CWEMF
CALIFORNIA Water & Environmental Modeling Forum

Woodard & Curran

DEPARTMENT OF WATER RESOURCES · STATE OF CALIFORNIA ·

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May 13th
2025

Advancing Hydrostratigraphic Model (HSM) and Groundwater Numerical Model Development with AEM and Hydrogeologic Data

PRESENTED BY

Sercan Ceyhan

Vivek Bedekar

CWEMF
2025 Annual Meeting

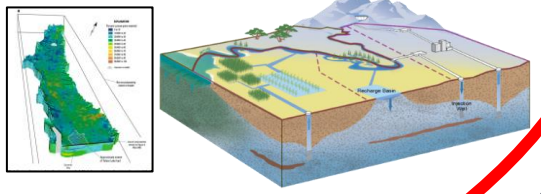
Agenda

- Analysis Tools within DWR's Basin Characterization Program
- Data2HSM Suite – Hydrostratigraphic Model
- Data2Texture – Texture Model
- Texture2Par – Aquifer Parameter
- Tool Integration and Release

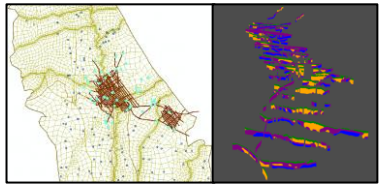
DWR's Basin Characterization Program

Collect & Compile Data

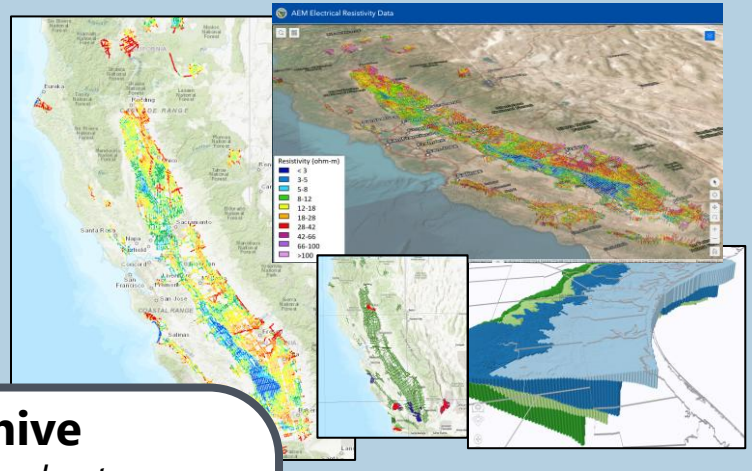
Texture Model & Hydrogeologic Conceptual Model



Integrated Analysis of All Subsurface Data

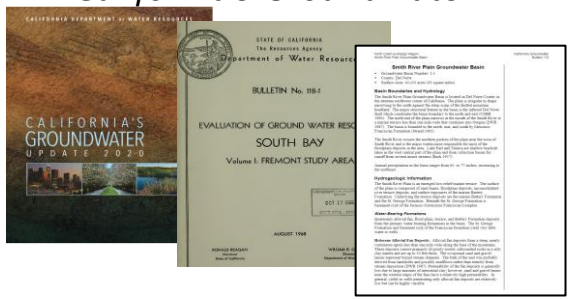


Data Access & Visualization



Data Archive

California's Groundwater



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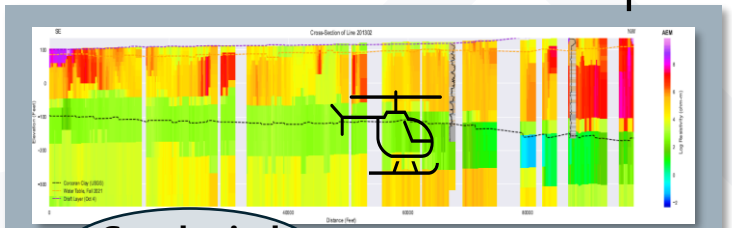
Analysis Tools Overview

Inputs

Tools

Outputs



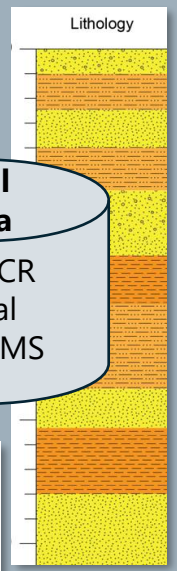
Geophysical Data

Statewide AEM
Infill AEM
tTEM/FloaTEM
NMR/e-logs

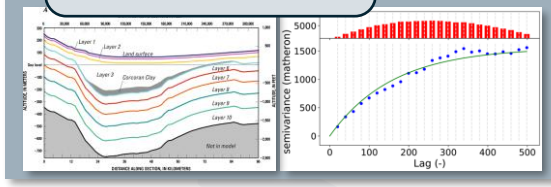
+

Well Data

OSWCR
Local
CalGEMS



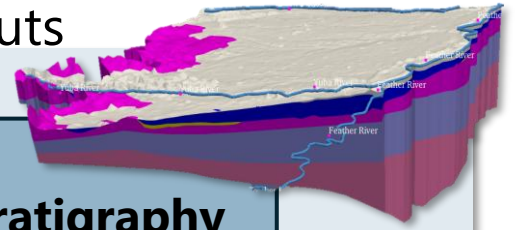
Geologic Interpretations



Data2HSM

Texture2Par

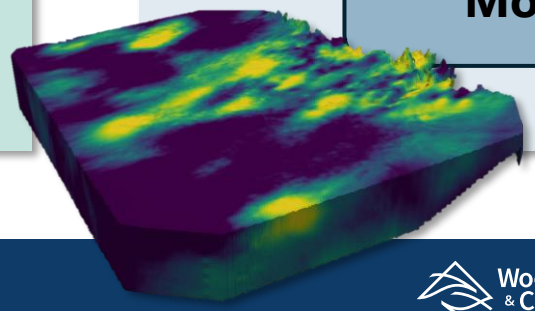
Data2Texture



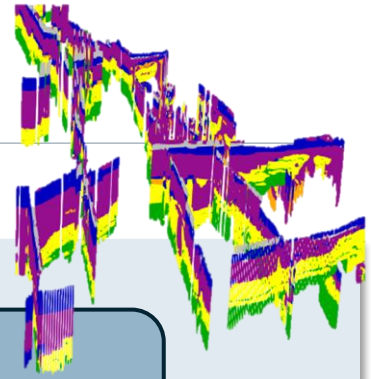
Stratigraphy

Aquifer Parameters

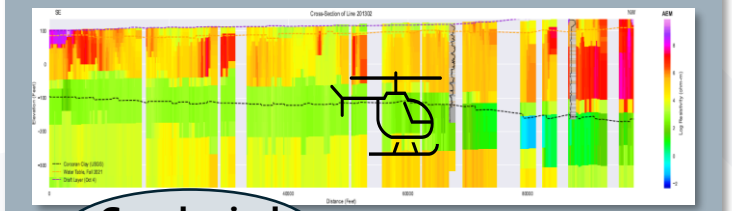
Texture Model



Analysis Tools Overview
Generate Stratigraphy on X-Sections



Inputs



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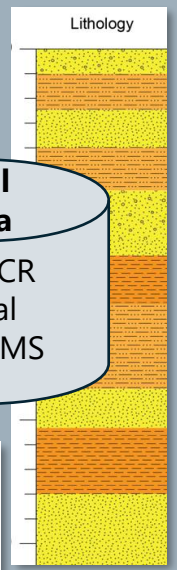
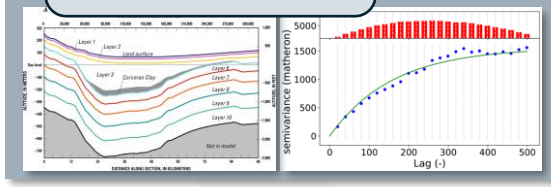


Geologic Interpretations



Tools

Data2HSM

Texture2Par

Data2Texture

Outputs

Stratigraphy

Aquifer Parameters

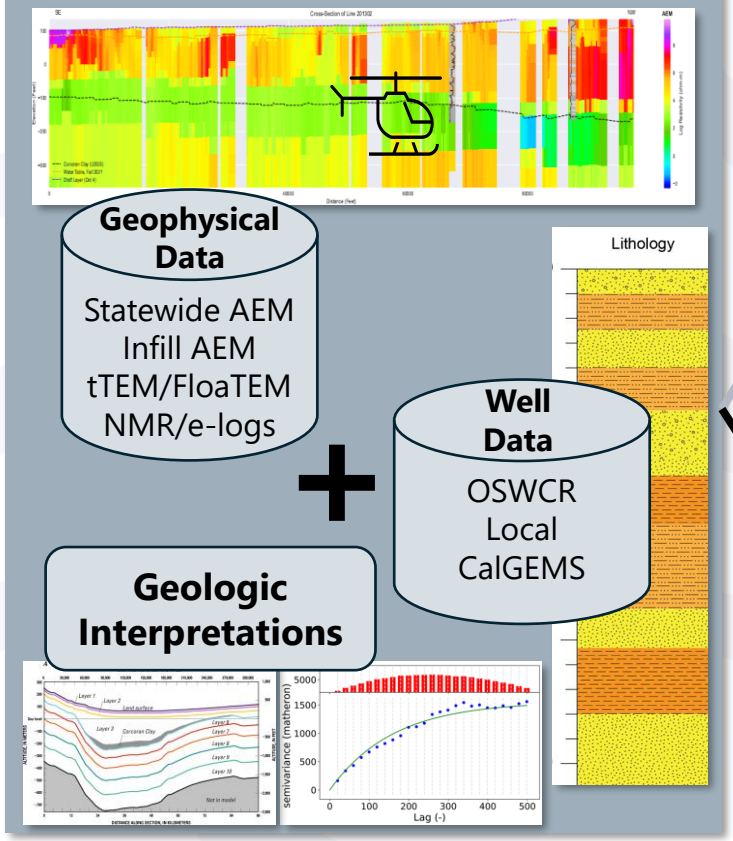
Texture Model

Analysis Tools Overview
Generate 3D Texture Model

Inputs

Tools

Outputs



Data2HSM

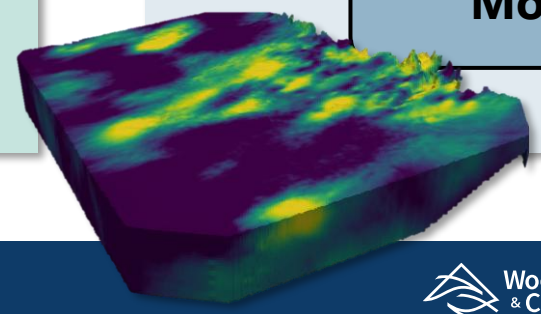
Texture2Par

Data2Texture

Stratigraphy

Aquifer Parameters

Texture Model

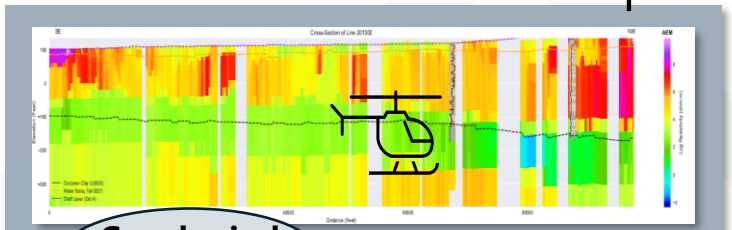


Analysis Tools Overview
Generate 3D Continuous Stratigraphy

Inputs

Tools

Outputs



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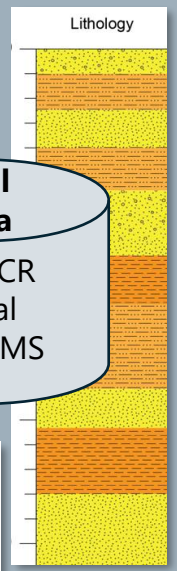

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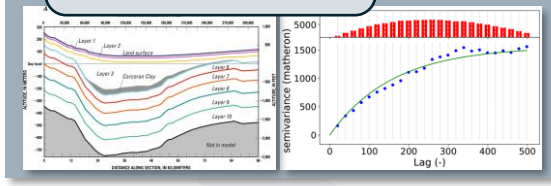
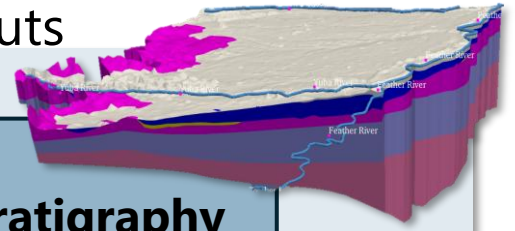


