APPENDIX H

Hydrogeological Technical Memo

Technical Memorandum

To: Mr. Dan Bartel
James Water Bank Authority

From: Thomas Harder, P.G., CH.G.
Thomas Harder & Co.

Date: 26-May-21

Re: James Canal Banking Project – 2020 Analysis

1. Introduction

This Technical Memorandum (TM) summarizes a supplemental analysis of potential recharge and recovery operations for the proposed James Canal Banking Project (the Project). Prior analyses of the Project were conducted by Thomas Harder & Co. (TH&Co) in August 2013[1] and November 2016[2]. For the original analysis, the Project included 1,343 acres of recharge area and 14 Project production wells. For the second analysis of the Project, TH&Co evaluated potential groundwater impacts with respect to a "reduced" project alternative whereby the Project recharge area was reduced from 1,343 acres to approximately 658 acres. The reduced Project included only 10 of the 14 production wells from the original analysis.

This analysis of the Project evaluated the impacts of the full 1,343-acre Project recharge area (Project Area; see Figure 1) using all 14 Project production wells and included the addition of the 589-acre Option Property. The analysis was conducted using an updated version of the calibrated numerical groundwater flow model that was used for the original study. A portion of the groundwater recovery for the Project was also simulated with non-Project wells located in the Rosedale-Rio Bravo Water Storage District (RRBWSD) and the Buena Vista Water Storage District (BVWSD) service areas. TH&Co used the same model as used for previous analyses of Project impacts but calibrated through December 2018. For a detailed description of the

[1] TH&Co., 2013. James Canal Banking Project - Analysis of Potential Groundwater Level Changes from Recharge and Recovery. Prepared for Rosedale-Rio Bravo Water Storage District and Buena Vista Water Storage District, August 9, 2013.
[2] TH&Co, 2016. James Canal Banking Project – Supplemental Analysis. Prepared for Rosedale-Rio Bravo Water Storage District and Buena Vista Water Storage District, November 21, 2016.

hydrogeological setting and groundwater flow model, see TH&Co., 2013. In addition, this analysis evaluated recovery from both Project wells and offsite production wells.

1.1. Purpose and Scope

The purpose of this analysis is to:

1. Evaluate potential groundwater level impacts from maximizing managed recharge in basins utilizing the full Project area and maximizing groundwater recovery from a combination of onsite Project wells and other offsite wells.
2. Evaluate groundwater levels resulting from Project recharge operations during high groundwater conditions and evaluate Project recovery during low groundwater conditions.

The scope of work to address the objectives included:

1. Developing Project recharge and recovery operational scenarios.
2. Analyzing the Project operational scenarios with the calibrated groundwater flow model of the area.

1.2. Types and Sources of Data

The calibrated groundwater flow model used in the analysis of groundwater level changes incorporates a comprehensive hydrogeological database of the Project Area. The types of data used to develop the model included geology, soils/lithology, groundwater levels, hydrogeology, surface water hydrology, and groundwater recharge and pumping, as summarized in TH&Co (2011)[3]. Information regarding the Project Area and revised recharge area was provided by GEI Consultants and Rosedale-Rio Bravo Water Storage District (RRBWSD).

1.3. Historical Groundwater Level Fluctuations

Groundwater levels in the Project area fluctuate significantly as a result of recharge and recovery operations at nearby banking projects. At monitoring well 30S/26E-22P, located in the south-central portion of the Option Property (see Figure 1), groundwater levels have fluctuated more than 160 feet from historical high levels observed in 1999 and 2006 to historical low levels observed in 2016 (see Figure 2).

[3] TH&Co., 2011. Hydrogeological Impact Evaluation Related to Operation of the Kern Water Bank and Pioneer Projects. Prepared for McMurtrey, Hartsock, & Worth and Rosedale-Rio Bravo Water Storage District, December 5, 2011.

2. Project Operational Parameters

2.1. Maximum Annual Recharge Capacity

For this analysis, annual recharge capacity is defined as the maximum volume of water that the Project can infiltrate into the subsurface in a year (see Table 1). The recharge capacity was estimated based on the size of the facility (wetted area), the time available to accept water (assumed to be 365 days), and the infiltration rate. The wetted area is estimated to be 1,663 acres for the full project, which is 80 percent of the planned recharge basin area (2,079 acres) as provided by GEI Consultants. The reduced wetted area accounts for berms, well pads, and other areas that will not be wetted and is consistent with other recharge projects in the vicinity.

Using an infiltration rate of 0.3 ft/day and the wetted area for the Project, as described above, the resulting annual recharge capacity for the full project and option property is approximately 182,066 acre-ft/yr (see Table 1).

2.2. Individual Well Pumping Rates

The potential pumping rate for individual Project wells was determined based on pumping rates for existing wells in the Project area. Individual well production rates in the Project area typically range from approximately 1,600 gallons per minute (gpm) to approximately 5,000 gpm. However, wells with both intermediate and deep perforated intervals (250 to 700 feet below ground surface; ft bgs) typically produce more than 3,000 gpm. For analysis purposes, it is assumed that each well is perforated in both the intermediate and deep aquifer systems. Maximum simulated individual well pumping rates used for the groundwater level analysis was approximately 2,230 gpm.

Individual well pumping rates for non-Project wells were estimated from their most recent recorded instantaneous discharge rates.

3. Project Operational Scenarios for Analysis Using the Groundwater Flow Model

3.1. Baseline Groundwater Level Conditions

Potential changes in groundwater levels specific to Project operations were evaluated relative to baseline groundwater level conditions for the period between 2005 and 2018. The baseline period (2001 through 2018) represents an extreme range in groundwater level conditions upon which the Project is superimposed, including near historical high groundwater conditions (2007) and historical low groundwater conditions (2016) (see Figure 2). The baseline conditions include all historical hydrological conditions, including recharge and recovery from other projects (e.g. KWB, Pioneer Project, etc.), which resulted in the calibrated groundwater levels in the model.

3.2. Project Operational Scenario

Baseline groundwater level conditions were compared against a Project operational scenario. The purpose of the scenario was to simulate the maximum amount of recharge the Project can accommodate while maintaining groundwater levels below the levels protective of liquefaction. Project recharge was introduced into the model for the same historical periods as simulated in Scenario 2 (see Table 2). However, recharge amounts were increased through a sensitivity analysis to assess the maximum recharge rates the Project could accommodate while maintaining groundwater levels at least 15 ft below ground surface (ft bgs). The analysis resulted in recharge rates ranging from 48,500 acre-ft/yr for the 2005-2006 time period to 182,067 acre-ft/yr for 2017 (see Table 2). The analysis showed that a cumulative amount of 341,123 acre-ft of water could be recharged by the Project across the five relatively high groundwater years (2005 through 2017 time period) without raising groundwater levels within 15 feet of the land surface (the groundwater depth considered protective of liquefaction potential).

For the Project operational scenario, groundwater recovery was spread out over four years to maximize recovery and minimize additional drawdown at nearby non-project wells. Groundwater pumping was simulated over four 10-month periods overlapped on March through December 2008, 2009, 2014, and 2015 groundwater level conditions. A total of 180,212 acre-ft of groundwater was recovered during this time (see Table 2). Of the 180,212 acre-ft of water recovered, 75 percent (135,159 acre-ft) was recovered from onsite Project wells, and 25 percent (45,053 acre-ft) was recovered from the 16 offsite production wells shown on Figure 3. A summary of the offsite production wells and their production rates can be found in Table 3. The results of the Project operational scenario showed that project-related pumping drawdown could be kept below 29 feet at nearby non-project wells at the recovery rates simulated (see Section 4 herein).

4. Findings

4.1. Groundwater Levels During Maximum Recharge Mounding

During Project operational scenario simulated recharge events, maximum groundwater mounding is predicted to remain below 15 ft bgs in the shallow/intermediate aquifer throughout the Project area (see Figure 4). Groundwater levels in the deeper aquifer are predicted to remain below approximately 25 ft bgs during maximum mounding (see Figure 5).

4.2. Groundwater Levels During Recovery

Groundwater pumping drawdown, relative to the baseline condition, is predicted to be greatest in the west central part of the Project area (see Figures 6 and 7). Maximum groundwater drawdown in Project wells is predicted to be as high as approximately 50 ft in the shallow/intermediate aquifer and up to 60 feet in the deep aquifer. Maximum pumping interference in the nearest non-project wells occurs in the deep aquifer and is predicted to range from approximately 13 to 29 ft (see Figure 7). Maximum pumping interference at the nearest private agricultural wells along the southeastern boundary of the Project is predicted to range from approximately 13 to 19 ft.

Maximum pumping drawdown near offsite production wells is predicted to be less than 10 feet (see Figures 8 and 9).

4.3. Predicted Changes in Groundwater Flow

Changes in groundwater flow resulting from Project recharge events depend on the timing and amounts of recharge. During 2006 groundwater level conditions, groundwater flow directions are not predicted to substantially change relative to the baseline in either the shallow/intermediate or deep aquifers (see Figures 10 and 11). Project groundwater recharge rates overlapped on 2012 and 2017 groundwater level conditions, as simulated in the Project operational scenario, are predicted to result in a localized groundwater mound beneath the Project area that results in groundwater flow emanating in each direction from the center of the mound (see Figure 12). The mound occurs in both the shallow/intermediate and deep aquifers (see Figure 13).

Groundwater pumping under the Project operational scenario is not predicted to result in significant changes in the regional groundwater flow direction in the Project area, relative to the baseline. As shown on Figure 14, groundwater in the shallow/intermediate aquifer under historical low baseline conditions flows to the northwest beneath the Project area. Project pumping overlapped on historical low baseline conditions is not predicted to substantially change the regional groundwater flow direction in the shallow/intermediate aquifer (see Figure 14). Groundwater flow under Project conditions still flows to the northwest beneath the Project area with small, localized pumping depressions. The groundwater flow direction in the deep aquifer with simulated Project pumping is also predicted to be similar to that of the baseline condition (see Figure 15).

5. Conclusions

The following summarizes our conclusions based on the supplemental analysis of Project recharge and recovery scenarios:

1. Based on infiltration rates estimated from recharge operational data at the adjacent banking facilities, the Project can accommodate a theoretical maximum recharge rate of approximately 182,066 acre-ft/yr for the full project. However, while the Project can accommodate that recharge rate under 2017 baseline groundwater level conditions, it cannot accommodate that recharge rate under 2005 baseline conditions as groundwater levels would likely rise above the ground surface.
2. Project recharge rates can be maximized by varying them based on groundwater level conditions at the time of the recharge, as shown from the Project operational simulation. During the highest groundwater level conditions (2005), up to 48,500 acre-ft of water can be recharged at the Project while maintaining acceptable groundwater levels for liquefaction potential. During 2017 groundwater level conditions, up to 182,066 acre-ft of water can be recharged in a year without causing a potential for liquefaction.
3. The Project can accommodate groundwater recovery rates ranging from 35,000 acre-ft/yr to 51,600 acre-ft/yr without exceeding the 29-ft pumping interference goal of the Project. Higher Project recovery rates are possible after periods of higher Project recharge rates.
4. Groundwater pumping in offsite production wells is predicted to result in less than 10 ft of additional drawdown in the BVWSD and RRBWSD production wells.
5. Changes in groundwater flow resulting from Project recharge events depend on the timing and amounts of recharge. Project groundwater recharge rates overlapped on 2012 and 2017 groundwater level conditions, as simulated in the Project operational scenario, are predicted to result in a localized groundwater mound beneath the Project area that results in groundwater flow emanating in each direction from the center of the mound.
6. Groundwater flow direction during maximum drawdown from the Project is not predicted to change significantly relative to the baseline.

