AGENDA
IRVINE RANCH WATER DISTRICT
SUPPLY RELIABILITY PROGRAMS COMMITTEE
WEDNESDAY, DECEMBER 6, 2023

This meeting will be held in-person at the District's headquarters located at 15600 Sand Canyon Avenue, Irvine, California. The meeting will be held in the second floor SC Committee room. 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=md6da991a88e2a998a9c4020c45bc92a6
Meeting Number (Access Code): 2494 256 9151
Meeting Password: mTWrmwpC734

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

PLEASE NOTE: Participants joining the meeting will be placed into the Webex lobby when (if) 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 11:30 a.m.

ATTENDANCE
Committee Chair: Doug Reinhart ______
Alternate Member: Peer Swan ______

ALSO PRESENT

Paul Cook	______	Paul Weghorst	______
Neveen Adly	______	Fiona Sanchez	______
Kent Morris	______	Kellie Welch	______
Natalie Palacio	______	Robert Huang	______
Marina Lindsay	______	______________	______
________________	______	______________	______

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 December 5, 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. WATER BANKING PROJECT FACILITIES, CAPACITIES, OPERATIONS AND PROGRAMS – PALACIO / WELCH / SANCHEZ / WEGHORST

   Recommendation: Receive and file.

6. ELECTROMAGNETIC SURVEY RESULTS FOR KERN FAN AREA – LINDSAY / WELCH / SANCHEZ / WEGHORST

   Recommendation: Receive and file.

ACTION

7. DRAFT TERMS FOR SHORT-TERM EXCHANGE PROGRAM WITH SILVERTIP – LINDSAY / WELCH / SANCHEZ / WEGHORST

   Recommendation: That the Board authorize the General Manager to execute a Short-Term Exchange Program Agreement with Silvertip based on the draft terms presented, subject to substantive changes approved by the Supply Reliability Programs Committee and special legal counsel.

OTHER BUSINESS

8. Receive Oral Updates from District's liaison to Dudley Ridge Water District and provide information on relevant activities.

9. Directors' Comments

10. Adjourn

December 6, 2023
Prepared by: N. Palacio / 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 provide an update on IRWD's actual and forecasted monthly recharge operations for 2023.

BACKGROUND:

Staff has prepared reference materials in tabular, map, and schematic formats to describe IRWD's water banking facilities, capacities, operations, storage, and exchange programs. These 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 as well as monthly recharge operations for calendar year 2023 at the IRWD Water Bank.

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 and in storage at the water banking projects, and Exhibit "C" provides after-loss estimates of water recharged and in storage at the projects.

The California Department of Water Resources (DWR) template agreements authorizing delivery of Central Coast Water Authority (CCWA) and Antelope Valley-East Kern Agency (AVEK) water to the IRWD Water Bank were approved at the end of September. The Kern County Water Agency (KCWA) approved IRWD's request to backdate deliveries from CCWA and AVEK to the beginning of September. Changes shown in red on Exhibits "B" and "C" depict deliveries of water from AVEK beginning in September and adjustments to deliveries from Dudley Ridge Water District. Since October, all IRWD recharge capacity has been dedicated to deliveries of AVEK water. Unpurchased reserve (migration) water from the 2020 delivery of Dudley Ridge Water District Table A water has been credited back to IRWD's account and is shown in red on Exhibits "B" and "C". The values reported in Exhibits "B" and "C" include deliveries that were made to the temporary recharge facilities on the West Enos property. Deliveries to the Kern Water Bank have yet to be reported and will be available in early 2024.

Summary of Programs:

A table summarizing IRWD's water purchase and exchange programs is presented as Exhibit "D". This table lists each purchase and exchange program 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 the table shows 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 Water District'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."

Exhibit "E" graphically depicts how storage of State Water Project (SWP) and non-SWP water has changed annually in the Strand and Stockdale Integrated Banking Projects. Exhibit "E" also depicts the balance of water owed to IRWD by Dudley Ridge. 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 depicting project wells, 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, Dudley Ridge, Metropolitan, and AVEK. These diagrams are provided as Exhibits "J", "K", "L", "M", "N", "O", and "P" 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 through year 2021 is provided as Exhibit "Q". 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.

Exhibit "Q" will be updated to reflect 2023 operations once all invoices have been received from Rosedale-Rio Bravo Water District for the recharge of the various supplies.

IRWD's Coordinated Agreement with Metropolitan:

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

2023 Actual and Forecasted Water Recharge Activities:

Exhibit "S" depicts actual and forecasted recharge operations for 2023. IRWD's annual contractual recharge limit of 17,500 AF on the Strand Ranch was reached in June. IRWD deliveries continue to the Stockdale West at a rate of 25 cfs, or approximately 50 AF per day. Water deliveries to the temporary recharge facilities on the West Enos property have stopped due to capacity limitations in the Cross Valley Canal (CVC) and other constraints. The GBJPA will be pursuing construction of the permanent basins, inter-basin structures and highway crossing associated with the West Enos property. An estimated 3,894 AF was recharged in 2023 for the benefit of IRWD on the West Enos property. Staff estimates that, through the end of the year, a total of 40,545 AF will have been delivered for recharge at the Strand, Stockdale, and West Enos facilities with 24,951 AF being available for use in IRWD's service area.

Operations Through Remainder of Year:

Beginning November 16, the CVC reached its maximum conveyance capacity limit, restricting IRWD's use to 4 cfs. The 4 cfs corresponds to IRWD's capacity ownership through Rosedale. As a result of this restriction, staff began using Homer LLC's CVC capacity under the Amended 2023 Pilot Water Management Program. IRWD is currently using up to 23 cfs of Homer's CVC capacity to continue AVEK deliveries to the Stockdale West recharge basins.

Water Supply Conditions:

Deliveries to IRWD's Water Bank in 2023 reflect the wet-year conditions in the State of California. At the Committee meeting, staff will present an update on water supply conditions including the Colorado River, SWP, Central Valley Project, and Kern River systems.

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 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" – Diagram of Long-term Water Exchange Program with Antelope Valley-East Kern
Exhibit "Q" – Cost of Water Tables
Exhibit "R" – Summary of IRWD's Coordinated Operating, Water Storage, Exchange and Delivery Agreement with Metropolitan and MWDOC
Exhibit "S" – Actual and Forecasted 2023 Recharge Operations

Exhibit "A"

TABLE 1

Current and Anticipated Water Banking Projects

Recharge, Storage and Recovery Capacities

December 6, 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.

Note: This page is intentionally left blank.

Exhibit "B"

TABLE 2

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

December 6, 2023

TRANSACTIONS	WATER BANKING ENTITY: IRWD		BUENA VISTA (BVWSD)	CENTRAL COAST (CCWA)	ANTELOPE VALLEY-EAST KERN (AVEK)	DUDLEY RIDGE WATER DISTRICT (DRWD)[3]	TOTAL BY WATER TYPE AND STORAGE LOCATION
	SWP[1]	NON-SWP[2]	NON-SWP	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
Recovery 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] Est.	-	(235)	-	-	-	-	(235)
2023 SWP Allocation (100%)[3]	875	-	-	-	-	874	1,749
2020 Reserve Water	13	-	-	-	-	-	13
BV Long Term Program Kern River Water Est.	-	8,750	8,750	-	-	-	17,500
BV 2023 Recharge Kern River Water Est.		2,250	2,250	-	-	-	4,500
CCWA 2023 Short Term Exchange Est.	225	-		225	-	-	450
AVEK Long Term Exchange Est.	2,998		-	-	2,998	-	5,996
DRWD 1-for-1 Long Term Exchange (Recharge) Est.	9,358	-	-	-	-	-	9,358
TOTAL ESTIMATED 2023 TRANSACTIONS	13,469	10,765	11,000	225	2,998	874	39,331
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	14,852	20,641	11,225	225	2,998	874	50,815
Total DRWD 1-for-1 Long Term Exchange Credit	7,142	-	-	-	-	-	7,142
TOTAL ESTIMATED STORED WATER TO DATE	34,027	24,170	11,225	225	2,998	917	73,562

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.

Note: This page is intentionally left blank.

Exhibit "C"

TABLE 3

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

December 6, 2023

TRANSACTIONS	**WATER BANKING ENTITY**						**TOTAL BY WATER TYPE AND STORAGE LOCATION**
	IRWD		BUENA VISTA (BVWSD)	CENTRAL COAST (CCWA)	ANTELOPE VALLEY-EAST KERN (AVEK)	DUDLEY RIDGE WATER DISTRICT (DRWD)[3]	
	SWP[1]	NON-SWP[2]	NON-SWP	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		-	-	-	-	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] Est.	-	(235)	-	-	-	-	(235)
2023 SWP Allocation (100%)[3]	750	-	-	-	-	749	1,499
2020 Reserve Water	12	-	-	-	-	-	12
BV Long Term Program Kern River Water Est.	-	7,501	7,896	-	-	-	15,397
BV 2023 Recharge Kern River Water Est.	-	1,929	2,030	-	-	-	3,959
CCWA 2023 Short Term Exchange Est.	193	-	-	193	-	-	386
AVEK Long Term Exchange Est.	2,570	-	-	-	2,570	-	5,140
DRWD 1-for-1 Long Term Exchange (Recharge) Est.	8,022	-	-	-	-	-	8,022
TOTAL ESTIMATED 2023 TRANSACTIONS	11,547	9,195	9,926	193	2,570	749	34,180
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	11,891	15,135	10,151	193	2,570	749	40,689
Total DRWD 1-for-1 Long Term Exchange Credit	6,978	-	-	-	-	-	6,978
TOTAL ESTIMATED STORED WATER TO DATE	30,902	18,664	10,151	193	2,570	792	63,272

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 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.

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

Note: This page is intentionally left blank.

Exhibit "D"

TABLE 4

Status of IRWD Purchase and Exchange Programs (AFTER LOSSES)

December 6, 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) Strand and Stockdale	STORED IN KERN (AF) Kern Fan (W.Enos)	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	29,369	8,121	27,900		10,803	0		10,803		10,803		
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	1,803	792	1,887	1,055	831			1,887	1,887		792	Yes
Central Coast Water Authority (SWPAO #17001)	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	NA	NA	8,022		7,796	226		8,022	15,000			No
				Credit	NA	NA	6,978				6,978	6,978				No
Central Coast Water Authority (SWPAO #19031)	2-for-1	2019	Short-Term	SWP Table A	298		323	298	25			323	323			No
Buena Vista Water Storage District [1]	2-for-1	2023	Short-Term	Kern River	2,030	2,030	1,929		1,268	661		1,929		1,929		Yes
Central Coast Water Authority (SWPAO #23012)	2-for-1	2023	Short-Term	SWP Table A	193	193	193		193			193	193			No
Antelope Valley East Kern Water Agency	2-for-1	2018	Long-Term	SWP Table A	2,570	2,570	2,570		1,675	895		2,570	2,570			No
				Total:	47,189	13,706	67,477	12,033	25,244	1,782	6,978	46,038	30,652	15,385	792	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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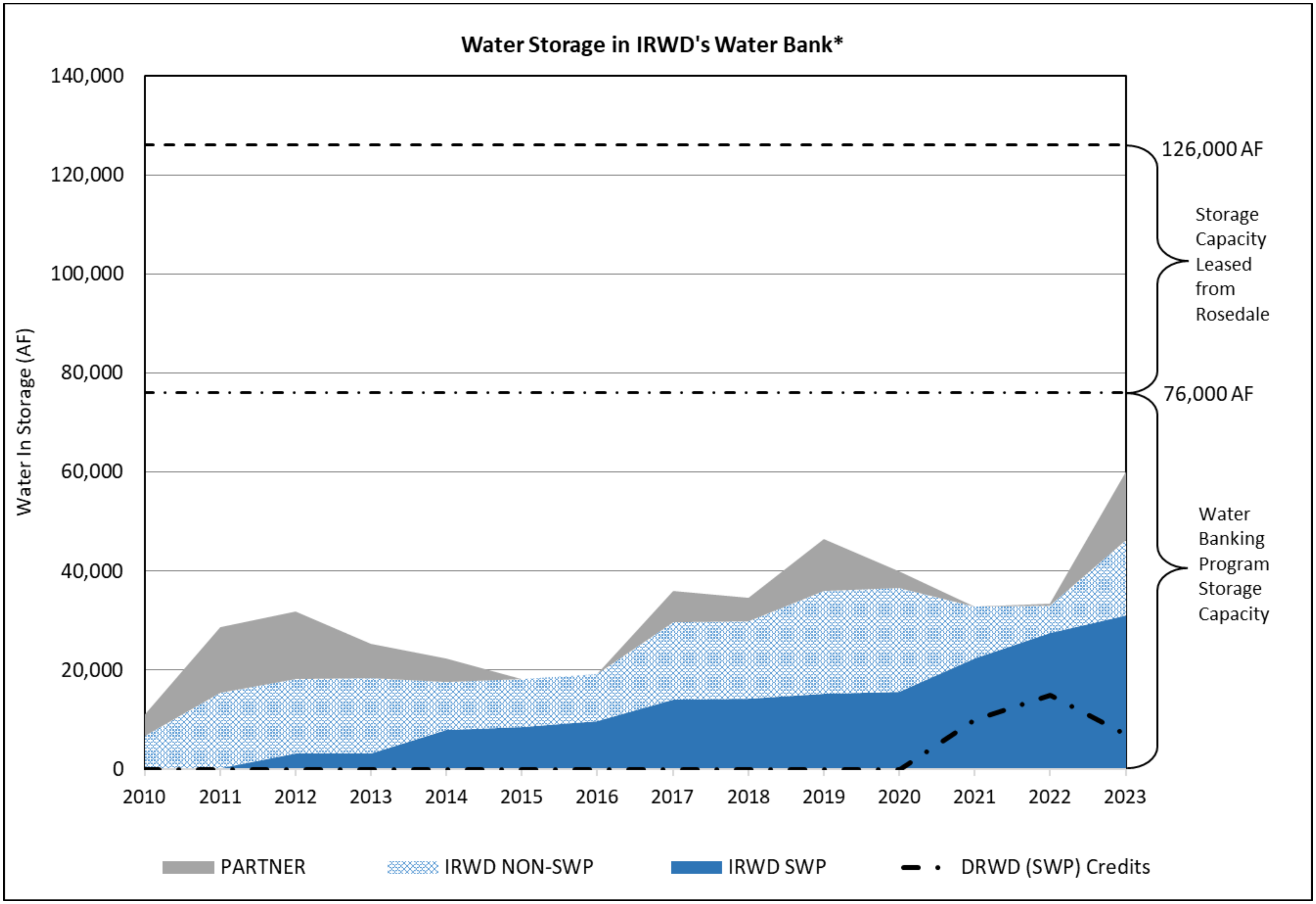
Exhibit "E"



*After losses

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Exhibit "F"

TABLE 5

IRWD Dedicated Water Banking Capacities for Existing and Proposed Exchange Programs

December 6, 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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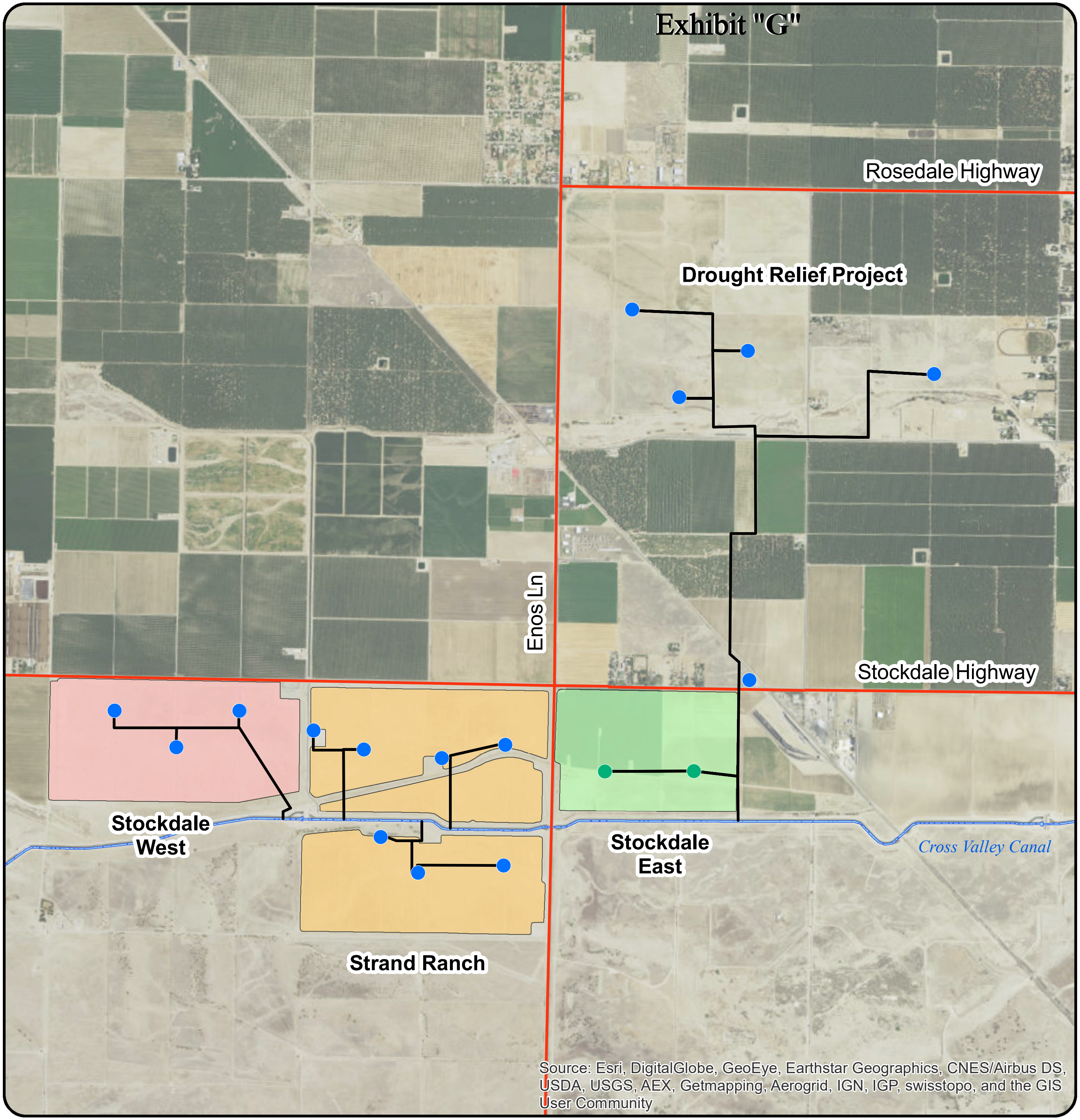

Irvine Ranch
WATER DISTRICT

Location Map:
IRWD Water Banking Projects
Wells and Turnin Pipelines

MAP FEATURES

- Extraction Well (blue)
- Extraction Well (green)
- Well Discharge Pipelines
- Stockdale East
- Stockdale West
- Strand Ranch

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

0 0.25 0.5 1 Miles

N

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

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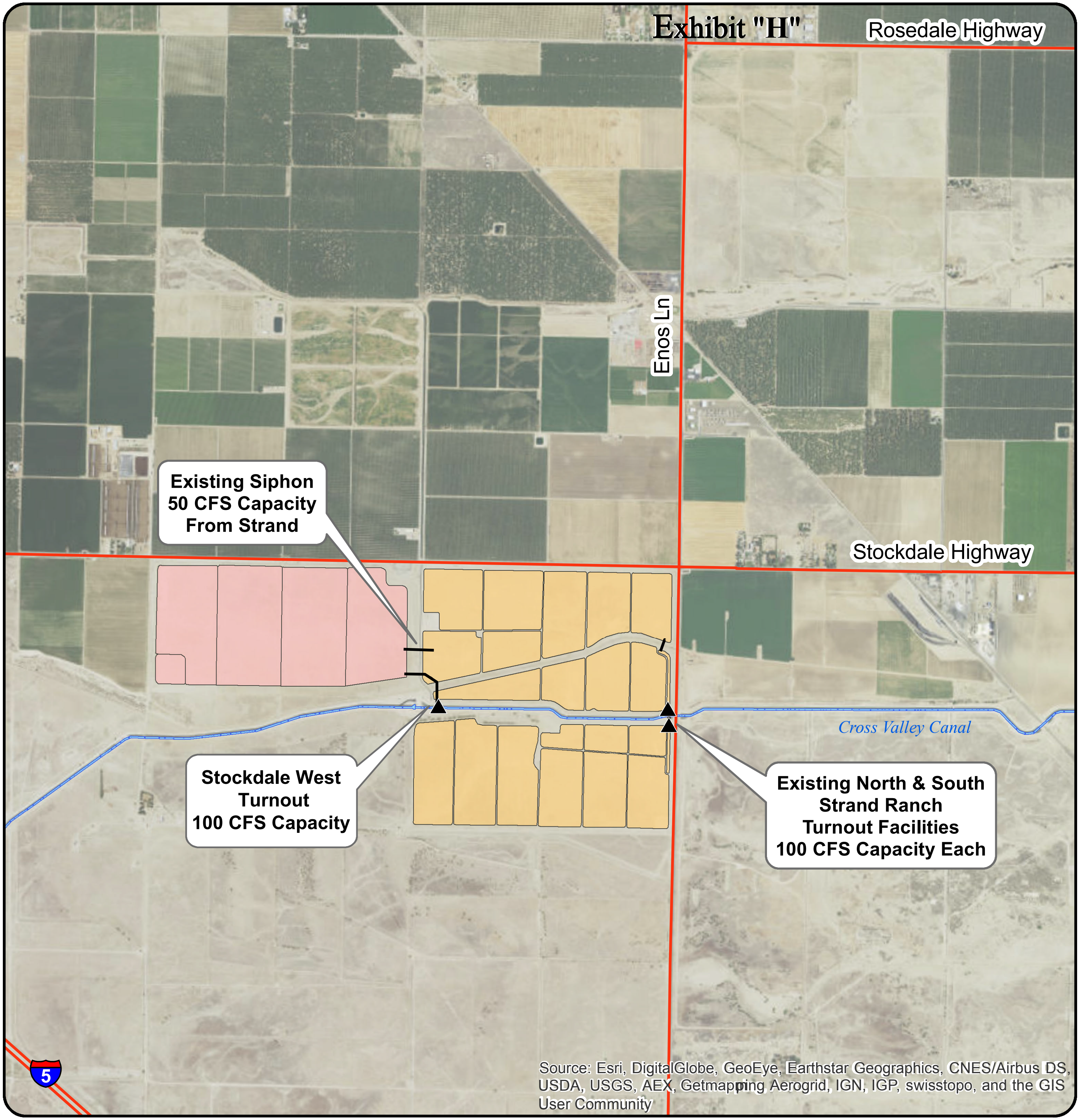

Irvine Ranch
WATER DISTRICT

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

MAP FEATURES

- ▲ Turnouts
- Stockdale West
- Strand Ranch

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

N

0 0.25 0.5 1
Miles

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

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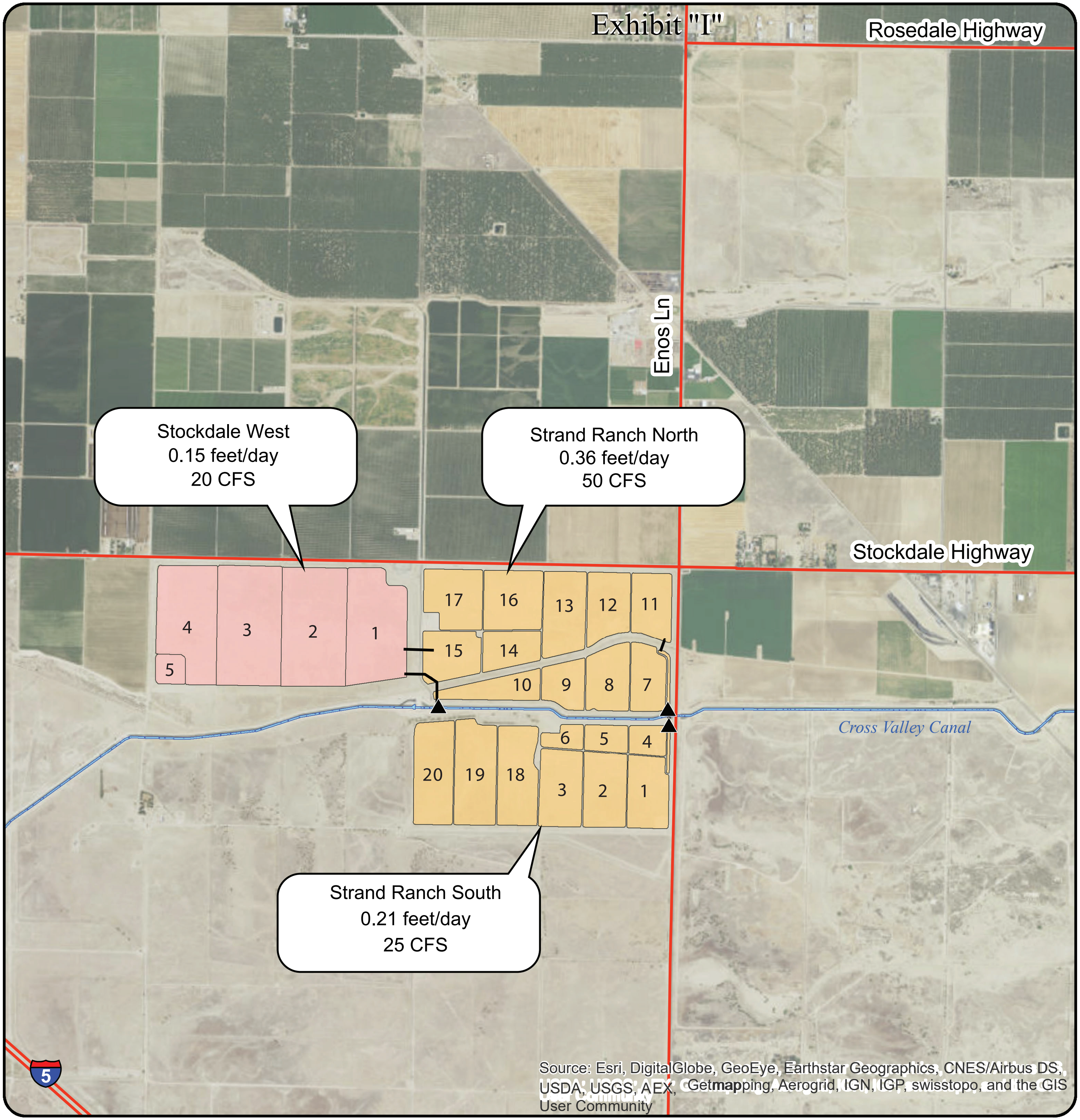

Irvine Ranch
WATER DISTRICT

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 August 22, 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"

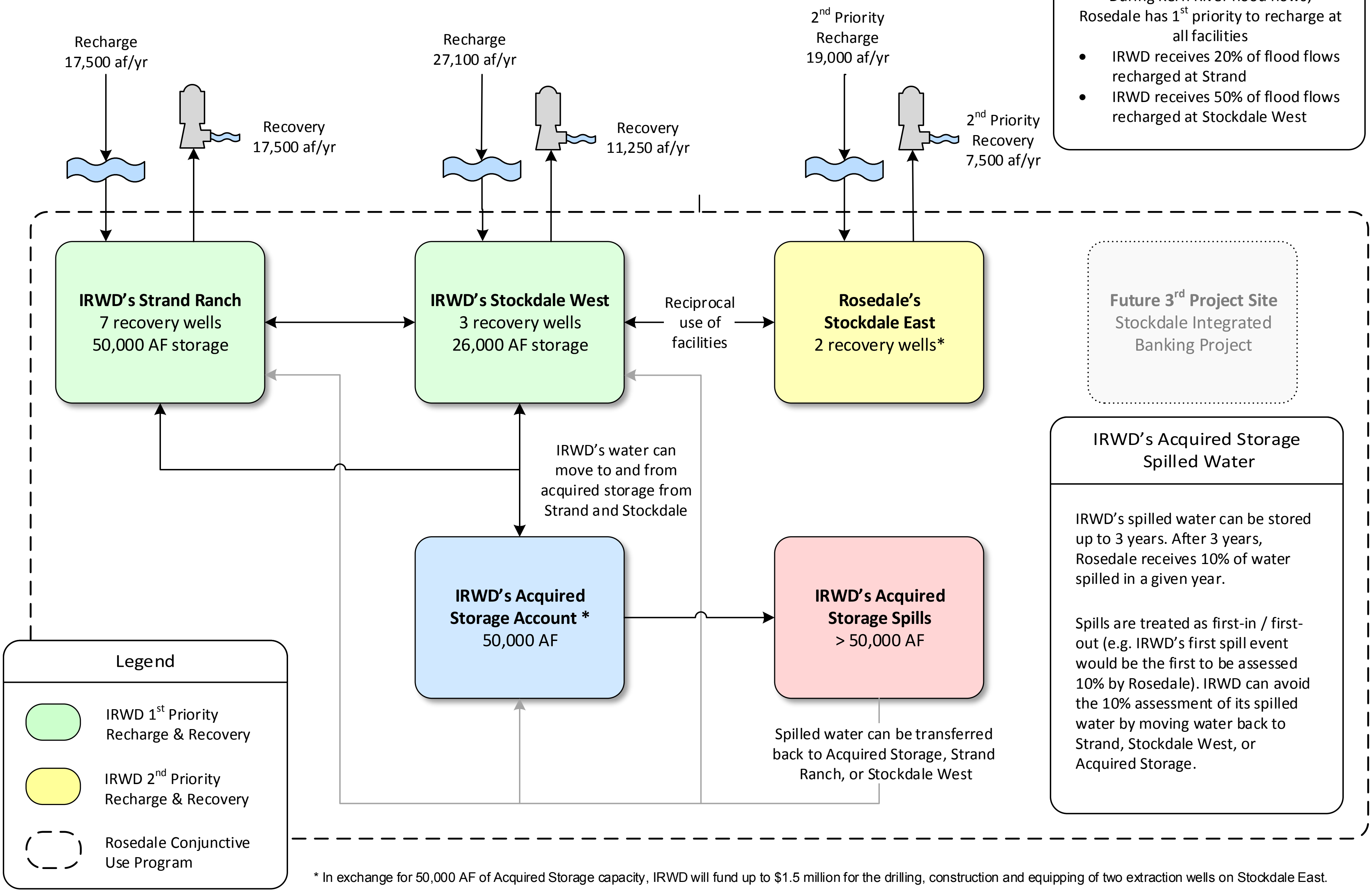
IRWD-Rosedale Water Banking and Exchange Program Agreements

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

Recharge of Flood Flows

During Kern River flood flows, Rosedale has 1st priority to recharge at all facilities

- IRWD receives 20% of flood flows recharged at Strand
- IRWD receives 50% of flood flows recharged at 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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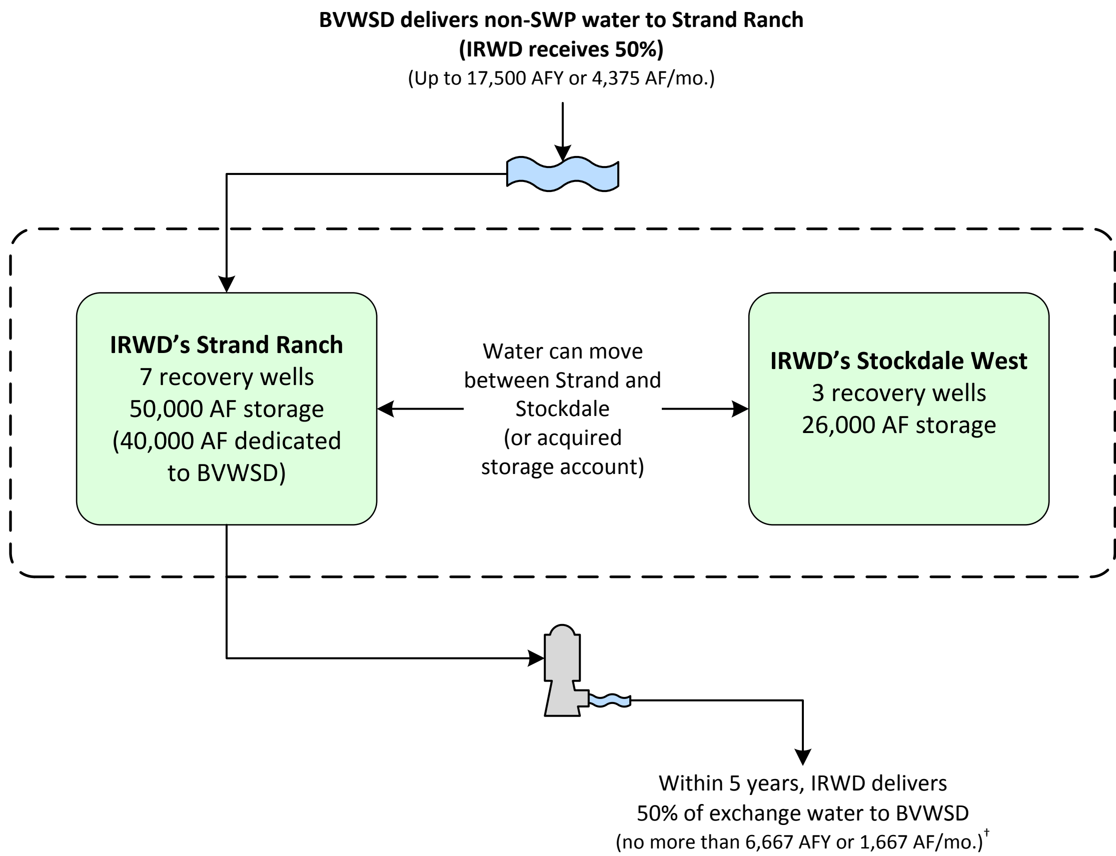
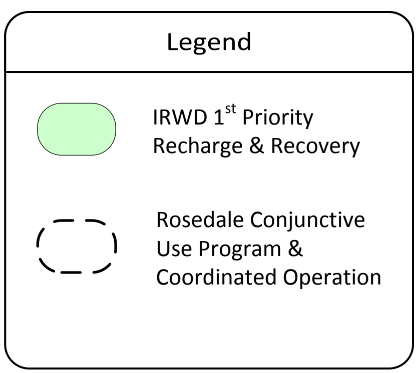
Exhibit "K"

