and 43 years before the cost of Concept 1 equals the cost of Concept 2. Considering the results of the land escalation analysis and the large difference in capital cost between Concept 1 and the other concepts, the surface recharge concept is decisively the best economic alternative.

9.0 Conclusions and Recommendations

Taking into consideration both the non-economic and economic evaluations, the following conclusions were made:

- Concept 1 – Surface Recharge Ponds are the most favorable recharge concept from both the non-economic and economic evaluations.
- Surface recharge ponds provide the benefit of simple access, operation and maintenance, which allows for easy cleaning of the basins in order to mitigate the effects of sediment clogging without the additional cost of treatment.
- Even when considering the potential escalation of real estate, Concept 1 still stands out as the better economic option.
- Concept 1 has a higher residual value considering the additional land as an asset.

Additional data collection specific to the Kern Valley area will be necessary in order to further evaluate the cost/benefit ratio of alternative recharge systems. Based on this conceptual-level analysis, it is recommended that IRWD focus future studies on Concept 1 - Surface Recharge Ponds and Concept 2- Subsurface Recharge Galleries. Although Concept 2 was identified as having a higher cost than Concept 1 under this initial evaluation, the collection of further data may allow for refinement of the assumptions, resulting in a more cost effective alternative. One concern with any of the subsurface alternatives is the potential for clogging over time, even if pretreatment is incorporated. The potential for clogging of subsurface systems should be further investigated through long-term pilot testing.

More extensive geotechnical and hydrologic studies will help refine the assumptions used in determining percolation rates and recharge system sizing. Soil porosity and hydraulic conductivity can vary widely within localized regions. Additional characterization of the soils through boring logs and infiltration tests will provide for more accurate assumptions during future studies. In addition, further geotechnical analysis will help isolate areas that may include confining layers that will adversely impact the shallow surface or subsurface recharge approaches described in this report. These analyses should be specific to potential recharge sites. Additionally, a water quality sampling plan is recommended in order to further evaluate the potential mechanisms for clogging. Measured constituents should include total suspended solids, turbidity, phosphorous, total nitrogen, total organic carbon, and particle size distribution.

Pilot level testing, followed by larger demonstration testing of the recharge concepts and sediment removal treatment technologies should be considered prior to investing in full-scale construction. Pilot testing will allow IRWD to compare some of the preferred recharge and pretreatment alternatives in a side-by-side venue, at the potential project site under similar environmental and source water conditions as the full scale operations. Pilot testing will also provide for collection of necessary data, such as variations in source water quality, initial percolation rates and rate decay over time, "scaled" performance of various alternatives, and other operating and maintenance information in order to develop more accurate sizing, capital and O&M estimates. Based on the outcome of the pilot testing, it may be necessary to conduct larger scale demonstration testing over a longer period of time, in order to accumulate a minimum of 2 years of solid data. IRWD has indicated that water may only be available every 3 years, therefore the actual duration of testing required in order to collect 2 years worth of data, may be closer to a 6 to 9-year duration. Pilot testing alone, may not adequately capture long-term impacts associated with the recharge alternatives or the pretreatment systems. Some of these factors may include; potential biological fouling which may develop over longer durations, long-term clogging impacts as a result of residual accumulation and compaction over time, and in the case of pretreatment or residual management, it may take additional time to determine the extent of accumulated material that will need to be managed and disposed.

With the increased recurrence of severe droughts within the region, and California's increased efforts associated with water conservation and water reclamation, the importance of water conservation and water banking is critical during these current times. IRWD should continue its pursuit with cost effective approaches to water banking and recharge opportunities. In addition, it may be prudent for IRWD to continue working with OCWD as they further develop their own local recharge programs. OCWD currently has many on-going studies that are evaluating similar conditions and impacts to recharge as IRWD. A collaborative effort may help both agencies efficiently and effectively collect the necessary data required to make informed decisions in the field of surface water recharge.

10.0 References

1. Orange County Water District – Recharge Water Sediment Removal Feasibility Study. Prepared by HDR. Draft submitted June 2009. Final submittal anticipated in September 2009.
2. CULTEC. (2008). Quick Stormwater Design Guide.
3. ESA. (May 2008). Strand Ranch Integrated Banking Project Final Environmental Impact Report.
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6. Western Development and Storage, Inc. for Bardeen Partners, Inc. (March 2004). Screening Baseline Property Assessment Strand Tract Kern County, California.
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Appendix A – Cost Estimates

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept Cost Summary

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Capital Cost Summary of Recharge Alternatives

Technology	Direct Cost Estimate (Above the Line Costs)	Contingency	Land Purchase Costs	Land Easement Costs	Total Escalated Capital Cost Range (including contingency)	
Concept 1 - Surface Recharge Ponds	$ 4,300,000	35%	$ 3,675,000	$ 2,000	$ 9,800,000	$ 11,600,000
Concept 2 - Subsurface Recharge Galleries	$ 12,100,000	35%	$ -	$ 351,000	$ 16,700,000	$ 21,800,000
Concept 3 - Shallow Injection Wells	$ 44,100,000	35%	$ -	$ 1,854,000	$ 61,700,000	$ 80,300,000
Concept 4 - Cultec Engineered Systems	$ 77,600,000	35%	$ -	$ 233,800	$ 105,300,000	$ 138,000,000
Concept 5 - Subsurface Conveyance System	$ 47,000,000	35%	$ -	$ 54,000	$ 69,400,000	$ 89,200,000

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept Cost Summary

Date September 2009
Prepared by K. Streams
Reviewed by S. Toland

Capital Cost Summary of Recharge Alternatives Plus Sediment Pretreatment

Technology	Direct Cost Estimate (Above the Line Costs)	Contingency	Land Purchase Costs	Land Easement Costs	Treatment Costs	Total Escalated Capital Cost Range (including contingency)	
Concept 1 - Surface Recharge Ponds	$ 4,300,000	35%	$ 3,675,000	$ 2,000	$ -	$ 9,800,000	$ 11,600,000
Concept 2 - Subsurface Recharge Galleries	$ 12,100,000	35%	$ -	$ 351,000	$ 9,500,000	$ 26,200,000	$ 31,300,000
Concept 3 - Shallow Injection Wells	$ 44,100,000	35%	$ -	$ 1,854,000	$ 9,500,000	$ 71,200,000	$ 89,800,000
Concept 4 - Cultec Engineered Systems	$ 77,600,000	35%	$ -	$ 233,800	$ 9,500,000	$ 114,800,000	$ 147,500,000
Concept 5 - Subsurface Conveyance System	$ 47,000,000	35%	$ -	$ 54,000	$ -	$ 69,400,000	$ 89,200,000

HR

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toiano

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept Cost Summary

i = 0.05
n = 40
f = 0.058

$$f = \frac{i(1+i)^n}{(1-i)^n - 1}$$

Annualized Cost - 40 Year Recovery

Technology	Direct Cost Estimate (Above the Line Costs)	Contingency	Land Purchase Costs	Land Easement Costs	Treatment Costs	Total Escalated Capital Cost Range (including contingency)		Total Annualized Capital Cost	Annual O&M Costs	20-YR Replacement Cost	Total Annualized Cost	Annualized Cost Per AF
Concept 1 - Surface Recharge Ponds	$ 4,300,000	35%	$ 3,675,000	$ 2,000	$ -	$ 9,800,000	$ 11,800,000	$ 700,000	$ 38,000	$ 2,709,435	$ 800,000	$ 80
Concept 2 - Subsurface Recharge Galleries	$ 12,100,000	35%	$ -	$ 351,000	$ 9,500,000	$ 26,200,000	$ 31,300,000	$ 1,900,000	$ 80,000	$ 11,122,313	$ 2,300,000	$ 230
Concept 3 - Shallow Injection Wells	$ 44,100,000	35%	$ -	$ 1,854,000	$ 9,500,000	$ 71,200,000	$ 89,800,000	$ 5,300,000	$ 80,000	$ 48,522,860	$ 6,600,000	$ 660
Concept 4 - Cultec Engineered Systems	$ 77,600,000	35%	$ -	$ 233,800	$ 9,500,000	$ 114,800,000	$ 147,500,000	$ 8,600,000	$ 80,000	$ 2,160,468	$ 8,700,000	$ 870
Concept 5 - Subsurface Conveyance System	$ 47,000,000	35%	$ -	$ 54,000	$ -	$ 69,400,000	$ 89,200,000	$ 5,200,000	$ 49,000	$ 2,188,390	$ 5,300,000	$ 530

Date: July 2009
Prepared by: K. Stearns
Reviewed by: B. Toland

LAND ESCALATION: 100 - YEAR ANALYSIS

Year	Land Escalation 5%	Land Escalation 3%	Land Escalation 1%	Cost of 250 Acres 5%	Cost of 250 Acres 3%	Cost of 250 Acres 1%	Cost of 250 Acres 3%	Cost of 250 Acres 1%
0	$ 14,000	$ 14,000	$ 14,000	$ 3,500,000	$ 3,500,000	$ 3,500,000	$ 3,500,000	$ 3,500,000
1	$ 14,700	$ 14,420	$ 14,140	$ 3,675,000	$ 3,605,000	$ 3,535,000	$ 3,605,000	$ 3,535,000
2	$ 15,435	$ 14,853	$ 14,281	$ 3,858,750	$ 3,713,150	$ 3,570,350	$ 3,713,150	$ 3,570,350
3	$ 16,207	$ 15,298	$ 14,424	$ 4,051,688	$ 3,824,545	$ 3,606,054	$ 3,824,545	$ 3,606,054
4	$ 17,017	$ 15,757	$ 14,568	$ 4,254,272	$ 3,939,281	$ 3,642,114	$ 3,939,281	$ 3,642,114
5	$ 17,868	$ 16,230	$ 14,714	$ 4,466,985	$ 4,057,459	$ 3,678,535	$ 4,057,459	$ 3,678,535
6	$ 18,761	$ 16,717	$ 14,861	$ 4,690,335	$ 4,179,183	$ 3,715,321	$ 4,179,183	$ 3,715,321
7	$ 19,699	$ 17,218	$ 15,010	$ 4,924,851	$ 4,304,559	$ 3,752,474	$ 4,304,559	$ 3,752,474
8	$ 20,684	$ 17,735	$ 15,160	$ 5,171,094	$ 4,433,695	$ 3,789,998	$ 4,433,695	$ 3,789,998
9	$ 21,719	$ 18,267	$ 15,312	$ 5,429,649	$ 4,566,706	$ 3,827,898	$ 4,566,706	$ 3,827,898
10	$ 22,805	$ 18,815	$ 15,465	$ 5,701,131	$ 4,703,707	$ 3,866,177	$ 4,703,707	$ 3,866,177
11	$ 23,945	$ 19,379	$ 15,619	$ 5,986,188	$ 4,844,819	$ 3,904,839	$ 4,844,819	$ 3,904,839
12	$ 25,142	$ 19,961	$ 15,776	$ 6,285,497	$ 4,990,163	$ 3,943,888	$ 4,990,163	$ 3,943,888
13	$ 26,399	$ 20,559	$ 15,933	$ 6,599,772	$ 5,139,868	$ 3,983,326	$ 5,139,868	$ 3,983,326
14	$ 27,719	$ 21,176	$ 16,093	$ 6,929,761	$ 5,294,064	$ 4,023,160	$ 5,294,064	$ 4,023,160
15	$ 29,105	$ 21,812	$ 16,254	$ 7,276,249	$ 5,452,886	$ 4,063,391	$ 5,452,886	$ 4,063,391
16	$ 30,560	$ 22,466	$ 16,416	$ 7,640,061	$ 5,616,473	$ 4,104,025	$ 5,616,473	$ 4,104,025
17	$ 32,088	$ 23,140	$ 16,580	$ 8,022,064	$ 5,784,967	$ 4,145,066	$ 5,784,967	$ 4,145,066
18	$ 33,693	$ 23,834	$ 16,746	$ 8,423,167	$ 5,958,516	$ 4,186,516	$ 5,958,516	$ 4,186,516
19	$ 35,377	$ 24,549	$ 16,914	$ 8,844,326	$ 6,137,271	$ 4,228,381	$ 6,137,271	$ 4,228,381
20	$ 37,146	$ 25,286	$ 17,083	$ 9,286,542	$ 6,321,389	$ 4,270,665	$ 6,321,389	$ 4,270,665
21	$ 39,003	$ 26,044	$ 17,253	$ 9,750,869	$ 6,511,031	$ 4,313,372	$ 6,511,031	$ 4,313,372
22	$ 40,954	$ 26,825	$ 17,426	$ 10,238,413	$ 6,706,362	$ 4,356,506	$ 6,706,362	$ 4,356,506
23	$ 43,001	$ 27,630	$ 17,600	$ 10,750,333	$ 6,907,553	$ 4,400,071	$ 6,907,553	$ 4,400,071
24	$ 45,151	$ 28,459	$ 17,776	$ 11,287,850	$ 7,114,779	$ 4,444,071	$ 7,114,779	$ 4,444,071
25	$ 47,409	$ 29,313	$ 17,954	$ 11,852,242	$ 7,328,223	$ 4,488,512	$ 7,328,223	$ 4,488,512
26	$ 49,779	$ 30,192	$ 18,134	$ 12,444,854	$ 7,548,069	$ 4,533,397	$ 7,548,069	$ 4,533,397
27	$ 52,268	$ 31,098	$ 18,315	$ 13,067,097	$ 7,774,512	$ 4,578,731	$ 7,774,512	$ 4,578,731
28	$ 54,882	$ 32,031	$ 18,498	$ 13,720,452	$ 8,007,747	$ 4,624,518	$ 8,007,747	$ 4,624,518
29	$ 57,626	$ 32,962	$ 18,683	$ 14,406,475	$ 8,247,979	$ 4,670,764	$ 8,247,979	$ 4,670,764
30	$ 60,507	$ 33,982	$ 18,870	$ 15,126,798	$ 8,495,419	$ 4,717,471	$ 8,495,419	$ 4,717,471
31	$ 63,533	$ 35,001	$ 19,059	$ 15,883,138	$ 8,750,281	$ 4,764,646	$ 8,750,281	$ 4,764,646
32	$ 66,709	$ 36,051	$ 19,249	$ 16,677,295	$ 9,012,790	$ 4,812,292	$ 9,012,790	$ 4,812,292
33	$ 70,045	$ 37,133	$ 19,442	$ 17,511,160	$ 9,283,173	$ 4,860,415	$ 9,283,173	$ 4,860,415
34	$ 73,547	$ 38,247	$ 19,636	$ 18,386,718	$ 9,561,669	$ 4,909,019	$ 9,561,669	$ 4,909,019
35	$ 77,224	$ 39,364	$ 19,832	$ 19,306,054	$ 9,848,519	$ 4,958,110	$ 9,848,519	$ 4,958,110
36	$ 81,085	$ 40,576	$ 20,031	$ 20,271,356	$ 10,143,974	$ 5,007,691	$ 10,143,974	$ 5,007,691
37	$ 85,140	$ 41,793	$ 20,231	$ 21,284,924	$ 10,448,293	$ 5,057,768	$ 10,448,293	$ 5,057,768
38	$ 89,397	$ 43,047	$ 20,433	$ 22,349,171	$ 10,761,742	$ 5,108,345	$ 10,761,742	$ 5,108,345
39	$ 93,867	$ 44,335	$ 20,638	$ 23,466,629	$ 11,084,594	$ 5,159,429	$ 11,084,594	$ 5,159,429
40	$ 98,560	$ 45,669	$ 20,844	$ 24,639,960	$ 11,417,132	$ 5,211,023	$ 11,417,132	$ 5,211,023
41	$ 103,488	$ 47,039	$ 21,053	$ 25,871,959	$ 11,759,646	$ 5,263,133	$ 11,759,646	$ 5,263,133
42	$ 108,662	$ 48,450	$ 21,263	$ 27,165,556	$ 12,112,436	$ 5,315,765	$ 12,112,436	$ 5,315,766
43	$ 114,095	$ 49,903	$ 21,476	$ 28,523,834	$ 12,475,809	$ 5,368,922	$ 12,475,809	$ 5,368,922
44	$ 119,800	$ 51,400	$ 21,690	$ 29,950,026	$ 12,850,083	$ 5,422,612	$ 12,850,083	$ 5,422,612
45	$ 125,790	$ 52,942	$ 21,907	$ 31,447,527	$ 13,235,585	$ 5,476,838	$ 13,235,585	$ 5,476,838
46	$ 132,080	$ 54,531	$ 22,126	$ 33,019,904	$ 13,632,653	$ 5,531,606	$ 13,632,653	$ 5,531,606
47	$ 138,684	$ 56,167	$ 22,348	$ 34,670,899	$ 14,041,633	$ 5,586,922	$ 14,041,633	$ 5,586,922
48	$ 145,618	$ 57,852	$ 22,571	$ 36,404,444	$ 14,462,882	$ 5,642,791	$ 14,462,882	$ 5,642,791
49	$ 152,899	$ 59,587	$ 22,797	$ 38,224,666	$ 14,896,768	$ 5,699,219	$ 14,896,768	$ 5,699,219
50	$ 160,544	$ 61,375	$ 23,025	$ 40,135,899	$ 15,343,671	$ 5,756,211	$ 15,343,671	$ 5,756,211

