

# Accelerating the Use of Public Geophysical Data for Recharging California's Groundwater

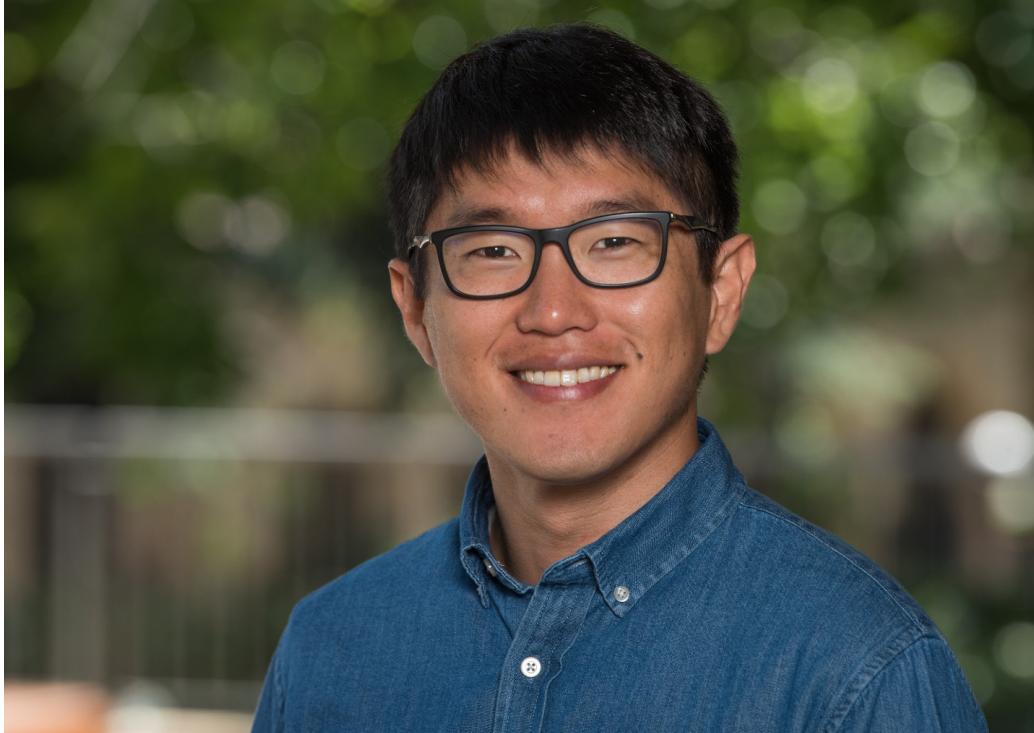
Seogi Kang<sup>1</sup>, Steve Purves<sup>2</sup>, and Knight Accelerator Team

<sup>1</sup>Stanford University

<sup>2</sup>Curvenote



# hello (a bit about me)



Seogi Kang

Postdoctoral associate in  
Stanford Environmental Geophysics Group

Computational geophysicist using various types of  
sensor data (ground, airborne, satellite, ...)

Passionate about open science  
(software, documentation, data)

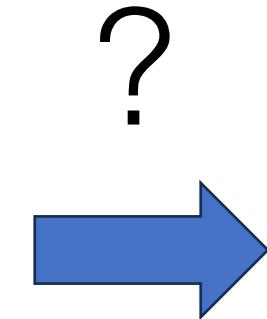
I am interested in extracting useful information from the sensor data to advance groundwater science and management.



Research knowledge  
(or tools)



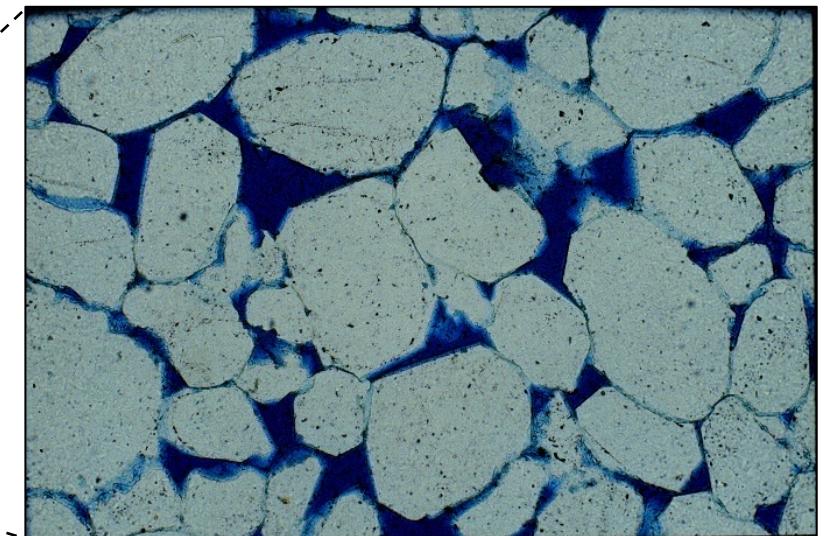
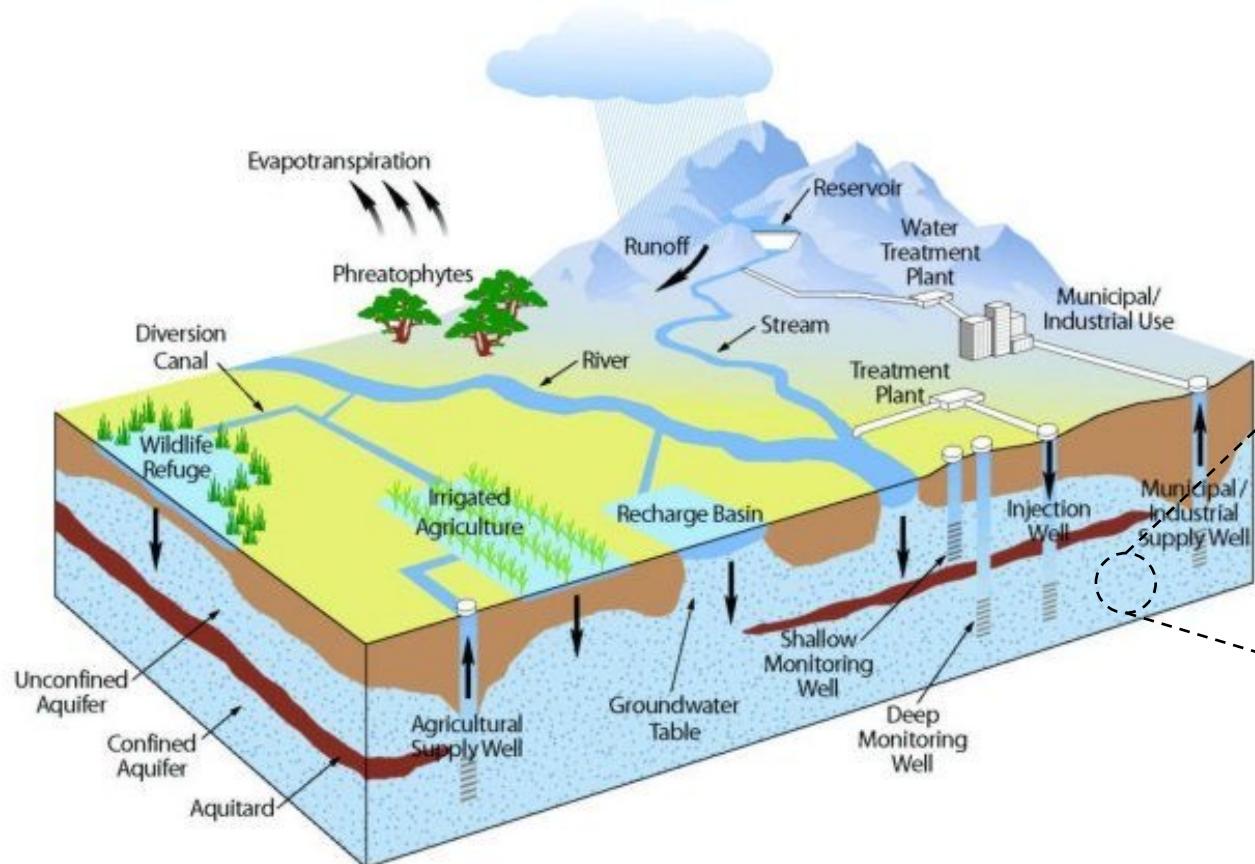
Public sensor data