Buena Vista Water Storage District Long Term Water Exchange Program

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



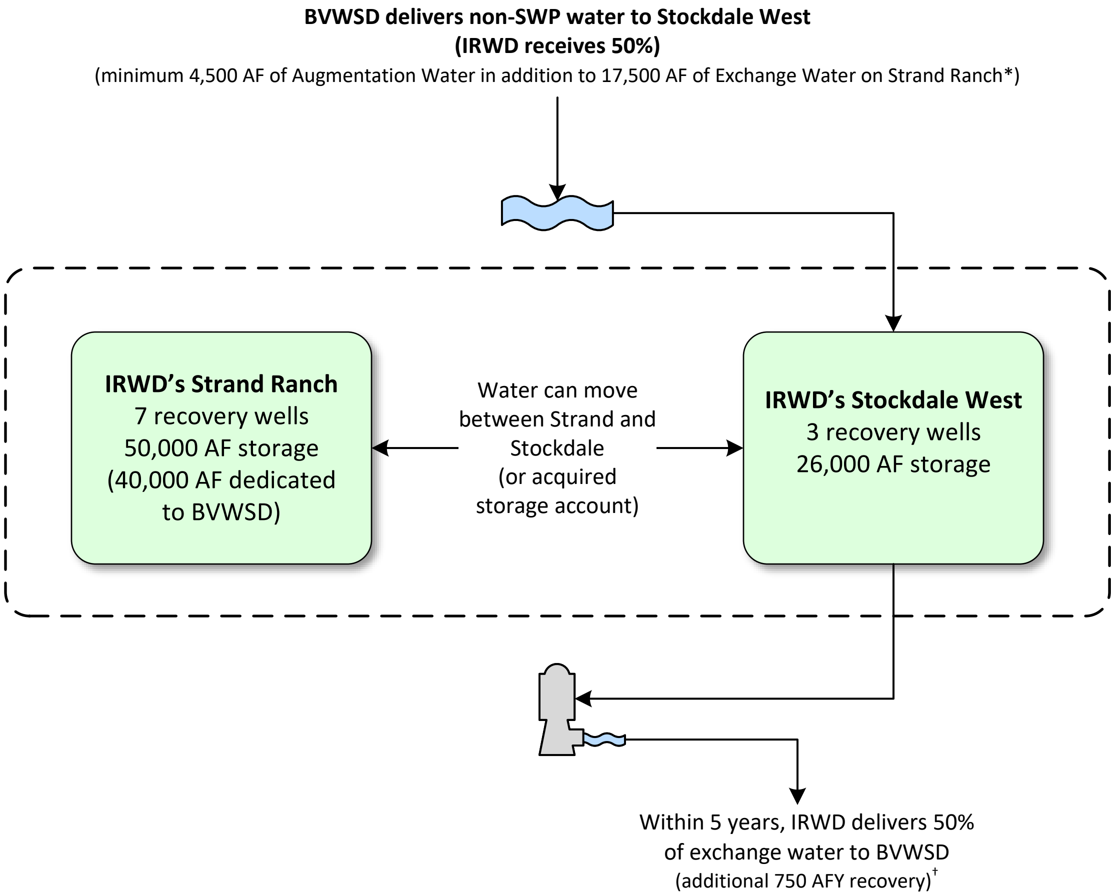


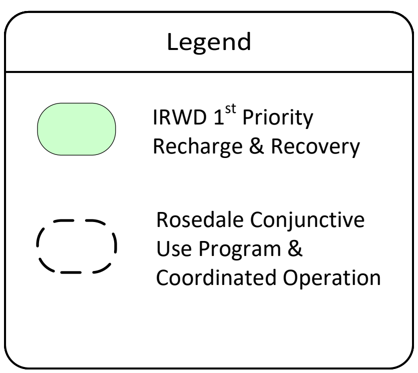
†IRWD shall remit one-half of the exchanged supply less one-half of reasonable losses back to BV no later than December 31st of the 4th year following the associated recharge event. IRWD pays for recovery of water returned to BV. Water to be remitted back to BV may remain in storage at Strand Ranch beyond 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 6/28/2023 through 12/31/2023





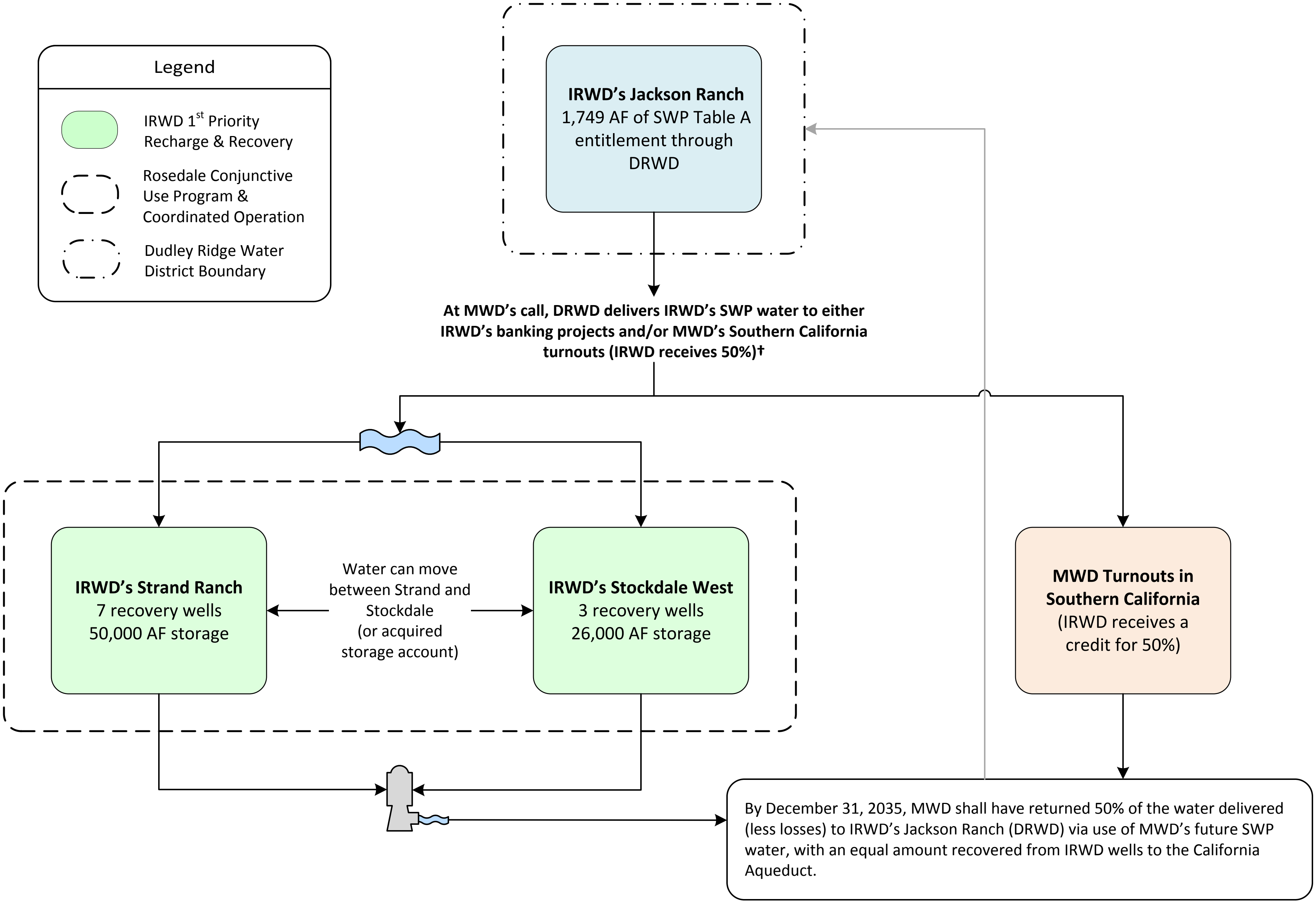
* IRWD agrees to pay BV $25 per AF for IRWD's share of the Augmentation Water and Exchange Water

†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. BV pays for recovery of its share of Augmentation Water. 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%

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

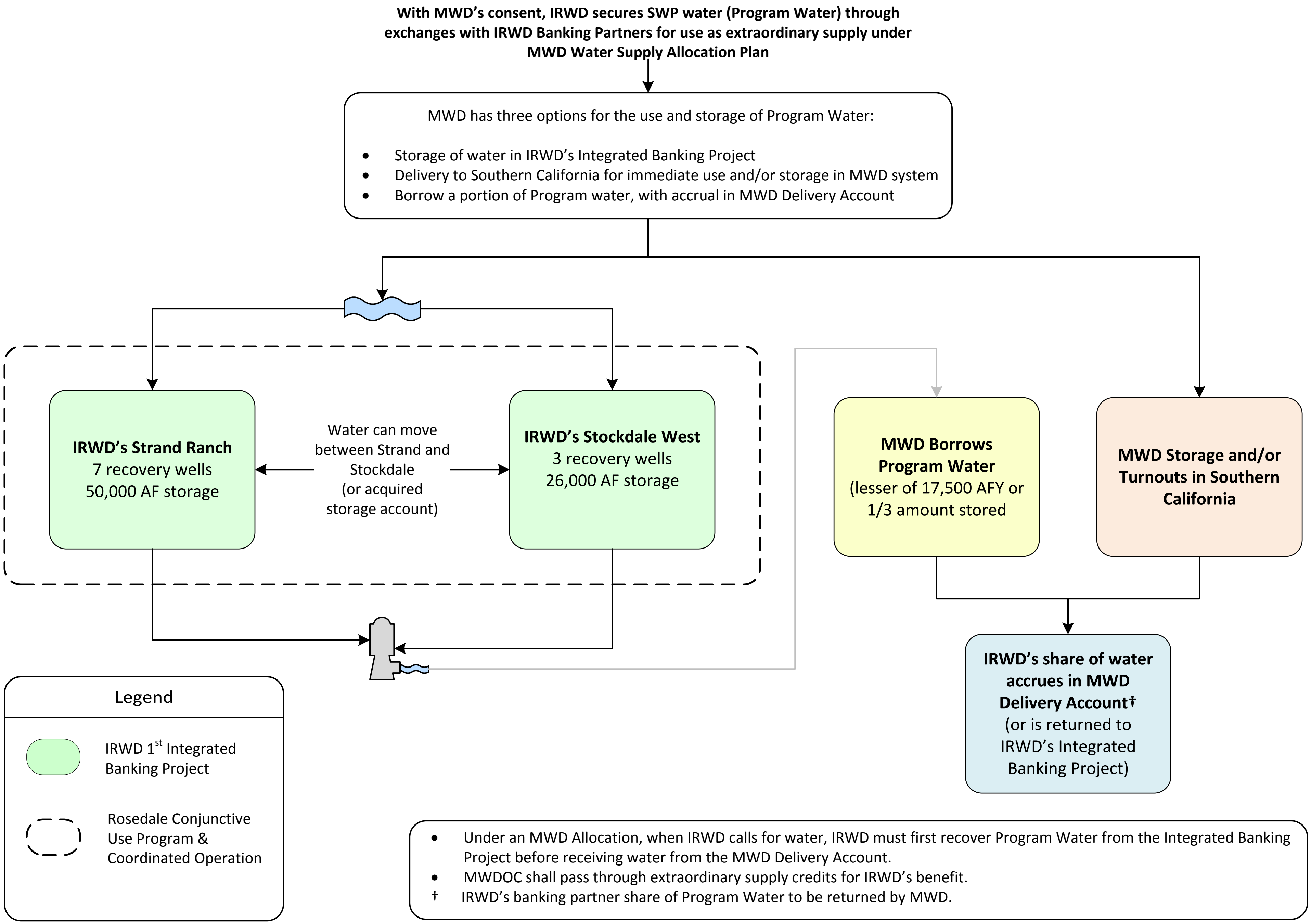

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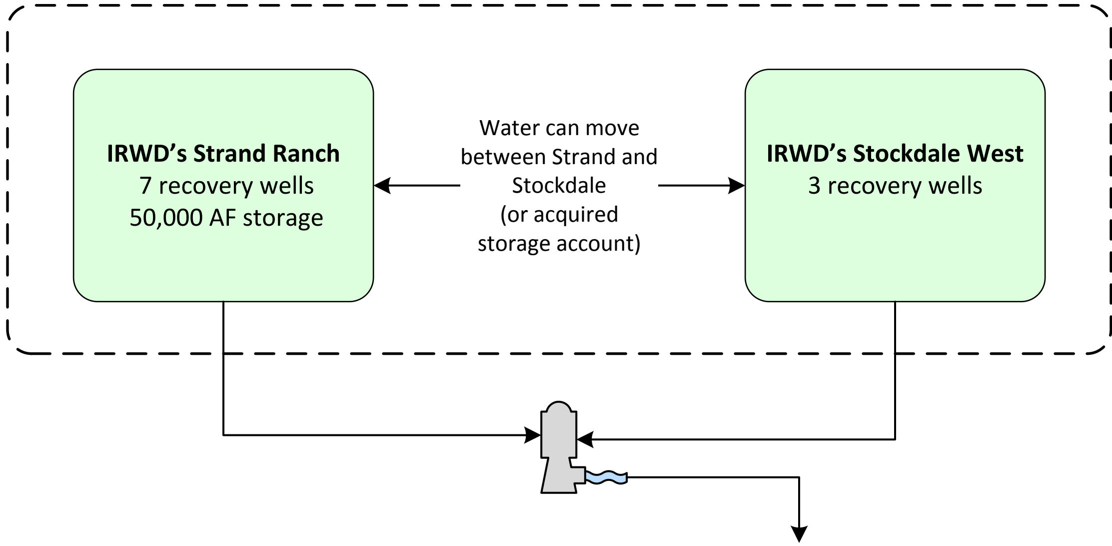
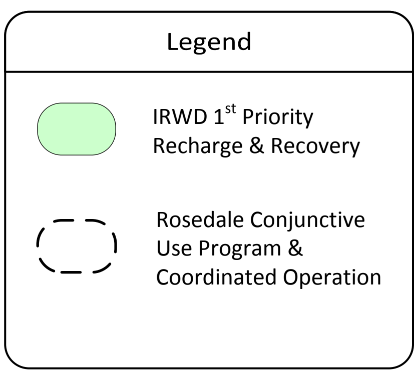
Exhibit "N"

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"

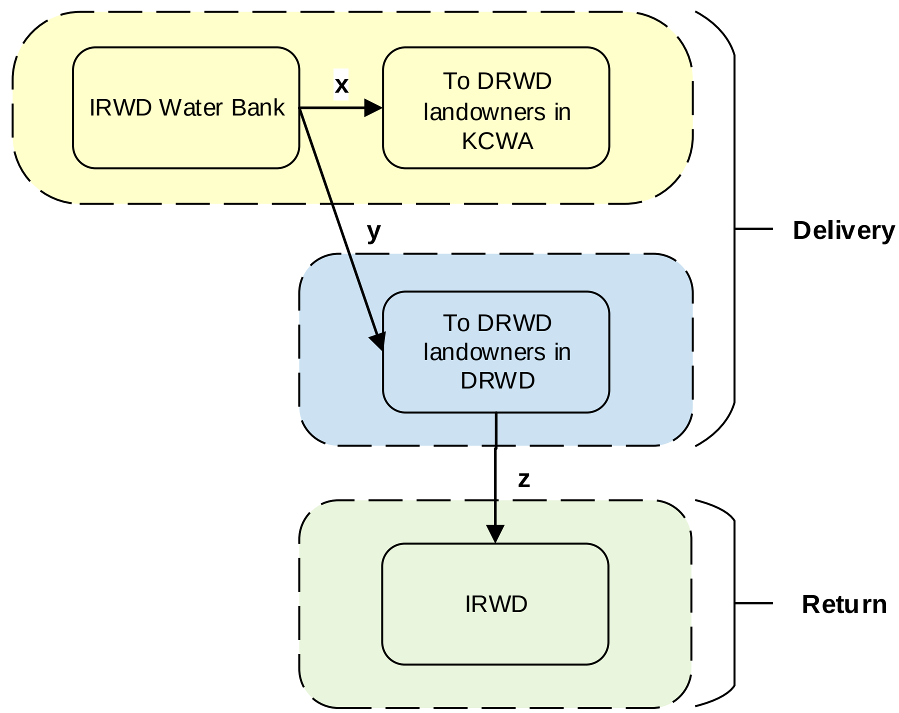
Dudley Ridge Water District Long Term 1-for-1 Water Exchange Program

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

Scenario A
(Per Sections 2, 3, 4.1.1, and 4.1.3)

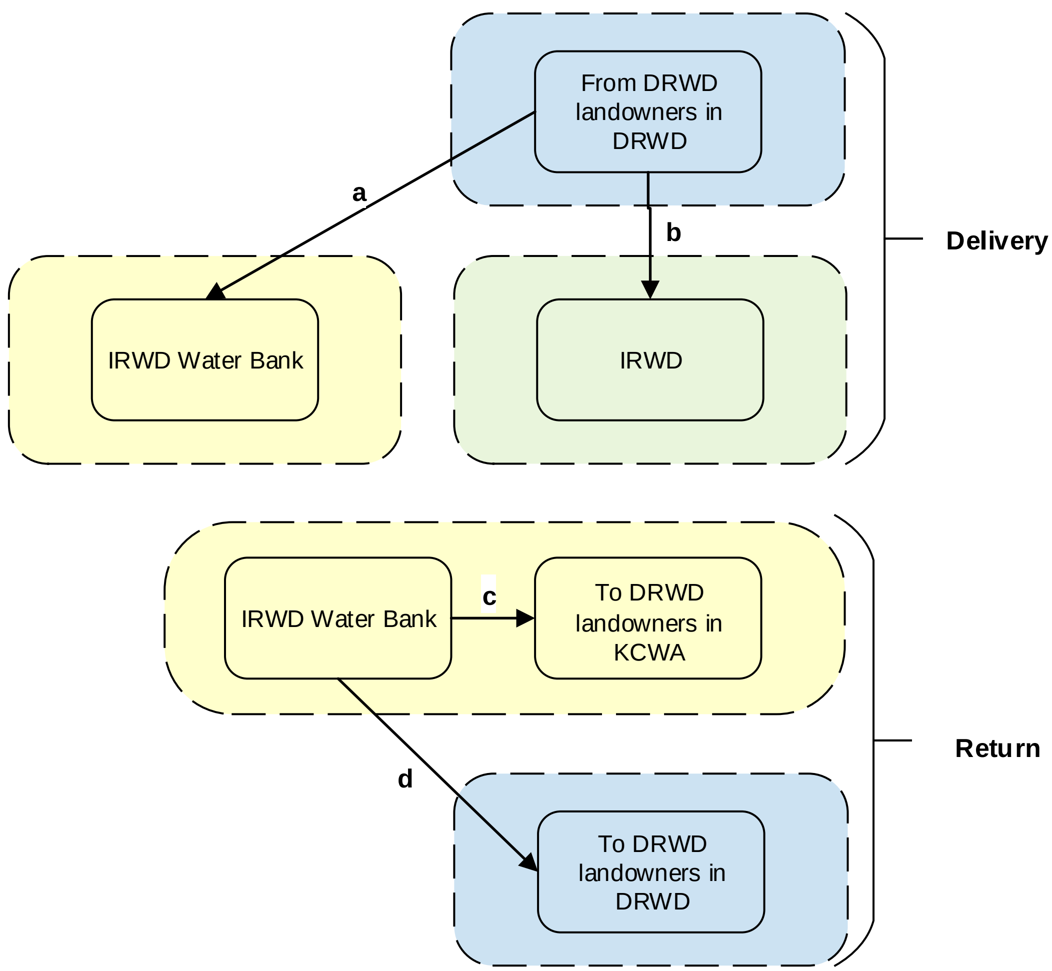
x= Non-Project Water required to stay in Kern County
y= Non-Project Water allowed to leave Kern County
z= DRWD Table A Water equal to x+y less applicable losses, if any

Per Section 4.1.3, z can be delivered to IRWD via in-ground transfer to IRWD, SWP delivery to IRWD banking facilitites, or SWP delivery to MWDSC



Scenario B
(Per Sections 2, 3, and 4.1.2)

a + b = c + d
(less applicable losses, if any)



Legend

- KCWA Service Area
- DRWD Service Area
- IRWD Service Area

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

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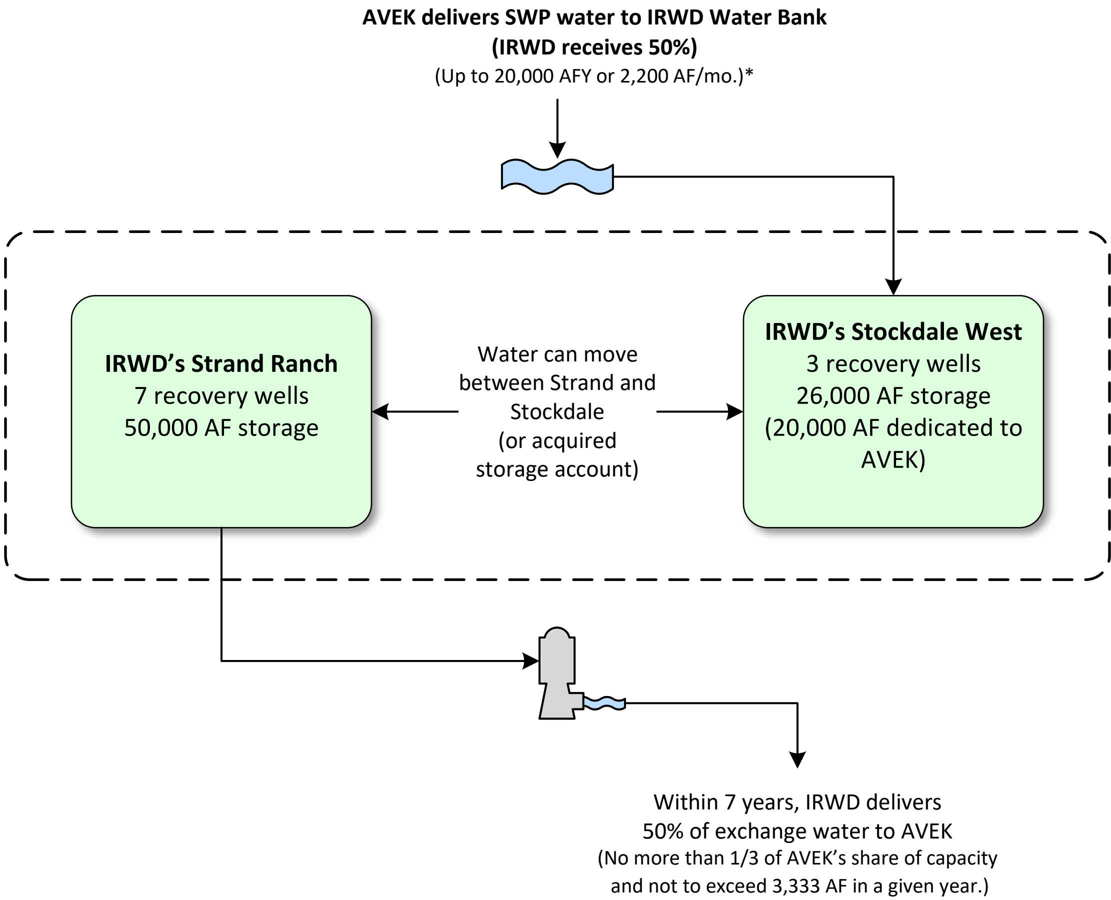
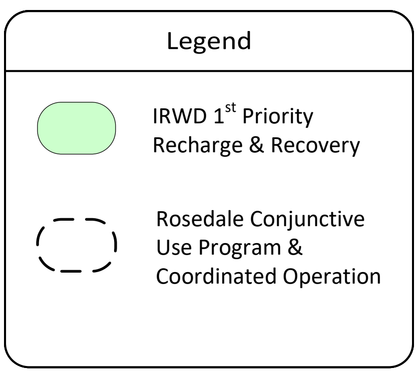
Exhibit "P"

Antelope Valle-East Kern Water Agency (AVEK) Long Term Water Exchange Program

Effective 12/21/2018 through 12/31/2035





*Up to 20,000 AF per year of AVEK Exchange Water may be delivered to IRWD for recharge using recharge facilities at the Strand Ranch and Stockdale West for storage in the Stockdale West Bank. IRWD shall remit one-half of stored supplies less one half of losses back to AVEK no later than December 31st of the 7th year, following the associated recharge event.

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Exhibit "Q"

TABLE 6

IRWD Water Banking Program Costs of Water Summary

December 6, 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 recharge variable operating costs ($5.00/AF), Rosedale administration fees ($3.00/AF), CVC pumping ($9.00/AF), operating and stand-by fees ($3.50/AF), and KCWA fees ($5.00/AF) plus $3,000 per transaction request. IRWD pays Buena Vista recovery costs. (Net of partner payments to IRWD for their share of water)

[3] Fixed costs include IRWD share of fixed operating costs ($25.00/AF), annual property taxes ($88,000), PG&E standby costs (up to $5,000/year) GSP fees ($8,450/year) and CVC expansion costs ($28,000/year)

[4] Capital component does not include land costs. Add $40/AF to include water banking land purchase 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 "R"

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.

---

[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.

Exhibit "S"

TABLE 7
IRWD 2023 Recharge Operations- BEFORE LOSSES
December 6, 2023

Actual and Forecasted Amounts:

Month	Central Coast (AF)	IRWD Table A (AF)	BV (AF)	DRWD 1:1 (AF)	IRWD Article 21 (AF)	AVEK (AF)	Total (AF)	Status	Expected Recharge (AF)	Expected Recharge Rate (CFS)
March	-	1,312	-	-	-	-	1,312	prelim	1,312	200
April	-	437	7,562	4,068	-	-	12,067	prelim	12,067	203
May	-	-	6,069	2,628	-	-	8,697	prelim	8,697	141
June	-	-	3,869	1,815	-	-	5,684	prelim	5,684	92
West Enos (June)	-	-	356	-	-	-	356	prelim	356	6
July	-	-	1,004	583	-	-	1,587	prelim	1,587	26
West Enos (July)	-	-	264	264	-	-	528	prelim	528	8.6
August	-	-	1,954	-	-	-	1,954	prelim	1,954	32
West Enos (Aug)	-	-	922	-	-	-	922	prelim	922	15
September	450	-	-		-	980	1,430	prelim	1,430	24
West Enos (Sept)	-	-	-		-	856	856	prelim	856	14
October		-	-	-	-	1,500	1,500	prelim	1,500	24
West Enos (Oct)	-	-	-	-	-	639	639	prelim	639	10
November	-	-	-	-	-	1,190	1,190	prelim	1,190	20
West Enos (Nov)	-	-	-	-	-	593	593	prelim	593	13.6
	450	1,749	22,000	9,358	-	5,758	39,315		39,316	
December	-	-	-	-	-	1,230	1,230		1,230	20
West Enos (Dec)	-	-	-	-	-	-	-		-	0
	450	1,749	22,000	9,358	-	6,988	40,545		1,230	20
Recharge goal:	450	1,749	17,500	10,000	8,000	10,000	47,699			
Recharge goal with Additional BV:			4,500				52,199			

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December 6, 2023
Prepared by: M. Lindsay / K. Welch
Submitted by: F. Sanchez / P. Weghorst
Approved by: Paul A. Cook

SUPPLY RELIABILITY PROGRAMS COMMITTEE

ELECTROMAGNETIC SURVEY RESULTS FOR KERN FAN AREA

SUMMARY:

Recharge rates in the Kern Fan Area west of Bakersfield are influenced by numerous factors including subsurface geology. Both IRWD and Rosedale-Rio Bravo Water Storage District operate water banking projects in this area. Airborne Electromagnetic (AEM) and Towed-Transient Electromagnetic (tTEM) survey technologies have been used to better understand subsurface geology in the area. Provided is an overview of the application and interpretation of survey results from both technologies. In summary, AEM technology is useful for collecting information for basin-scale areas at greater depths, whereas tTEM offers more detail over land parcel areas at shallower depths.

BACKGROUND:

IRWD and Rosedale have developed water banking projects in the Kern Fan Area within Kern County. The IRWD Water Bank consists of the Strand and Stockdale West Integrated Banking Projects. The Rosedale Conjunctive Use Program consists of numerous properties dedicated to recharge, storage, and recovery of banked water supplies. The recharge basins within the two programs experience varied infiltration rates largely based on the location of the properties. A location map of the IRWD Water Bank and Rosedale Conjunctive Use Program recharge properties is attached as Exhibit “A.”

Infiltration rates are influenced by numerous factors including surface soils, subsurface geology, moisture content, suspended sediment concentrations, permeable pathways to groundwater, and water chemistry. Subsurface geology is typically a strong indicator of expected infiltration rates at a future recharge site. Technologies used to determine subsurface composition vary and can include lithology evaluations, ground-penetrating radar, seismic surveys, and electromagnetic surveys. Two main electromagnetic survey methods that are commonly used to evaluate potential areas of recharge include AEM and tTEM survey technologies. An overview of these technologies is provided in Exhibit “B”. The following is a description of the application of these technologies in the Kern Fan Area west of Bakersfield.

Towed Transient Electromagnetic Survey Technology:

In February 2020, Rosedale contracted with the Ramboll Group to perform a geophysical investigation using tTEM technology at four test areas in Rosedale’s service area including portions of IRWD’s Strand and Stockdale West Ranches and Rosedale’s Stockdale East recharge basins. Ramboll compared known lithology with tTEM resistivity measurements to characterize subsurface geology at the four areas.

Resistivity is the electrical resistance that corresponds to differences in subsurface materials including clays and sands. The tTEM technology provides local-scale resistivity data down to 200 feet below ground surface. Clays and fine materials have a low resistivity, while coarse materials like sands and gravels have higher resistivity with the greatest infiltration potential. Coarse materials typically allow for better infiltration, while clays are less permeable. Use of tTEM technology is well suited to the survey of land parcel areas.

In June 2020, the results of the Ramboll study were reviewed with the Supply Reliability Programs Committee. A summary of the results is shown in Exhibit "C". These results depict the Stockdale East area as having the greatest infiltration potential.

Airborne Electromagnetic Survey Technology:

The Department of Water Resources (DWR) conducted AEM surveys of the eight selected areas depicted in Exhibit "D". The surveys included the State's high- and medium-priority groundwater basins being managed in compliance with the Sustainable Groundwater Management Act. AEM survey data was collected through numerous helicopter flights. All the data collected is publicly available at DWR's online AEM Data Viewer. These survey results provide basin-scale data down to 900 feet below ground surface.

Application to Kern County Subbasin:

In March 2023, DWR published the report of AEM results for the Kern County Subbasin that is provided as Exhibit "E". The report provides details on the AEM data collected as well as the related procedures, interpretations, and uncertainty analyses. DWR used existing lithology and geophysical logs to further estimate site geology. AEM technology is well suited to survey large geographic areas where access to land is not readily available and general recharge potential is not understood.

Stanford FastPath Application:

Stanford University developed the FastPath application that uses DWR's AEM survey results, other geophysical data, driller's logs, and proprietary modeling to map permeable pathways in a user specified area. This tool was designed to aid in the evaluation of potential sites for aquifer recharge and groundwater banking, without drilling additional boreholes.

Staff ran the Stanford FastPath model using AEM survey results from the Kern Fan Area west of Bakersfield to identify areas with good potential permeable pathways that may yield higher infiltration rates. These results are provided in the AEM Model Results Map as Exhibit "F". At the Committee meeting, staff will present an overview of staff's interpretation of the results.

Future Considerations:

AEM technology is useful for collecting subsurface geology information for basin-scale areas at greater depths, whereas tTEM offers more detail on land parcels at shallower depths. The FastPath tool can be used to identify areas where detailed tTEM surveys might be applied in the future. The combination of these technologies can assist with due diligence evaluations of future recharge lands.

FISCAL IMPACTS:

None.

ENVIRONMENTAL COMPLIANCE:

Not applicable.

RECOMMENDATION:

Receive and file.

LIST OF EXHIBITS:

Exhibit “A” – IRWD Water Banking Property Location Map
Exhibit “B” – Electromagnetic Technology Application Diagrams (AEM and tTEM)
Exhibit “C” – Electromagnetic Survey Results: Ramboll 2020 Report
Exhibit “D” – Department of Water Resources Survey Area Key, Map of Survey Locations
Exhibit “E” – Department of Water Resources Survey Area 4 AEM Report
Exhibit “F” – FastPath Modeled Electromagnetic Survey Results for Kern Fan Area

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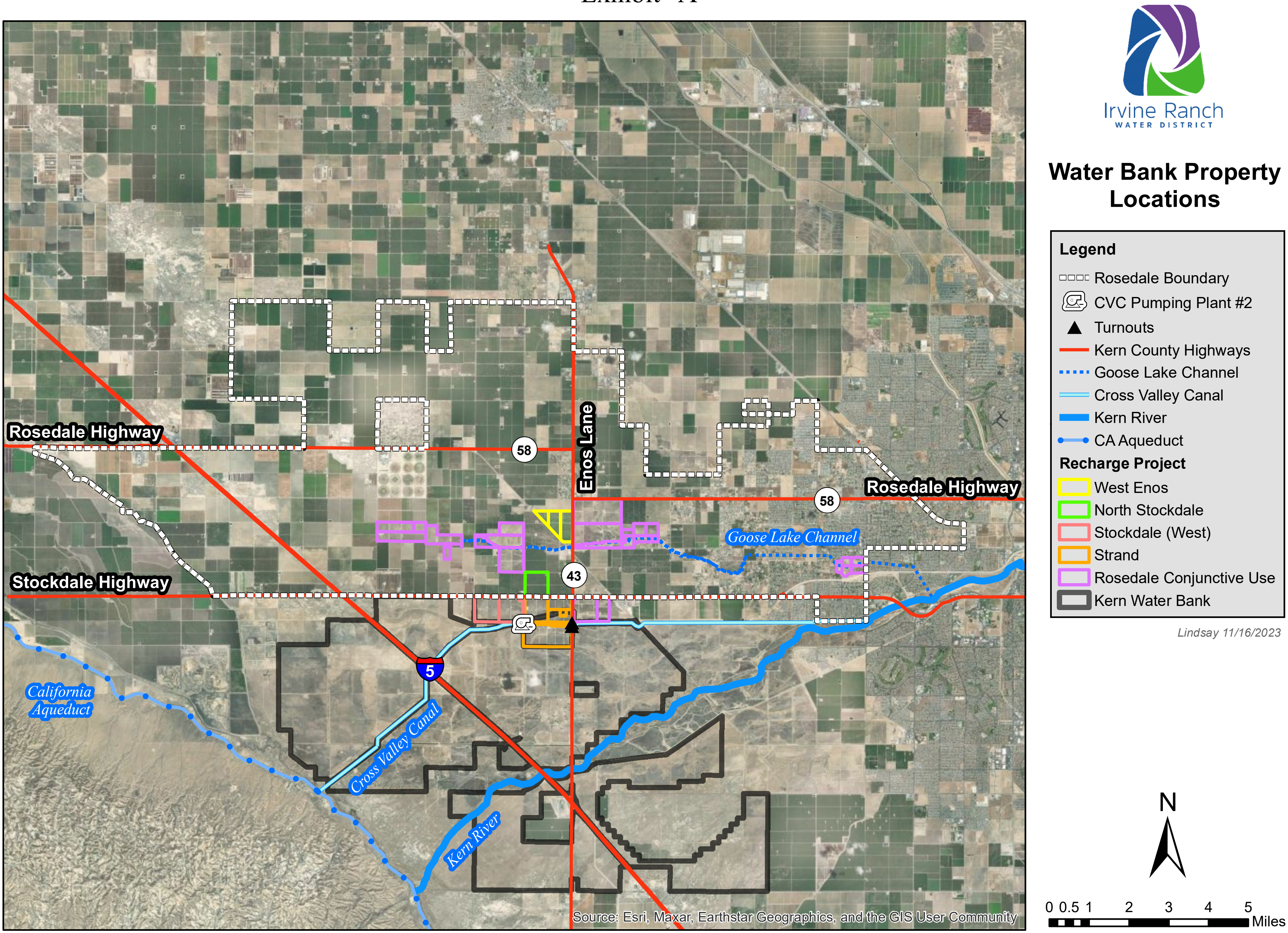
Exhibit "A"



Irvine Ranch
WATER DISTRICT
Water Bank Property Locations
Legend
Rosedale Boundary
CVC Pumping Plant #2
Turnouts
Kern County Highways
Goose Lake Channel
Cross Valley Canal
Kern River
CA Aqueduct
Recharge Project
West Enos
North Stockdale
Stockdale (West)
Strand
Rosedale Conjunctive Use
Kern Water Bank
Lindsay 11/16/2023
Rosedale Highway
Rosedale Highway
Stockdale Highway
Enos Lane
58
58
43
5
Goose Lake Channel
California Aqueduct
Cross Valley Canal
Kern River
N
0 0.5 1 2 3 4 5
Miles
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

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Exhibit "B"

Electromagnetic Survey Technologies

AEM

Basin Scale

Airborne EM

Speed: ~100 km/hour
Vertical resolution: 3-5 m at the surface
Lateral resolution: 30-50 m at the surface
Line spacing: 100s of meters to kilometers
Depth of investigation: about 300 m

Resolution degrades with depth and varies upon subsurface resistivity

tTEM

Local Scale

Towed Transient EM

Speed: ~7 km/hour
Vertical resolution: 0.5-1 m at the surface
Lateral resolution: 5-10 m at the surface
Line spacing: about 10 meters
Depth of investigation: 40-60 m

Resolution degrades with depth and varies upon subsurface resistivity

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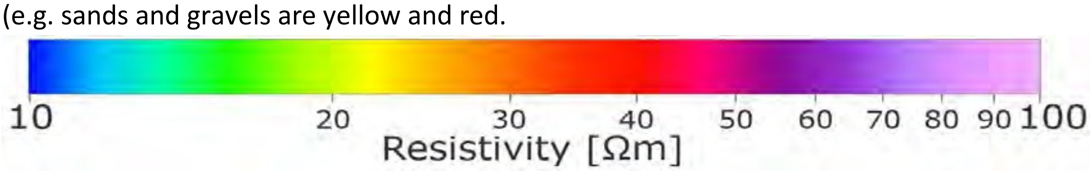
Exhibit "C"

tTEM Results from Ramboll 2020 Study

Mean Resistivity in the Interval from 0 to about 200 ft Below Ground (1)

(1) Resistivity color scale used in this report where a low resistivity represents low infiltration potential (e.g. a clays are blue) and a high resistivity represents a high infiltration poeential (e.g. sands and gravels are yellow and red.