LAND ESCALATION: 100 - YEAR ANALYSIS

Year	Land Escalation 5%	Land Escalation 3%	Land Escalation 1%	Cost of 250 Acres 5%	Cost of 250 Acres 3%	Cost of 250 Acres 1%	Cost of 250 Acres 3%	Cost of 250 Acres 1%
51	$ 168,571	$ 63,216	$ 23,255	$ 42,142,694	$ 15,803,981	$ 5,813,773	$ 15,803,981	$ 5,813,773
52	$ 176,999	$ 65,112	$ 23,488	$ 44,249,829	$ 16,278,101	$ 5,871,911	$ 16,278,101	$ 5,871,911
53	$ 185,849	$ 67,066	$ 23,723	$ 46,462,320	$ 16,766,444	$ 5,930,630	$ 16,766,444	$ 5,930,630
54	$ 195,142	$ 69,078	$ 23,960	$ 48,785,436	$ 17,269,437	$ 5,989,937	$ 17,269,437	$ 5,989,937
55	$ 204,899	$ 71,150	$ 24,199	$ 51,224,708	$ 17,787,520	$ 6,049,836	$ 17,787,520	$ 6,049,836
56	$ 215,144	$ 73,285	$ 24,441	$ 53,785,944	$ 18,321,146	$ 6,110,334	$ 18,321,146	$ 6,110,334
57	$ 225,901	$ 75,483	$ 24,686	$ 56,475,241	$ 18,870,780	$ 6,171,438	$ 18,870,780	$ 6,171,438
58	$ 237,196	$ 77,748	$ 24,933	$ 59,299,003	$ 19,436,903	$ 6,233,152	$ 19,436,903	$ 6,233,152
59	$ 249,056	$ 80,080	$ 25,182	$ 62,263,953	$ 20,020,011	$ 6,295,484	$ 20,020,011	$ 6,295,484
60	$ 261,509	$ 82,482	$ 25,434	$ 65,377,151	$ 20,620,611	$ 6,358,438	$ 20,620,611	$ 6,358,438
61	$ 274,584	$ 84,957	$ 25,688	$ 68,646,008	$ 21,239,229	$ 6,422,023	$ 21,239,229	$ 6,422,023
62	$ 288,313	$ 87,506	$ 25,945	$ 72,078,306	$ 21,876,406	$ 6,486,243	$ 21,876,406	$ 6,486,243
63	$ 302,729	$ 90,131	$ 26,204	$ 75,682,224	$ 22,532,698	$ 6,551,105	$ 22,532,698	$ 6,551,105
64	$ 317,865	$ 92,835	$ 26,466	$ 79,466,335	$ 23,208,679	$ 6,616,617	$ 23,208,679	$ 6,616,617
65	$ 333,759	$ 95,620	$ 26,731	$ 83,439,652	$ 23,904,940	$ 6,682,783	$ 23,904,940	$ 6,682,783
66	$ 350,447	$ 98,488	$ 26,998	$ 87,611,635	$ 24,622,088	$ 6,749,611	$ 24,622,088	$ 6,749,611
67	$ 367,969	$ 101,443	$ 27,268	$ 91,992,216	$ 25,360,750	$ 6,817,107	$ 25,360,750	$ 6,817,107
68	$ 386,367	$ 104,486	$ 27,541	$ 96,591,827	$ 26,121,573	$ 6,885,278	$ 26,121,573	$ 6,885,278
69	$ 405,686	$ 107,621	$ 27,817	$ 101,421,418	$ 26,905,220	$ 6,954,130	$ 26,905,220	$ 6,954,130
70	$ 425,970	$ 110,850	$ 28,095	$ 106,492,489	$ 27,712,377	$ 7,023,672	$ 27,712,377	$ 7,023,672
71	$ 447,268	$ 114,175	$ 28,376	$ 111,817,114	$ 28,543,748	$ 7,093,909	$ 28,543,748	$ 7,093,909
72	$ 469,632	$ 117,600	$ 28,659	$ 117,407,970	$ 29,400,060	$ 7,164,848	$ 29,400,060	$ 7,164,848
73	$ 493,113	$ 121,128	$ 28,946	$ 123,278,368	$ 30,282,062	$ 7,236,496	$ 30,282,062	$ 7,236,496
74	$ 517,769	$ 124,762	$ 29,235	$ 129,442,286	$ 31,190,524	$ 7,308,861	$ 31,190,524	$ 7,308,861
75	$ 543,658	$ 128,505	$ 29,528	$ 135,914,401	$ 32,126,240	$ 7,381,950	$ 32,126,240	$ 7,381,950
76	$ 570,840	$ 132,360	$ 29,823	$ 142,710,121	$ 33,090,027	$ 7,455,769	$ 33,090,027	$ 7,455,769
77	$ 599,382	$ 136,331	$ 30,121	$ 149,845,627	$ 34,082,728	$ 7,530,327	$ 34,082,728	$ 7,530,327
78	$ 629,352	$ 140,421	$ 30,423	$ 157,337,908	$ 35,105,210	$ 7,605,630	$ 35,105,210	$ 7,605,630
79	$ 660,819	$ 144,633	$ 30,727	$ 165,204,804	$ 36,158,366	$ 7,681,686	$ 36,158,366	$ 7,681,686
80	$ 693,860	$ 148,972	$ 31,034	$ 173,465,044	$ 37,243,117	$ 7,758,503	$ 37,243,117	$ 7,758,503
81	$ 728,553	$ 153,442	$ 31,344	$ 182,138,296	$ 38,360,410	$ 7,836,088	$ 38,360,410	$ 7,836,088
82	$ 764,981	$ 158,045	$ 31,658	$ 191,245,211	$ 39,511,223	$ 7,914,449	$ 39,511,223	$ 7,914,449
83	$ 803,230	$ 162,786	$ 31,974	$ 200,807,471	$ 40,696,559	$ 7,993,594	$ 40,696,559	$ 7,993,594
84	$ 843,391	$ 167,670	$ 32,294	$ 210,847,845	$ 41,917,456	$ 8,073,530	$ 41,917,456	$ 8,073,530
85	$ 885,561	$ 172,700	$ 32,617	$ 221,390,237	$ 43,174,980	$ 8,154,265	$ 43,174,980	$ 8,154,265
86	$ 929,839	$ 177,881	$ 32,943	$ 232,459,749	$ 44,470,229	$ 8,235,808	$ 44,470,229	$ 8,235,808
87	$ 976,331	$ 183,217	$ 33,273	$ 244,082,736	$ 45,804,336	$ 8,318,166	$ 45,804,336	$ 8,318,166
88	$ 1,025,147	$ 188,714	$ 33,605	$ 256,286,873	$ 47,178,466	$ 8,401,347	$ 47,178,466	$ 8,401,347
89	$ 1,076,405	$ 194,375	$ 33,941	$ 269,101,217	$ 48,593,820	$ 8,485,361	$ 48,593,820	$ 8,485,361
90	$ 1,130,225	$ 200,207	$ 34,281	$ 282,556,278	$ 50,051,635	$ 8,570,214	$ 50,051,635	$ 8,570,214
91	$ 1,186,736	$ 206,213	$ 34,624	$ 296,684,092	$ 51,553,184	$ 8,655,917	$ 51,553,184	$ 8,655,917
92	$ 1,246,073	$ 212,399	$ 34,970	$ 311,518,296	$ 53,099,779	$ 8,742,476	$ 53,099,779	$ 8,742,476
93	$ 1,308,377	$ 218,771	$ 35,320	$ 327,094,211	$ 54,692,773	$ 8,829,900	$ 54,692,773	$ 8,829,900
94	$ 1,373,796	$ 225,334	$ 35,673	$ 343,448,921	$ 56,333,556	$ 8,918,199	$ 56,333,556	$ 8,918,199
95	$ 1,442,485	$ 232,094	$ 36,030	$ 360,621,368	$ 58,023,563	$ 9,007,381	$ 58,023,563	$ 9,007,381
96	$ 1,514,610	$ 239,057	$ 36,390	$ 378,652,436	$ 59,764,270	$ 9,097,455	$ 59,764,270	$ 9,097,455
97	$ 1,590,340	$ 246,229	$ 36,754	$ 397,585,058	$ 61,557,198	$ 9,188,430	$ 61,557,198	$ 9,188,430
98	$ 1,669,857	$ 253,516	$ 37,121	$ 417,464,311	$ 63,403,914	$ 9,280,314	$ 63,403,914	$ 9,280,314
99	$ 1,753,350	$ 261,224	$ 37,492	$ 438,337,526	$ 65,306,031	$ 9,373,117	$ 65,306,031	$ 9,373,117
100	$ 1,841,018	$ 269,061	$ 37,867	$ 460,254,402	$ 67,285,212	$ 9,466,848	$ 67,285,212	$ 9,466,848

LAND ESCALATION ANALYSIS: COMPARISON OF CAPITAL COST (LOW RANGE)

	(low range)	to Concept 1	Escalation 5%	Escalation 3%	Escalation 1%
Concept 1	$ 9,767,227	$ -	-	-	-
Concept 2	$ 26,188,951	$ 16,421,724	31	51	>100
Concept 3	$ 71,155,970	$ 61,388,743	56	97	>100
Concept 4	$ 114,734,331	$ 104,967,104	70	>100	>100
Concept 5	$ 69,329,069	$ 59,561,842	58	95	>100

LAND ESCALATION ANALYSIS: COMPARISON OF CAPITAL COST (HIGH RANGE)

	(low range)	to Concept 1	Escalation 5%	Escalation 3%	Escalation 1%
Concept 1	$ 11,564,934	$ -	-	-	-
Concept 2	$ 31,277,982	$ 19,713,048	34	57	>100
Concept 3	$ 89,767,152	$ 78,202,218	64	>100	>100
Concept 4	$ 147,496,543	$ 135,931,609	75	>100	>100
Concept 5	$ 89,142,504	$ 77,577,570	63	>100	>100

HDR

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept 1 - Surface Recharge Ponds

Key Assumptions:
1) All pipes are gravity
2) Unit cost based on 2008 reference. Not yet adjusted with CCI.

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DIVISION 2 - SITE WORK							
Clearing and Grubbing	250	ACRE	$ 240.00	included	$ 60,000		Unit Cost based on previous IRWD Strand Ranch Construction cost. (10% of RS Means published unit cost. RS Means 2008, 31 11 10 10 - 0020, pg 207)
Excavation, Bulk, Scraper	1,210,097	BCY	$ 0.90	included	$ 1,089,087		Unit Cost based on previous IRWD Strand Ranch Construction cost. (35% of RS Means published unit cost. RS Means 2008, 31 23 16.13 -5110 pg. 211)
Backfill - For Berm Around Pond	1,210,097	CY	$ 0.75	included	$ 907,573		Unit Cost based on previous IRWD Strand Ranch Construction cost. (34% of RS Means published unit cost. RS Means 2008 31 23 23 14 -2400, pg 223. Assuming reuse of excavated materials for trapezoidal berm around pond)
Site Dewatering	-	CY	$ 6.26	included	$ -		RS Means 2008, 31 23 19 20 - 0100, pg. 221. Assuming excavation is shallow & dewatering is not required
Hauling	-	CY	$ 7.48	included	$ -		RS Means 2008, 31 23 23 18 - 1250, pg. 225. 20 CY Dump Trailer, 10 mile round trip. Assume all fill reused on site
						$ 2,056,660	
DIVISION 3 - CONCRETE							
Canal Tie-in Structure	1	LS	$ 150,000.00	included	$ 150,000		Per Prior project experience
Basin Headwall/Distribution Channel	1	LS	$ 150,000.00	included	$ 150,000		Per Prior project experience
						$ 300,000	
DIVISION 5 - METALS N/A							
DIVISION 11 - EQUIPMENT N/A Assuming Gravity Flow - No pump station							
DIVISION 13 - SPECIAL CONSTRUCTION N/A							
DIVISION 15 - MECHANICAL Transmission Piping (6-foot diameter)	2,640	LF	$ 720.00	included	$ 1,900,800	$ 1,900,800	Assuming Unit cost $10/InchDiam/LF pipe & 0.5 mile to recharge pond, Includes piping installation, trench excavation, backfill, and speed shoring
DIRECT COSTS						$4,257,460	
Field Overhead & Mobilization (% of Construction Total)				7%		$298,022	
Subtotal 1						$4,555,482	
Contractor Profit (% of Subtotal 1)				10%		$455,648	
Subtotal 2						$5,011,030	
Insurance & Bonds (% of Subtotal 2)				2.5%		$125,276	
Subtotal 3						$5,136,306	
Contingency (% of Subtotal 3)				35%		$1,797,707	
Subtotal 4						$6,934,013	
Land Purchase Costs	262.50	ACRE		$14,000	$ 3,675,000	$10,609,013	Per IRWD Kickoff Meeting, Includes cost of pond +5% additional land for berms and access
Easement Purchase Costs	0.73	ACRE		$1,400	$ 1,018	$10,610,031	Per IRWD Kickoff Meeting; Includes cost of easement for Distribution Piping
Escalation to 2012 (% of Subtotal with Land Costs)				9%		$954,903	

TOTAL		$11,564,934
Range (with and without contingency)	$9,767,227	$11,564,934

O&M COST

DESCRIPTION	QUANTITY	UNITS	UNIT COST	TOTAL COST	NOTES
Annual Maintenance per Rosedale GM (ratio to 250 acres)	1	LS	$ 38,000.00	$ 38,000	Cost based on 9/1/09 email from Kelle Welch per discussion with Rosedale's GM
20-Yr Scraping Activity (assume 4" material removal)	-			$ 2,709,435	
Excavation, Bulk, Scraper	*134,444*	*BCY*	*$ 0.90*	*$ 121,000*	Unit cost based on HDR CCI division.
Hauling - 20 mile RT	*134,444*	*BCY*	*$ 11.50*	*$ 1,546,111*	Unit cost based on HDR CCI division.
Tipping Fees	*6,002*	*Ton*	*$ 100.00*	*$ 600,198*	Unit cost based on HDR CCI division.
Scraping indirects (overhead, profit, insurance, bonds)				*$ 442,125*	Based on percentages used for Capital Cost indirects, above. Excludes contingency and escalation
Total Annualized O&M (40-YR life cycle)				$ 105,736	

HDR

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept 2 - Subsurface Recharge Galleries

Date: September 2009
Prepared by: K. Stroemu
Reviewed by: S. Toland

Key Assumptions
1) All pipes are gravity
2) Does not include the cost of pretreatment
3) Unit cost based on 2008 reference. Not yet adjusted with CCI

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DIVISION 2 - SITE WORK							
Clearing and Grubbing	250	ACRE	$ 240.00	included	$ 60,000		Unit Cost based on previous IRWD Strand Ranch Construction cost. (10% of RS Means published unit cost. RS Means 2008, 31 11 10 10 - 0020, pg. 207)
Excavation, Trench	549,539	BCY	$ 1.09	included	$ 598,998		Unit Cost based on previous IRWD Strand Ranch Construction cost. (35% of RS Means published unit cost. RS Means 2008, 31 23 16 13 -5110, pg. 211) Assuming total depth of trench to be excavated is 5 ft
Backfill (gravel pipe bedding zone)	109,919	CY	$ 17.72	included	$ 1,948,207		RS Means 2008, 31 23 23.17 - 1300, pg. 225; Assuming 12" deep of gravel. Includes 40% discount for economics of scale
Backfill (native material)	439,820	CY	$ 0.75	included	$ 329,715		Unit Cost based on previous IRWD Strand Ranch Construction cost. (34% of RS Means published unit cost. RS Means 2008. 31 23 23 14 -2400, pg. 223) Assuming using native backfill for 4 of the 5 feet, Rest to be used onsite
Site Dewatering	-	CY	$ 6.26	included	$ -		RS Means 2008, 31 23 19.20 - 0100, pg. 221; Assuming excavation is shallow & dewatering is not required
Hauling	-	CY	$ 7.48	included	$ -		RS Means 2008, 31 23 23 18 - 1250, pg. 225; 20 CY Dump Trailer; 10 mile round trip; Assume all fill reused on site
Filter Fabric	302,470	SY	$ 1.65	included	$ 499,075		
						$ 3,435,994	
DIVISION 3 - CONCRETE							
Canal Tie-In Structure	1	LS	$ 150,000.00	included	$ 150,000		Per Prior project experience
						$ 150,000	
DIVISION 5 - METALS							
N/A							
DIVISION 11 - EQUIPMENT							
N/A Assuming Gravity Flow - No pump station							
DIVISION 13 - SPECIAL CONSTRUCTION							
N/A							
DIVISION 15 - MECHANICAL							
Transmission Piping (6-foot diameter)	2,640	LF	$ 720.00	included	$ 1,900,800		Assuming Unit cost $10/InchDiam/LF pipe & 0.5 mile to recharge gallery; includes piping installation, trench excavation, backfill, and speed shoring
Perforated Drain Pipe (6-inch diameter) - Laterals	1089000	LF	$ 5.21	included	$ 5,671,512		RS Means 2008, 33 46 16 35 - 0060, pg. 316; Does not include excavation and backfill. Includes 30% discount for economics of scale
Perforated Drain Pipe (8-inch diameter) - Headers	91790	LF	$ 7.31	included	$ 670,801		RS Means 2008, 33 46 16 35 - 0080, pg. 316; Does not include excavation and backfill. Includes 30% discount for economics of scale
Valving	137	EA	$ 1,628.50	included	$ 223,105		RS Means 2008, 33 12 16 10 -3180, pg. 302; 1 isolation valve per module
						$ 8,466,218	
DIRECT COSTS						$12,052,212	
Field Overhead & Mobilization (% of Construction Total)				7%		$843,655	
Subtotal 1						$12,895,867	
Contractor Profit (% of Subtotal 1)				10.0%		$1,289,587	
Subtotal 2						$14,185,454	
Insurance & Bonds (% of Subtotal 2)				2.5%		$354,636	
Subtotal 3						$14,540,090	
Contingency (% of Subtotal 3)				35%		$5,089,032	
Subtotal 4						$19,629,122	
Land Purchase Costs	0	ACRE		$14,000	$ -	$19,629,122	
Easement Purchase Costs	250	ACRE		$1,400	$ 350,679	$19,979,800	Per IRWD Kickoff Meeting, includes cost of easement for Module Laterals, Headers and Distribution Piping
Escalation to 2012 (% of Subtotal with Land Costs)				9%		$1,798,182	

TOTAL		$21,777,982
Range (with and without contingency)	$16,688,951	$21,777,982

O&M COST

DESCRIPTION	QUANTITY	UNITS	UNIT COST	TOTAL COST	NOTES
Annual Sediment Treatment System O&M	1	LS	$ 80,000	$ 80,000	
20-Yr Replacement Cost of Perforated Laterals	1	LS	$ 11,122,313	$ 11,122,313	Accounts for excavation, replacement of gravel, perforated piping and backfill. Also includes Contractor indirects (overhead, profit, insurance, bonds)
Total Annualized O&M (40-YR life cycle)				$ 356,058	

HDR

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept 3 - Shallow Injection Wells

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Key Assumptions:
1) All pipes are gravity
2) Does not include the cost of pretreatment
3) Unit cost based on 2008 reference. Not yet adjusted with CCI