Guiding information for  
practitioners' decision

97% of all liquid freshwater

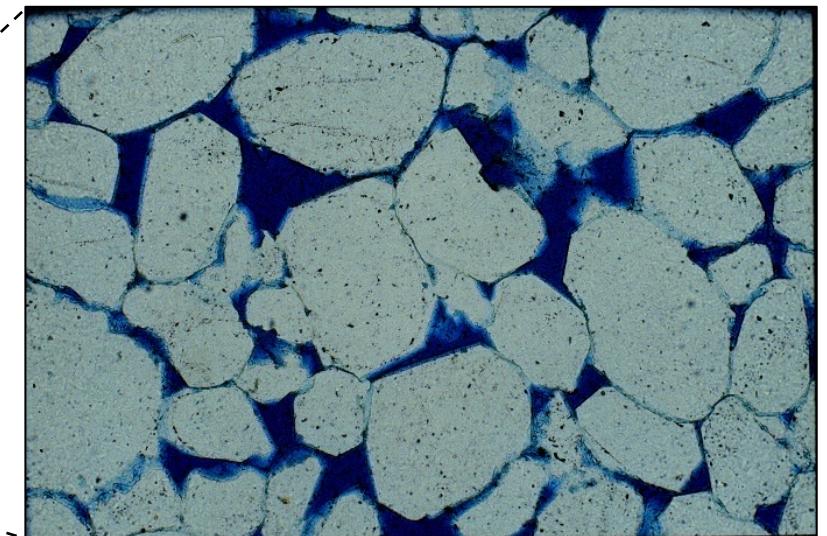
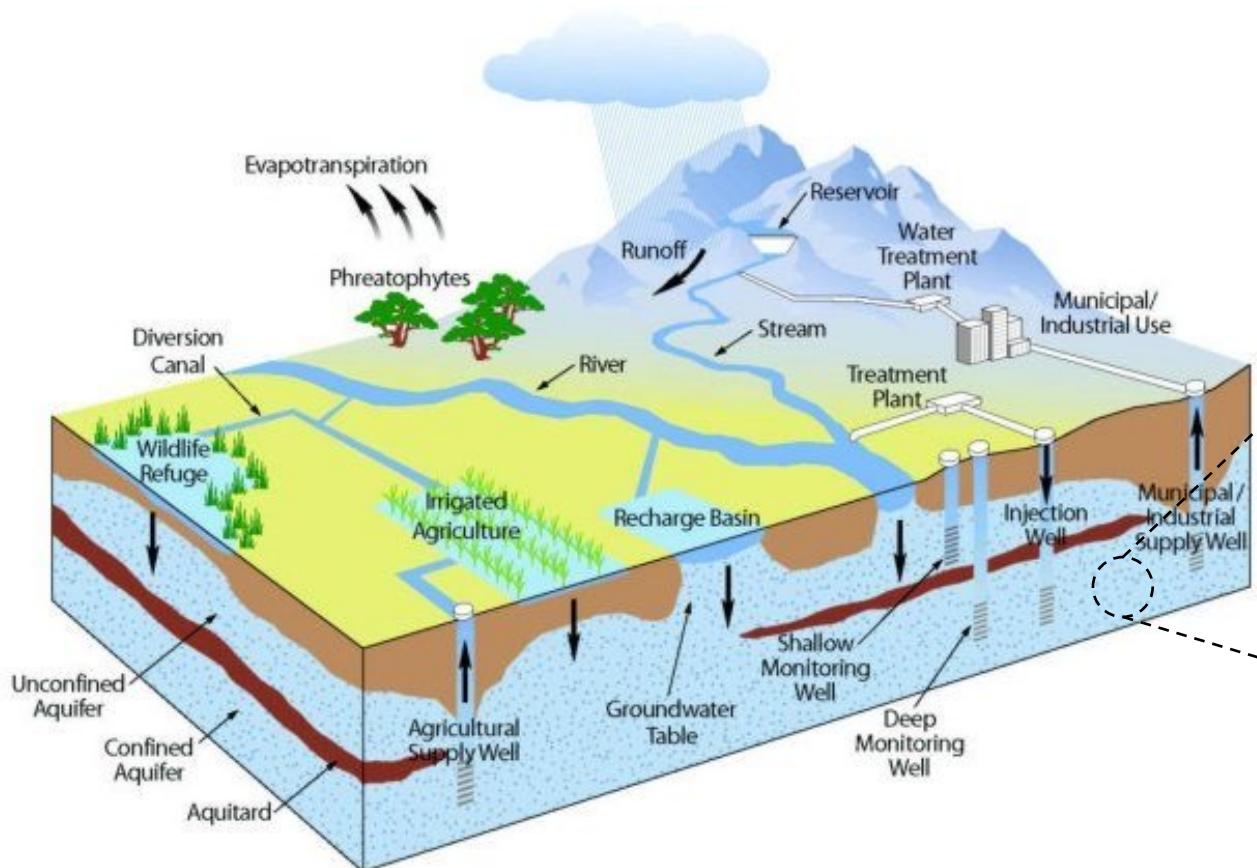
## Groundwater



population growth  
climate change

97% of all liquid freshwater

Groundwater



# Central Valley of California

Very productive farmland

Significant amount of surface & ground water

Severe droughts in California: 2012-2016

Sustainable Groundwater Management Act  
(SGMA, 2014)



The Central Valley lost about  $3 \text{ km}^3/\text{year}$  of groundwater  
(so, for the past decade we lost  $30 \text{ km}^3$ )

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Shasta Reservoir ( $\sim 6 \text{ km}^3$ )



X 5

WATER IN << WATER OUT

NO WATER FOR IRRIGATION



Almond Farmers Ripping Out Trees



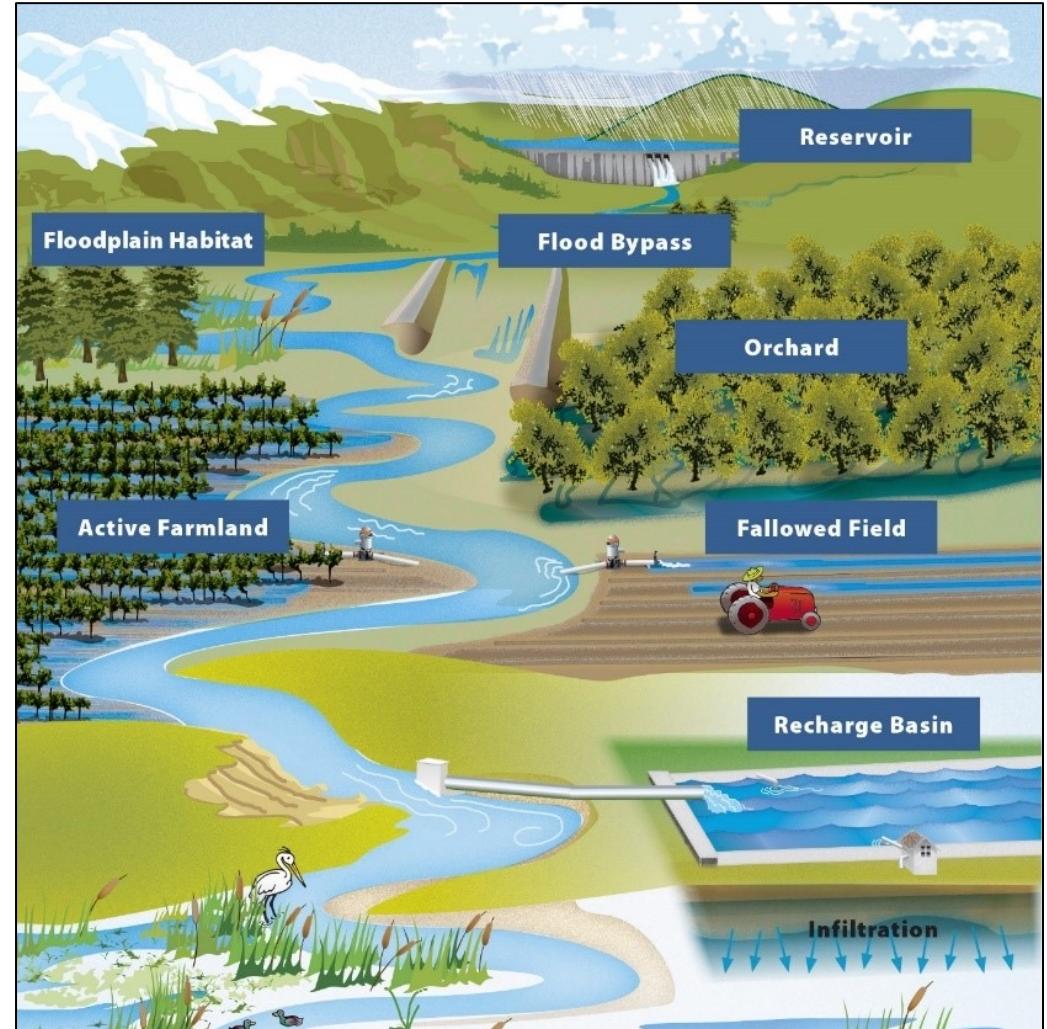
Morris (from Bloomberg; 2021)