Data2HSM

Data2Texture

Texture2Par



Stratigraphy

Aquifer Parameters

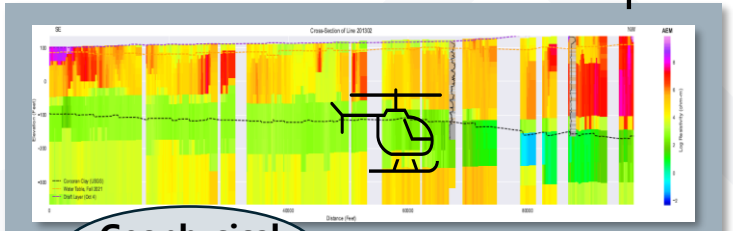
Texture Model

Analysis Tools Overview
Generate Aquifer Parameters for GWM Calibration

Inputs

Tools

Outputs



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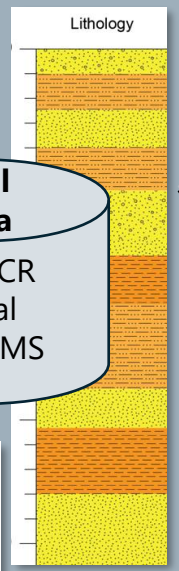
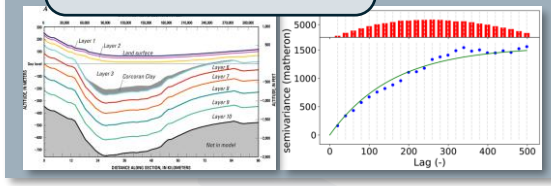


Geologic Interpretations

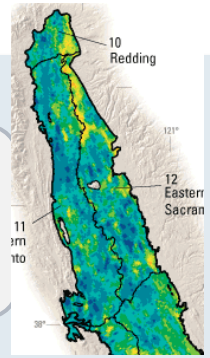


Data2HSM

Texture2Par

Data2Texture

Stratigraphy



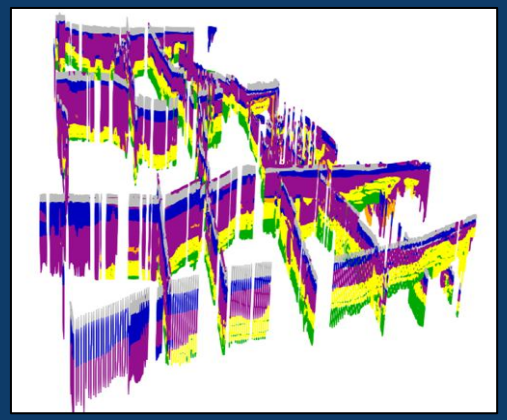
Aquifer Parameters

Texture Model

Data2HSM

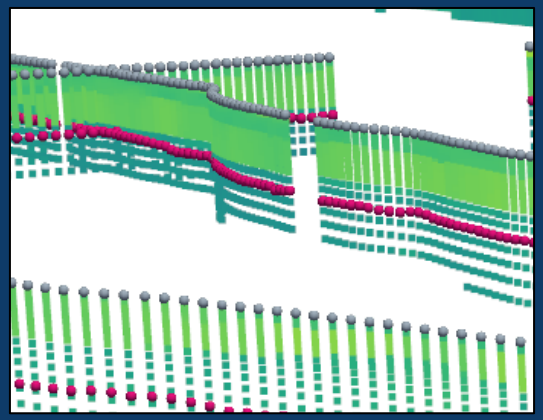
Data2HSM Suite of Tools

Gaussian Mixture Model



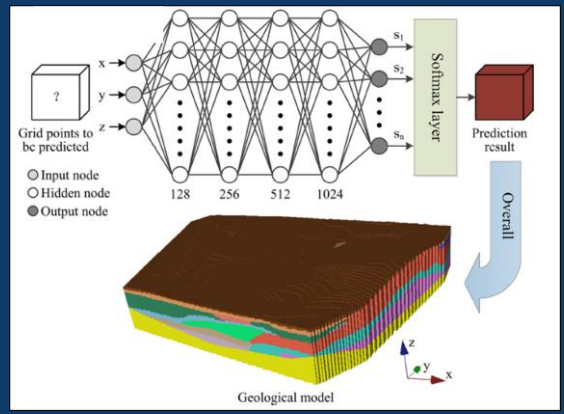
Clusters distinct HSUs using unsupervised ML methods.

Smart Interpretation



Surface Identification using Simple Polynomial Regression

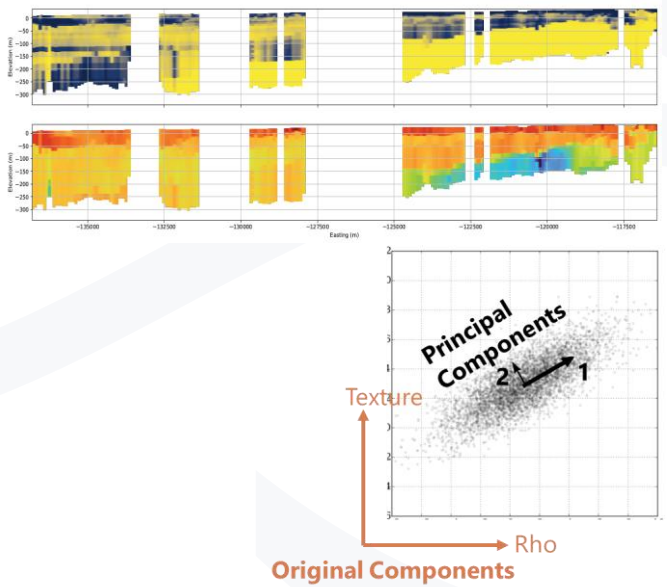
GeoPDNN



Models Stratigraphic Surfaces Using Neural Network prediction

Data2HSM : Gaussian Mixture Model
Example HCM Development

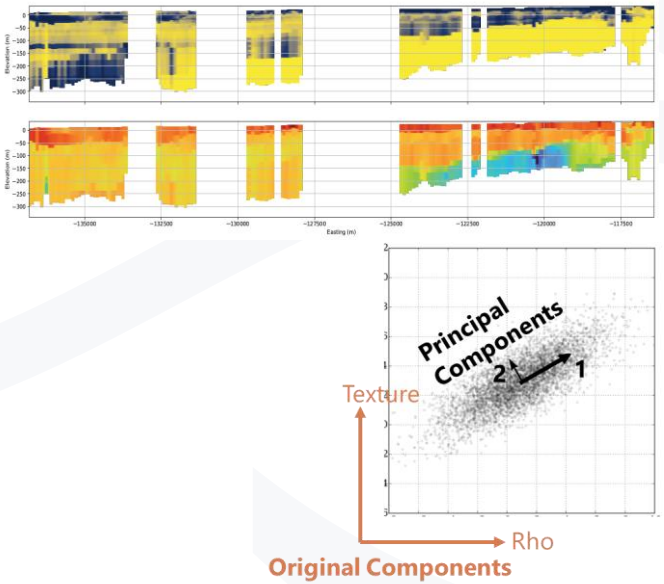
Resistivity and Coarse Fraction data preprocessed and ran through PCA

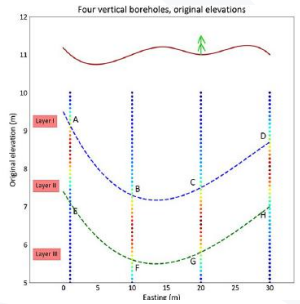


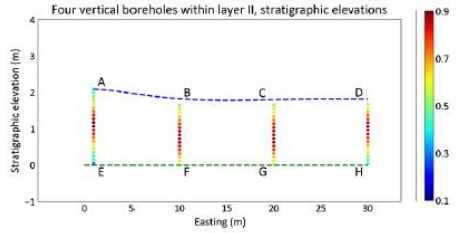
Data2HSM : Gaussian Mixture Model
Example HCM Development

Resistivity and Coarse Fraction data preprocessed and ran through PCA

Stratigraphic Coordinate Transformation (SCT) performed







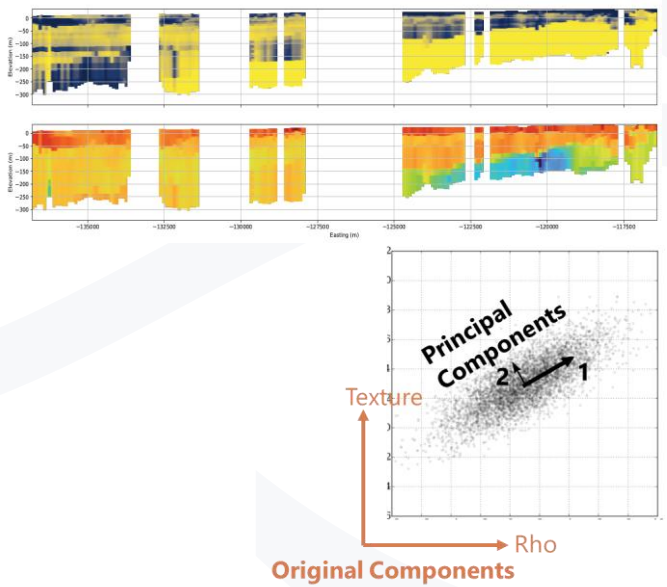
Latifi, A. M., & Boisvert, J. B. (2022)

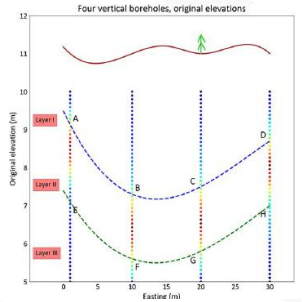
Data2HSM : Gaussian Mixture Model
Example HCM Development

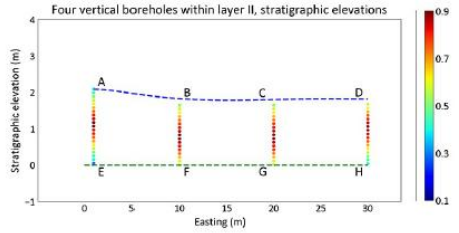
Resistivity and Coarse Fraction data preprocessed and ran through PCA

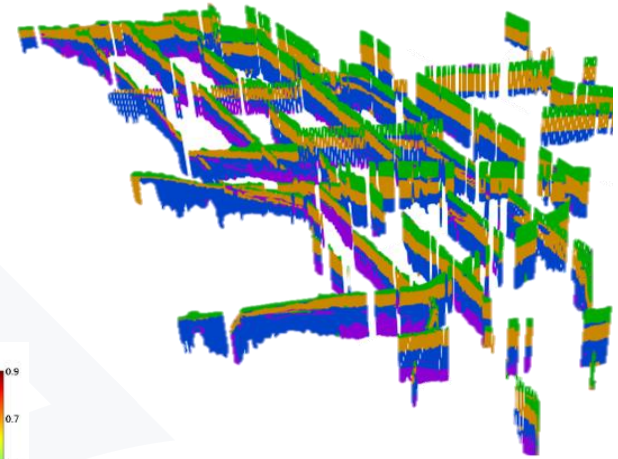
Stratigraphic Coordinate Transformation (SCT) performed

Gaussian Mixture Model trained on PCA results + SCT depth









Latifi, A. M., & Boisvert, J. B. (2022)

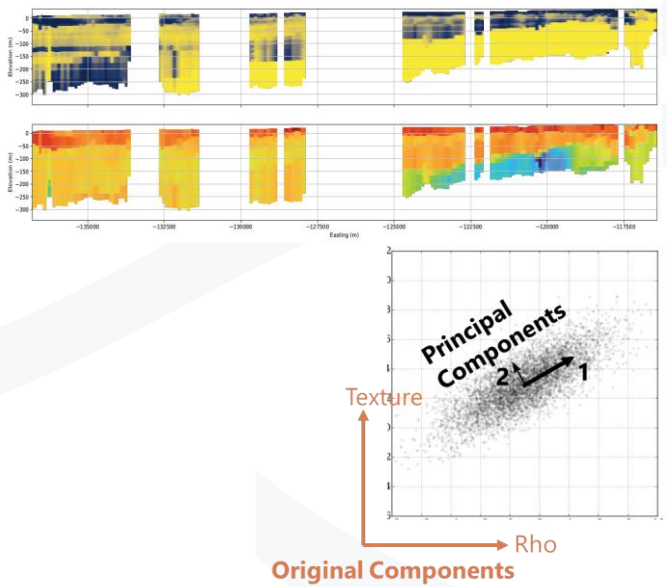
Data2HSM : Gaussian Mixture Model
Example HCM Development

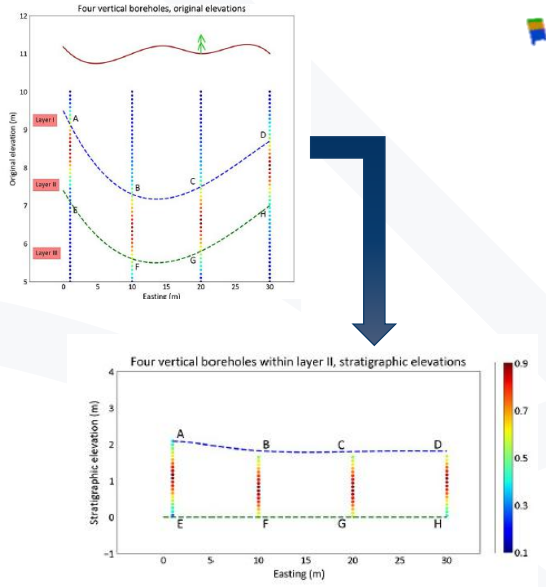
Resistivity and Coarse Fraction data preprocessed and ran through PCA

Stratigraphic Coordinate Transformation (SCT) performed

Gaussian Mixture Model trained on PCA results + SCT depth

Trained GMM predicts clusters onto 3D interpolated resistivity and CF models





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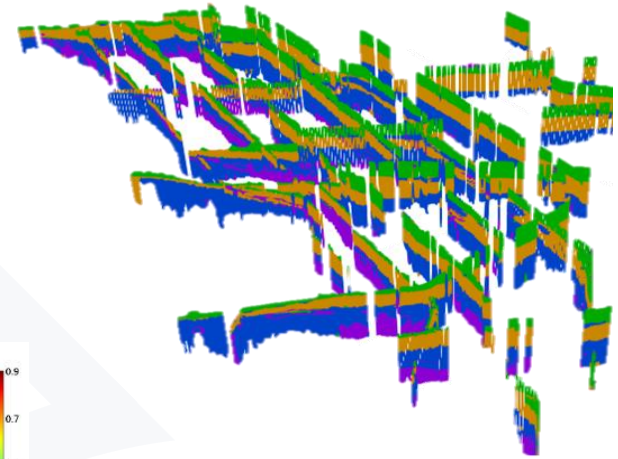
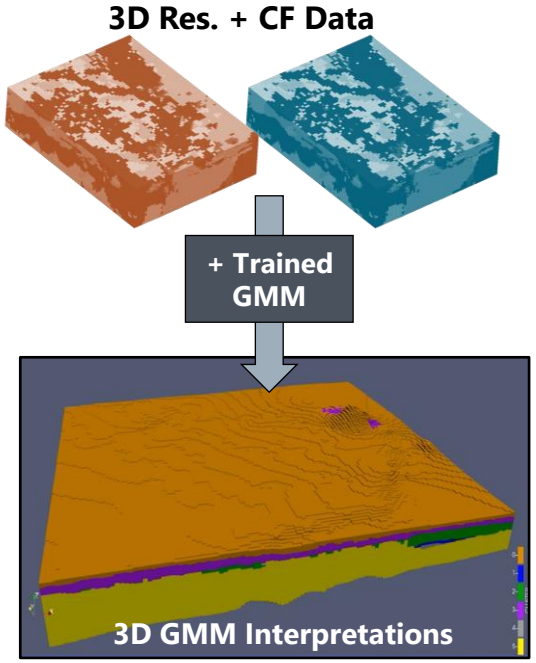
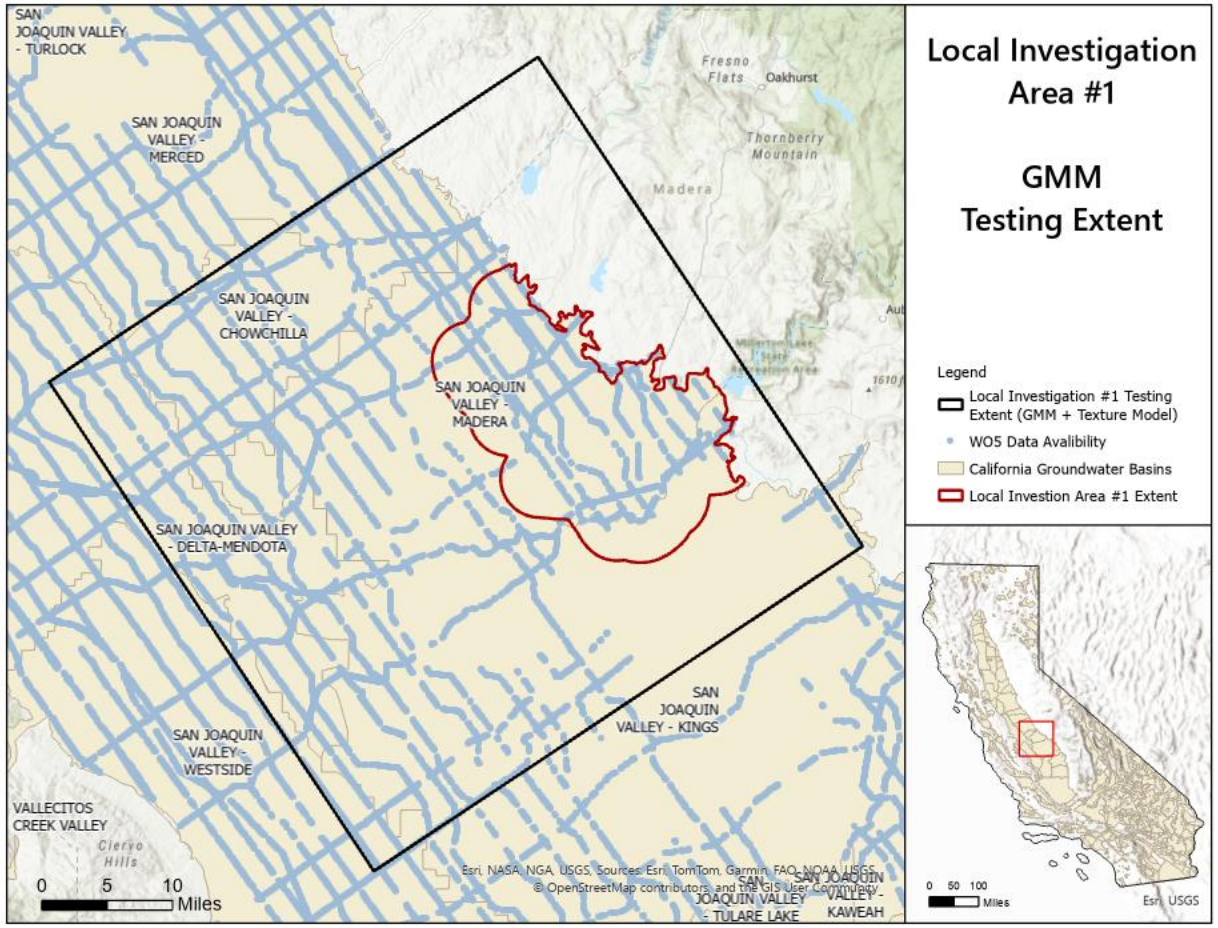
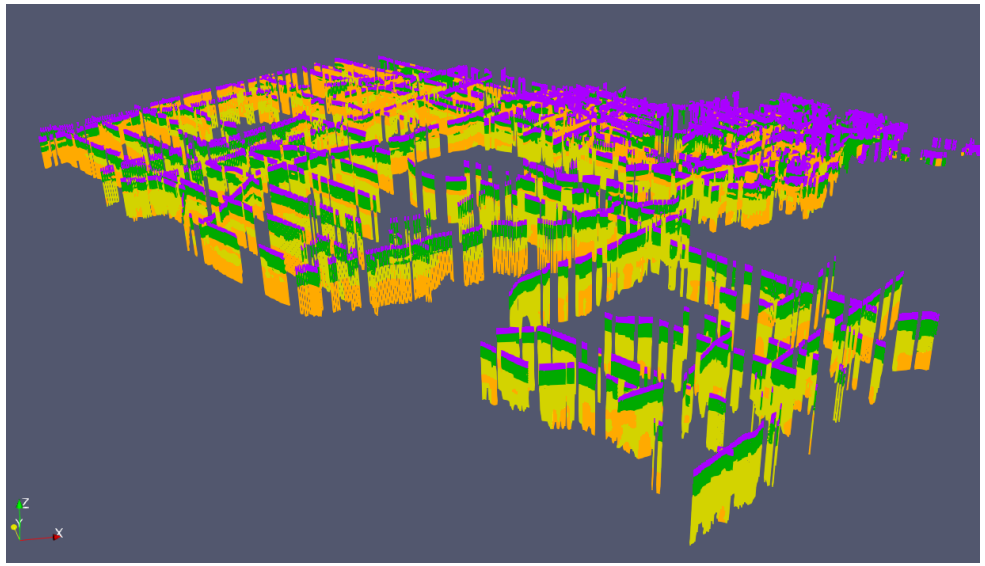




Data2HSM : Gaussian Mixture Model

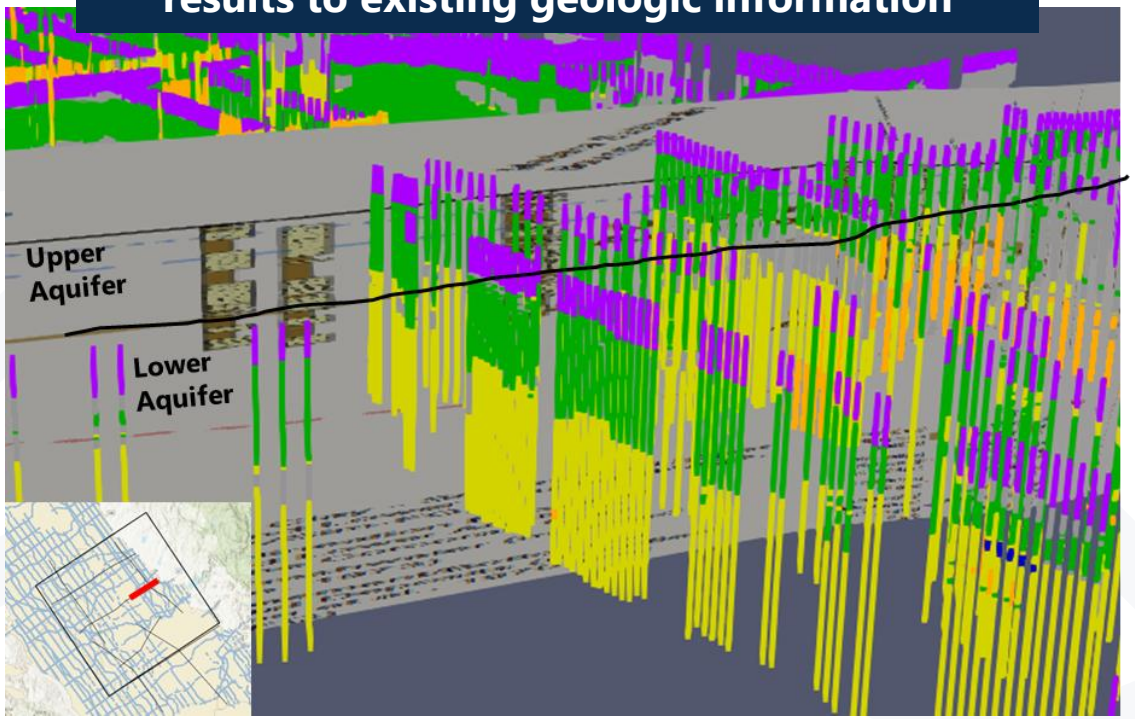
Example HCM Development – Local Investigation Area #1



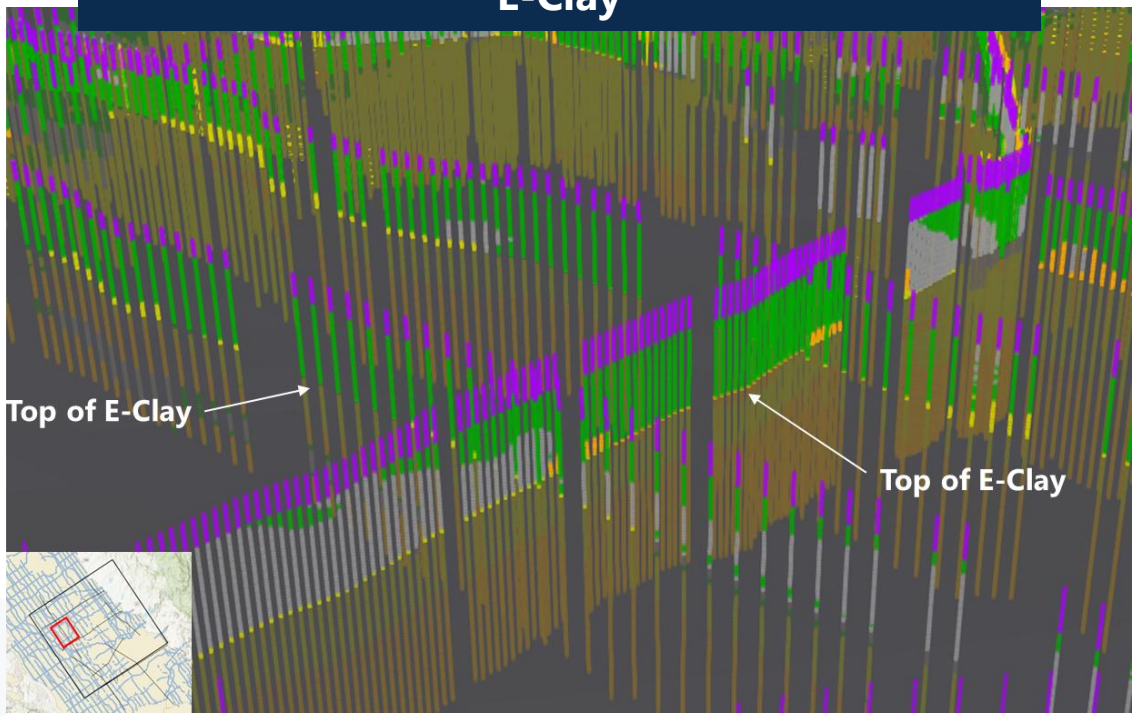


Data2HSM : Gaussian Mixture Model
Example HCM Development – Local Investigation Area #1

Testing with AEM flight lines to compare results to existing geologic information

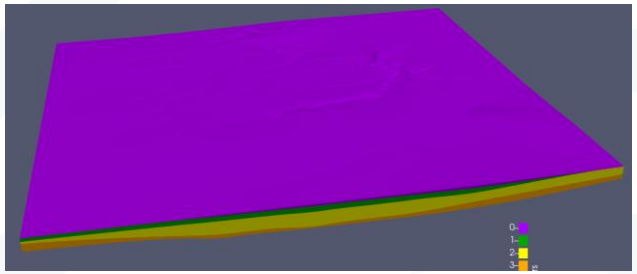


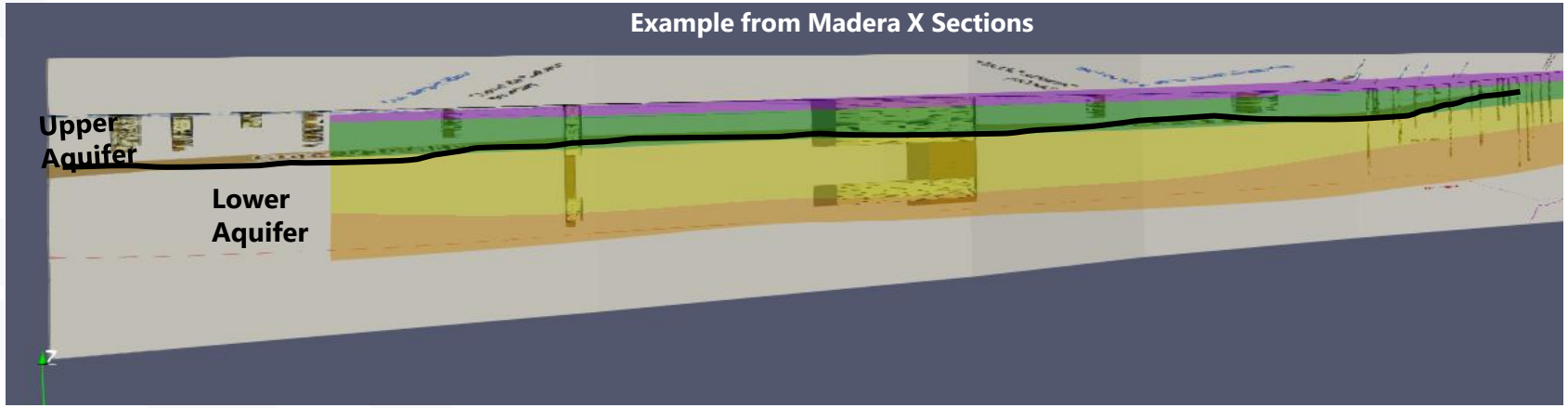
Focused on tool's ability to delineate E-Clay

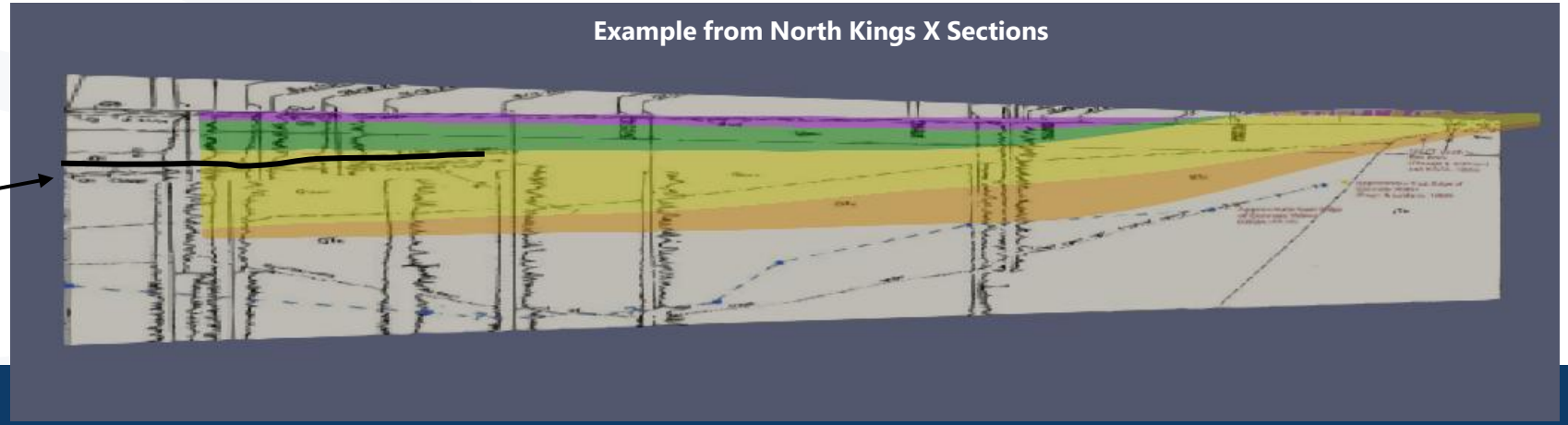


Data2HSM : Gaussian Mixture Model
Example HCM Development – Local Investigation Area #1

Optional post-processing step:
Using Topological Analysis Methods to clean up final clusters
Spline surfaces generated for each layer to produce 3D HSM

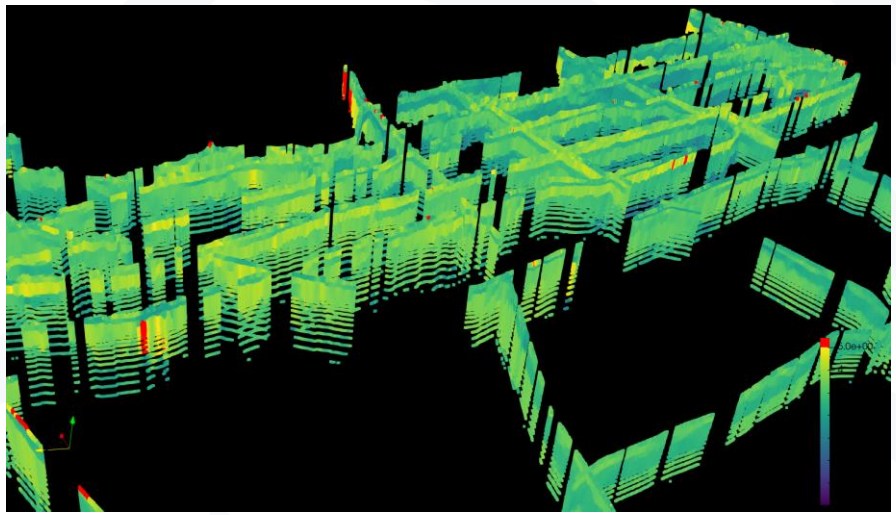






Data2HSM : Smart Interpretation

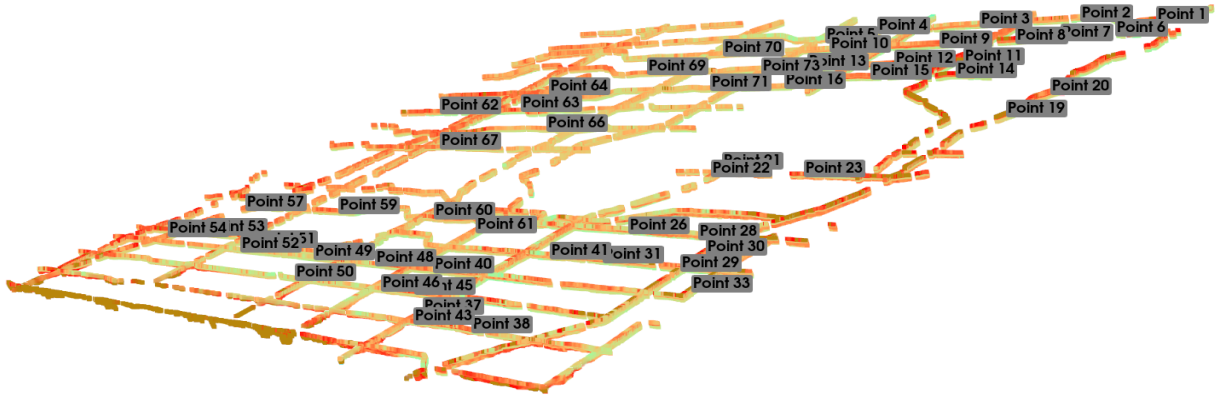
Resistivity or Texture data loaded



Data2HSM : Smart Interpretation

Resistivity or Texture data loaded

Training Points interactively selected or inputted by User



Based on Gulbrandsen, M.L., Cordua, K.S., Bach, T. et al. Smart Interpretation – automatic geological interpretations based on supervised statistical models. Comput Geosci 21, 427–440 (2017). https://doi.org/10.1007/s10596-017-9621-8

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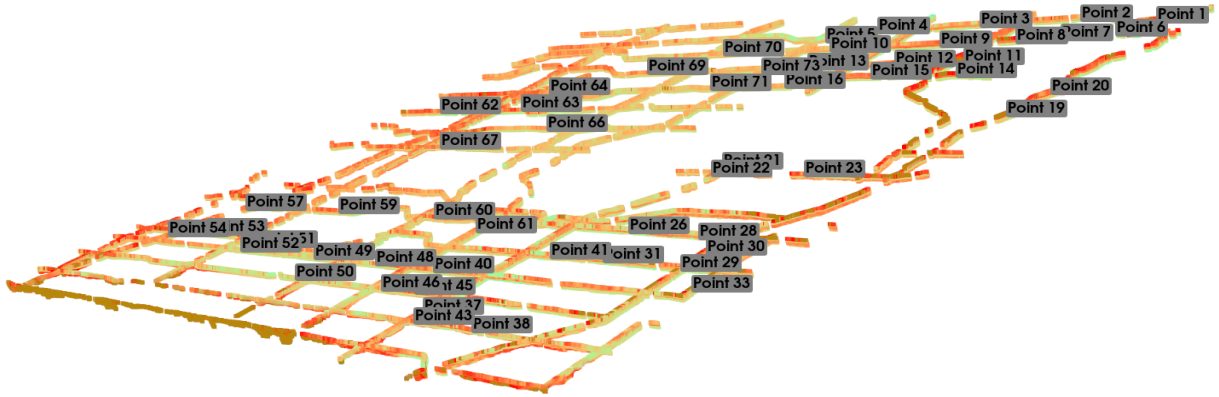
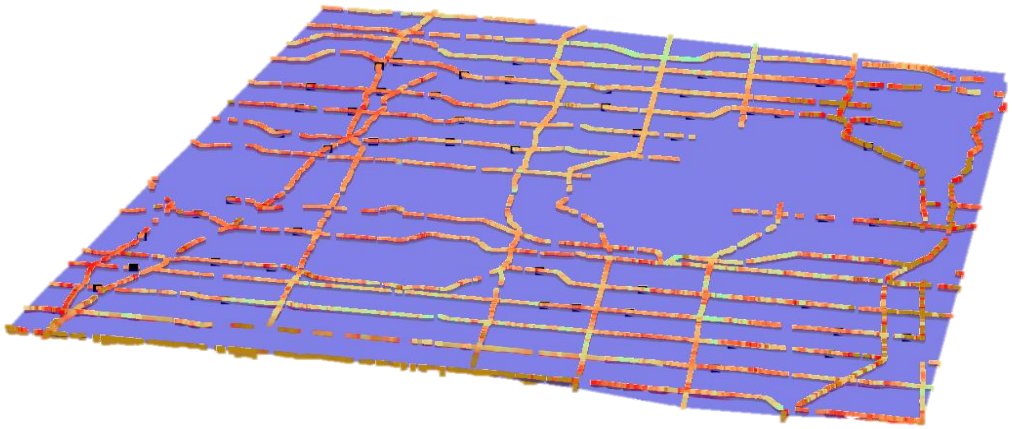
Data2HSM : Smart Interpretation

Resistivity or Texture data loaded

Training Points interactively selected or inputted by User

Points ran through polynomial regression model





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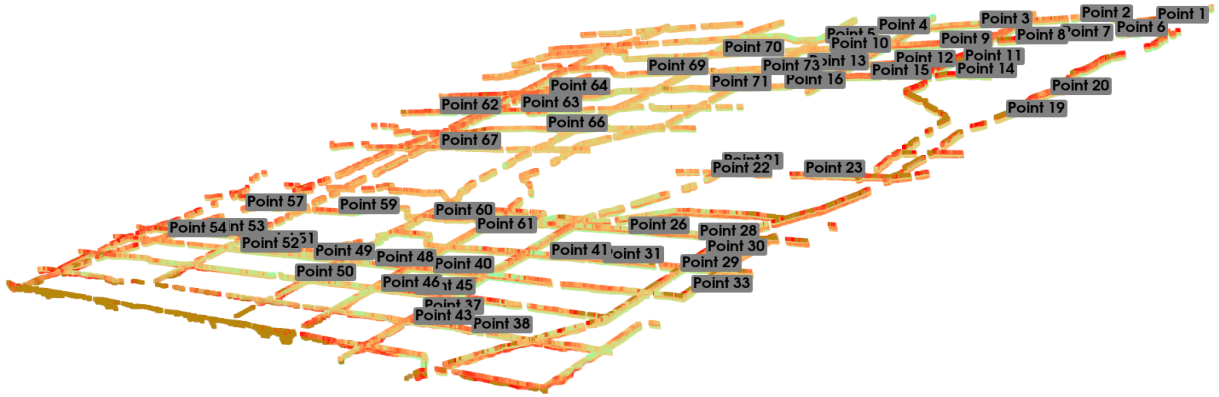
Data2HSM : Smart Interpretation

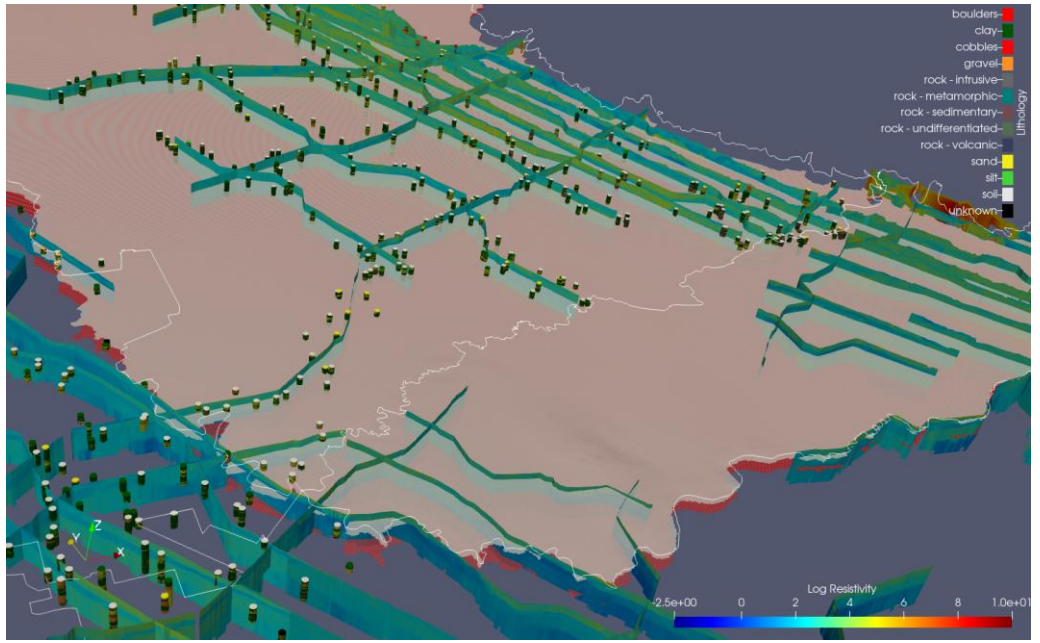
Resistivity or Texture data loaded

Training Points interactively selected or inputted by User

Points ran through polynomial regression model

Predicted surfaces can be used for HCM development





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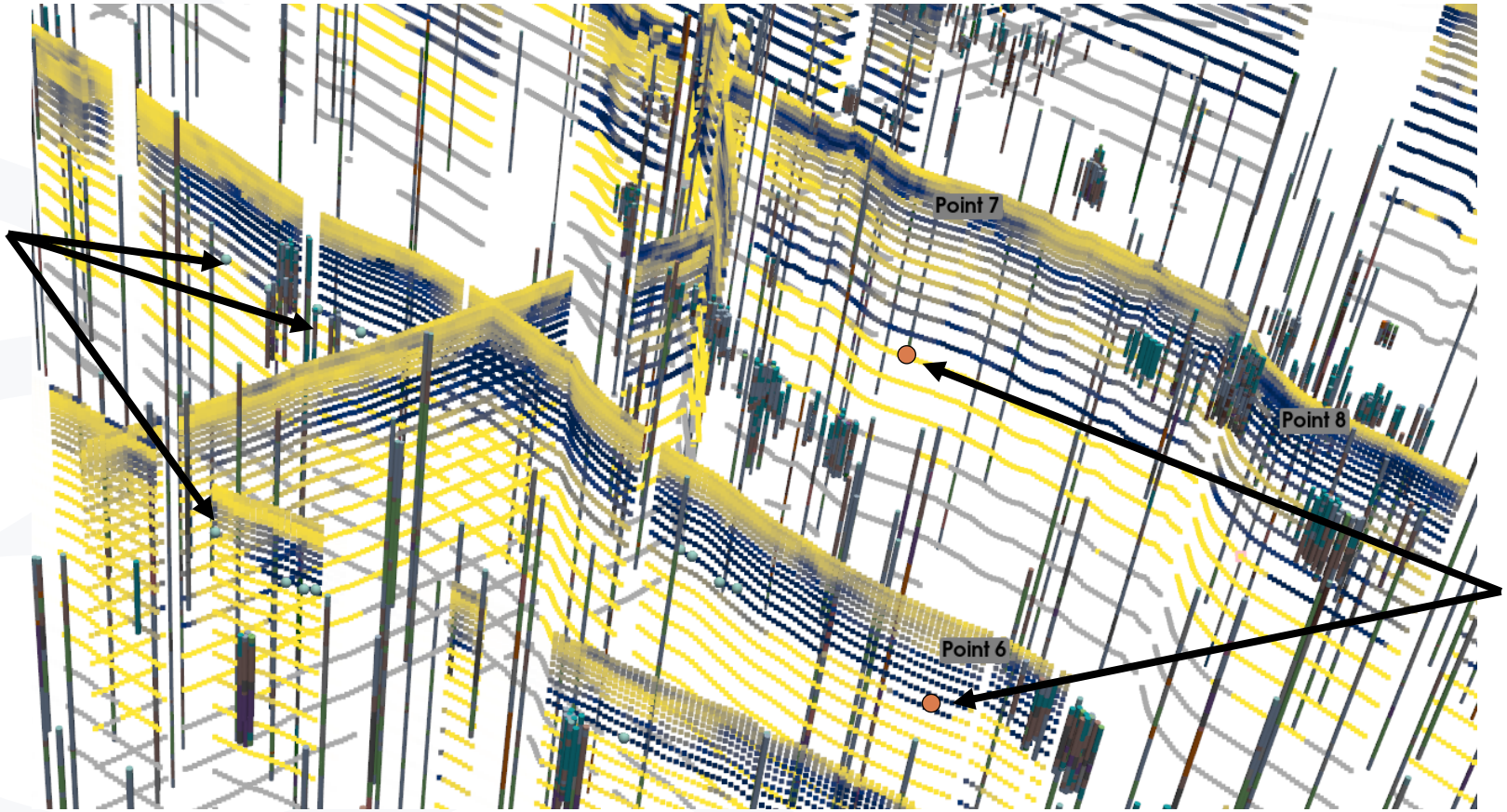
Data2HSM : Smart Interpretation
Additional Features

→ **Ability to use non-co-located data as training points**

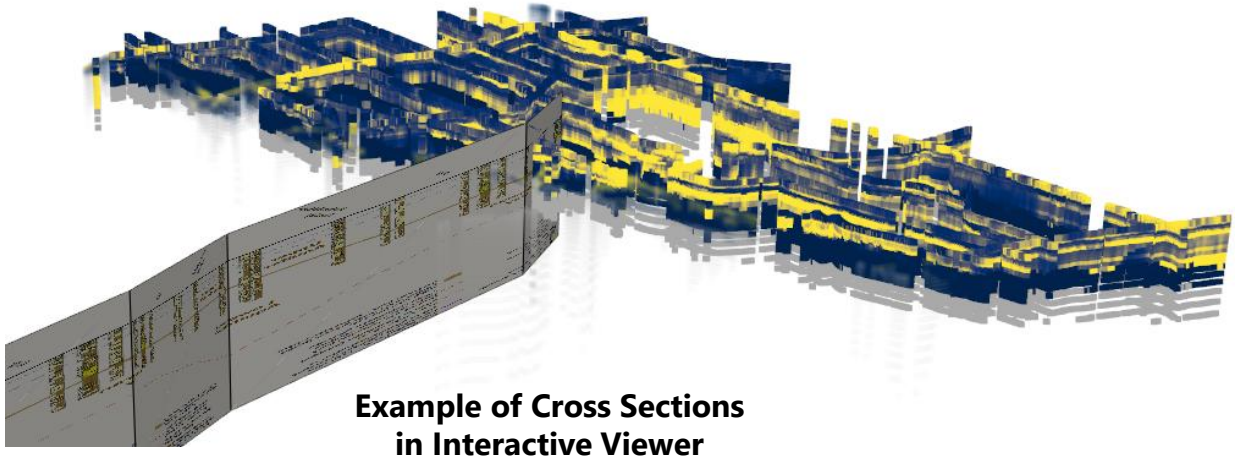
Uploaded borehole data that can be used as training points



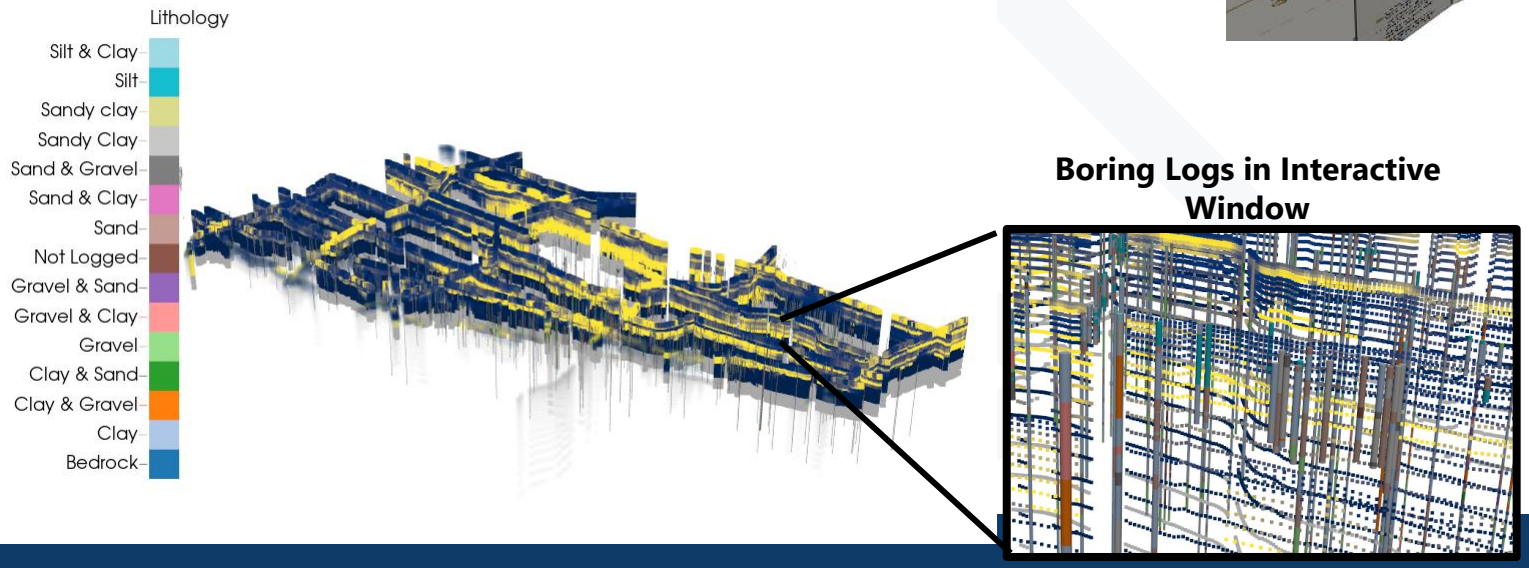
User-Selected Training Points can still be added

Data2HSM : Smart Interpretation
Additional Features

→ **Ability to bring in external well logs and cross sections to inform layer selection**



Example of Cross Sections in Interactive Viewer

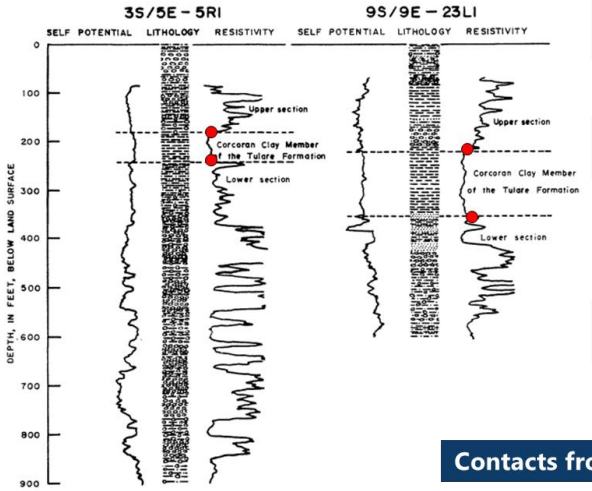


Boring Logs in Interactive Window

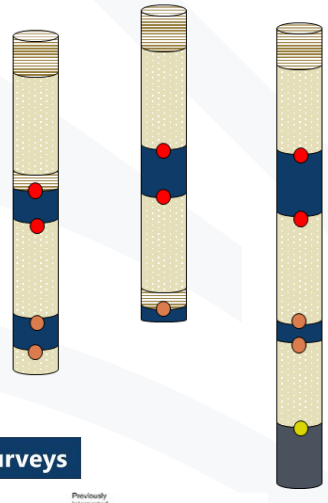
Data2HSM: GeoPDNN
Example HCM Development

Point based dataset formatted for tool

Contacts identified in Resistivity, SP, Gamma logs

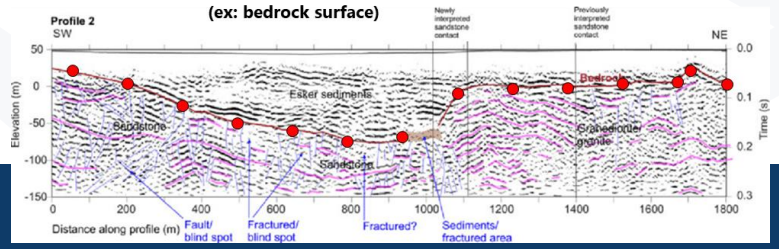


Layers identified in Well Logs



Contacts from seismic surveys

(ex: bedrock surface)

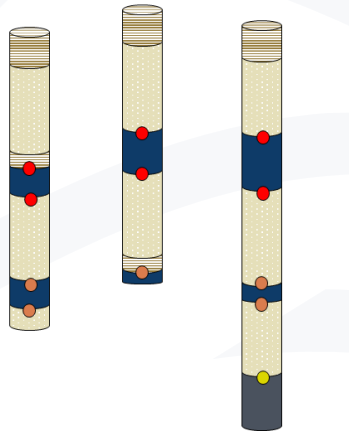


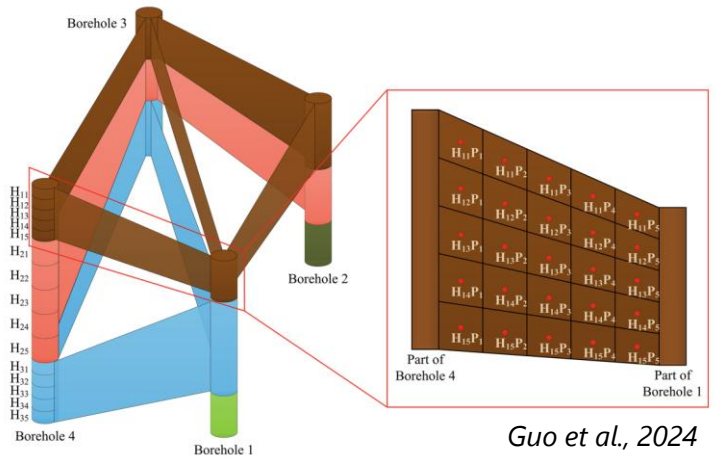
Data2HSM: GeoPDNN
Example HCM Development

Point based dataset formatted for tool

Points resampled to ensure balanced representation of all layers in dataset

Layers identified in Well Logs





Guo et al., 2024

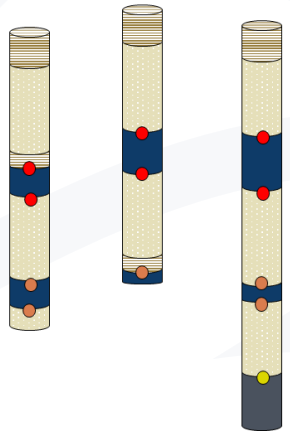
Data2HSM: GeoPDNN
Example HCM Development

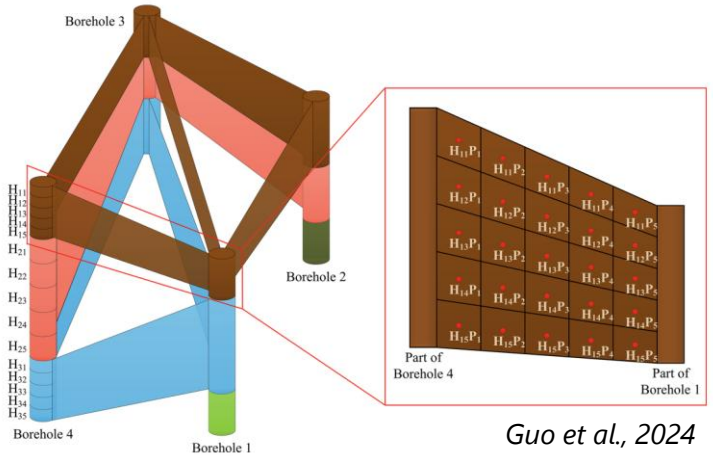
Point based dataset formatted for tool

Points resampled to ensure balanced representation of all layers in dataset

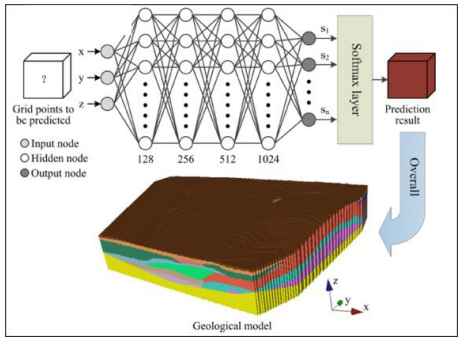
Neural Network trained with semi-supervised learning to improve model performance

Layers identified in Well Logs





Guo et al., 2024



Guo et al. GeoPDNN: A Semisupervised Deep Learning Neural Network Using Pseudolabels for Three-dimensional Urban Geological Modelling and Uncertainty Analysis from Borehole Data. Geoscientific Model Development 17, 957-973 (2024). https://doi.org/10.5194/gmd-17-957-2024

Data2HSM: GeoPDNN
Example HCM Development

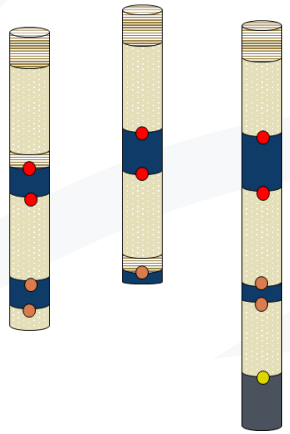
Point based dataset formatted for tool

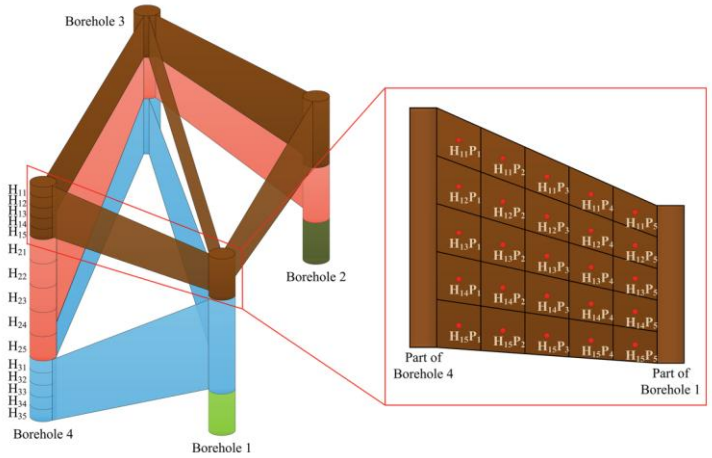
Points resampled to ensure balanced representation of all layers in dataset

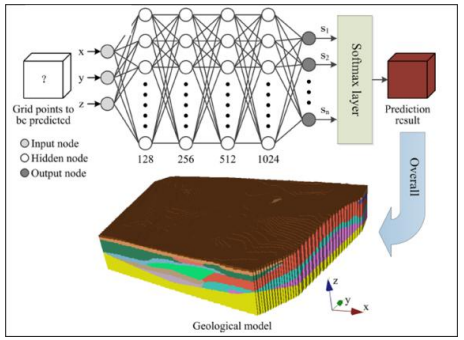
Neural Network trained with semi-supervised learning to improve model performance

Predicted surfaces can be used for HCM surfaces

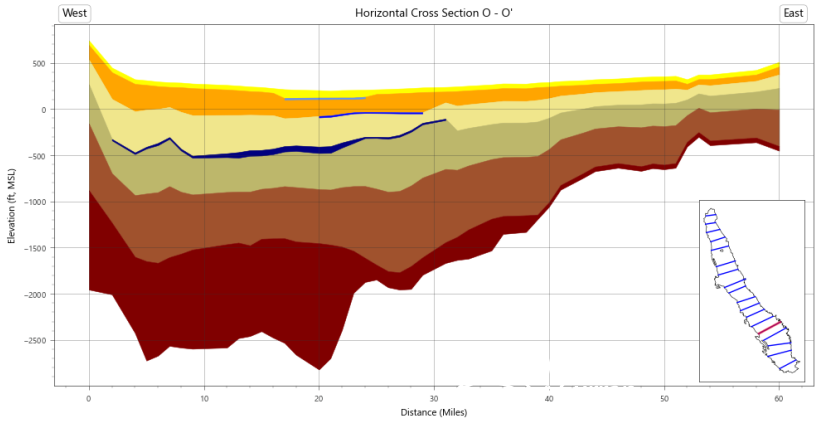
Layers identified in Well Logs







Guo et al., 2024



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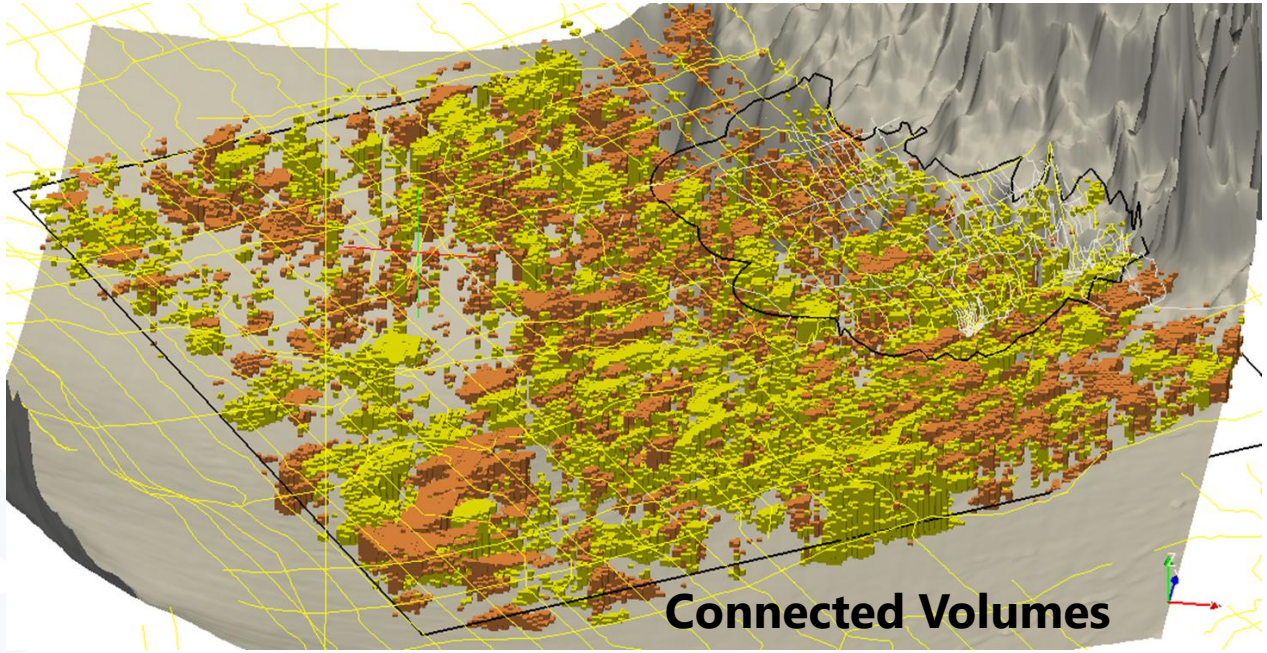
Data2Texture and Texture2Par

Data2Texture

- Data2Texture is an advanced spatial data interpolation and simulation tool for estimating the distribution of sediment textures.
- Potential applications
  - Create 2D and 3D texture models
  - Identify candidate recharge areas for MAR
  - Explore geologic formations and features
  - Develop and refine hydrogeologic conceptual models (HCMs)
  - Improve groundwater models

How does Data2Texture work?

- Interpolate well log data (texture data) to a user-defined grid
- Combine texture data with secondary data sources
  - e.g., texture estimated from AEM surveys
- Generate 2D or 3D Texture Model



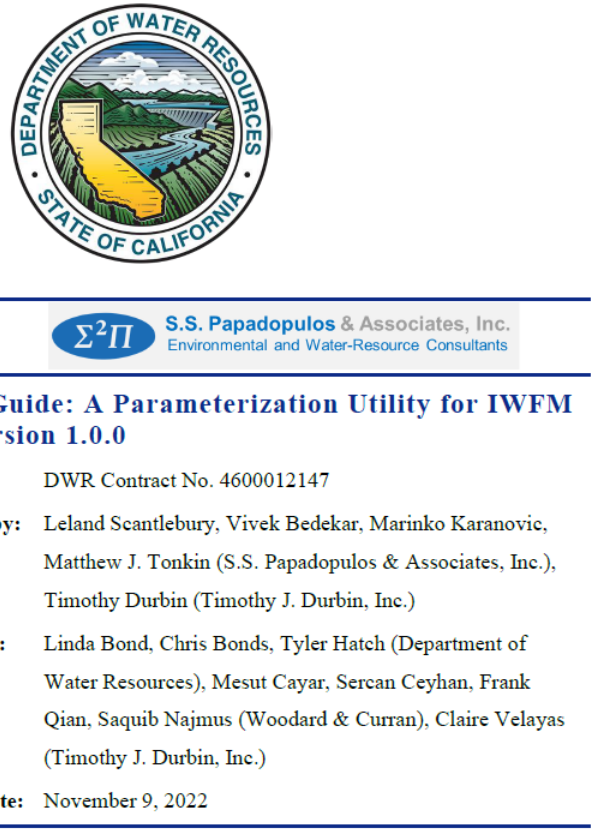
Data2Texture Features

- 2D/3D Simple and Ordinary (Co)kriging
- Kriging with drift (Universal Kriging)
- 2D/3D Anisotropy
- Many different types of variogram types supported
- Command-line utility

Texture2Par

- Texture2Par is a groundwater model pre-processor and parameterization utility.
- The main purpose of this tool is to produce aquifer property input file for groundwater models.
- It works with the IWFM and MODFLOW families of hydrologic simulation codes.

Texture2Par V1 can be downloaded from the CNRA Portal:
https://data.cnra.ca.gov/dataset/svsim/resource/621ad13b-8fa5-411e-8a95-685e20c5d5bf



Woodard & Curran | S.S. Papadopulos & Associates, Inc. Environmental and Water-Resource Consultants

Texture2Par User's Guide: A Parameterization Utility for IWFM and MODFLOW, Version 1.0.0

Work Conducted Under: DWR Contract No. 4600012147

Technical Work Completed by: Leland Scantlebury, Vivek Bedekar, Marinko Karanovic, Matthew J. Tonkin (S.S. Papadopulos & Associates, Inc.), Timothy Durbin (Timothy J. Durbin, Inc.)

Technical Work Reviewed by: Linda Bond, Chris Bonds, Tyler Hatch (Department of Water Resources), Mesut Cayar, Sercan Ceyhan, Frank Qian, Saquib Najmus (Woodard & Curran), Claire Velayas (Timothy J. Durbin, Inc.)

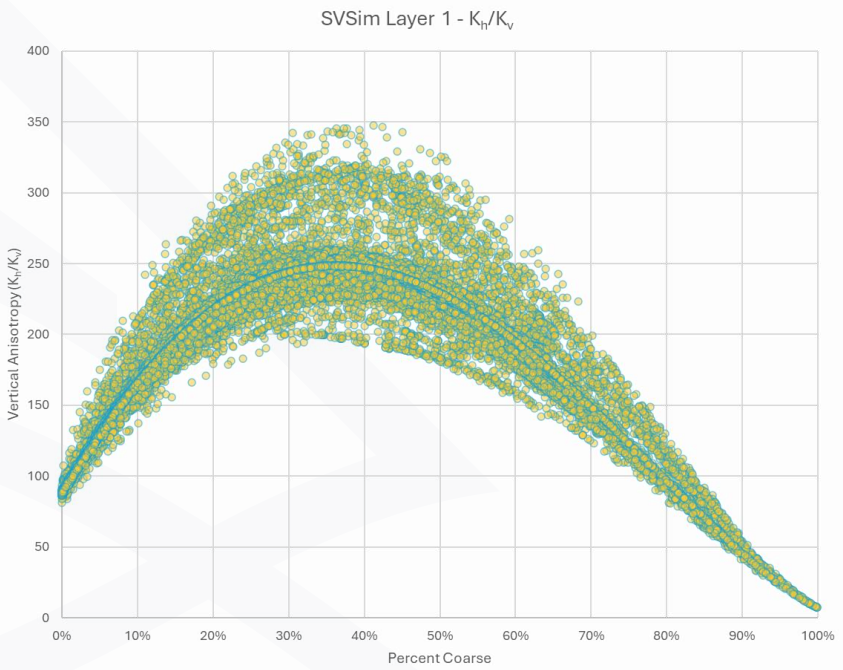
Date: November 9, 2022

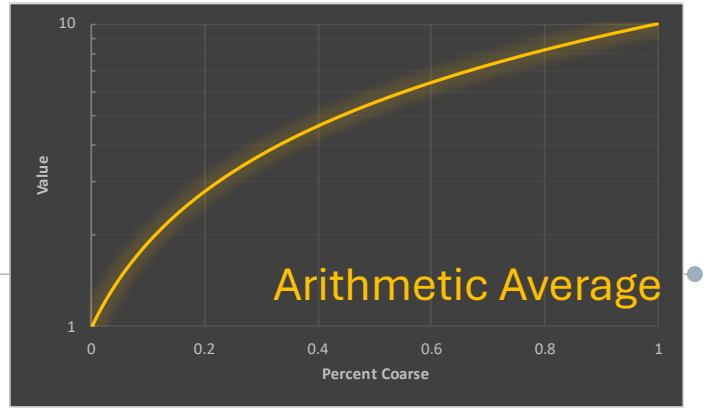
What's new in Texture2Par Version 2?

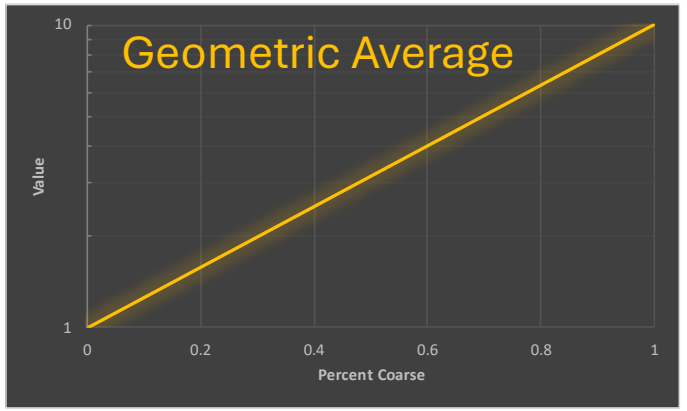
- Co-kriging capability with multiple data sources
  - Airborne electromagnetic (AEM) data: resistivity, texture
  - Other potential inputs such as tTEM
- Can handle *n* texture classes
- Block input structure – flexibility is built into the workflow process

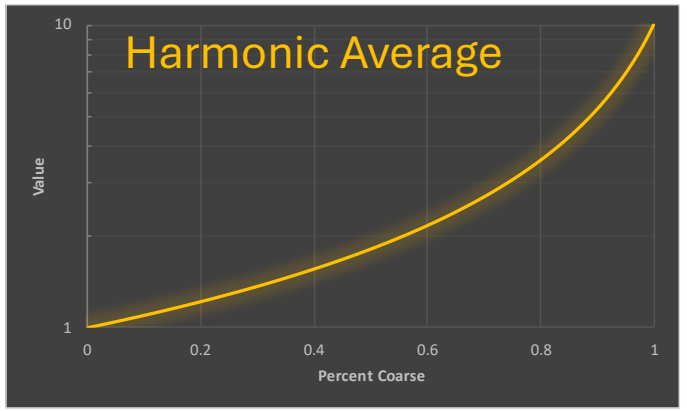
Texture2Par Features

→ Power Law Averaging
- Horizontal and vertical hydraulic conductivity
- Specific storage
- Specific yield
- Subsidence parameters









Texture2Par Features

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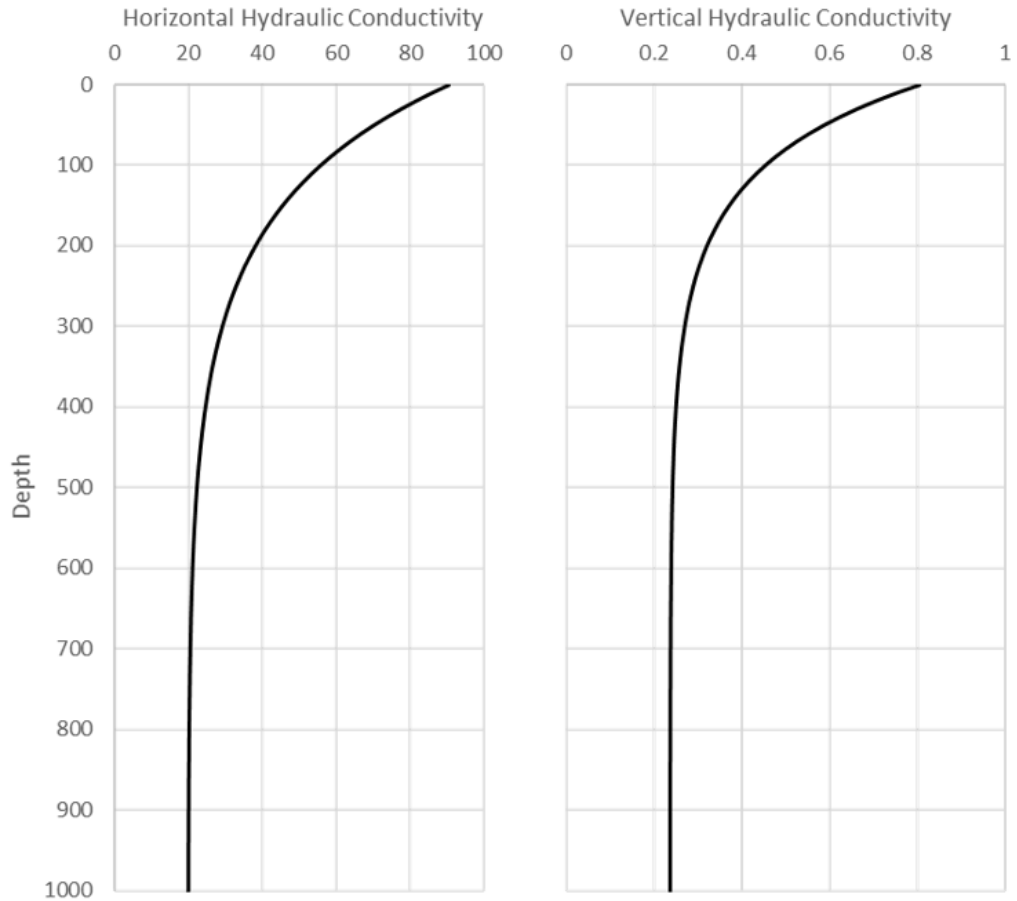
- Depth decay for compaction



Texture2Par Features

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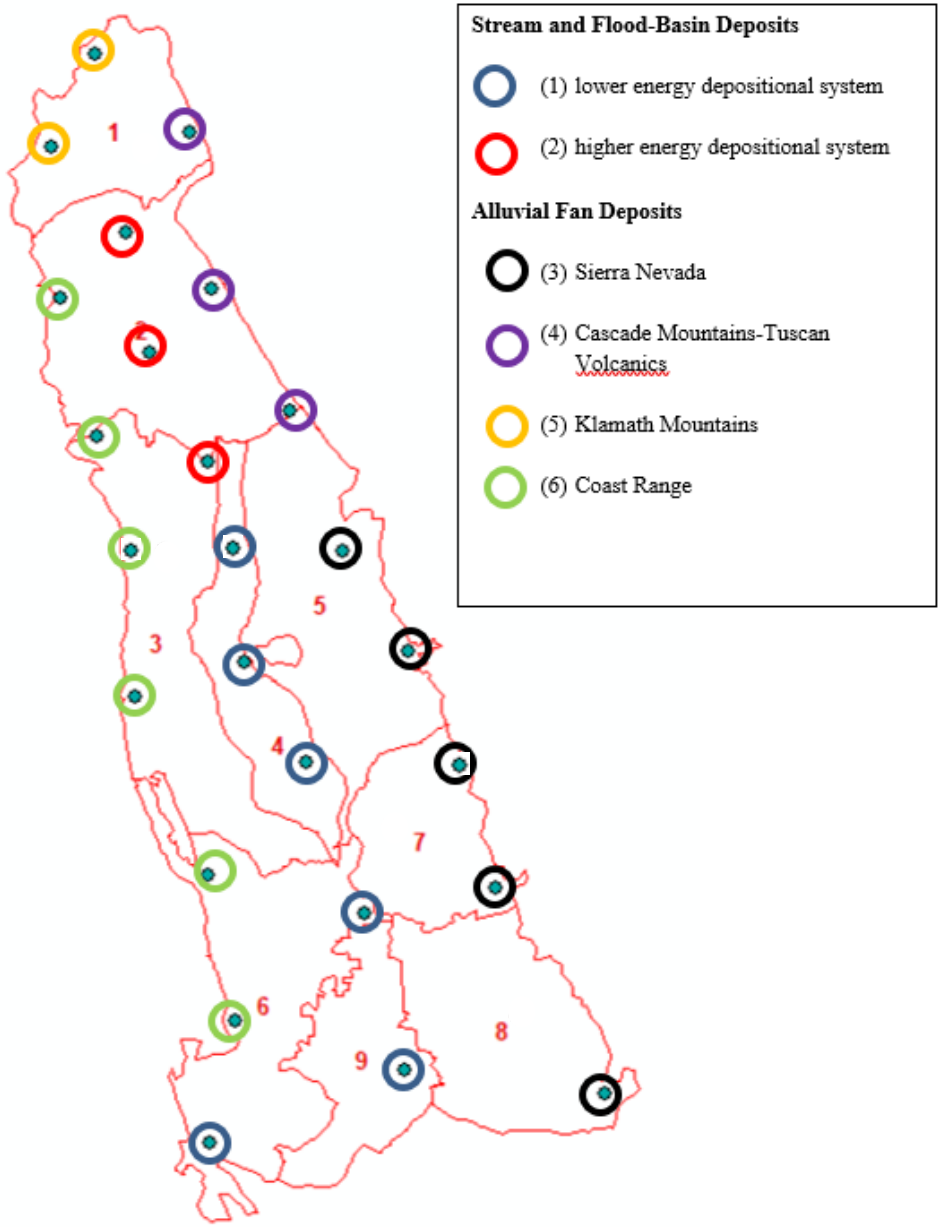
- Pilot points
  - For large-scale (basin-scale) heterogeneity
  - End-member texture properties



Texture2Par Features

- → Power Law Averaging
  - Horizontal and vertical hydraulic conductivity
  - Specific storage
  - Specific yield
  - Subsidence parameters
- → Depth decay for compaction
- → Pilot points
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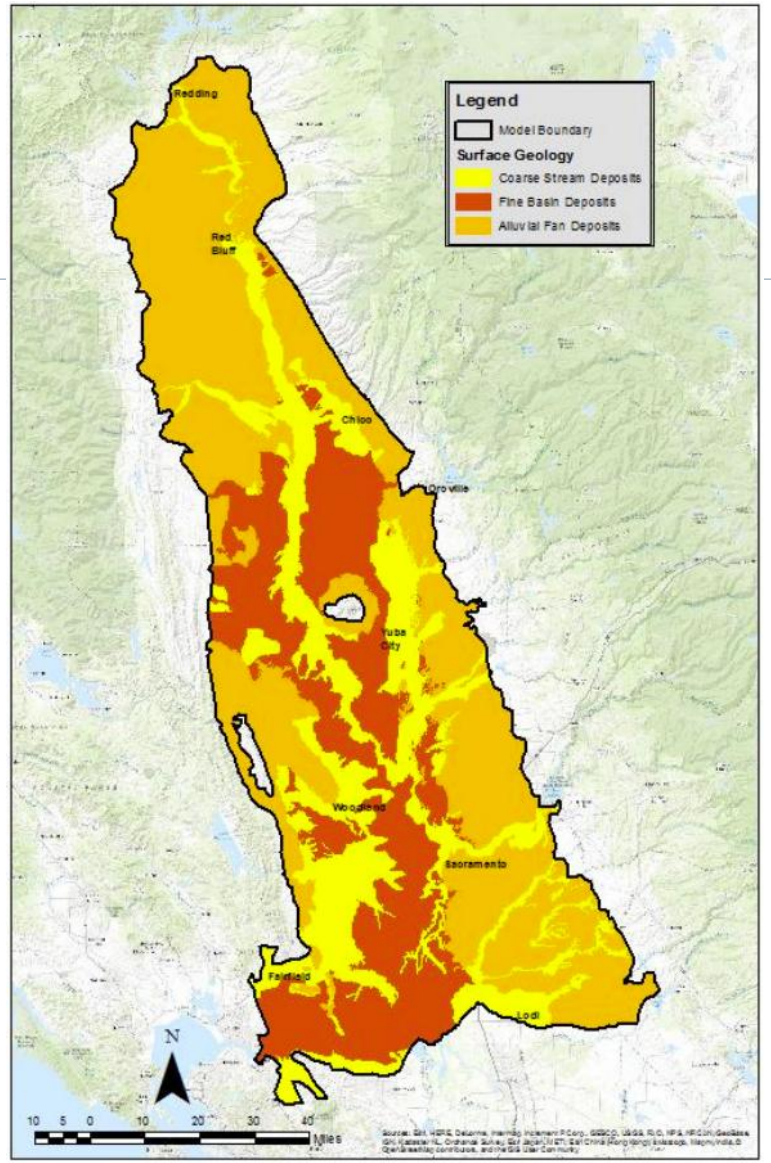
  - End-member texture properties
- → Zones
  - Hydrostratigraphic Units (HSUs)
  - Pilot Point Zones

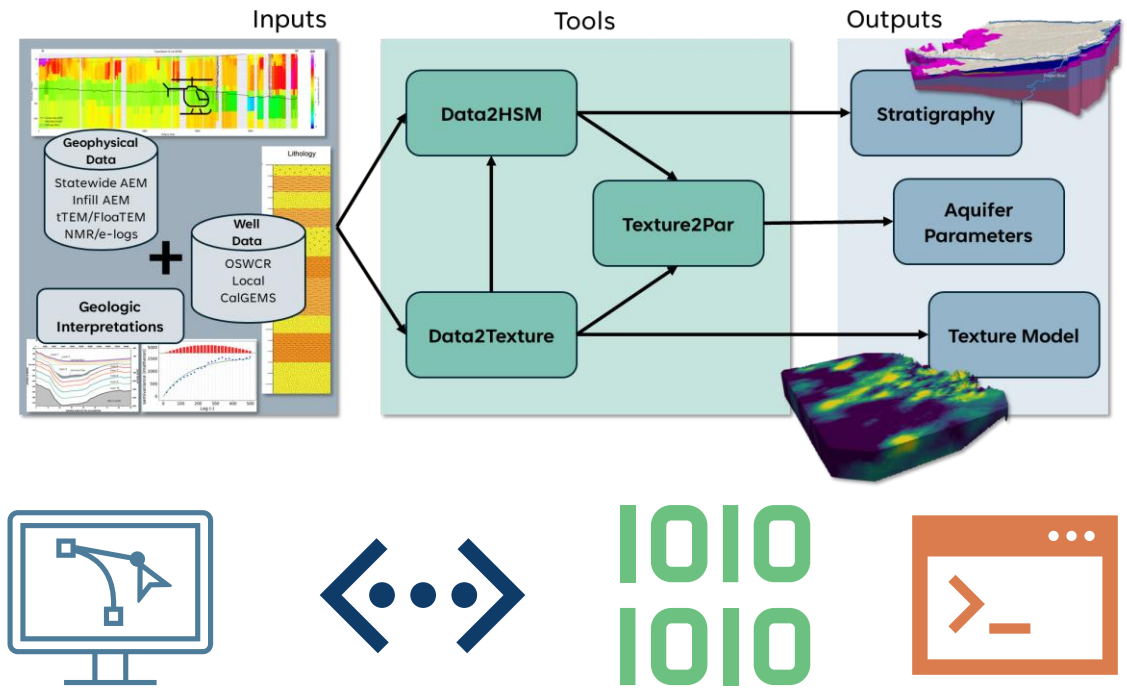


Bond, L., Durbin, T.J. 2018. Sacramento Valley Groundwater-Surface Water Simulation Model Technical Memorandum 1B (SVSim TM-1B) Department of Water Resources and Timothy J. Durbin, Incorporated. 102 p.

Tool Integration and Release

Tool Integration

- Integrate to work as a single program
- Develop integrated tool and user interface
- Complete testing in different basins and with different models
- Create distribution tests for version control
- Prepare tool documentation, guidance, and training documents



Tool Release

→ **Public Beta Release Coming Soon!**

- Anticipated in **late spring/early summer 2025**

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→ Key Updates:

- DWR's Basin Characterization Exchange group meets monthly to share updates on project and gather feedback
- **May 20th, 2025,** meeting will spotlight Data2Texture and Texture2Par tools
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→ Stay Informed:

- For more details and updates, please visit **DWR's Basin Characterization website**: https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118/Basin-Characterization

Tool Release

Basin Characterization Exchange Hub

Register for May 20th BCX Meeting

Thank you!

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