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DIVISION 2 - SITE WORK							
Clearing and Grubbing	1,323	ACRE	$ 240.00	included	$ 317,520		Unit Cost based on previous IRWD Strand Ranch Construction cost. (10% of RS Means published unit cost. RS Means 2008 31 11 10 10 - 0020, pg. 207)
Excavation, Trench	1,457,985	CY	$ 1.09	included	$ 1,592,120		Unit Cost based on previous IRWD Strand Ranch Construction cost. (35% of RS Means published unit cost. RS Means 2008 31 23 16 13 - 5200, pg. 211)
Backfill (gravel pipe bedding zone)	121,499	CY	$ 17.72	included	$ 2,153,444		RS Means 2008, 31 23 23 17 - 1300, pg. 225, Assuming 12" deep of gravel. Includes 40% discount for economics of scale
Backfill (native material)	1,336,487	CY	$ 0.75	included	$ 1,002,365		Unit Cost based on previous IRWD Strand Ranch Construction cost. (34% of RS Means published unit cost. RS Means 2008 31 23 23 14 -2400, pg. 223) Assuming reusing 11' of original backfill; rest to be used onsite
Site Dewatering	218,698	CY	$ 6.25	included	$ 1,389,048		RS Means 2008, 31 23 19 20 - 0100, pg. 221; Assuming appox 15% of trench excavation must be dewatered
Hauling	-	CY	$ 7.48	included	$ -		RS Means 2008, 31 23 23.18 - 1250, pg. 225; 20 CY Dump Trailer; 10 mile round trip. Assume all fill reused on site
Speed Shoring	26,136,000	SF	$ 1.00	included	$ 26,136,000		Speed Shoring Per J. Moncrief. Assuming shoring is required for all lateral trench installation
Filter Fabric	362,964	SY	$ 1.65	included	$ 598,890		RS Means 2008, 33 46 26 10 0100, pg. 317
						$ 32,570,497	
DIVISION 3 - CONCRETE							
Concrete Caisson	5,448	VLF	$ 36.00	included	$ 196,128		RS Means 2008, 31 63 26 13 - 0200, pg. 246, Assuming 12 feet deep
Canal Tie-In Structure	1	LS	$ 150,000.00	included	$ 150,000		Per Prior project experience
						$ 346,128	
DIVISION 5 - METALS							
N/A							
DIVISION 11 - EQUIPMENT							
N/A Assuming Gravity Flow - No pump station							
DIVISION 13 - SPECIAL CONSTRUCTION							
N/A							
DIVISION 15 - MECHANICAL							
Transmission Piping (6-foot diameter)	2,640	LF	$ 720.00	included	$ 1,900,800		Assuming Unit cost $10/InchDiam/LF pipe & 0.5 mile to recharge wells; includes piping installation, trench excavation, backfill, and speed shoring
Perforated Drain Pipe (12-inch diameter) - Laterals	1089600	LF	$ 7.82	included	$ 8,519,582		RS Means 2008, 33 46 16.30 -2140, pg. 316; Does not include excavation and backfill. Includes 30% discount for economics of scale
Valving	454	EA	$ 1,628.50	included	$ 739,339		RS Means 2008, 33 12 16 10 -3180, pg. 302; 1 isolation valve per module
						$ 11,159,721	
DIRECT COSTS						$44,076,347	
Field Overhead & Mobilization (% of Construction Total)				7%		$3,085,344	
Subtotal 1						$47,161,691	
Contractor Profit (% of Subtotal 1)				10%		$4,716,169	
Subtotal 2						$51,877,860	
Insurance & Bonds (% of Subtotal 2)				2.5%		$1,296,947	
Subtotal 3						$53,174,807	
Contingency (% of Subtotal 3)				35%		$18,611,182	
Subtotal 4						$71,785,989	
Land Purchase Costs	0	ACRE		$14,000	$ -	$71,785,989	Per IRWD Kickoff Meeting
Easement Purchase Costs	1,324	ACRE		$1,400	$ 1,853,600	$73,639,589	Per IRWD Kickoff Meeting
Escalation to 2012 (% of Subtotal with Land Costs)				9%		$6,627,563	

TOTAL		$80,267,152
Range (with and without contingency)	$61,655,970	$80,267,152

O&M COST

DESCRIPTION	QUANTITY	UNITS	UNIT COST	TOTAL COST	NOTES
Annual Sediment Treatment System O&M	1	LS	$ 80,000	$ 80,000	
20-Yr Replacement Cost of Perforated Laterals	1	LS	$ 48,522,860	$ 48,522,860	Accounts for excavation, dewatering, shoring, replacement of gravel, filter fabric, perforated piping and backfill. Also includes Contractor indirects (overhead, profit, insurance, bonds)
Total Annualized O&M (40-YR life cycle)				$ 1,293,072	

HDR

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept 4 - CULTEC Engineered Systems

Key Assumptions
1) All pipes are gravity
2) Does not include the cost of pretreatment
3) Unit cost based on 2008 reference. Not yet adjusted with CCI

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DIVISION 2 - SITE WORK							
Clearing and Grubbing	167	ACRE	$ 240.00	included	$ 40,080		Unit Cost based on previous IRWD Strand Ranch Construction cost (10% of RS Means published unit cost. RS Means 2008, 31 11 10 10 - 0020, pg 207)
Excavation	1,345,786	CY	$ 1.09	included	$ 1,466,907		Unit Cost based on previous IRWD Strand Ranch Construction cost (35% of RS Means published unit cost. RS Means 2008, 31 23 16 13 -3110, pg 211) Assuming total depth of trench to be excavated is 5 ft
Backfill (native material)	1,076,629	CY	$ 0.75	included	$ 807,472		Unit Cost based on previous IRWD Strand Ranch Construction cost (34% of RS Means published unit cost. RS Means 2008, 31 23 23 14 -2400, pg 223, Assuming reusing 7' of original backfill; rest to be reused on site)
Backfill (gravel pipe bedding zone)	269,157	CY	$ 17.72	included	$ 4,770,543		RS Means 2008, 31 23 23.17 - 1300, pg. 225, Assuming 12" deep of gravel. Includes 40% discount for economics of scale
Site Dewatering	-	CY	$ 6.26	included	$ -		RS Means 2008, 31 23 19.20 - 0100, pg. 221, Assuming excavation is shallow & dewatering is not required
Hauling	-	CY	$ 7.48	included	$ -		RS Means 2008, 31 23 23.18 - 1250, pg. 225, 20 CY Dump Trailer; 10 mile round trip; Assume all fill reused on site
						$ 7,085,002	
DIVISION 3 - CONCRETE							
Canal Tie-In Structure	1	LS	$ 150,000.0	included	$ 150,000	$ 150,000	Per Prior project experience
DIVISION 5 - METALS							
N/A							
DIVISION 11 - EQUIPMENT							
N/A Assuming Gravity Flow - No pump station							
DIVISION 13 - SPECIAL CONSTRUCTION							
N/A							
DIVISION 15 - MECHANICAL							
Transmission Piping (6-foot diameter)	2,640	LF	$ 720.00	included	$ 1,900,800		Assuming Unit cost $10/InchDiam/LF pipe & 0.5 mile to system. Includes piping installation, trench excavation, backfill, and speed shoring
CULTEC RECHARGER V8	322,667	EA	$ 185.00		$ 59,693,395		Per unit cost from CULTEC quote
CULTEC Feed F-110 Connectors	29,041	EA	$ 40.00		$ 1,161,640		Per unit cost from CULTEC quote
CULTEC Poly Liner	29,041	roll	$ 200.00		$ 5,808,200		Per unit cost from CULTEC quote
CULTEC 410 Filter Fabric	322,667	EA	$ 5.55		$ 1,790,802		Per unit cost from CULTEC quote
						$ 70,354,837	
DIRECT COSTS						$77,589,838	
Field Overhead & Mobilization (% of Construction Total)				7%		$5,431,289	
Subtotal 1						$83,021,127	
Contractor Profit (% of Subtotal 1)				10%		$8,302,113	
Subtotal 2						$91,323,240	
Insurance & Bonds (% of Subtotal 2)				2.5%		$2,283,081	
Subtotal 3						$93,606,321	
Contingency (% of Subtotal3)				35%		$32,762,212	
Subtotal 4						$126,368,533	
Land Purchase Costs	0	ACRE		$14,000	$ -	$126,368,533	Per IRWD Kickoff Meeting
Easement Purchase Costs	167	ACRE		$1,400	$ 233,800	$126,602,333	Per IRWD Kickoff Meeting
Escalation to 2012 (% of Subtotal with Land Costs)				9%		$11,394,210	

TOTAL		$137,996,543
Range (with and without contingency)	$105,234,331	$137,996,543

O&M COST

DESCRIPTION	QUANTITY	UNITS	UNIT COST	TOTAL COST	NOTES
Annual Sediment Treatment System O&M	1	LS	$ 60,000	$ 60,000	
20-Yr Replacement of Filter Fabric	1	LS	$ 2,160,468	$ 2,160,468	Accounts for filter fabric replacement based on assumptions that the Cultec system is accessible. Also accounts for contractor indirects
Total Annualized O&M (40-YR life cycle)				$ 134,012	

HDR

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Concept 5 - Subsurface Conveyance System

Date: September 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Key Assumptions
1) All pipes are gravity
2) Does not include the cost of treatment and recharge basin for remaining flows
3) Assumes 1/2 of flow is recharged via a recharge basin
4) Unit cost based on 2008 reference. Not yet adjusted with CCI

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DIVISION 2 - SITE WORK							
Clearing and Grubbing	38	ACRE	$ 240.00	included	$ 9,231		Unit Cost based on previous IRWD Strand Ranch Construction cost (10% of RS Means published cost. RS Means 2008, 31 11 10 10 - 0020, pg 207)
Excavation, Trench	620,562	BCY	$ 1 09	included	$ 677,654		Unit Cost based on previous IRWD Strand Ranch Construction cost. (35% of RS Means published unit cost. RS Means 2008, 31 23 16 13 - 5200, pg. 211)
Backfill (gravel pipe bedding zone)	93,084	CY	$ 17 72	included	$ 1,649,827		RS Means 2008, 31 23 23 17 - 1300, pg. 225, Assuming 12" deep of gravel. Includes 40% discount for economics of scale.
Backfill (native material)	527,478	CY	$ 0 75	included	$ 395,609		Unit Cost based on previous IRWD Strand Ranch Construction cost. (34% of RS Means published unit cost. RS Means 2008, 31 23 23 14 -2400, pg 223; Assuming reusing 9' of original backfill; rest to be reused on site.)
Site Dewatering	9,308	CY	$ 6 26	included	$ 58,271		RS Means 2008, 31 23 19 20 - 0100, pg. 221; Assuming appox 15% of trench excavation must be dewatered
Hauling	-	CY	$ 5.24	included	$ -		RS Means 2008, 31 23 23 18 - 1250, pg. 225; 20 CY Dump Trailer; 10 mile round trip. Includes 30% discount for economics of scale
Shoring	4,188,462	SF	$ 1 00	included	$ 4,188,462		Speed Shoring Per J. Moncrief, Assuming shoring is required for all lateral trench installation
Filter Fabric	418,804	SY	$ 1 65	included	$ 691,027	$ 7,670,080	RS Means 2008, 22 46 26 10 0100, pg 317
DIVISION 3 - CONCRETE							
Canal Tie-In Structure	1	LS	$ 150,000 00	included	$ 150,000		Per Prior project experience
Basin Headwall/Distribution Channel	1	LS	$ 150,000.00	included	$ 150,000		Per Prior project experience
Concrete Manholes	419	EA	$ 1,652 00	included	$ 691,934	$ 991,934	RS Means 2008, 33 39 13 10 1130, pg 318, Assuming manhole every 1,000 feet
DIVISION 5 - METALS							
N/A							
DIVISION 11 - EQUIPMENT							
N/A Assuming Gravity Flow - No pump station							
DIVISION 13 - SPECIAL CONSTRUCTION							
N/A							
DIVISION 15 - MECHANICAL							
Transmission Channel - Assumes 6-ft x 10-ft tall inverted trench box	209,423	LF	$ 182 70	included	$ 38,261,596	$ 38,261,596	RS Means 2008 31 11 13 10 -3070, pg 296 (Extrapolating for 1/2 Pipe Costs) Includes 30% discount for economics of scale
DIRECT COSTS						$46,923,610	
Field Overhead & Mobilization (% of Construction Total)				7%		$3,284,653	
Subtotal 1						$50,208,263	
Contractor Profit (% of Subtotal 1)				10%		$5,020,826	
Subtotal 2						$55,229,089	
Bonds (% of Subtotal 2)				2 5%		$1,380,727	
Subtotal 34						$56,609,817	
Contingency (% of Subtotal 3)				35%		$19,813,436	
Subtotal 4						$76,423,252	
Land Purchase Costs	0.00	ACRE		$14,000	$ -	$76,423,252	Per IRWD Kickoff Meeting
Easement Purchase Costs	38	ACRE		$1,400	$ 53,846	$76,477,099	Per IRWD Kickoff Meeting
Recharge Basin Costs	1	LS		$5,305,016	$ 5,305,016	$81,782,114	Assume 0 5 of Total Cost of Concept 1
Escalation to 2012 (% of Subtotal with Land Costs)				9%		$7,360,390	

TOTAL		$89,142,504
Range (with and without contingency)	$69,329,069	$89,142,504

O&M COST

DESCRIPTION	QUANTITY	UNITS	UNIT COST	TOTAL COST	NOTES
Annual Surface Recharge Basin O&M (one-half of Concept 1 O&M cost)	1	LS	$ 19,000	$ 19,000	
Annual Subsurface Conveyance O&M (Periodic Vactor Cleaning)	1	LS	$ 30,000	$ 30,000	
20-Yr Surface Recharge Scraping (one-half of Concept 1)	1	LS	$ 1,354,717	$ 1,354,717	
20-Yr Replacement of Filter Fabric	1	LS	$ 833,672	$ 833,672	Accounts for filter fabric replacement, including contractor indirects.
Total Annualized O&M (40-YR life cycle)				$ 103,710	

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
Treatment Costs

Date: July 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Key Assumptions:
1) All pipes are gravity
2) Does not include the cost of treatment and recharge basin for remaining flows
3) Assumes 1/2 of flow is recharged via a recharge basin
4) Unit cost based on 2008 reference. Not yet adjusted with CCI

SPEC SECTION AND DESCRIPTION	QUANTITY	UNITS	UNIT COST	INSTALLATION	TOTAL COST	DIVISION SUBTOTALS	NOTES
DAF	1	LS	$ 8,938,321	included	$ 8,938,321	$ 8,900,000	OCWD Project Reference
Actiflo	1	LS	$ 7,977,855	included	$ 7,977,855	$ 8,000,000	OCWD Project Reference
Aqua Diamond	1	LS	$ 9,480,206	included	$ 9,480,206	$ 9,500,000	OCWD Project Reference
High Rate Sedimentation	1	LS	$ 10,784,050	included	$ 10,784,050	$ 10,800,000	OCWD Project Reference
Memcor Microfiltration	1	LS	$ 20,152,578	included	$ 20,152,578	$ 20,200,000	OCWD Project Reference
Conventional Sedimentation	1	LS	$ 12,736,106	included	$ 12,736,106	$ 12,700,000	OCWD Project Reference

Irvine Ranch Water District
Kern Valley Groundwater Recharge Evaluation
27 MGD Aqua Diamond - Operations & Maintenance Cost

Date: July 2009
Prepared by: K. Streams
Reviewed by: S. Toland

Pre-Treatment Only

ITEM	QUANTITY	UNIT	UNIT COST	TOTAL COST
Facility Operations & Maintenance				
Filter Replacement (Every 7 years)	32	EA	$798.92	$ 25,565
Labor	1	Staff Person	$80,000	$ 80,000
Equipment Replacement	1	LS	$25,000	$ 25,000
Aqua Diamond Facility Power	79935	kWh	$0.14	$ 11,191
TOTAL				**$ 116,191**
				0.68
				$ 78,429

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Irvine Ranch
WATER DISTRICT

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April 20, 2023
Prepared by: M. Lindsay / K. Welch
Submitted by: F. Sanchez / P. Weghorst
Approved by: Paul A. Cook

SUPPLY RELIABILITY PROGRAMS COMMITTEE

WATER SUPPLY CONDITIONS AND WATER BANKING CONSIDERATIONS UPDATE

SUMMARY:

To improve IRWD's water supply reliability, the District has developed a diverse water supply portfolio that includes water banking projects in Kern County that are available to supplement supplies during major droughts and supply interruptions. Provided below is an update on current water supply conditions in the Colorado River, State Water Project (SWP), Central Valley Project (CVP), and Kern River systems. Current expectations and considerations for securing water for recharge at the IRWD Water Bank in Kern County are also provided.

BACKGROUND:

Approximately 18% of IRWD's water supply is imported through Metropolitan Water District from the Colorado River and SWP. Over the past several years, extreme drought conditions have impacted supplies available from these sources. The extreme drought has reinforced the need to secure sources of water for IRWD's Water Bank. The following is an overview of water supply conditions in California as well as expectations and considerations for securing water for recharge at the IRWD Water Bank. At the Committee meeting, staff will present further details through the draft presentation that is provided as Exhibit "A".

Colorado River:

Metropolitan typically relies on the Colorado River for approximately 25% of its imported water. A combination of drought, climate change and population growth have contributed to reduced water levels in Lake Mead and Lake Powell, causing the Bureau of Reclamation to declare in 2021 the first Colorado River shortage condition. Reclamation prepares a 24-Month Study which assesses future Colorado River conditions and the most probable elevation conditions at Lake Mead over the next two years. At the meeting, staff will provide an update on the latest 24-Month Study results. Staff will also update the Committee on Reclamation's efforts to evaluate alternatives that could reduce Colorado River water use.

State Water Project:

Due to recent winter storms, the California Department of Water Resources (DWR) increased the SWP Table A allocation from 35% to 75% on March 24. The allocation is expected to further increase with spring snowmelt and additional precipitation events. The SWP's two largest reservoirs, Lake Oroville Reservoir and San Luis Reservoir, continue to fill. In anticipation of the spring snowmelt, Lake Oroville is releasing water through the spillway to reduce future flood risks to downstream communities. San Luis Reservoir, which serves as a key water facility for both the SWP and the federal CVP, is currently at 99% capacity. At the meeting, staff will provide the latest storage update for Lake Oroville and San Luis Reservoir.

Central Valley Project:

CVP Reservoirs have also continued to fill, with releases being made for flood control purposes. Storage in Lake Shasta, the largest reservoir on the CVP system, has increased more than 1.5 million acre-feet in the last two months. Millerton Lake releases at Friant Dam have continued with substantial precipitation events that have occurred through early April. At the Committee meeting, staff will provide an update on storage levels in Millerton Lake.

The Friant Water Authority began construction on the Friant-Kern Canal Middle Reach Capacity Correction Project in January 2022. The project was initiated to restore conveyance capacity to 4,000 cubic feet per second (cfs) after major land subsidence reduced capacity to 1,600 cfs. Construction of the project is ongoing, causing limited delivery capacity to lower Friant Water Users. In mid-March the Friant-Kern Canal construction work was temporarily interrupted by a severe breach in the new parallel canal.

Lake Isabella Dam and Kern River:

In 2006, safety concerns were raised for Lake Isabella Dam due to seismic stability issues. These concerns prompted the United States Army Corps of Engineers (ACOE) to implement the Lake Isabella Dam Safety Modification Project and to enact temporary risk reduction measures that lowered the maximum storage at Lake Isabella by 36%. On April 4, 2023, the ACOE announced that the project was completed. The gross pool level has been returned to 100% capacity, increasing needed storage. The Kern River watershed snowpack is more than 400% of normal and snowmelt is underway. High-flow Kern River conditions exist downstream of the reservoir. This summer, as Lake Isabella water levels approach the maximum storage capacity with significant inflows, there will be an increased probability of Kern River flood flow releases.

Expectations and Considerations for IRWD's Water Banking Program:

High-flow Kern River water is available for diversion into the Rosedale-Rio Bravo Water Storage District service area. The diversion of Kern River water directly to the IRWD Water Bank is currently not possible because river diversion facilities at the Cross Valley Canal (CVC) are constrained by ongoing repairs. Furthermore, delivering significant amounts of water to the IRWD Water bank via the Rosedale Slough is not hydraulically possible at this time. It is possible to divert Kern River exchange water into the CVC that is stored in the SWP. Buena Vista Water Storage District is expected to be making such deliveries to the IRWD Water Bank by the time the Committee meets.