Table 1

James Canal Banking Project
Annual Recharge Capacity Estimates

	Basin						
	JC SW	JC NW	JC N	JC NE	JC SE	Option Property	Total
Total Basin Size (acres)[1]	208	384	142	171	169	589	1,663
Estimated Infiltration Rate (ft/day)	0.3	0.3	0.3	0.3	0.3	0.3	NA
Monthly Infiltration Capacity (acre-ft/month)[2]	1,903	3,514	1,299	1,565	1,546	5,387	15,214
Annual Infiltration Capacity (acre-ft/yr)	22,776	42,048	15,549	18,725	18,506	64,463	182,066

Notes:

[1]Estimated as 80% of the property.
[2]acre-ft = acre-feet.
NA = Not applicable.

James Canal Banking Project - Supplemental Analysis
Summary of Model Operational Scenarios

Facility	Recharge: Annual Recharge Rate (acre ft)	Recharge: Combined Recharge Rate (acre ft/yr)	Recharge: Total Recharged (acre ft)	Recharge: Simulated Period of Recharge	Recovery: Anuual Recovery Rate (acre ft/yr)	Recovery: Total Recovered (acre ft)	Recovery: Simulated Period of Recovery
JC-SW	9,000/22,776/ 22,776	48,500/ 110,556/ 182,067	341,123	Jan 2005 - Dec 2006, Jan 2011 - Dec 2012, Jan 2017 - Dec 2017	42,000/ 35,000/ 51,606/ 51,606	180,212	Mar 2008 - Dec 2008, Mar 2009 - Dec 2009, Mar 2014 - Dec 2014, Mar 2015 - Dec 2015
JC-NW	7,000/15,000/ 42,048						
JC-N	7,000/15,549/ 15,549						
JC-NE	9,000/18,725/ 18,725						
JC-SE	9,000/18,506/ 18,506						
Opt Prop	7,500/20,000/ 64,463						

Table 3

Summary of Off-Site Production Wells

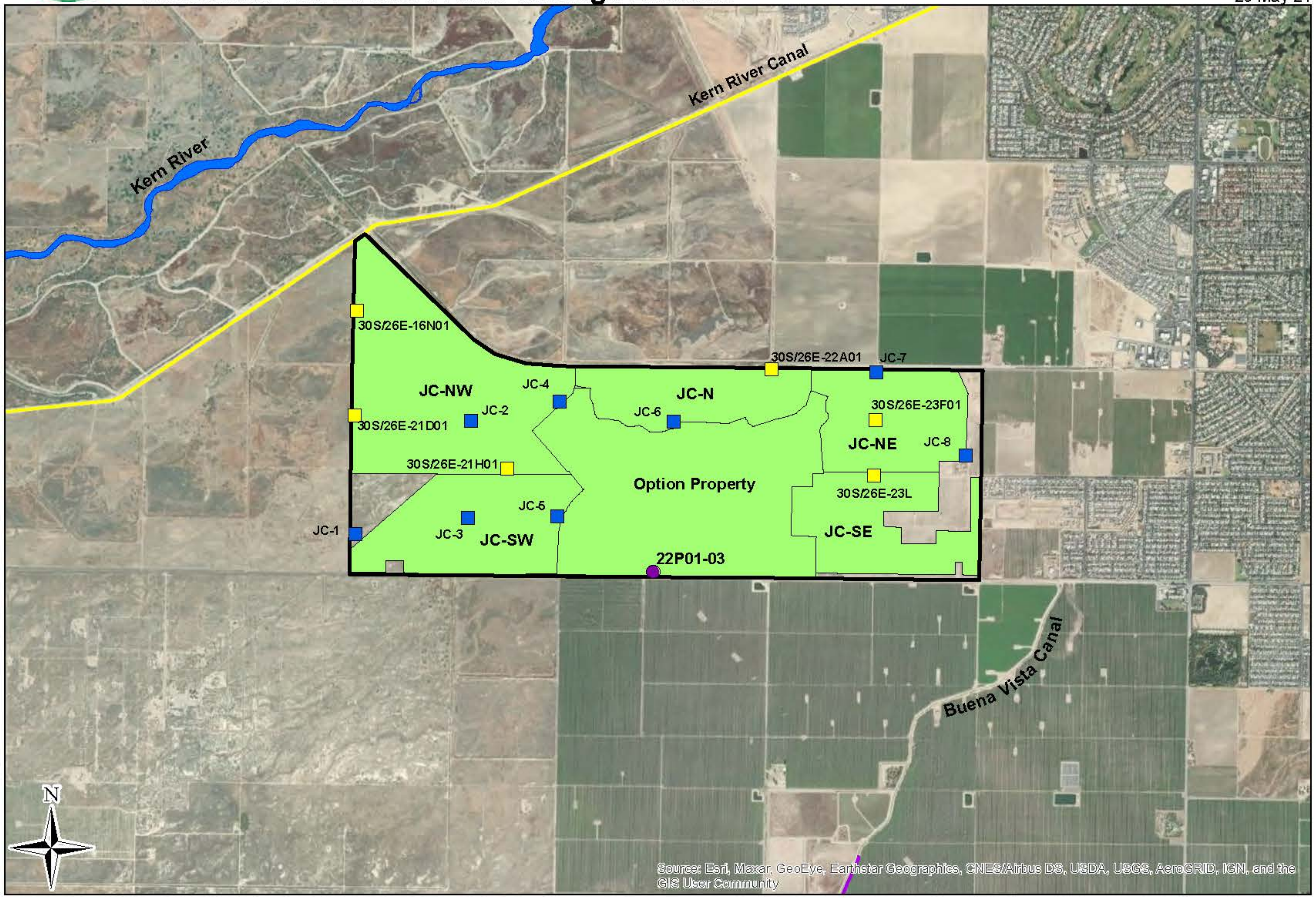
Well Name	Entity	Perforation Interval	Aquifer	Pumping Rate (gpm)[1]
Enns 1	RRBWSD	185 to 455	Intermediate	509
Enns 2	RRBWSD	460 to 740	Deep	509
Enns 3	RRBWSD	180 to 420	Intermediate	509
WB-1	RRBWSD	370 to 480 510 to 550 610 to 790	Intermediate & Deep	509
WB-2	RRBWSD	380 to 550 570 to 740	Intermediate & Deep	509
WB-3	RRBWSD	380 to 515 540 to 750	Intermediate & Deep	509
SUP-1	RRBWSD	270 to 535 565 to 660 790 to 960	Intermediate & Deep	509
SUP-2	RRBWSD	370 to 430 460 to 630	Intermediate & Deep	509
SUP-4	RRBWSD	365 to 545 570 to 610 630 to 780	Intermediate & Deep	509
SUP-5	RRBWSD	370 to 560 600 to 670	Intermediate & Deep	509
SUP-6	RRBWSD	410 to 610 700 to 920	Deep	509
DW01	BVWSD	143 to 633	Intermediate & Deep	305
DW02	BVWSD	147 to 637	Intermediate & Deep	305
DW03	BVWSD	141 to 631	Intermediate & Deep	305
DW05	BVWSD	144 to 634	Intermediate & Deep	305
DW06	BVWSD	137 to 627	Intermediate & Deep	305

Notes:

[1] gpm = gallons per minute.

Rosedale-Rio Bravo Water Storage District

26-May-21



0 0.5 1 2 Miles

NAD 83 State Plane CA Zone 5

Thomas Harder & Co.
Groundwater Consulting

James Canal Banking Project 2020 Analysis

Map Features

- Proposed New Well Site
- Proposed Existing Well
- Observation Well 22P
- James Canal Recharge Zone*
- Project Area
- Lined Canal
- Unlined Canal
- Water Courses

*Assumes wetted area will be 80% of total area.

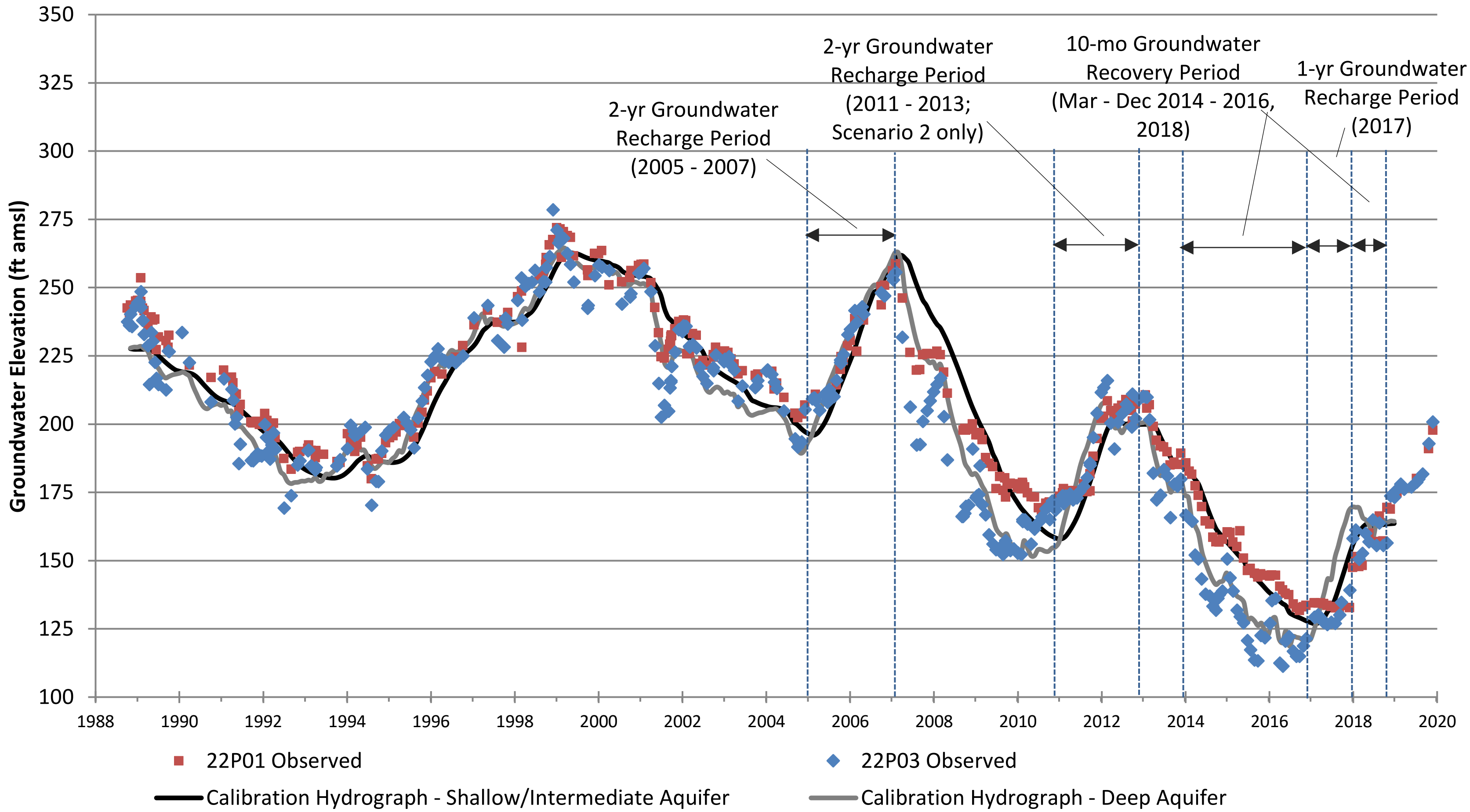
Model Recharge Zones in the Project Area

Figure 1

Rosedale Rio-Bravo Water Storage District
James Canal Banking Project

Figure 2

Hydrologic Conditions for Recharge and Recovery Periods
Baseline Hydrograph - 30S/26E-22P