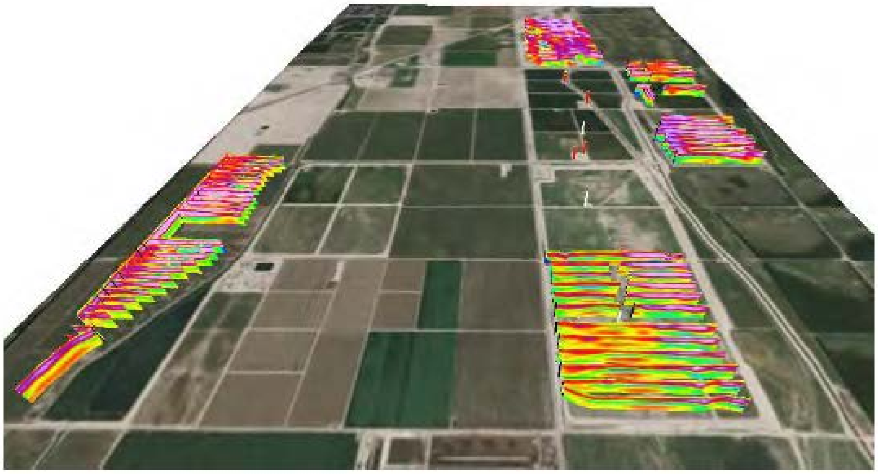


Figure 23 Fence diagram seen from West.

Ramboll - Kern Fan shallow hydrogeologic assessment

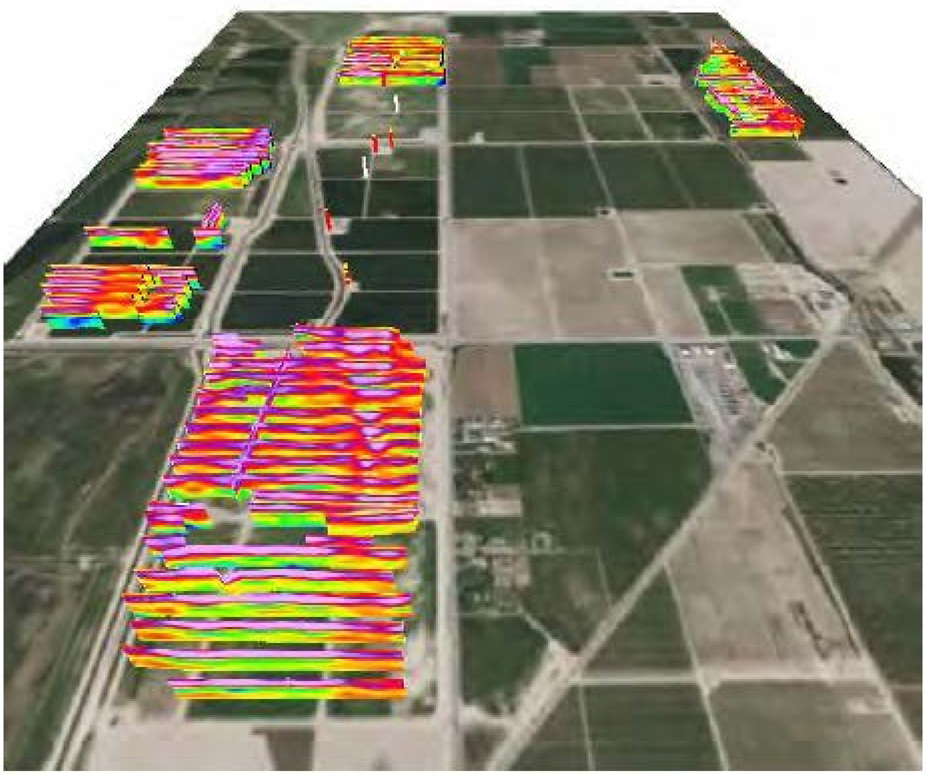
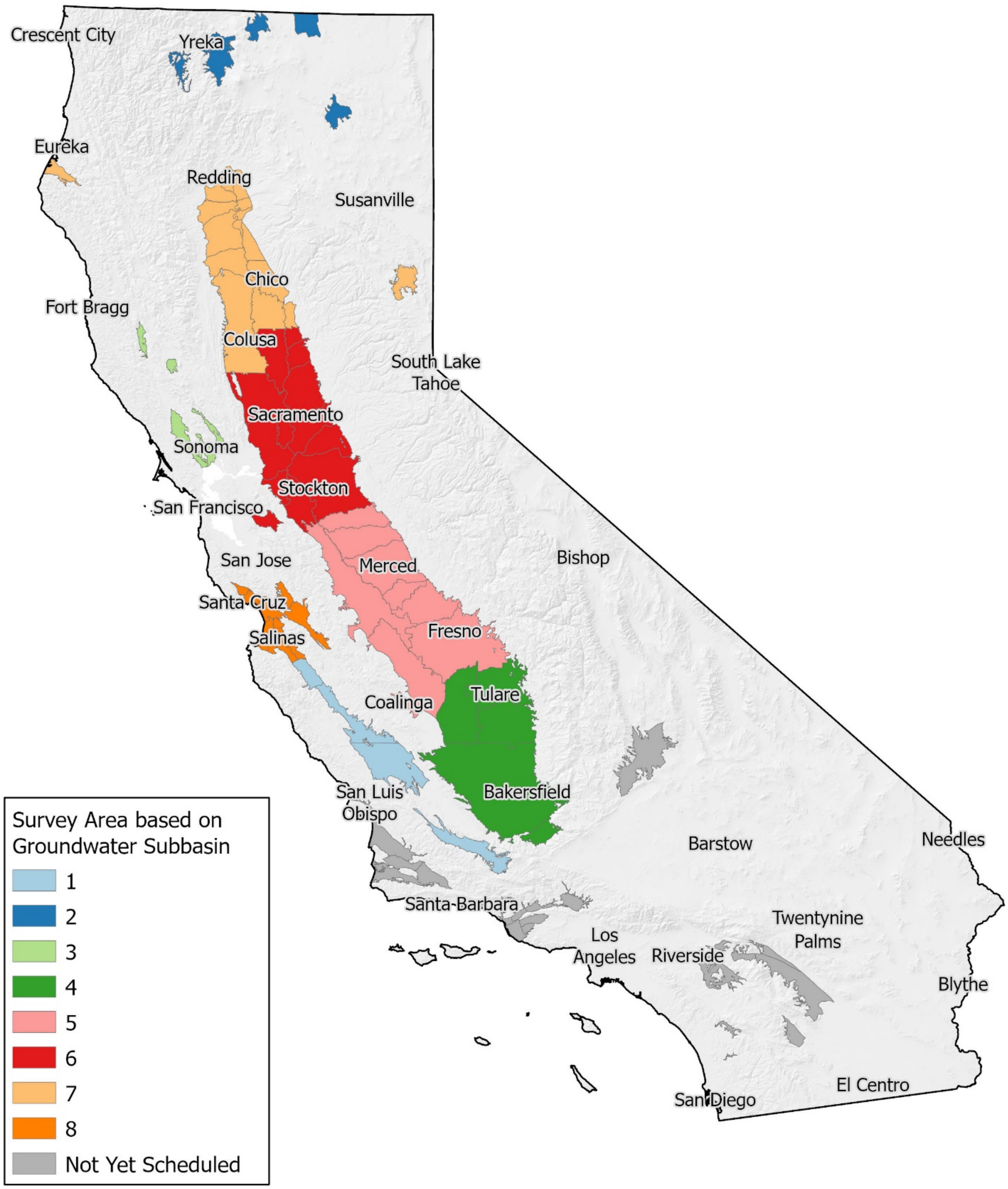


Figure 24 Fence diagram seen from East.

Exhibit "D"

AEM Survey Areas



For a complete list of groundwater subbasins surveyed in each survey area, please visit:
https://water.ca.gov/Programs/Groundwater-Management/Data-and-Tools/AEM and click on AEM Survey Schedule.

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THE CALIFORNIA DEPARTMENT OF WATER RESOURCES' STATEWIDE AIRBORNE ELECTROMAGNETIC SURVEY PROJECT

DATA REPORT FOR SURVEY AREA 4
KERN COUNTY AND WHITE WOLF GROUNDWATER SUBBASINS

RAMBØLL
Eclogite Consulting
GEI Consultants
SKYTEM
RAS REALtime Aquifer Services
HydroGeophysics Group AARHUS UNIVERSITY
Sinton HELICOPTERS

CALIFORNIA AIRBORNE ELECTROMAGNETIC SURVEYS
KERN COUNTY AND WHITE WOLF GROUNDWATER SUBBASINS

Project name	California Airborne Electromagnetic Surveys for the Kern County and White Wolf Groundwater Subbasins
Project no.	1690021880, Work Order 04
Recipient	California Department of Water Resources – Sustainable Groundwater Management Office
Document type	Report
Version	2
Date	March 2, 2023
Prepared by	Ahmad-Ali Behroozmand, Chris Petersen, Ian Gottschalk, Julián Consoli, Max Halkjaer, Paul Thorn, Peter Thomsen, Mikkel Toftdal, Frederik Christensen, Jeppe Schjerning
Checked by	Timothy Parker
Approved by	Max Halkjaer, Timothy Parker
Description	This is a data report describing the acquisition, processing, inversion and lithology transform for the AEM survey conducted in the Kern County and White Wolf Groundwater Subbasins. In addition, the report provides a description of the well data collected along the planned flight lines and the projects data management system.

PROFESSIONAL GEOLOGIST
TIMOTHY
K.
PARKER
No.5584
STATE OF CALIFORNIA

Timothy K. Parker, PG

03/02/2023
Date

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LIST OF ABBREVIATIONS AND ACRONYMS

ACT	Accumulated Clay Thickness
AEM	Airborne Electromagnetic
CF	Clay Fraction
DMS	Data Management System
DOI	Depth of Investigation
DWR	Department of Water Resources
EC	Electrical Conductivity
EM	Electromagnetics
GAMA	Groundwater Ambient Monitoring and Assessment
GIS	Geographic Information System
GPS	Global Positioning System
GSP	Groundwater Sustainability Plan
km	Kilometer
L	Liter
m	Meter
mg	Milligrams
OSWCR	Online System for Well Completion Reports
PLSS	Public Land Survey System
QA	Quality Assurance
QC	Quality Control
SGMA	Sustainable Groundwater Management Act
SR	State Route
SWRCB	State Water Resources Control Board
TDS	Total Dissolved Solids
TEM	Time-domain (or Transient) Electromagnetics
USCS	Unified Soils Classification System

ACKNOWLEDGEMENTS
DWR would like to acknowledge the AEM Survey project partners including the Kaweah, Tulare Lake and Tule Basins Groundwater Sustainability Agency (GSA), Monterey County, Marina Coast Water District, County of San Luis Obispo, City of Paso Robles GSA, Shandon-San Juan Water District GSA, San Miguel CSD GSA, California Geologic Survey, California Department of Fish and Wildlife, California Department of Food and Agriculture, California State Water Resources Control Board, and United States Geologic Survey. This project was funded through the California Drought, Water, Parks, Climate, Coastal Protection and Outdoor for all Fund (Senate Bill 5, Proposition 68).

PROJECT TEAM

The project team for the AEM Survey covering the Kern County and White Wolf includes:

Ramboll – responsible for coordination of the contractors, onsite geophysicist during data acquisition, data processing and inversion, lithology model, initial hydrostratigraphic model, reporting and quality control of deliverables.

GEI – collected and compiled well data into the data management system and assisted in report preparation.

SkyTEM – coordinated the AEM surveys field operation, providing the AEM equipment and leading the field work.

Sinton Helicopters – provide helicopter, pilots, AEM instrumentation and flew the AEM survey.

AECOM – assisted DWR with outreach to the local GSA's and authorities, plan the location of the flight lines, assisting with the initial collection of well data from the GSA's.

Eclogite – digitized well lithology and geophysical logs.

Real Time Aquifer Services – provided additional geophysical logs in digital format.

Aarhus University, Denmark – assisted with the lithology model and the initial hydrostratigraphic model.

AEM Data Report and Use Disclaimer

This Data Report was prepared by the Project Team for the California Department of Water Resources (DWR). DWR makes no warranties, representations or guarantees, either expressed or implied, as to the accuracy, completeness, correctness, or timeliness of the information provided in this report or related datasets that are accessible through the California Open Data Portal, nor accepts or assumes any liability arising from use of the AEM data or reports. Neither the Department nor any of the sources of the information utilized by the contractor to develop the report and datasets shall be responsible for any errors or omissions, or for the use or results obtained from the use of this information. Classifications and boundaries shown in this report are graphical representations only, and do not establish legal rights or define legal boundaries. A Groundwater Sustainability Agency is not required to use the AEM report and underlying data, and their use does not guarantee the adequacy of a Groundwater Sustainability Plan that relies on such data.

0. EXECUTIVE SUMMARY

Regional airborne geophysical surveys are being conducted by the California Department of Water Resources (DWR) and its contractors in all of the state's high- and medium-priority groundwater basins to collect data on the geometry and geologic properties of the underlying aquifer systems that provide groundwater to local communities (Figure 0-1). The focus of this report is the Kern County and White Wolf geophysical survey (Figure 0-1). The regional geophysical surveys, which use the airborne electromagnetics (AEM) technique, have been compared to an MRI to see beneath the ground surface. The AEM data and products from the surveys are being provided to assist local water managers and the state as they implement the Sustainable Groundwater Management Act (SGMA) to manage groundwater for long term sustainability. The AEM surveys are funded by voter-approved Proposition 68, and all the data from the surveys are being made publicly available online.

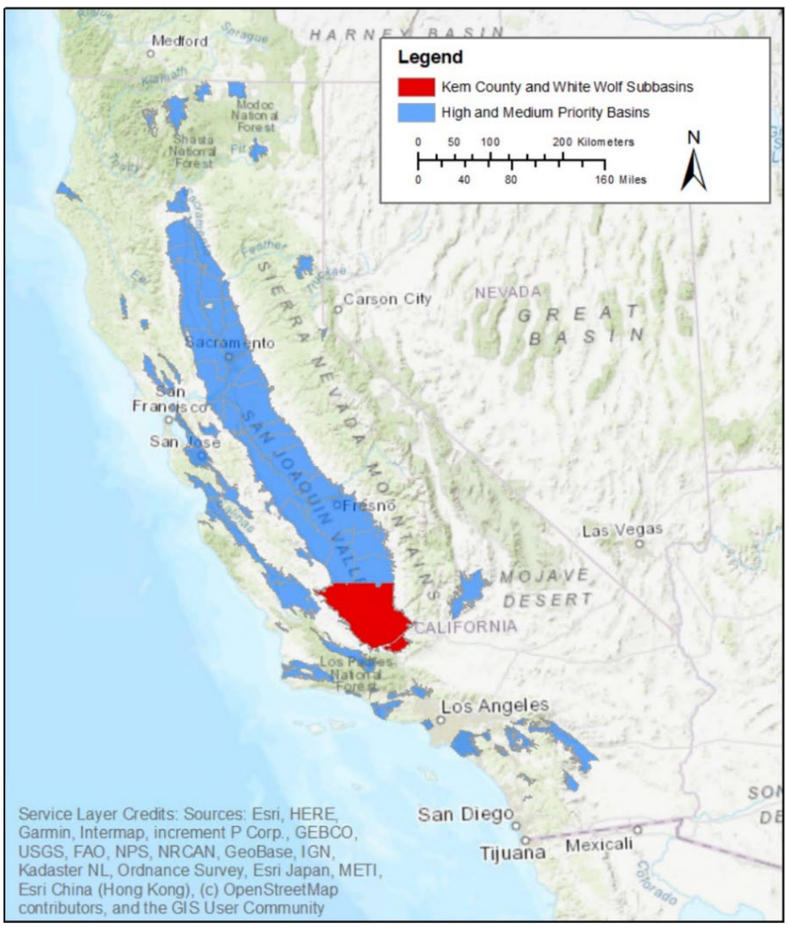


Figure 0-1 SGMA high and medium priority basins in California. The Kern County and White Wolf Groundwater Subbasins are marked in red.

The AEM survey technique utilizes a helicopter flying approximately 80 kilometers per hour (50 miles per hour) with the geophysical equipment suspended below, mounted on a large hexagonal frame about 30 meters (100 feet) above the ground surface (Figure 0-2). The AEM equipment sends a pulsating weak electromagnetic signal into the ground and measures the response, which provides an electrical resistivity profile the earth's geological layers and structures down to depths of as much as 300 meters (1,000 feet). Aquifer systems consist of (1) aquifers typically composed of sands and gravels that have high resistivities, and (2) aquitards composed of silt and clays that have low resistivities. The resistivity profiles help in mapping the overall aquifer systems dimensions and extent. The AEM survey data is then analyzed in detail, correlated with data from nearby wells, and modeled to produce subsurface maps of the resistivity, lithology, and an initial hydrostratigraphic model.

Figure 0-2 Helicopter towing the hexagonal SkyTEM system while collecting AEM data during the survey.

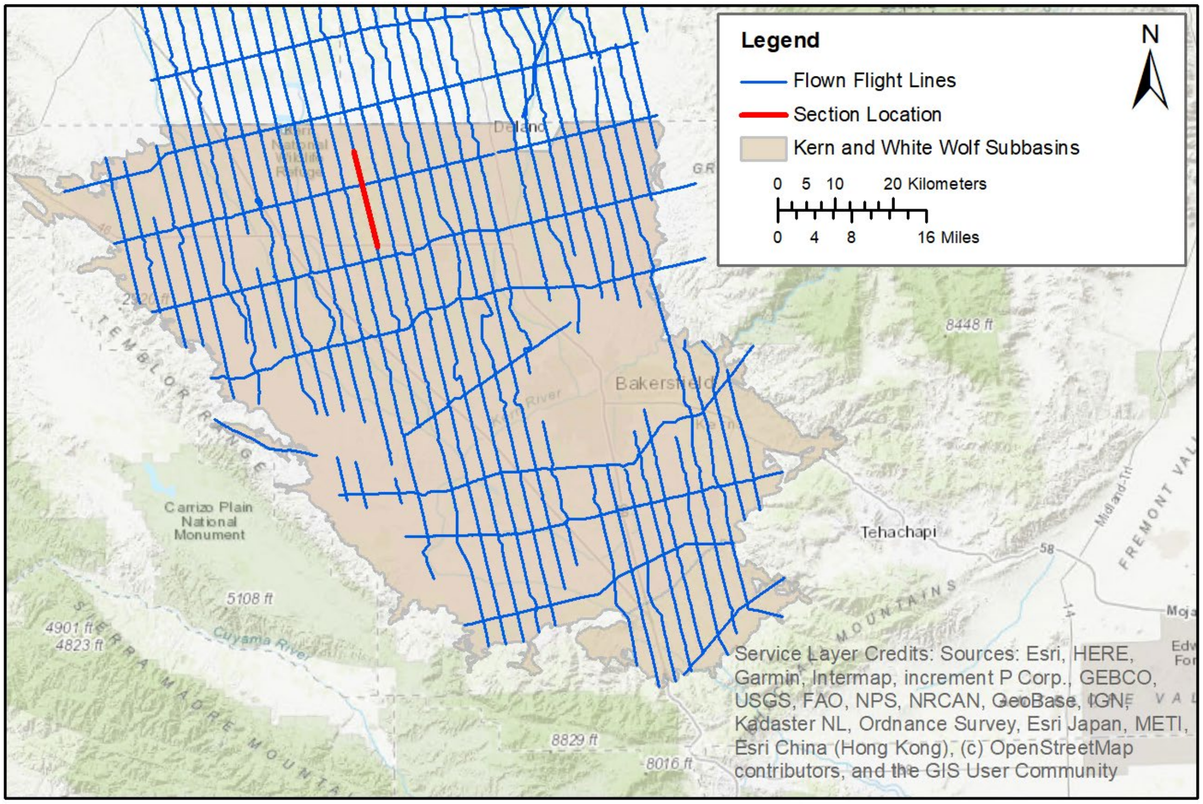


Figure 0-3 Outline of The Kern County and White Wolf Groundwater Subbasins and the flight lines showing where the AEM survey was flown. The red line shows the location of the vertical profile shown in Figure 0-4.

Kern County and White Wolf AEM Survey

The Kern County and White Wolf survey was conducted in December 2021 and March 2022, totaling 2,421.4 line-km (1,504.6 line-miles). Prior to the survey, public outreach was conducted, providing information on the survey to local residents, media and law enforcement agencies. Both during and after AEM data acquisition, measures were taken to ensure acceptable data quality. This included daily AEM system tests, evaluation of the unprocessed AEM data, and conducting repeat AEM lines to ensure the reproducibility of the collected data.

Well lithology and oil and gas geophysical logs located along the AEM flight lines were compiled to provide additional data to support and ground-truth. The surveys were complied with the objective of obtaining two high quality lithology logs in each of the Public Land Survey System one-mile square sections that the flight lines cross. High quality lithology logs are defined as having a verified location accuracy of less than 50 meters (164 feet), wells that are at least 30 meters (98 feet) deep and have an average description interval of less than 30 meters (98 feet). In total, there were 920 high quality lithology logs and 145 geophysical logs compiled. Groundwater levels and water quality data (as total dissolved solids [TDS]), both of which can affect the subsurface resistivity, were also compiled.

The AEM data was then processed to filter out potential noise in the data and, if necessary, remove the data where interference is too great to effectively filter. Potential sources for noise in the data includes electric power transmission lines, railroads, pipelines, and any significant metallic objects. Subsequent to AEM data processing, resistivity models were produced that in general, provide profiles indicative of coarse-grained (sands and gravels) and fine-grained (silts and clays), represented by higher and lower resistivities, respectively. Two types of models were produced: a smooth resistivity model, showing the gradual resistivity transition with depth, and sharp resistivity model, where subsurface boundaries are inferred from the AEM data. Figure 0-4 shows a vertical resistivity section with the 30-layer sharp resistivity model (top section).

The AEM modeled resistivity was then processed, combining the detailed high-quality well lithologic data with information on the spatial heterogeneity from the resistivity to provide an interpretation of lithology. In the first step of the process, the well lithology data descriptions were aggregated into either (1) coarse or (2) fine material classifications. Then computer-based numerical calculations using an inversion algorithm were preformed to iteratively compare the modeled resistivity with the simplified lithology from the lithology log data to produce a model of the coarse fraction thickness consistent with the lithology log coarse fraction thickness. The second section on Figure 0-4 shows the interpretation of the coarse fraction thickness along the AEM flight line.

The resistivity and coarse fraction data were combined to produce an initial hydrostratigraphic model for the subbasins, designating areas or layers of the subsurface having similar hydrogeologic properties. This was done utilizing a clustering algorithm, where the relationship between resistivity and coarse fraction were divided into groups with similar properties. As resistivity and coarse fraction is inherently related to the earth’s hydrogeological properties, each group of datapoints represents an individual hydrostratigraphic unit. The datapoints were then plotted on the profiles to produce an initial hydrostratigraphic model, containing 5 separate groups based on the resistivity and coarse fraction along the flight line.

The resistivity models will be useful for local groundwater management agencies to refine hydrogeologic conceptual models and groundwater flow models. This may also assist in the identification of recharge areas and interconnected surface water.

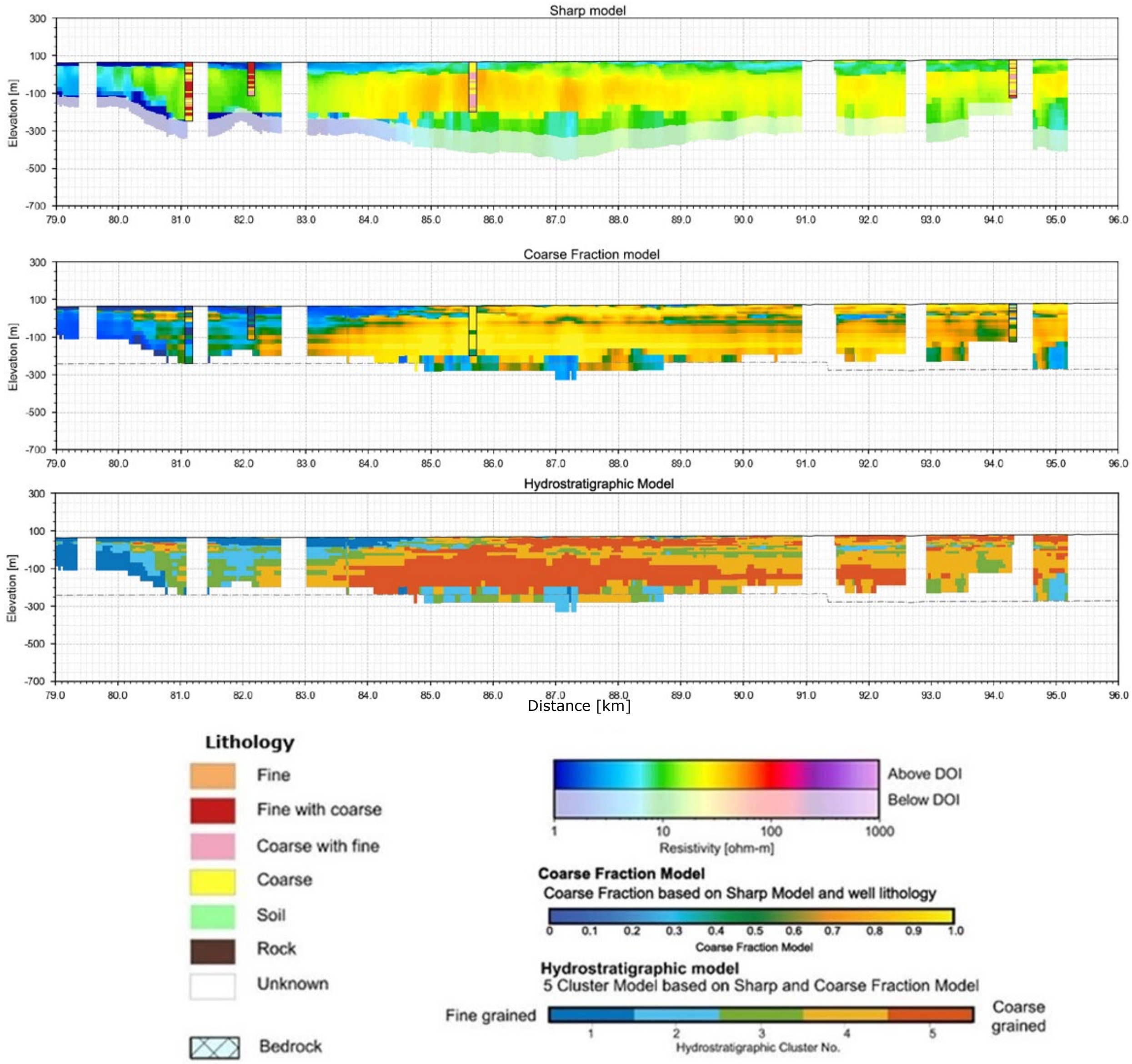


Figure 0-4 Vertical resistivity section series from a AEM flight line in the survey area. The top section shows the 30-layer sharp resistivity model, the second section shows the coarse fraction model, and the bottom section shows the initial hydrostratigraphic model. The location of the section is shown on Figure 0-3.

1. INTRODUCTION

The California Department of Water Resources (DWR) is currently conducting airborne electromagnetic (AEM) surveys in California's high- and medium-priority groundwater basins. The data from the surveys are collected in order to assist local water managers as they implement their respective GSPs to comply with the Sustainable Groundwater Management Act (SGMA) to sustainably manage groundwater.

An electromagnetic (EM) survey is a geophysical technique conducted from the land surface or the air that measures the electrical properties of the earth's subsurface materials. AEM is an airborne EM technique that includes a large hexagonal frame containing the geophysical equipment suspended by cable beneath a helicopter about 100 feet above the ground surface along a defined flight path. During the survey, the system sends a weak pulsating electromagnetic signal that penetrates up to around 300 meters (1,000 feet) into the earth. The returning signal pulse is picked up by receivers in the frame. The data collected provides a measurement of the electrical resistivity of the different geological strata, providing information on the distribution of coarse-grained and fined-grained materials in the subsurface as well as groundwater salinity.

This report presents information on the AEM survey conducted in the Kern County and White Wolf Groundwater Subbasins of the San Joaquin Valley Groundwater Basin. The subbasins are located in the southern San Joaquin Valley and the basins are designated either high- or medium priority by the state (Figure 1-1). The report provides full documentation of the data collection, processing and analysis, including the methods used, results, uncertainty and quality control.

1.1 Overview of the California State-wide AEM Survey

The DWR has a long history of data collection, monitoring, and reporting to support characterizing California's groundwater basins. *California's Groundwater*, DWR Bulletin 118, Update 2020 (DWR 2020) is the State's official publication on the occurrence and nature of groundwater in California. The publication defines the groundwater basin boundaries and features current knowledge of groundwater resources including information on the location, characteristics, use, management status, and conditions for each of the State's 10 hydrologic regions. With the passage of the Sustainable Groundwater Management Act (SGMA) in 2014, there is an increased need for local and state agencies and the public to better understand groundwater basin characteristics in order to make informed management decisions to achieve sustainability in the next two decades.

The objective of the Proposition 68 funded AEM survey program is to support the State's continued effort to improve groundwater basin characterization and to provide groundwater sustainability agencies (GSAs) and interested parties with a regional and statewide dataset. Which GSAs can utilize as one way to support the technical requirements of DWR’s Groundwater Sustainability Plan (GSP) Regulations and SGMA. The data collection effort will provide essential information about subsurface hydrogeologic characteristics of groundwater basins that will reduce uncertainty and could improve the potential for successful implementation of GSPs and groundwater recharge projects. The focus of the AEM surveys is all of California’s high- and medium-priority groundwater basins (Figure 1-1) where data collection is feasible, as these are the groundwater basins that are required to develop GSPs and achieve long-term sustainability within 20 years under SGMA.

1.1.1 DWR AEM Survey Flight Line Planning

DWR conducts the AEM survey flight line planning with input from local, state and federal agencies and then transmits the flight line plan to Ramboll for execution. The AEM survey flight lines are developed with the goal of collecting high-quality data that are beneficial to local, state, and federal agencies by supporting basin characterization and the implementation of SGMA. The steps to developing the survey flight lines are described below.

Step 1: An approximate 2-mile by 8-mile grid was first oriented to capture large-scale hydrogeologic features within the surveyed area, with input from DWR’s Region Office staff. Large-scale hydrogeologic features that were considered included aquifer structures, geologic bedding and buried feature orientations, faults, and presence of brackish to saline groundwater.

Step 2: For a combination of safety considerations and potential for noise in the collected data, flight lines were modified to avoid, or minimize the interaction with, the following:

- Urban areas
- Structures containing people or confined livestock
- Oil and gas well fields
- Highways
- Transmission lines
- Railroads
- Pipelines
- Vineyards (most vines are supported by metal posts)

Step 3: Flight lines were modified to incorporate important areas identified by GSAs and state and federal agencies.

Step 4: The flight lines were finally modified to be co-located with existing high-quality lithology or geophysical data gathered from public databases or provided from the GSAs.

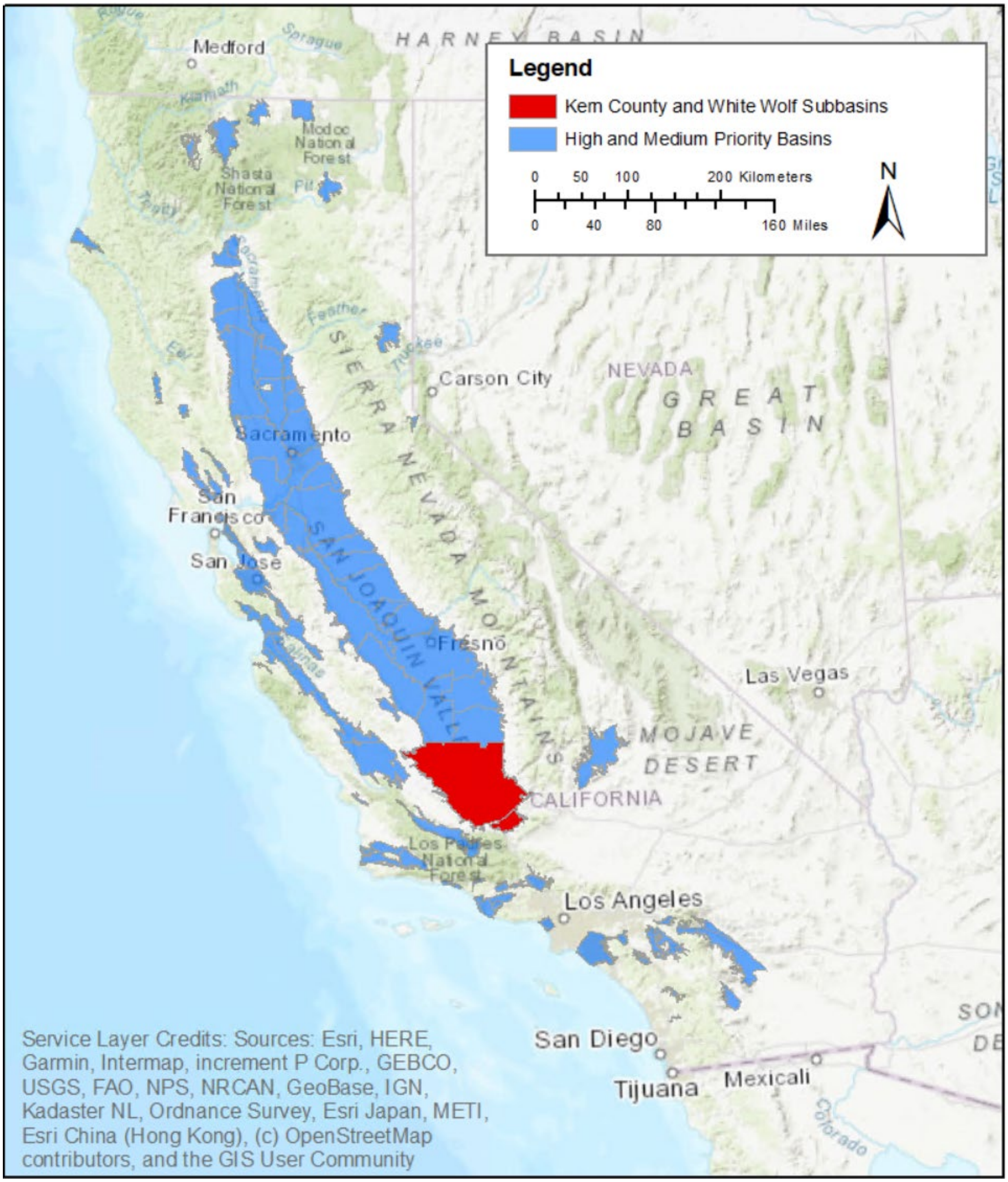


Figure 1-1 Map of California showing the SGMA medium- and high-priority basins, highlighted in blue. The Kern County and White Wolf Groundwater Subbasins, the subject of this report, are highlighted in red.