Should flood flow releases be made from Lake Isabella, Rosedale will have first priority right to the use of the recharge basins at IRWD's Water Bank. IRWD will receive 20% of any flood water that Rosedale is able to recharge at the Strand Ranch and 50% of any flood water recharged at the Stockdale West facilities. Because of the limited Kern River water diversion capabilities, staff is expecting that even during periods of Kern River flood releases that IRWD will be able to continue recharging Kern River exchange water and Table A water from the SWP that are delivered to the IRWD Water Bank through the CVC.

With the SWP reservoirs nearly full, staff expects DWR to increase the SWP Table A allocation above the current 75%. Staff expects that much of SWP Contractor Table A supplies will remain in storage in the SWP as carryover water into the next year. Accordingly, it is anticipated that IRWD will have opportunities to bank SWP supplies available to IRWD and its exchange partners through at least the end of 2023. Staff expects that Article 21 supplies will be available to IRWD through the end of May.

FISCAL IMPACTS:

None.

ENVIRONMENTAL COMPLIANCE:

Not applicable.

RECOMMENDATION:

Receive and file.

LIST OF EXHIBITS:

Exhibit “A” – Water Supply Conditions and Water Banking Considerations Draft Presentation

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WATER SUPPLY CONDITIONS AND WATER BANKING CONSIDERATIONS UPDATE

Irvine Ranch Water District

SUPPLY RELIABILITY PROGRAMS COMMITTEE

APRIL 20, 2023

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PRESENTATION OVERVIEW

- Water Supply Conditions Update:
  - Colorado River
  - State Water Project (SWP)
  - Central Valley Project (CVP)
  - Lake Isabella Dam and Kern River
- Water Banking Considerations

California Aqueduct, SWP

Irvine Ranch Water District

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COLORADO RIVER

Irvine Ranch Water District

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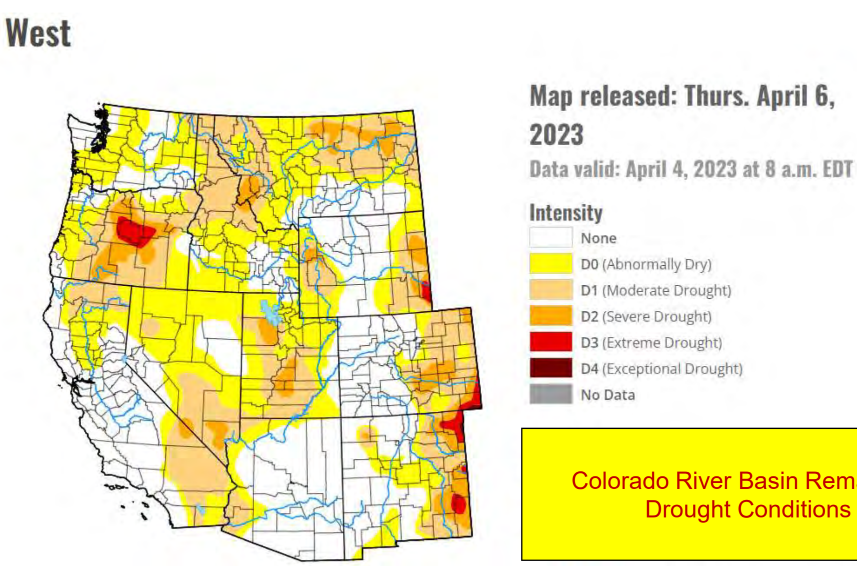
WESTERN U.S. DROUGHT MONITOR



Colorado River Basin Remains in Drought Conditions

Irvine Ranch Water District

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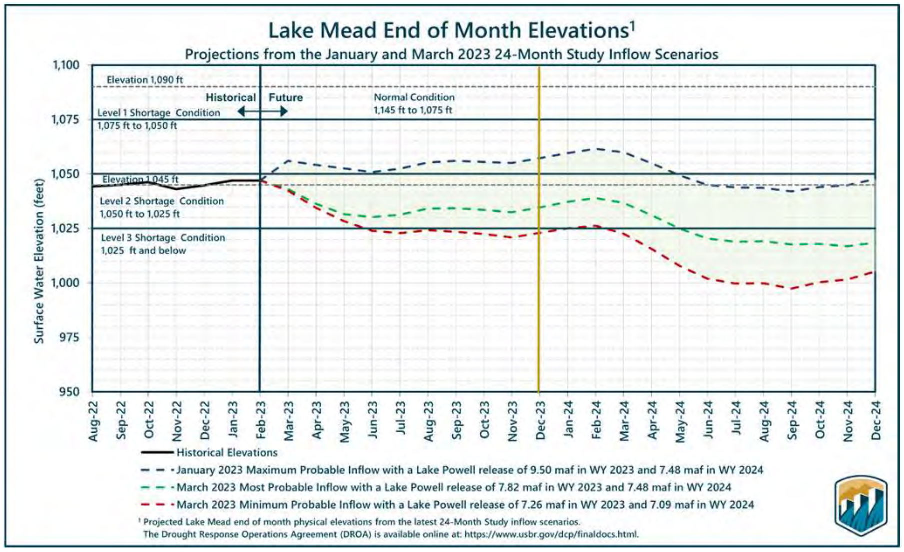
LAKE MEAD – 24-MONTH STUDY RESULTS



Irvine Ranch Water District

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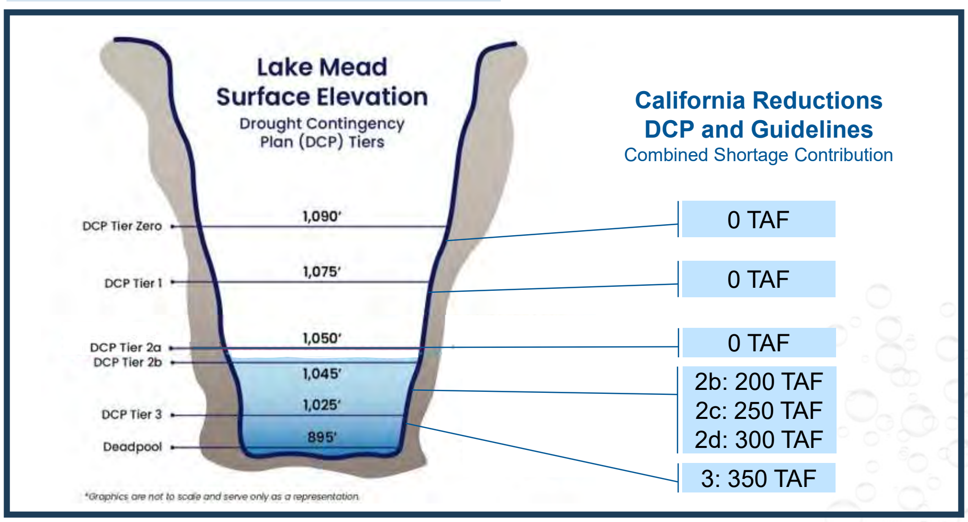
LAKE MEAD – DCP TIERS AND CALIFORNIA CUTS

Lake Mead Level, April 12, 2023: 1,046 ft



Irvine Ranch Water District

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COLORADO RIVER WATER USE REDUCTIONS

- Negotiations among the seven Basin States continue.
- Bureau of Reclamation released Draft Supplemental EIS:
  - *Alternative 1*: Water reductions based on priority of water rights
  - *Alternative 2*: Equal percentage reductions for Arizona, Nevada, and California
  - (Also, potential for a hybrid of Alternative 1 and 2)
- Reclamation decision expected August 2023.

Irvine Ranch Water District

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STATE WATER PROJECT

Irvine Ranch Water District

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STATE WATER PROJECT ALLOCATION

- Increased from 35% to 75% on March 24
- Article 21 Water Available
- Allocation expected to increase in April

Atmospheric River (30+ in California for WY 2023)

Irvine Ranch Water District

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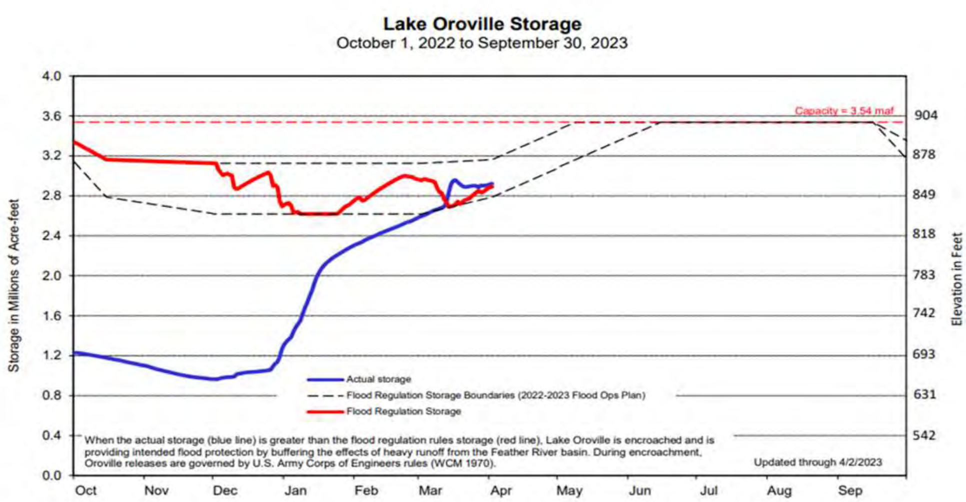
LAKE OROVILLE – STORAGE AND FLOOD REGULATIONS



Irvine Ranch Water District

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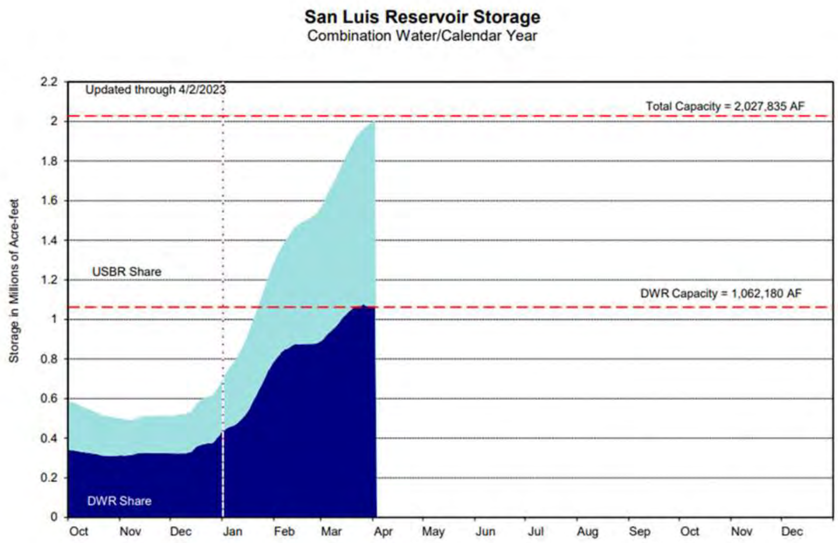
SAN LUIS RESERVOIR – STORAGE AND SHARED CAPACITY



Irvine Ranch Water District

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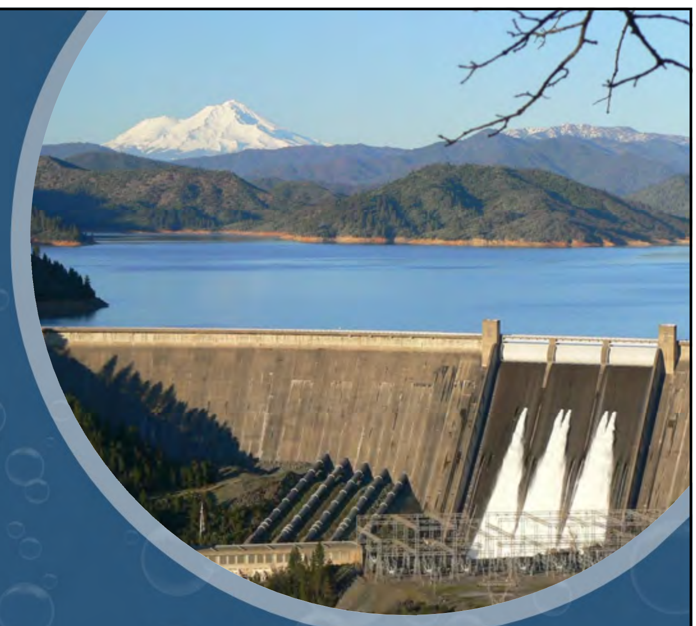
CENTRAL VALLEY PROJECT



Irvine Ranch Water District

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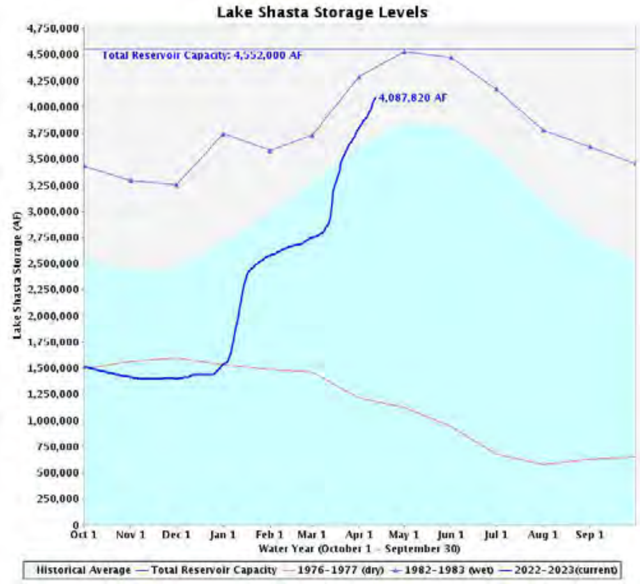
SHASTA RESERVOIR – STORAGE LEVELS



Irvine Ranch Water District

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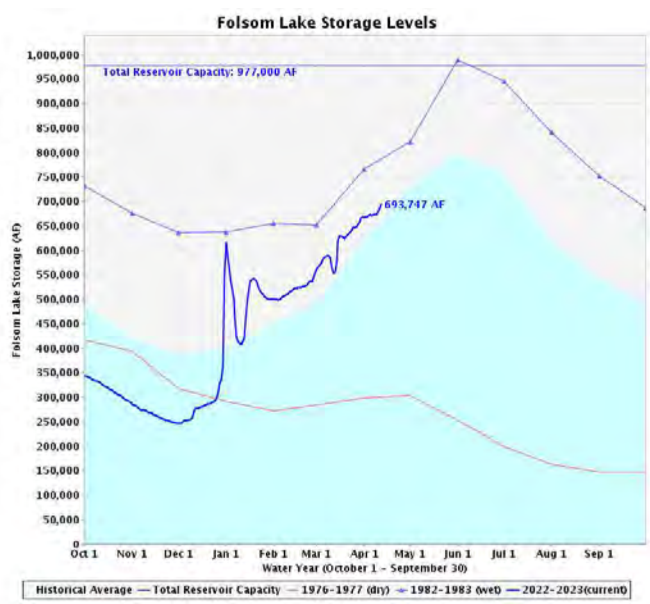
FOLSOM LAKE – STORAGE LEVELS



Irvine Ranch Water District

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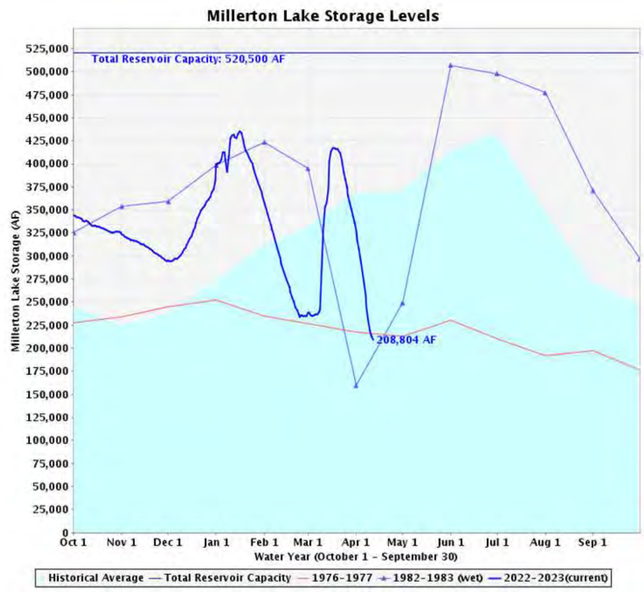
MILLERTON LAKE – STORAGE LEVELS



Irvine Ranch Water District

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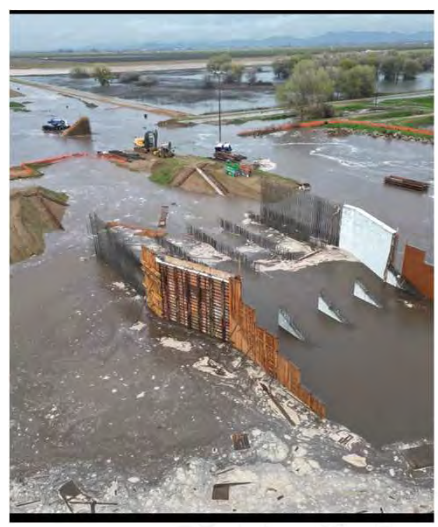
FRIANT-KERN CANAL – CONSTRUCTION UPDATE

- Middle Reach Capacity Correction Project
  - Construction of parallel canal
- Canal reaches suffered “severe breach” causing delays in construction
- Delivery of potential Section 215 water limited by capacity constraints



Friant-Kern Canal Breach, March 11, 2023

Irvine Ranch Water District

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LAKE ISABELLA DAM AND KERN RIVER

Irvine Ranch Water District

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LAKE ISABELLA DAM - CONSTRUCTION UPDATE

- Repairs and maintenance complete
- Army Corps “Initial Fill Plan” approved on March 30th
- Gross Pool Level of 568,025 AF reinstated

Lake Isabella (photographed prior to construction)

Irvine Ranch Water District

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LAKE ISABELLA AND KERN RIVER SUPPLIES

- Kern River Watershed Snowpack: 429% of Normal as of April 12
- Increased flows into Lake Isabella
- Reservoir storage at 53% of Gross Pool Level
- Extensive runoff expected in spring and into summer
- Increased probability of flood releases
- Current releases greater than 5,000 cfs

Irvine Ranch Water District

WATER BANKING PROGRAM CONSIDERATIONS

- SWP allocation expected to increase
  - Article 21 available into the future
- High flow Kern River water available
- Kern River flood flows expected:
  - Rosedale to have first-priority use of IRWD recharge basins:
    - 20 percent to IRWD on Strand Ranch
    - 50 percent to IRWD on Stockdale West
  - Difficult to divert flood flows to IRWD Water Bank
  - SWP deliveries to IRWD Water Bank may continue

Lake Oroville, March 2023

Irvine Ranch Water District

April 20, 2023
Prepared by: M. Lindsay / K. Welch
Submitted by: F. Sanchez / P. Weghorst
Approved by: Paul A. Cook

SUPPLY RELIABILITY PROGRAMS COMMITTEE

WATER BANKING PROJECT FACILITIES, CAPACITIES, OPERATIONS AND PROGRAMS

SUMMARY:

Staff has prepared information related to IRWD’s water banking facilities, capacities, operations, and exchange programs. The information is regularly updated to reflect changes in the status of IRWD’s projects, programs, and operations. At the Committee meeting, staff will review this information and present information on current and scheduled deliveries and recharge rates at the IRWD Water Bank. Staff will also provide an update on efforts to secure additional water for recharge at IRWD’s water banking projects.