# Urgent need for recharging California's groundwater

## FLOOD-MAR (Managed Aquifer Recharge)

*"Voluntary resource management strategy that uses flood water for managed aquifer recharge (MAR) on various sites."*

- CDWR (2022) -



# Climate change – more extreme weather events:

## FLOODS



South Yuba River

More floodwater

Increased frequencies  
decreased time span

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## FLOODS



South Yuba River

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## DROUGHTS

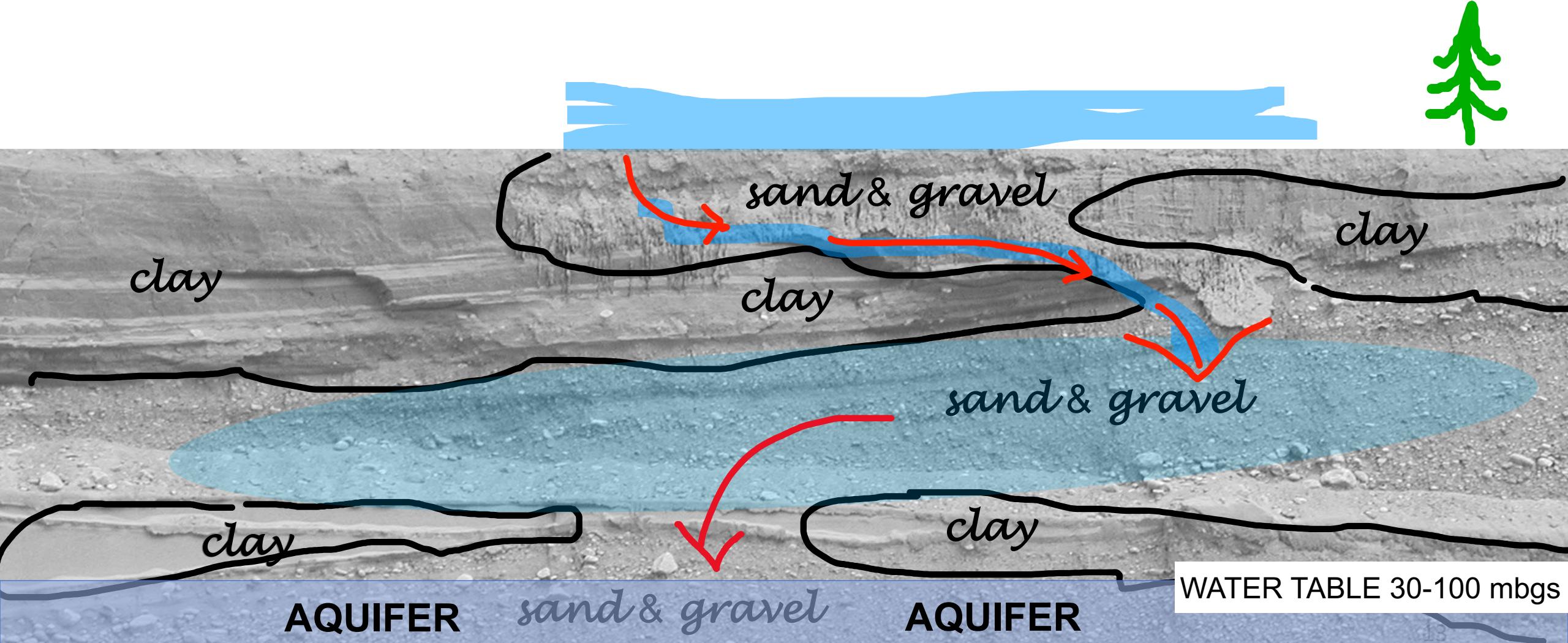


Lake Oroville

More use of groundwater

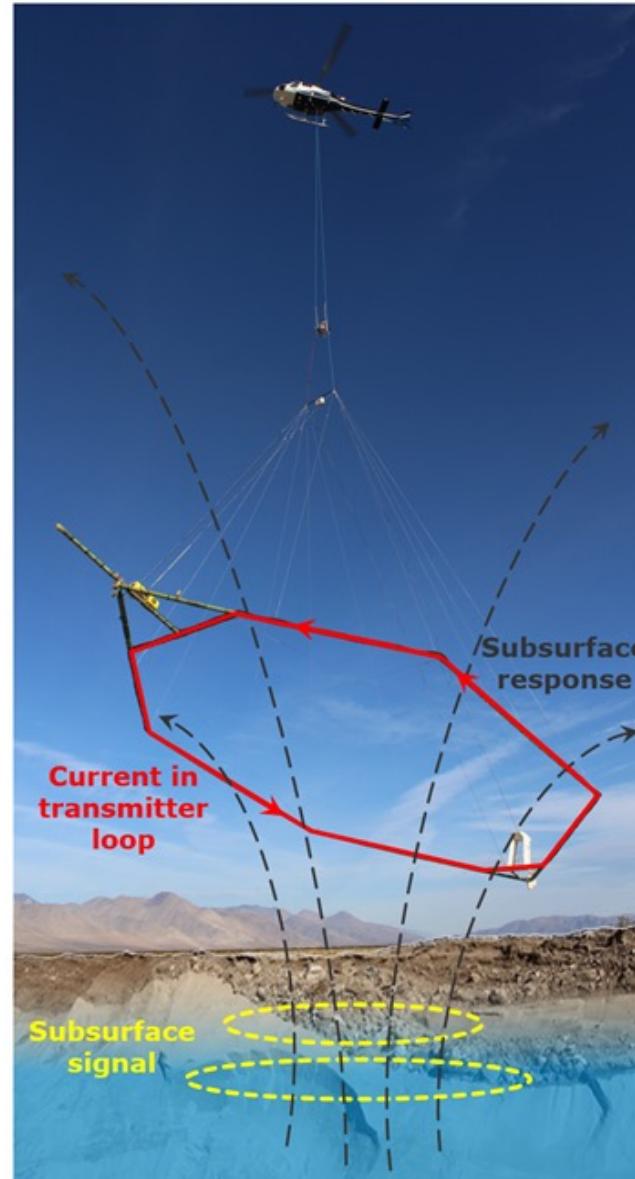
Need to implement FLOOD-MAR in many places quickly

Need to locate the relevant recharge sites RAPIDLY



# Electromagnetic (EM) imaging

Airborne EM  
(Basin scale)



Towed EM  
(Local scale)



# Electromagnetic (EM) imaging

## Basin scale – airborne EM method



Water basin mapping  
(several days)

About 100 km/hour

200-400 m depth

About 3 m vertical  
resolution at surface  
(decrease with depth)

Line spacing:  
500 m – 10 km (or more)

## Local scale – towed EM method



Knight (2018)

Mapping farm (e.g., 100 acre) in a few days

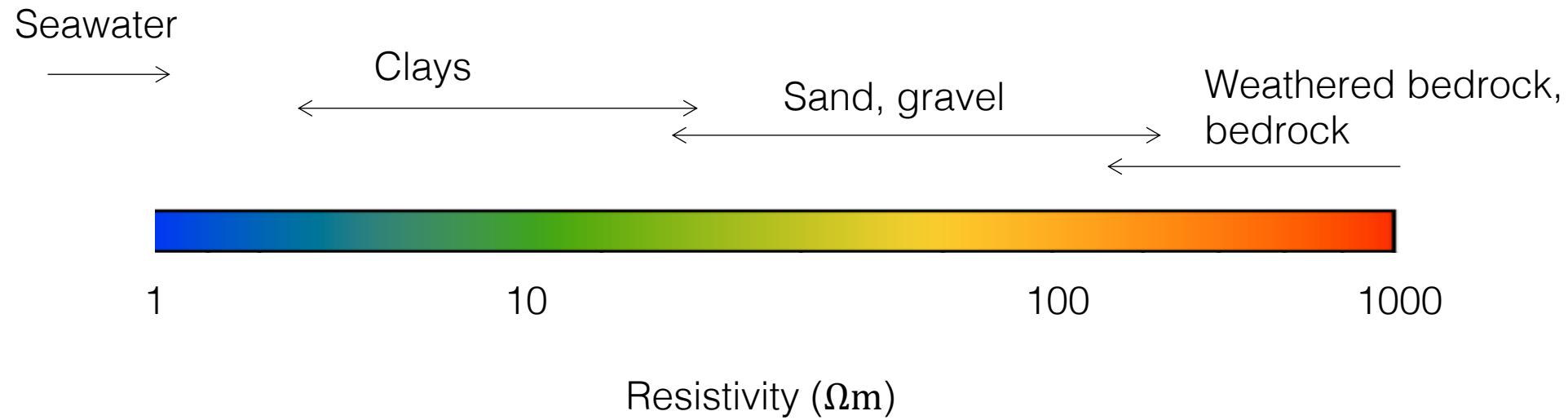
About 7 km/hour

40-60 m depth

About 1 m vertical resolution at surface  
(decrease with depth)

