CWEMF
CALIFORNIA Water & Environmental Modeling Forum

Woodard & Curran

DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

2025 CWEMF Annual Meeting

Aquifer Recharge Potential(ARP) Analysis – Development and Application

May 13th, 2025

Mesut Cayar, PhD, PE

Outline and Objective

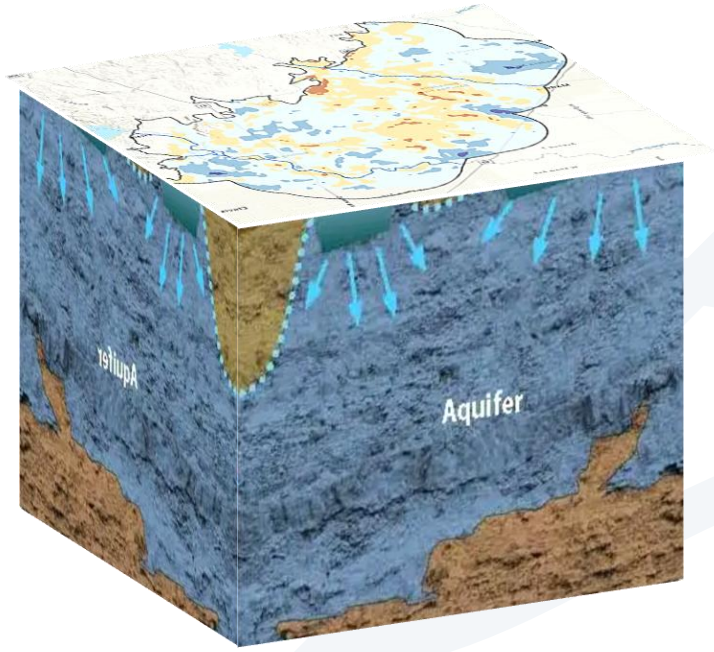
- **Objective**
  - Preview the approach and process for developing the Aquifer Recharge Potential (ARP) analyses and maps, as described in the Draft ARP Process Document
- **Outline**
  - Overview of Aquifer Recharge Potential (ARP) analyses
  - ARP Map Types
  - Methodology
    - Gather Sub-index Data
    - Bin and Rank Data
    - Weight Data Combine to Develop ARP Maps
  - Conclusions and Next Steps

Aquifer Recharge Potential Overview

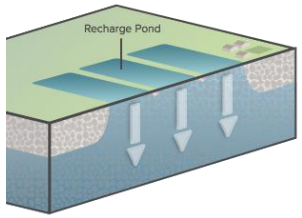
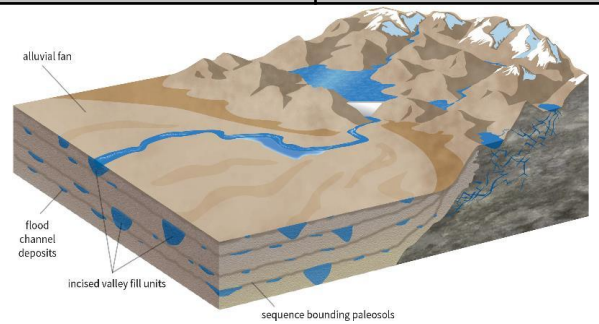
ARP maps identify locations that have relatively more and less **potential for managed aquifer recharge**

The focus is on **basin characterization** and **natural infrastructure**, *not* anthropogenic considerations (e.g., water rights, conveyance, land use, etc.)

- SAGBI
- Depth to Water
- Depth to Shallow Clay
- Average Percent Coarse
- Interconnected Coarse Bodies



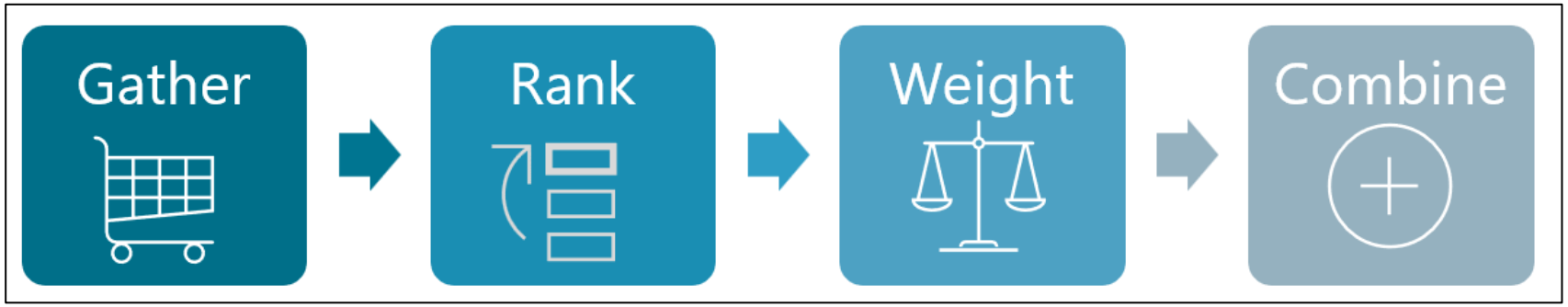
Aquifer Recharge Potential Map Types

ARP Map	Shallow (Natural)	Shallow (Built)	Deep Preferential Pathways (Natural)	Deep Preferential Pathways (Built)	Deep Aquifer Storage
Schematic		Coming soon!			Coming soon!
Infiltration Type	Pathways from the surface to the shallow portion of the aquifer		Pathways from the surface to the deeper portion of the aquifer through a preferential pathway		Injection into the deep portion of the aquifer
Soil Consideration	Through soil layer	Bypassing soil layer	Through soil layer	Bypassing soil layer	Bypassing soil layer & shallow aquifer
Recharge Methods	Ag-MAR, surface water spreading, managed natural lands	Reverse tile drains, dedicated groundwater recharge facilities	Minimally developed groundwater recharge facilities, Ag-MAR, surface water spreading	Dedicated groundwater recharge facilities, dry wells	Aquifer storage and recovery - injection wells

Flood mitigation, shallow supply, habitat rehabilitation

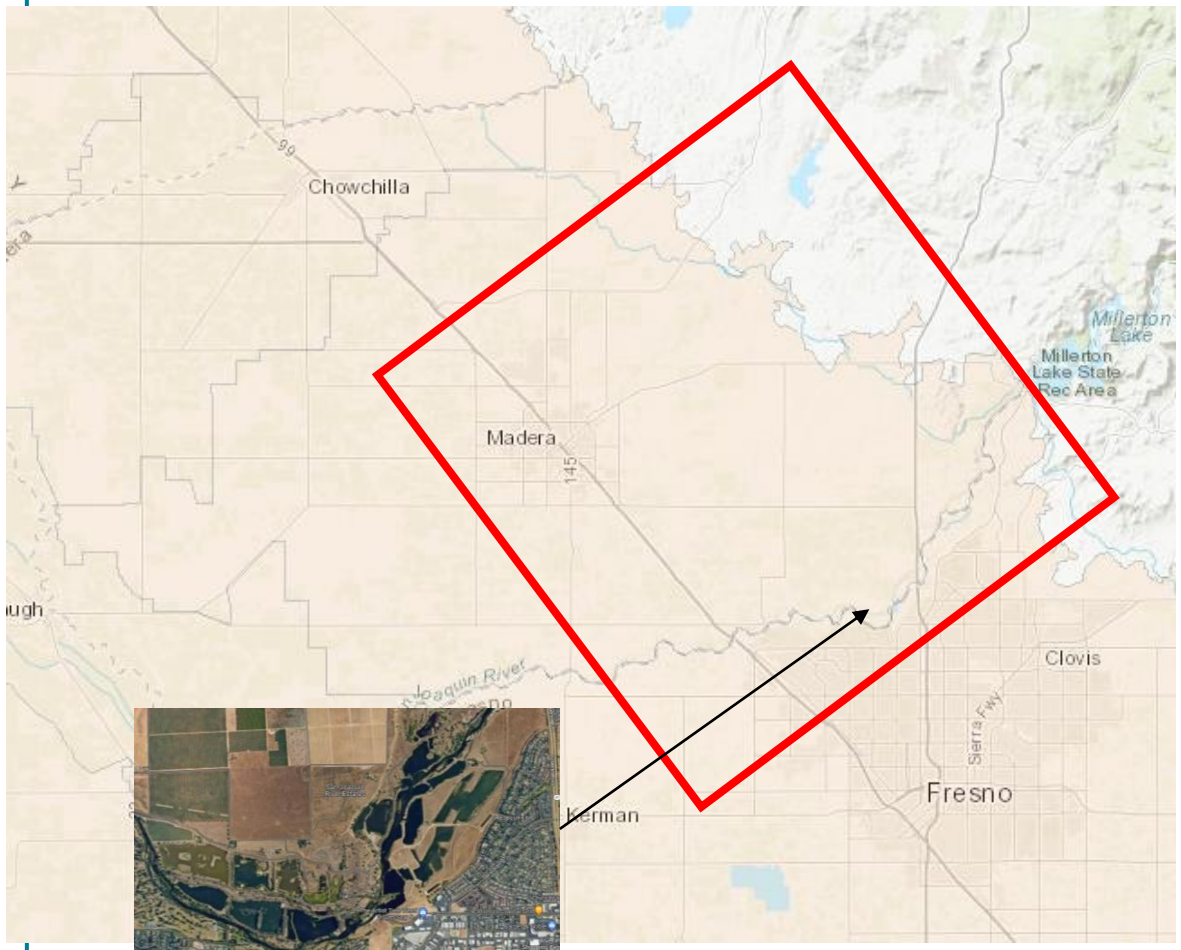
Deep groundwater well supply, subsidence mitigation

Aquifer Recharge Potential Mapping Process



Madera & North Kings Local Investigation

Project Site: Between Upper San Joaquin and Fresno Rivers

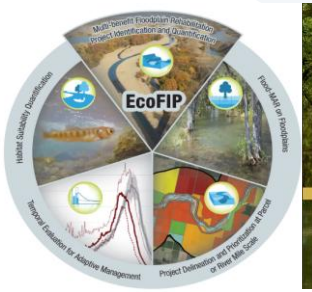


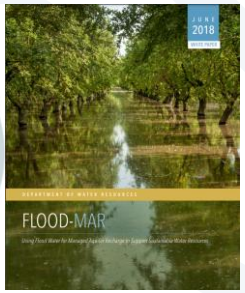
Goals:

- Identify aquifer recharge potential to support domestic well and deep well water supply.
- Characterize native material under river system to improve understanding of ISW and multi-benefit habitat restoration.