BACKGROUND:

To facilitate discussions with the Committee, staff has prepared reference materials in tabular, map, and schematic formats to describe IRWD’s water banking facilities, capacities, operations, storage, and exchange programs. The reference materials are updated regularly to reflect changes in the status of the projects, programs, and operations. The following is an overview of the reference materials.

Capacity and Operations Tables:

A table presenting storage, recharge and recovery capacities of existing and planned IRWD water banking projects, including capacities available to IRWD in the Kern Water Bank, is provided as Exhibit “A”. Exhibits “B” and “C” provide an update on water banking recovery and recharge operations, as well as the balance of the water stored in the Kern Water Bank. Exhibit “B” provides before-loss estimates of water recharged at the water banking projects, and Exhibit “C” provides after-loss estimates of water recharged at the projects. Changes shown in red on Exhibits “B” and “C” depict an updated State Water Project (SWP) Table A Allocation from 30 to 75 percent. In addition, changes to Exhibits “B” and “C” reflect an estimated 4,000 AF of deliveries of Dudley Ridge return water. The delivery of 450 AF of Table A water from the Central Coast Water Authority is not yet shown in Exhibits “B”, “C”, and “D” because exchange related transactions are not yet complete.

Summary of Programs:

A table presenting a summary of IRWD’s water purchase and exchange programs is presented as Exhibit “D”. The table lists each purchase and exchange program that IRWD has entered into and presents information related to the type of exchange, year executed, agreement type, and water type. IRWD and partner shares are listed and show the total amount of water included in each program. The balances listed for IRWD and its partners show the amount of water remaining in storage, with IRWD’s balances specifying whether the water is stored in

Metropolitan's system, Kern County, or owed to IRWD by Dudley Ridge. The table also provides details related to the exportability of IRWD's supplies. Changes shown in red on Exhibit "D" correspond with the changes made to Exhibits "B" and "C." All Central Coast Water currently stored is exportable to IRWD.

Exhibit "E" graphically depicts how storage of SWP and non-SWP water has changed annually in the Strand and Stockdale Integrated Banking Projects. The table provided as Exhibit "F" shows how capacities in the water banking projects have been dedicated to IRWD's existing and proposed exchange programs.

Project Maps:

To support the tables and figures provided as Exhibits "A", "B", "C", "D", "E" and "F", staff has prepared maps that depict project wells and pipelines, recharge basins and Cross Valley Canal turnout locations, along with the most current recharge rates. These maps are provided as Exhibits "G", "H", and "I", respectively. Exhibit "I" has been updated with current recharge rates for IRWD's Water Bank. The facilities shown on the maps are associated with the Strand Ranch, Stockdale West, Stockdale East, and Drought Relief Projects.

Program Agreement Diagrams:

Schematic diagrams have been prepared that depict IRWD water banking and exchange programs with Rosedale-Rio Bravo Water Storage District, Buena Vista Water Storage District, Dudley Ridge, and Metropolitan Water District. These diagrams are provided as Exhibits "J", "K", "L", "M", "N", and "O", as described in the List of Exhibits.

Cost of Water Table:

A table presenting a summary of the costs of water from each of IRWD's unbalanced exchange partnerships is provided as Exhibit "P". The table lists each of IRWD's unbalanced exchange partnerships and presents information related to the period over which water was acquired, water type, IRWD's share of water, and various cost components as well as the total cost of water delivered to IRWD's service area. Cost components include fixed and variable operating costs, estimated future IRWD recovery costs, the 2023 Metropolitan Full Service Untreated Tier-1 Rate and a capital cost of water. The variable costs include an administrative fee issued by the Kern County Water Agency for staff time related to processing Transaction Request Forms. The costs of water are presented on a dollar per acre-foot basis.

IRWD's Coordinated Agreement with Metropolitan:

An overview of IRWD's Coordinated Operating, Water Storage, Exchange, and Delivery Agreement with Metropolitan Water District and Municipal Water District of Orange County (MWDOC) is provided as Exhibit "Q". The benefits to IRWD are foundational to the success of IRWD's water banking project and programs.

2023 Water Recharge Activities:

Since April 4, 2023, water deliveries from the State Water Project (SWP) have been made to the IRWD Water Bank at the rate of 200 cfs, or approximately 400 AF per day. The water is being delivered to IRWD from Dudley Ridge to satisfy return obligations associated with Dudley Ridge's prior use of non-SWP water from IRWD's Water Bank. These returns are occurring consistent with the 1-for-1 long term exchange program that is depicted in Exhibit "O". Dudley Ridge is working with the California Department of Water Resources to get approval to deliver SWP Article 21 water to the IRWD Water Bank. Deliveries from Buena Vista are expected to begin soon which will consist of Kern River water that is currently stored in the SWP. These deliveries will be made pursuant to the long-term 2-for-1 exchange program between IRWD and Buena Vista that is depicted in Exhibit "K". At the meeting, staff will present information on current and expected recharge activities at IRWD's Water Bank including a schedule and rate of deliveries.

Other Program Opportunities:

At the Committee meeting, staff will provide an update on efforts to develop unbalanced exchange programs with Metropolitan Water District, Antelope Valley-East Kern Water Agency, Santa Clarita Valley Water Agency, Santa Clara Valley Water Agency, and Mojave Water Agency.

FISCAL IMPACTS:

None.

ENVIRONMENTAL COMPLIANCE:

Not applicable.

RECOMMENDATION:

Receive and file.

LIST OF EXHIBITS:

Exhibit "A" – Recharge, Storage and Recovery Capacities of Current and Anticipated Water Banking Projects
Exhibit "B" – Water Banking Storage, Recharge, and Recovery Operations before Losses
Exhibit "C" – Water Banking Storage, Recharge, and Recovery Operations after Losses
Exhibit "D" – Status of IRWD Purchase and Exchange Programs
Exhibit "E" – Historic Water Storage in Strand and Stockdale Projects
Exhibit "F" – Dedicated Capacities of Current Water Banking Projects
Exhibit "G" – Map of Water Banking Project Wells and Pipelines
Exhibit "H" – Map of Water Banking Recharge Basins and Cross Valley Canal Turnout Facilities

Exhibit "I" – Map of Water Banking Recharge Rates
Exhibit "J" – Diagram of IRWD-Rosedale Water Banking and Exchange Program Agreements
Exhibit "K" – Diagram of Long-term Water Exchange Program with Buena Vista Water Storage District and Diagram of One-year Program to Augment Recharge Using Stockdale West Recharge Facilities with Buena Vista Water Storage District
Exhibit "L" – Diagram of Unbalanced Exchange Program Diagram with Dudley Ridge
Exhibit "M" – Diagram of Coordinated Operating, Water Storage, Exchange, and Delivery Agreement with Metropolitan
Exhibit "N" – Diagram of Template Wheeling Agreement with Metropolitan
Exhibit "O" – Diagram of Dudley Ridge One-for-One Exchange
Exhibit "P" – Cost of Water Table
Exhibit "Q" – Summary of IRWD's Coordinated Operating, Water Storage, Exchange and Delivery Agreement with Metropolitan and MWDOC

Exhibit "A"

TABLE 1
Current and Anticipated Water Banking Project
s Recharge, Storage and Recovery Capacities
April 20, 2023

WATER BANKING PROJECT	OWNERSHIP AND WELL INFO		ALLOCATED CAPACITY (AF)					1st PRIORITY RECOVERY CONDITIONS (CFS)		2nd PRIORITY RECOVERY CONDITIONS (CFS)	
	IRWD OWNED	WELLS EXISTING	TOTAL STORAGE CAPACITY	ANNUAL RECHARGE 1ST PRIORITY	ANNUAL RECHARGE 2ND PRIORITY	ANNUAL RECOVERY 1ST PRIORITY	ANNUAL RECOVERY 2ND PRIORITY	RECOVERY CAPACITY AS PLANNED[1]	RECOVERY CAPACITY (Average Daily Production 1/1/2021 - 7/31/2022)	RECOVERY CAPACITY AS PLANNED	RECOVERY CAPACITY CURRENT CONDITIONS
Strand Ranch	Yes	7	50,000	17,500	-	17,500	-	40.0	20.5	-	-
Stockdale West	Yes	3	26,000	27,100	-	11,250	-	15.0	11.6	-	-
Stockdale East	No	2	-	-	19,000	-	7,500	-	-	10.0	9.0
IRWD Acquired Storage Account[2]	No	-	50,000	-	-	-	-	-	-	-	-
Drought Relief Project Wells[2]	No	3	-	-	-	-	-	15.0	16.5	-	-
Kern Water Bank Storage Account[4]	No	-	9,495	3,200	-	1,520	<5,000	-	-	-	-
TOTALS		**15**	135,495	47,800	19,000	30,270	12,500	70.0	48.6	10.0	9.0
Partner Capacities[3]			38,000	22,300	9,500	10,850	0	35.5	25.0	-	-
IRWD Capacities (does not include Kern Water Bank capacities)			88,000	22,300	9,500	17,900	7,500	34.5	25.0	-	-
IRWD's recovery ***during*** 6 month partner recovery period (AF)								12,420	9,000	-	-
IRWD's recovery ***after*** 6 month partner recovery period (AF)								5,480	6,733	-	-
TOTALS (AF)								17,900	15,733	-	-
Number of months needed to recover IRWD's total AF after partners' recovery (Assumes IRWD has use of total recovery capacity after partners' recovery)								8.6	10.2	-	-
Strand Ranch monthy recharge amount assuming 0.3 ft/day average recharge rate (AF)										4,518	
Stockdale West monthy recharge amount assuming 0.3 ft/day average recharge rate (AF)										2,331	

[1] Based on designed Strand recovery capacity assuming 370' bgs. Assumes 5 cfs for each of the Stockdale West and Drought Relief wells in order to meet IRWD's Water Banking, Transfers, and Wheeling policy position. Assumes partners' water is recovered over 6 months.

[2] IRWD has use of Acquired Storage and Drought Relief Project wells until January 12, 2039, unless the term of the agreement is extended.

[3] One half of storage capacity at Stockdale West and Strand Ranch will be allocated for partners.

[4] Kern Water Bank capacities based on 6.58% of Dudley Ridge Water District's 9.62% share of the Kern Water Bank. Annual recharge amount is based on an average of recharge rates for high and low groundwater level conditions. 5,000 AF of recovery capacity may be available for second priority use.

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Exhibit "B"

TABLE 2

IRWD's Water Banking Storage, Recharge and Recovery Operations - BEFORE LOSSES

April 14, 2023

TRANSACTIONS	WATER BANKING ENTITY					TOTAL BY WATER TYPE AND STORAGE LOCATION
	IRWD		BUENA VISTA (BVWSD)	CENTRAL COAST (CCWA)	DUDLEY RIDGE WATER DISTRICT (DRWD)[3]	
	SWP[1]	NON-SWP[2]	NON-SWP	SWP	SWP	
BEGINNING WATER IN STORAGE 2022 (AF)						
Total Kern Water Bank[4]	-	3,848	-	-	-	3,848
Total MWD System	8,062	-	-	-	-	8,062
Total Kern County	5,234	14,416	-	-	-	19,650
Total DRWD 1-for-1 Long Term Exchange Credit[5]	11,000	-	-	-	-	11,000
TOTAL STORED WATER (1/1/2022)	24,296	18,264	-	-	-	42,560
(RECOVERY) AND RECHARGE IN 2022 (AF)						
KWB Recovery for use on Jackson Ranch [6]	-	(84)	-	-	-	(84)
2022 SWP Allocation (5%)	44	-	-	-	43	87
2019 Reserve Water	76	225	225	-		526
Kern River Water	-	(5,000)	-	-	-	(5,000)
DRWD 1-for-1 Long Term Exchange Credit	5,500	-	-	-	-	5,500
Reocvery of Banked SWP Water for MWD	(3,927)	-	-	-	-	(3,927)
MWD Credit for SWP Water	3,927	-	-	-	-	3,927
TOTAL 2022 TRANSACTIONS	5,620	(4,859)	225	-	43	1,029
Total Kern Water Bank[9]	-	3,764	-	-	-	3,764
Total MWD System	12,033	-	-	-	43	12,076
Total Kern County	1,383	9,641	225	-	-	11,249
Total DRWD 1-for-1 Long Term Exchange Credit	16,500	-	-	-	-	16,500
TOTAL STORED WATER (1/1/2023)	29,916	13,405	225	-	43	43,589
(RECOVERY) AND RECHARGE IN 2023 (AF)						
KWB Recovery for use on Jackson Ranch[6] (estimated)	-	(235)	-	-	-	(235)
2023 SWP Allocation (75%)[3]	656	-	-	-	656	1,312
Kern River Water	-	-	-	-	-	-
DRWD 1-for-1 Long Term Exchange (Recharge)	4,000	-	-	-	-	4,000
Recovery of Banked SWP Water for MWD	-	-	-	-	-	-
MWD Credit for SWP Water	-	-	-	-	-	-
TOTAL ESTIMATED 2023 TRANSACTIONS	4,656	(235)	-	-	656	5,077
ESTIMATED WATER IN STORAGE 2023 (AF)						
Total Kern Water Bank	-	3,529	-	-	-	3,529
Total MWD System	12,033	-	-	-	43	12,076
Total Kern County	6,039	9,641	225	-	656	16,561
Total DRWD 1-for-1 Long Term Exchange Credit	12,500	-	-	-	-	12,500
TOTAL ESTIMATED STORED WATER TO DATE	30,572	13,170	225	-	699	44,666

NOTES:

-MWD = Metropolitan Water District of Southern California.

[1] IRWD's SWP includes 295 AF from CVWD that stays in Kern County.

[2] IRWD's Non-SWP total includes 2,403 AF, net of losses, of Kern County Water Agency Article 21 Water.

[3] DRWD water supply will be returned by MWD or IRWD's Strand Ranch to IRWD's Jackson Ranch. MWD took delivery of IRWD's 2022 SWP allocation in June 2022. MWD will not take delivery of IRWD's 2023 SWP Allocation.

[4] IRWD's KWB Account balance includes SWP, Friant and Kern River water. The KWB account balance is included in the Non-SWP column because it is not exportable to IRWD's service area. The 2022 beginning KWB balance was revised by DRWD based on KCWA 2021 end of year balances.

[5] Per the DRWD Long-Term 1-for-1 Exchange Program, Non-SWP water delivered to DRWD landowners will be returned to IRWD as SWP water at a later date. To account for the SWP water that will be returned at a later date, the amount of water owed will be shown as a credit. Total assumes all water is returned to IRWD Water Bank which adds in a 10% loss factor.

[6] Water recovered from IRWD's Kern Water Bank account for use on Jackson Ranch.

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Exhibit "C"

TABLE 3

IRWD's Water Banking Storage, Recharge and Recovery Operations - AFTER LOSSES

April 14, 2023

TRANSACTIONS	WATER BANKING ENTITY					TOTAL BY WATER TYPE AND STORAGE LOCATION
	IRWD		BUENA VISTA (BVWSD)	CENTRAL COAST (CCWA)	DUDLEY RIDGE WATER DISTRICT (DRWD)[3]	
	SWP[1]	NON-SWP[2]	NON-SWP	SWP	SWP	
BEGINNING WATER IN STORAGE 2022 (AF)						
Total Kern Water Bank[4]	-	3,848	-	-	-	3,848
Total MWD System	8,062	-	-	-	-	8,062
Total Kern County	4,199	10,492	-	-	-	14,691
Total DRWD 1-for-1 Long Term Exchange Credit[5]	10,000		-	-	-	
TOTAL STORED WATER (1/1/2022)	22,261	14,340	-	-	-	36,601
(RECOVERY) AND RECHARGE IN 2022 (AF)						
KWB Recovery for use on Jackson Ranch[6]	-	(84)	-	-	-	(84)
2022 SWP Allocation (5%)	44	-	-	-	43	87
2019 Reserve Water	72	213	225	-	-	510
Kern River Water	-	(5,000)	-	-	-	(5,000)
DRWD 1-for-1 Long Term Exchange Credit	5,000	-	-	-	-	5,000
Recovery of Banked SWP Water for MWD	(3,927)	-	-	-	-	(3,927)
MWD Credit for SWP Water	3,927	-	-	-	-	3,927
TOTAL 2022 TRANSACTIONS	5,116	(4,871)	225	-	43	513
Total Kern Water Bank	-	3,764	-	-	-	3,764
Total MWD System	12,033	-	-	-	43	12,076
Total Kern County	344	5,705	225	-	-	6,274
Total DRWD 1-for-1 Long Term Exchange Credit	15,000	-	-	-	-	15,000
TOTAL STORED WATER (1/1/2023)	27,377	9,469	225	-	43	37,114
(RECOVERY) AND RECHARGE IN 2023 (AF)						
KWB Recovery for use on Jackson Ranch[6] (estimated)	-	(235)	-	-	-	(235)
2023 SWP Allocation (75%)[3]	561	-	-	-	560	1,121
Kern River Water	-	-	-	-	-	-
DRWD 1-for-1 Long Term Exchange (Recharge)	3,417	-	-	-	-	3,417
Recovery of Banked SWP Water for MWD	-	-	-	-	-	-
MWD Credit for SWP Water	-	-	-	-	-	-
TOTAL ESTIMATED 2023 TRANSACTIONS	3,978	(235)	-	-	560	4,303
ESTIMATED WATER IN STORAGE 2023 (AF)						
Total Kern Water Bank	-	3,529	-	-	-	3,529
Total MWD System	12,033	-	-	-	43	12,076
Total Kern County	4,322	5,705	225	-	560	10,812
Total DRWD 1-for-1 Long Term Exchange Credit	11,583	-	-	-	-	11,583
TOTAL ESTIMATED STORED WATER TO DATE	27,938	9,234	225	-	603	38,000

NOTES:

-Water in storage has been adjusted to account for losses. IRWD's water stored in Kern County is adjusted 15% for losses (5% for out of county loss, 6% surface loss, and 4% reserve loss); Water stored for BVWSD in Kern County is adjusted 10% (6% for surface loss and 4% for reserve loss); no losses for water directly delivered to MWD system.