Step 5: The flight lines were transmitted to the consultant team, where they are further examined by SkyTEM and Ramboll to adjust for potential infrastructure interference and safety considerations.

All flight line planning was conducted using ArcGIS, and publicly available data were utilized when available.

1.1.2 Statewide AEM Survey Planning and Coordination

Coordination and engagement with a wide range of organizations helps to ensure that the end use of the high-value AEM data are optimized to support sustainable groundwater management activities, in addition to providing benefits to a range of state, federal, and Tribal government hydrogeologic and geologic related projects. For each priority groundwater basin to be surveyed, DWR coordinates and engages with local, state, federal agencies, and Tribal governments (where present) to develop the survey design to meet a broad number of objectives. DWR also provides ongoing coordination, communication and public outreach throughout the process to support the AEM project logistics and to ensure the community is informed of the activities, as outlined below.

Local Coordination

DWR coordinates with local GSAs within each groundwater basin planned for an AEM survey to identify important areas within their basin where they want to ensure that AEM data is collected. For many GSAs, these include areas of known data gaps, areas being considered for groundwater recharge or other projects, or areas critical to GSP implementation.

Local Data Request

DWR also requests that the local basin GSAs share high-quality, digitized lithology or geophysical logs (that are not currently available in state databases) with DWR to support the AEM data interpretation. Integration of existing lithology and geophysical logs supports and reduces the uncertainty in the interpretation of the AEM data and is incorporated into the groundwater basin flight line planning process (described in Section 3.1)

State and Federal Agency Coordination

DWR is collaborating and coordinating with state and federal agencies listed below that may benefit from the AEM data to support other state- and federal-related interests, such as fault and seismic hazard mapping, canal and aqueduct maintenance, land subsidence, managed aquifer recharge, and groundwater modeling. DWR solicits input on flight line planning, requests area maps and descriptions and provides updates on the AEM survey program status and schedule.

State Agencies

- California Department of Fish and Wildlife
- California Department of Food and Agriculture
- California Department of Water Resources
- California Geological Survey
- State Water Resources Control Board

Federal Agencies

- United States Bureau of Reclamation
- United States Geological Survey

Tribal Government Engagement

DWR elected not to survey Tribal Trust Lands (as defined by the United States Bureau of Indian Affairs) unless the Tribe within the surveyed basin indicates that data collection and publication is acceptable.

DWR engages with Tribes within the surveyed basin through meetings and letters to Tribal leaders with information about the AEM project and an invitation to elect to join the surveys. DWR will only survey Tribal Trust Lands (as defined by the United States Bureau of Indian Affairs) if the specific Tribe(s) within the basin to be surveyed indicates that data collection and publication is acceptable. Notifications of surveys are provided in lieu of invitations if data collection over the Tribal Trust Land is not possible due to technical limitations. Technical limitations can be caused by the proximity of a potential survey area to urban areas, buildings, or electromagnetic noise sources, like infrastructure and other metallic features.

The AEM Survey Schedule webpage (https://gis.water.ca.gov/app/AEM-schedule) provides a map showing the AEM survey progress and locations of federally recognized Tribal Trust Lands and the surveyed basins.

1.1.3 AEM Survey Public Outreach

Prior to initiating the surveys within a groundwater basin, DWR conducts outreach to the public to provide an overview of the project and to notify interested parties of the upcoming work. Conducting outreach is a priority for DWR to ensure that the public is comfortable with the low-flying helicopter and is aware of the importance of the project. DWR's public outreach plan in each survey area includes the following activities:

- Posting a social media announcement on DWR's LinkedIn and Twitter pages and sharing with local GSAs to be re-posted on their social media websites.
- Providing a press release to local media outlets to be shared with their subscribers; interviews were also conducted by DWR staff when requested.
- Sending notification letters (in English and Spanish) via United States Postal Services to parcel owners within a 500-meter buffer beneath the planned flight path.

These public outreach activities were conducted within one month prior to the start of the AEM survey in the Kern County and White Wolf Subbasins.

Ramboll, SkyTEM, and Sinton Helicopters conducted outreach to county law enforcement to notify them of the AEM surveys and to provide background information about the project. Prior to the surveying the following sheriff offices were contacted via mail and telephone:

- Kern County Sheriff

1.2 Kern County and White Wolf AEM Survey

For the Kern County and White Wolf AEM survey, shown on Figure 1-2, a total of 2,421.4 line-km (1,504.6 line-miles) was flown, and data acquired in from November 30 – December 15 and March 8 - 11. During the survey, the acquired AEM survey data was downloaded from the AEM instrumentation, initially checked for quality, and uploaded to a secure server for storage and subsequent analysis on a daily basis.

Parallel to the collection and processing of the AEM data, well information along the flight lines was gathered and compiled in a project data management system. The well data collected includes lithology, geophysical logs, water level measurements and water quality (TDS) measurements. The processed and inverted AEM resistivity data was then analyzed in combination with the well data, providing information on how resistivity relates to lithology. This report provides a summary and documentation of the listed tasks, including the methods used, results, uncertainty, and quality control.

1.3 Basin Geology

This report has a focus on the AEM data collected in the Kern County and White Wolf Groundwater Subbasins. However, the basins' hydrogeology determines the resistivity distribution in the subsurface; therefore, a very basic hydrogeological description of the Kern County and White Wolf Groundwater Subbasins is provided in this section, providing the general background for this section. For more information, please see the descriptions in Bulletin 118 (https://water.ca.gov/programs/groundwater-management/bulletin-118) as well as the GSPs submitted for the Subbasins (https://sgma.water.ca.gov/portal/gsp/status).

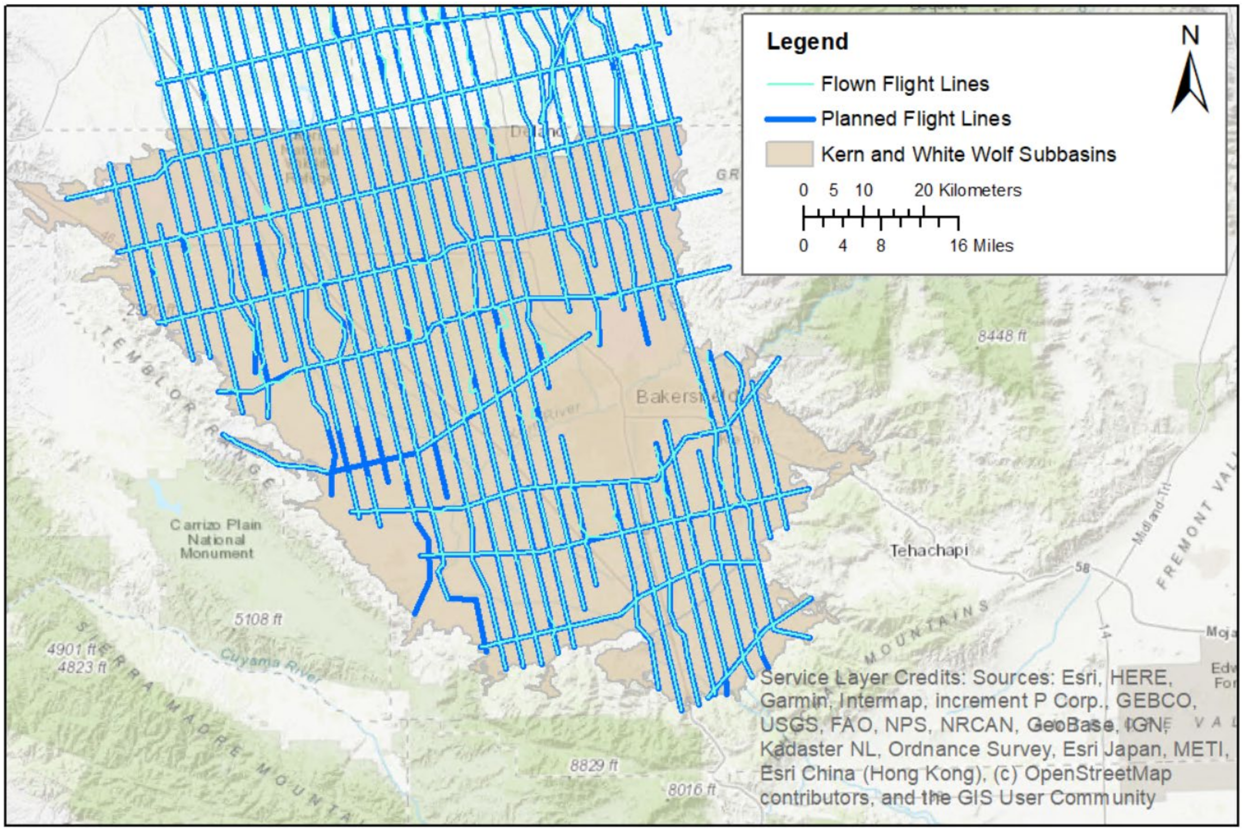


Figure 1-2 Map showing the flight lines flown in the Kern County and White Wolf Groundwater Subbasins. The subbasins are shown in brown.

The surface geology of the Kern County Groundwater Subbasin is primarily comprised of Quaternary alluvium, overlain by beds and fans of older alluvium and Pliocene/Pleistocene sandstone, shale and gravel deposits found along the western and eastern boundaries of the subbasin (CGS, 2010). The subbasin is bounded to the east by the crystalline bedrock of the Sierra Nevada to the east (DWR, 2003) and to the south by the White Wolf Fault (CGS, 2010). Major water bearing units in the subbasin are Tertiary and Quaternary continental deposits (DWR, 2003).

The White Wolf Groundwater Subbasin is a structural trough filled with continental and marine deposits bounded to the north by the White Wolf Fault, and to the south, east, and west by alluvial and bedrock contacts (DWR, 2018). The surficial geology is comprised primarily of Quaternary alluvium, with older alluvium and Pliocene/Pleistocene sandstone, shale and gravel deposits found along the subbasin margins (CGS, 2010). Water bearing formations are primarily composed of alluvium.

1.4 Report Contents and Appendices

The data report for the Kern County and White Wolf Groundwater Subbasins survey is divided up into a main body and 11 appendices. The purpose of the main report is to provide a general overview of the activities conducted and a basic description of the methodology and results. The main report is divided into six sections. The first section includes an introduction to the California statewide AEM survey and the specific survey for Kern County and White Wolf Groundwater Basins. Section 2 gives a brief description of the geography and hydrogeology. Section 3 provides a description of the data collection, including the acquisition of the AEM data as well as the gathering of well data along the planned flight lines. Section 4 presents the AEM processing and inversion methods, results, and uncertainty.

The report appendices provide detailed technical documentation of all the activities conducted including survey methodology. The results and quality control measures undertaken before, during, and upon completion of the AEM surveys, and include:

- Appendix 1 - Detailed description and presentation of the well data gathered along the planned flight lines, a description of the data management system, and the quality control checks of the collected well data included in the data management system.
- Appendix 2 - Technical details on the acquisition and quality control of the AEM data.
- Appendix 3 - Technical details of the processing and inversion of the AEM data, including methodology, results, uncertainty and quality control.
- Appendix 6 – Profile atlas containing the smooth resistivity model and the total magnetic intensity.
- Appendix 7 – Profile atlas containing the 30-layer sharp inversion model, the 4-layer model and the resistivity uncertainty analysis.
- Appendix 10 - Resistivity maps, broken out for specific elevation intervals and as depth intervals.
- Appendix 11 - Description of the deliverables.

Appendix 4 and Appendix 5, containing a description of the lithology model and initial hydrostratigraphic model, and Appendix 8 and Appendix 9, containing the profile atlas of the lithology model and initial hydrostratigraphic model, are awaiting the modeling results and will be added to the report at a later date.

2. HYDROGEOLOGIC DATA ACQUISITION AND COMPILATION

Lithologic data, resistivity logs, water level measurements, and water quality (TDS) measurements from wells were assembled for the Kern County and White Wolf Groundwater Subbasins. The data were compiled for wells along the planned flight lines before they were flown. This data was then quality control checked and assembled into a data management system (DMS) for this project. This section provides a brief description of the results for the collection of the well data. A detailed description of the data compilation process and results is presented in Appendix 1.

2.1 Well Lithology Logs

For this project, the contractual objective was to obtain a minimum of two “best available” lithology logs from available well completion reports for each Public Land Survey System (PLSS) one-mile square section the flight lines cross. Best available lithology logs are defined as logs which can be accurately located within 50 meters (m) (165 feet [ft]), and that contain high-quality lithologic descriptions based on the detail in both the description and discretization. A lithology log is considered high quality if the log’s descriptions extend more than 30 m (100 ft) below ground surface, and the average description interval is less than 30 m (100 ft) (i.e., there are at least one lithologic description for every 30 m on average); otherwise, it is considered a low-quality lithology log.

In total, the planned flight lines cross 1,811 PLSS sections, as shown on Figure 2-1. There are a total of 920 high-quality lithology logs distributed across 592 PLSS sections that the flight lines cross. There are 256 sections that contain two or more high-quality lithology logs, 336 sections that contain only one high-quality log, and 1,219 sections that contain no high-quality logs. In total, there are 114 sections that contain only low-quality logs and 1,105 sections that do not contain any lithology logs. Of the 920 high-quality lithology logs, 98 were obtained directly from the local agencies, 183 were digitally available from the Online System for Well Completion Reports (OSWCR) database, and 639 were digitized for this project (as described in Appendix 1).

Note that in Figure 2-1, the flight lines cross into adjacent subbasins to the north. These subbasins are also part of Survey Area 4 but are covered in a separate report.

The well lithology log data was added to the project DMS. The lithologic descriptions in the DMS was then standardized with regards to their different descriptors to conform with the Unified Soils Classification System (USCS). They were then simplified into three basic textures: fine, coarse and rock. The data entered into the DMS was quality control checked with regards to the well placement and lithology transcription. All wells digitized by the project team were quality control checked. A random control check of 10% of the wells provided by local agencies and from the OSWCR database was then conducted.

2.2 Well Geophysical Logs

For this project, high-quality electrical resistivity logs were compiled from wells from the CalGEM database that are within the PLSS sections in which the flight lines cross. High-quality electrical resistivity logs are defined as being located with an accuracy of 50 m (165 ft), with measurements over the interval of 0 to 300 m (1,000 ft) below ground surface, and that have a hard copy log image of sufficient quality to be digitized. However, logs that were more than 40-years old or within an oil field were not included due to the changing hydrological conditions in the basin over time (potential changes in water levels and groundwater salinity), and the metal infrastructure within oil fields that interfere with the AEM survey signal. In the study area, there were 104 resistivity logs in the CalGEM database within the sections which met the criteria.

Geophysical logs were also compiled for the DMS by RealTime Aquifer Services (RAS), a part of the contractor team, as well as by AECOM via the local agencies. RAS provided 12 geophysical logs located within PLSS sections crossed by a flight line, and the local agencies provided 29.

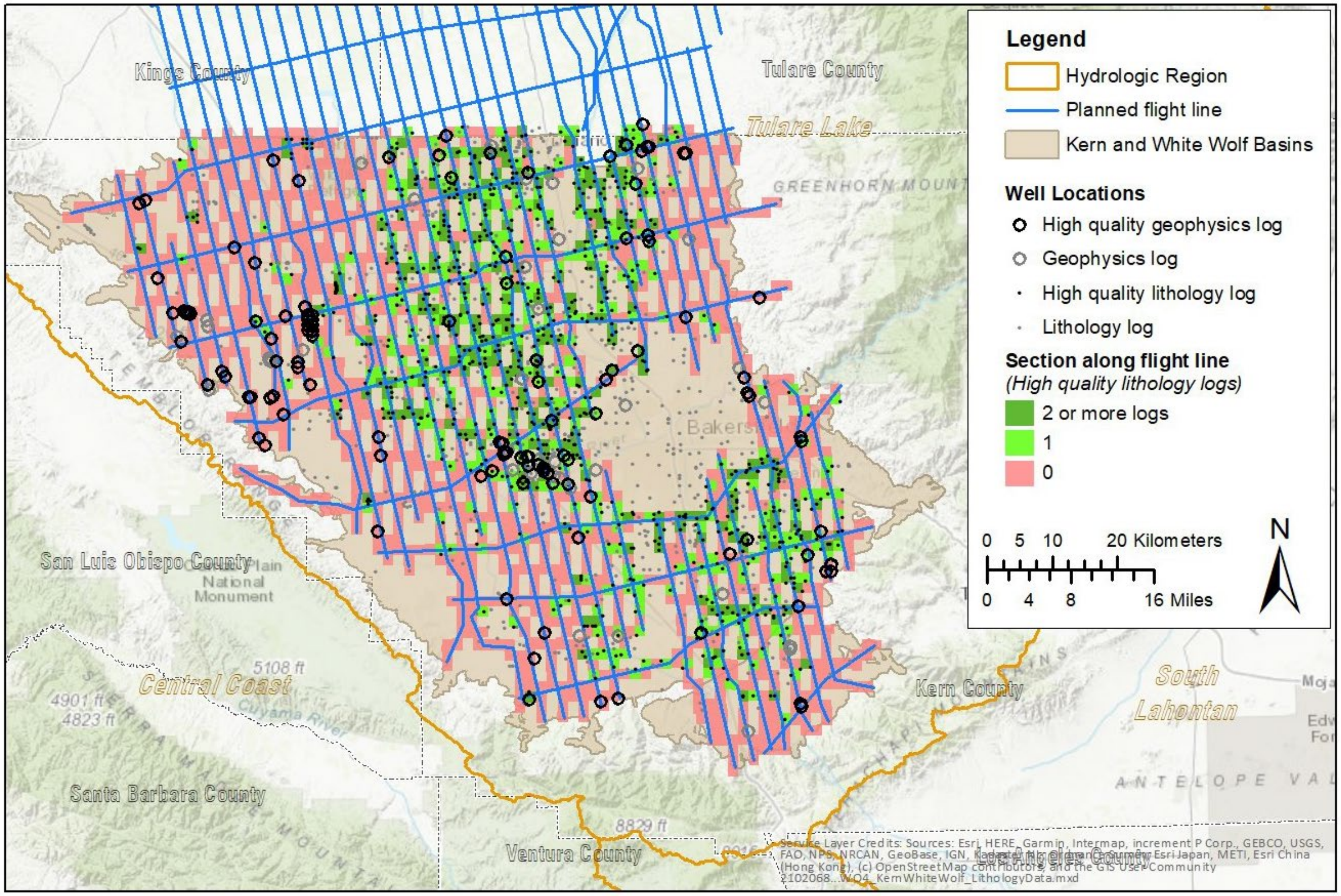


Figure 2-1 The location of well lithology and geophysical logs within the study area used in the AEM survey. The map shows the flight lines in blue and the wells within the PLSS sections that the flight lines cross. The sections with two or more high-quality lithology logs are shown in dark green, sections with one high-quality log in light green, and sections without high-quality logs as light red.

2.3 Groundwater Occurrence

Information on the depth to groundwater is important in the interpretation of geophysical data because the electrical resistivity of subsurface lithologies differs between unsaturated and saturated conditions. Understanding the depth to groundwater supports the AEM data inversion process. Figure 2-2 shows depths to groundwater for select wells in the study area. For more detailed information on groundwater occurrence see the GSPs for the basins.

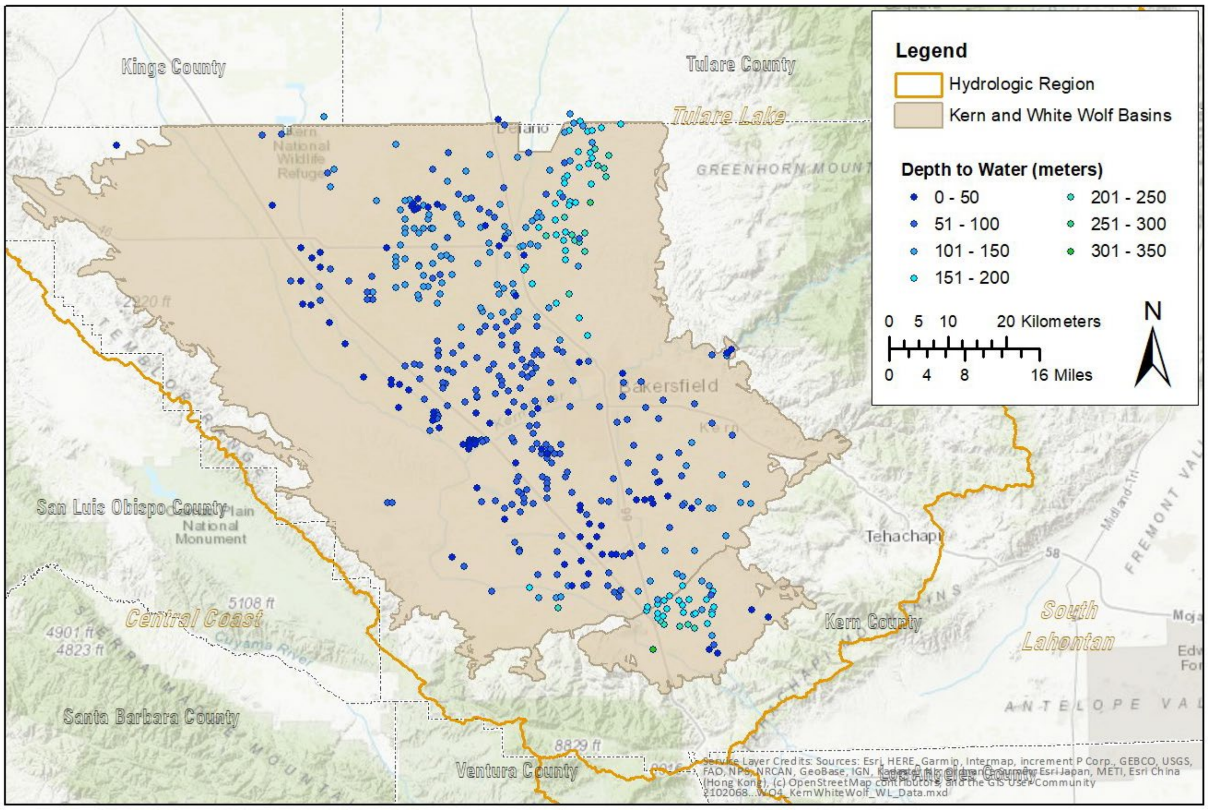


Figure 2-2 A map showing the depths to groundwater in the study area for select wells between 2020 and 2022. Shallow depths to water (< 50 m) are shown in blue, depths to water between 151 and 200 m are in blue-green, and depths to water between 301 and 350 m are in green.

2.4 Total Dissolved Solids in Groundwater

Groundwater quality is important to geophysical interpretation because electrical conductivity varies depending on the dissolved constituents in groundwater. These can vary by depth, aquifer, and geographic location within a groundwater basin. A measure of the amount of dissolved constituents is recorded in total dissolved solids (TDS) concentrations. In addition to TDS measurements, electrical conductivity (EC) is often measured directly. TDS and EC vary proportionally to one another. Both measurements were assembled from the State Water Resources Control Board's (SWRCB) Groundwater Ambient Monitoring and Assessment (GAMA) system. The GAMA system is the most comprehensive, readily available, and reliable water quality dataset. It includes data collected from various federal, state, and local programs. This dataset is being updated by the state as new water quality data is reported to the state for compliance monitoring.

Figure 2-3 shows available water quality data throughout the study area. For sites with concurrent TDS and EC measurements, TDS was used. TDS and EC vary proportionally to each other, but the conversion factor (from EC in micromhos per centimeter to TDS in milligrams per liter) depends on the specific constituents within the sample and can range from 0.5 to 0.75 (Rusydi 2018). For plotting purposes, an average conversion factor of 0.625 was used. TDS values within the study area range from less than 450 milligrams per Liter (mg/L) to over 3,150 mg/L.

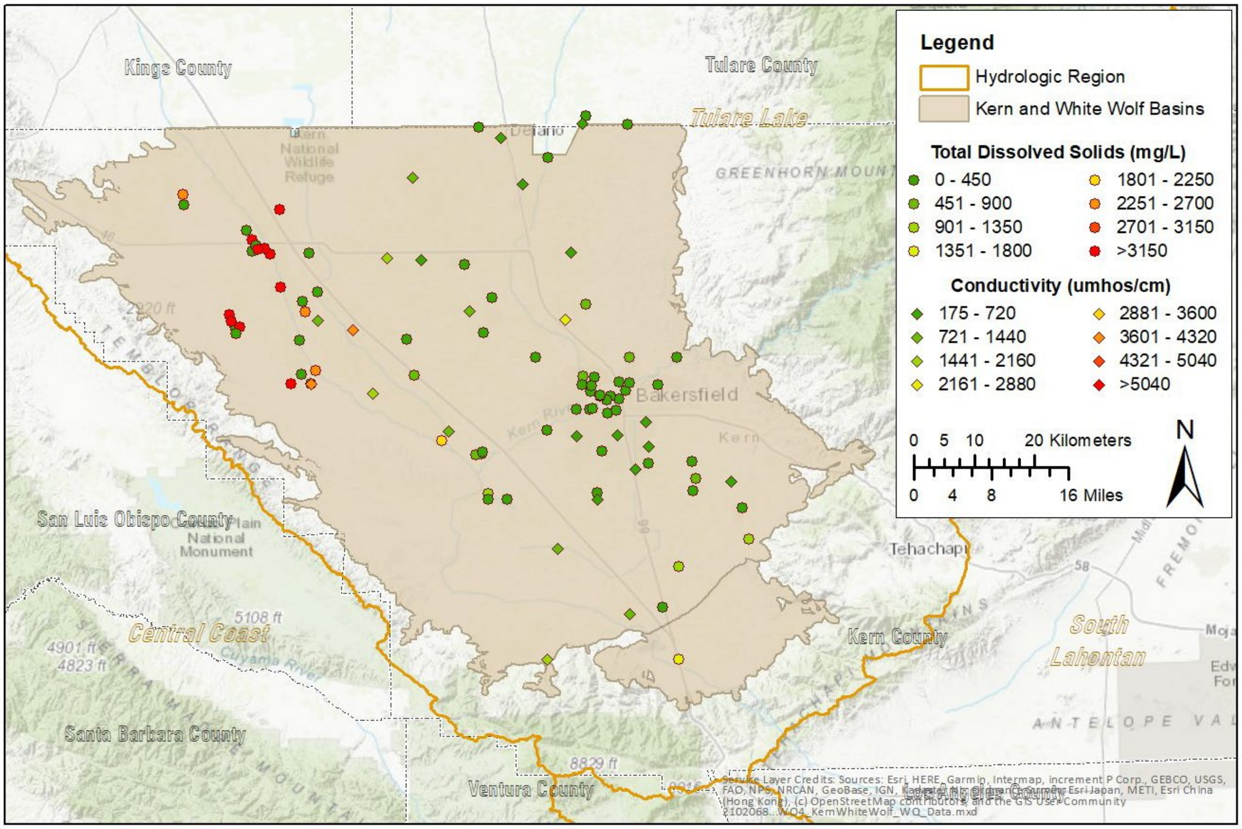


Figure 2-3 Map showing the TDS and conductivity for select wells in the study area between 2005 and 2018.

3. AIRBORNE ELECTROMAGNETICS SURVEY

3.1 Basin AEM Survey Methodology, Objectives and Flight Line Planning

This section introduces the methodology used for the AEM data acquisition, describes survey objectives, and discusses procedures taken for flight planning.

3.1.1 AEM Survey Methodology

The AEM survey method being used is a time-domain or transient electromagnetic method, known as TEM. The TEM methods are based on the principle of inducing electrical currents into the subsurface and receiving Earth's response over a short period of time. The TEM-instrumentation consists of a transmitter loop, a receiver coil, electronic instrumentations, and several auxiliary devices.

During each transient measurement, direct current is initiated through the transmitter loop. After a short time, the current is abruptly turned off. This abrupt turn-off induces electrical currents (called eddy currents) in the subsurface, which in return, generates secondary magnetic fields that decay with time. The decaying magnetic fields are measured using the receiver coil as a voltage timeseries, also referred to as a sounding. An optimization algorithm, called inversion, is then applied to the processed data to yield estimates of the subsurface electrical resistivity structure, called resistivity models.

The TEM system can be deployed on the ground surface for stationary measurements or carried on moving platforms such as sleds, boats or, in the case of AEM, carried by a helicopter or airplane. Figure 3-1 provides an image of the actual AEM system, operated by SkyTEM Surveys, and helicopter, owned by Sinton Helicopters, being used in the DWR AEM statewide surveys.

An example of a single sounding of AEM data and corresponding resistivity model of the subsurface is shown in Figure 3-2. During the inversion, the entire AEM dataset is inverted together and the resistivity model for each sounding is constrained. This is done by introducing a dependency in between models for neighboring soundings, as discussed in Section 4 and Appendix 3.

More information on the physical principles of the TEM method can be found in Ward and Hohmann (1988) and Schamper et al. (2013) and in Appendix 2. A detailed description of the SkyTEM/AEM system used in this survey can be found in Section 3.2.1 and Appendix 2.

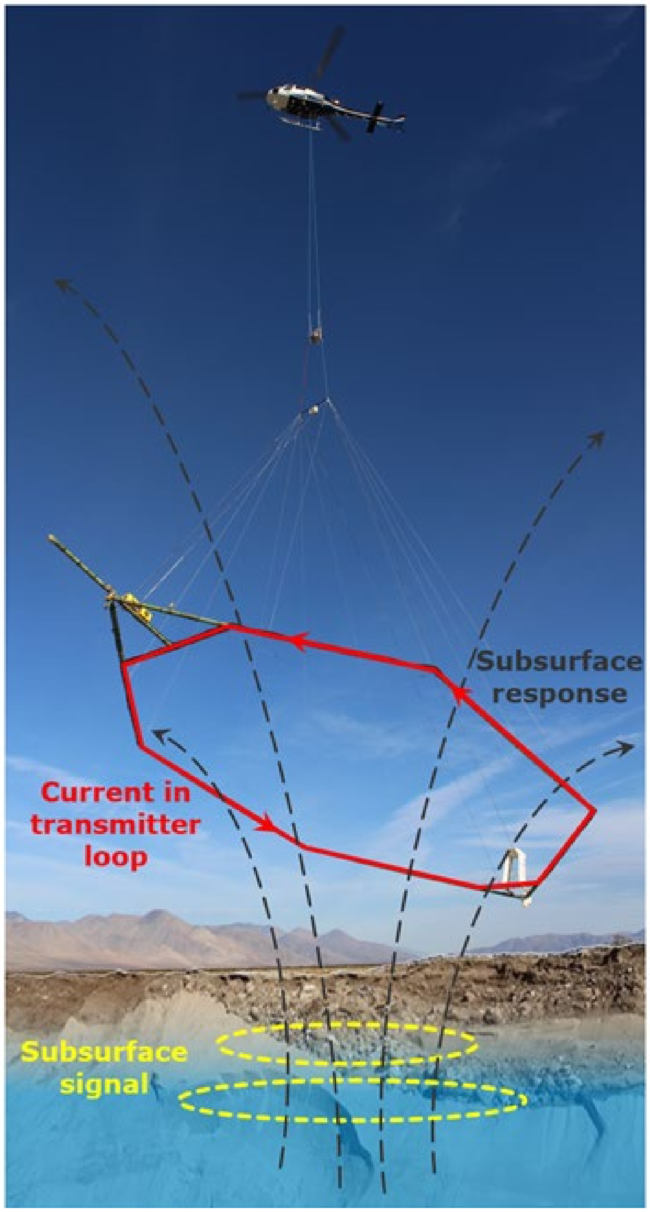


Figure 3-1 Figure showing the AEM Survey Schematic including the transmitter loop (current in red), subsurface signal (in yellow), and subsurface response (in dashed black lines) which is picked up by the system receiver. Note: the illustration does not include primary magnetic fields.

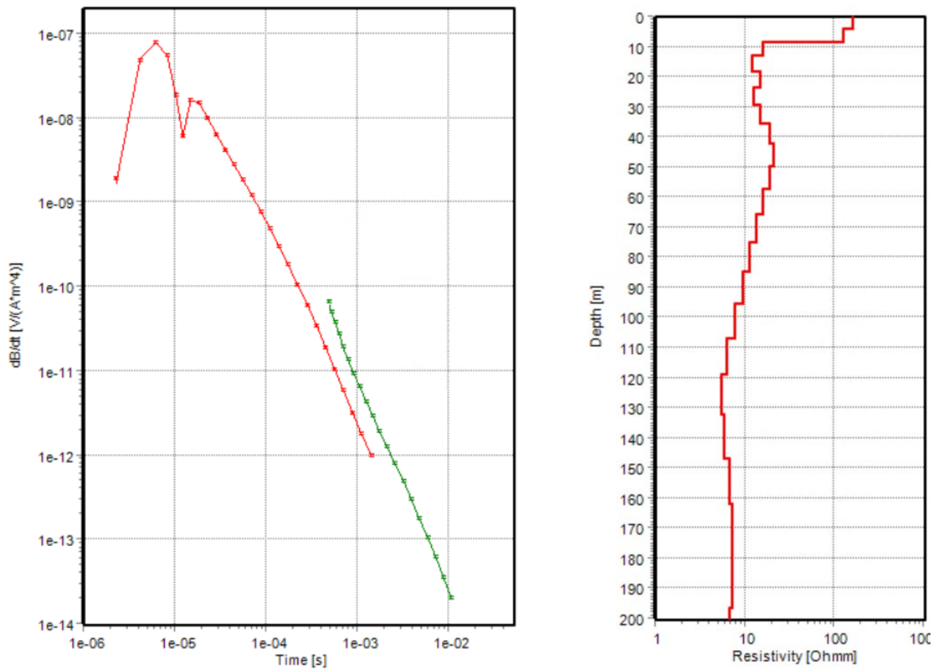


Figure 3-2 An example of a single sounding of acquired AEM data (change in magnetic field as a function of time) shown on the left-hand side, and a corresponding resistivity model showing the modeled resistivity from the ground surface to a depth of 200 m (650 ft).

3.1.2 Kern County and White Wolf AEM Survey Flight Line Planning

The flight lines for the AEM survey were prepared by DWR as discussed in Section 1.1.2, and provided to Ramboll for execution. Ramboll, SkyTEM and Sinton Helicopters conducted a review of the planned flight lines on aerial photos from Google Earth and aeronautical charts to identify possible safety considerations in relation to:

- Built up areas which will need to be diverted around
- Trees and forested areas which the pilot will need to climb in elevation or divert around
- Towers, power lines, and other infrastructure that the pilot will need to climb in elevation or divert around
- Major roads which the pilot will need to navigate around
- Restricted air space
- Restricted areas due to endangered species

A proposed flight line plan was then prepared incorporating the safety review of the DWR flight lines and landing zone bases (small airports) that were identified for survey logistics, equipment checks and data downloads, and fueling. The safety considerations and proposed flight line plan were presented to DWR for final review, and subsequently approved for execution.

Figure 3-3 shows a map of the planned flight lines along with the land use within the Kern County and White Wolf Groundwater Subbasins. During flight line execution, Sinton Helicopters sometimes had to diverge slightly from the planned flight while flying based on visual observation of potential safety issues such as the presence of people, livestock or other safety hazards (shown in Figure 3-5).