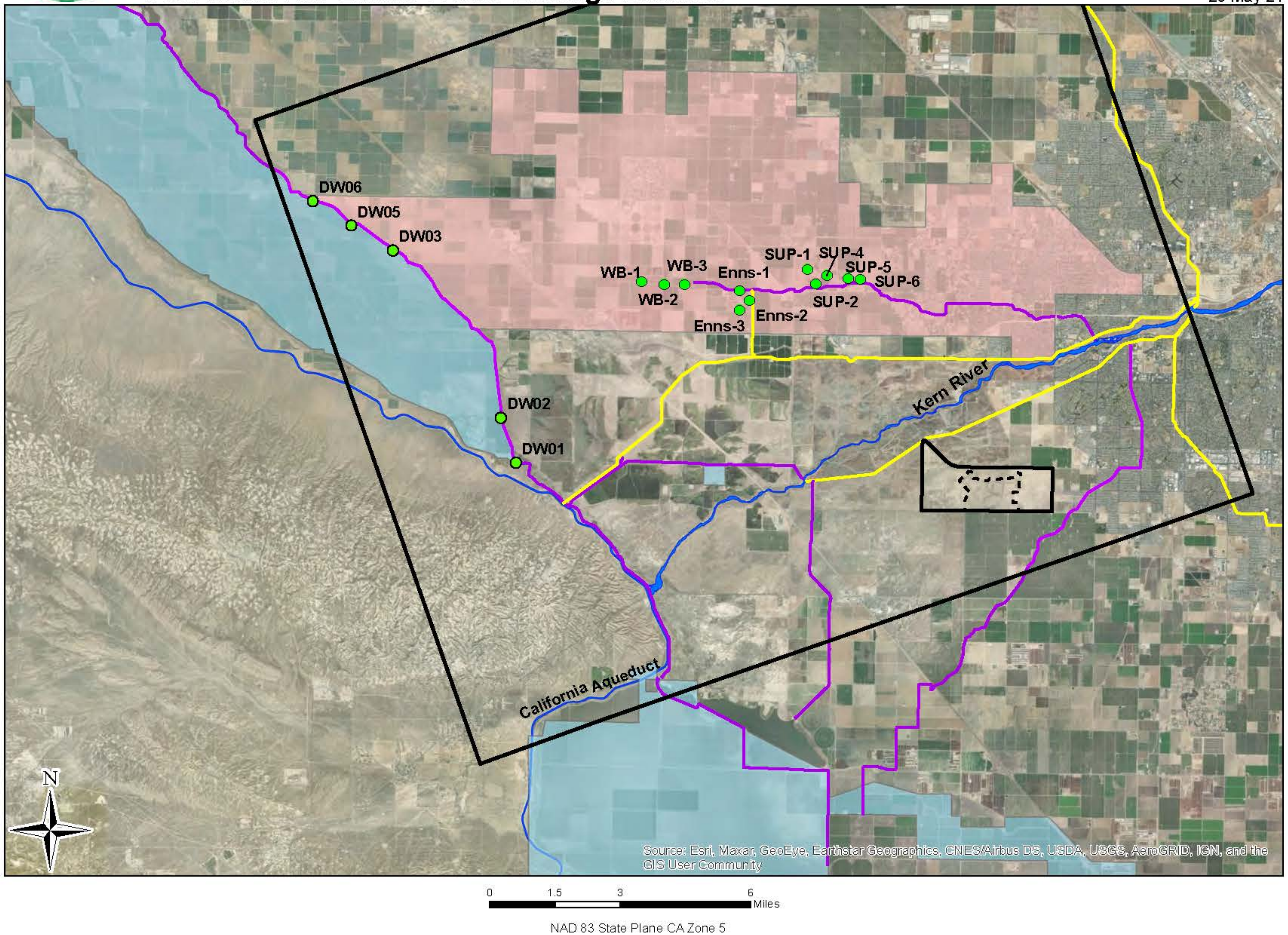
Thomas Harder & Co.
Groundwater Consulting

26-May-21

Rosedale-Rio Bravo Water Storage District

26-May-21

James Canal Banking Project
2020 Analysis



Map Features

- Offsite Production Well
- Project Area
- Option Property
- Buena Vista Water Storage District
- Rosedale-Rio Bravo Water Storage District
- Model Domain
- Lined Canal
- Unlined Canal
- Water Courses

Thomas Harder & Co.
Groundwater Consulting

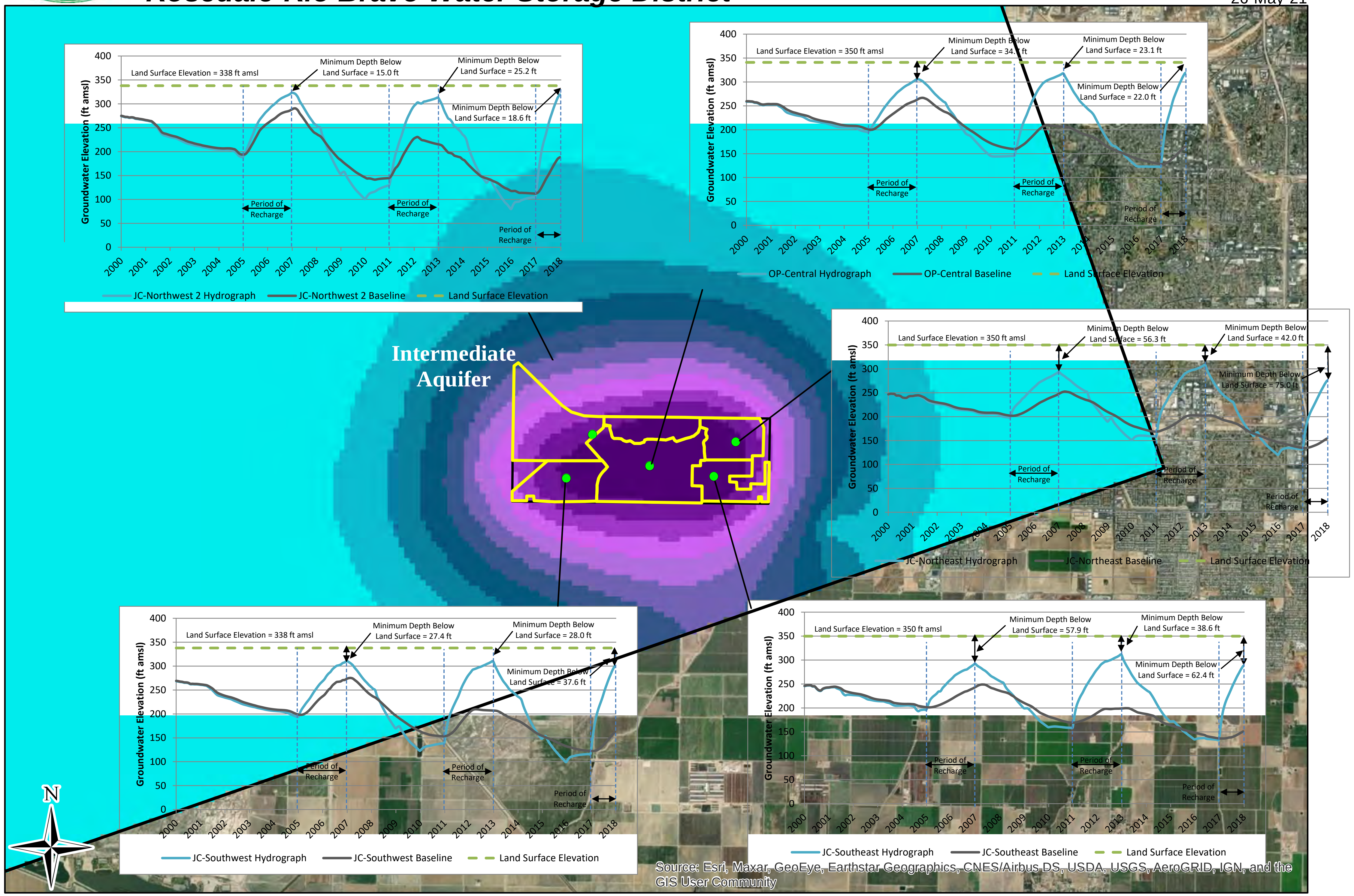
Offsite Production Wells

Figure 3

Rosedale-Rio Bravo Water Storage District

26-May-21

James Canal Banking Project
2020 Analysis



0 1 2 4 Miles

NAD 83 State Plane CA Zone 5

Map Features

Maximum Groundwater Level Mounding (ft)

- > 100
- 90 to 100
- 80 to 90
- 70 to 80
- 60 to 70
- 50 to 60
- 40 to 50
- 30 to 40
- 20 to 30
- 10 to 20
- 0 to 10
- < 0
- Observation Point
- Recharge Zone
- Project Area
- Model Domain

Thomas Harder & Co.
Groundwater Consulting

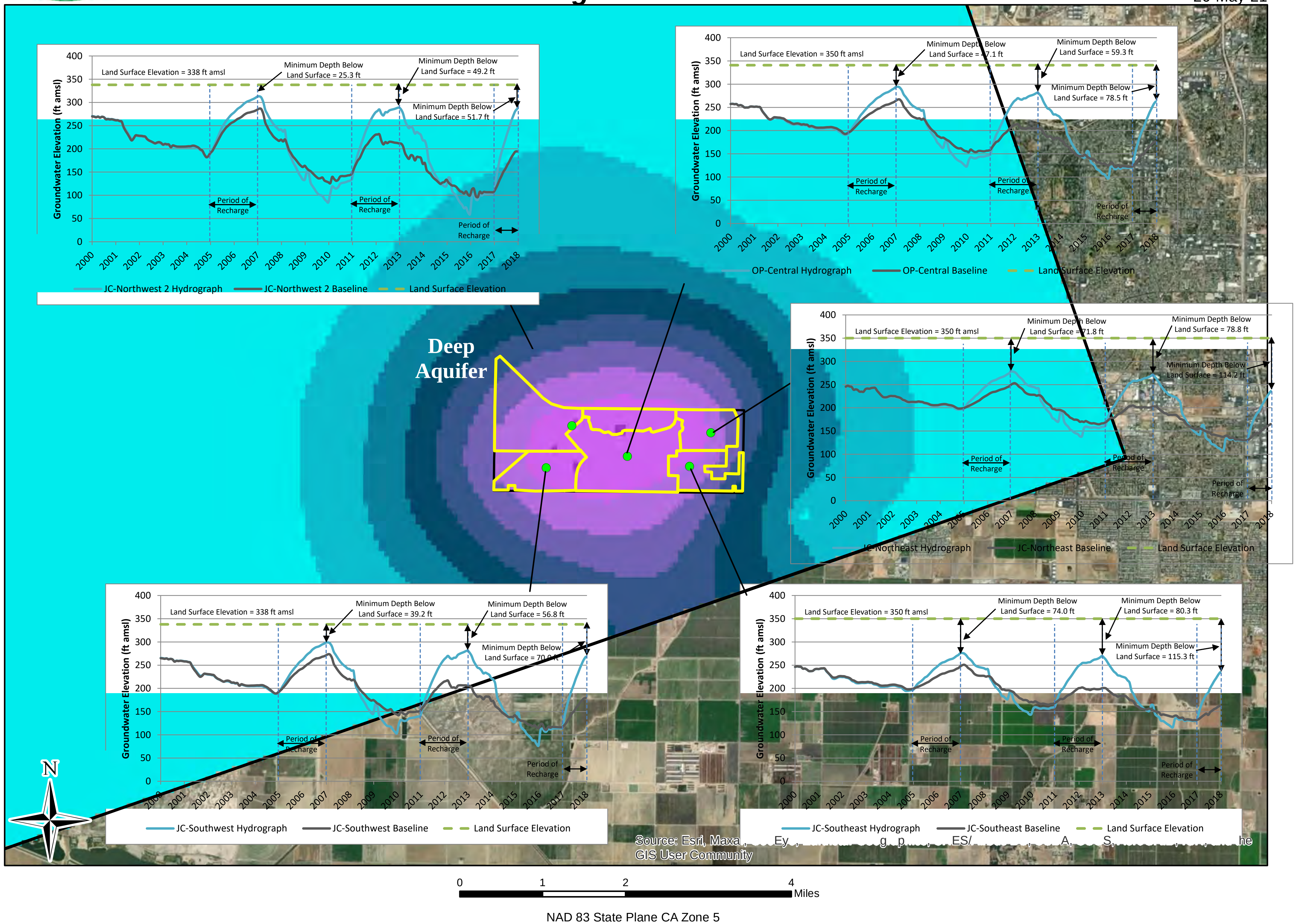
Intermediate Aquifer Maximum Model-Predicted Groundwater Recharge Mounding December 2012