-MWD = Metropolitan Water District of Southern California.

[1] IRWD's SWP includes 251 AF from CVWD that stays in Kern County.

[2] IRWD's Non-SWP total includes 2,403 AF of Kern County Water Agency Article 21 Water.

[3] DRWD water supply will be returned by MWD or IRWD's Strand Ranch to IRWD's Jackson Ranch. MWD took delivery of IRWD's 2022 SWP allocation in June 2022. MWD will not take delivery of IRWD's 2023 SWP Allocation.

[4] IRWD's KWB Account balance includes SWP, Friant and Kern River water. The KWB account balance is included in the Non-SWP column because it is not exportable to IRWD's service area. The 2022 beginning KWB balance was revised by DRWD based on KCWA 2021 end of year balances.

[5] Per the DRWD Long-Term 1-for-1 Exchange Program, Non-SWP water delivered to DRWD landowners will be returned to IRWD as SWP water at a later date. To account for the SWP water that will be returned at a later date, the amount of water owed will be shown as a credit. Total assumes all water is returned to IRWD Water Bank which adds in a 10% loss factor. Final amounts may be subject to additional CVC losses.

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Exhibit "D"

TABLE 4
Status of IRWD Purchase and Exchange Programs (AFTER LOSSES)
April 14, 2023

PARTNER	EXCHANGE RATIO	YEAR EXECUTED	AGREEMENT TYPE	WATER TYPE	PARTNER WATER		IRWD WATER								
								IRWD BALANCE				EXPORTABILITY			
					PARTNER SHARE (AF)	PARTNER BALANCE (AF)	IRWD SHARE (AF)	IN MWD SYSTEM (AF)	STORED IN KERN (AF)	OWED BY DUDLEY RIDGE WD	TOTAL (AF)	EXPORTABLE TO IRWD (AF)	NON-EXPORTABLE (AF)	FOR USE ON JACKSON RANCH (DRWD)	SELLABLE (Y/N)
Semitropic Water Storage District	NA	2008	Purchase	SWP Article 21	NA	NA	2,842		2,403		2,403		2,403		Yes
Carpinteria Valley Water District	2-for-1	2008	Short-Term	SWP Table A	277		250		250		250		250		Yes
Buena Vista Water Storage District [1]	2-for-1	2010	Pilot	Kern River	4,108		3,903								Yes
	2-for-1	2011	Long-Term	Kern River	21,473	225	20,399		3,302		3,302		3,302		
Antelope Valley East Kern Water Agency	2-for-1	2011	Pilot	SWP Table A	2,229		2,337	2,337			2,337	2,337			No
Carpinteria Valley Water District	2-for-1	2011	Pilot	SWP Table A	624		655	655			655	655			No
Dudley Ridge Water District (SWPAO #13012)	2-for-1	2013	SWPAO	SWP Table A	1,876		1,876	1,876			1,876	1,876			Yes
				SWP Article 21	1,553		1,554	1,554			1,554	1,554			Yes
Metropolitan Water District [2]	1-for-1	2014	Short-Term	SWP Table A	NA	NA	4,000	4,000			4,000	4,000			No
Dudley Ridge Water District (SWPAO #17030)	2-for-1	2018	SWPAO	SWP Table A	1,614	603	1,685	1,055	630		1,686	1,686		603	Yes
Central Coast Water Authority	2-for-1	2017	Short-Term	SWP Table A	258		258	258			258	258			No
Dudley Ridge Water District [3] (SWPAO #19001)	1-for-1	2017	Long-Term	SWP Table A			3,417		3,417		3,417	15,000			No
				Credit			11,583			11,583	11,583				No
Central Coast Water Authority	2-for-1	2019	Short-Term	SWP Table A	298		323	298	25		323	323			No
				Total:	**34,310**	**828**	**55,082**	**12,033**	**10,027**	**11,583**	**33,644**	**27,689**	**5,955**	**603**	**NA**

[1] Water acquired through BVWSD will be exportable after it is exchanged for SWP Table A through 1-for-1 exchange with Dudley Ridge Water District.

[2] Source of water was Buena Vista Water Storage District Kern River high flow water.

[3] To account for the SWP water that will be returned to IRWD, the amount of water owed is shown as a credit. The total net of losses is 15,000 AF.

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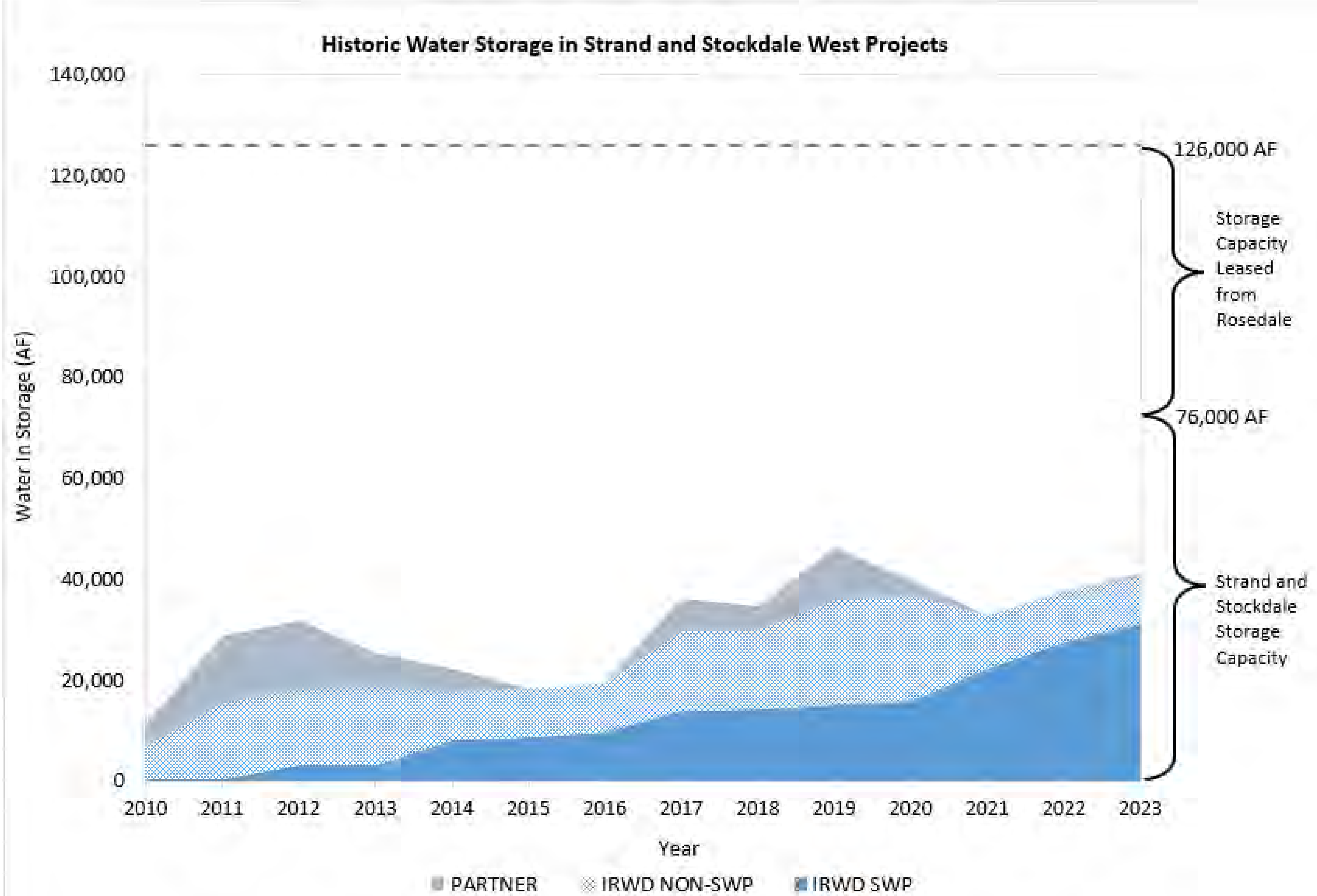
Exhibit "E"



*After losses

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Exhibit "F"

TABLE 5

IRWD Dedicated Water Banking Capacities for Existing and Proposed Exchange Programs

April 20, 2023

STORAGE CAPACITY

Program	Dedicated Storage Capacity Strand Ranch (AF)	Dedicated Storage Capacity Stockdale West (AF)	Dedicated Storage Capacity Leased Storage Account (AF)	Kern Water Bank Storage Capacity (AF)
Total Capacity	50,000	26,000	50,000	9,495
BVWSD	40,000	-	-	-
DRWD	10,000	-	-	-
AVEK	-	20,000	-	-
Total Dedicated	50,000	20,000	-	-
Total Remaining	-	6,000	50,000	9,495

RECHARGE CAPACITY

Program	Dedicated Recharge Capacity Strand Ranch (AF)	Dedicated Recharge Capacity Stockdale West (AF)	Dedicated Recharge Capacity Leased Storage Account (AF)	Kern Water Bank Recharge Capacity (AF)
Total Capacity	17,500	27,100	-	3,200
BVWSD	17,500	-	-	-
DRWD	-	-	-	-
AVEK	-	20,000	-	-
Total Dedicated	17,500	20,000	-	-
Total Remaining	-	7,100	-	3,200

RECOVERY CAPACITY

Program Partner	Dedicated Recovery Capacity Strand Ranch (AF)	Dedicated Recovery Capacity Stockdale West (AF)	Dedicated Recovery Capacity Leased Storage Account (AF)	Kern Water Bank Recovery Capacity (AF)
Total Capacity	17,500	11,250	-	1,520
BVWSD	6,667	-	-	-
DRWD	-	-	-	-
AVEK	-	3,333	-	-
IRWD	10,833	7,084	-	1,520
Total Dedicated	17,500	10,417	-	1,520
Total Remaining	-	833	-	-

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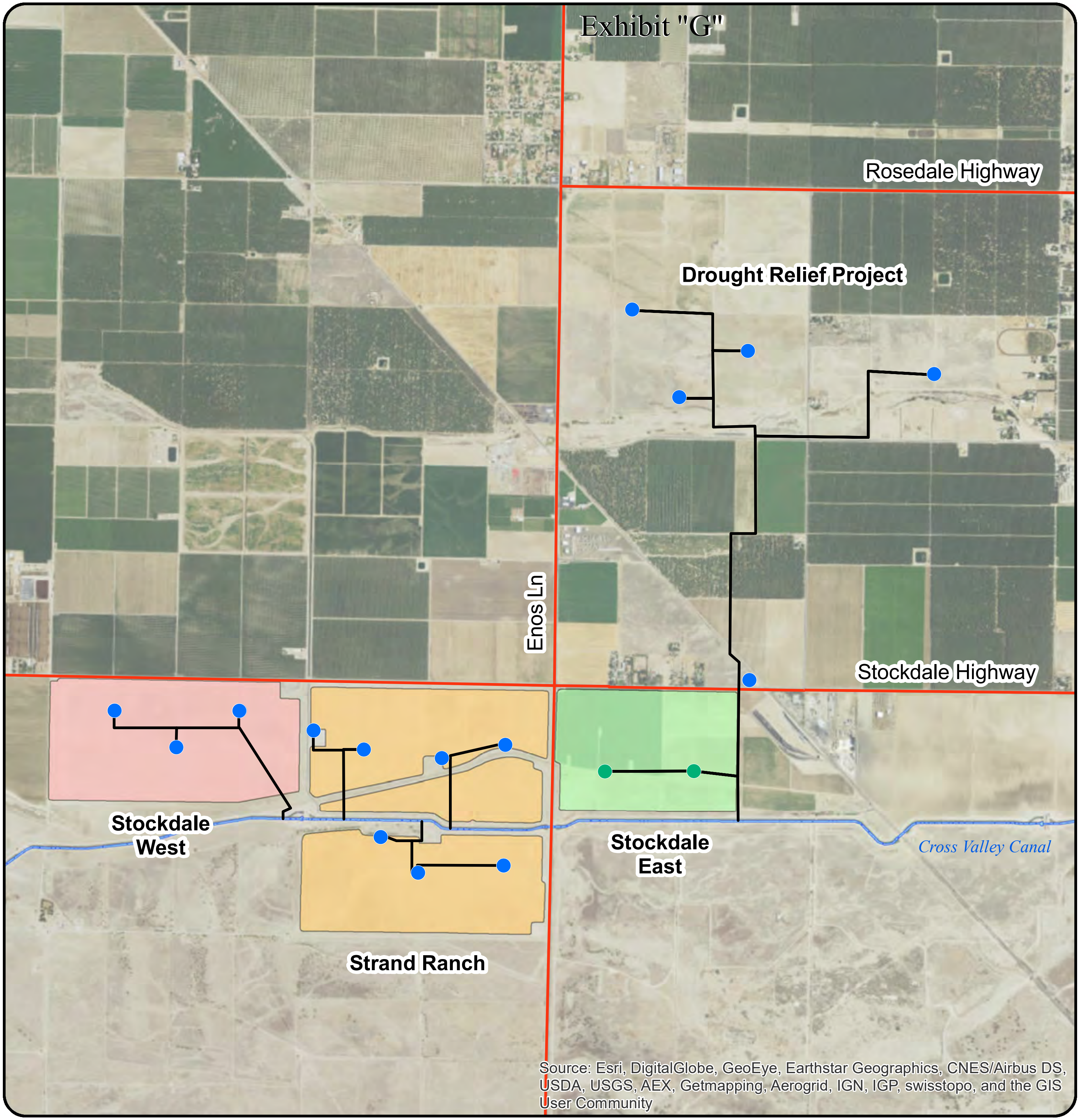

Irvine Ranch WATER DISTRICT

Location Map: IRWD Water Banking Projects Wells and Turnin Pipelines

MAP FEATURES

- Extraction Well
- Extraction Well
- Well Discharge Pipelines
- Stockdale East
- Stockdale West
- Strand Ranch

This figure shows the location of IRWD's water banking project sites and extraction wells.

NAD 83 State Plane Zone 5 (feet)
Central Meridian: -118

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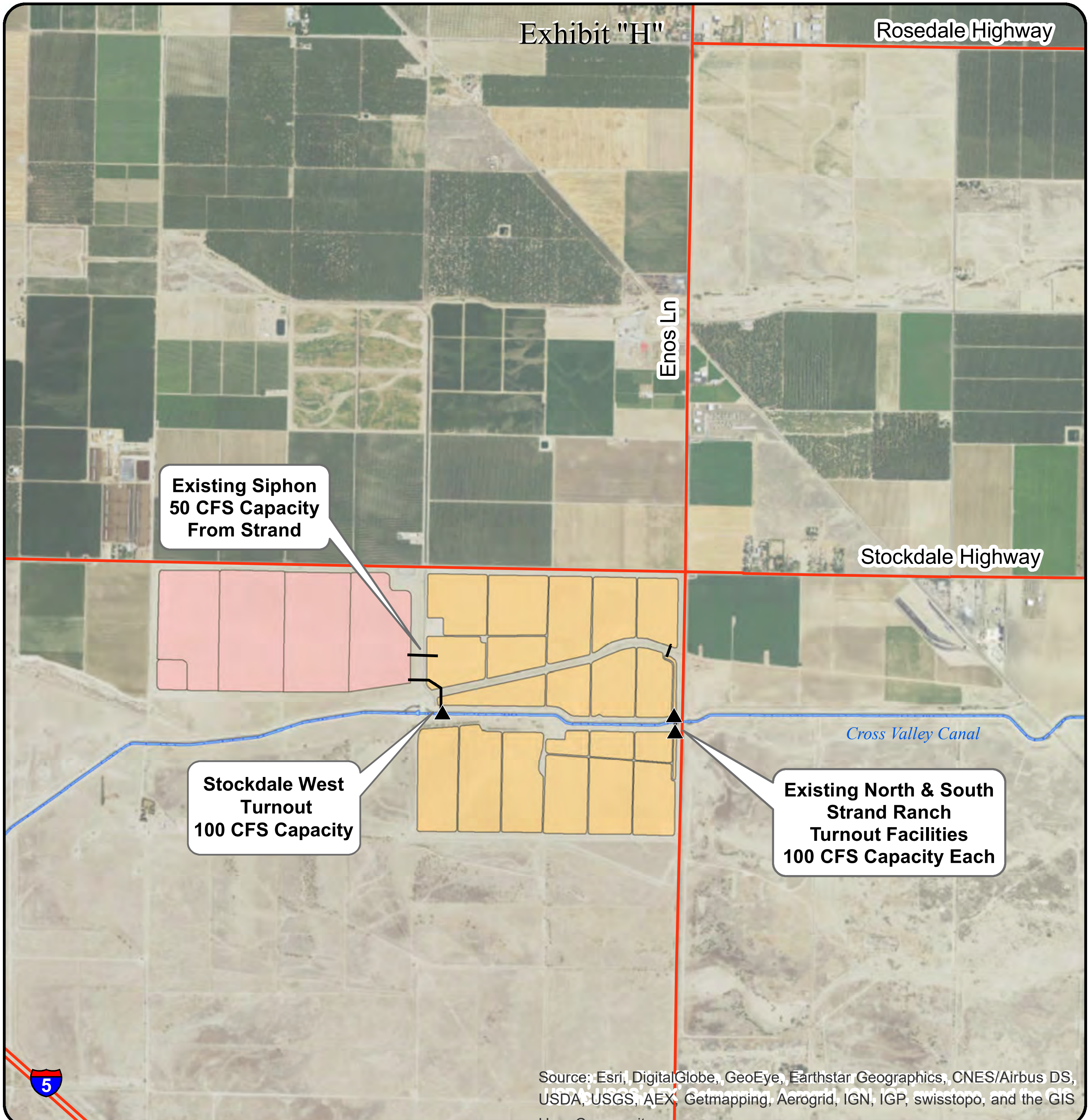

Irvine Ranch
WATER DISTRICT

Location Map: IRWD Water Banking Projects Recharge Basins &Turnout Facilities

MAP FEATURES

- Turnouts
- Stockdale West
- Strand Ranch

This figure shows the location of recharge basins, pipelines and turnout facilities.