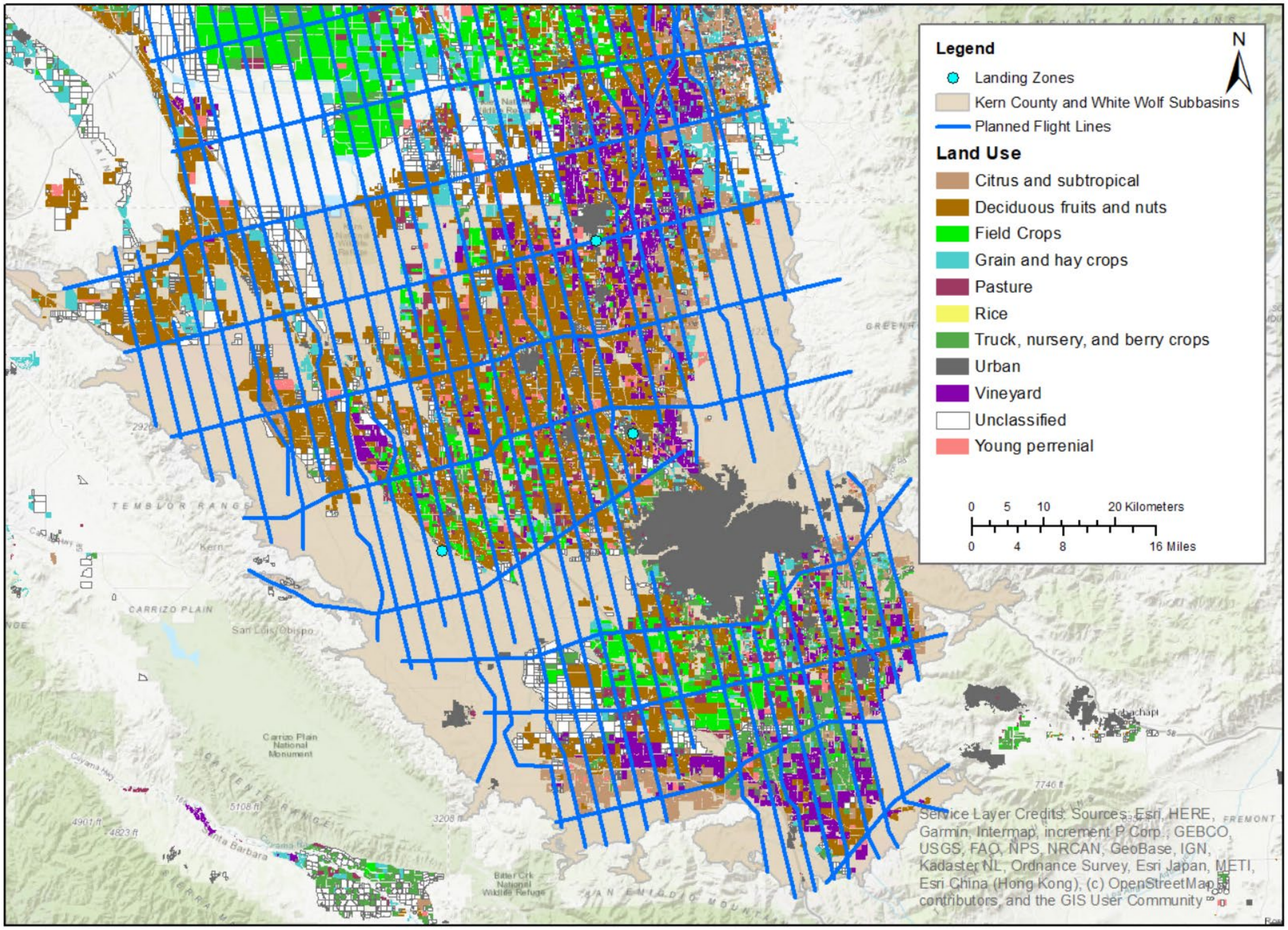


Figure 3-3 A map showing the planned flight lines (dark blue), the landing zones (light blue circle) and the surrounding land use types.. Urban areas are shown in grey, vineyards are in purple, and the remaining areas are various types of agriculture.

3.2 Basin AEM Survey

3.2.1 Basin AEM Survey Equipment and Instrumentation

The helicopter-borne SkyTEM312M time-domain electromagnetic system was used during this survey. Throughout this report, the terms SkyTEM, SkyTEM312M, and AEM are used synonymously to indicate the geophysical survey equipment.

The AEM system is carried as a sling load, suspended 30 m (98 ft) beneath the helicopter and flown 30-50 m (98-164 ft) above the land surface (Figure 3-4) while flying at a groundspeed of 80-100 kph (50–62 mph). The system is designed for hydrogeological, environmental, and mineral investigations. The SkyTEM312M system has a transmitter loop area of 342 m^2 (3,681 ft^2) contained within a hexagonal frame towed beneath the helicopter.

In addition to acquiring electromagnetic data, which provides information about the resistivity structure of the subsurface, the system also collects magnetic data, which is primarily used for mapping magnetic anomalies, fractures, and faults. Auxiliary data is also recorded and include GPS data for positional accuracy, the pitch and roll of the system, laser altimeter data for elevation, and video for a record of the ground surface along the flight path. A more comprehensive description of the TEM methodology can be found in Appendix 2.

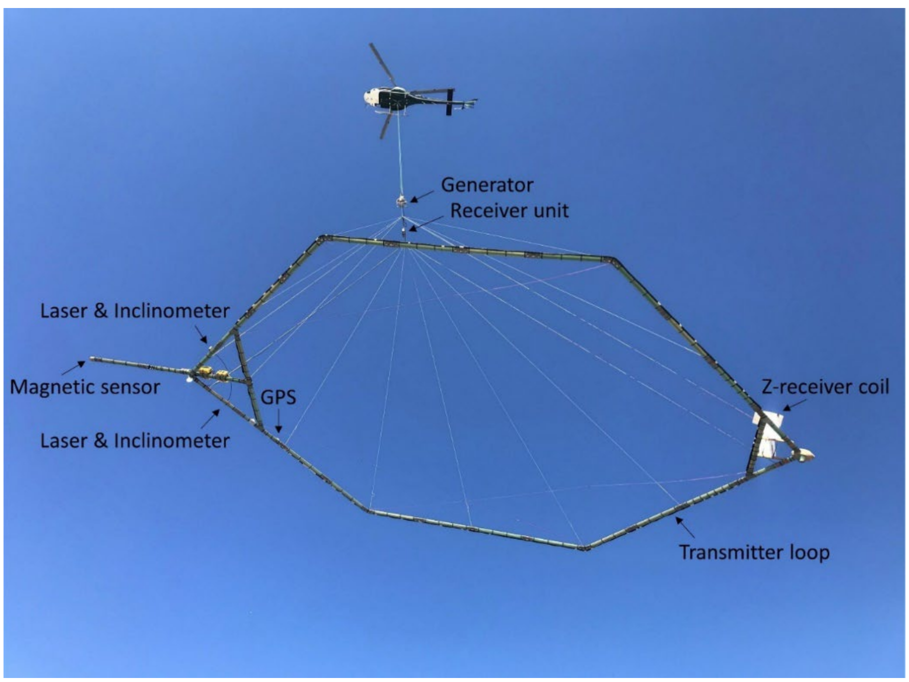


Figure 3-4 AEM Equipment and instrumentation configuration. The picture shows the helicopter towing the hexagonal transmitter loop. The front of the loop contains the GPS, laser, inclinometer and magnetic sensor. At the back of the loop is the Z-receiver coil. Suspended between the transmitter loop and the helicopter are the generator and receiver unit.

3.2.2 Landing Zones

Multiple locations were used as landing zone bases throughout the survey. These included the Shafter Airport, Minter Field (November 30, 2021, December 1-15, 2021, and March 8-11, 2022), Delano Airport (December 3, 2021) and Elk Hills – Buttonwillow Airport (December 11-12, 2021), see Figure 3-5.

3.2.3 Basin AEM Survey Data Acquisition

The AEM survey was carried out between November 30 – December 15, 2021, and March 8-11, 2022. A total of 2,421.4 line-km (1,504.6 line-miles) of data was acquired.

Before, during and after the acquisition of the AEM data, several measures were taken to ensure that the AEM system functions properly, and the quality of the acquired data was acceptable. During the initial on-site SkyTEM system set-up phase, very high-altitude tests, waveform, configuration settings and null positions were checked in collaboration with SkyTEM to ensure that the configuration and specifications were as agreed upon in the contract.

During the survey, SkyTEM provided daily updates, including a map of daily production, high-altitude test, raw electromagnetic, magnetic, and reference line data (see Appendix 2), which was quality control checked on a daily basis by Ramboll. The quality of the data evaluated daily during The Kern County and White Wolf Groundwater Subbasins AEM survey was found to be acceptable.

Figure 3-5 shows the actual flown flight lines compared with the planned flight lines. In general, it was not necessary to deviate significantly from the planned flight lines in the Kern County and White Wolf Groundwater Subbasins. Figure 3-6 shows three photos of the AEM array during data acquisition.

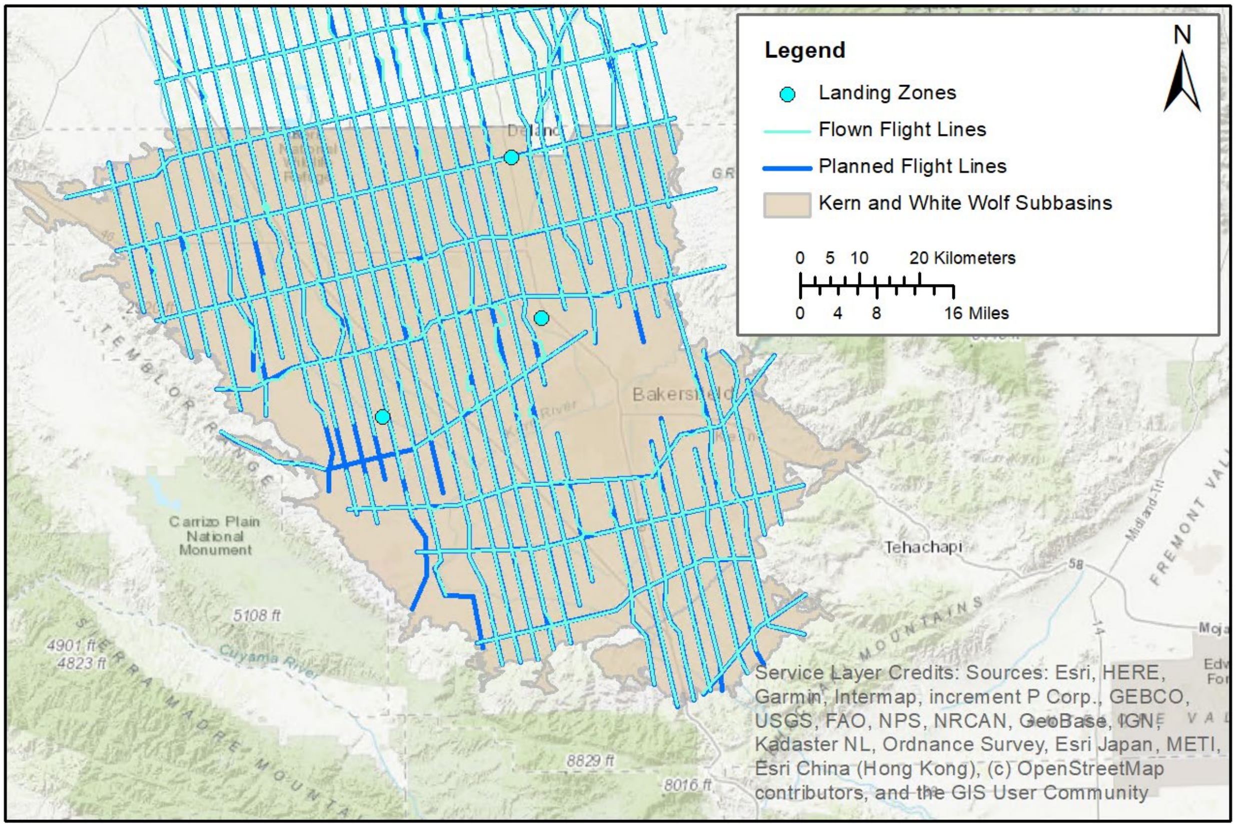


Figure 3-5 Map showing the planned and flown flight lines in the Kern County and White Wolf Groundwater Subbasins. The planned flight lines are shown as the thicker dark blue lines and the actual flown lines are shown as thin light blue lines. The light blue dots show the location of the landing zone bases for the flights conducted in the area.

Figure 3-6 Photos of the AEM flights for top photo shows the AEM system taking off at Shafter Airport. The bottom left shows the helicopter towing the array during the survey NE of Shafter and the bottom right shows the system landing at Buttonwillow Airport.

3.2.4 Reference Lines

Reference lines are flight lines that are repeated, with the purpose to compare the initial and repeated flight line results to ensure the reproducibility of the AEM system during the survey to validate instrument performance, to identify any potential drift and to document the stability of the data processing and inversion algorithms. One or more reference lines were flown during each production day during the November 30 – December 15, 2021, and March 8-11, 2022 surveys, which resulted in a total of twenty reference lines in 2 locations ranging from ~ 1,000 m to ~ 1,400 m (3,280 - 4,593 ft) in length.

The results of the reference lines demonstrate that the AEM system was not affected by drift or instrumentation issues. It also showed that the processing and inversion schemes were consistent, and the results demonstrate that the data is highly repeatable. More information and the results of the reference lines can be found in Appendix 2.

4. AEM DATA PROCESSING, INVERSION, AND RESULTS

The AEM dataset acquired during the survey comprises a set of voltage time series, which is the response signal resulting from the electromagnetic pulses produced by the AEM transmitter loop. Auxiliary data (e.g., GPS and height measurements) is also acquired. To obtain quantitative information on the subsurface resistivity from the raw AEM data, the data must go through the steps of processing and inversion. Processing refers to actions that prepare the data for inversion, including the removal of noisy or coupled AEM data, and the application of averaging filters to the data. Filters are applied to obtain usable, noise-free data and optimize lateral resolution. Inversion refers to the numerical optimization algorithm that identifies the subsurface resistivity distribution that agrees with the AEM data. Here, we present an overview of the processing and inversion, as well as a selection of the resulting resistivity models. A more thorough review of the processing and inversion is presented in Appendix 3, and the full set of resistivity models resulting from the processing and inversion steps are shown in Appendix 6.

4.1 AEM Data Processing and Inversion

After the raw (electromagnetic & auxiliary) data was checked for quality, they were imported into the Aarhus Workbench software for data processing and inversion, which comprised the following steps:

1. Process auxiliary data (e.g., GPS, height)
2. Process AEM data automatically and manually
3. Run inversion on the AEM data
4. Calculate the depth of investigation from AEM data
5. Run uncertainty analysis on AEM data

4.1.1 Data Processing

The first data to be processed are the auxiliary data: these data include pitch and roll (tilt) data, transmitter height data, and GPS data. The tilt and transmitter height data affect the raw AEM measurement and must be accounted for during the inversion. While the GPS data are needed to relate each measurement with its correct geographic position. Each type of auxiliary data was quality control checked before being used in the inversion. To relate the resistivity models to the topography of the landscape, a terrain elevation was assigned to each electromagnetic sounding using a digital elevation model (DEM). For more information about these steps see Appendix 3.

Next, the raw AEM data (voltage timeseries) were processed to prepare for inversion. The AEM system continuously makes electromagnetic measurements, which results in approximately 25-35 measurements per kilometer along each flight line. The AEM data processing comprises an automatic and a manual component. The automatic processing requires selection of appropriate filters and other parameters. After automatic processing, the data are manually reviewed for noise, as well as interference from infrastructure, such as powerlines or pipes. The distance of AEM data locations to human-made structures was considered, and portions of the dataset were selectively removed. The AEM data processing is an iterative process, which requires revisiting the data after each step, and again after provisional inversion results is visualized. Detailed information about the voltage timeseries data processing steps and settings are provided in Appendix 3.

4.1.2 Inversion

Once the auxiliary and AEM data was processed, they data was used to produce resistivity models through inversion. The inversion is an iterative optimization, where the resistivity model at each location where AEM data was acquired (i.e., each sounding) along each flight line, is used to calculate synthetic AEM data. These synthetic AEM data are compared to the processed AEM data acquired during the survey. The misfit between the observed and synthetic data is used as a criterion to update the resistivity model, and the process is repeated. While minimizing the data misfit, the employed inversion scheme enables applying vertical constraints (i.e., between the resistivity values of adjacent layers) and spatial constraints (i.e., along and between flight lines), to allow the migration of information to nearby AEM data. Once the synthetic AEM data match the acquired AEM data within a specified tolerance, the resistivity model is considered final.

All AEM data were inverted simultaneously using the spatially constrained inversion (SCI) approach (Viezzoli et al., 2008), which accounts for all model parameters, AEM data and spatial constraints. The system setup information (AEM equipment metrics) is used during the inversion when calculating the synthetic AEM data. The inversion algorithm requires user input on specific values, including the depth discretization of the resistivity model (i.e., the estimate of the subsurface resistivity structure), the initial estimate of resistivity values, and horizontal and vertical constraints. Each value is selected based on the AEM system setup, depth interval of interest, and background geologic information of the study area; multiple inversions may be run on the same dataset to find the optimal values for these input values. Typically, two to three inversions are run on the dataset to 1) finalize the processing of the data (e.g., by removing noisy or coupled data that appear in the inversion result) and 2) obtain final input values for the inversion. Detailed information of the inversion approach can be found in Auken et al. (2015) and Appendix 3.

4.1.2.1 Inversion Schemes

Using the SCI approach with a different setup, the AEM data can be inverted to result in different types of resistivity-depth models. The following inversion schemes were used in this study:

- <u>Smooth inversion</u>: in this scheme, many layers (20-30) are used in the model, where each layer thickness is larger than that of the layer above it. Each layer thickness remains fixed during iterations of the inversion, but the resistivity value of each layer is allowed to vary. Using spatial constraints, resistivity values are restricted to stay within a factor of neighboring resistivity values, resulting in smoothly varying resistivity-depth models.

- Few-layer inversion: in this scheme, a small number of layers (typically 3-6) are used in the model; both the resistivity and thickness of each layer are allowed to vary during the inversion. The few-layer inversion can represent sharp boundaries in the subsurface, unlike the smooth inversion. The few-layer inversion is used in this project for the uncertainty analysis since the uncertainty in the thickness and depth of each layer can be analyzed (unlike in the smooth and sharp inversions).
- Sharp inversion: Like the smooth inversion, the sharp inversion uses many layers. Like the few-layer inversion, the sharp inversion is favorable when expecting sharp layer boundaries. However, unlike the smooth inversion, the sharp inversion is designed to support both gradual and abrupt changes in resistivity values (Vignoli et al., 2015). Furthermore, the sharp inversion overcomes the limitation in the few-layer inversion of setting a small, constant number of layers in the inversion over a large survey area, where conditions are likely to change spatially. Because of these advantages, the results from the sharp inversion were used to develop the lithology model and initial hydrostratigraphic model.

For detailed description of the three inversion schemes, see Appendix 3.

4.1.2.2 Depth of Investigation

The resistivity models resulting from each inversion were used to calculate the depth of investigation (DOI). The DOI is dependent upon the geology, water quality and data quality: areas with thick conductive clays and saline water will typically have a shallower DOI than sands and fresh water. The DOI gives an indication of the depth to which a resistivity-depth model can be considered reliable, and below which there is an elevated uncertainty. Since the AEM method is a diffusive method, it is not possible to define an exact DOI, below which there is no information on the resistivity structure. Thus, resistivity information below the DOI still may be useful, but interpretation of resistivity values below the DOI is cautioned. In this study, the DOI was calculated using sensitivity information output from the inversion, following the approach presented by Christiansen et al. (2012). More information about the DOI can be found in Appendix 3. The resulting DOI varies throughout the survey area; a histogram of all DOI values can be seen in Figure 4-1. Along the western side of the survey area, the DOI is typically below 150 m (490 ft), while in the rest of the survey area, it is typically 175- 250 m (575 – 1150 ft).

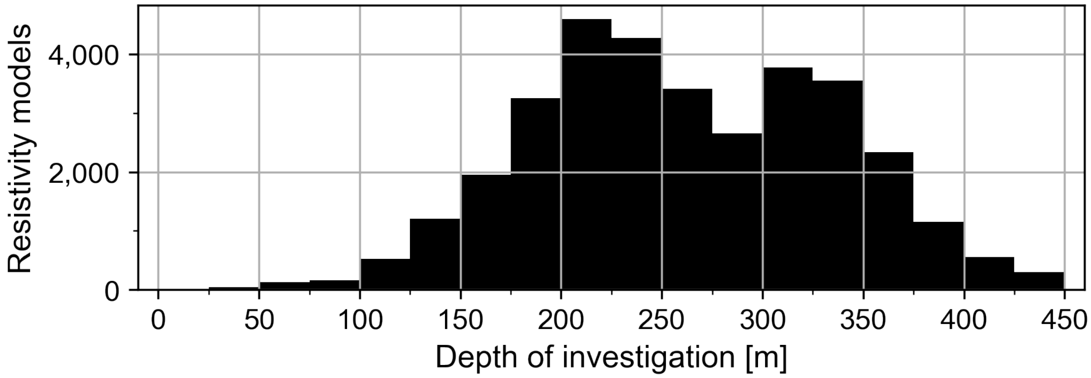


Figure 4-1 Depth of investigation histogram for all resistivity models in the smooth inversion. Most resistivity models have a DOI between 175 and 350 m.

4.1.2.3 Inversion Uncertainty Analysis

The acquired AEM data are affected by environmental noise, both natural and anthropogenic, which is presented as the standard deviation, or error bars, on the data. The uncertainty in the raw AEM data propagates through the inversion to the parameters of the output resistivity models. In the case of the smooth and sharp inversions, the parameters with associated uncertainty are resistivity values for all layers of the model. The few-layer inversion, which allows the thickness of each layer to vary, has two additional parameters with associated uncertainty: the layer thickness and depth to the bottom of each layer.

For the employed inversion approaches, the model parameter uncertainties are estimated based on the *a posteriori* model covariance matrix and presented as normalized standard deviation factors (STDFs). The STDFs are classified in different intervals, ranging from very well determined parameters (low STDFs) to undetermined parameters (high STDFs). For details about the calculation of the model parameter uncertainties and how to read the uncertainty sections, see Appendix 3. The uncertainty analysis sections for the few-layer model, corresponding with the resistivity sections, are presented in Appendix 3, Section 8.3. The uncertainty analyses for the smooth and sharp models are provided as tables and databases described in Appendix 11.

4.2 Selected Results

The resistivity models resulting from the inversion of AEM data can be presented as vertical sections or as plan-view maps. In this section, selected results of each are illustrated.

The entire set of vertical sections are presented in Appendix 6 and Appendix 7: Appendix 6 presents the results of the smooth inversion, and Appendix 7 presents the results of the sharp inversion, few-layer inversion, and the uncertainty analysis. In this section as well as in the appendices, the data displayed in the vertical sections are projected onto vertical planes, the location of which is defined by a profile line. These profile lines are based on the planned flight lines to keep each profile with as few turns as possible. Each profile is up to 17 km, and a 1 km overlap is applied to adjacent profiles along the same flight line.

The entire set of plan-view resistivity maps are shown in Appendix 10. In this section, as well as in Appendix 10, the plan-view maps display horizontal “slices”, where each slice is the average resistivity over a vertical interval, defined by either depth or elevation.

A color scale was developed to illustrate the resistivity models as vertical sections and plan-view maps. On each resistivity color scale, cool colors (blues, greens) represent lower resistivity values, while warm colors (reds, purples) represent higher resistivity values. For the resistivity models in this survey, an interval of 3-300 ohm-m was used to illustrate structural variations across the survey area. The color scale is shown in Figure 4-2 through Figure 4-9.

4.2.1 Vertical Resistivity Sections

In this section, three vertical model-sections (Figure 4-2 through Figure 4-4) across the surveyed area are provided to illustrate the geographical variations with a focus on how the generated resistivity models compare to well lithology logs, geophysical logs (e-logs), and water levels. Detailed geologic structures (folding and possible faulting) are evident along the sections. In addition, an example of model uncertainties calculated for a specific flight section is illustrated in Figure 4-6.

4.2.1.1 Section 201300, Distance Interval 0-16 km

Figure 4-2 shows a section spanning 16 km in the White Wolf subbasin. Two deep geophysical resistivity logs and two water level measurements can be seen along the section. The resistivity data from boreholes begins close to the DOI of the AEM data, providing complementary information to the AEM data that extends the understanding of the resistivity structure to the deeper subsurface. In the depth interval they overlap, the borehole and AEM resistivity data agree closely.

4.2.1.2 Section 200600, Distance Interval 79-96 km

Figure 4-3 shows a 17-km-long section at the northeastern edge of the Kern County subbasin. The water level measurements along the profile descend gradually from 30 meters (m) below ground surface (bgs) at the 82 km mark to 80 m bgs at the 89.5 km mark. The boreholes on the section are all deep and comprise mostly fine material in the central portion of the section, with coarser material recorded closer to the foothills. The resistivity values from borehole geophysical logs correspond closely to the values from AEM data.

4.2.1.3 Section 200700, Distance Interval 15-32 km

Figure 4-4 illustrates an area in the Kern County subbasin characterized by low resistivity values through most of the section. Resistivity data from boreholes between 22 and 23 km show similarly low resistivity values (blues). However, in the first 5 km and last 6 km of the section, distinctly higher resistivity values (greens, yellows) are apparent. Water levels along the section are extremely shallow.

4.2.1.4 Section 103200, Distance Interval 127-144 km

Figure 4-5 illustrates an area in the eastern Kern County subbasin where low resistivity values (blues) at the start of the section dip and underly a region of higher resistivity. The transition from higher to lower resistivity values is supported by borehole geophysical data at the end of the section. The borehole lithology similarly supports the transition, showing a shift from coarser to finer sediment at this boundary. Water levels also present close to this transition.

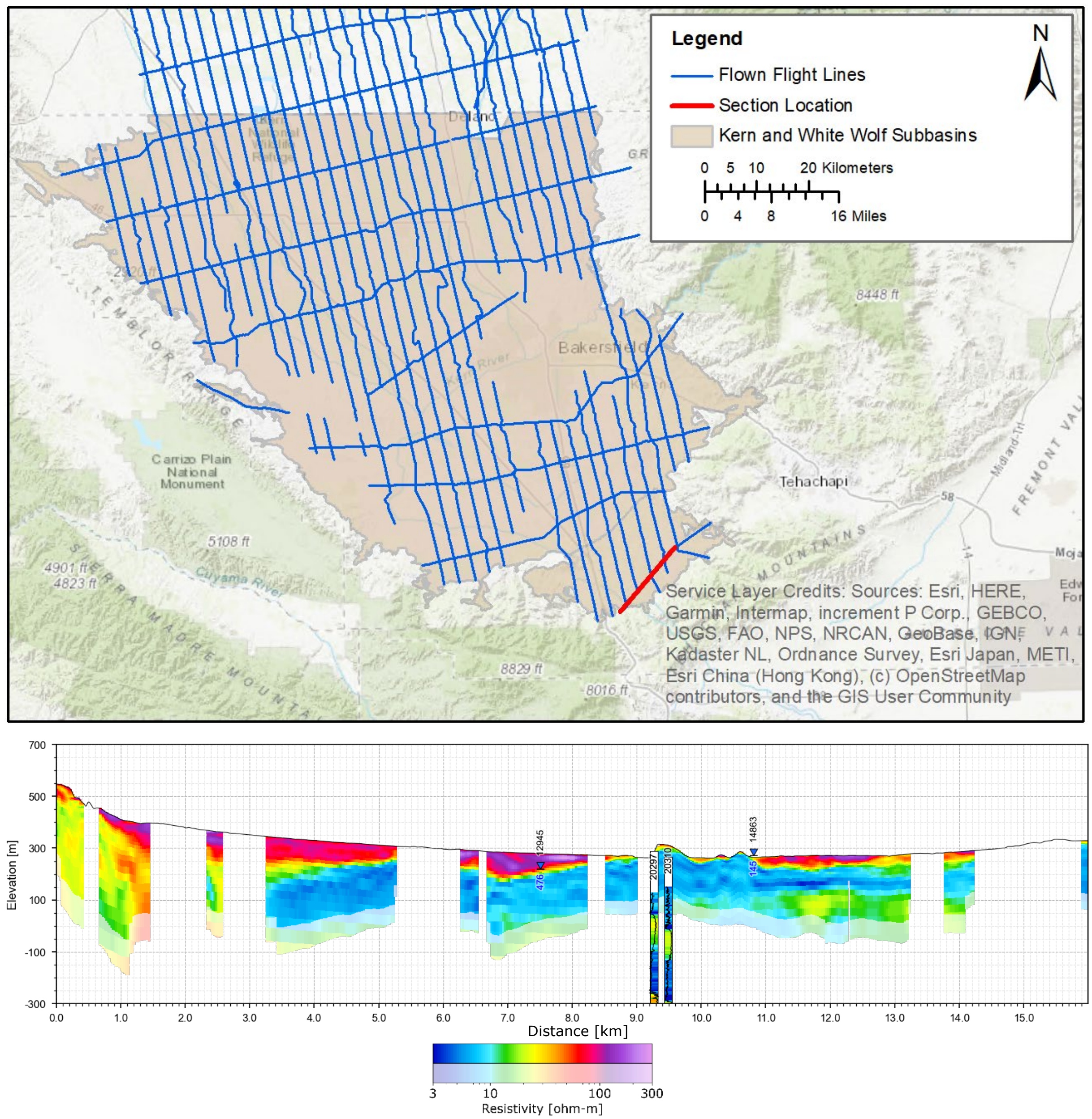


Figure 4-2 Resistivity along Section 201300, distance interval 0-16 km. The location of the section is shown as the red line in the top panel, while the vertical resistivity section from southwest to northeast is shown in the bottom panel. Faded colors near the bottom of the cross-section represent resistivity values below the DOI. Lithology data (colored rectangles) and water level measurements (blue triangles) measured from nearby boreholes are projected onto the section, with the well IDs shown above and the projection distance shown below the borehole.

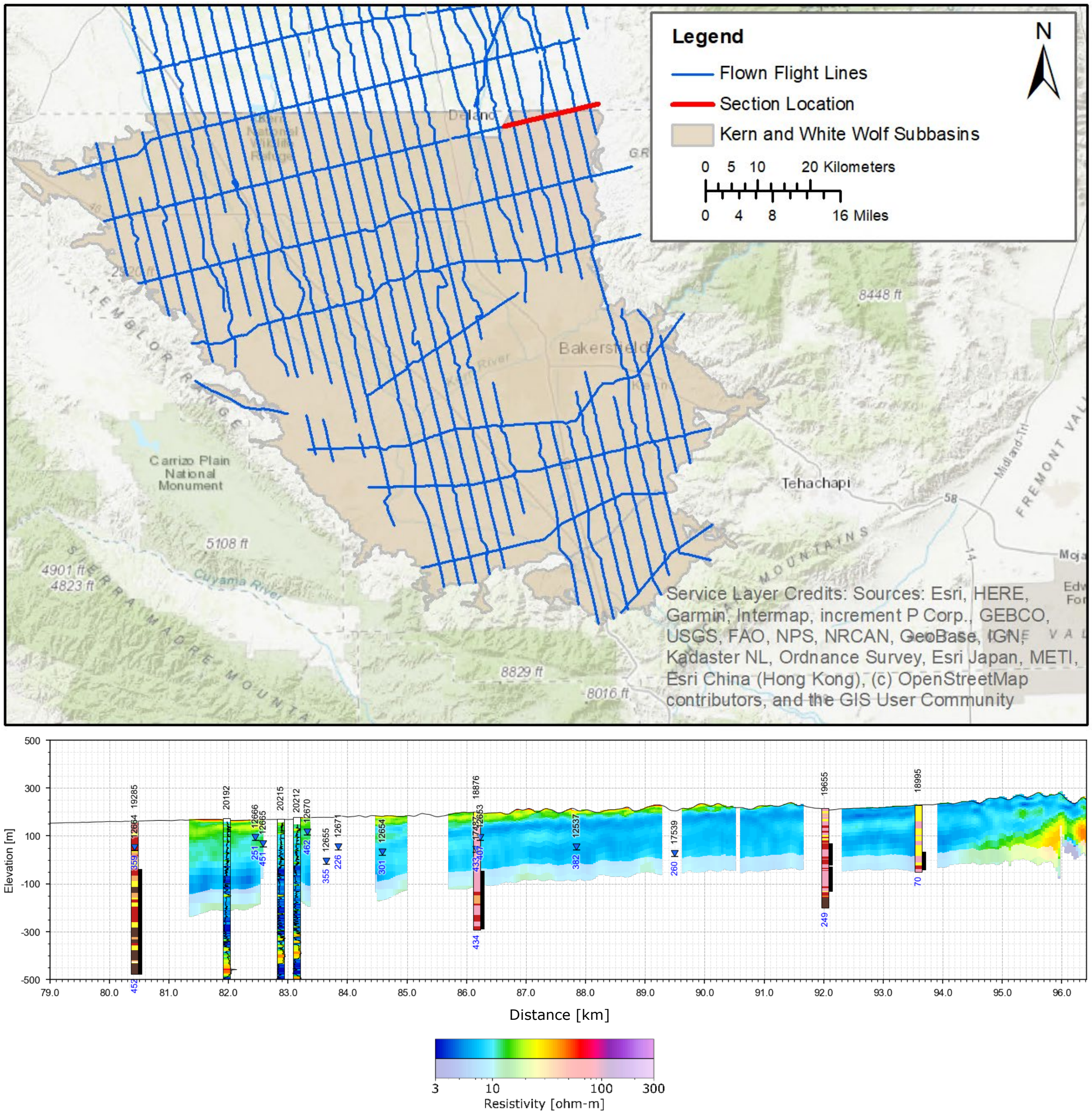


Figure 4-3 Resistivity along Section 200600, distance interval 79-96 km. The location of the section is shown as the red line in the top panel, while the vertical resistivity section from west to east is shown in the bottom panel. Faded colors near the bottom of the cross-section represent resistivity values below the DOI. Lithology data (colored rectangles) and water level measurements (blue triangles) measured from nearby boreholes are projected onto the section, with the well IDs shown above and the projection distance shown below the borehole.