Process:

1. ☑ Infill AEM and digitized additional logs
2. ☑ Texture model (with AEM data and newly digitized lithology logs)
3. ☑ ARP maps
4. Field investigations





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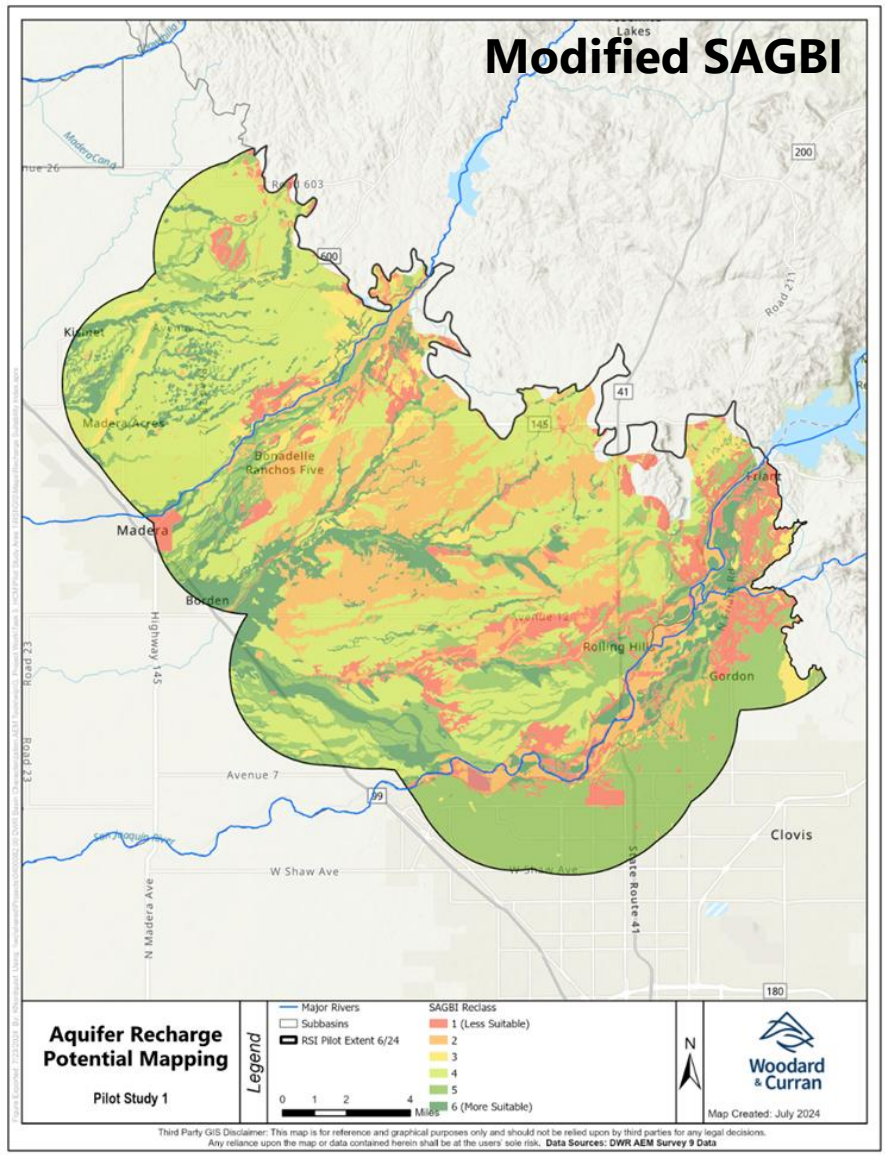
Gather

Gather Sub-index Data - Soil Conditions

- Represents **infiltration capacity through soils**
- SAGBI incorporates a range of components for recharge potential and to avoid adverse impacts on crops
- Modified versus unmodified SAGBI



Source: SAGBI was developed by the California Soil Resource Lab at UC Davis and UC-Agriculture and Natural Resources

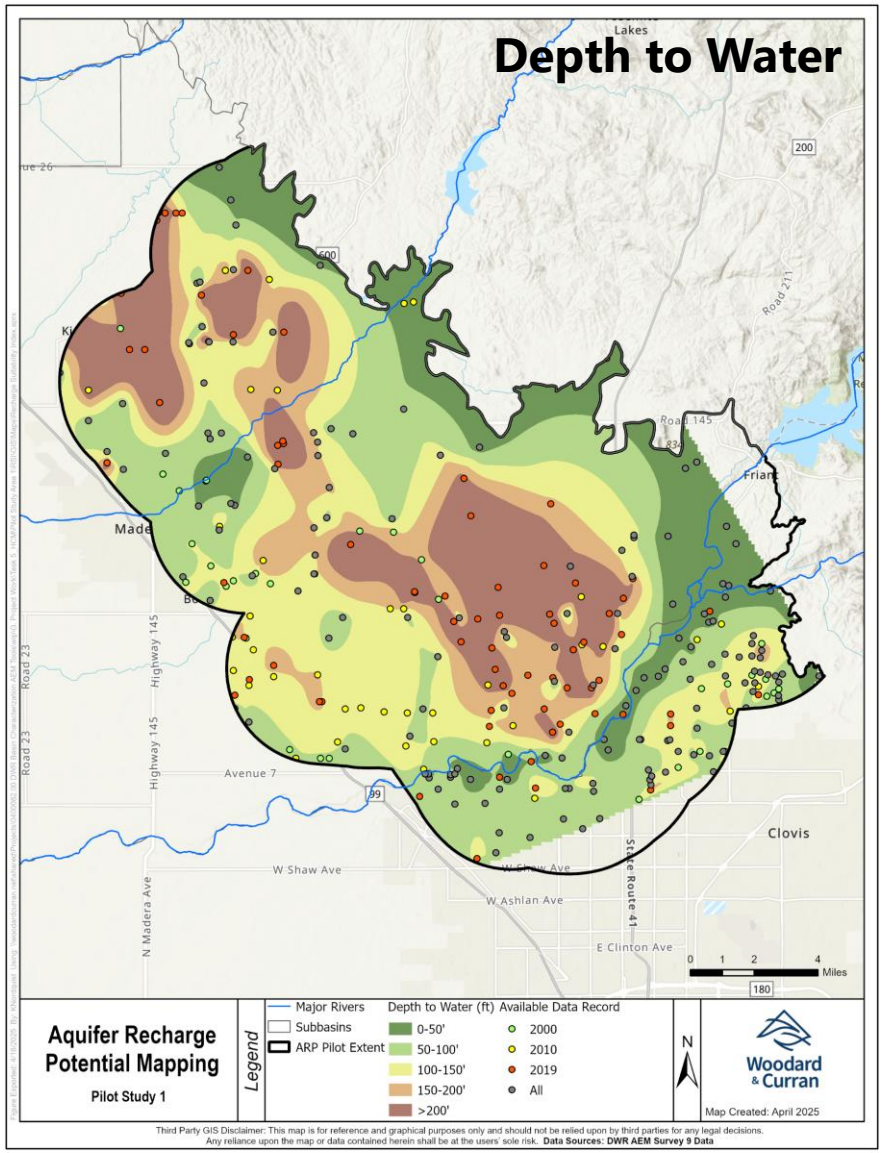
UCDAVIS University of California Agriculture and Natural Resources

- Deep Percolation
- Root Zone Residence Time
- Chemical Limitations
- Topographic Limitations
- Surface Condition

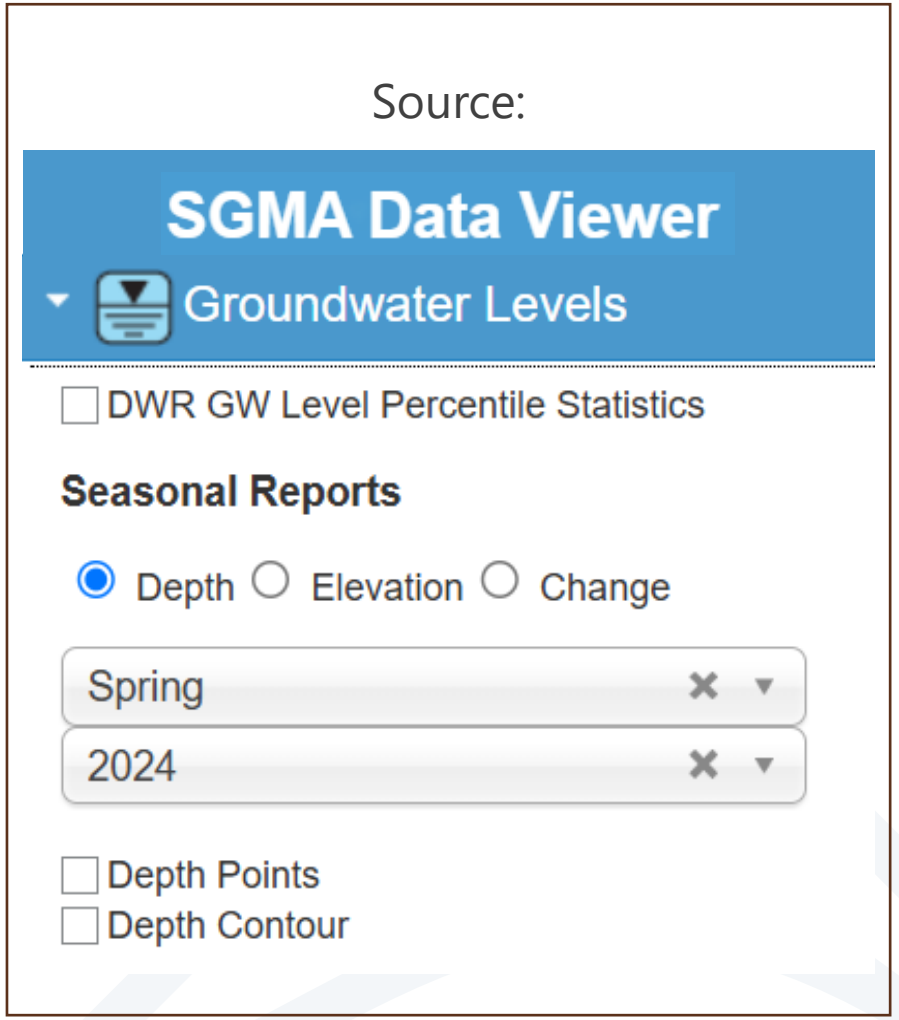
Gather

Gather Sub-index Data - Depth to Water

- Represents **storage capacity and management objectives**
- Recommended to use **recent spring conditions** reflective of the aquifer of interest, if confining layers are present
- Interpolate into rasters from point or contour data



Source:



And/or locally available data

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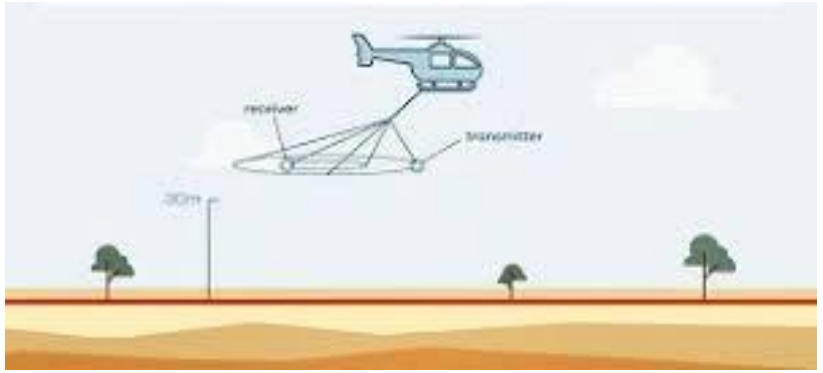
Gather Sub-index Data - Texture Model Inputs