0 0.25 0.5 1
Miles

N

NAD 83 State Plane Zone 5 (feet)
Central Meridian: -118

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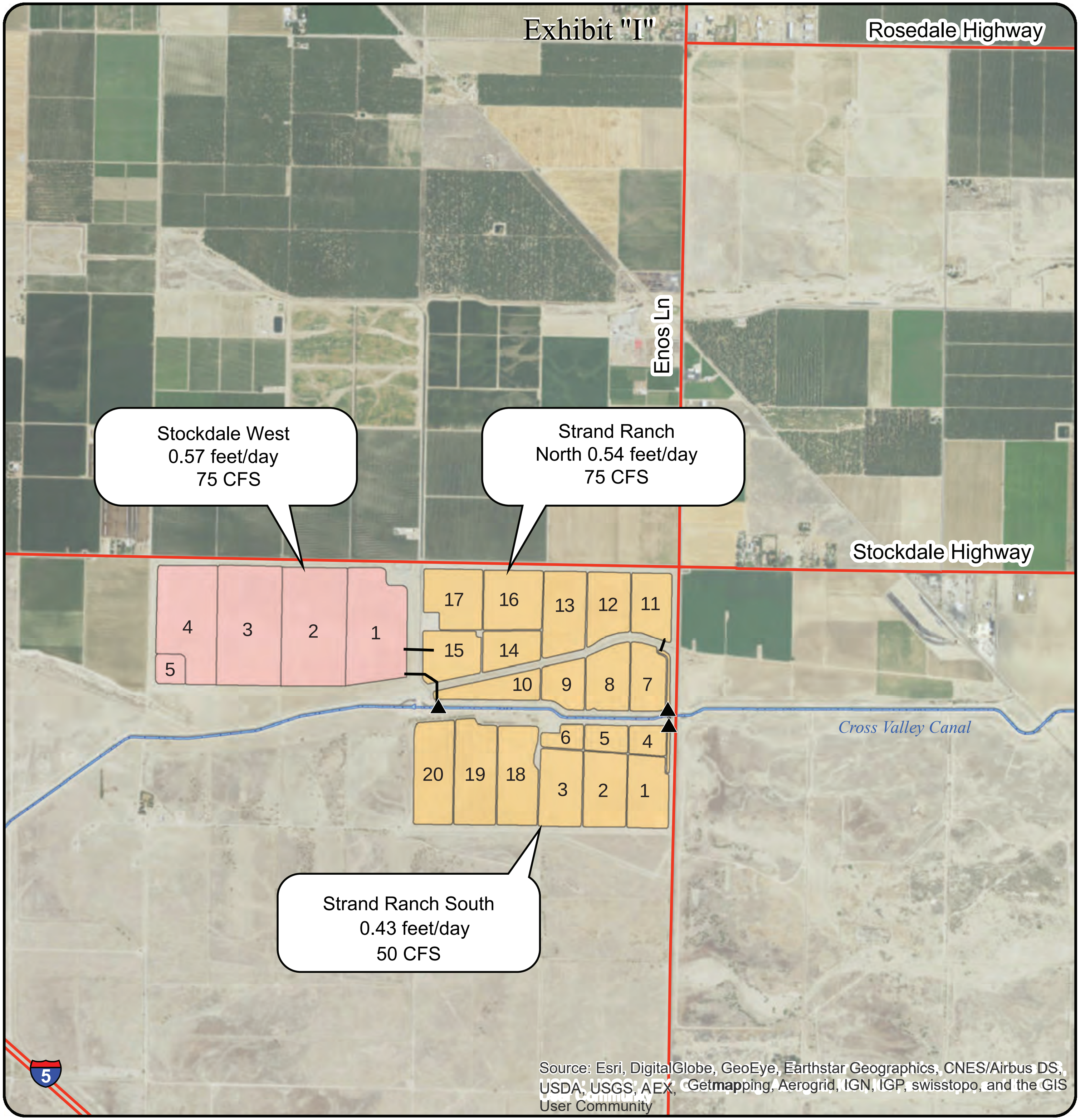

Irvine Ranch
WATER DISTRICT

Location Map:
IRWD Water Banking Projects
Recharge Rates

MAP FEATURES

- ▲ Turnouts
- Stockdale West
- Strand Ranch

This figure shows the location of recharge basins and their associated recharge rates as of April 14, 2023.

N

0 0.25 0.5 1
Miles

NAD 83 State Plane Zone 5 (feet)
Central Meridian: -118

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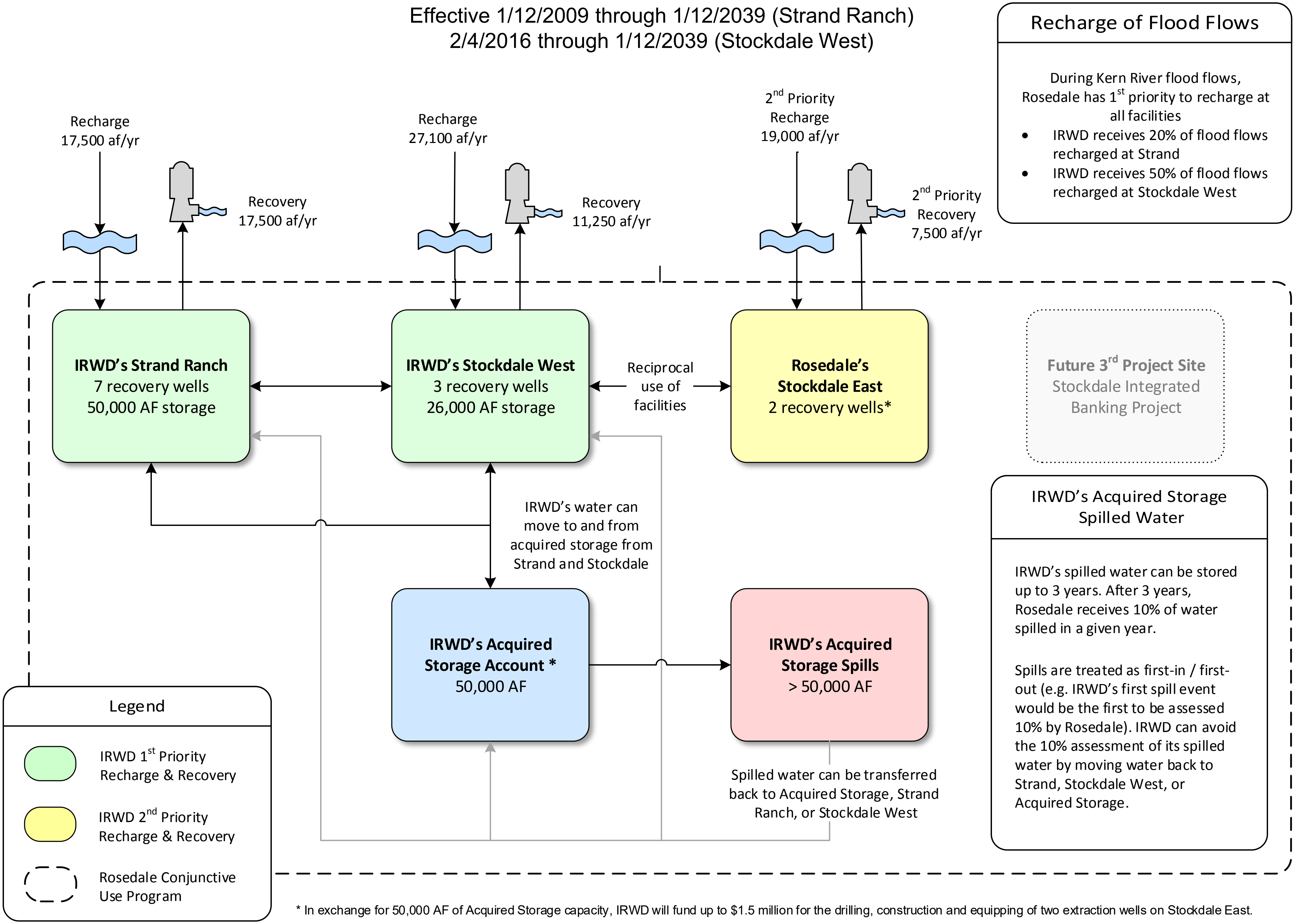
Exhibit "J"

IRWD-Rosedale Water Banking and Exchange Program Agreements

Effective 1/12/2009 through 1/12/2039 (Strand Ranch)
2/4/2016 through 1/12/2039 (Stockdale West)



* In exchange for 50,000 AF of Acquired Storage capacity, IRWD will fund up to $1.5 million for the drilling, construction and equipping of two extraction wells on Stockdale East.

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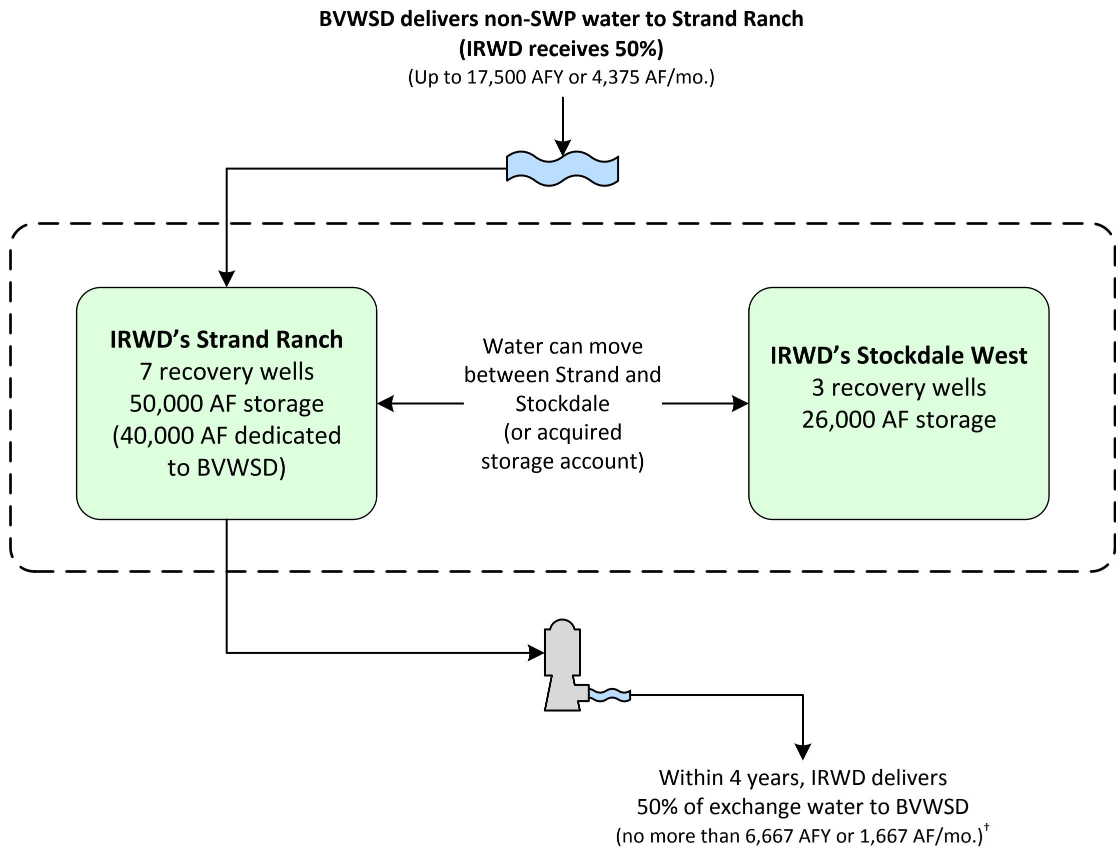
Exhibit "K"

Buena Vista Water Storage District Long Term Water Exchange Program

Effective 1/1/2011 through 1/12/2039



Legend

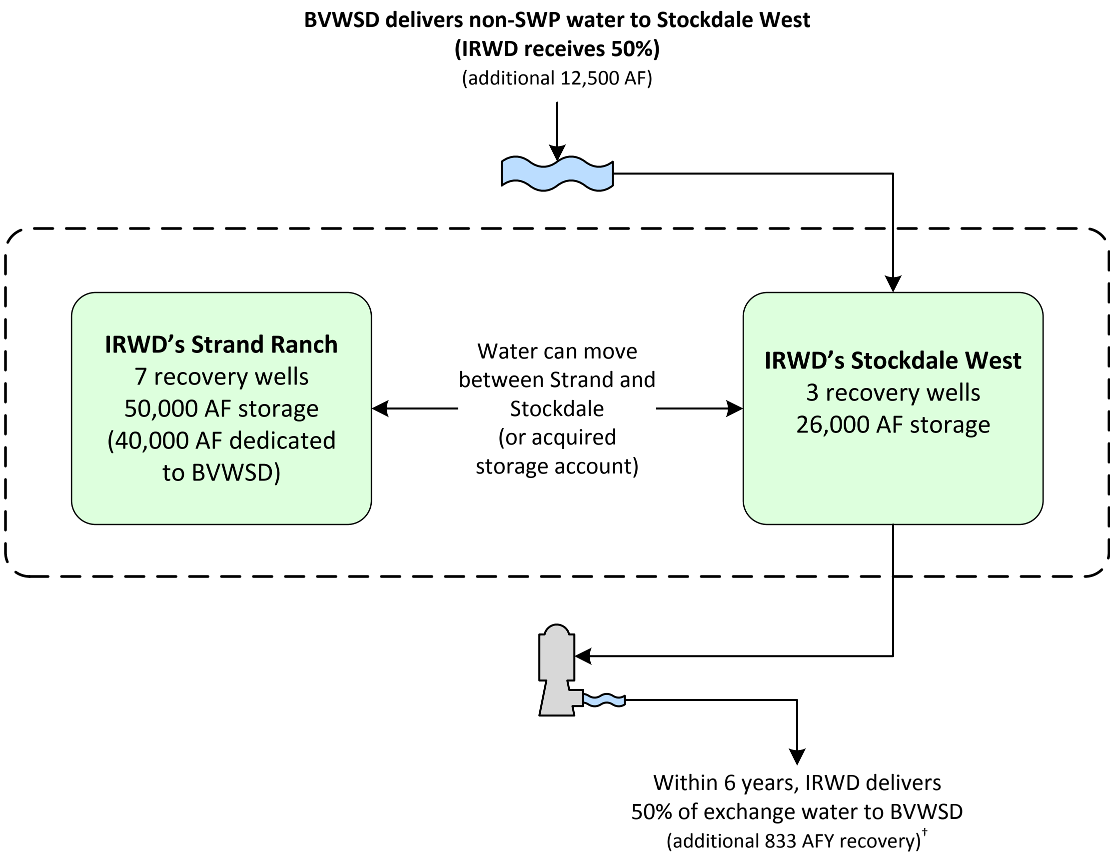
- IRWD 1st Priority Recharge & Recovery
- Rosedale Conjunctive Use Program & Coordinated Operation

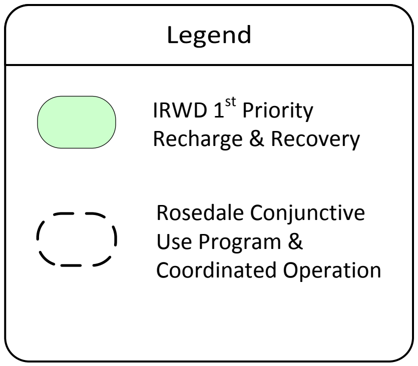
†IRWD shall remit one-half of the exchanged supply less one-half of reasonable losses back to BV no later than December 31st of the 4th year following the associated recharge event. IRWD pays for recovery of water returned to BV. Water to be remitted back to BV may remain in storage at Strand Ranch beyond the 4th year, in exchange for a greater percent being transferred to IRWD as compensation per the table shown to the right:

Year Following Recharge Event	Percent Transferred to IRWD	Percent Returned to BV During or Before Indicated Year
1	50%	50%
2	50%	50%
3	50%	50%
4	50%	50%
5	60%	40%
6	70%	30%
7	80%	20%
8	90%	10%
9	100%	0%

Buena Vista Water Storage District One-Year Program to Augment Recharge Using Stockdale West Recharge Facilities

Effective 4/1/2017 through 3/30/2018



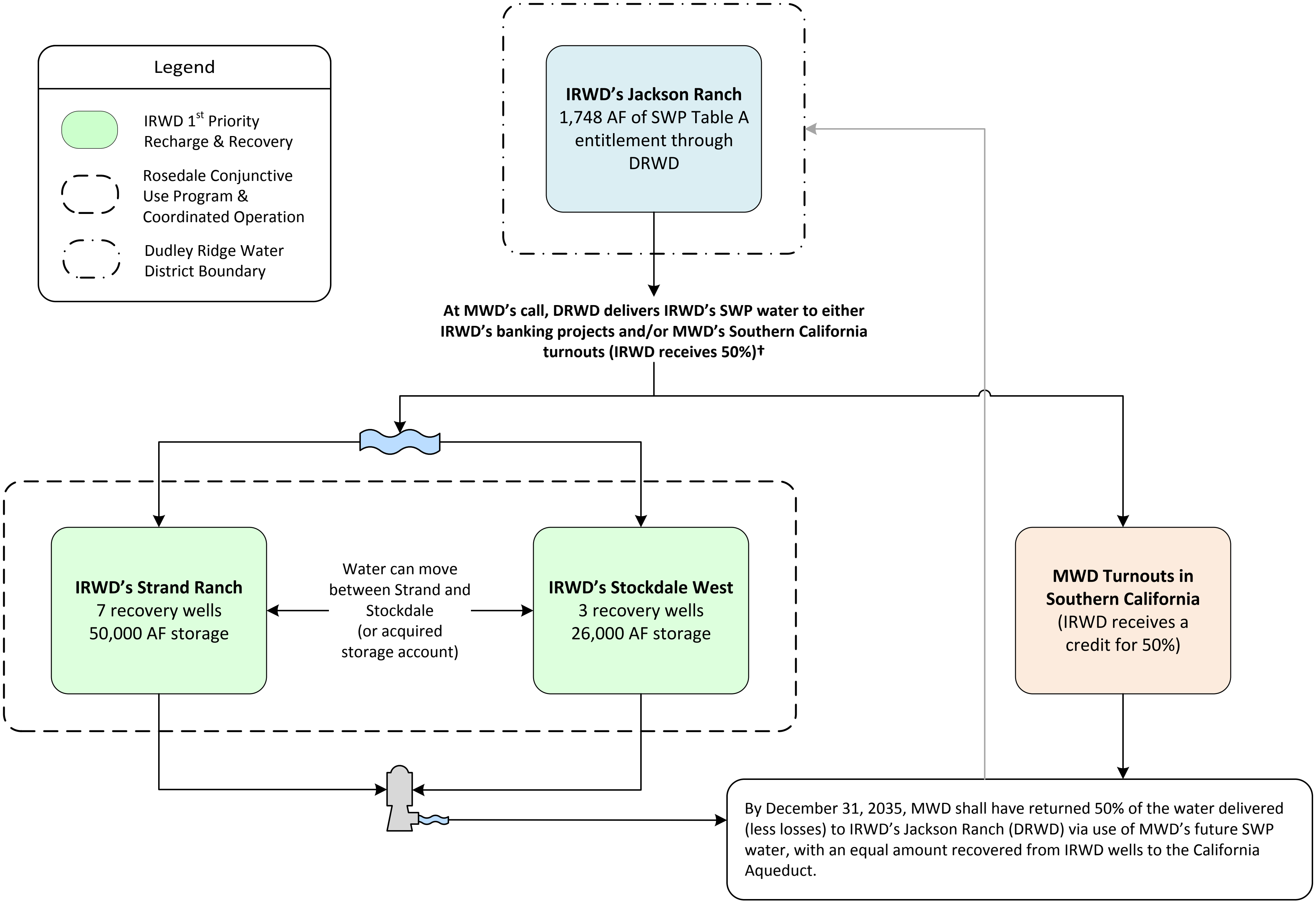


†IRWD shall remit one-half of the exchanged supply less one-half of reasonable losses back to BV no later than December 31st of the 6th year following the associated recharge event. IRWD pays for recovery of water returned to BV. Water to be remitted back to BV may remain in storage at Strand Ranch beyond the 6th year, in exchange for a greater percent being transferred to IRWD as compensation per the table shown to the right:

Year Following Recharge Event	Percent Transferred to IRWD	Percent Returned to BV During or Before Indicated Year
1	50%	50%
2	50%	50%
3	50%	50%
4	50%	50%
5	50%	50%
6	50%	50%
7	75%	25%
8	100%	0%
9	100%	0%

Exhibit "L"

Dudley Ridge Water District (DRWD) Unbalanced Exchange Program Up to 12,240 AF delivered from 6/7/2018 through 12/31/2027



†Consistent with IRWD-MWD coordinated operating agreement.