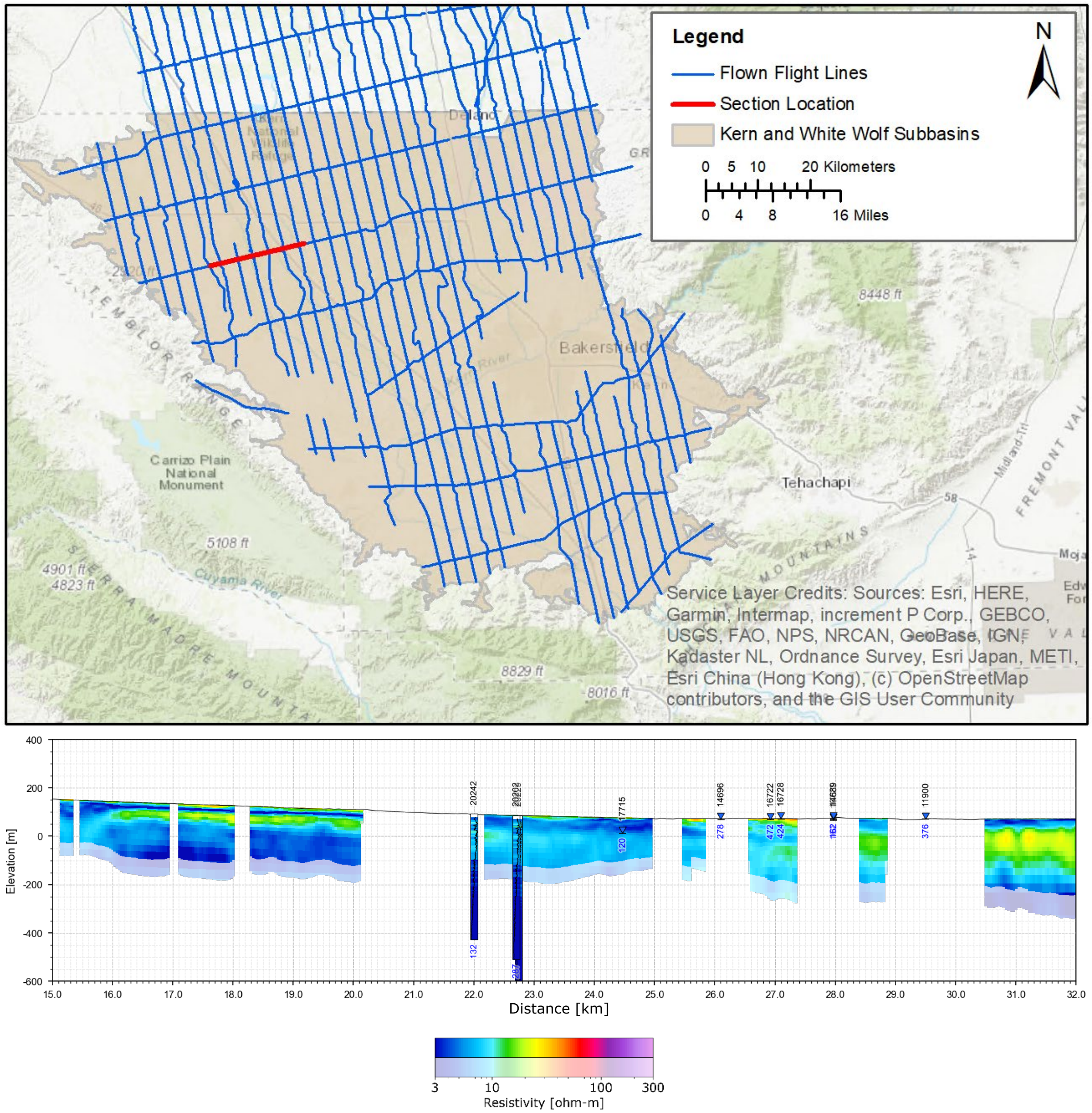


Figure 4-4 Resistivity along Section 200700, distance interval 15-32 km. The location of the section is shown as the red line in the top panel, while the vertical resistivity section from west to east is shown in the bottom panel. Faded colors near the bottom of the cross-section represent resistivity values below the DOI. Lithology data (colored rectangles) and water level measurements (blue triangles) measured from nearby boreholes are projected onto the section, with the well IDs shown above and the projection distance shown below the borehole.

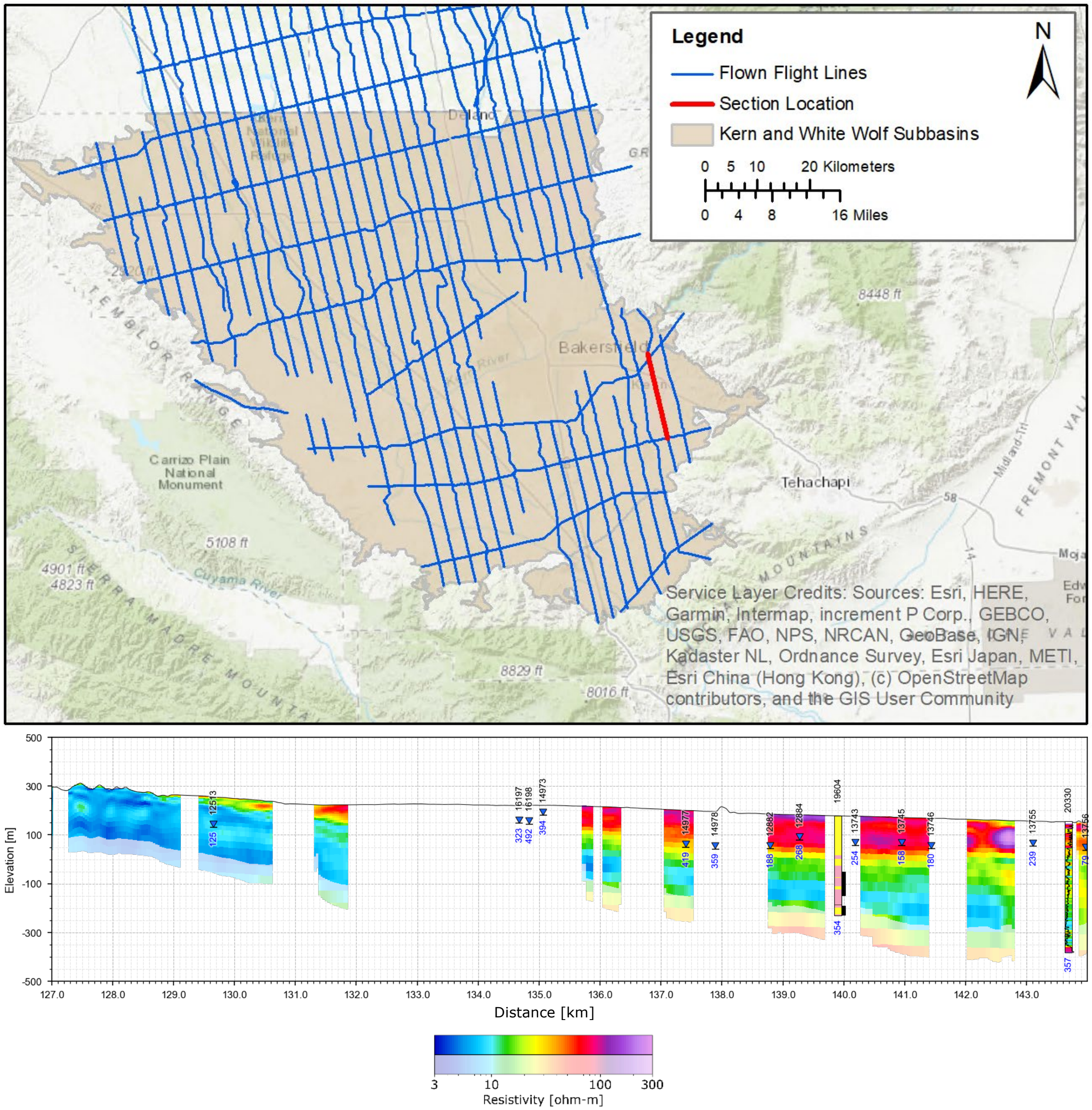


Figure 4-5 Resistivity along Section 103200, distance interval 127-144 km. The location of the section is shown as the red line in the top panel, while the vertical resistivity section from north to south shown in the bottom panel. Faded colors near the bottom of the cross-section represent resistivity values below the DOI. Lithology data (colored rectangles) and water level measurements (blue triangles) measured from nearby boreholes are projected onto the section, with the well IDs shown above and the projection distance shown below the borehole.

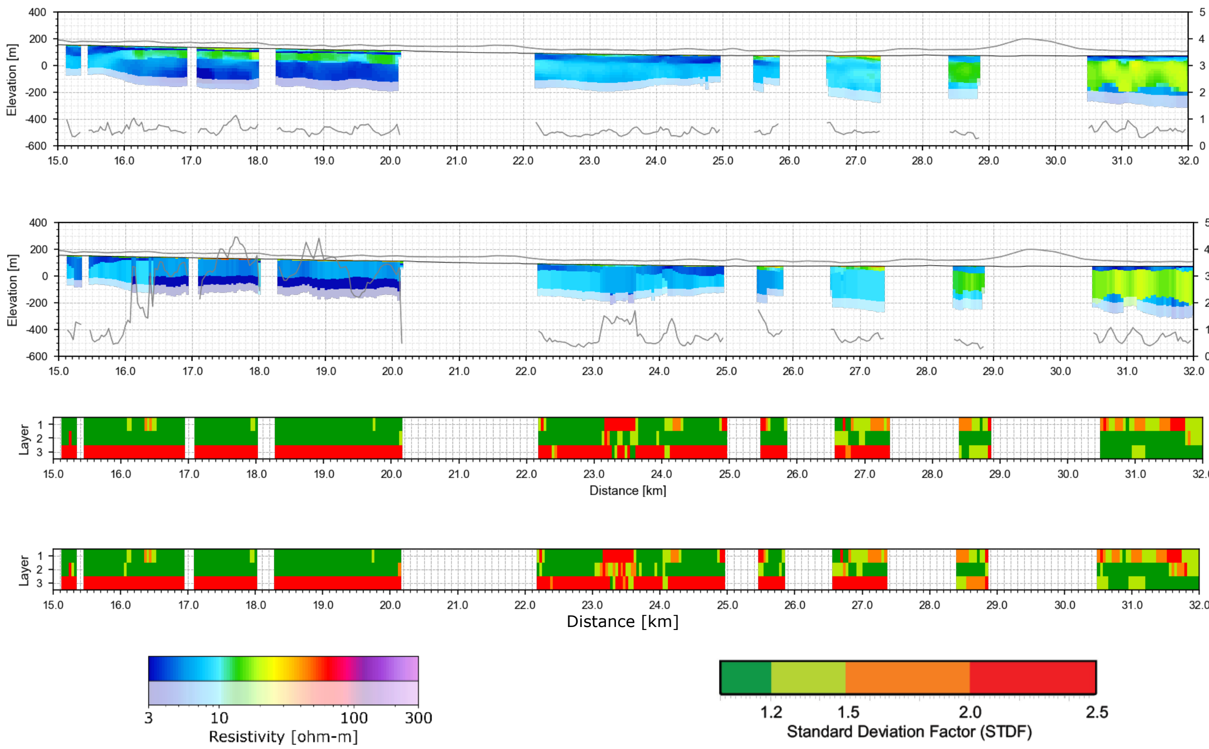


Figure 4-6 Few-layer model and associated uncertainty along Section 200700, distance interval 15-32 km. The top panel shows the few-layer resistivity model used for sensitivity analysis of the model parameters. Uncertainty for the resistivity of each layer is shown in panel 2. Uncertainty for the thickness of the top three layers is shown in panel 3, and the uncertainty for the depth to the bottom of the top three layers is shown in panel 4.

4.2.2 Mean Resistivity Plan-View Maps

Mean resistivity plan-view maps of horizontal slices along the flight lines are displayed at different depth and elevation intervals; these maps illustrate detailed structures and provide insight into variations across the surveyed area at each interval. Three representative maps of mean resistivity values at different depth and elevation intervals are provided in Figure 4-7 through Figure 4-9.

Figure 4-7 illustrates the mean resistivity over the depth interval 0-5 m (0-16 ft) below ground surface. Regions of extremely low resistivity (dark blue) can be seen in the western and southern portions of the survey area, while higher resistivity values (greens, yellows, reds) are seen across the rest of the survey area, with variation over a short lateral distance.

Figure 4-8 shows the mean resistivity in the depth interval 30-60 m (100-200 ft) below ground surface. At this depth interval, a band of low resistivity can be seen running along both the western and eastern edges of the survey area. The region south and west of Bakersfield contains more high-resistivity values (reds).

Figure 4-9 shows the mean resistivity in the elevation interval -80 to -100 m (-260 to -330 ft) above means sea level (amsl). At this elevation, many resistivity values are not displayed, as they are below the DOI. A band of high resistivity (reds) can be seen from the northern extent of the survey area to southwest of Bakersfield.

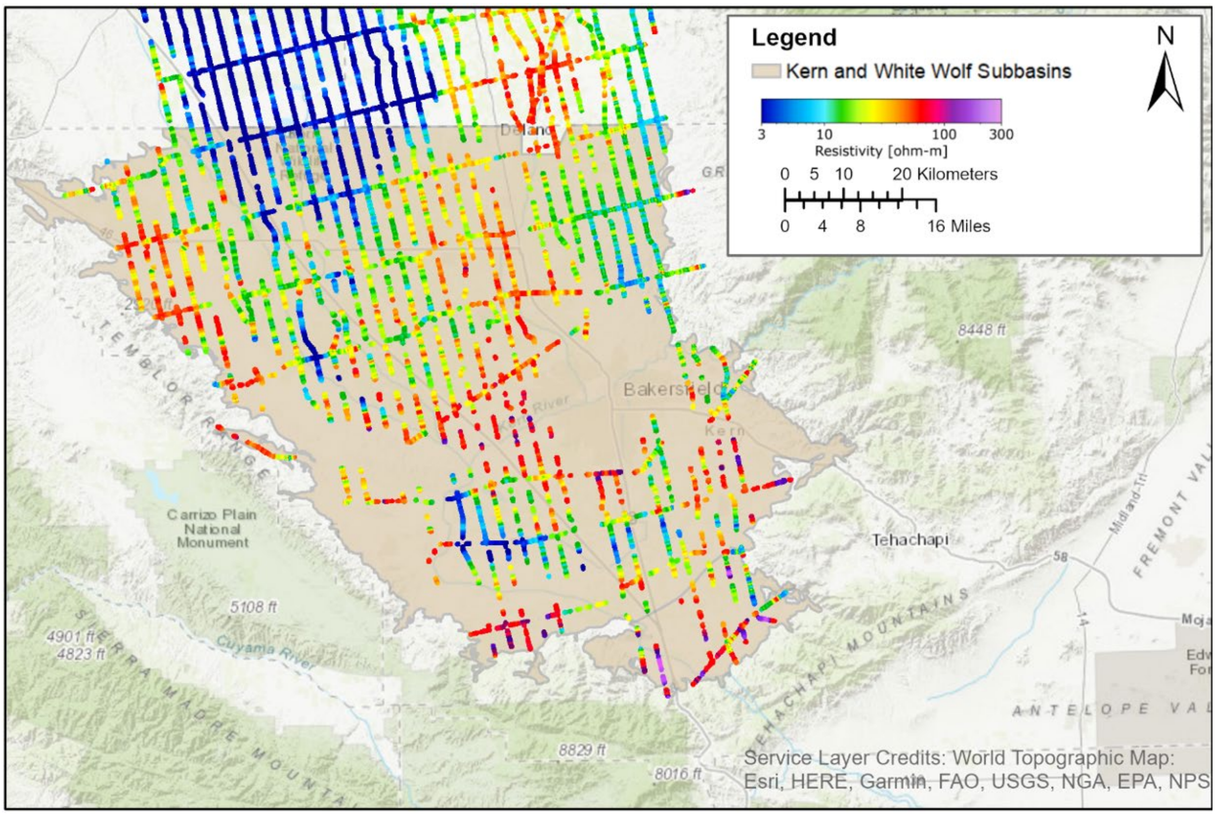


Figure 4-7 Mean resistivity plan-view map in the depth interval 0-5 m (0-16 ft) below ground surface. The colors represent the resistivity, with blue colors representing the lower resistivities, below 10 ohm-m, the yellow and green colors representing the moderate resistivities, between 10 and 50 ohm-m, and the orange and red colors representing the higher resistivities, over 50 ohm-m.

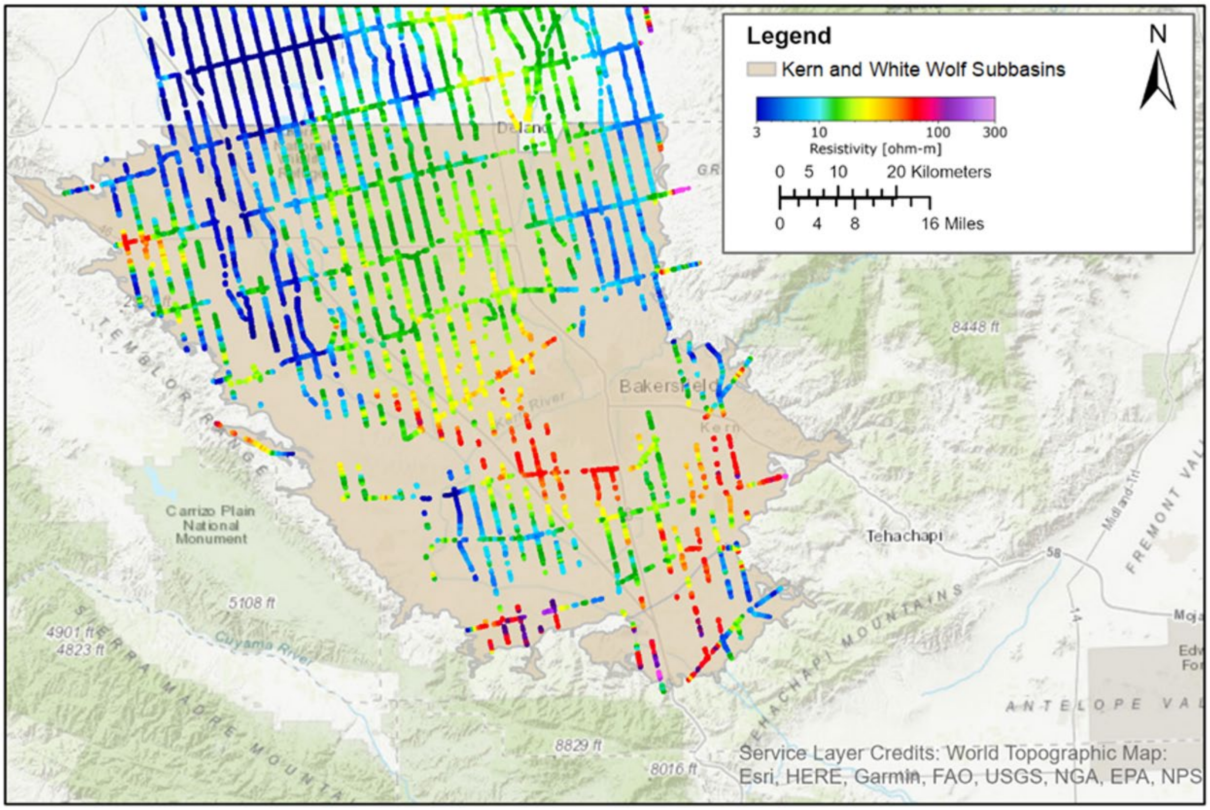


Figure 4-8 Mean resistivity plan-view map in the depth interval 30-60 m (100-200 ft) below ground surface. The colors represent the resistivity, with blue colors representing the lower resistivities, below 10 ohm-m, the yellow and green colors representing the moderate resistivities, between 10 and 50 ohm-m, and the orange and red colors representing the higher resistivities, over 50 ohm-m.

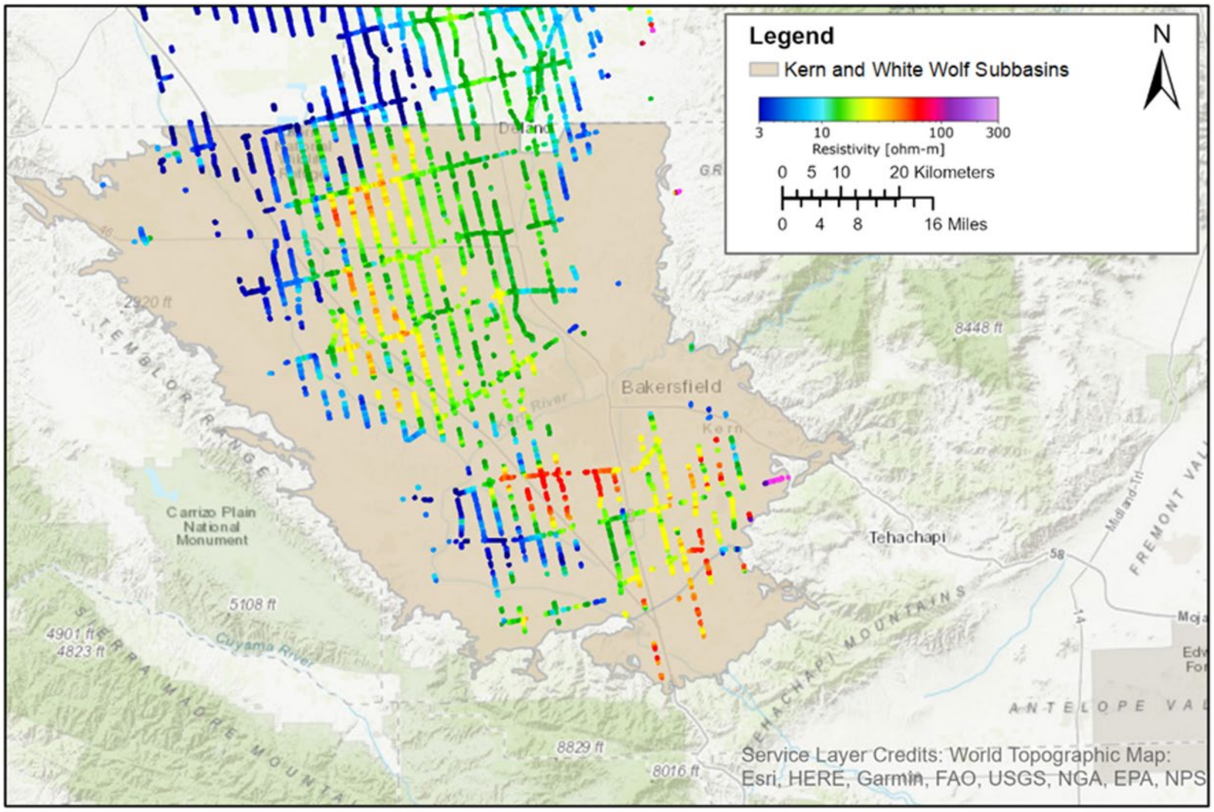


Figure 4-9 Mean resistivity plan-view map in the elevation interval -80 to -100 m (-260 to -330 ft) amsl. The colors represent the resistivity, with blue colors representing the lower resistivities, below 10 ohm-m, the yellow and green colors representing the moderate resistivities, between 10 and 50 ohm-m, and the orange and red colors representing the higher resistivities, over 50 ohm-m.

5. LITHOLOGY MODEL

Lithology Transform and Interpretation Disclaimer
This report provides a resistivity-to-lithology transform and applies it to interpret the AEM resistivity data for lithology. The lithology transform and interpretation are based on available existing supporting data and are designed for informational purposes only. These resources are not intended for regulatory purposes as part of the Sustainable Groundwater Management Act. The Department of Water Resources makes no warranties, representations or guarantees, either expressed or implied, as to the accuracy, completeness, correctness, or timeliness of the information that is presented in the lithology transform and lithology interpretations provided in this report, nor accepts or assumes any liability arising from use of this report or underlying data.

5.1 Introduction

The resistivity values estimated using the AEM method provide value for groundwater management because of the relationship between electrical resistivity and subsurface properties of interest. This includes the degree of saturation, groundwater salinity, and lithology. Generally, resistivity will decrease with an increase in fine sediment, salinity, and saturation. The relationship between resistivity values, lithology, and salinity can be seen in Figure 5-1, where the resistivity range corresponding to gravel and sand is higher than that of glacial tills and higher still than that of clays. Similarly, saltwater has a much lower resistivity than does freshwater. Consolidated rocks such as granite will typically have very high resistivities. Shales, on the other hand, can take on a wide range of resistivity values.

The wide range of resistivity values spanned by each bar in Figure 5-1 (most spanning over an order of magnitude) underscores the variable and site-specific nature of the relationship between resistivity and earth materials. Locally variable conditions can cause coarse sediments to have higher resistivity in some areas than in others, and mixtures of sediments (e.g., glacial till) result in resistivity values between those of coarse and fine.

The sharp resistivity model from the data processing and inversion (Section 4.1.2.1) was used for developing the resistivity-to-lithology transform, since the model prefers to keep resistivity values relatively consistent but can also accommodate lateral and horizontal variations. The sharp inversion model has 30 layers, with the first layer thickness of 2 m (7 ft), with the layers gradually increasing with depth to 600 meters (1,970 ft). However, the lower boundary in the resistivity-to-lithology transform was set as the first layer boundary above the DOI (Section 4.1.2.2).

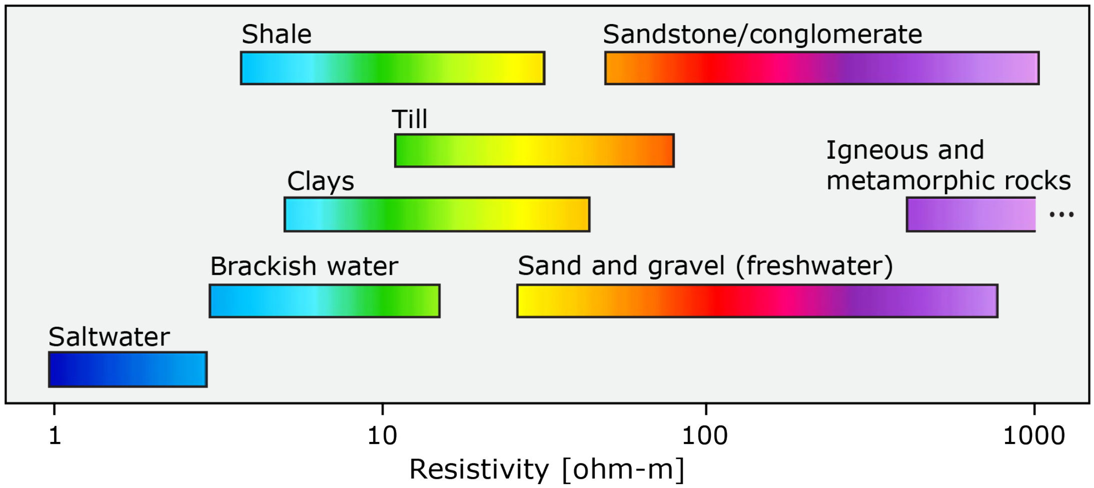


Figure 5-1 Typical relationship between resistivity, lithology, and salinity (after Palacky, 1987).

Establishing a transform to predict lithology from resistivity is a challenging task, because (1) in addition to lithology, the resistivity measurement also depends on other subsurface properties (water saturation and water quality), (2) the relationship between resistivity and lithology varies spatially and 3) the transform does not apply to certain geologic variations such as consolidated rocks. One or more of these conditions are typically found across groundwater basins in California and therefore a successful transform should address these dependencies.

The Accumulated Clay Thickness method is specifically developed for translating resistivity models in large AEM datasets—such as those acquired in this project—into models of the fractional thickness of clay sediment (Foged et al. 2014). The resulting clay fraction models can be used to better understand the spatial distribution of coarse and fine sediment and can be an integral data component to support the development of a hydrostratigraphic or groundwater flow model. In this approach, we focus on coarse sediments, and thus ACT refers to Accumulated Coarse Thickness, which is the complement of Accumulated Clay Thickness.

To predict the lithology using the resistivity models, a 3D grid of translator functions was applied. The ACT method has the advantageous property that the resistivity-lithology relationship is not represented by just one “global” translator function. Rather, the translator functions in the grid can vary spatially, calibrated from nearby well lithology data, allowing the resistivity-to-lithology to implicitly account for changes in resistivity due to changes in salinity and saturation, as well as to regional variability in the resistivity-lithology relationship. This section provides a summary of the methods and results of the resistivity-to-lithology transform. A detailed description of the theory, methods and results from the lithology transform are presented in Appendix 4. The resistivity-to-lithology transform results and uncertainty for each line is shown on the profiles presented in Appendix 8.

The resistivity-to-lithology transform was conducted for the entire Survey Area 4, which in addition to Kern County and White Wolf Groundwater Subbasins, also includes Kaweah, Tulare Lake and Tule Groundwater Subbasins. These were conducted together in order to maximize the data available for the resistivity-to-lithology transform.

5.2 Resistivity-to-Lithology Transform Methodology

The resistivity-to-lithology transform used in the Kern County and White Wolf Groundwater Subbasins follows a modified workflow based on a methodology specifically developed for large AEM datasets (see Foged et al., 2014), using Aarhus Workbench Hydro Structural Modeling module. The resistivity models produced from inversion (Section 4) are used along with well completion report lithology log data (Section 2) to optimize a set of translator functions, each of which can map the resistivity of a depth interval (ACT layer) to the amount of coarse material, quantified as the coarse fraction (CF) within the same layer.

The workflow used to develop the lithology models is followed for each basin/subbasin separately, allowing for adaptation of the conditions addressed in the previous section. The process is as follows:

1. Prepare the data needed for lithologic modeling and evaluate whether the employed methodology is appropriate for the given basin/subbasin.
2. If the methodology is appropriate, establish the resistivity-to-lithology transform.
3. If the methodology is deemed not to be appropriate, implement a manually defined resistivity-lithology transform.
4. Evaluate the transform results.

First, the hydrogeologic setting of the surveyed area was assessed to obtain a general understanding of the different geological units. If necessary, the surveyed area was split into separate lithology modeling areas. The lithology modeling was completed for the whole survey area.

Within each lithology modeling area, further analysis was restricted to regions where the transform modeling is valid. Specific cases that can affect the transform results and the approaches to handle those regions in the analysis are discussed in Section 5.4. Next, a correlation analysis was performed to evaluate the resistivity-lithology relationship within each lithology modeling area. This was done by analyzing the histograms of resistivity for each lithologic unit.

Texture descriptions from lithology logs within 800 m (2,600 ft) of the flown flight lines were used in the analysis. The resistivity data were projected to the actual well log location and both the AEM resistivity models and lithology logs were re-discretized to common transform layers. The texture description from each depth interval from each lithology log was aggregated into either “fine” or “coarse”, where fine corresponds to a CF of 0, and coarse corresponds to a CF of 1. Fine materials were considered to include clay and silt sediments (lower permeability), while coarse materials were considered to include sand and gravel (higher permeability). As an intermediary step, the lithology log descriptions were first simplified to four texture categories: fine, fine with coarse, coarse with fine, and coarse.

Next, initial ACT settings were established with the lateral spacing between nodes in the grid of translator functions set at 10,000 m (32,800 ft) to accommodate the relatively sparse lateral coverage of the AEM data (approximately 3 km spacing. The vertical spacing was set to 5 m for the first three layers, followed by 6 m for four layers, after which the vertical spacing was set to follow the vertical spacing of the resistivity model. In addition, the lower boundary in the resistivity-to-lithology transform was set as the first layer boundary above DOI (Section 4.1.2.2).

After establishing the initial ACT settings, the volume of available lithology data within the 3D grid were analyzed to assess whether sufficient data exist for transform modeling. If so, the ACT numerical optimization was performed, and the results were evaluated and visualized.

If no correlation was found between lithology and resistivity for a basin or if the volume of available lithology data was insufficient, selected well data were manually compared to nearby resistivity values to determine a relationship between resistivity and lithology. In this case, the translator function parameters would be manually determined, and a uniform translator function would be applied throughout the 3D grid. Finally, if a relationship could not be manually established, transforming resistivity to lithology was determined not to be applicable since additional or refined well data are required.

During the resistivity-to-lithology transform, each translator function in the grid is optimized using nearby resistivity models from the survey area and the simplified texture description from nearby lithology logs. Each translator function has the form of the function in Figure 5-2. Nearby resistivity values are input into each translator function to predict the CF. Predicted CF values are compared to the simplified texture values from nearby lithology logs, and the translator function is adjusted through an automated process to minimize the difference between the CF in the lithology logs and the predicted CF from the translator function. The translator function provides a lower resistivity limit m_{lower}, where all layers with a resistivity lower than this limit will contain only fine sediments, and an upper resistivity limit, m_{upper}, where all layers with a resistivity higher than this limit will contain no fine sediments.

Along each of the flight lines in this project, simplified texture descriptions from nearby lithology logs were compared to the sharp resistivity model.

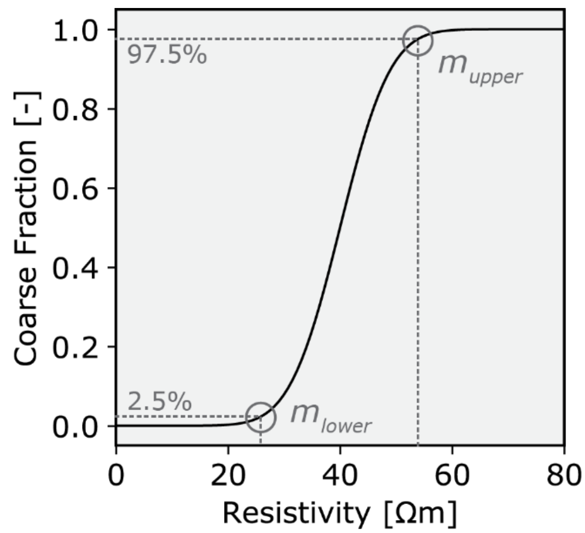


Figure 5-2 An example of a single fraction translator function (after Foged et al., 2014) in the 3D grid. The coarse fraction (CF) ranges from 0 (minimal coarse material) to 1 (coarse dominated). The value m_{lower} represents the lower value where all resistivities below this value represent layers containing only clay, and m_{upper} represents the upper value, where all resistivities higher than this value represents layers containing no clay. In this example, the lower limit is at 25 ohm-m and the upper limit is at 55 ohm-m.

The final step is to calculate the coarse fraction model uncertainty. The uncertainty is based on the uncertainty of the AEM model resistivity related to the transfer function for the specific layer. In other words, the range in resistivity is used for calculating a range in coarse fraction from the specific translator function. This is then converted to a standard deviation factor for the coarse fraction, typically between 1.0 and 1.3, where 1.0 is the most certain with uncertainty increasing as the standard deviation factor increases.

5.3 Transform Results

Figure 5-3 contains a selected profile along a flight line in Kern County and White Wolf Groundwater Subbasins, which shows the lithology model resulting from the resistivity-to-lithology transform in the upper cross-section, and the uncertainty index associated with the lithology model in the lower cross-section. Regions identified as consolidated rock are masked with a hatching pattern. The depth below which no resistivity-lithology pairs were available within the inversion cell is shown as a dashed line through the cross-sections. The lithology models for all flown sections are presented in Appendix 8.

The initial results from the lithology model illustrate the viability in utilizing this approach applied to AEM data in the Kern County and White Wolf Groundwater Subbasins. Since the survey is at reconnaissance level with a wide flight line spacing, the results of the resistivity-to-lithology transform can only be applied directly along the flight lines; areas where no AEM data were acquired are unknown.