Figure 4

Rosedale-Rio Bravo Water Storage District

26-May-21

James Canal Banking Project
2020 Analysis



Map Features

Maximum Groundwater Level Mounding (ft)

- > 100
- 90 to 100
- 80 to 90
- 70 to 80
- 60 to 70
- 50 to 60
- 40 to 50
- 30 to 40
- 20 to 30
- 10 to 20
- 0 to 10
- < 0
- Observation Point
- Recharge Zone
- Project Area
- Model Domain

Thomas Harder & Co.
Groundwater Consulting

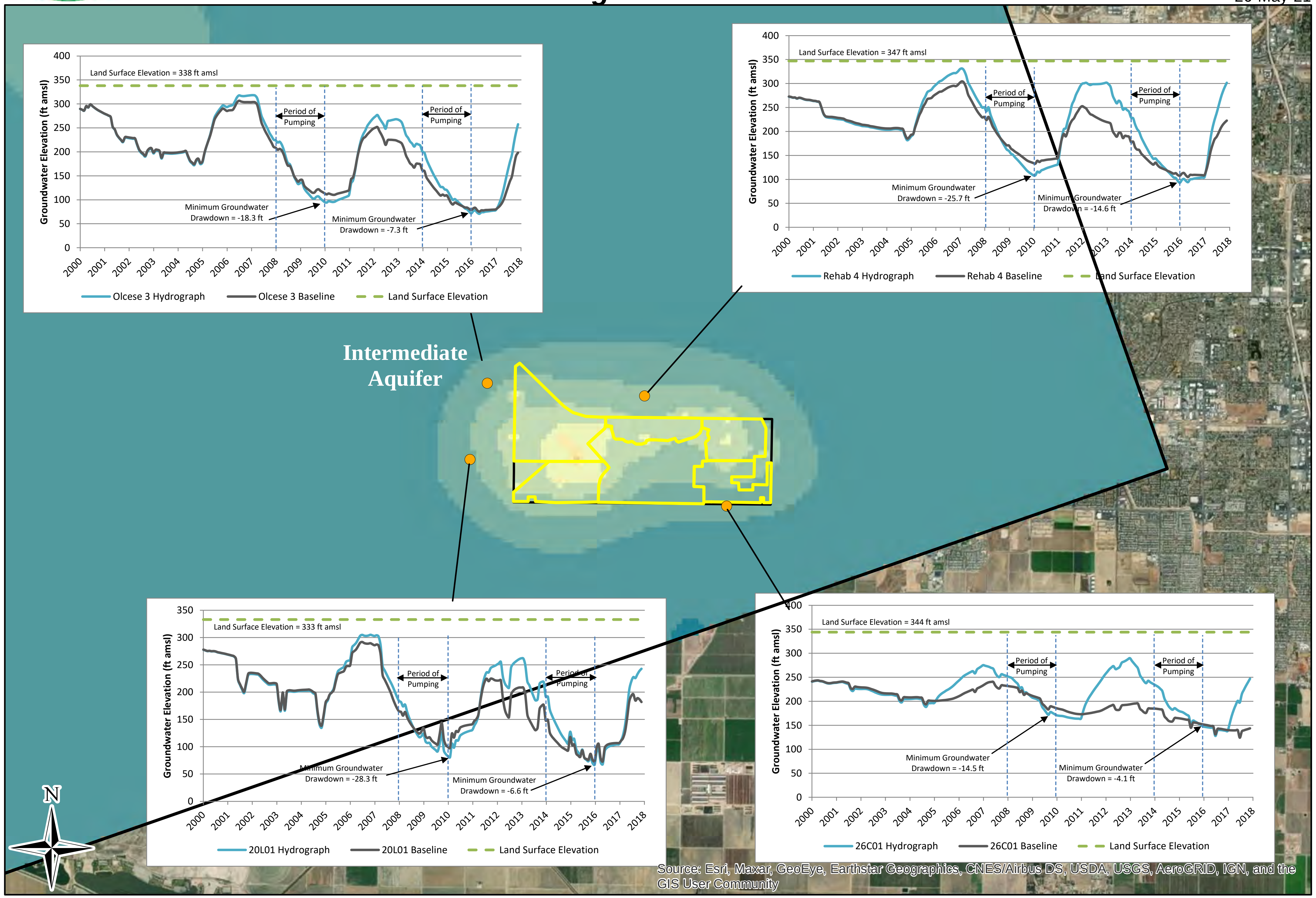
Deep Aquifer
Maximum Model-Predicted
Groundwater Recharge Mounding
December 2012

Figure 5

Rosedale-Rio Bravo Water Storage District

26-May-21

James Canal Banking Project
2020 Analysis



Map Features

Maximum Groundwater Level Drawdown (ft)

- 10 to 20
- 0 to 10
- 0 to -10
- -10 to -20
- -20 to -30
- -30 to -40
- -40 to -50
- -50 to -60
- -60 to -70
- -70 to -80
- -80 to -90
- -90 to -100
- Production Well
- Recharge Zone
- Project Area
- Model Domain

0 1 2 4 Miles

NAD 83 State Plane CA Zone 5

Thomas Harder & Co.
Groundwater Consulting

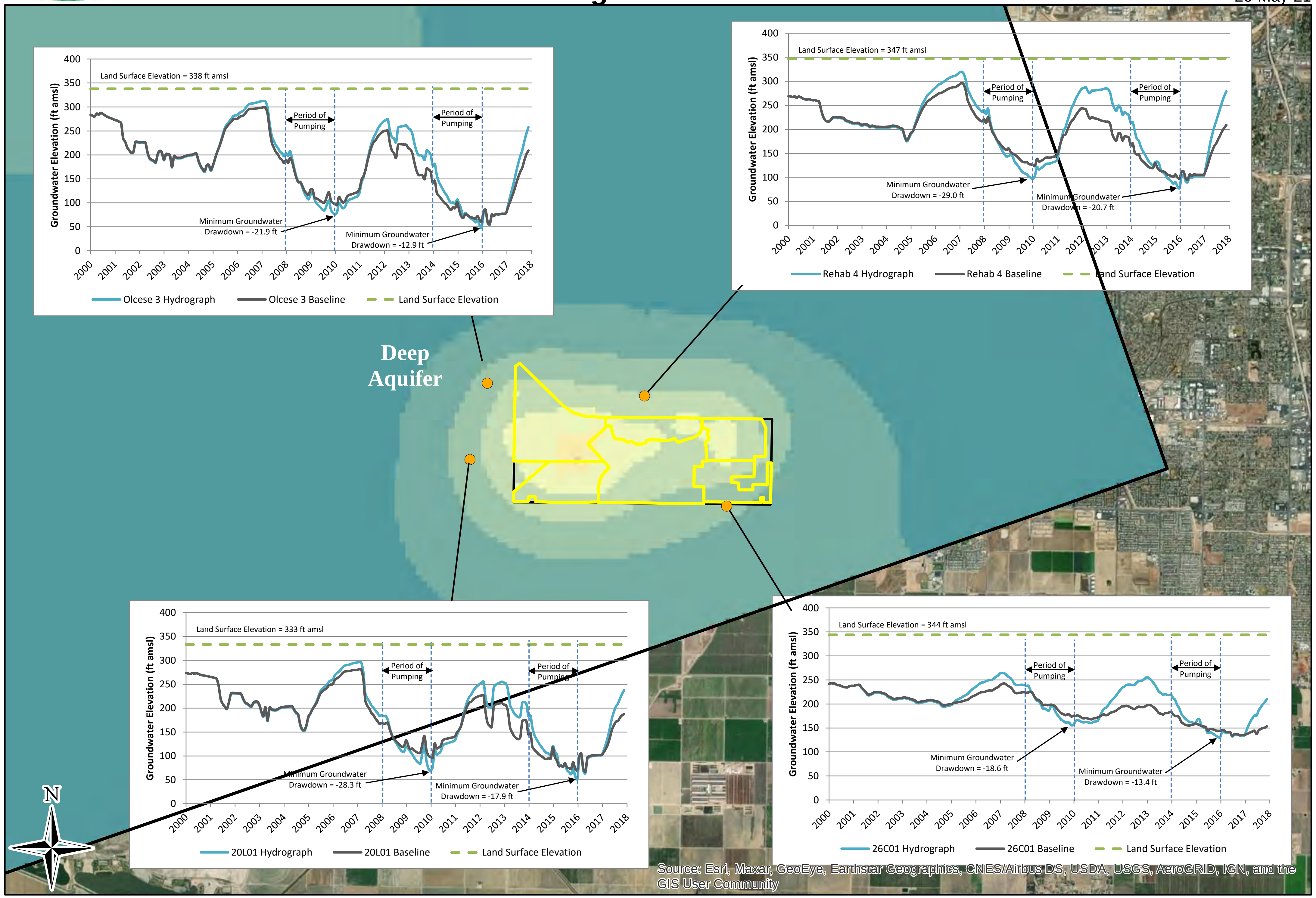
Intermediate Aquifer
Maximum Model-Predicted Groundwater Pumping Drawdown
December 2015