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Exhibit "M"

Coordinated Operating, Water Storage, Exchange and Delivery Agreement Between MWD, MWDOC and IRWD

Effective 5/1/2011 through 11/4/2035

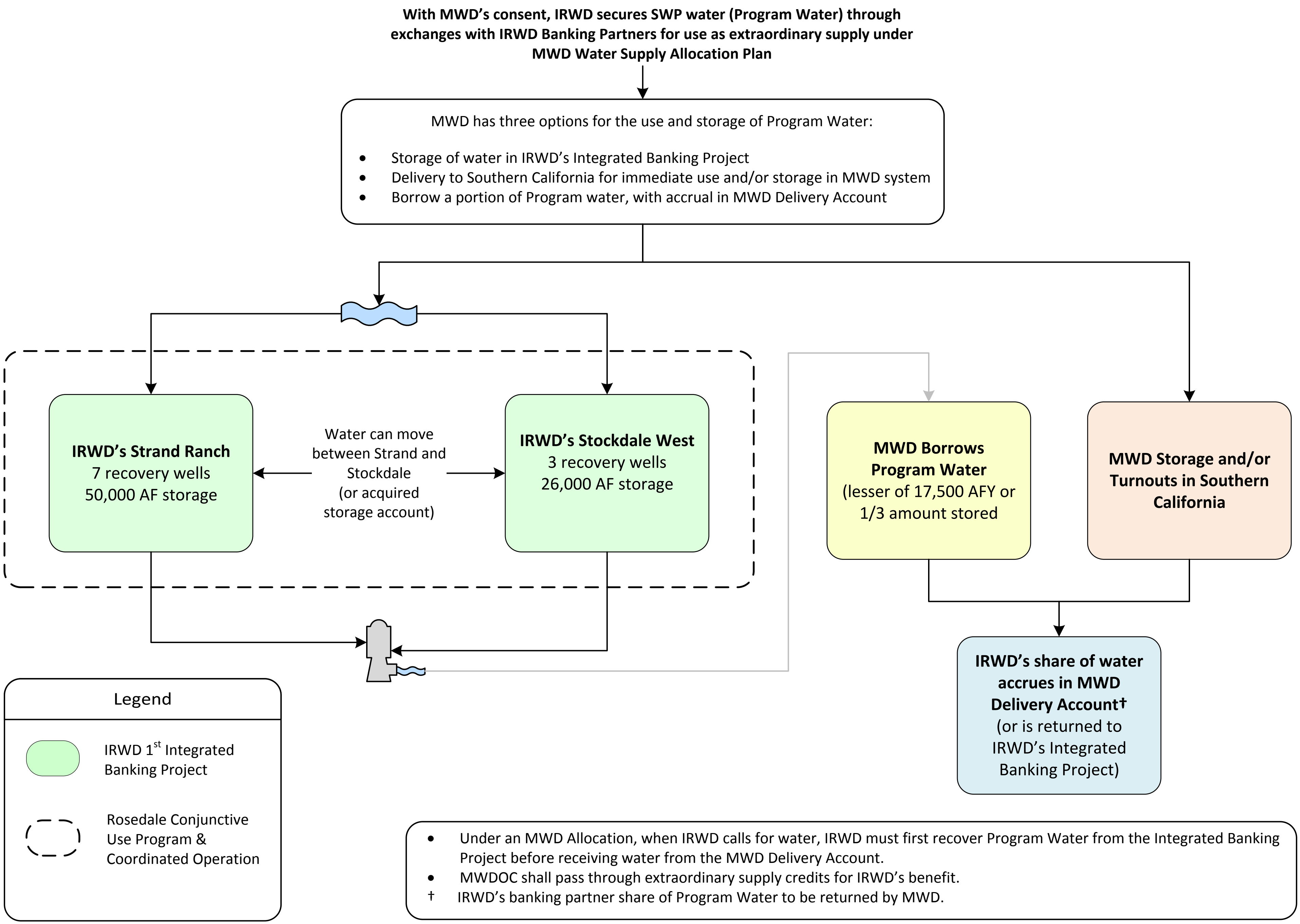

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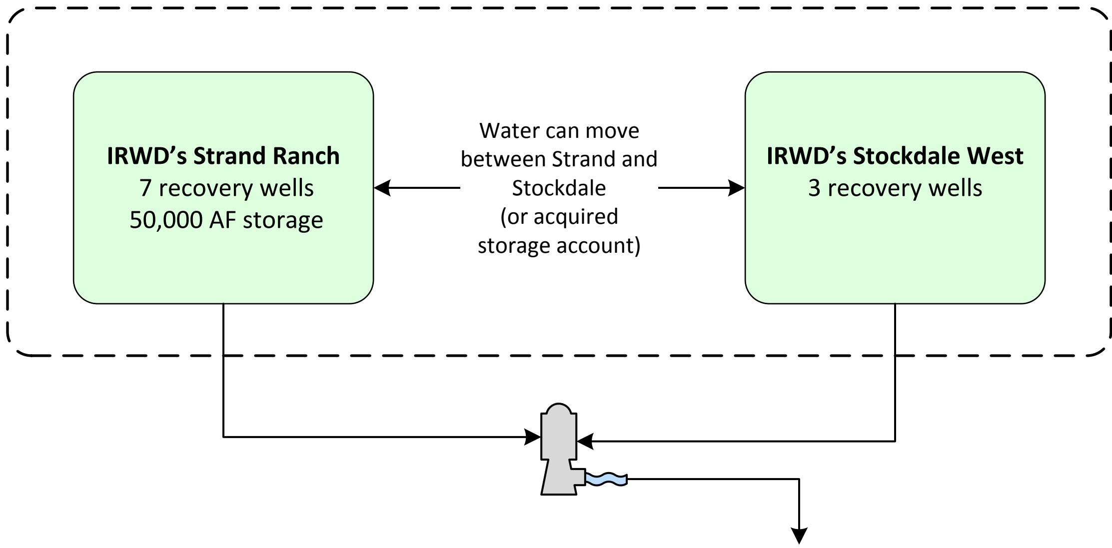
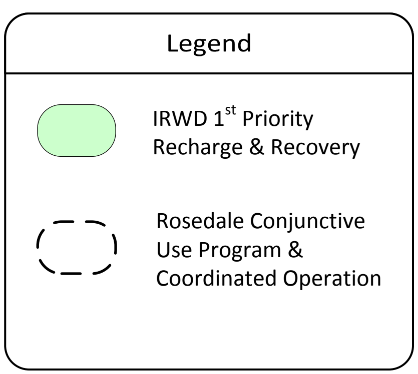
Exhibit "N"

Agreement for Conveyance of Water Between MWD, MWDOC, and IRWD (Wheeling Agreement)

Template for future agreements



IRWD recovers its share of non-SWP water from its Integrated Banking Projects for use as extraordinary supply under a declared MWD Water Supply Allocation. MWD will coordinate the conveyance and delivery of recovered water to be used within IRWD's Service Area. Delivery can also occur through an operational exchange.*



*The recovered water must be used within IRWD's service area. IRWD to pay MWD wheeling charges, including system access rate, water stewardship rate, and treatment surcharge (if applicable), for each acre foot of recovered water wheeled by MWD. IRWD will pay the actual costs of power incurred by MWD to convey recovered water in the California Aqueduct to IRWD delivery points.

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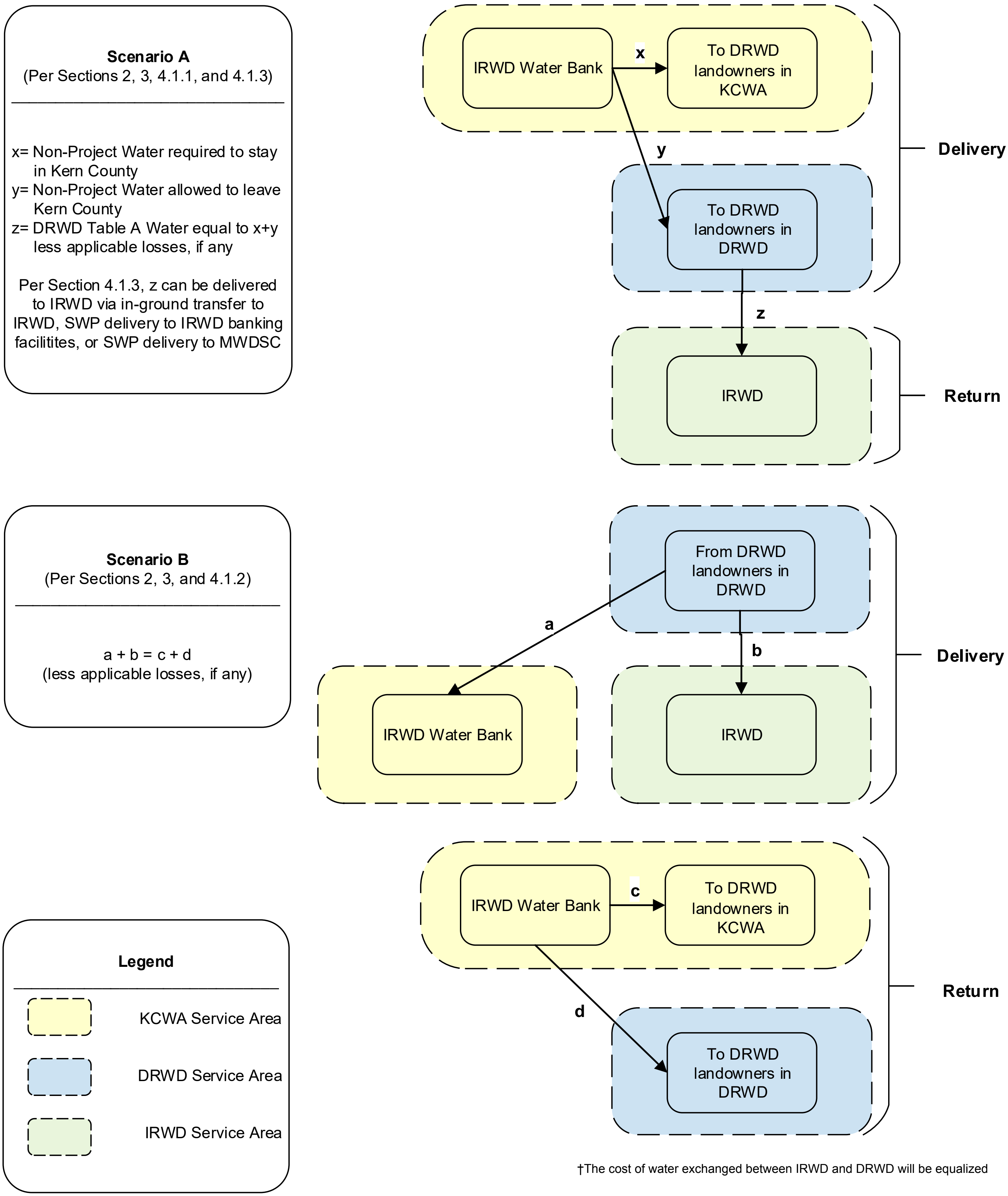
Exhibit "O"

Dudley Ridge Water District Long Term 1-for-1 Water Exchange Program

Effective 5/31/2017 through 11/4/2035



†The cost of water exchanged between IRWD and DRWD will be equalized

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Exhibit "P"

TABLE 6
IRWD Water Banking Program Costs of Water Summary
April 20, 2023

Program Partner	Time Period	Water Type	IRWD Amount (AF)	Variable costs[2] ($/AF) *(A)*	Fixed Cost Component[3] ($/AF) *(B)*	Fixed & Variable ($/AF) *(C)*	Capital Component[4] ($/AF) *(D)*	Cost of Water ($/AF) *(E)*	Estimated Recovery of Water[5] ($/AF) *(F)*	2023 MWD Tier 1 Untreated Rate + SAC Surcharge[6] ($/AF) *(G)*	Cost of Water in IRWD Service Area ($/AF) *(H)*
						A+B		*C+D*			*E+F+G*
Buena Vista	2010-2015	Kern River	12,832	**$ 75.98**	$ 48.36	**$124.34**	$ 190.00	**$ 314.34**	$ 120.00	$ 855.00	**$ 1,289.34**
Buena Vista[1]	2017-2021	Kern River	11,256	**$159.16**	$ 48.36	**$207.52**	$ 190.00	**$ 397.52**	$ 120.00	$ 855.00	**$ 1,372.52**
AVEK	2012-2014	SWP Table A	2,229	**$ 11.70**	$ 48.36	**$ 60.06**	$ 190.00	**$ 250.06**	$ 120.00	$ 855.00	**$ 1,225.06**
AVEK[7]	2012-2014	SWP Table A	108	**$ 11.70**	$ 48.36	**$ 60.06**	$ 190.00	**$ 250.06**	$ -	$ 855.00	**$ 1,105.06**
Carpinteria	2010-2015	SWP Table A	874	**$ 27.04**	$ 48.36	**$ 75.40**	$ 190.00	**$ 265.40**	$ 120.00	$ 855.00	**$ 1,240.40**
Carpinteria[7]	2010-2015	SWP Table A	31	**$ 27.04**	$ 48.36	**$ 75.40**	$ 190.00	**$ 265.40**	$ -	$ 855.00	**$ 1,120.40**
Central Coast[7]	2017-2021	SWP Table A	556	**$ 30.34**	$ 48.36	**$ 78.70**	$ 190.00	**$ 268.70**	$ -	$ 855.00	**$ 1,123.70**
DRWD[7]	2014-2021	SWP Table A /Article 21	4,452	**$362.67**	$ 48.36	**$411.03**	$ 190.00	**$ 601.03**	$ -	$ 855.00	**$ 1,456.03**
		Total	**32,338**								

[1] Water purchased in 2019 includes commodity charge of $110/AF

[2] Variable Costs include Rosedale variable operating costs, Rosedale administration fees, CVC pumping, operating and stand-by fees, and KCWA fees. (Net of partner payments to IRWD for their share of water)

[3] Fixed costs include Rosedale fixed operating costs, property taxes, PG&E standby costs, GSP fees, CVC expansion costs and other minor fix costs

[4] Capital component does not include land costs.

[5] Increased PG&E costs for recovering water.

[6] Assumes IRWD would take delivery as extraordinary supply through Irvine Lake to the Baker Water Treatment Plant.

[7] No recovery costs for DRWD water delivered in 2014-2016 and water recovered in 2022 as part of MWD borrowing.

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Exhibit "Q"

Summary of IRWD's Coordinated Operating, Water Storage, Exchange and Delivery Agreement with Metropolitan Water District and Municipal Water District of Orange County (MWDOC)

Agreement approved (unanimously) by the IRWD Board on November 22, 2010;
Agreement Term: April 21, 2011 to November 4, 2035

Summary of Benefits to IRWD:

1. IRWD benefits from all State Water Project (SWP) water IRWD secures; Metropolitan's borrowing of this water is temporary.
2. On behalf of IRWD, Metropolitan uses its SWP exchange and conveyance capacities to move IRWD's water for banking.
3. IRWD can "store" water in Metropolitan's system as a credit, freeing up space in IRWD's Water Bank with the water stored closer to the IRWD service area.
4. IRWD does not incur conveyance or evaporation losses on its water that is conveyed in Metropolitan's system and stored in Metropolitan's reservoirs.
5. IRWD avoids groundwater recovery (pumping) costs when Metropolitan issues a credit for IRWD's SWP supplies in Southern California (currently $122/AF[1]).
6. IRWD pays Metropolitan's melded system power rate – currently $167/AF, not DWR's current power costs of $395/AF[2] ($228/AF savings).
7. Deliveries are on-demand to IRWD at its service connections in Orange County, which are not subject to lower priorities for wheeling.
8. Metropolitan pays all SWP costs, including variable OMP&R supply costs, associated with SWP water secured by IRWD[3].
9. IRWD pays Metropolitan's Full-Service Tier-1 Untreated Rate, which is currently $799/AF, for deliveries at its service connections allowing IRWD to avoid higher Metropolitan wheeling charges currently estimated at $856/AF[4].
10. IRWD only pays once for supply at the current Tier-1 Supply Rate of $243/AF.
11. Deliveries to IRWD's service area qualify as Extraordinary Supply during a Water Supply Allocation, allowing IRWD to avoid Metropolitan's Allocation Surcharge of between $1,480/AF and $2,960/AF.
12. IRWD increases local water supply reliability for its ratepayers.

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[1] Estimated from IRWD's current groundwater pumping costs and Water Bank related operations costs. Metropolitan has the option to extinguish credits by returning water to the IRWD Water Bank. In recent borrowing letter agreement, Metropolitan agreed to waive its ability to return borrowed water to the Water Bank.

[2] Melded system and actual power costs were taken from Metropolitan's April 2022 Bi-Annual Budget Report and 2022 Cost of Service Study.

[3] Does not include fixed costs paid by IRWD's unbalanced exchange partners. In 2014 and 2017, Metropolitan's SWP costs were $1,097/AF and $359/AF, respectively.

[4] The Coordinated Agreement requires IRWD to pay Metropolitan its Full-Service Tier 1 Rate for exchange deliveries at IRWD service connections. IRWD is expected to take delivery of such deliveries to the Baker Water Treatment Plant. Metropolitan's current Tier-1 Untreated Rate = $799/AF. Current Metropolitan wheeling charges of $856/AF are estimated using Metropolitan's current System Access Rate ($389/AF), estimated demand management charge ($72/AF), and actual power costs ($395/AF).

Summary of Benefits to MWD:

1. Metropolitan maintains control of all SWP supplies entering its service area as required by its SWP Contract with California Department of Water Resources (DWR).
2. Metropolitan's investments in the SWP are protected by not causing a reduction in revenue received by Metropolitan for payment of SWP fixed charge obligations.
3. Metropolitan can temporarily borrow SWP water secured by IRWD.
4. Metropolitan is assured that IRWD is not competing for water supplies.
5. Increased regional water supply reliability.