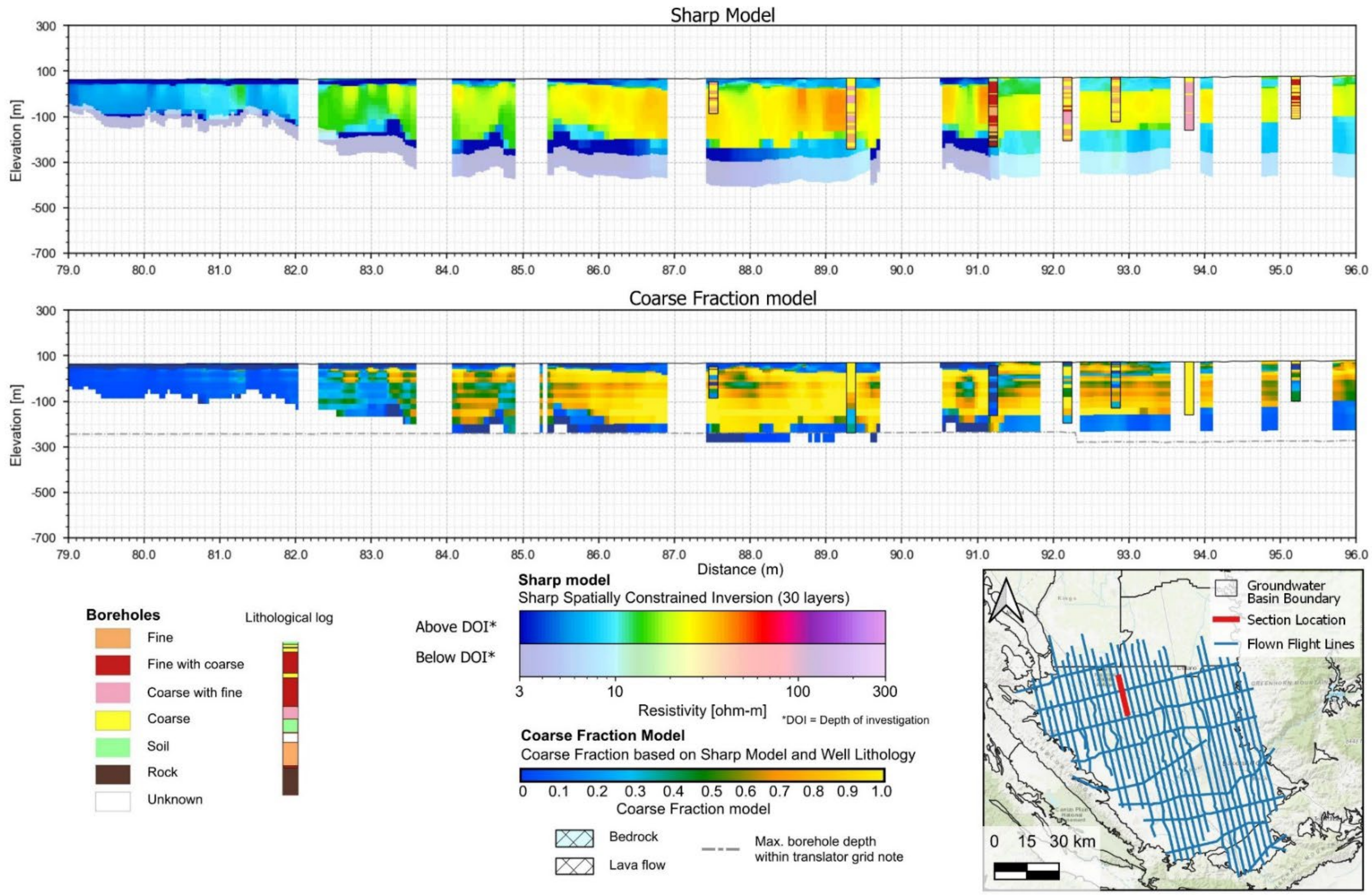


Figure 5-3 Lithology model resulting from the resistivity-to-lithology transform along Profile 101400 in Kern County and White Wolf Groundwater Subbasins. The top cross-section shows the sharp model resistivity. The bottom cross-section shows the calculated coarse fraction, where the yellow colors show the sediments/materials with high coarse content (scale value 1.0) transitioning to the dark blue colors showing sediments with the highest clay content (scale value 0.0). The areas with bedrock and lava flows are cross-hatched on the Coarse Fraction Model profile. The vertical columns show the accumulated coarse thickness as calculated in the individual lithology logs. The red line on the map shows the location of the profile.

5.4 Specific Cases Affecting Resistivity

Specific cases that can affect resistivity measurements beyond the lithology include, but are not limited to, the degree of sediment saturation, presence of saline water, and the degree of consolidation (rock). These specific cases are discussed below.

5.4.1 Saturated and Unsaturated Sediments

Resistivity is not only influenced by the lithology but also by the water quality and degree of saturation in the subsurface. Unsaturated sediments tend to have a higher resistivity than saturated sediment. This difference in the rock physics relationship between saturated and unsaturated zones can be taken into consideration in the translator function, where a separate translator function is produced for the unsaturated and saturated zone. Separating the unsaturated and saturated zones requires information on the elevation of the water table at the location of each well used in the transform; these data are primarily obtained through water level measurements in unconfined aquifers. In some cases, it is determined that an insufficient density of water level data is available to reliably estimate the water table elevation across the survey area to separate the saturated from the unsaturated sediments in the resistivity-to-lithology transform. However, even without sufficient information on the water table elevation, through use of the 3D grid of translator functions, the resistivity-to-lithology transform is still able to implicitly account for spatial variation in the depth to saturated sediments.

Figure 5-4 shows a schematic of the grid of translator functions above and below the water table. The colored bars, representing the resistivity models produced from AEM data, have warmer colors (higher resistivity) above the water table shown as a blue line, than below the water table. The nodes of the grid of translator functions, shown as black dots, are separated laterally and vertically by the thickness of each ACT model cell. It is noted that, while the translator function nodes are shown on top of the resistivity model cells in this two-dimensional schematic, the nodes of the applied translator grid in 3D did not necessarily intersect a cell in the resistivity model. A translator function (with the shape of the curve in Figure 5-2) is fit to the borehole lithology and resistivity data within each depth interval. Because each translator function is fit separately, a different transform can result above and below the water table.

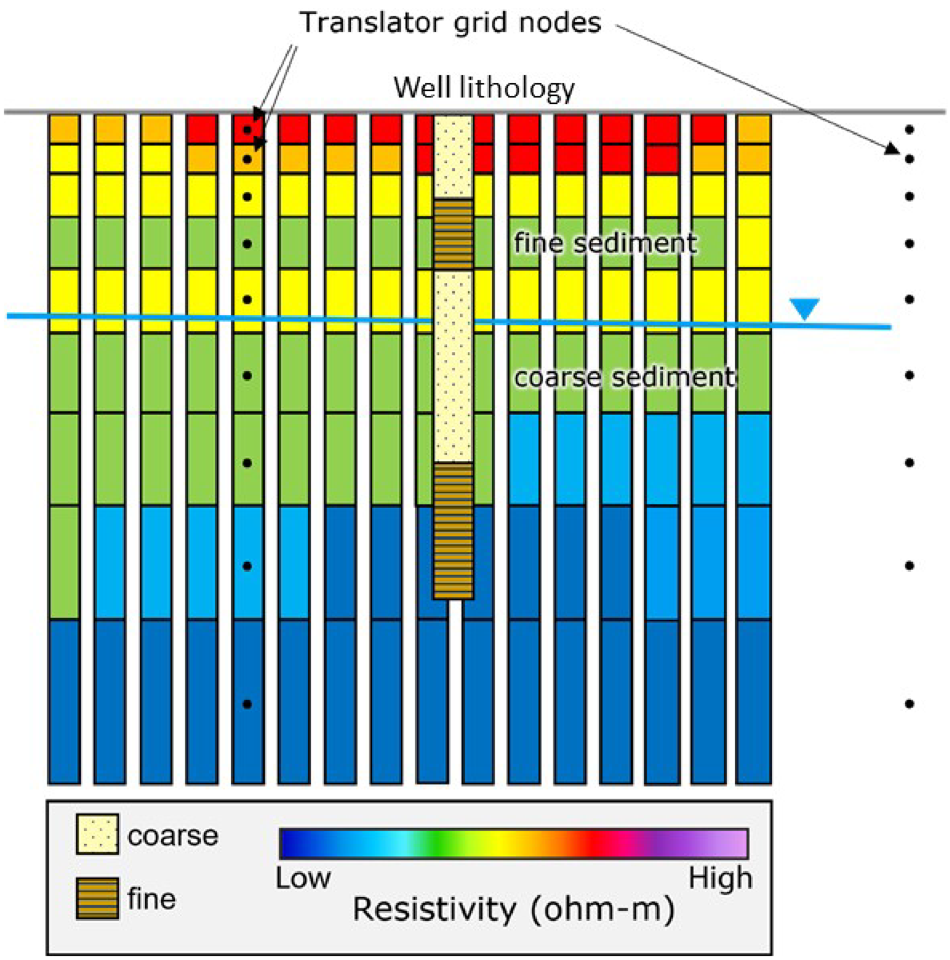


Figure 5-4 Schematic demonstrating the ability of the resistivity-to-lithology transform to implicitly account for the change from unsaturated to saturated sediments. The well shows the simplified lithology from log descriptions.

In the case of Figure 5-4, even if the depth to the water table is unknown, the translator functions above the water table will be fit to the generally higher resistivity values, while those below the water table will be fit to the lower resistivity values. Although the transform can accommodate a small to moderate groundwater gradient in the boundary between unsaturated and saturated sediment, it should be noted that because the grid of translator functions has a large lateral spacing, a steep gradient is expected to cause some smearing in the lithology model resulting from the resistivity-to-lithology transform.

5.4.2 Saline Water

Groundwater salinity can also influence the observed resistivity in the saturated zone. Groundwater with higher TDS values will have lower resistivity. As with the transition from unsaturated to saturated zones, the resistivity-to-lithology transform can implicitly account for variations in salinity, assuming (1) the salinity does not change rapidly over a short lateral distance, (2) the salinity is not very high, and (3) the salinity of the coarser sediment is similar or lower than that of the fine sediment. If the salinity varies rapidly over a short distance, smearing will occur in the translator function in a similar way as when the water table gradient is steep. Once the salinity becomes high (about 3,000 mg/L), differences in the resistivity between coarse and fine materials are damped. Finally, if the salinity of the coarse sediment is higher than that of the fine sediment, the translator function will fail, since the function (Figure 5-2) assumes that coarser sediment is more resistive than finer sediment. Coarse sediment may contain more saline water than fine sediment, for example, in areas affected by seawater intrusion, since the water saturating coarse sediments (aquifer) is more readily displaced by intruding seawater than the water saturating fine sediments (aquitard).

To circumvent potential challenges to the resistivity-to-lithology transform in areas of elevated salinity, one of two approaches is applied: (1) the resistivity-to-lithology transform can either be divided into different zones (e.g., a freshwater zone and a saline zone) with each zone evaluated for whether the resistivity-to-lithology transform should be applied, or (2) the saline zone is removed from the analysis.

The western third of Survey Area 4 has a significant area with low resistivity where TDS values indicate elevated groundwater salinity. The division between the western part of the survey (called Area West) and the eastern part of the survey (called Area East) is shown on Figure 5-5.

The extent of Area West was determined by the following criteria:

1. Resistivity was predominately under 5 ohm-m;
2. Well lithology showing coarse sediments in the same interval as low resistivity in the AEM data;
3. Available water quality data showing elevated TDS levels (over 3,000 mg/L)

Figure 5-6 shows two profiles, from west to east, crossing both Area West and Area East. A sharp contrast in resistivity can be seen, where resistivities lower than 10 ohm-m (dark blue) towards the west with resistivities predominately higher than 10 ohm-m (light blue) towards the east. This change marks the boundary between Area West and Area East.

Insufficient lithology data in Area West did not allow for the resistivity-to-lithology transform to be conducted. Thus, Area West was deactivated, and the ACT analysis was only conducted for Area East. Instead, a manual analysis of the relationship between lithology and resistivity was conducted for Area West.

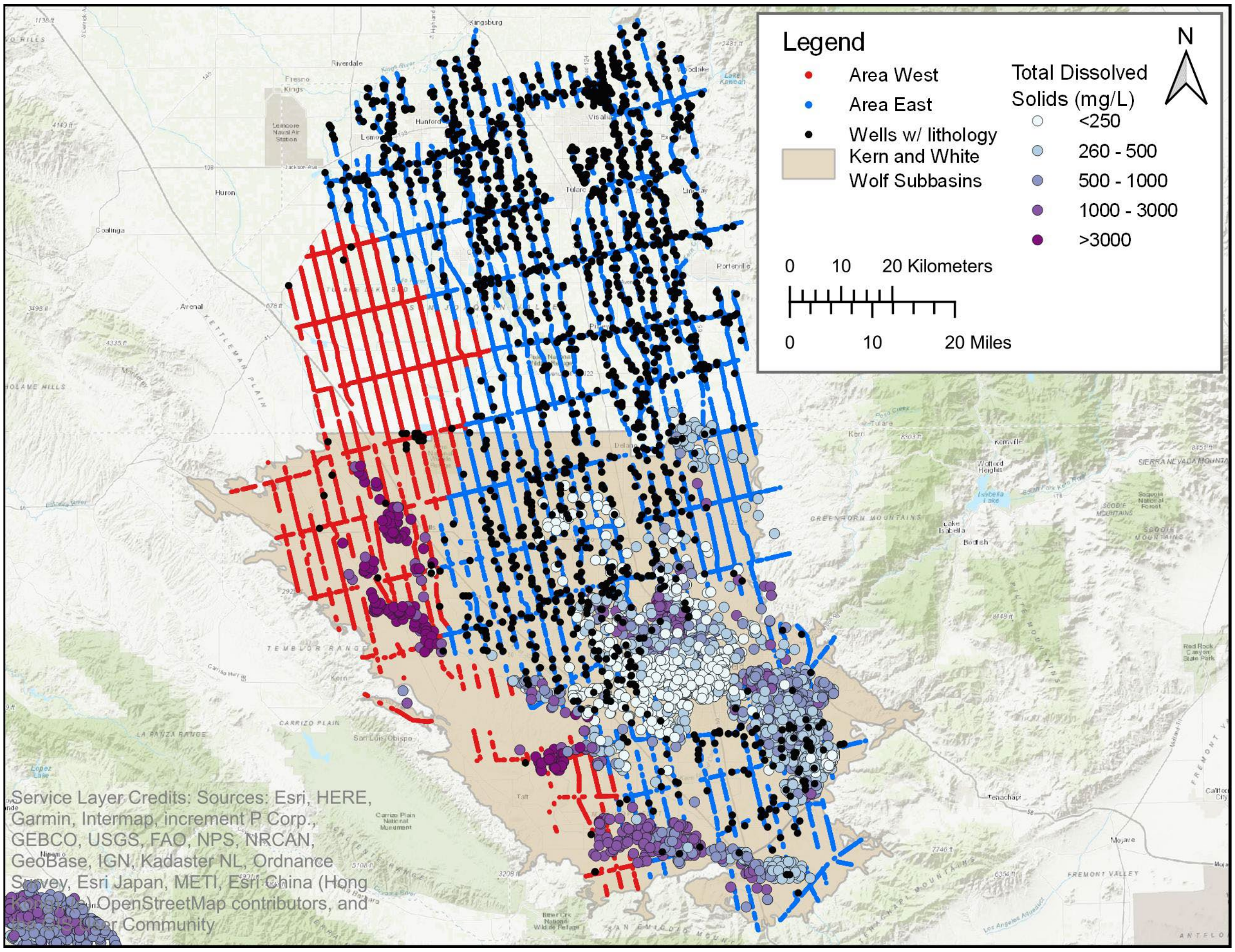


Figure 5-5 Division of Area East, where the ACT modeling was conducted, and Area West, where the ACT modeling was not possible. The map also shows the wells that contain lithology and water quality information. The map shows the entire Survey Area 4.

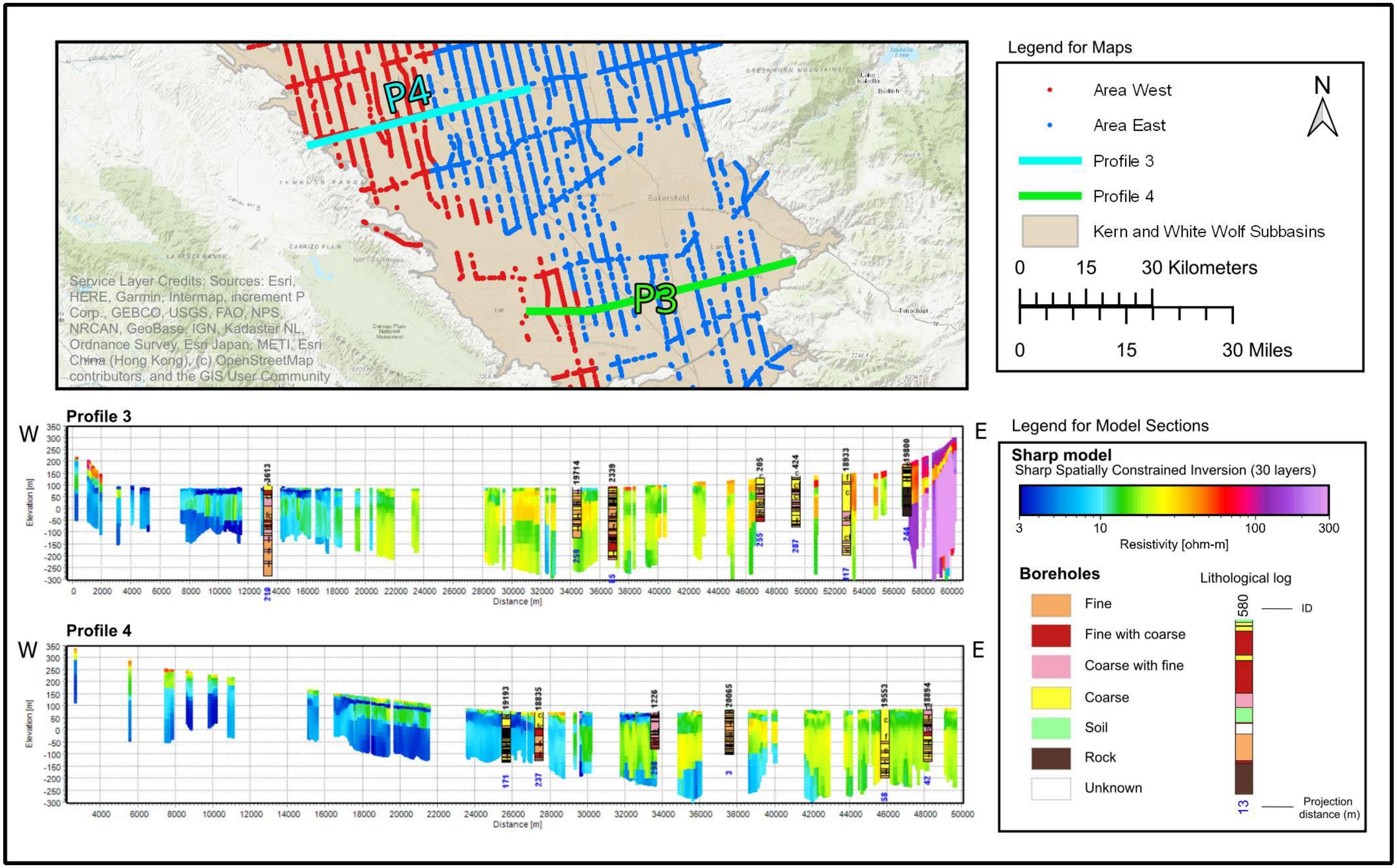


Figure 5-6 Profile sections of the going through the survey area.

Figure 5-7 shows the results of the correlation analysis between resistivity from the AEM measurements and the lithology from well logs in Area West. Only resistivity values within 800 m of a well are used. Furthermore, only layers with a layer thickness of more than 5 m are included in the histogram. The red vertical bar in each of the histograms in Figure 5-7 indicates the mean of the distribution, while the black vertical bars indicate one standard deviation around the mean.

The histograms in Figure 5-7 show very little variation between in the resistivity distribution of the four groupings, fine, fine with coarse, coarse with fine and coarse. All four groupings have a mean resistivity between 5 and 7 ohm-m, with similar distributions. This lack of difference indicates that lithology has only a minor impact on resistivity in Area West. This shows that ACT modeling in the Area West would be very difficult, even if there was a sufficient number of wells with lithology information.

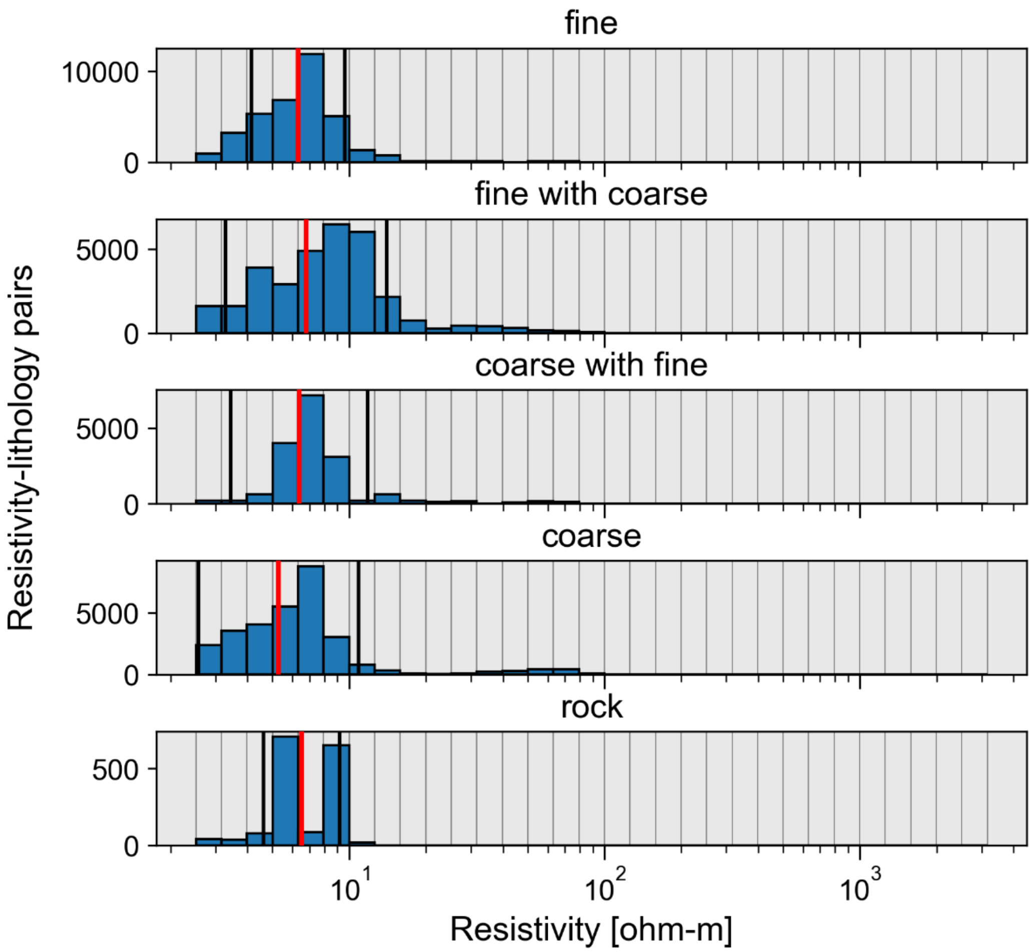


Figure 5-7 Resistivity-lithology correlation for the western part of Survey Area 4 including Kern County and White Wolf Groundwater Subbasins as well as Tule, Tulare Lake, and Kaweah Groundwater Subbasins. The red line indicates the mean value, and black lines indicate one standard deviation above and below the mean.

In spite of this lack of difference in the resistivity-lithology correlation in Area West, when the resistivity scale is adjusted to 1 to 10 ohm-m for the area, layering in the resistivity measurements can be observed. Figure 5-8 shows two profiles that illustrate this. These subtle changes in resistivity creating the layering effect could be due to changes in lithology. However, there is a general lack of lithologic data from wells in Area West that could be used to determine whether or not changes in lithology is playing a role in the observed layering in the AEM data.

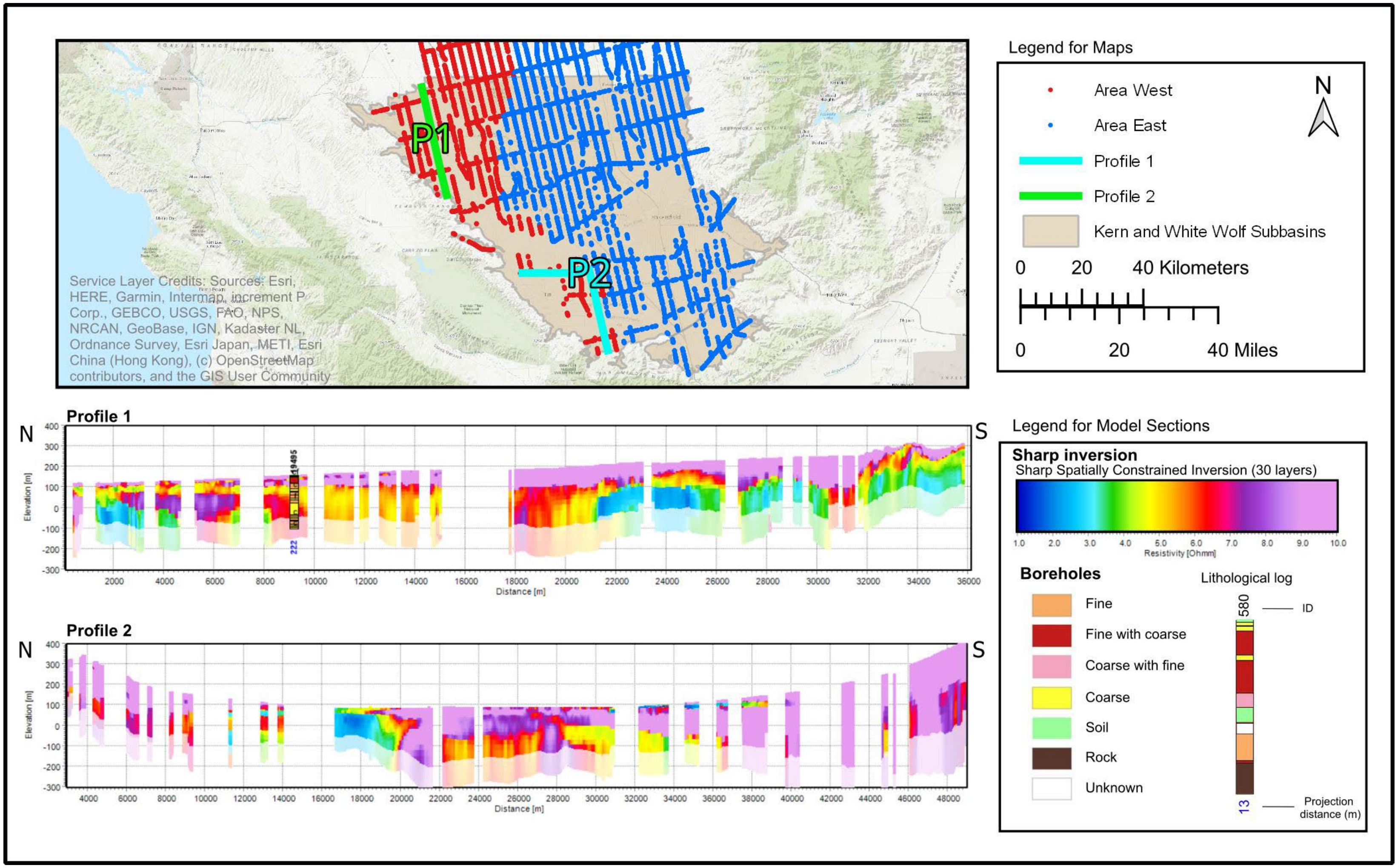


Figure 5-8 Profile sections of the western area. Notice the change in color scale showing resistivities from 1 to 10 ohm-m.

Maps showing the total thickness of layers in the Area West with resistivities between 0-5 ohm-m and between 5-10 ohm-m are shown on Figure 5-9 and Figure 5-10, respectively. This is to provide information on the extent of the sediments with the low resistivities. In these figures, the data from 0 to 10 m depth has been disabled to allow for a better visualization of the structures.

A comparison of these two maps shows an interesting feature. Just to the north of Kern County Subbasin, there is a contiguous area where the layers with resistivity below 5 Ohm-m exceeds 100 m in thickness, while resistivity exceeding 5 Ohm-m is absent. On the other hand, to the north and south of this area, there are varying thicknesses of resistivity under and over 5 Ohm-m, showing more variations in the resistivity under 10 Ohm-m.

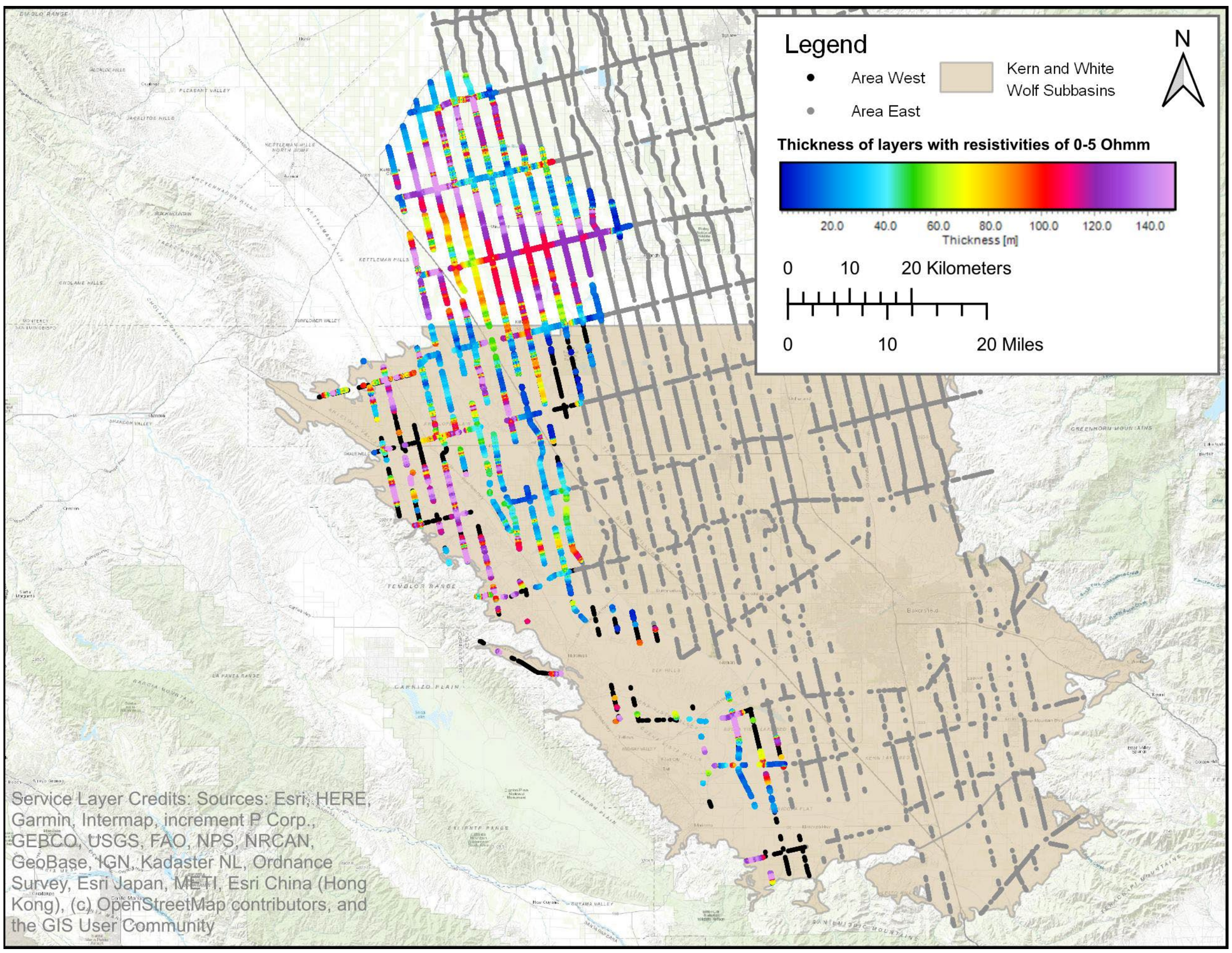


Figure 5-9 Total thickness of layers in the western area with resistivity between 0-5 Ohm-m. The map shows the entire western area for Survey Area 4.

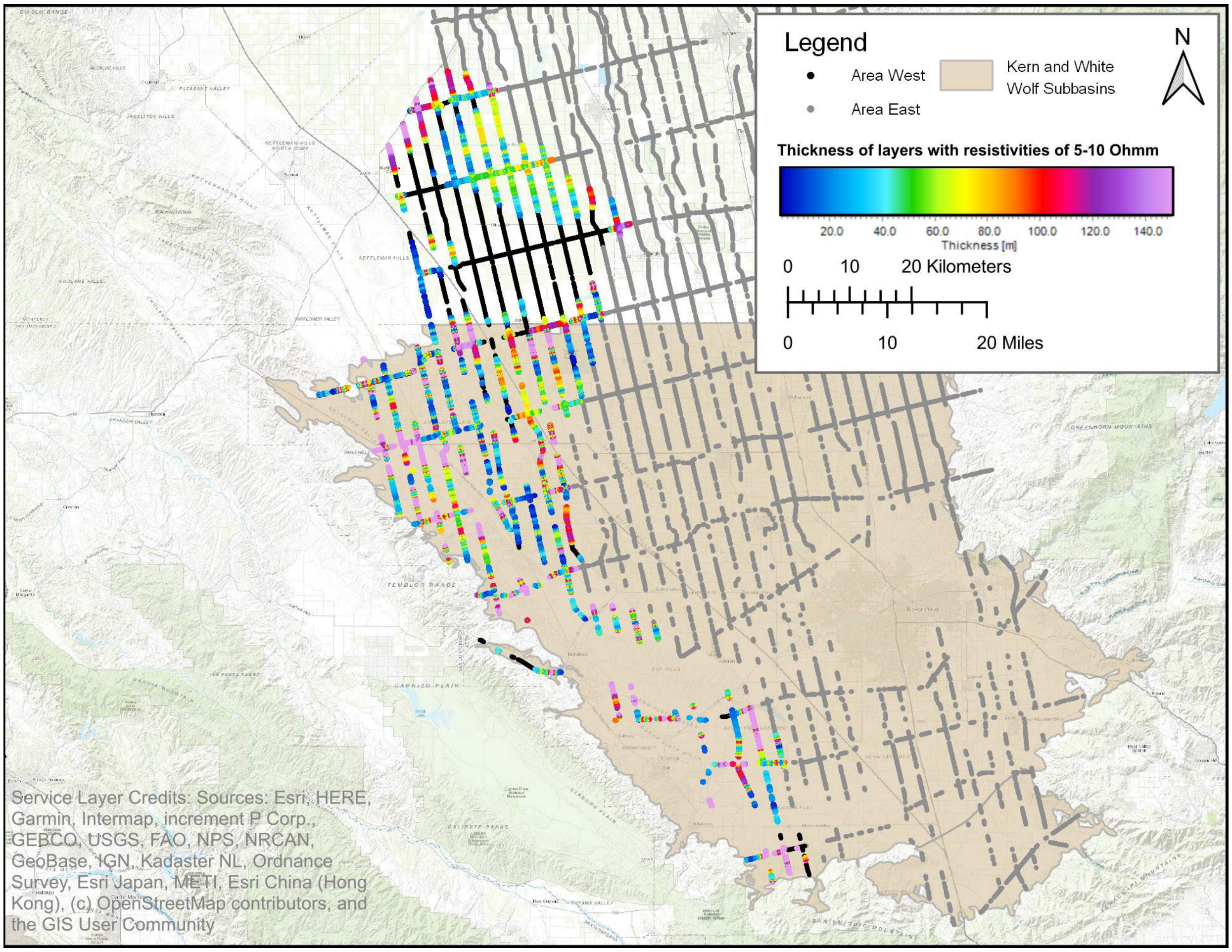


Figure 5-10 Total thickness for layer in the western area with resistivity between 5-10 Ohm-m

5.4.3 Consolidated Rocks

Consolidated rocks (e.g., bedrock) have different hydraulic properties than unconsolidated sediment, often forming a hydraulic barrier within a groundwater basin. The resistivity-to-lithology transform applied in this project was developed for unconsolidated sediments: the translator function considers a spectrum of fine to coarse sediment.

Since many igneous and metamorphic rocks tend to have a high resistivity (Figure 5-1), the resistivity-to-lithology transform will interpret these rocks as coarse sediment (a high CF value). Given their high resistivity, these rocks can often be distinguished from unconsolidated materials in the resistivity models. On the other hand, consolidated sedimentary rocks, including shales and sandstones, take on a wide range of resistivity values that may be similar to those of unconsolidated sediment. The transform will interpret these rocks as either fine or coarse sediment, depending on their resistivity values in comparison to those of nearby unconsolidated sediment. Thus, when analyzing the lithology model resulting from the resistivity-to-lithology transform, it is important to first remove any areas corresponding to consolidated rocks.