Figure 6

Rosedale-Rio Bravo Water Storage District

26-May-21

James Canal Banking Project
2020 Analysis



0 1 2 4 Miles

NAD 83 State Plane CA Zone 5

Map Features

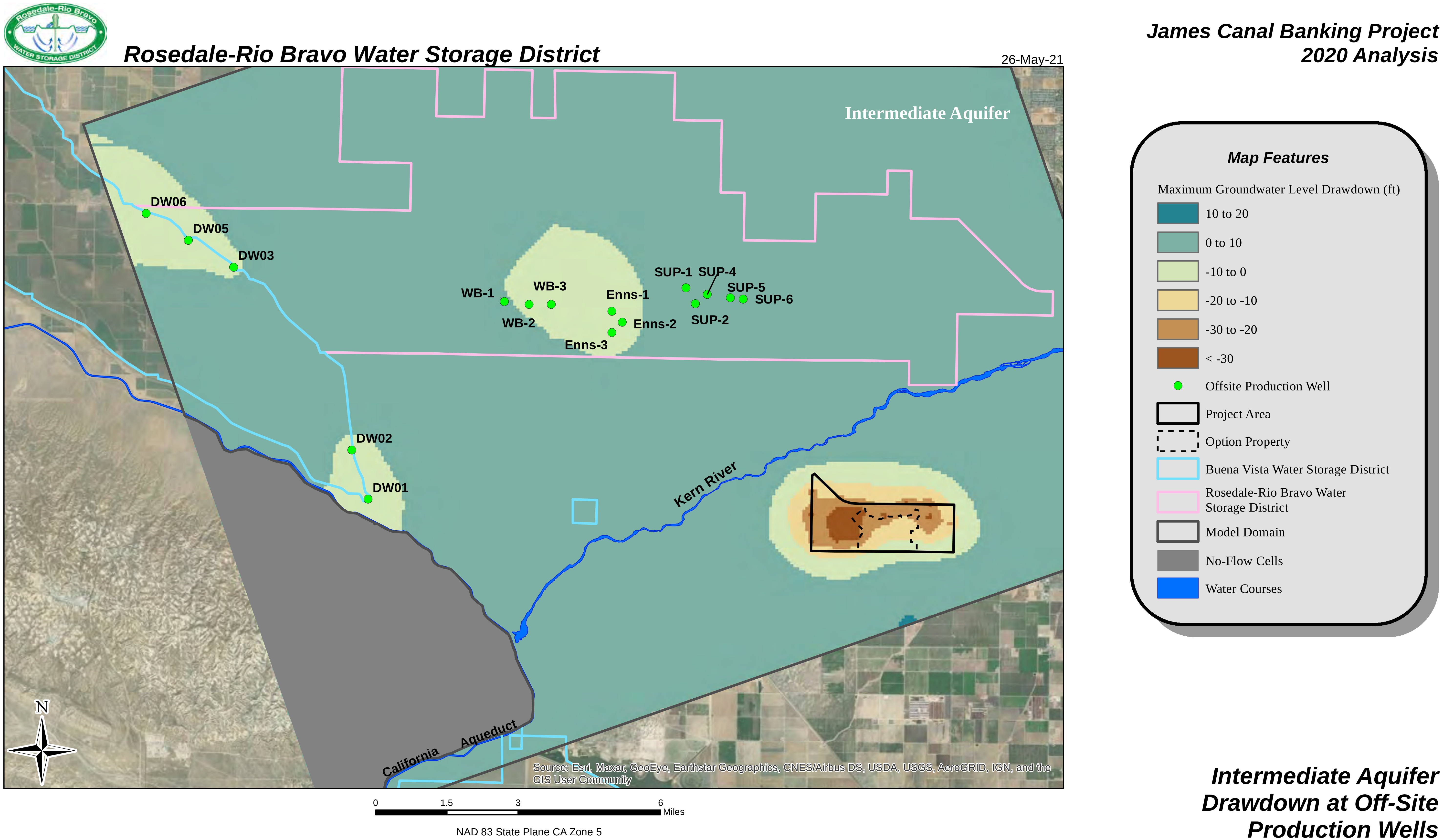
Maximum Groundwater Level Drawdown (ft)

- 10 to 20
- 0 to 10
- -10 to 0
- -20 to -10
- -30 to -20
- -40 to -30
- -50 to -40
- -60 to -50
- -70 to -60
- -80 to -70
- -90 to -80
- -100 to -90
- Production Well
- Recharge Zone
- Project Area
- Model Domain

Thomas Harder & Co.
Groundwater Consulting

Deep Aquifer
Maximum Model-Predicted
Groundwater Pumping Drawdown
December 2015

Figure 7



James Canal Banking Project
2020 Analysis

Intermediate Aquifer Drawdown at Off-Site Production Wells December 2015

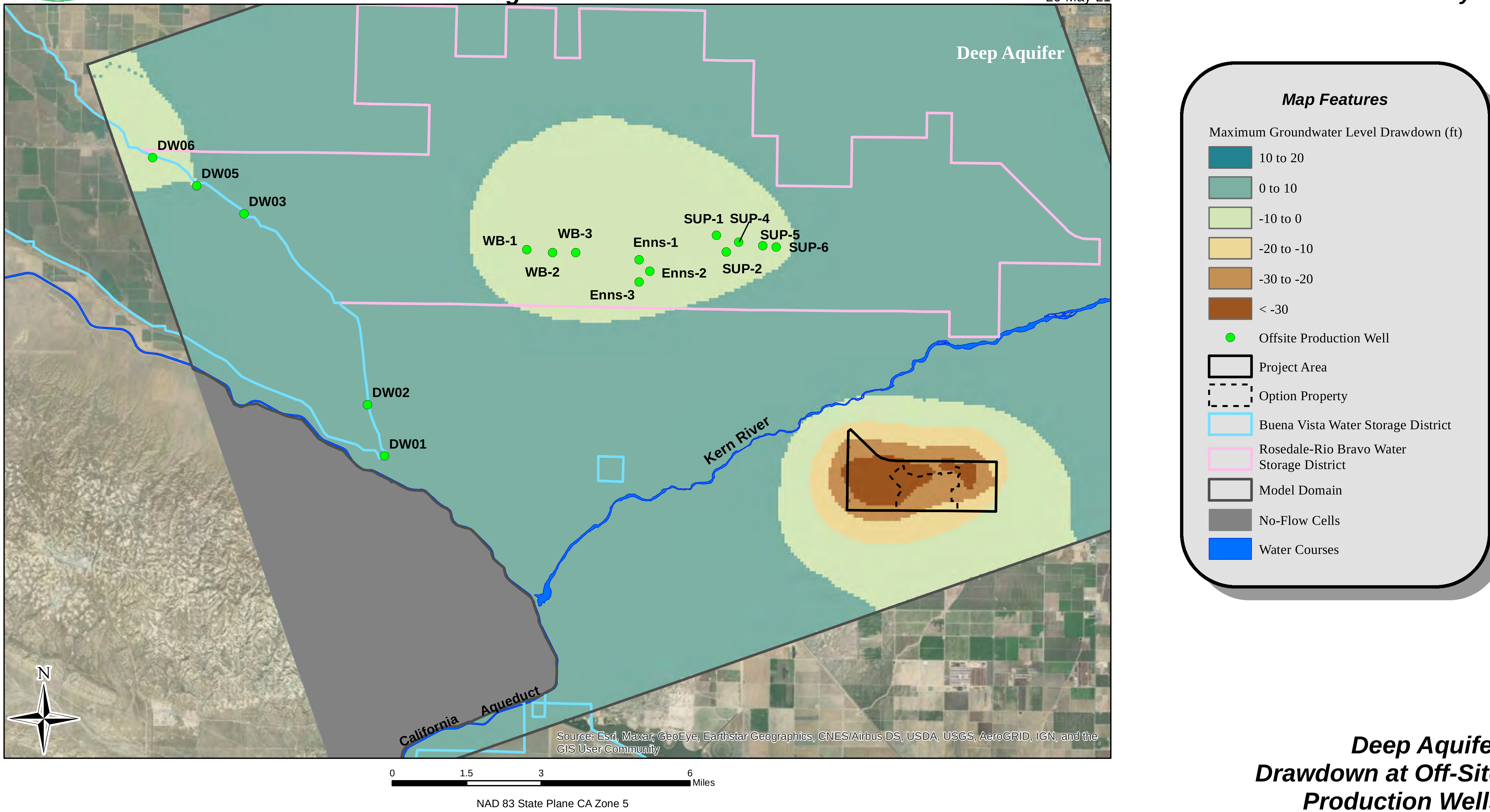
Figure 8

Thomas Harder & Co.
Groundwater Consulting

Rosedale-Rio Bravo Water Storage District

26-May-21

James Canal Banking Project
2020 Analysis



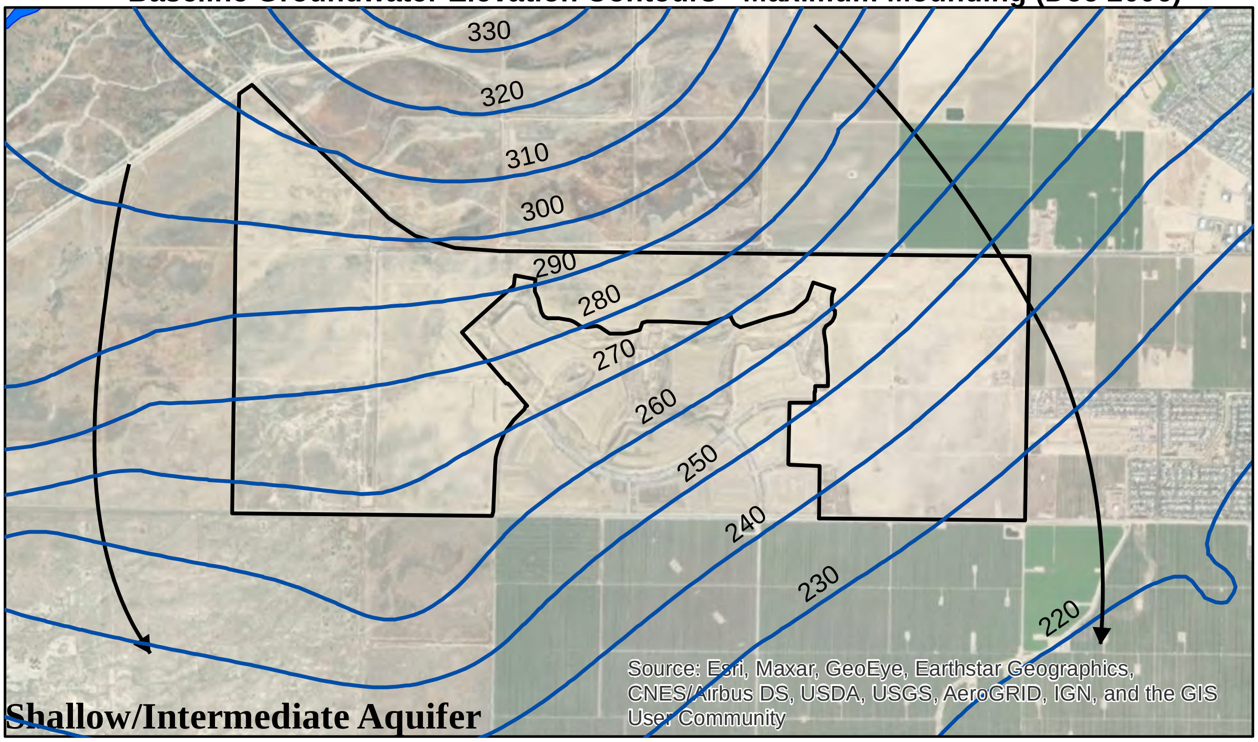
Thomas Harder & Co.
Groundwater Consulting