Line spacing:  
about 10 m (or more)

# Electrical resistivity: $\rho$ ( $\Omega\text{m}$ )

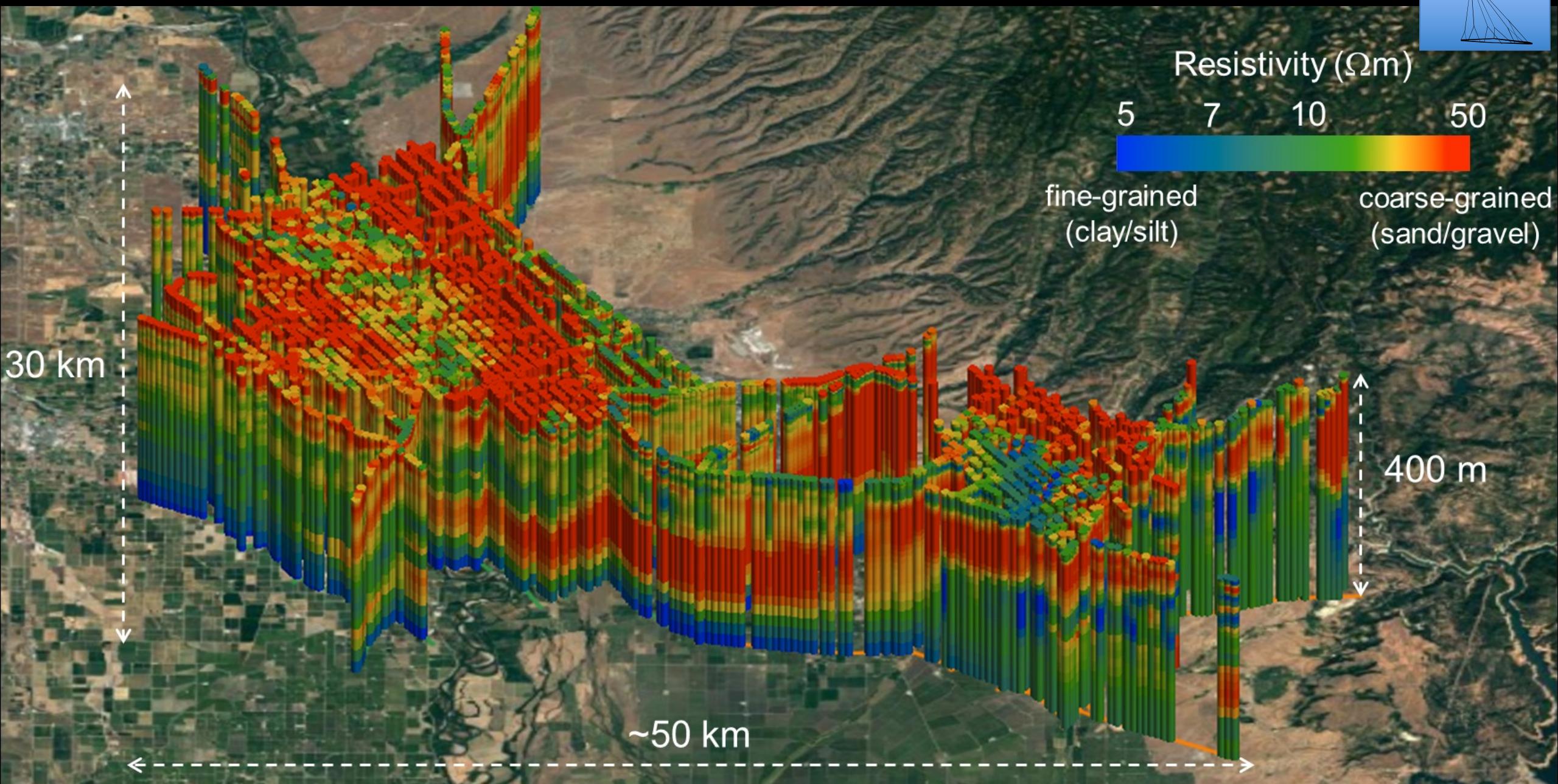


Varies over many orders of magnitude

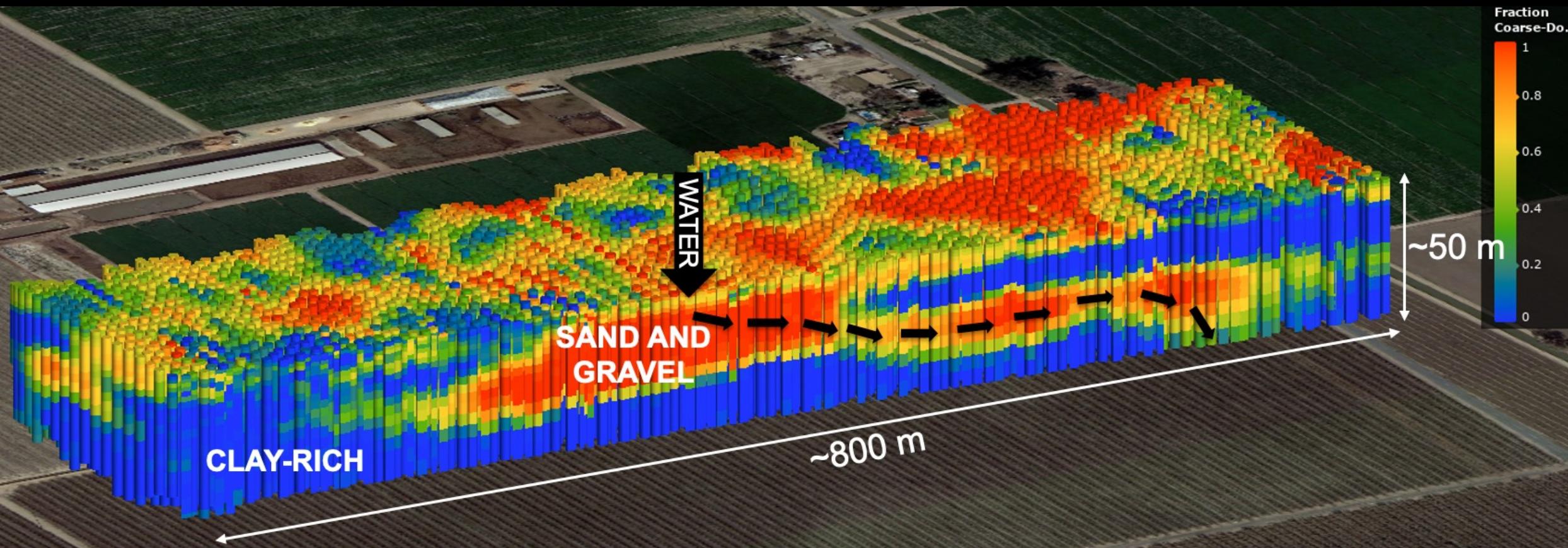
Depends on many factors:

- Sediment/Rock type – clay content is key factor
- Water content
- Connectivity of pores
- Salinity of the water