In the surveyed area, resistivity values corresponding to consolidated rock were removed from further analysis through inspection of geologic maps, water quality measurements, and the resistivity models produced from inversion.

6. INITIAL HYDROSTRATIGRAPHIC MODEL

6.1 Introduction

The data acquired during an AEM survey can provide valuable information for developing or refining a hydrostratigraphic model of the surveyed area. However, due to the large amounts of data acquired during a typical AEM survey, including this project, manually interpreting the hydrostratigraphic units corresponding to the resistivity or lithology model can be labor intensive.

Here, an automated approach was applied to produce a model consisting of zones of similar properties from a resistivity model and a lithology model. This resulting model could be used to help develop a better understanding of the regional hydrostratigraphy, or as the basis for a numerical groundwater flow model. The approach uses a clustering algorithm, which classifies a set of data points into a predefined number of groups with similar properties. It is a widely used approach for pattern recognition, image processing and analysis of large datasets where grouping is required. Since resistivity is related to the hydrogeologic properties of interest, the clustering approach relies on the assumption that groups defined from resistivity and borehole lithology data also have similar hydrogeologic properties.

There are other approaches, not pursued here, that can provide an automated conversion of AEM data into an interpreted hydrostratigraphic model. These include, for example, the use of multipoint statistics (Gulbrandsen et al, 2021) or the Octree algorithm for 3D voxel modeling (Jorgensen et al, 2013). It is not within the scope of this project to provide a critical review of the different methodologies that can be applied in the interpretation of AEM data to a hydrostratigraphic model. Rather, clustering is presented as an example of an approach that could be used, illustrating the value of AEM data as input to a 3D hydrostratigraphic model. The clustering approach used for this project was chosen for the following reasons:

(1) It provides an automated grouping providing a representation of the hydrostratigraphy
(2) The grouping is data driven, reproducible, and is geographically and depth independent
(3) The process requires only the measured resistivity and lithology log data

This section provides a description of the clustering methodology and the resulting initial hydrostratigraphic model in Kern County and White Wolf Groundwater Subbasins. The clustering was conducted for the ACT model Area East for the entire Survey Area 4, including Kaweah, Tulare Lake and Tule Groundwater Subbasins.

6.2 Methodology

The clustering modeling methodology, developed by Marker et al. (2015), consists of an algorithm that pairs a lithology model, outlined in Section 4.2.2, with a resistivity model, outlined in Section 4, to produce a defined number of groups, each of which consists of similar resistivity and lithology values. The resistivity value for each cell in the sharp inversion resistivity model is paired with the corresponding lithology model CF value across the entire basin. The result is a set of resistivity-CF pairs that can be visualized as a scatter plot. To aggregate the groups of similar resistivity-lithology value pairs, a clustering algorithm is applied to the pairs, with a predetermined user-defined number of groups, or clusters. The resultant groups then represent points with similar resistivity and lithology and are thus presumed to have similar hydrogeologic properties.

At first glance, combining the CF values with the resistivity values that produced said CF values may seem circular. However, as described in Section 5, the lithology data used in the resistivity-to-lithology transform is simplified as either coarse or fine. This simplification is necessary for the computation-intensive numerical calculations in the ACT transform. However, details in the lithology information are lost in the process, resulting in some details contained within the resistivity model being muted or absent in the lithology model. By adding the resistivity information back into the clustering process, these details can be captured in the resultant initial hydrostratigraphic model.

The process of developing the initial hydrostratigraphic model begins with determining the number of groups, or clusters, to be identified. Determining the number of groups requires an understanding of the depositional environment(s) of the groundwater basin, including the basin's geologic structure and complexity as well as other parameters which could influence resistivity, such as changes in water quality (both horizonal and vertical) and the depth to saturated sediment. If the basin hydrogeology changes significantly across the survey area, the application of the clustering algorithm can be divided into multiple zones.

Once the number of clusters for each cluster model has been determined, the set of resistivity-CF pairs from the resistivity model and corresponding lithology model is entered into the clustering algorithm, which iteratively works to identify the best partitions between groups. The results of the clustering algorithm in the whole survey lithology modeling area are shown as a scatterplot in Figure 6-1. The CF value for each resistivity-CF pair is shown along the x-axis, while resistivity value is shown on the y-axis. Each point is colored according to the group it was placed in. Cluster 1, represented by 22% of all the clustered datapoints, contains the lowest resistivities and lowest CF values. This cluster represents the units with the highest amount of clay materials in the initial hydrostratigraphic model. Each following group has a sequentially higher CF and resistivity. A more detailed description of the clustering process is presented in Appendix 5.

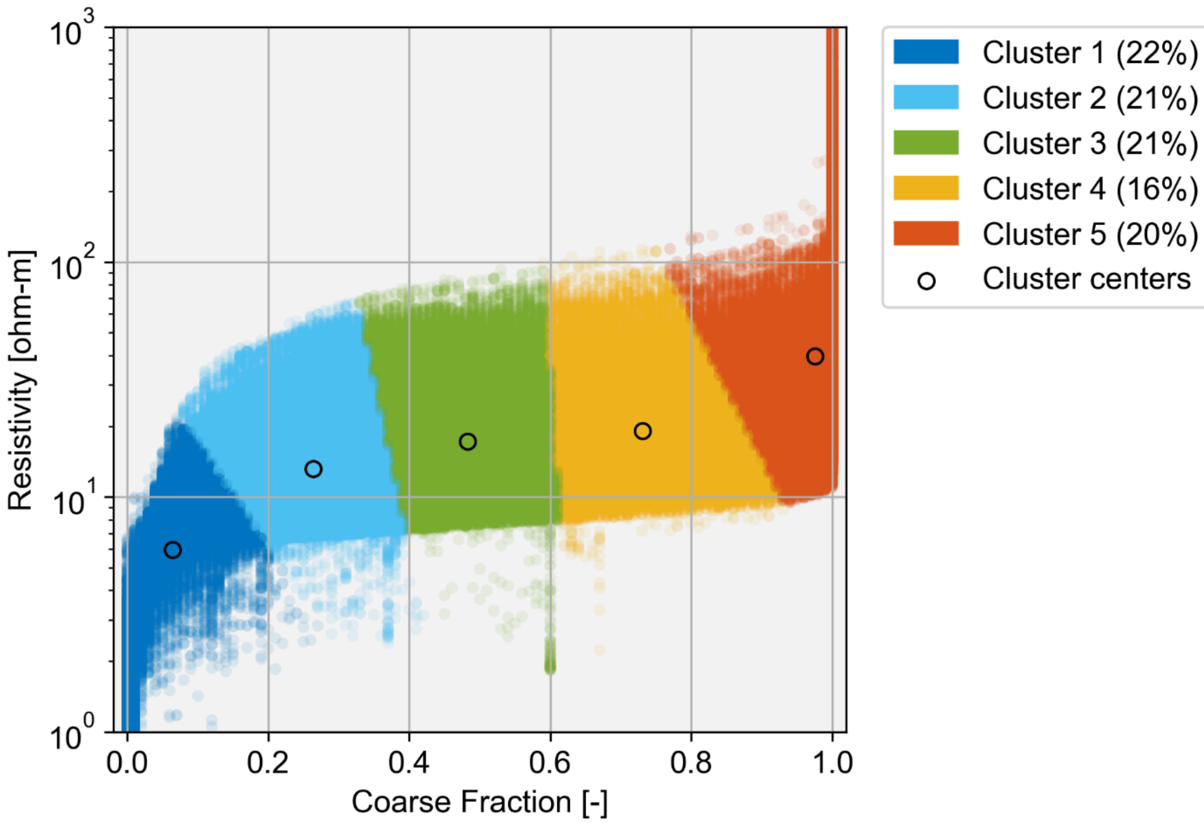


Figure 6-1 The results of the clustering algorithm applied to the data in Survey Area 4. Percentages in the legend indicate the ratio of resistivity-CF pairs included in the respective group. Note that there is overlap of points within the cluster model.

6.3 Clustering Algorithm Implementation

First, the magnitude and extent of groundwater salinity was considered. As described in Section 5.4.2, the western part of the Survey Area 4, Area West, contained elevated salinity and was not included in the ACT modeling. Cluster modeling was not conducted in Area West. In the eastern part of Survey Area 4, Area East, available TDS measurements show TDS generally under 1,000 mg/L, though with small areas where TDS increases to between 1,000-3,000 (see Figure 2-3). Since TDS remained below 3,000 mg/L, it was determined that salinity did not have a significant influence on resistivity and subsequently did not affect the cluster modeling process.

Five groups were chosen for the clustering algorithm to for Area East. This decision was based on the observed hydrogeology of the basin, where the different groups could accommodate the different hydrogeology, including coarse layers above and below the aquifer, mixed units, silty fines, and clayey fines. The choice of five groups was used a starting point producing an initial hydrostratigraphic model, which was subsequently evaluated as to whether a new iteration with more or fewer cluster groups was needed.

6.4 Results

The five different cluster groups representing the initial hydrostratigraphic model layers were plotted as profiles along all the flight lines where AEM data was acquired. The initial hydrostratigraphic model was evaluated for how well the chosen five-group model represents the hydrostratigraphy and whether a different number of clusters was needed. An example profile showing the result of the initial hydrostratigraphic model from Kern County and White Wolf Groundwater Subbasins is shown on Figure 6-2. Evaluation of the profile lines suggests that the clustering resulted in reasonable, continuous layers and the layering correlated well with the basin’s geological features. Thus, it was determined that a second iteration with a different number of clusters was not needed. Profiles of all the initial hydrostratigraphic models are shown on the data sheets in Appendix 9.

The uncertainty for the clustering model is presented as an index showing how close the data point is to an adjoining cluster boundary. The basis of the uncertainty index is that the closer a specific point is to another cluster boundary, the greater the chance is that that specific point may have hydrostratigraphic properties closer to the neighbor cluster and the lower the numeric value. Thus, points that have an uncertainty index of over 0.5 are closer to the cluster center than the neighboring cluster and have a high certainty of belonging in that cluster. However, points with an uncertainty index of under 0.2 will be near the neighboring cluster and thus have much higher uncertainty whether that specific point belongs in its own cluster or the neighboring cluster. An example of the results showing the uncertainty index is shown on Figure 6-2, and the uncertainty index for all the clustering results are shown on the profiles on the data sheets in Appendix 9.

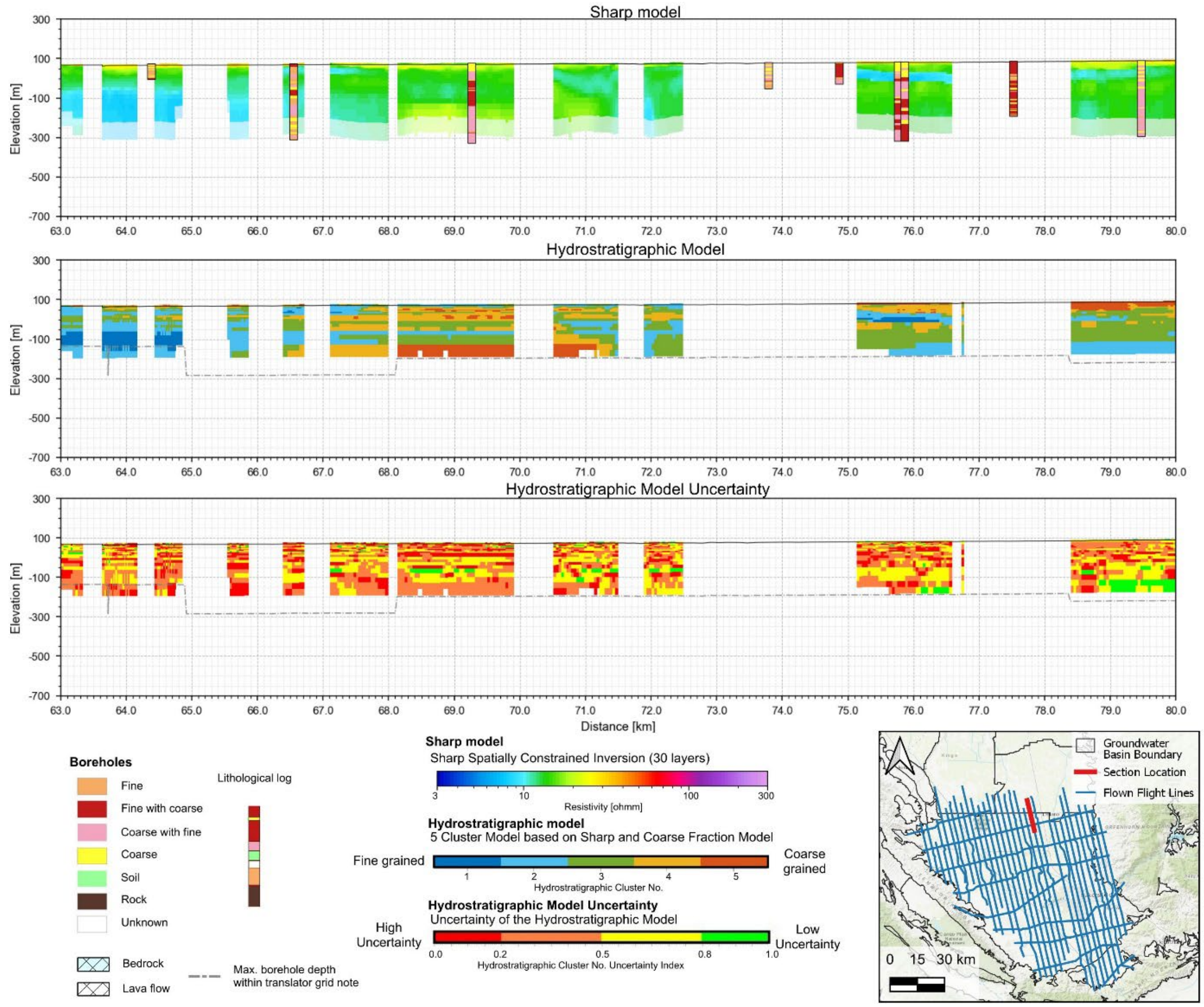


Figure 6-2 Initial hydrostratigraphic model along flight line 200200 in Kern County and White Wolf Groundwater Subbasins. Profile A shows the sharp resistivity model used as an input to the cluster model. Profile B shows the results of the initial hydrostratigraphic model along the profile. Profile C shows the uncertainty index associated with the cluster, with 0.0 indicating the highest uncertainty (red) and 1.0 indicated the lowest uncertainty (green). Note that the presence of bedrock is blanked. The index map showing the profile location is shown at the bottom right.

6.5 Perspectives on the Initial Hydrostratigraphic Model

The cluster modeling process provides the opportunity to handle the large amount of resistivity data produced from an AEM survey to construct an initial hydrostratigraphic model. The model is generated solely on a statistical analysis of the gathered data and its relationship with observed coarse versus fine materials and is completely independent from external biases that affect where model boundaries are drawn. As a result, the hydrostratigraphic model resulting from the clustering approach is reproducible.

The main limitation for the use of the clustering model to develop an initial hydrostratigraphic model is the wide spacing of the AEM flight lines. Ideally, the AEM line spacing should be close together, allowing for a 3D AEM model to be developed. With a line spacing in a 2 x 8-mile grid, the spacing is too large to extrapolate the data to the area between the grid lines. Thus, the results of the initial hydrostratigraphic model are only representative along the line where AEM data have been collected. A closer line spacing, on the order of 250 m, will allow for the data to be interpolated between the lines into a 3D model grid, providing the possibility for a direct input into a numerical flow model.

The development of the hydrostratigraphic model is an iterative process. For this project, only one iteration was conducted and thus, the result is considered an initial hydrostratigraphic model. More iterations could be conducted and compared with the known hydrostratigraphy of the basin to provide more realizations. In addition, in the process outlined by Marker et al. (2015), cluster models with varying number of clusters can be evaluated in the flow model calibration process. In this case, the flow model could be used as input to help define the necessary number of clusters in the hydrostratigraphic model when used as input to a numerical flow model. This is an opportunity that could be realized with further infill along the flight lines where AEM data are interpreted.

7. REFERENCES

Auken, E., A.V. Christiansen, C. Kirkegaard, G. Fiandaca, C. Schamper, A.A. Behroozmand, et al. 2015. An overview of a highly versatile forward and stable inverse algorithm for airborne, ground-based and borehole electromagnetic and electric data. Explor. Geophys. 46:223–235. doi: 10.1071/EG13097

California Geological Survey (CGS). 2010. Geologic Map of California. Scale 1:750,000.

DWR. 2020. California's Groundwater – Bulletin 118 – Update 2020.

Foged, N., P. A. Marker, A. V. Christansen, P. Bauer-Gottwein, F. Jørgensen, A-S. Høyer, and E. Auken, 2014. Large-scale 3-D modeling by integration of resistivity models and borehole data through inversion. Hydrology and Earth System Sciences 18, no. 11.

Gulbrandsen, M., Rasmussen, T. and Jensen, N., 2021. Indian Wells Valley – The Multiple Point Statistics Method. The Groundwater Acrchitecture Project (GAP): Utilizing advanced geophysical and computational methods for the development of hydrogeolgic conceptual models. https://mapwater.stanford.edu/.

Jorgensen, F., Moller, R., Nebel, L, Jensen, N., Chritiansen, A. and Sandersen, P. 2013. A method for cognitive 3D geological voxel modelling of AEM data. Bull. Eng. Geol. Environ. DOI 10.1007/s10064-013-0487-2.

Marker, P.A., Foged, N., He, X., Christiansen, A.V., Refsgaard, J.C., Auken, E., Bauer-Gottwein, P., 2015. An automated method to build groundwater model hydrostratigraphy from airborne electromagnetic data and lithological borehole logs. 2015. Hydrological Earth System Science Discussions, vol. 12, pp. 1555-1598.

Rusydi, A.F., 2018. Correlation between conductivity and total dissolved solids in various type of water: A review. IOP Conference Series: Earth Environmental Science 118 012019.

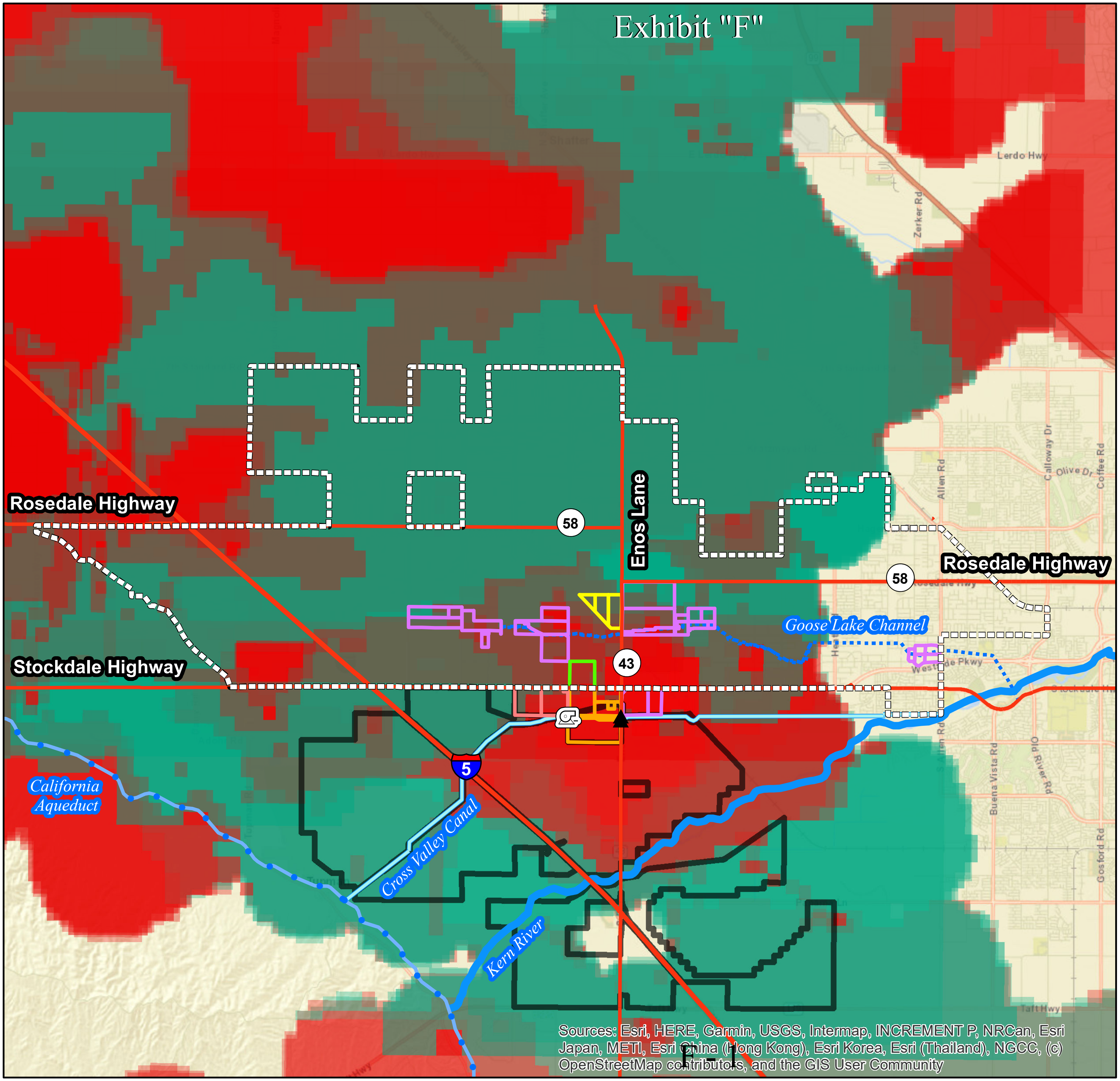
Schamper C., Pedersen, J., Auken, E., Christiansen, A., Vittecoq, B., Deparis, J., Jaouen, T., Lacquement, F., Nehlig, P., Perrin, J. and Reninger, P. (2013). Airborne Transient EM Methods and Their Applications for Coastal Groundwater Investigations. In: Wetzelhuetter C. (eds) Groundwater in the Coastal Zones of Asia-Pacific. Coastal Research Library, vol 7. Springer, Dordrecht.

Viezzoli, A., Christiansen, A. V., Auken, E., and Sørensen, K. I., 2008, Quasi-3D modeling of airborne TEM data by spatially constrained inversion: Geophysics, 73, F105–F113. doi:10.1190/1.2895521

Vignoli, G., Fiandaca, G., Christiansen, A. V., Kirkegaard, C., and Auken, E., 2015, Sharp Spatially Constrained Inversion with applications to transient electromagnetic data: Geophysical Prospecting, 63, pp 243-255. doi: 10.1111/1365-2478.12185

Ward SH, Hohmann GW (1988) Electromagnetic theory for geophysical applications. Electromagnetic Methods in Applied Geophysics, vol. 1, (ed MN Nabighian), pp 131–311, SEG publication.

Exhibit "F"



Irvine Ranch WATER DISTRICT

AEM Model Results & Staff Interpretation

Legend

- Rosedale Boundary
- CVC Pumping Plant #2
- Turnouts
- Kern County Highways
- Goose Lake Channel
- Cross Valley Canal
- Kern River
- CA Aqueduct

Recharge Project

- West Enos
- North Stockdale
- Stockdale (West)
- Strand
- Rosedale Conjunctive Use
- Kern Water Bank

AEM Model Results

- Good Potential Permeable Pathways
- Lesser Potential Permeable Pathways

11/28/2023

Airborne Electromagnetic Survey results were prepared by the Department of Water Resources and later processed in the FastPath application, developed by Stanford University. The following results include 10 runs in the model using various combinations of well profiles and AEM survey flight paths with resistivity readings. Green indicates good potential permeable pathways with a higher likelihood of good infiltration rates and direct connection to groundwater. Red indicates a lesser potential permeable pathway to groundwater. All results from the model are included at 70% transparency and layered. Areas appearing in grey or with muted colors, have mixed results.

N

0 0.5 1 2 3 4 5 Miles

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December 6, 2023
Prepared by: M. Lindsay / K. Welch
Submitted by: F. Sanchez / P. Weghorst
Approved by: Paul A. Cook

SUPPLY RELIABILITY PROGRAMS COMMITTEE

DRAFT TERMS FOR SHORT-TERM EXCHANGE PROGRAM WITH SILVERTIP

SUMMARY:

Staff has prepared draft terms for a Short-Term Exchange Program that would allow Silvertip LLC, a new landowner in Dudley Ridge Water District, to deliver water into storage at the IRWD Water Bank, with one-half of the water being transferred to IRWD. The recharge and recovery of Silvertip's water would occur after meeting the needs of IRWD and its other exchange partners. Staff recommends that the Board authorize the General Manager to execute an agreement with Silvertip based on the draft terms presented at the meeting, subject to substantive changes approved by the Supply Reliability Programs Committee and legal counsel.

BACKGROUND:

Early in 2023, Silvertip LLC purchased 2,100 acres of land in Dudley Ridge Water District with the right to use up to 16,300 acre-feet (AF) per year of State Water Project (SWP) Table A water. Silvertip anticipates having excess supplies and has expressed interest in storing water in the IRWD Water Bank. In October, staff met with Silvertip to discuss implementing a Short-Term Exchange Program that would allow Silvertip to deliver its SWP water into storage at the IRWD Water Bank on a 2-for-1 basis. Silvertip is interested in banking its share of the water to be later recovered for use on its lands in either Dudley Ridge or Kern County. Staff has developed draft terms for a proposed Short-Term Exchange Program with Silvertip as described below.

Short-Term Exchange Program Terms:

The proposed draft Short-Term Exchange Program terms would allow Silvertip to deliver up to 8,000 AF of its Dudley Ridge SWP water supplies to the IRWD Water Bank, with 50% of the water being transferred to IRWD through Metropolitan Water District. Delivery of Silvertip's water into storage would occur prior to the end of calendar year 2025 after the recharge needs of IRWD and its other exchange partners have been met. Silvertip's share of the water would be returned by the end of the sixth year either by in-ground transfer(s) to another banking project or by pumping wells at the IRWD Water Bank. The pumping of wells for Silvertip would occur after meeting the needs of IRWD and its other exchange partners. The proposed draft terms are provided as Exhibit "A". Staff recommends that the Board authorize the General Manager to execute a Short-Term Exchange Program Agreement with Silvertip based on the draft terms.

FISCAL IMPACTS:

IRWD and Silvertip would each be responsible for recharge and recovery costs associated with their respective share of the water delivered into storage under the Short-Term Exchange Program. Silvertip would pay for all fixed SWP costs associated with making the water available for recharge, including the water that will be transferred to IRWD.

ENVIRONMENTAL COMPLIANCE:

Final Environmental Impact Reports for the Strand Ranch and Stockdale Integrated Banking Project were prepared, certified, and approved in compliance with the California Environmental Quality Act (CEQA) of 1970 as amended, codified at California Public Resources Code Sections 21000 et. seq., and the State CEQA Guidelines in the Code of Regulations, Title 14, Division 6, Chapter 3. Rosedale, as lead agency, filed Notices of Determination for both the Strand Ranch and Stockdale Integrated Banking Projects with the County of Kern. IRWD, as a responsible agency, filed Notices of Determination with the County of Orange and with the County of Kern.

RECOMMENDATION:

That the Board authorize the General Manager to execute a Short-Term Exchange Program Agreement with Silvertip based on the draft terms presented, subject to substantive changes approved by the Supply Reliability Programs Committee and special legal counsel.

LIST OF EXHIBITS:

Exhibit "A" – Draft Terms for Short-term Exchange Program between Irvine Ranch Water District and Silvertip

Exhibit "A"

Draft Terms for a Short-Term Exchange Program Between
Irvine Ranch Water District and Silvertip
December 6, 2023

Parties	The Irvine Ranch Water District (IRWD) and Silvertip LLC (Silvertip)
Coordination with State Contractors and the State	Dudley Ridge Water District (DRWD) has a long-term water supply contract with the California Department of Water Resources (DWR). Through its subsidiary, Westside Agriculture, Silvertip is a landowner in DRWD with a water entitlement of 16,300 acre-feet (AF) of DRWD Table A. IRWD is also a landowner in DRWD with a water entitlement of 1,749 AF of DRWD Table A. Metropolitan Water District of Southern California has a long-term water supply contract with DWR. IRWD receives SWP supplies from Metropolitan through the Municipal Water District of Orange County (MWDOC), a member agency of Metropolitan. Kern County Water Agency (KCWA) also has a long-term water supply contract with DWR. Consent from KCWA is required to deliver DRWD water into storage in Kern County. IRWD and Silvertip would cooperate with DWR, DRWD, KCWA, and Metropolitan in preparing all necessary agreements to facilitate the Exchange Program. IRWD and Silvertip shall each be responsible for their own costs associated with coordination.
Program Term	The Program Term will last six years from the effective date of this Exchange Program Agreement. Delivery of Exchange Water into storage would be accomplished prior to the end of calendar year 2025. Upon mutual written agreement, the term may be extended.
IRWD's Water Bank	The IRWD Water Bank, located in Kern County, is owned by IRWD and operated by Rosedale-Rio Bravo Water Storage District. IRWD holds first- priority rights to the use of the recharge and recovery facilities, except when the Kern River Watermaster offers water to all takers willing to sign a notice/order or the Kern River Watermaster offers Kern River water to the California Aqueduct/Kern River Intertie. Under such conditions, Rosedale has first-priority right to the use of the recharge facilities.
Quantity	Through 2025, up to 8,000 AF of Exchange Water allocated to Silvertip may be delivered to Metropolitan at the IRWD Water Bank for temporary storage and later recovery of 50 percent (less losses) of such delivered water for Silvertip's use. Upon delivery into storage in the IRWD Water Bank, 50 percent of the Exchange Water, up to 4,000 AF (less losses), will be transferred to Metropolitan, on behalf of IRWD. (Losses are as described below.)

Exchange Water	Silvertip expects to supply the specified quantity of its DRWD SWP water supplies to the IRWD Water Bank by the end of 2025 (the Exchange Water) utilizing either Article 56(c) "carryover water" and/or calendar year 2024 or 2025 Table A water. The Parties would cooperate in scheduling the Exchange Water deliveries with deliveries associated with other IRWD deliveries and exchange programs. The recharge of Exchange Water would occur after the recharge needs of IRWD and its other exchange partners are met and are subject to available recharge capacity, available Cross Valley Canal (CVC) capacity, and terms of IRWD's Coordinated Operating, Water Storage, Exchange and Delivery Agreement with Metropolitan and the Municipal Water District of Orange County (Coordinated Agreement).
Return Water	Silvertip will either transfer in-ground its share of stored Exchange Water (less losses as described below) to a Silvertip Water Banking Project or IRWD will return Silvertip's share of the Exchange Water to Silvertip less losses by pumping wells at an annual rate of not more than one-third of the total amount delivered into storage by Silvertip (the Return Water). The pumping of wells to produce Return Water will occur subject to the use of the wells to meet the needs of IRWD and its other exchange partners. No later than May 1 of each year of this agreement, Silvertip shall provide IRWD with a schedule requesting delivery of the Return Water. The Parties will cooperate in scheduling the Return Water deliveries with deliveries associated with other IRWD banking and exchange programs. Silvertip shall be responsible for obtaining approvals of in-ground transfers and the delivery of Return Water to its lands in DRWD or in Kern County.
Delivery Points	The Point of Delivery (POD) for the Exchange Water under this program shall be at an IRWD Water Bank Turnout on the CVC. The POD for the Return Water shall be at an IRWD Water Bank Turn-in to the CVC. POD for Return Water transferred in-ground would be a designated Silvertip Banking Project. DRWD, on behalf of Silvertip, shall coordinate with KCWA for the conveyance of Exchange Water and Return Water utilizing the CVC. DRWD, on behalf of Silvertip, shall coordinate any required approval with the DWR for delivery of Silvertip's Exchange Water and Return Water.
Water Losses	Water banking losses shall be shared equally between IRWD and Silvertip (estimated to be between 11% and 15%). Silvertip and IRWD each may incur additional conveyance losses of 1% to 2% in the CVC for conveyance of each agency's share of the water, as measured and assessed by KCWA.
Recharge Costs	IRWD shall pay all costs assessed to IRWD by Rosedale for recharging water at the IRWD Water Bank. Silvertip would reimburse IRWD for 50 percent of these costs paid by IRWD upon delivery of Return Water to Silvertip. Costs are assessed by Rosedale consistent with that certain Water Banking and Exchange Program Agreement between Rosedale and IRWD dated January 13, 2009. These estimated costs may include Rosedale's administrative charge of about $4 per AF, third party wheeling charges assessed by KCWA of $5 per AF, CVC Standby, applicable actual CVC pumping and O&M costs of about $15 per AF, and applicable fixed and variable O&M Water Bank costs of about $3 per AF. Silvertip would be responsible for paying one-half of KCWA transaction request fee of $3,000.

Recovery Costs	Silvertip shall pay any costs assessed by Rosedale for the extraction of Return Water utilizing capacities within the IRWD Water Bank including costs associated with groundwater pumping, Rosedale's administrative charge, other associated O&M costs, and any costs assessed by the KCWA. Silvertip shall be responsible for any costs associated with the use of CVC pumping or CVC capacity for the conveyance of the Return Water. Silvertip would be responsible for paying the KCWA transaction request fee of $3,000 associated with delivery of its Return Water. Silvertip would be responsible for any costs assessed by KCWA for in-ground transfer of its Return Water. Silvertip shall be responsible for any costs assessed by Rosedale under the Long-Term Operations Plan for implementing provisions to prevent operation impacts. It is expected that banking projects, such as the IRWD Water Bank, may be required to contribute $2.00 per AF for recovered water to a fund, which may be used to meet mitigation obligations.
SWP Variable OMP&R Costs	Metropolitan will pay the DWR Variable Operation, Maintenance, Power, and Replacement (OMP&R) charges estimated at $30 per AF associated with the delivery of the Exchange Water from the Delta to IRWD POD consistent with the Coordinated Agreement. For delivery of Return Water to Silvertip POD, Silvertip will pay the DWR Variable OMP&R charges from the Delta to Silvertip's POD.
Water Quality	The quality of the Exchange Water and the Return Water will be limited as follows: if and to the extent that either party delivers water to and into the California Aqueduct, the quality of water shall meet the water quality standards established by DWR for pump-in to the California Aqueduct.
Environmental Compliance	Both parties shall comply with the California Environmental Quality Act (CEQA) and cooperate with one another with respect to CEQA compliance that may be required by DWR for the proposed Exchange Program. IRWD has already conducted environmental review under CEQA for the Strand and Stockdale Integrated Banking Projects that takes into consideration the delivery, storage and recovery of SWP water. Rosedale certified and IRWD approved the CEQA documents for the Strand and Stockdale Integrated Banking Projects. Corresponding Notices of Determination were filed by both Rosedale and IRWD. IRWD and Silvertip will share equally any additional costs associated with any further environmental review or permitting for delivering Silvertip water into storage, if deemed necessary. Both IRWD and Silvertip shall each be responsible for any other environmental review or permitting necessary to implement the Exchange Program within their own respective service areas.
Water Rights	It is expressly agreed, understood, and acknowledged by IRWD and Silvertip that any existing or future delivery of Exchange Water to the IRWD Water Bank by Silvertip will not result in or be considered a sale or transfer of Silvertip's contractual rights to SWP water or a sale or transfer of IRWD's ownership in the IRWD Water Bank.
General Expenses	Each Party shall be responsible for its own fees and expenses arising out of the negotiation and execution of the Exchange Program Agreement, obtaining necessary approvals, and the like.

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