Deep Aquifer Drawdown at Off-Site Production Wells December 2015

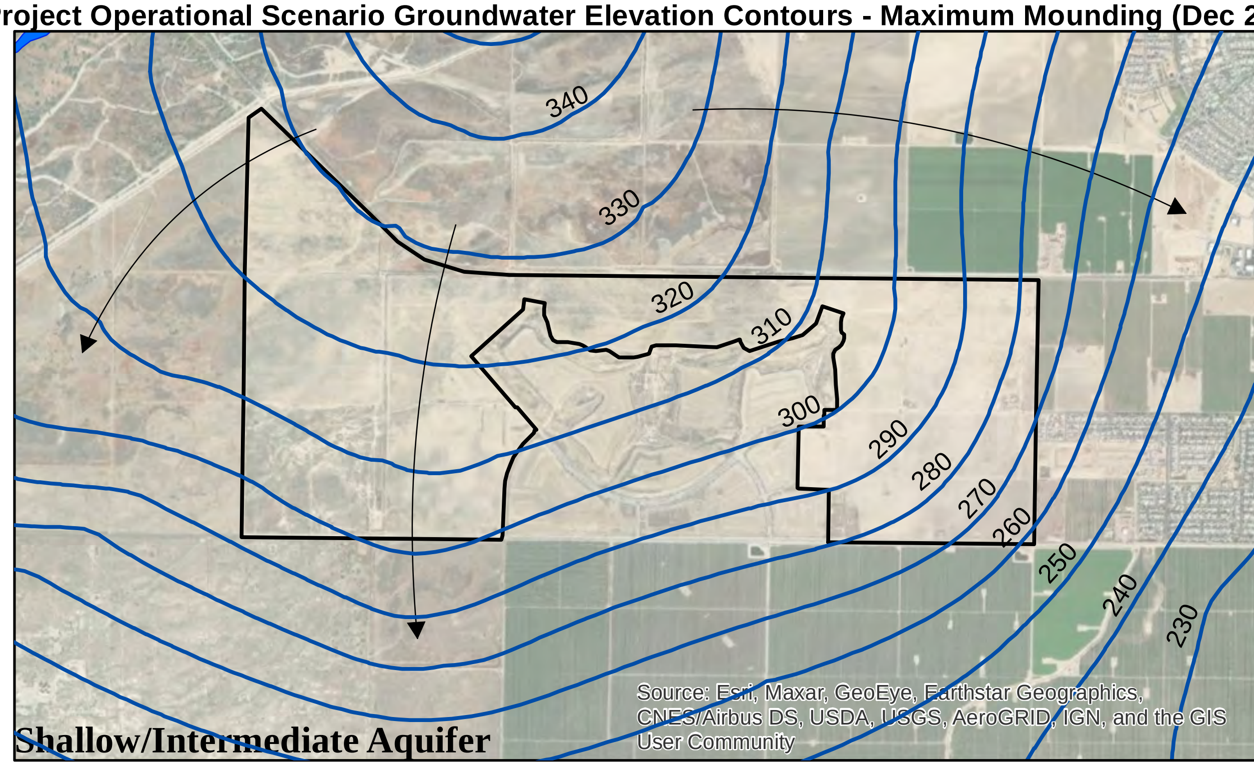
Figure 9

Rosedale-Rio Bravo Water Storage District 26-May-21

Baseline Groundwater Elevation Contours - Maximum Mounding (Dec 2006)



Project Operational Scenario Groundwater Elevation Contours - Maximum Mounding (Dec 2006)



Groundwater Flow Direction

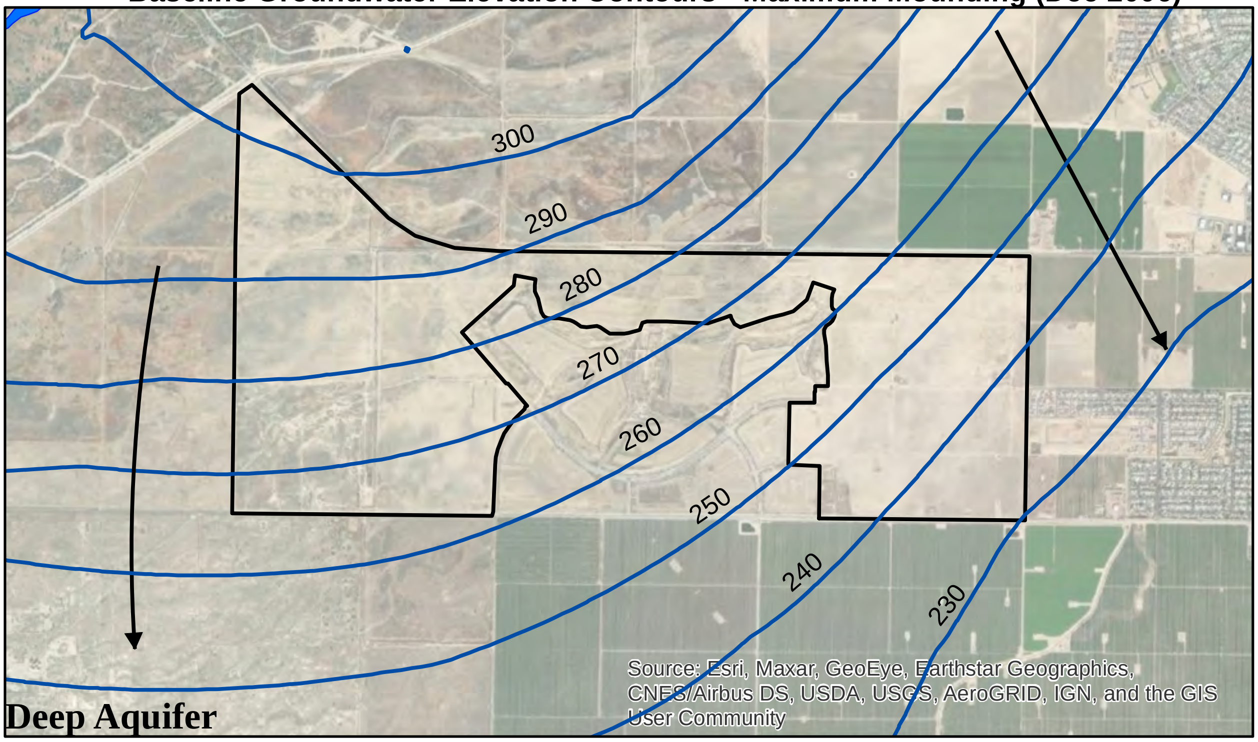
0 0.25 0.5 1 Mile

NAD 83 State Plane CA Zone 5
Groundwater contours in ft amsl

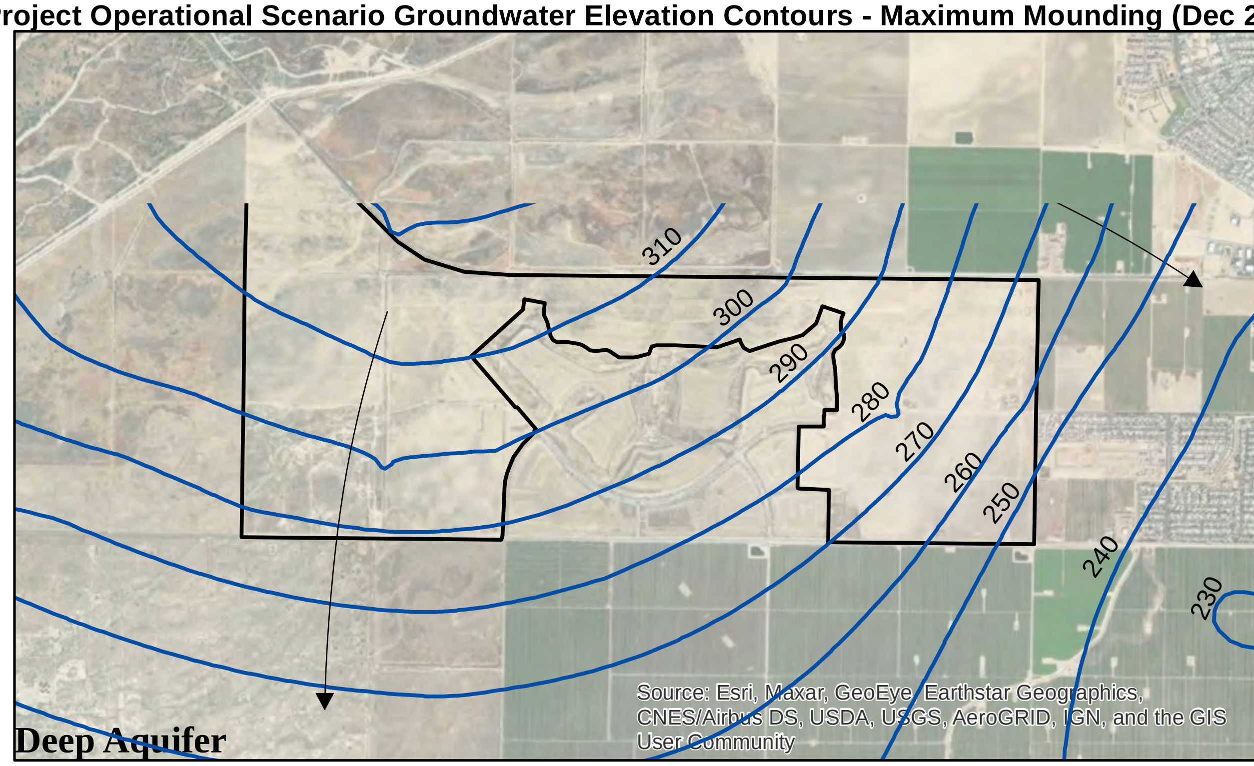
Thomas Harder & Co.
Groundwater Consulting

Figure 10

Baseline Groundwater Elevation Contours - Maximum Mounding (Dec 2006)



Project Operational Scenario Groundwater Elevation Contours - Maximum Mounding (Dec 2006)