# Basin scale – Airborne EM

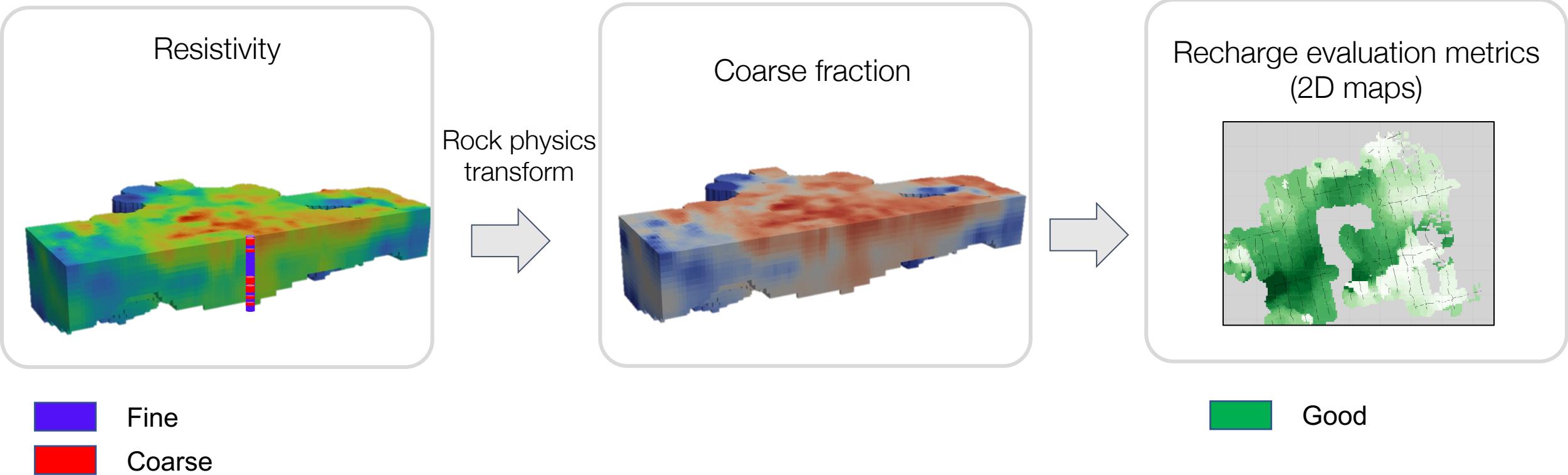


# Local scale – Towed EM



Goebel et al. (2021)

# Workflow to generate recharge evaluation metrics



# Key knowledge of the tool is published

The image shows two academic journal article snippets from the 'Vadose Zone Journal'. The top snippet is titled 'Recharge site assessment through the integration of surface geophysics and cone penetrometer testing' by Meredith Goebel and Rosemary Knight. The bottom snippet is titled 'Managed aquifer recharge site assessment with electromagnetic imaging: Identification of recharge flow paths' by Karissa Pepin, Rosemary Knight, Meredith Goebel-Szenher, and Seogi Kang. Both snippets are labeled as 'ORIGINAL RESEARCH ARTICLE'.

**ORIGINAL RESEARCH ARTICLE**

**Vadose Zone Journal**

**Recharge site assessment through the integration of surface geophysics and cone penetrometer testing**

Meredith Goebel | Rosemary Knight

**ORIGINAL RESEARCH ARTICLE**

**Vadose Zone Journal**

**Managed aquifer recharge site assessment with electromagnetic imaging: Identification of recharge flow paths**

Karissa Pepin | Rosemary Knight | Meredith Goebel-Szenher | Seogi Kang

Yet, the tool is not accessible (or useable) for people facing the problems (e.g., water managers, engineers, ...)

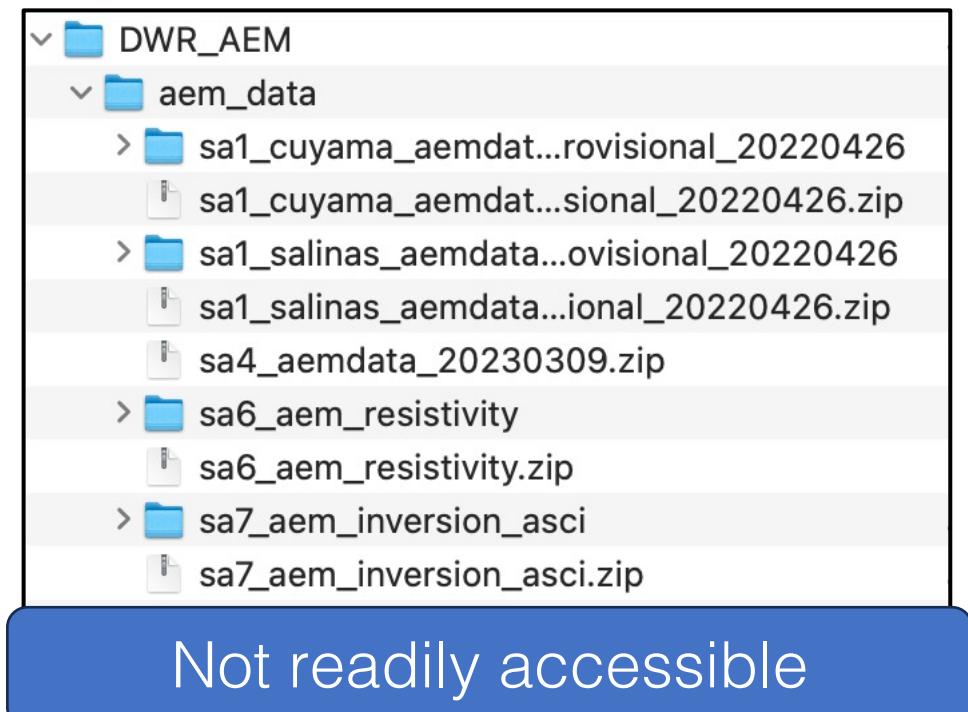
# EM geophysical data are publicly available but ...

State-wide airborne EM project led by CDWR

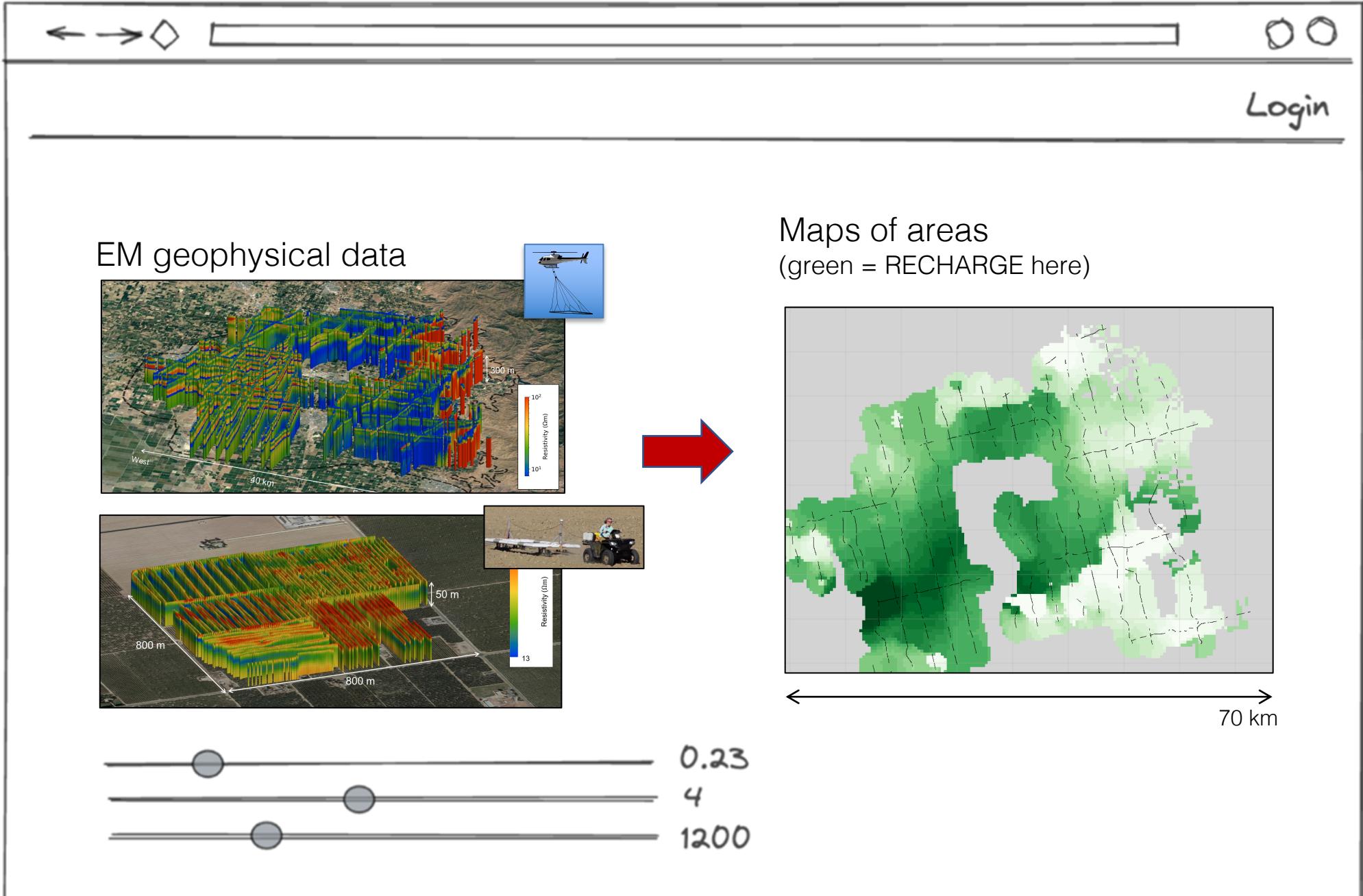


Covers California's high- and medium-priority groundwater basins

\$13M project covering 25,000 line-km data



# Web Application & Educational Resources



# Sustainability Accelerator Project

(1-year project ending this August)