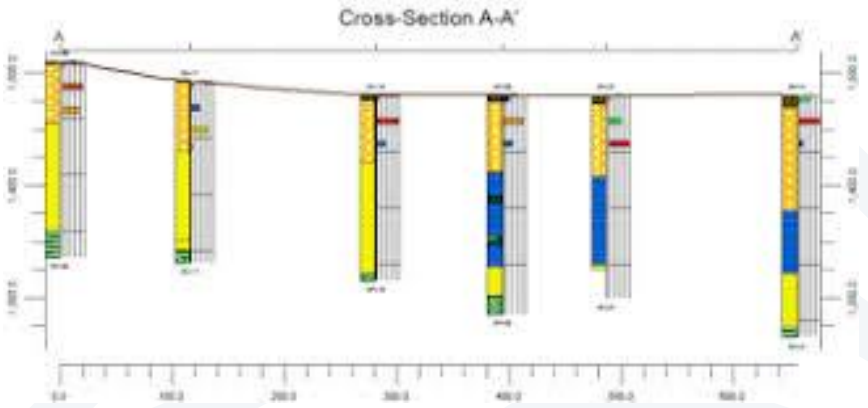
Boring Logs

AEM Data along Flight Paths

Geophysical Logs

3D Texture Model

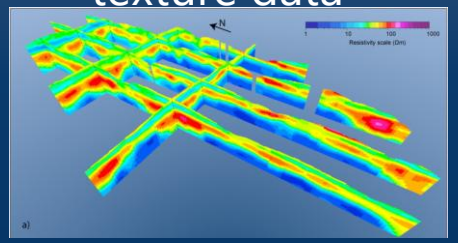




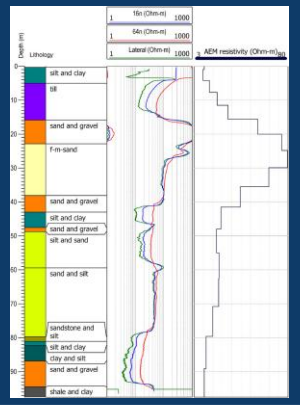
Inputs

Outputs

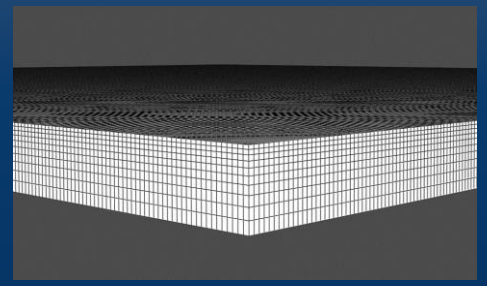
Compile **AEM data** along flight paths with texture data



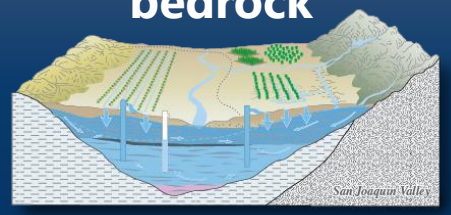
Compile available **boring logs** with texture data



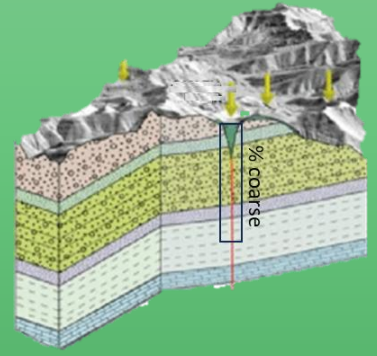
Generate **3D grid** of sediment texture



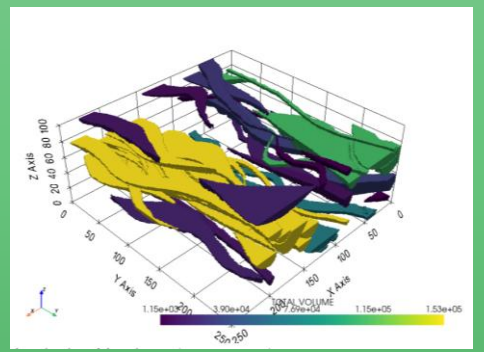
Vertically clip to **bedrock**



Calculate average **sediment coarseness**



Identify **connected bodies**



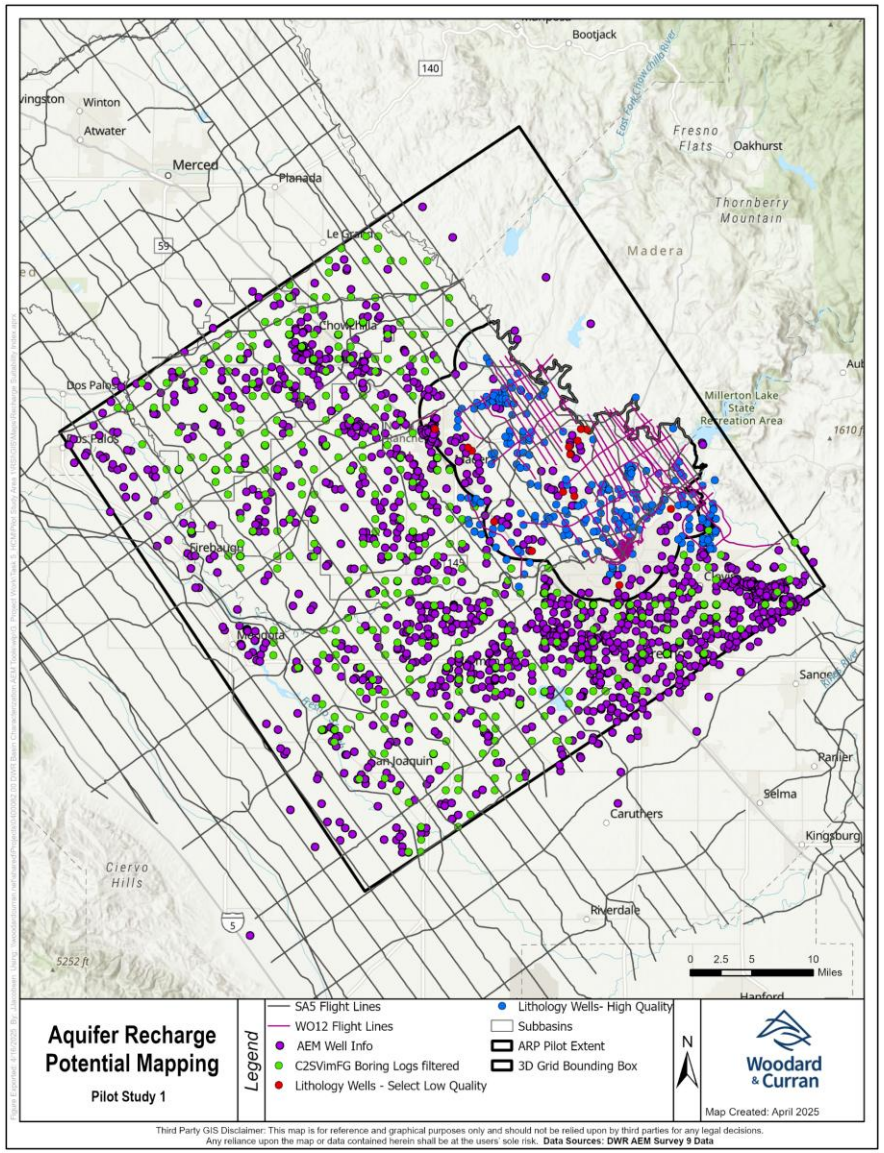
Identify interconnected **coarse** bodies