Groundwater Flow Direction

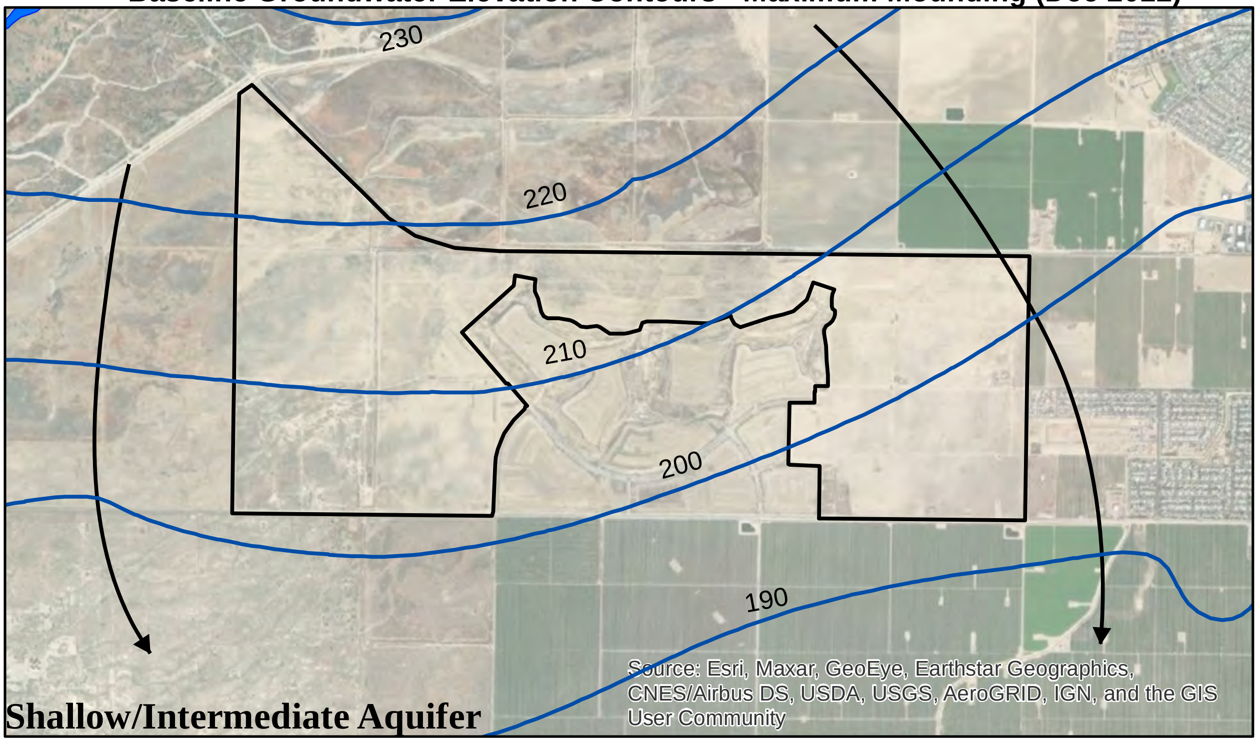
0 0.25 0.5 1 Mile

Thomas Harder & Co.
Groundwater Consulting

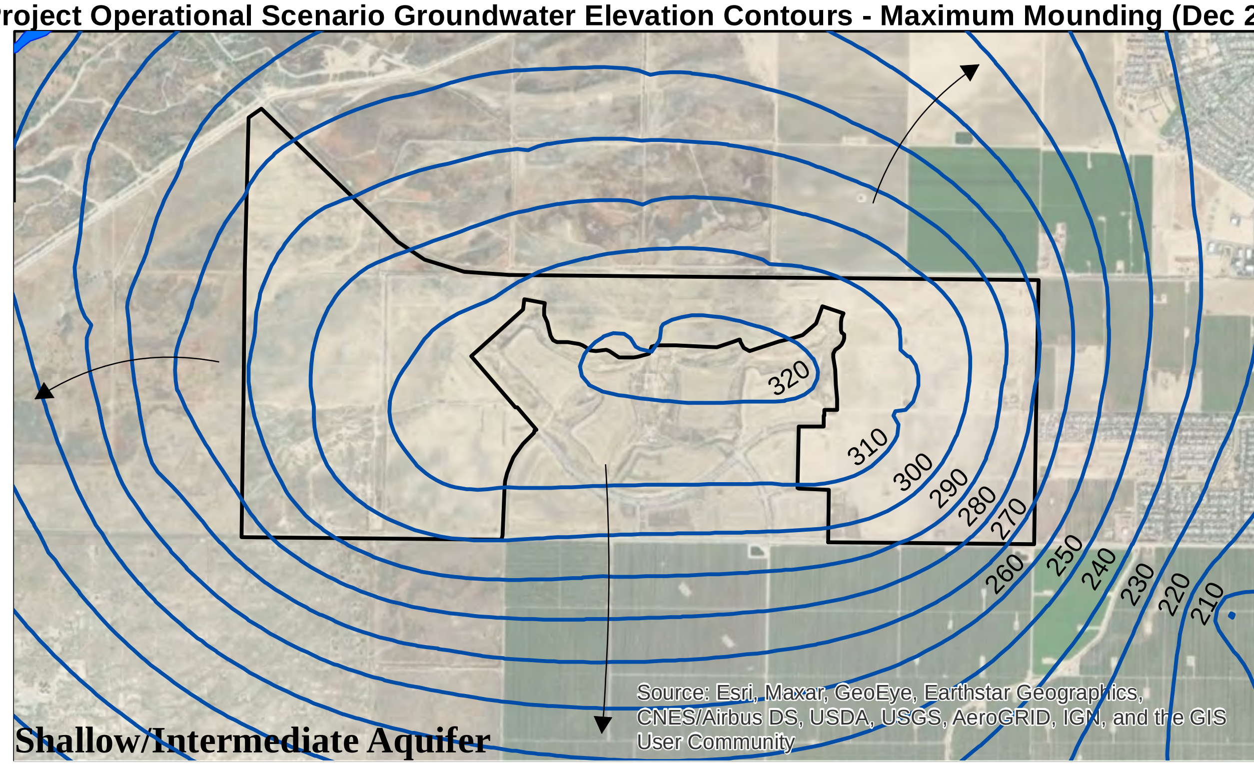
NAD 83 State Plane CA Zone 5
Groundwater contours in ft amsl

Figure 11

Baseline Groundwater Elevation Contours - Maximum Mounding (Dec 2012)



Project Operational Scenario Groundwater Elevation Contours - Maximum Mounding (Dec 2012)



Groundwater Flow Direction

0 0.25 0.5 1 Mile

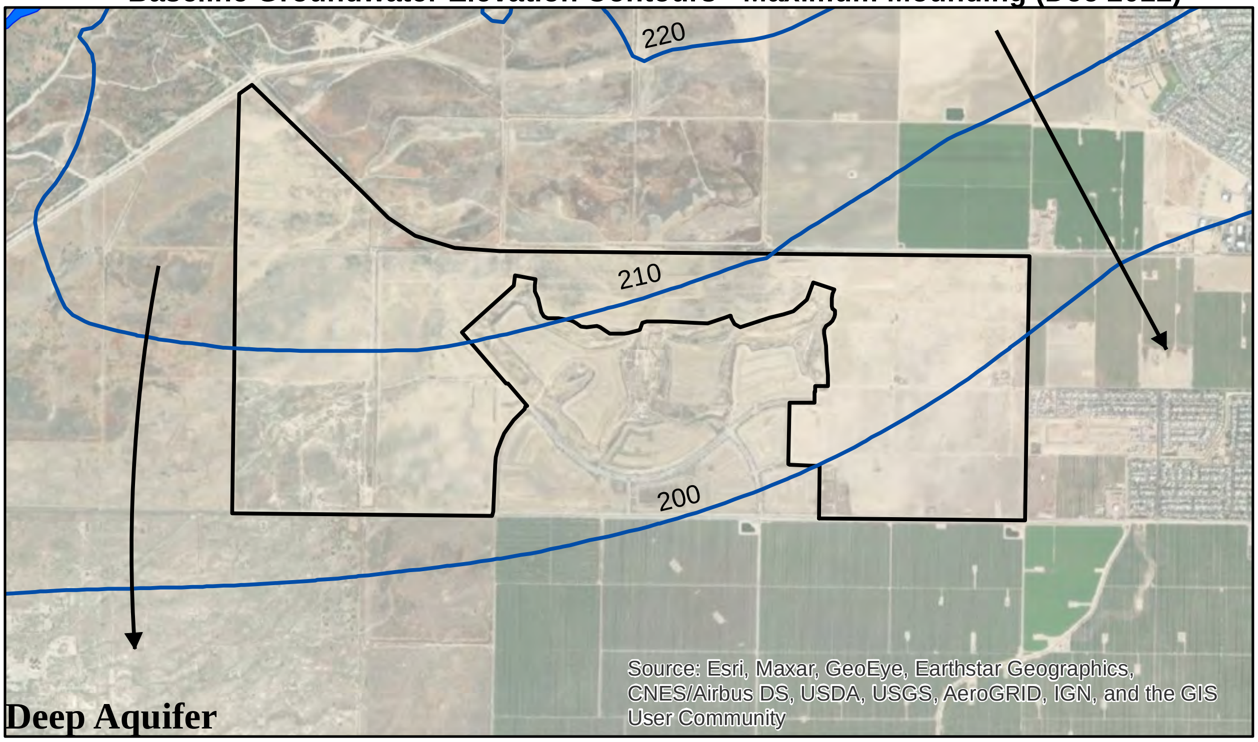
NAD 83 State Plane CA Zone 5
Groundwater contours in ft amsl

Thomas Harder & Co. Groundwater Consulting

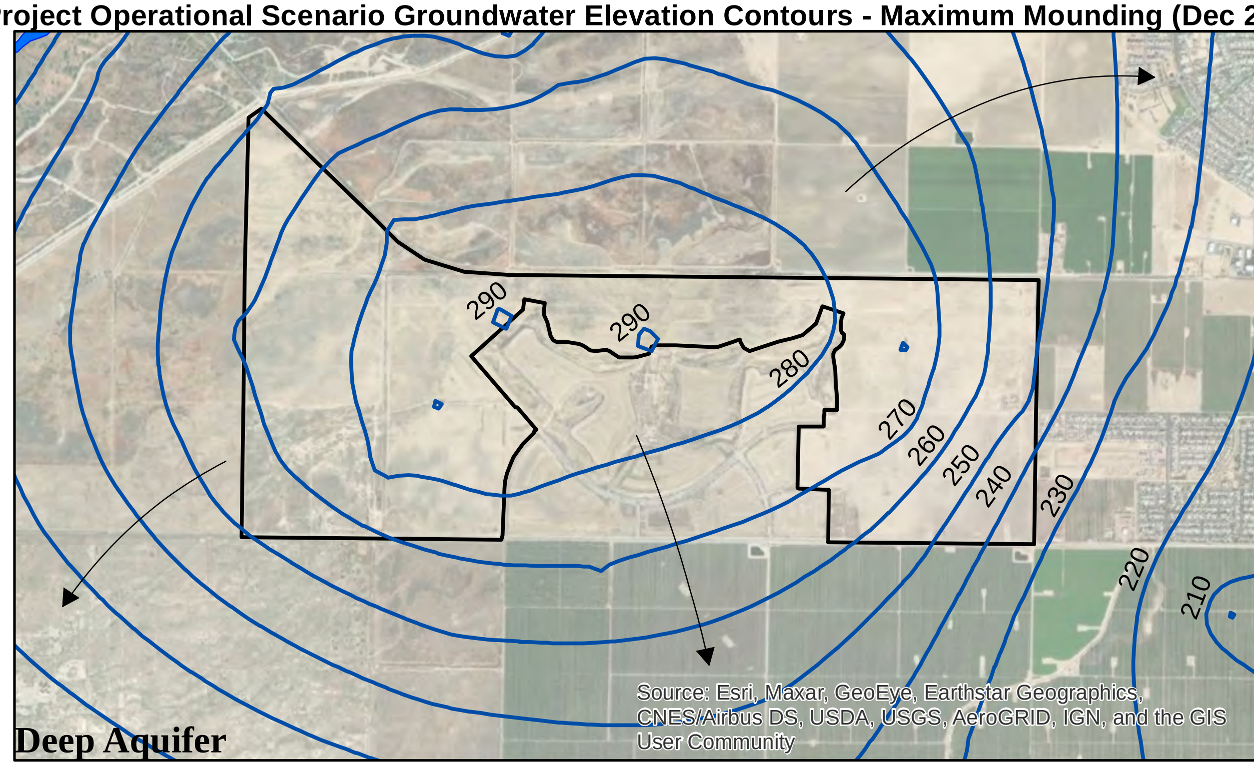
Figure 12

Rosedale-Rio Bravo Water Storage District 26-May-21

Baseline Groundwater Elevation Contours - Maximum Mounding (Dec 2012)



Project Operational Scenario Groundwater Elevation Contours - Maximum Mounding (Dec 2012)



Groundwater Flow Direction

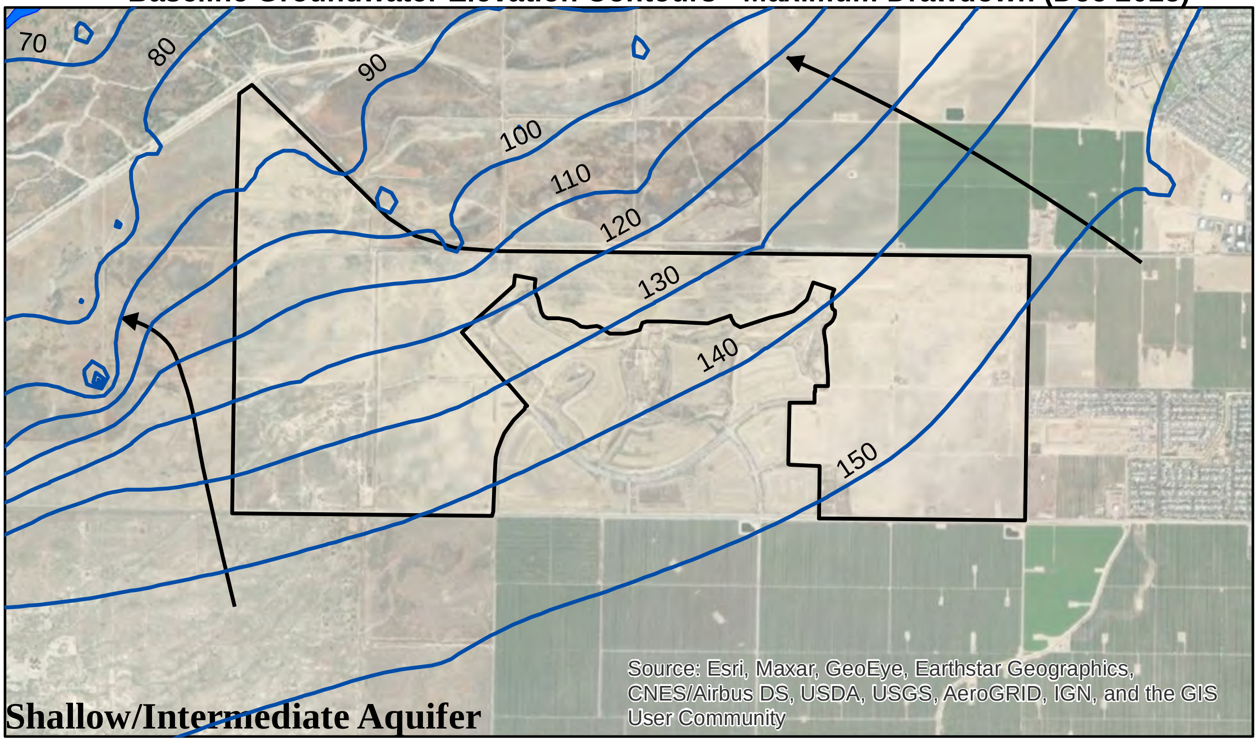
0 0.25 0.5 1 Mile

NAD 83 State Plane CA Zone 5
Groundwater contours in ft amsl

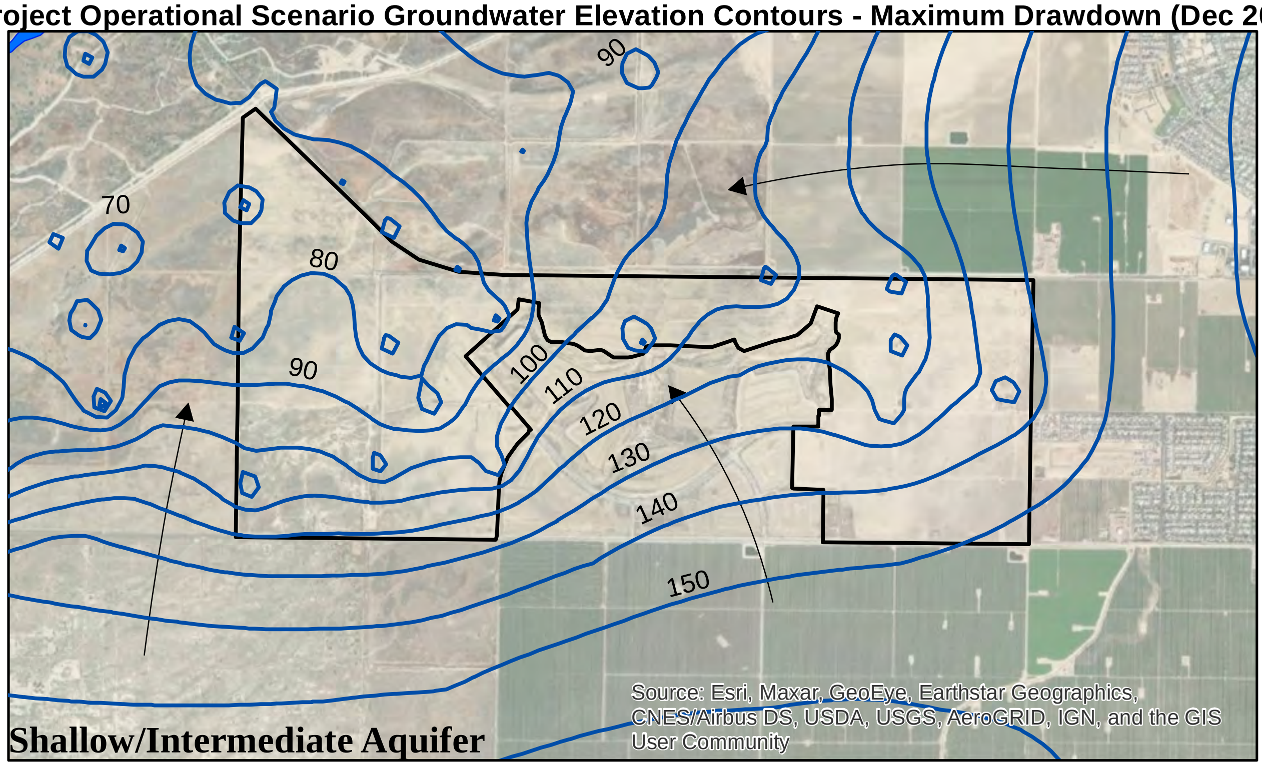
Thomas Harder & Co.
Groundwater Consulting

Figure 13

Baseline Groundwater Elevation Contours - Maximum Drawdown (Dec 2015)



Project Operational Scenario Groundwater Elevation Contours - Maximum Drawdown (Dec 2015)



Groundwater Flow Direction

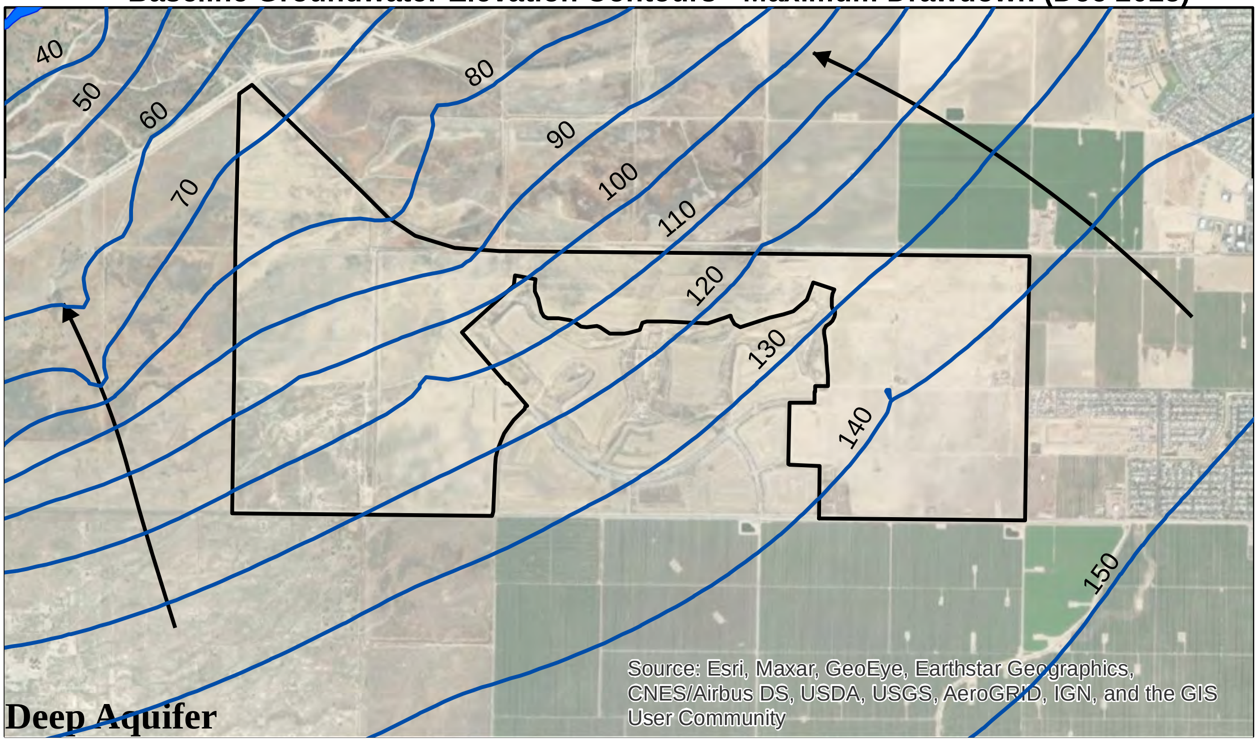
0 0.25 0.5 1 Mile

NAD 83 State Plane CA Zone 5
Groundwater contours in ft amsl

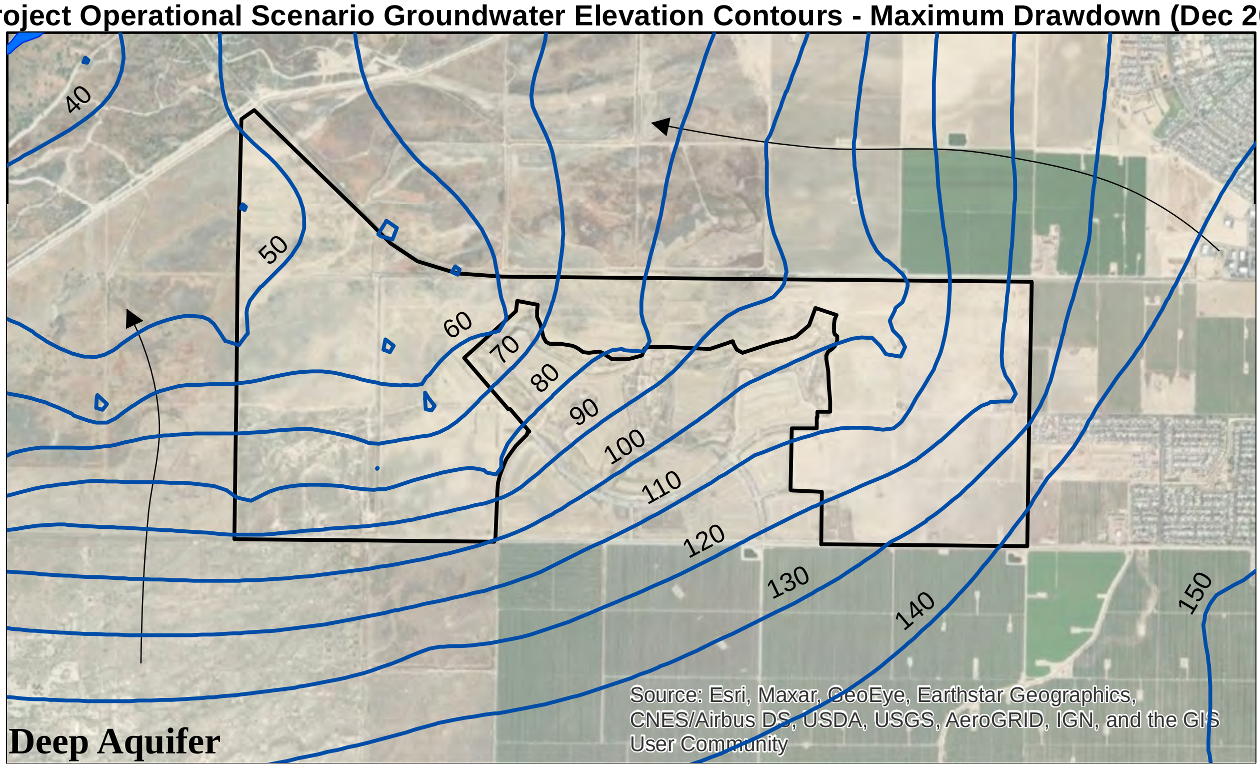
Thomas Harder & Co. Groundwater Consulting

Figure 14

Baseline Groundwater Elevation Contours - Maximum Drawdown (Dec 2015)



Project Operational Scenario Groundwater Elevation Contours - Maximum Drawdown (Dec 2015)



Groundwater Flow Direction

0 0.25 0.5 1 Mile

NAD 83 State Plane CA Zone 5
Groundwater contours in ft amsl

Thomas Harder & Co.
Groundwater Consulting

Figure 15