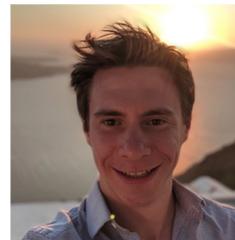
**Stanford  
Doerr**

School of  
Sustainability

Environmental Geophysics  
*Rosemary Knight*

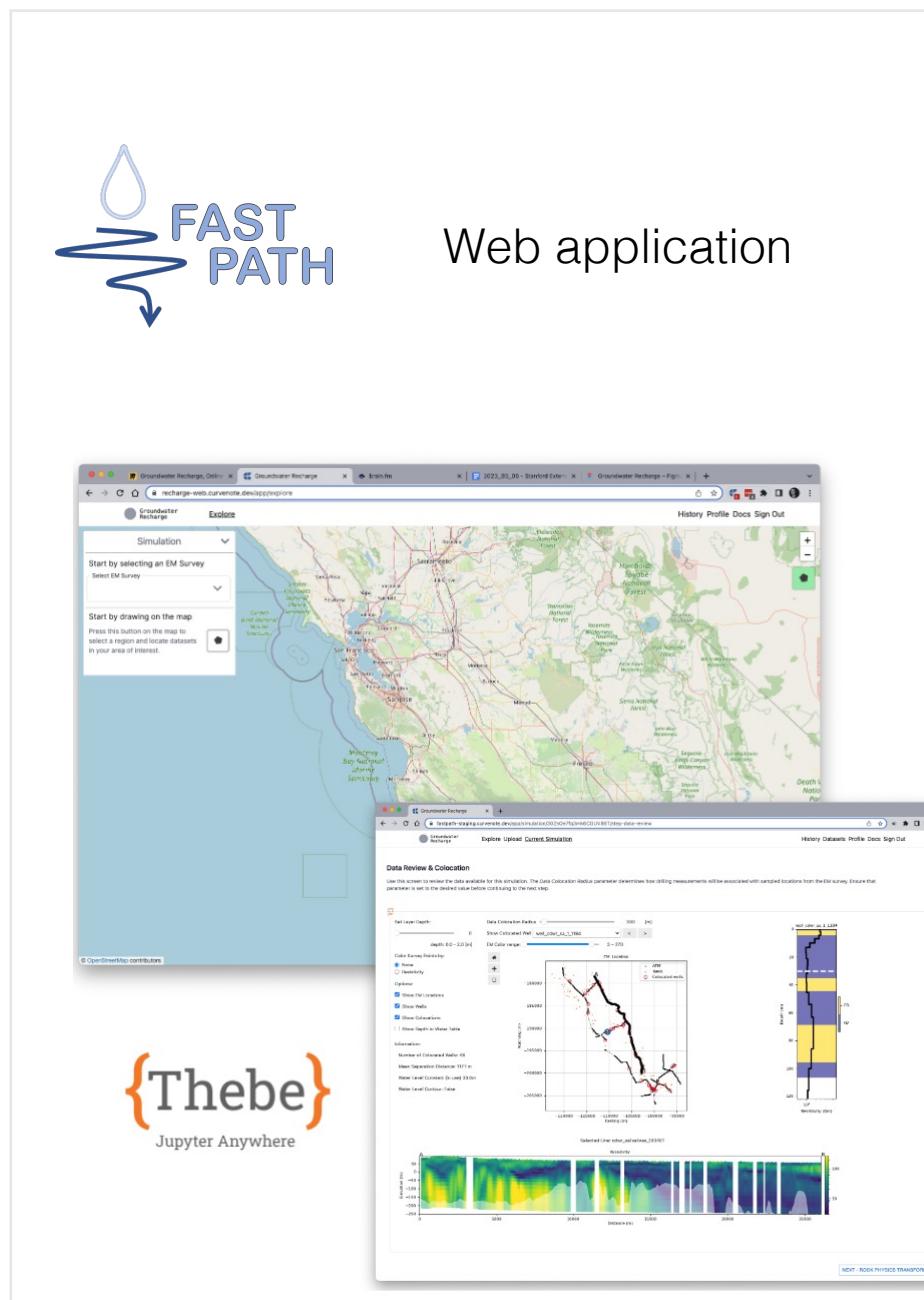
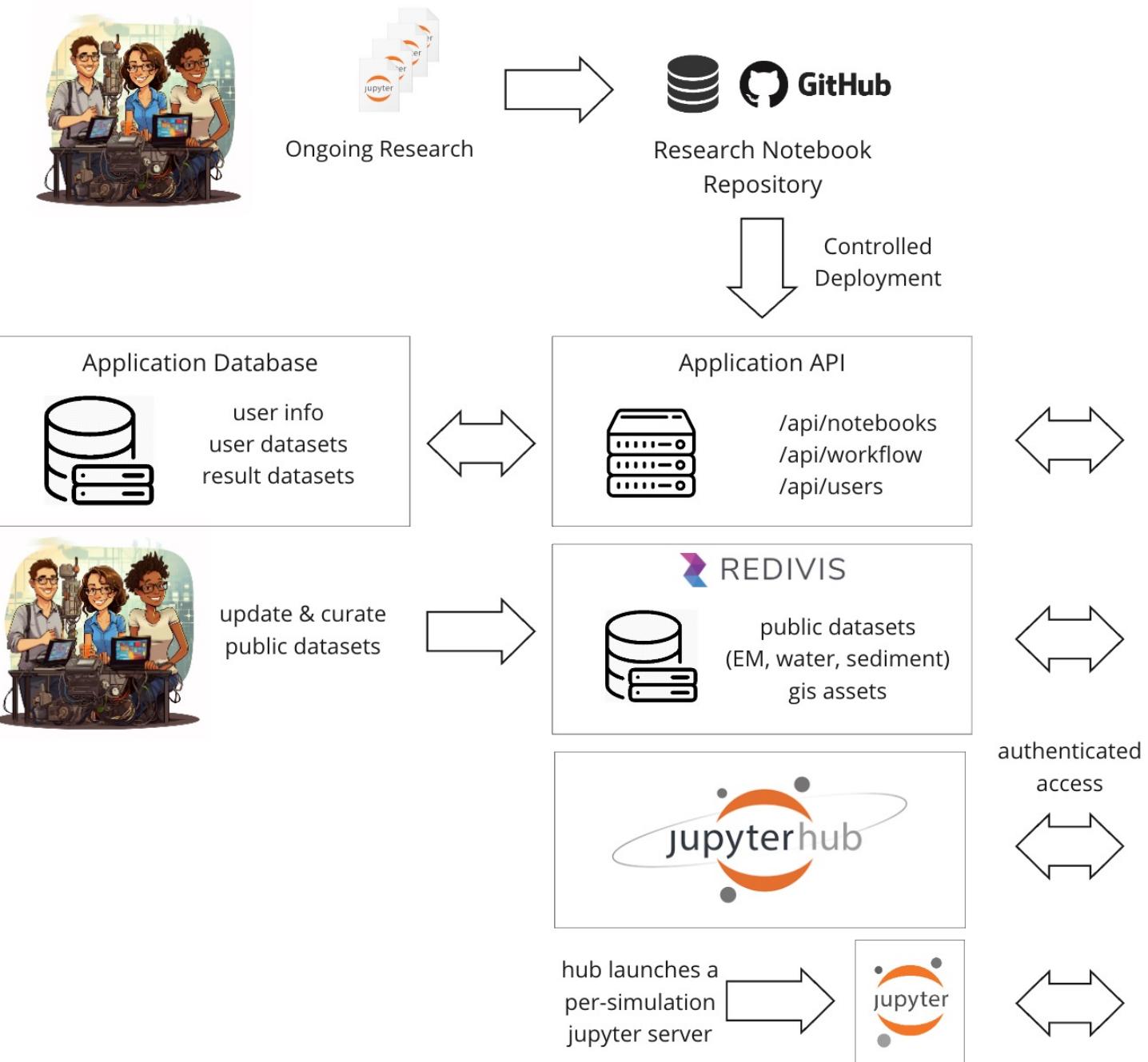


Web application  
development:



Partners:

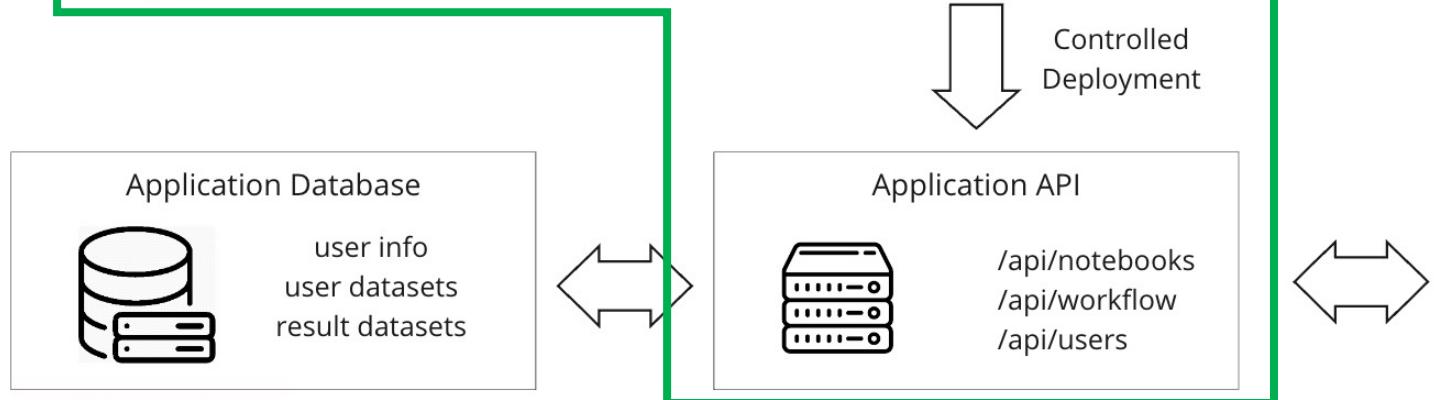




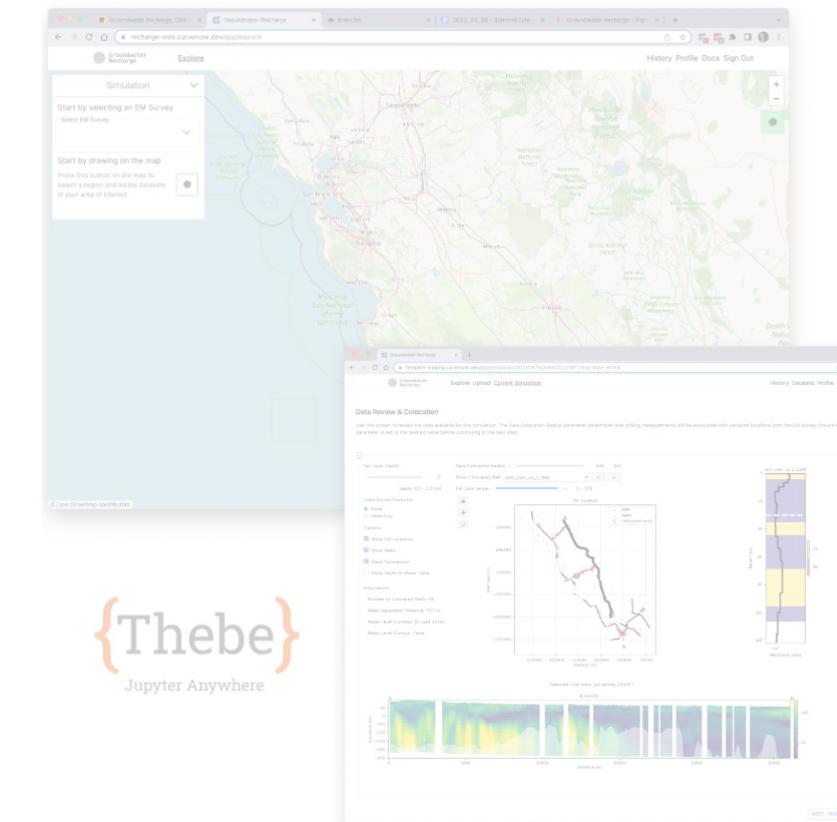
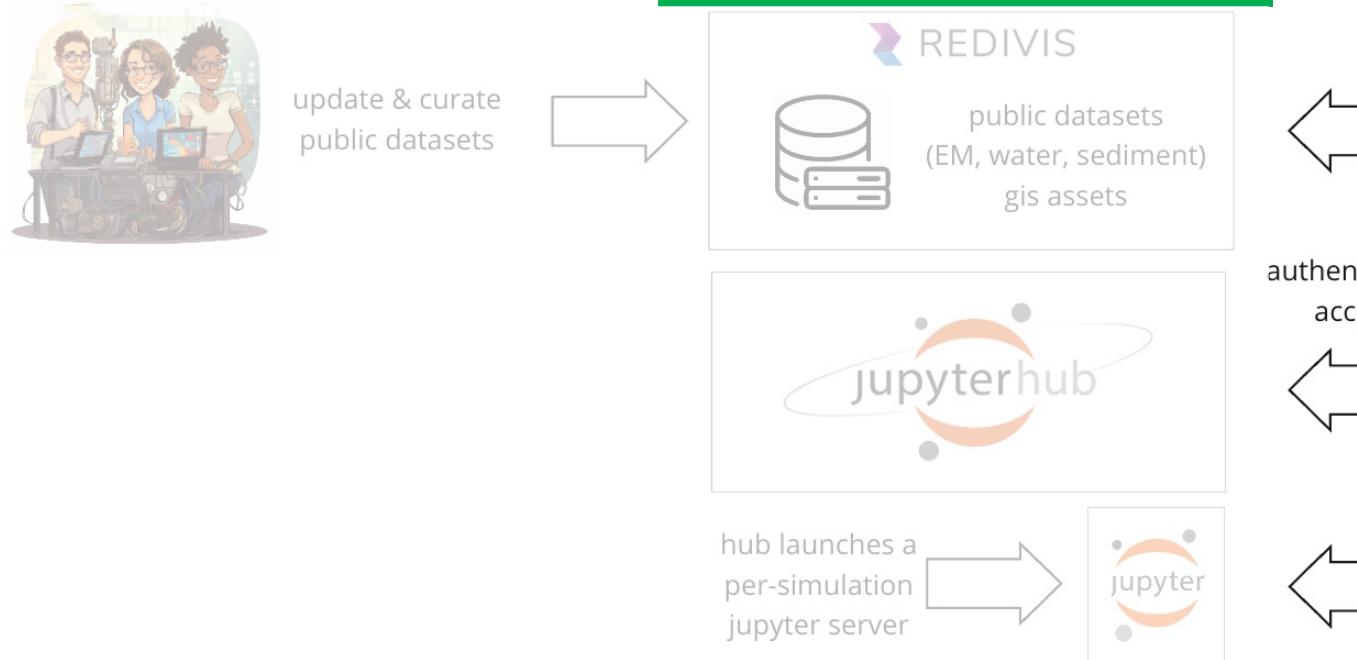


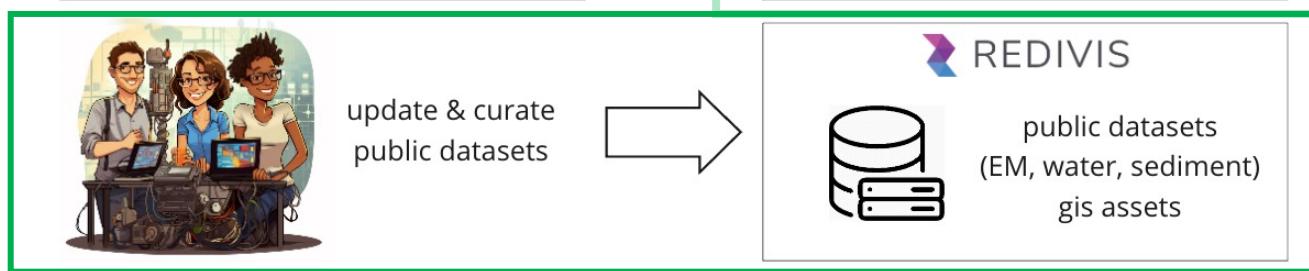
Academic researchers:

Python package (PyPI) – research codes  
Jupyter notebook + ipywidgets – applications