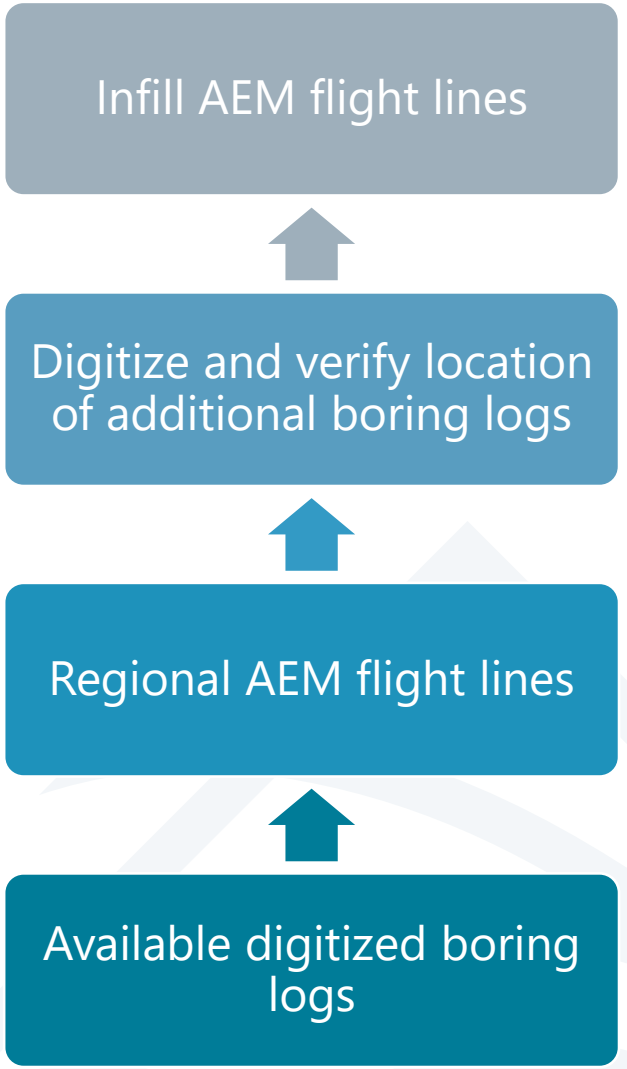
Identify **clay** footprints

Image sources: Korus 2021, Hoyer 2015

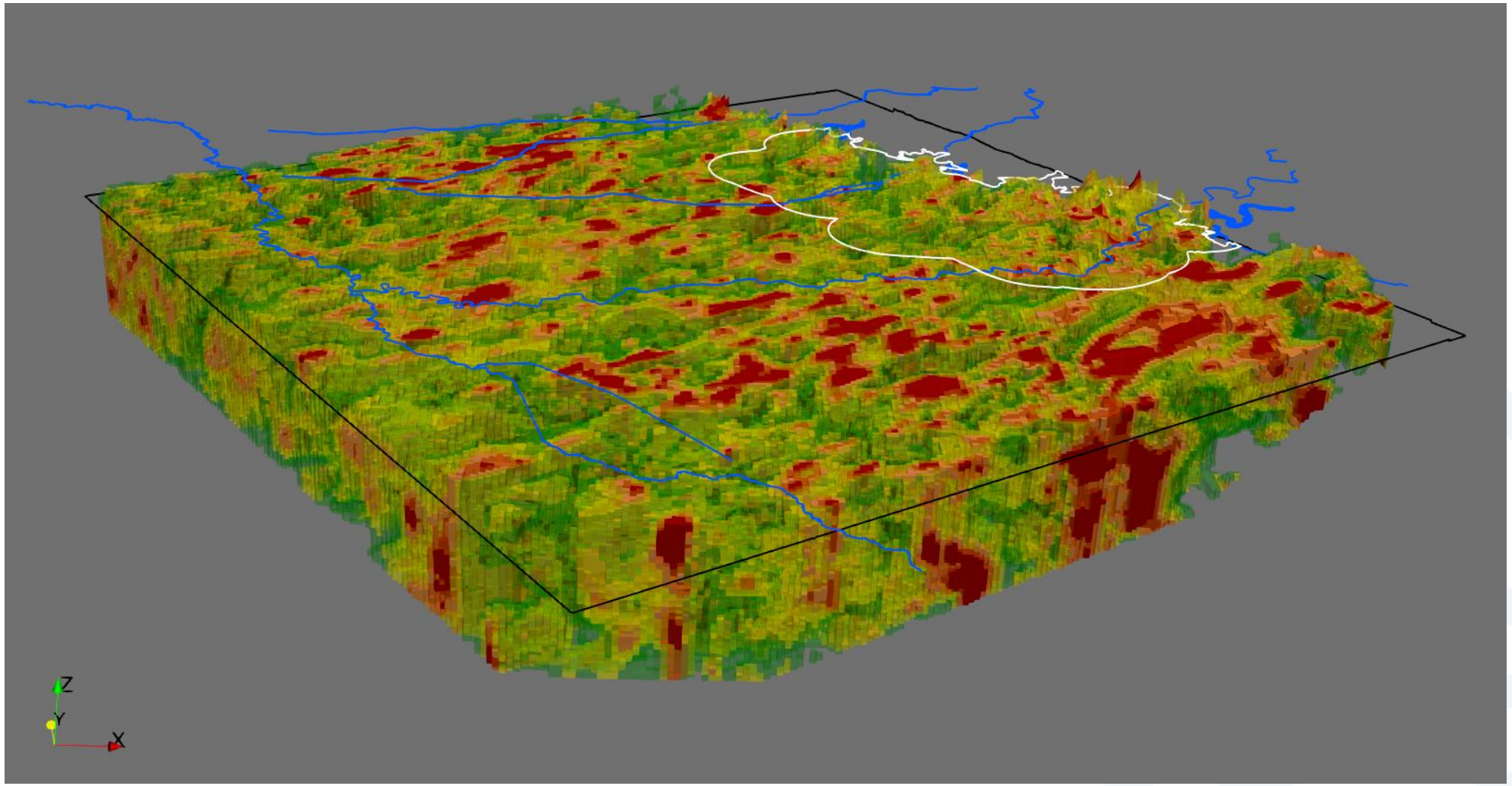
Texture Model Input Data

- Higher data density supports higher resolution texture model
- AEM data enhances understanding of subsurface texture





Three-Dimensional Texture Model



Bin and Rank Data

Rank

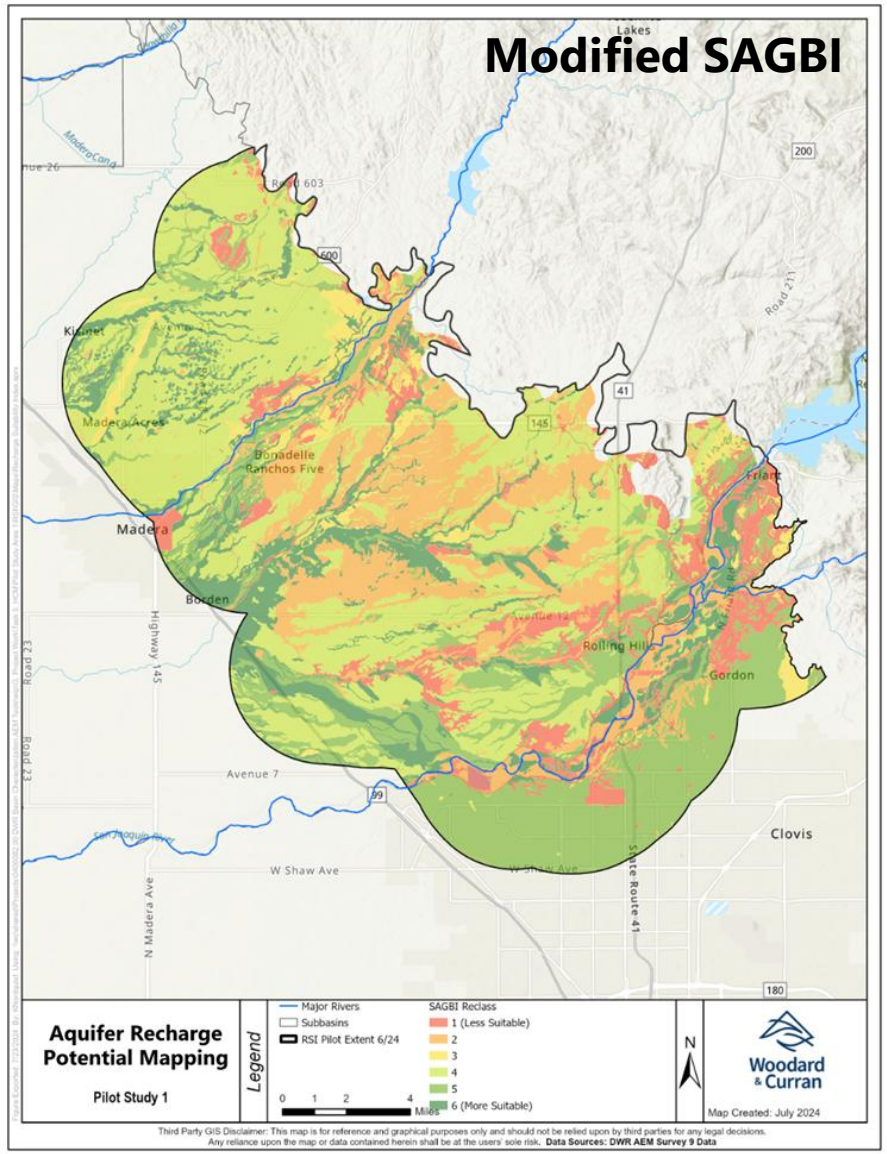
- Each sub-index was "binned," or scored, so sub-indices could be compared on a similar basis
- The bins were established based on enhancement or detriment to recharge potential
- 5 is the highest rank, most suitable for recharge
- 1 is the lowest rank, least suitable for recharge

Rank Number	Soil Conditions	Depth to Groundwater	Depth to Shallow Fine-Grained Layer	Shallow Sediment Coarseness	Interconnected Coarse Body
	SAGBI score (unitless)	*Depth to groundwater from ground surface (feet)*	*Depth to groundwater ground surface (feet)*	*Percent classified as coarse grained (%)*	*Percent coarse (%)*
1 (least suitable for recharge)	0-15	0-25 feet	0-16.4 feet	0-30%	No access to an interconnected coarse body in top 15 feet
2	>15-29	>25-50 feet	>16.4-32.8 feet	>30-50%	No value defined
3	>29-49	>50-75 feet	>32.8-49.2 feet	>60-70%	50-75%
4	>49-69	>75-100 feet	>49.2-98.4 feet	>70-90%	>75-90%
5 (most suitable for recharge)	>69-85	>100 feet	>98.4 feet, or not present	> 90-100%	>90-100%
6 (most suitable SAGBI only)	>85-100	-	-	-	-

Rank

Soil Conditions

- SAGBI maintains 6 ranks
- SAGBI bins match the rating class due to:
  - grower and water manager familiarity with soil types
  - importance of surface infiltration rates to recharge

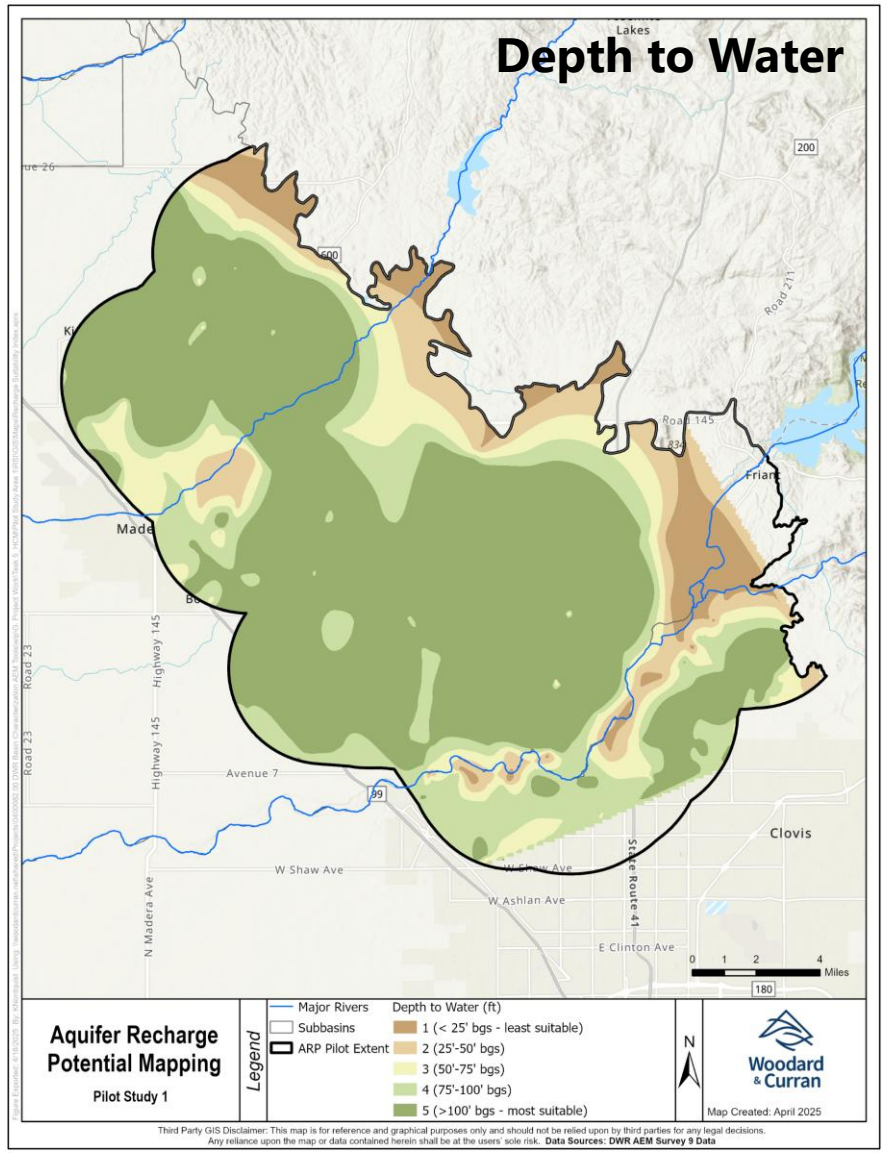


	SAGBI Rating	Rating Class
6	85 - 100	Excellent
5	69 - 85	Good
4	49 - 69	Moderately Good
3	29 - 49	Moderately Poor
2	15 - 29	Poor
1	0 - 15	Very Poor

Rank

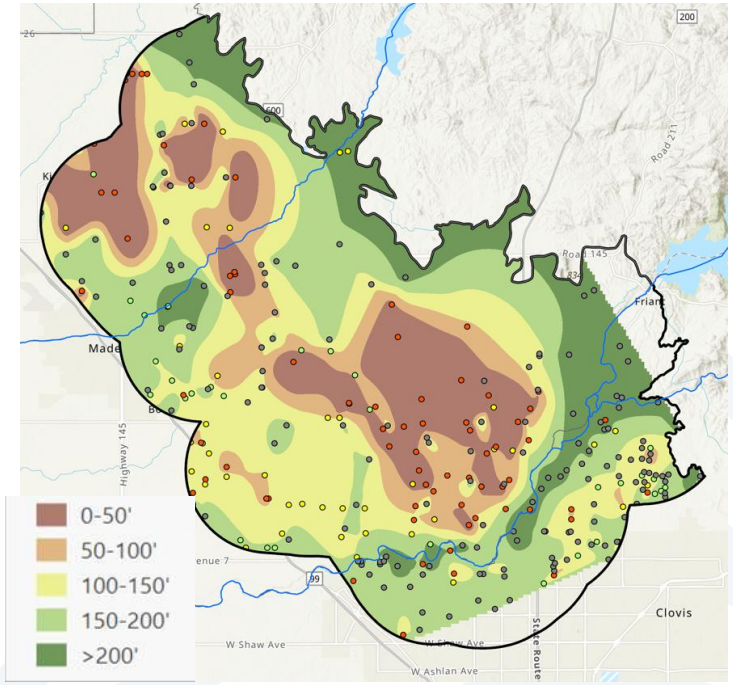
Depth to Water

- Penalized shallow groundwater table since it reduces storage capacity and could cause water logging
- Highest rank at 100 feet deep since there is only a marginal advantage of a deeper water table



Depth to Water (ft)

- 1 (< 25' bgs - least suitable)
- 2 (25'-50' bgs)
- 3 (50'-75' bgs)
- 4 (75'-100' bgs)
- 5 (>100' bgs - most suitable)



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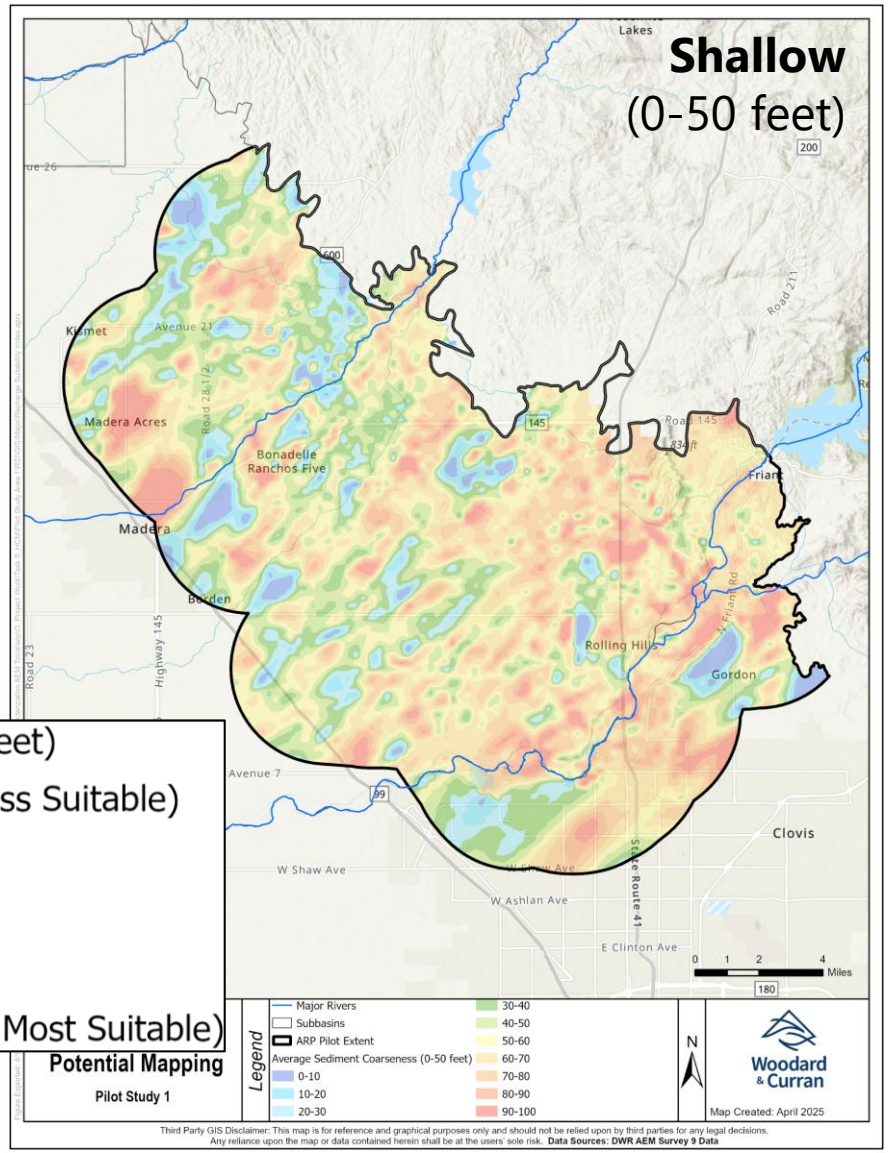
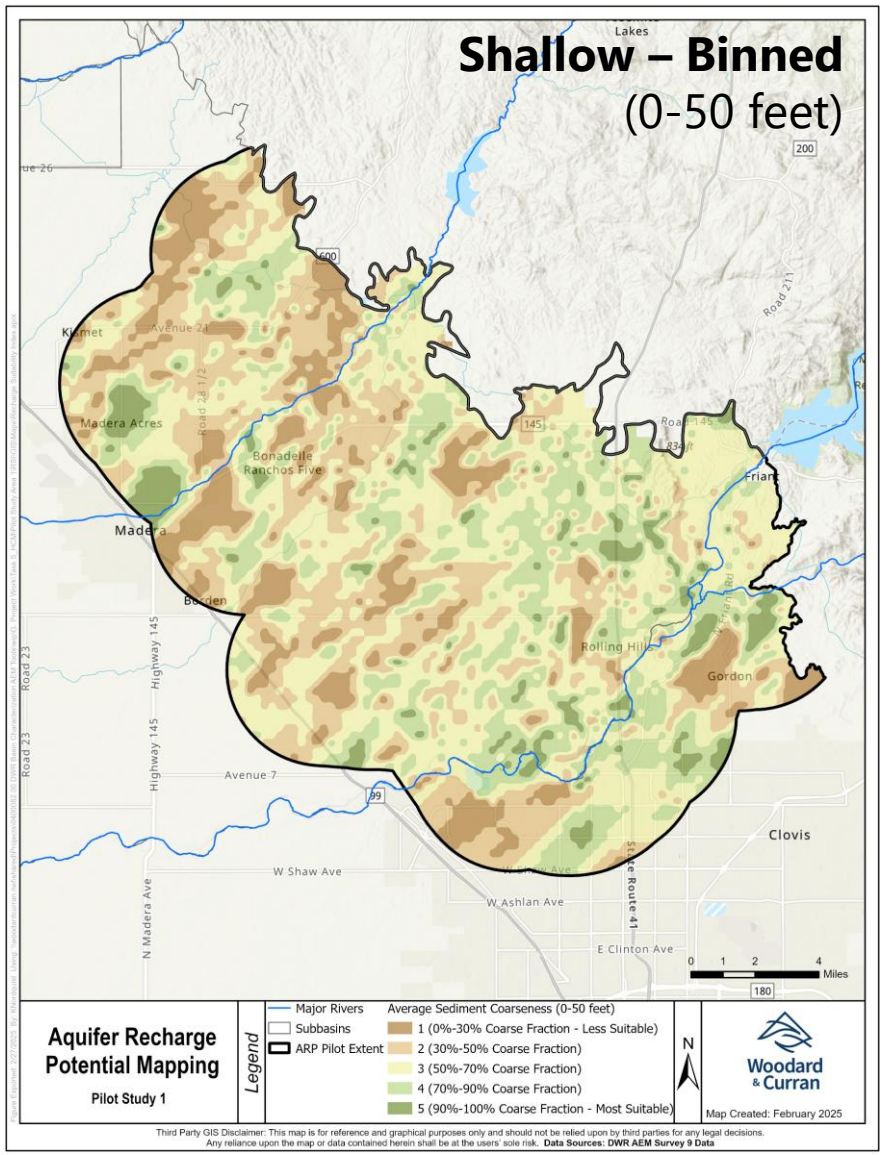
Average Coarse Fraction

- Represents **shallow percolation efficiency**
- Captures the average texture within the top 50 ft
- Binned to emphasize coarsest areas

Average Sediment Coarseness (0-50 feet)

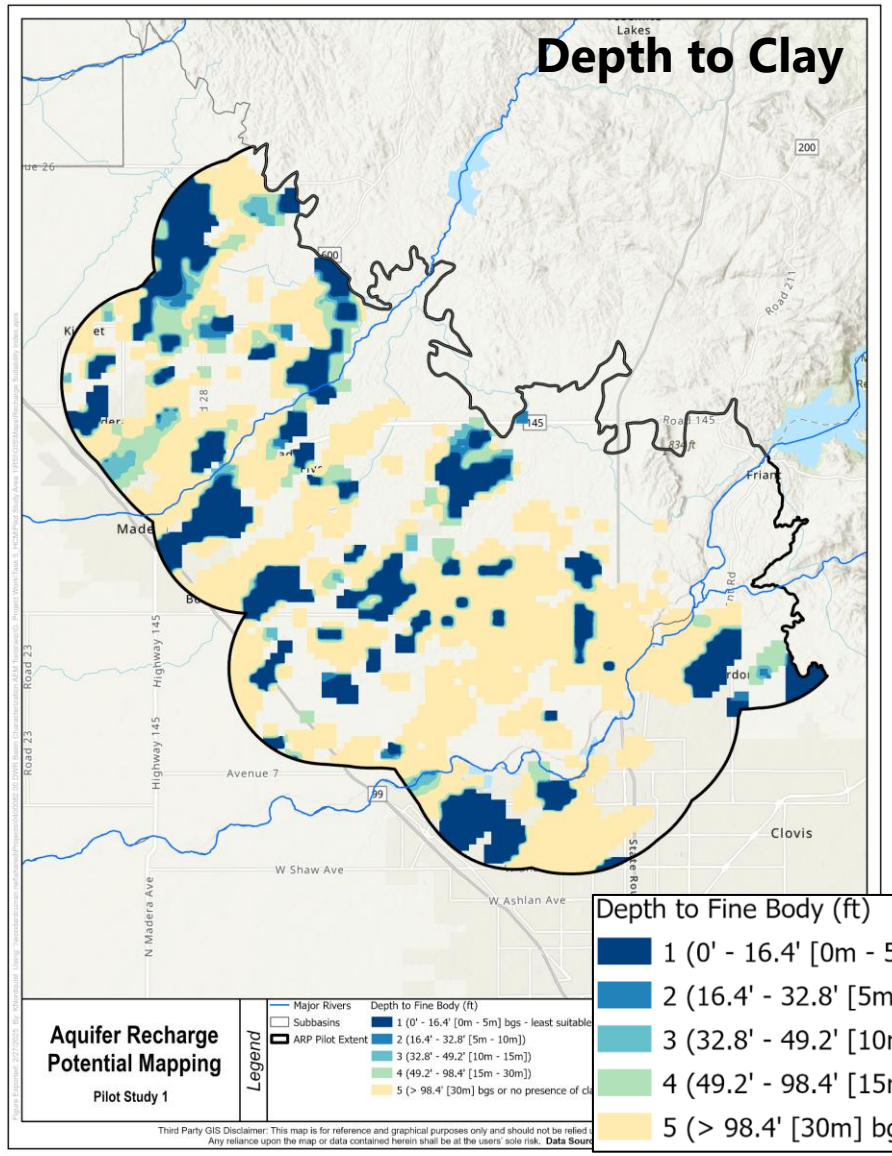
- 1 (0%-30% Coarse Fraction - Less Suitable)
- 2 (30%-50% Coarse Fraction)
- 3 (50%-70% Coarse Fraction)
- 4 (70%-90% Coarse Fraction)
- 5 (90%-100% Coarse Fraction - Most Suitable)

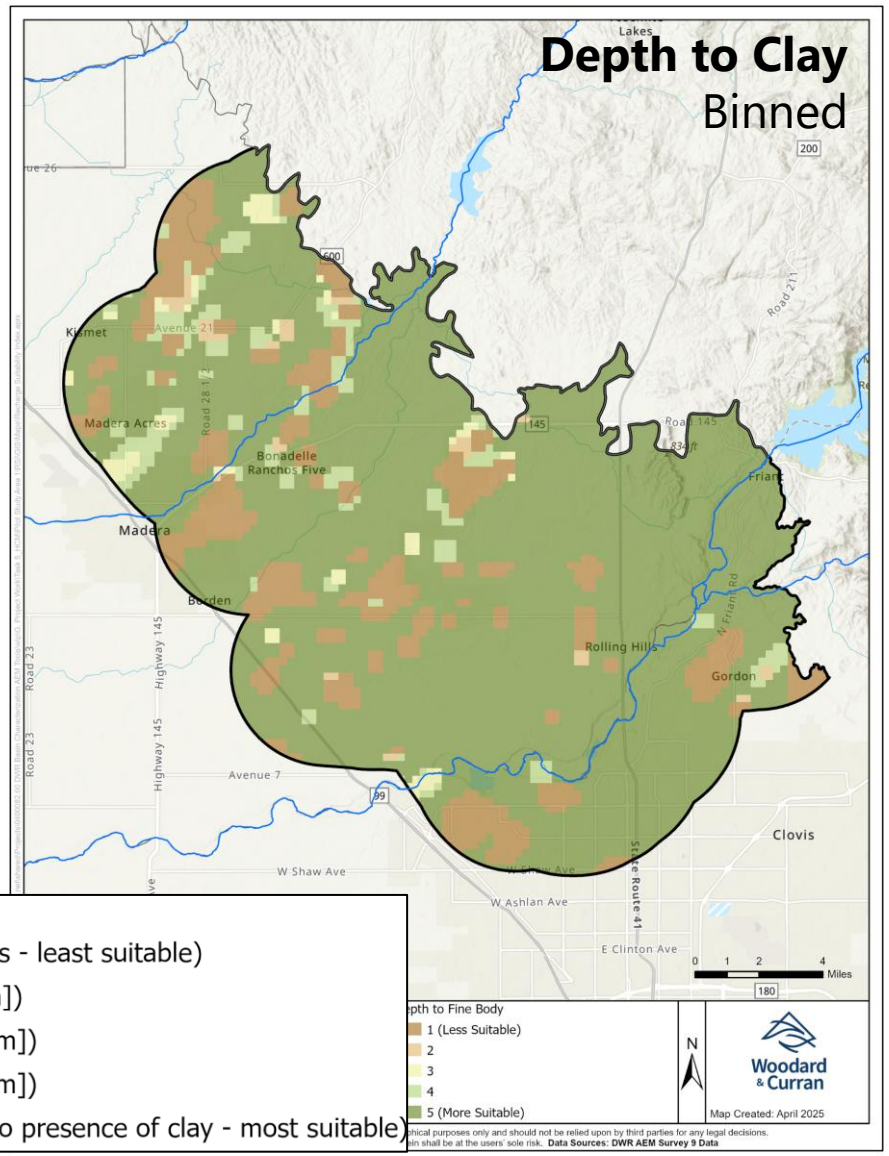




Depth to Shallow Fine-Grained Layer

- Represents **downward flow limitation**
- Captures large, **interconnected fine bodies** that are near the surface
- Limited by the texture model resolution which may not be able to identify small clay lenses





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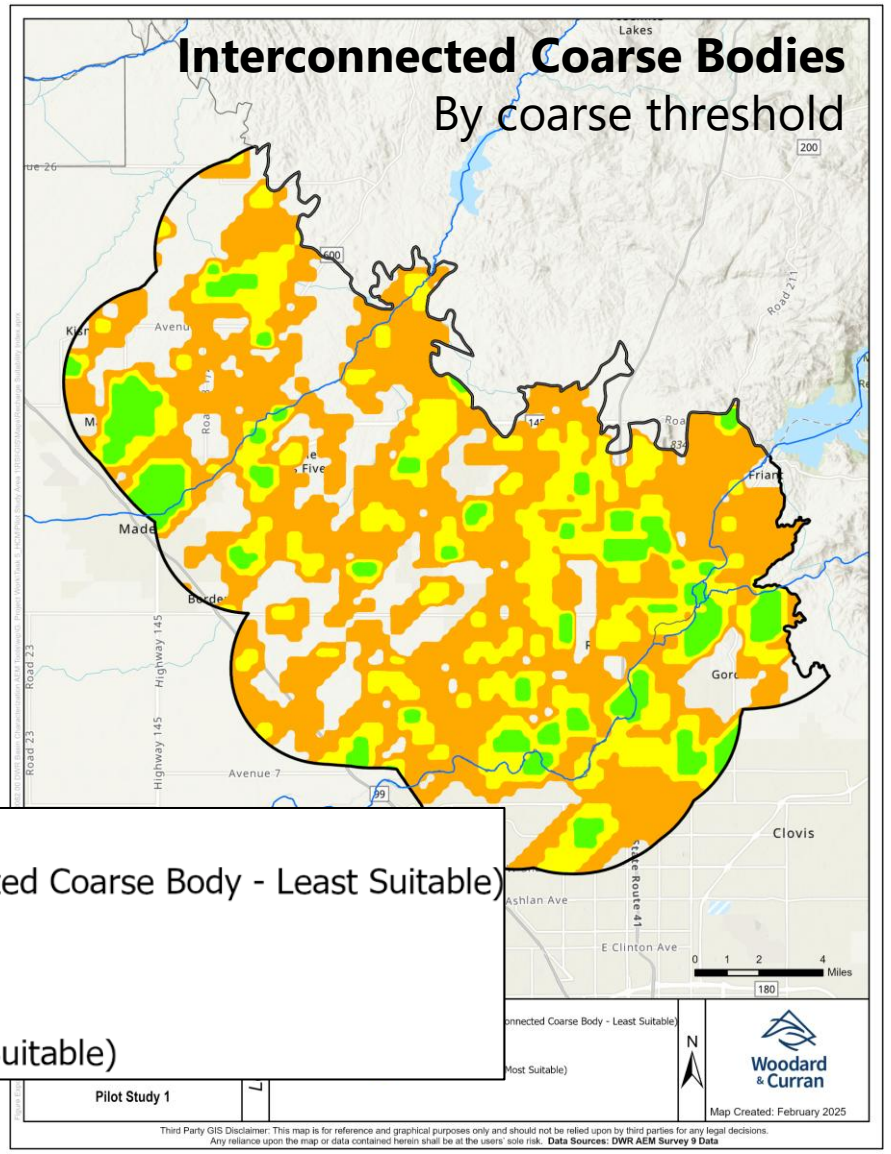
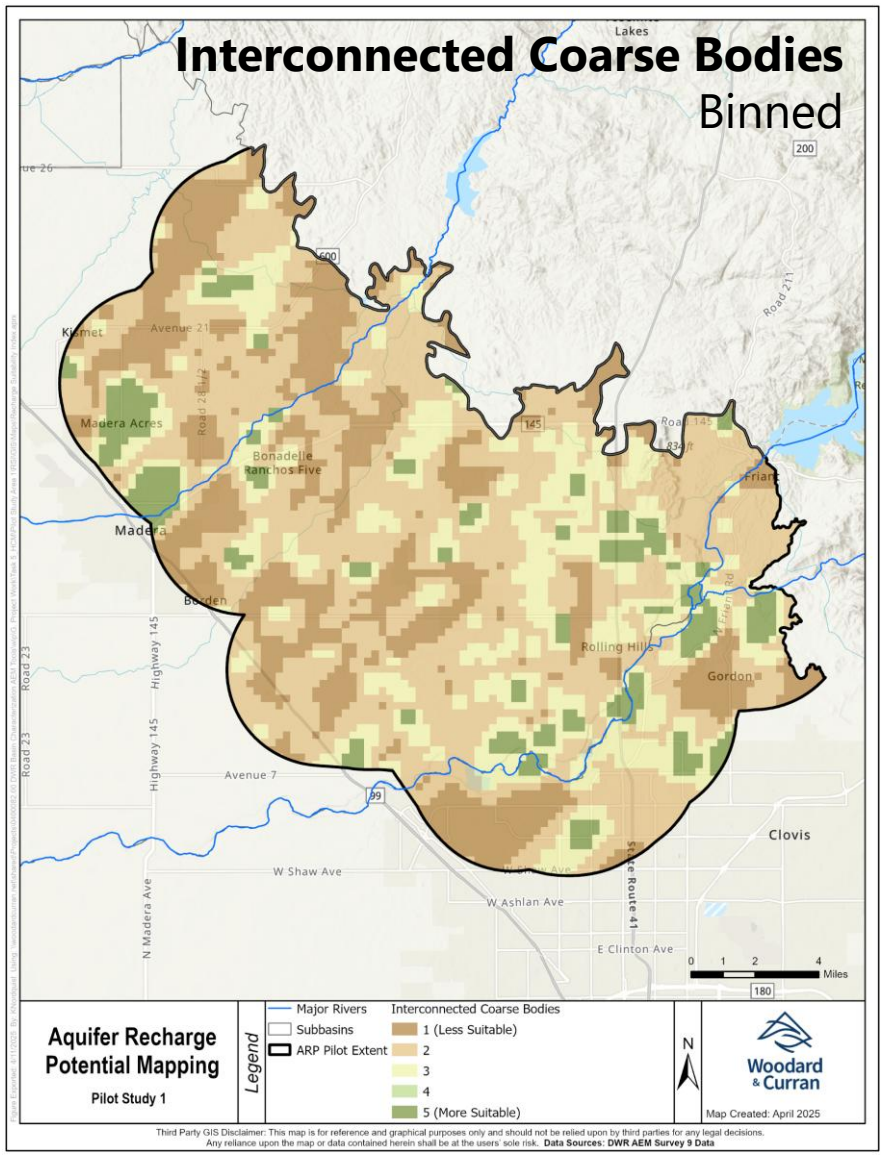
Interconnected Coarse Bodies (50-90%)

Rank

- Reflects **efficient percolation pathways to deeper aquifer**
- Captures well-defined **areas of coarse bodies** that are near the surface





Interconnected Coarse Bodies

- 1 (No Access to an Interconnected Coarse Body - Least Suitable)
- 2 (50% - 75% Coarse)
- 3 (75% - 90% Coarse)
- 5 (90% - 100% Coarse - Most Suitable)

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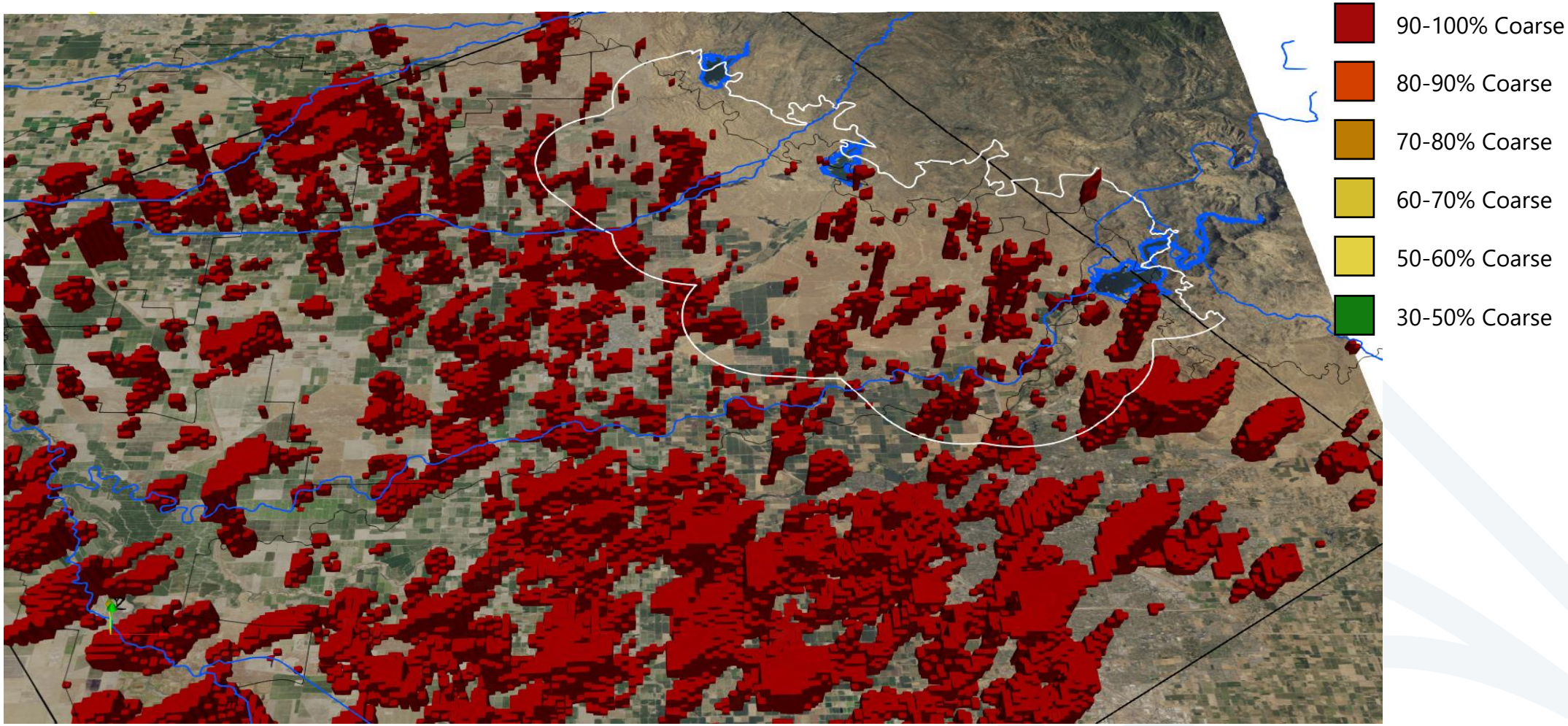
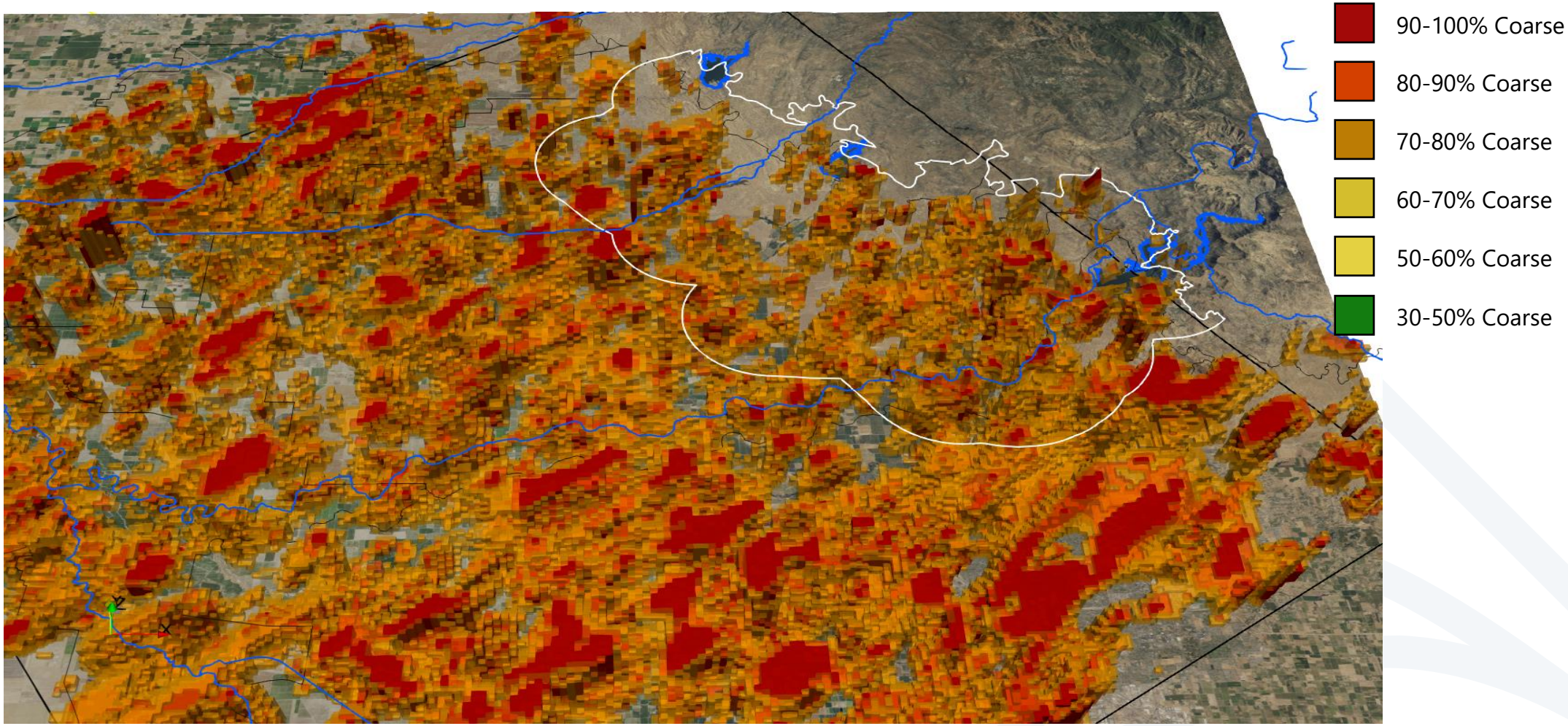
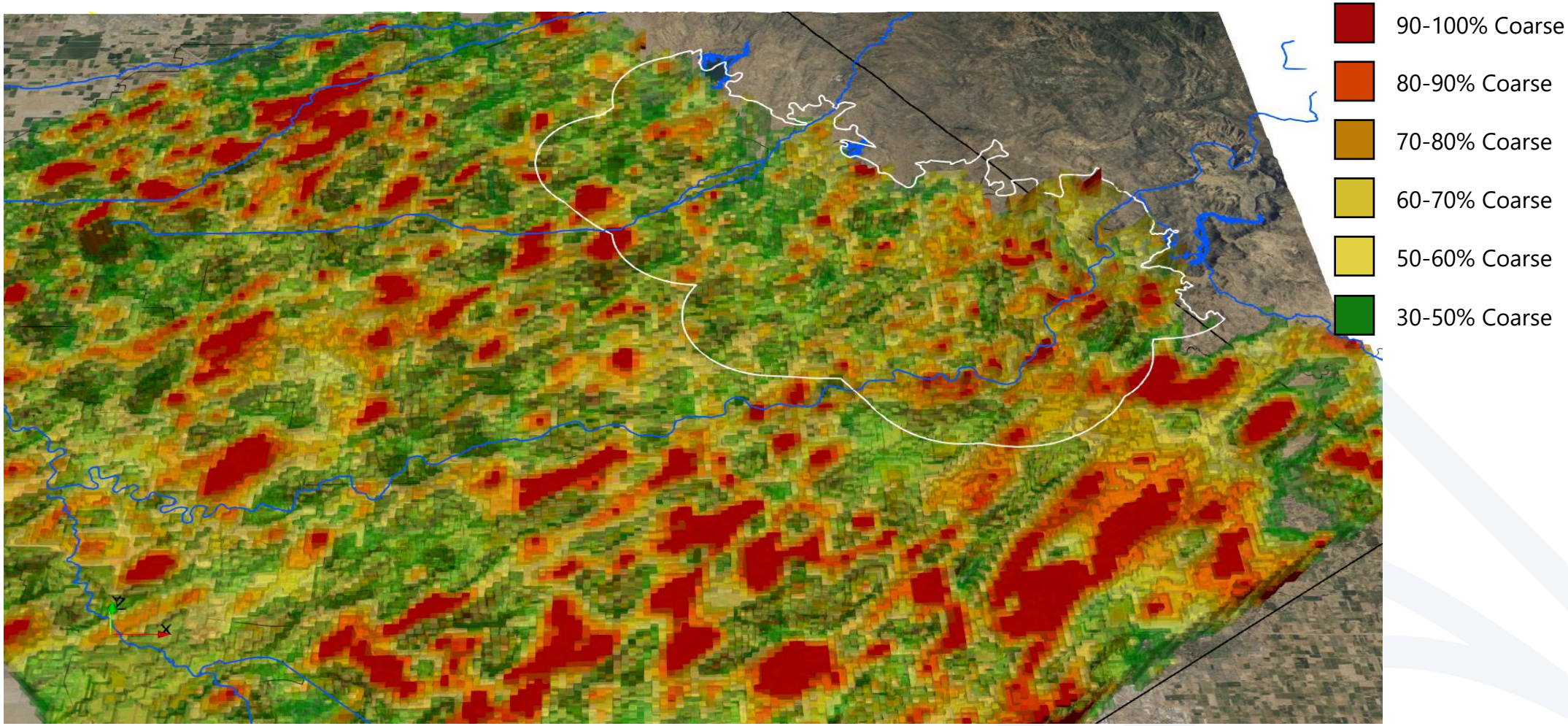
Coarse Bodies 90-100% Coarse



Coarse Bodies 70-100% Coarse



Coarse Bodies 30-100% Coarse



Weight Data

	Datasets				
	Soil Conditions	**Depth to Water**	**Depth to Shallow Fine-Grained Layer**	**Shallow Sediment Coarseness**	**Interconnected Coarse Bodies**
Purpose	Infiltration capacity through soils	Storage capacity and management objectives	Downward flow limitation	Shallow percolation efficiency	Efficient percolation pathways to deeper aquifer (e.g., paleovalleys and incised valley fills)
ARP Map Type	**Weights**				
Shallow (Natural)	5	3	2	5	3
Deep Preferential Pathway (Natural)	3	1	0	0	5
Deep Preferential Pathway (Built)	0	1	0	0	5

Combine

Combine

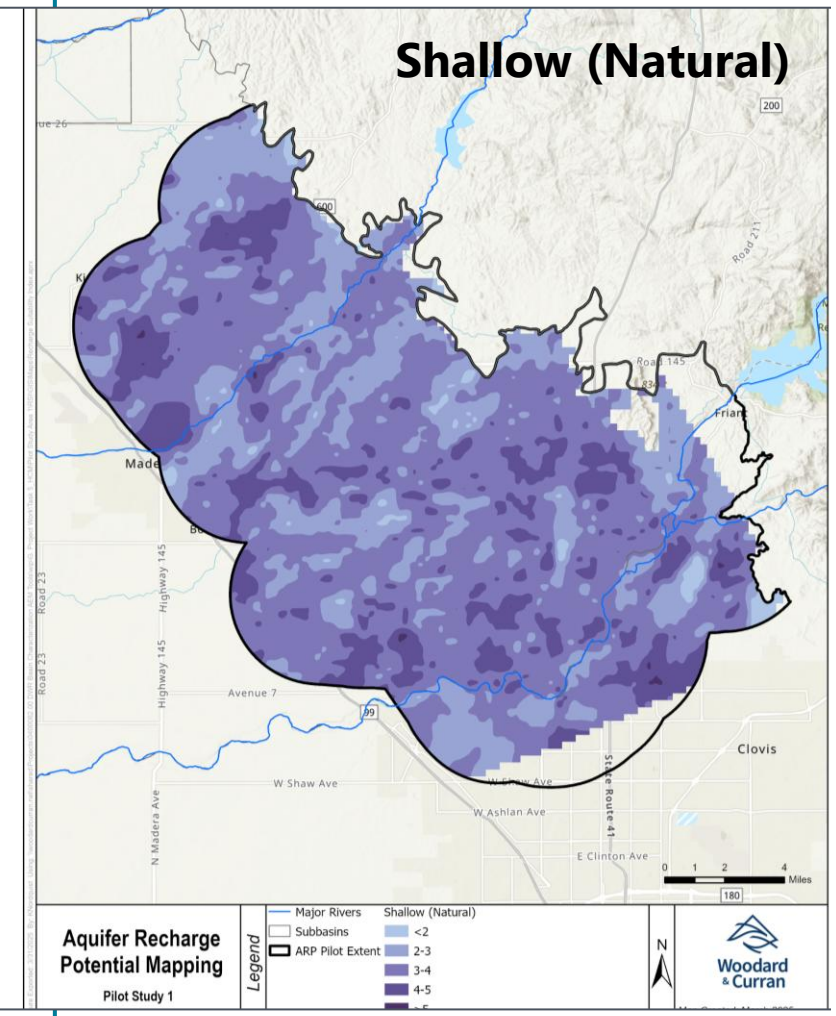
- Shallow Natural ARP =

SAGBI	Depth to Water	Depth to Shallow Clay	Shallow Sediment Coarseness	Interconnected Coarse Bodies
• Excellent • Good • Moderately Good • Moderately Poor • Poor • Very Poor	• Deep • Moderately deep • Shallow	• Not present • Deep • Shallow	• Coarse sediment • Intermediate sediment • Fine sediment	• Access to very coarse flow pathways • Access to less coarse pathways • No access to coarse pathways
5	3	2	5	3

Better

Worse

ARP Results


Shallow (Natural)
Aquifer Recharge Potential Mapping
Pilot Study 1
Legend
Major Rivers
Subbasins
ARP Pilot Extent
Shallow (Natural)
<2
2-3
3-4
4-5
Clovis
Avenue 7
W Shaw Ave
W Ashlan Ave
E Clinton Ave
Highway 145
Road 23
N Madera Ave
State Route 41
Miles
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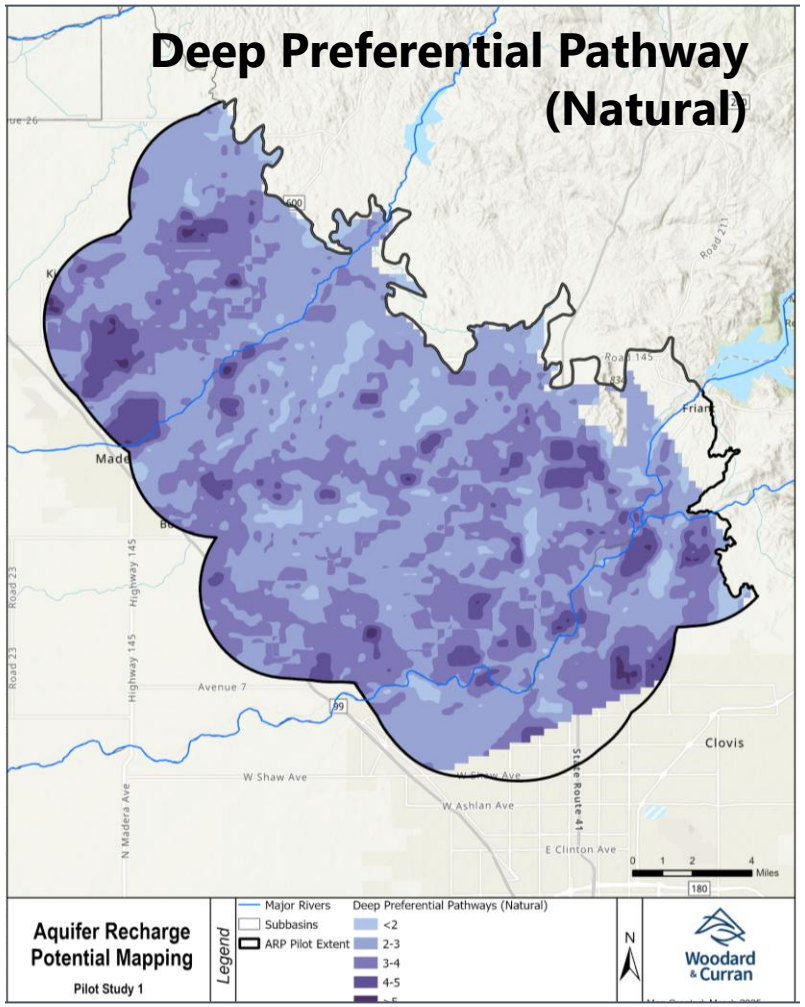
Deep Preferential Pathway (Natural)
Aquifer Recharge Potential Mapping
Pilot Study 1
Legend
Major Rivers
Subbasins
ARP Pilot Extent
Deep Preferential Pathways (Natural)
<2
2-3
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Clovis
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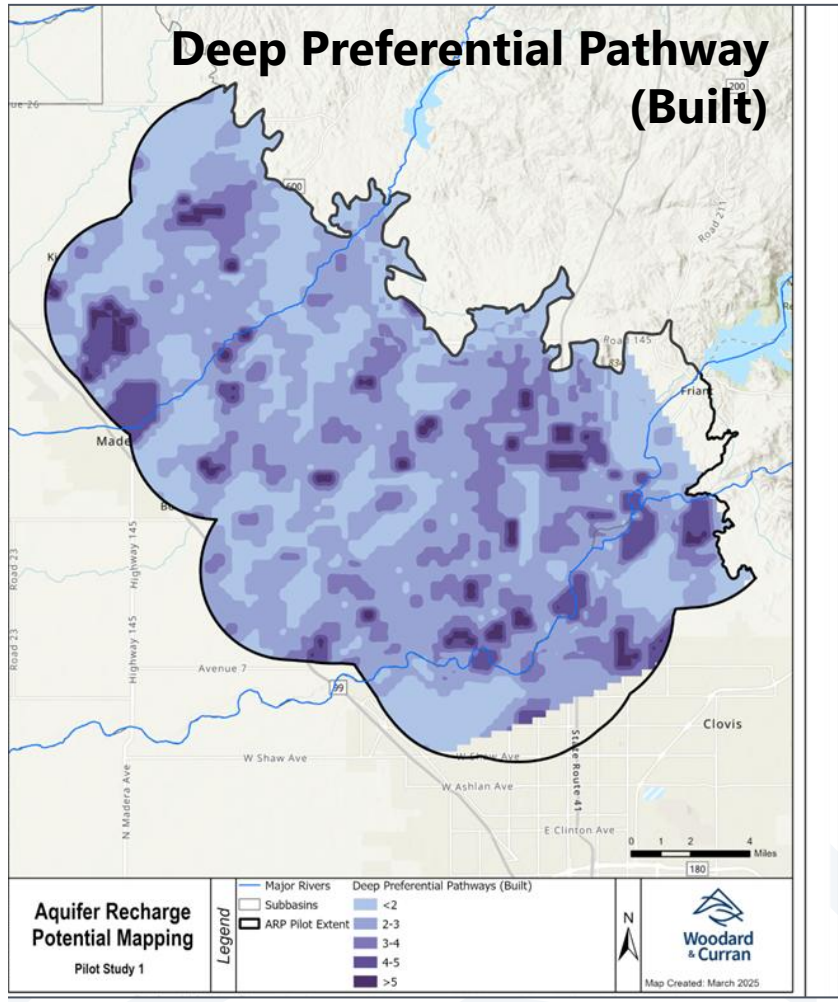
Miles
Woodard & Curran


Deep Preferential Pathway (Built)
Aquifer Recharge Potential Mapping
Pilot Study 1
Legend
Major Rivers
Subbasins
ARP Pilot Extent
Deep Preferential Pathways (Built)
<2
2-3
3-4
4-5
>5
Clovis
Avenue 7
W Shaw Ave
W Ashlan Ave
E Clinton Ave
Highway 145
Road 23
N Madera Ave
State Route 41
Miles
Map Created: March 2025
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<2 Relatively *less suitable* recharge location
2-3
3-4
4-5
>5 Relatively *more suitable* recharge location

Current Improvements and Upcoming Work

Current Improvements

- AEM improves heterogeneity of texture data
- New nuanced sub-indices from 3D texture model (e.g., connected coarse bodies)
- Flexible for local needs

Upcoming Work

- Expand ARP maps throughout the Central Valley
- Develop tools for dynamic ARP sub-indices bins and ranks
- Leverage ARP maps to identify locations of additional field studies (e.g., tTEM and FloaTEM)

Conclusions

ARP is a **powerful tool** to identify locations with relatively more and less **potential for recharge**

AEM data enhances the resolution and understanding of **subsurface texture**, which is critical for ARPs

ARP is adaptable for local needs and considerations

We want your input!

Draft ARP Process Document

- The Draft ARP Process Document is posted on the CNRA Data Portal
- Please provide your comments and feedback
- Send an email to Basin.Characterization@water.ca.gov

Questions and Acknowledgments

- **Department of Water Resources:**
  - Katherine Dlubac
  - Steven Springhorn
  - Benjamin Brezing
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  - Adrien Camille
  - Jack Baer
  - Kyle Norquist
- **S.S. Papadopulos & Associates:**
  - Vivek Bedekar
  - Michael Ou
- **Ramboll:**
  - Paul Thorn

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