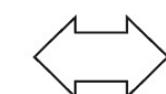
Web application



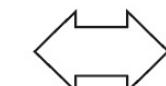


Academic researchers:  
Create and curate the public database.  
(REDIVIS – online database)

authenticated  
access

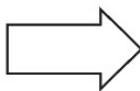


hub launches a  
per-simulation  
jupyter server

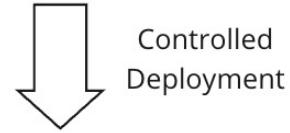




Ongoing Research



Research Notebook  
Repository



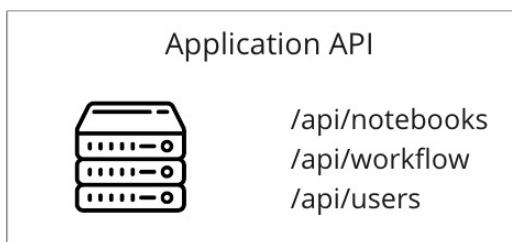
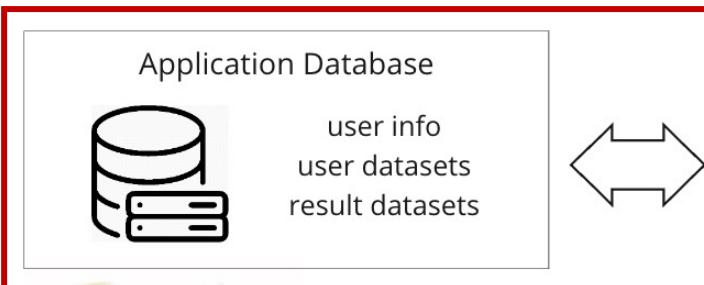
Controlled  
Deployment

# Curvenote

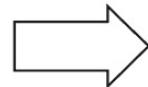
ALL OTHER STUFF...!

web application

PATH



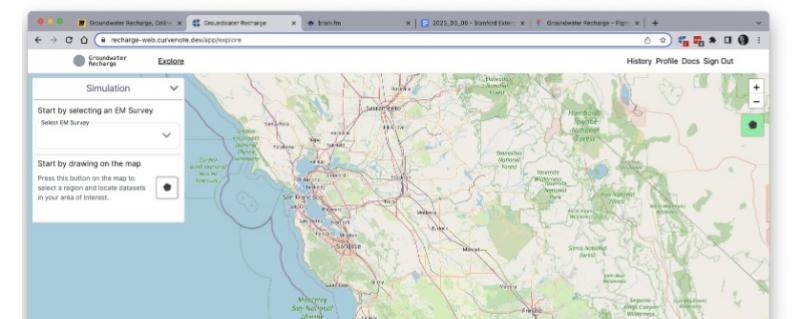
update & curate  
public datasets



authenticated  
access

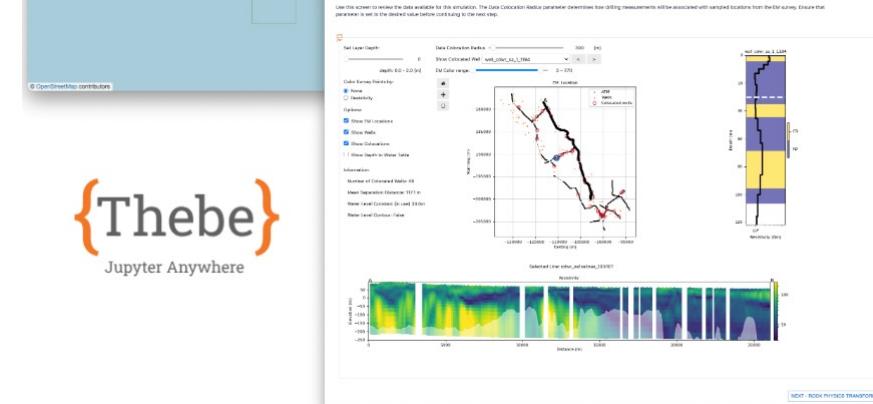


hub launches a  
per-simulation  
jupyter server



{Thebe}

Jupyter Anywhere



# Live demo

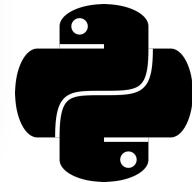
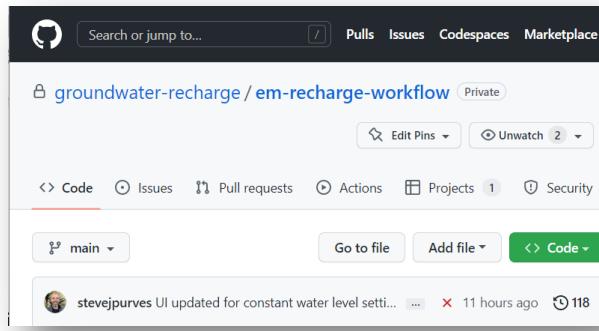


<https://fastpath.stanford.edu>

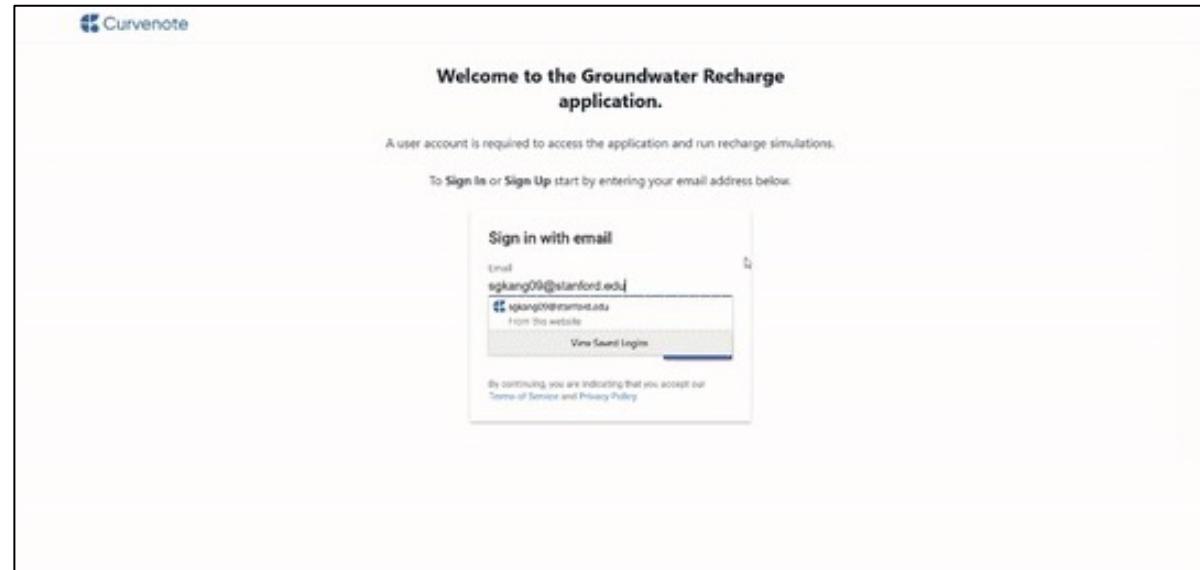
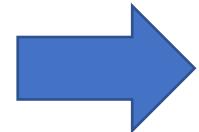
The web-application will be  
launched 15<sup>th</sup> August 2023

A screenshot of a web browser window titled "Groundwater Recharge". The address bar shows "recharge-web.curvenote.dev". The page header includes the Curvenote logo, "Home", "Impact", a green "RECHARGE NOW!" button, and "Sign Out". A red arrow points to the "RECHARGE NOW!" button. The main content area features a banner with the text "Stanford | Doerr School of Sustainability" and "Recharging California's Groundwater" over an aerial image of agricultural fields and a blue canal. Below the banner, the title "Harnessing the Power of Geophysical Imaging to Recharge California's Groundwater" is displayed in bold black text. A section titled "Transformative Potential" explains the project's goal of advancing geophysical methods for groundwater imaging. A "Get Started" button is located below this text. At the bottom, there is a small image showing a 3D visualization of subsurface geological structures.

# Accelerating the research knowledge into action



Research codes  
Public database



<https://curvenote.com/>

Web application

# Thanks!

## Contact:

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 <https://twitter.com/sgkang09>

 <https://sgkang09.github.io>

 <https://www.linkedin.com/in/seogi-kang>

Presentation available at: <https://github.com/sgkang/scipy-2023-talk>

# Acknowledgement

EM data: acquired with the SkyTEM system; acquisition oversight, planning, and processing by Ramboll and Aqua Geo Frameworks; state-wide AEM project was funded by CDWR.

Funding was provided by a grant to R. Knight from the Stanford Doerr School of Sustainability.

Thanks to Ian Matthews for helping to interact with REDIVS database tools.

Thanks to our project partners:

