Introduction of Texas Water Development Board (TWDB) Groundwater Availability Modeling (GAM) Program

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Contract Manager

Groundwater Availability Modeling

Texas Water Development Board

Agenda

- Introduction to Groundwater Availability Modeling (GAM) Program.
- Introduce project and team
- Bureau of Economic Geology Presentation
  - Introduction to Project Objectives and Methods
  - Data Requests
  - Schedule
  - Questions, Input, Comments from Stakeholders

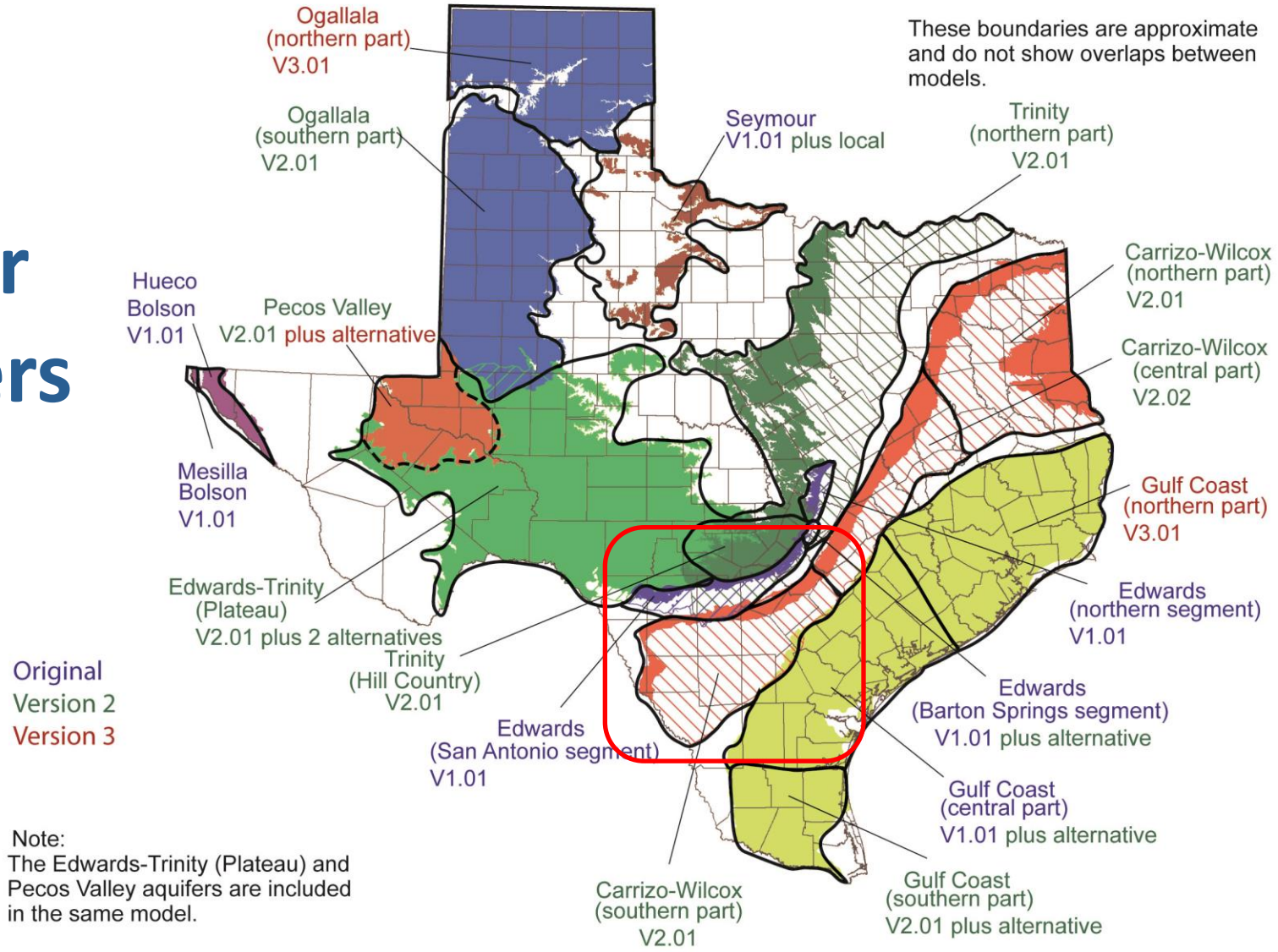
Disclaimer

The following presentation is based upon professional research and analysis within the scope of the Texas Water Development Board's statutory responsibilities and priorities but, unless specifically noted, does not necessarily reflect official Board positions or decisions.

Groundwater Availability Modeling Program

- **Aim**: Produce groundwater flow models for the major and minor aquifers of Texas.
- **Purpose**: Develop various tools that can be used to aid in groundwater resources management by stakeholders.
- **Public process**: Stakeholder involvement during model development process and during associated aquifer related projects-as applicable.
- **Models**: Freely available, standardized, thoroughly documented. Reports available over the internet.
- **Living tools**: Periodically updated.

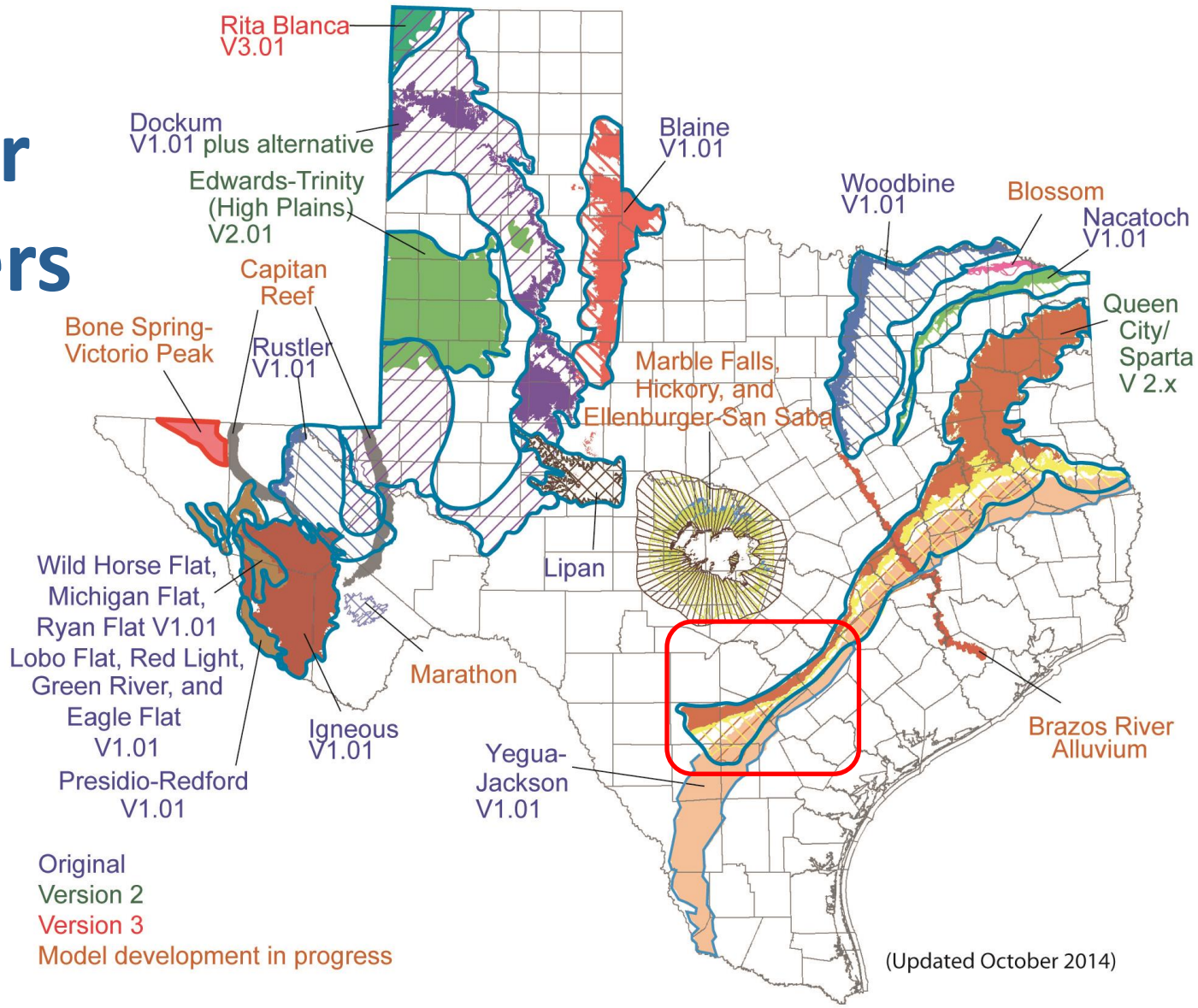
Major Aquifers



Note:
The Edwards-Trinity (Plateau) and Pecos Valley aquifers are included in the same model.

Updated December 2014

Minor Aquifers



Why Stakeholder Advisory Forums?

- Keep stakeholders updated about progress of the model-related project
- Provide stakeholders with the opportunity to provide input and data to assist with model-related project development
- Discuss limitations and applications of the project

Mapping fresh, brackish, and saline groundwater in the Queen City, Sparta, and Carrizo-Wilcox aquifers

- (1) delineate fresh, brackish, and saline groundwater in the Carrizo-Wilcox, Queen City, and Sparta aquifers—both vertically and horizontally— and
- (2) quantify volumes of available fresh, brackish, and saline groundwater using the geologic framework of the existing groundwater availability model for the southern portion of the aforementioned aquifers

Mapping fresh, brackish, and saline groundwater in the Queen City, Sparta, and Carrizo-Wilcox aquifers

- After we sent request for qualifications, House Bill 30 (84th legislation) was passed.
- This project addresses some but not all of the directives
- Received Board approval to expand this project to address all of HB 30 directives

Contact Information

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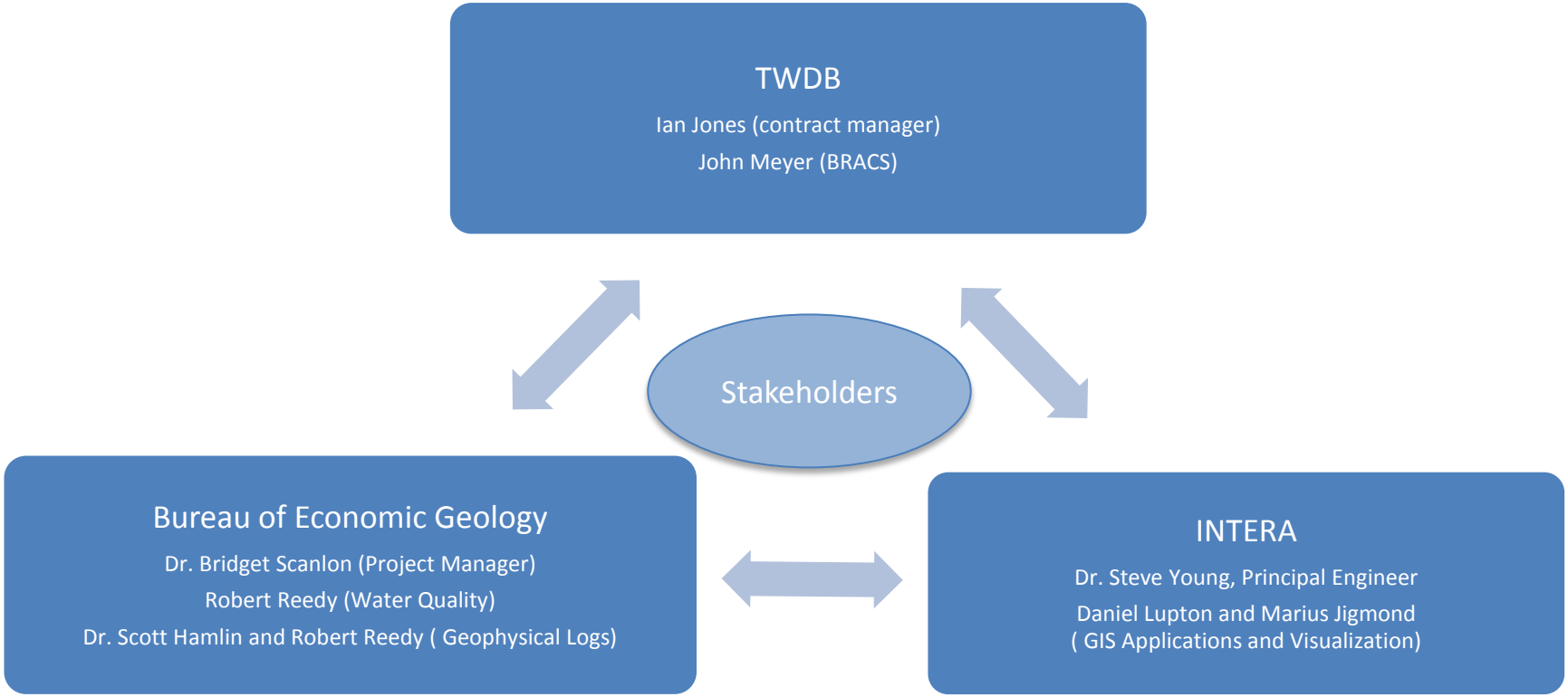
Web information (includes meeting information):

http://www.twdb.texas.gov/groundwater/models/research/czwx_qcsp_s_mapping/czwx_qcsp_s_mapping.asp

Project Team



Mapping Fresh, Brackish, and Saline Groundwater in the Queen City, Sparta, and Carrizo-Wilcox Aquifers mainly in Groundwater Management Area 13

Scott Hamlin[1], Steve Young[2], and Bob Reedy[1], and Bridget Scanlon[1]

Ian Jones, Contract Manager (TWDB)

[1]Bureau of Economic Geology, Jackson School of Geosciences, Univ. of Texas at Austin, Texas

[2]INTERA Inc., Austin, Texas

Meeting at Evergreen Underground Water Conservation District, Nov 19, 2015

Relationship between current TWDB Project and House Bill 30

- Our current project contract is being amended to incorporate House Bill 30 requirements for suggesting potential brackish groundwater production areas and scheduling
- We will estimate potential production areas in the Carrizo-Wilcox Aquifer in 2016 and the Queen City and Sparta aquifers in 2017
- After TWDB staff evaluates the potential areas and recommends the final areas, we will calculate water volumes in those areas.

Background

- Definition of water types:
  - Fresh: ≤1,000 mg/L Total Dissolved Solids (TDS)
  - Brackish: 1,000 – 10,000 mg/L TDS
    - Slightly saline: 1,000 – 3,000 mg/L;
    - moderately saline, 3,000 – 10,000 mg/L TDS
  - Saline: ≥ 10,000 mg/L TDS
  - Seawater: 35,000 mg/L TDS

Tasks

- Task 1: Project management
- Task 2: Groundwater quality
- Task 3: Use of geophysical log interpretation to map fresh, brackish, and saline groundwater
- Task 4. GIS-based application to calculate volumes of fresh, brackish, and saline groundwater
- Task 5. Visualization and groundwater quality

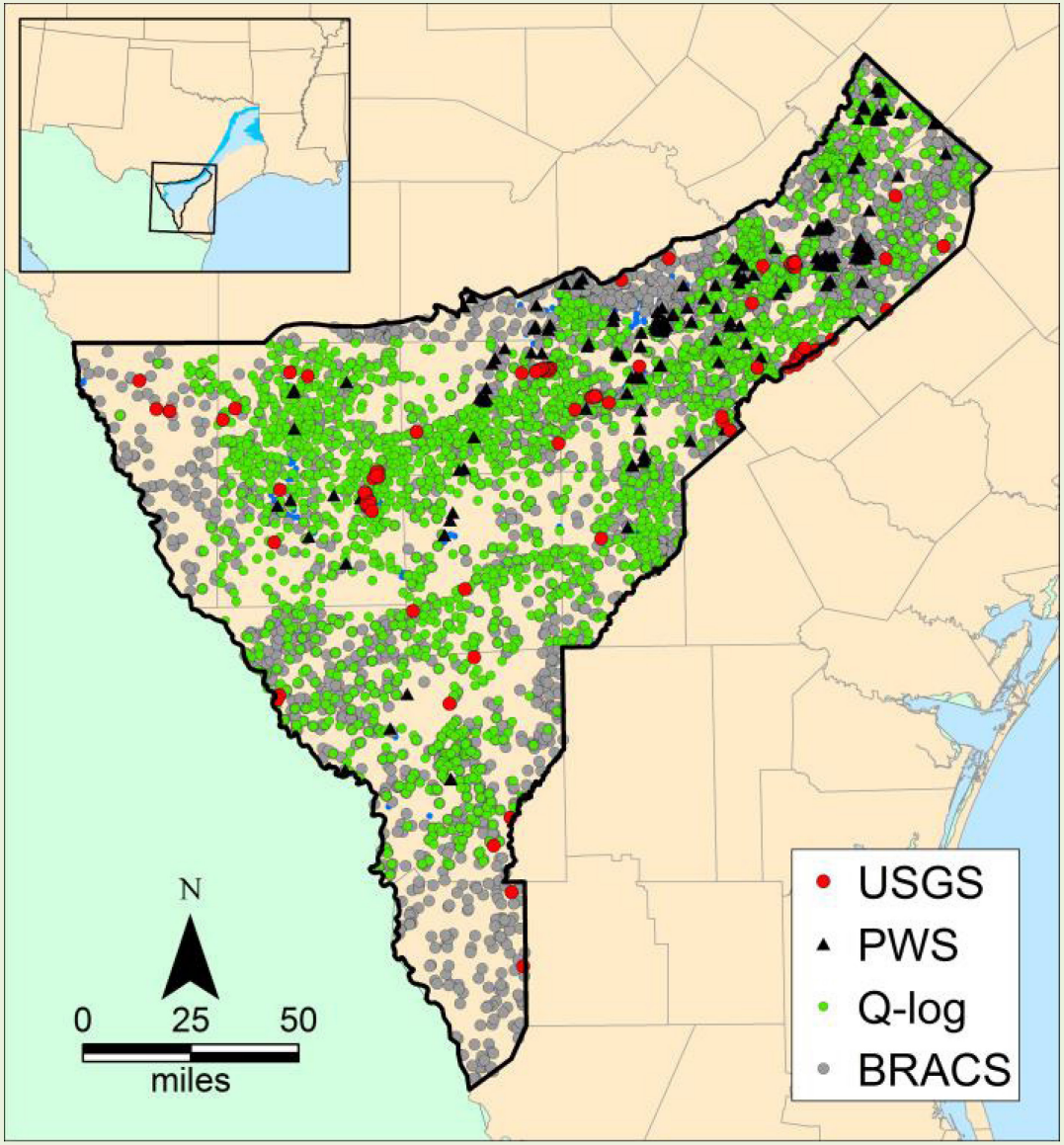
Task 2: Groundwater Quality

- 2.1: Develop a geochemical database including TWDB, TCEQ PWS, USGS
  - Produced water data from USGS
  - Data on rig supply wells from industry
- 2.2: Characterization of Groundwater Quality
  - Map hydrochemical facies to apply empirical approach of TDS from well logs and to assess salinity sources
  - TDS from TWDB, TCEQ, produced water, Class II disposal wells
  - Ionic makeup of groundwater
  - Groundwater quality: suitability for desalination, silica, iron, boron, naturally occurring radioactive materials (NORMs)
  - Suitability for hydraulic fracturing: scaling issues from high levels of barium sulfate and boron interference with gels

Task 3: Use of Geophysical Log Interpretation to Map Fresh, Brackish, and Saline Groundwater

- 3.1: Evaluation of geophysical well logs, including availability, log quality, and data management (5,200 wells in BRACs database, 3,300 geophysical well logs)
- 3.2: Interpreting groundwater salinity from geophysical logs – 500 to 600 selected logs
- 3.3: Groundwater salinity and lithology mapping

Subtask 3.1: Distribution of Geophysical Well Logs



Geophysical well logs from BRACs database, RRC Q logs, TCEQ PWS wells, and USGS produced water wells

Characterization of Brackish Groundwater in the Carrizo-Wilcox Aquifer

Case study: Eagle Ford Shale Play

Shell-UT Unconventional Research Program 2013-2014

ELECTRIC LOGS

- Borehole measurements of electrical properties versus depth
- Commonly run in oil and gas wells, less commonly in water wells
- Respond to variations in both pore-fluid composition and rock properties
- Can be used to estimate groundwater salinity where rock properties are relatively constant
- Graphically display variations in **Spontaneous Potential (SP)** and **Resistivity** with depth

LOG TYPES

SP log records relative difference in electrical potential

- Positive SP: groundwater salinity < borehole fluid salinity
- Neutral SP: groundwater salinity = borehole fluid salinity
- Negative SP: groundwater salinity > borehole fluid salinity
- **Qualitative indicator of groundwater salinity**

Resistivity log records resistance to an induced current

- High resistivity: low salinity groundwater
- Low resistivity: high salinity groundwater
- **Quantitative indicator of groundwater salinity**

Distinguishing Lithology from Groundwater salinity

- Works best in simple sand/mud sequences
- Mud and shale – neutral SP and low resistivity
- Sand and sandstone – groundwater salinity effects

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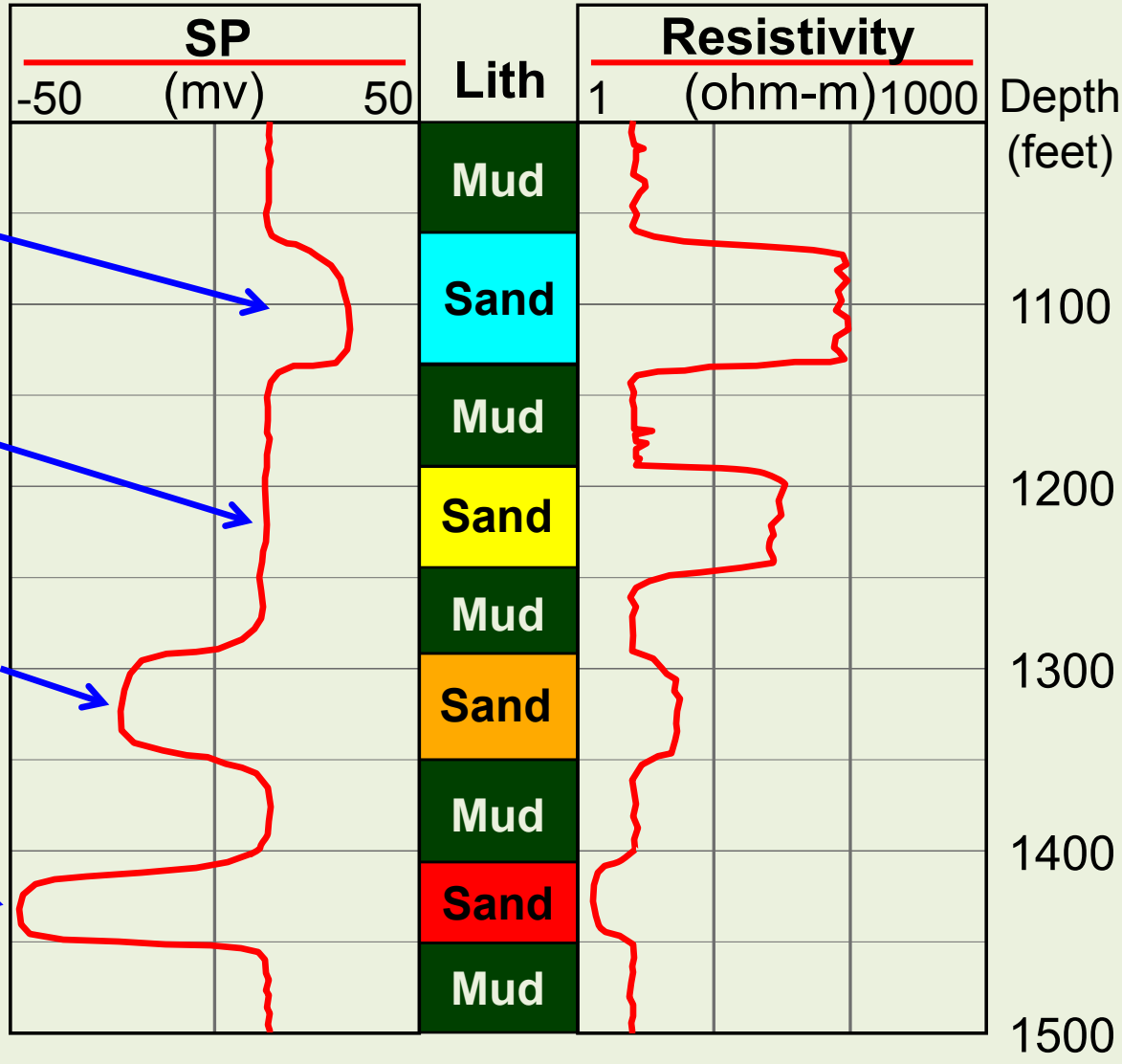
Electric Log Response to Groundwater Salinity



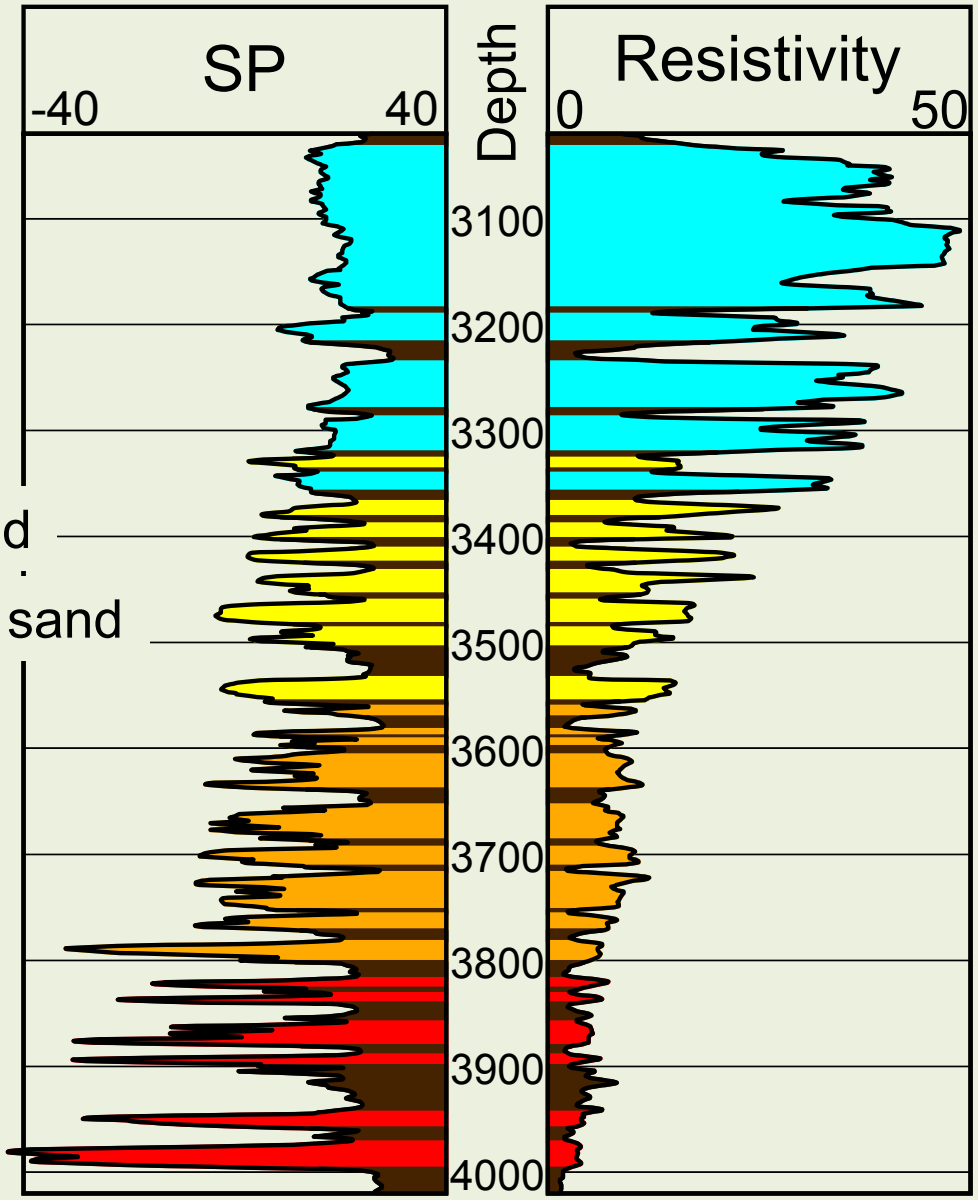
Freshwater sand
- SP positive
- Res very high

Slightly saline water sand
- SP neutral
- Res high

Moderately saline water sand
- SP negative
- Res low

Very saline water sand
- SP very negative
- Res very low

Carrizo-Wilcox Electric Log example showing groundwater salinity increase with depth



- Freshwater sand
- Slightly saline water sand
- Moderately saline water sand
- Very saline water sand
- Shale or mud

Log trends with depth:

SP – increasing negative

Res – decreasing

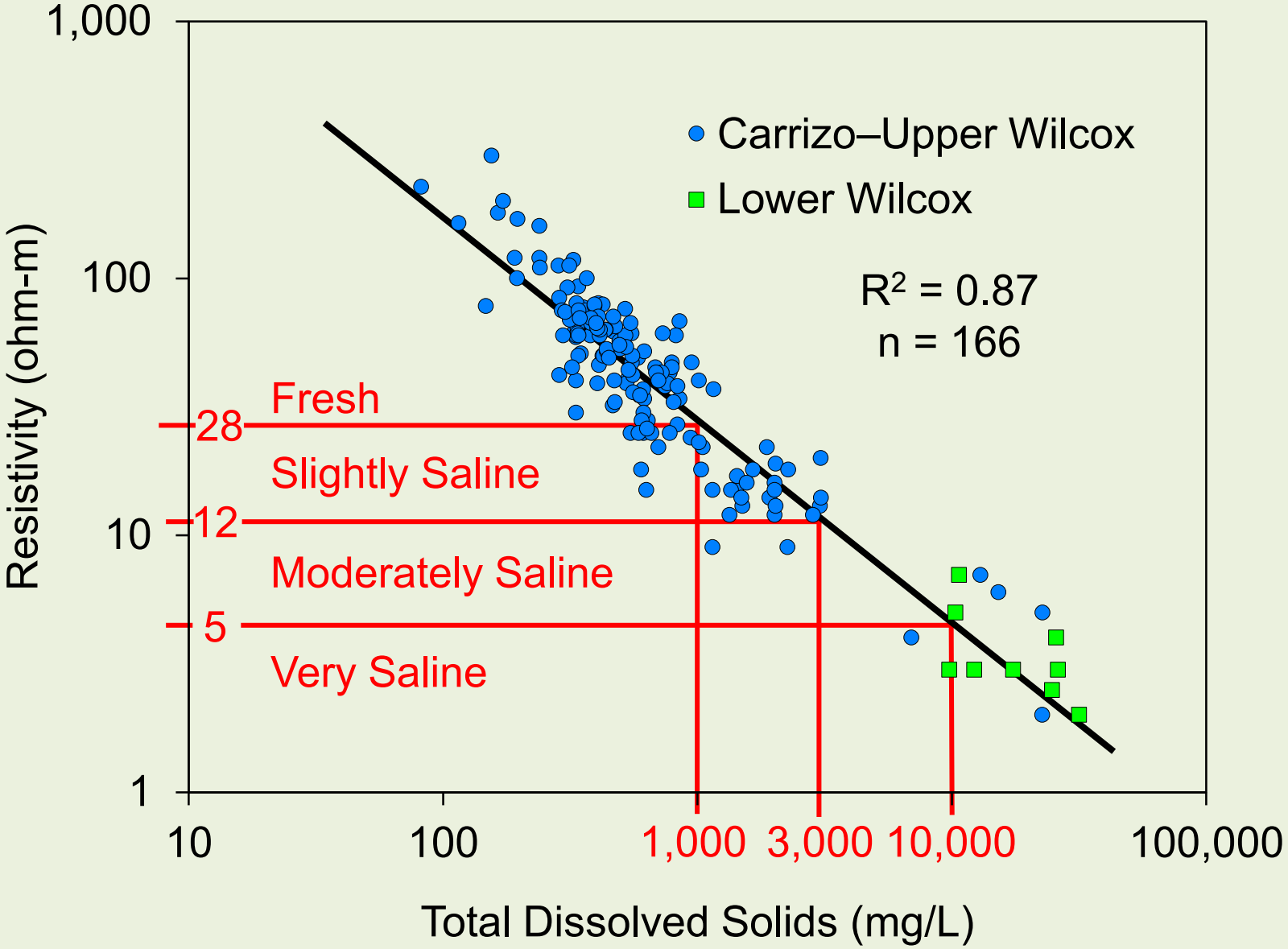
Estimating Groundwater Salinity – Methods

1. Empirical relationship between resistivity of a water-filled formation (R_0) and formation water salinity (TDS) – primary method

2. Calculation of formation **water** resistivity (R_w) using a modified version of the Archie equation – used as a check and where TDS data are scarce

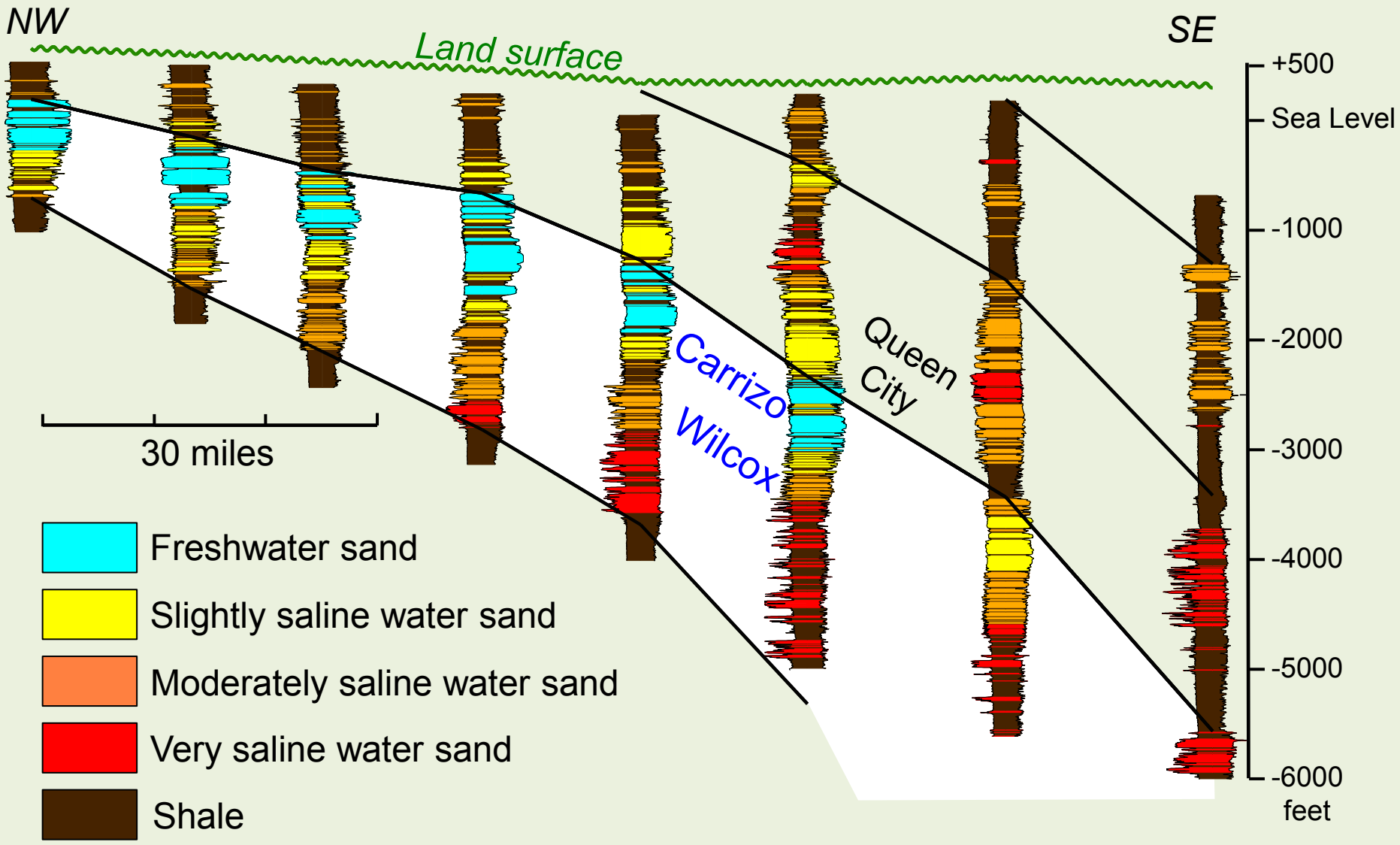
Correlating Resistivity with Groundwater Chemical Analyses

All Data

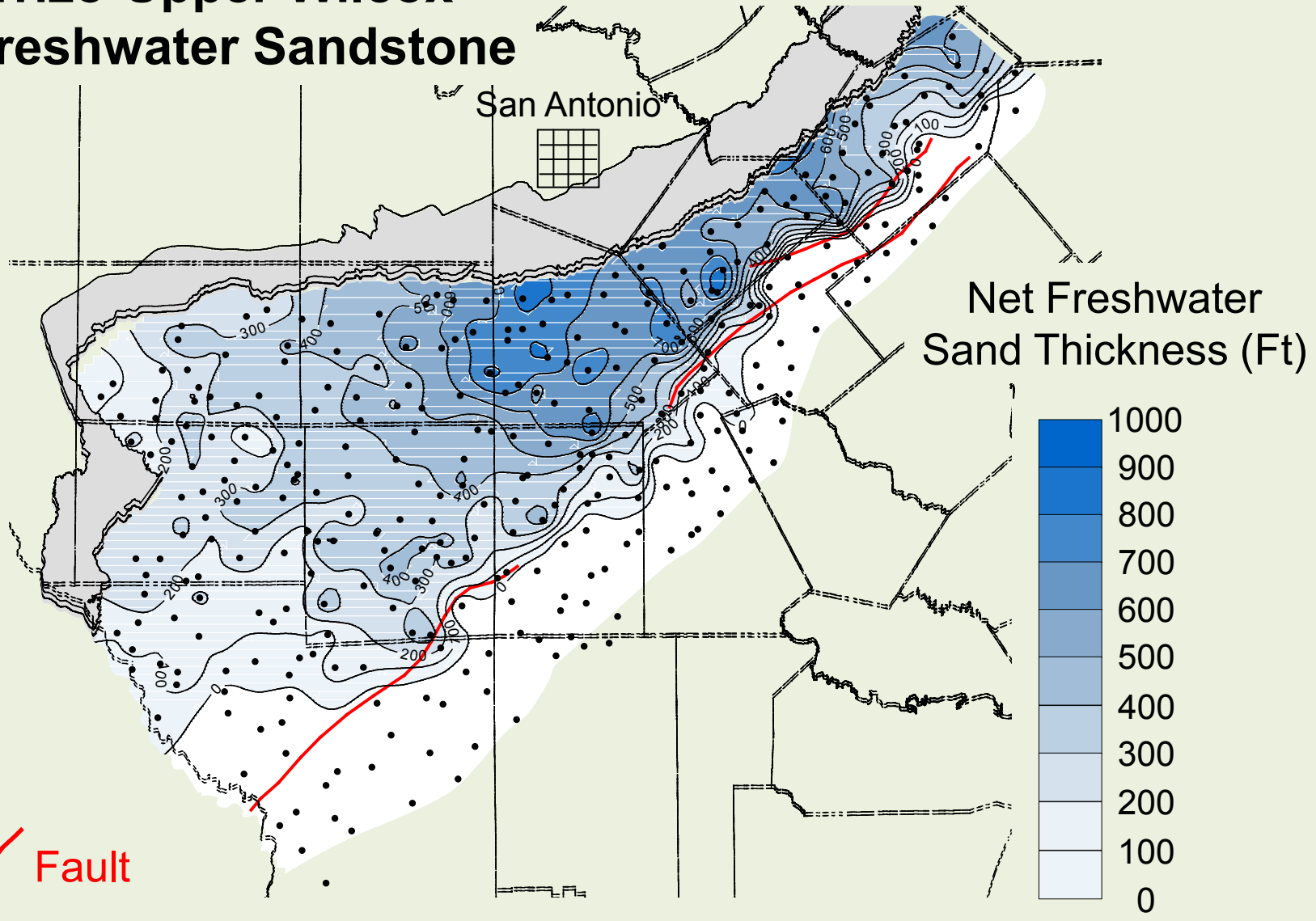


South Texas Carrizo-Wilcox Cross Section

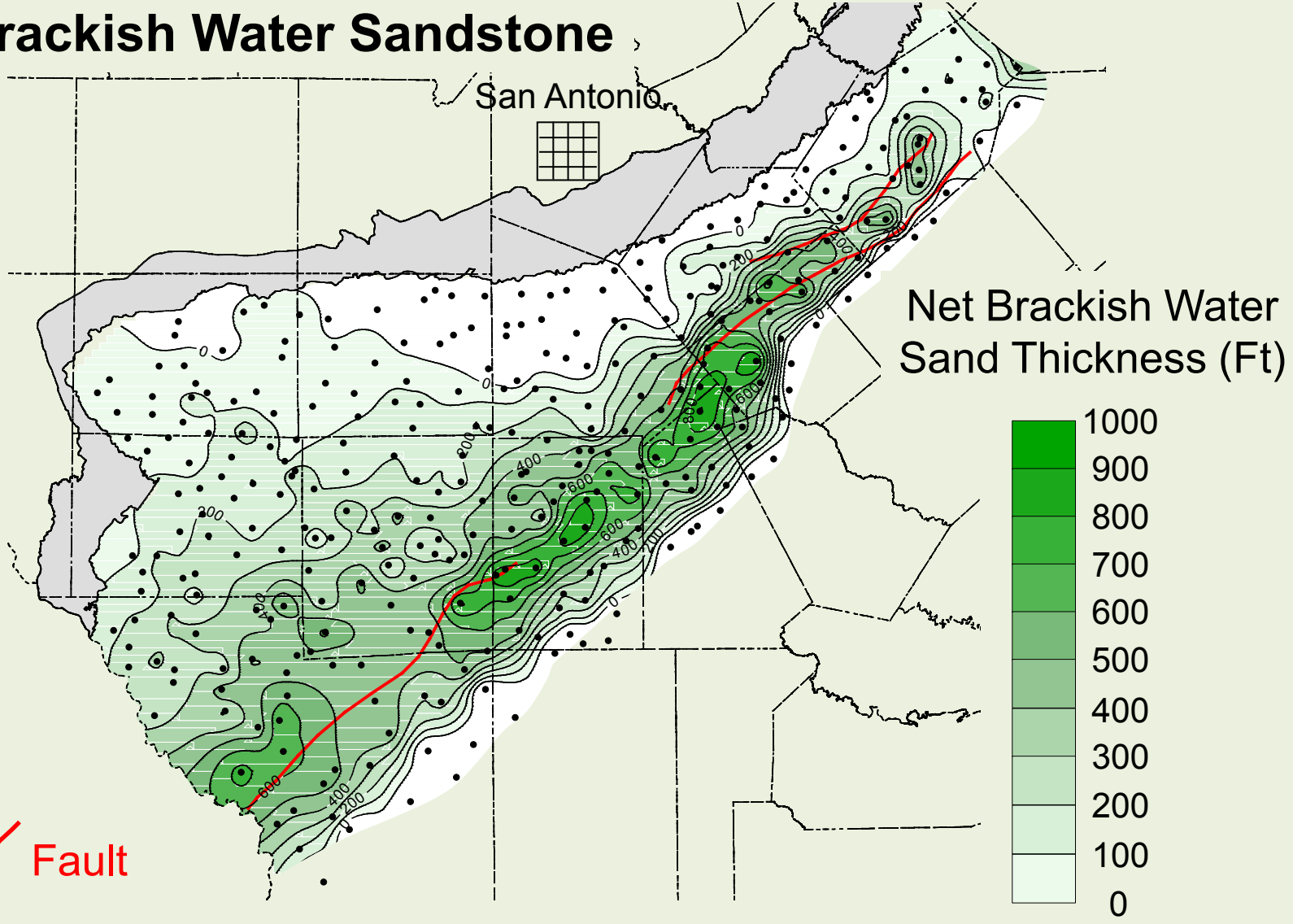
Vertical lithology/salinity profiles + stratigraphic correlation between wells



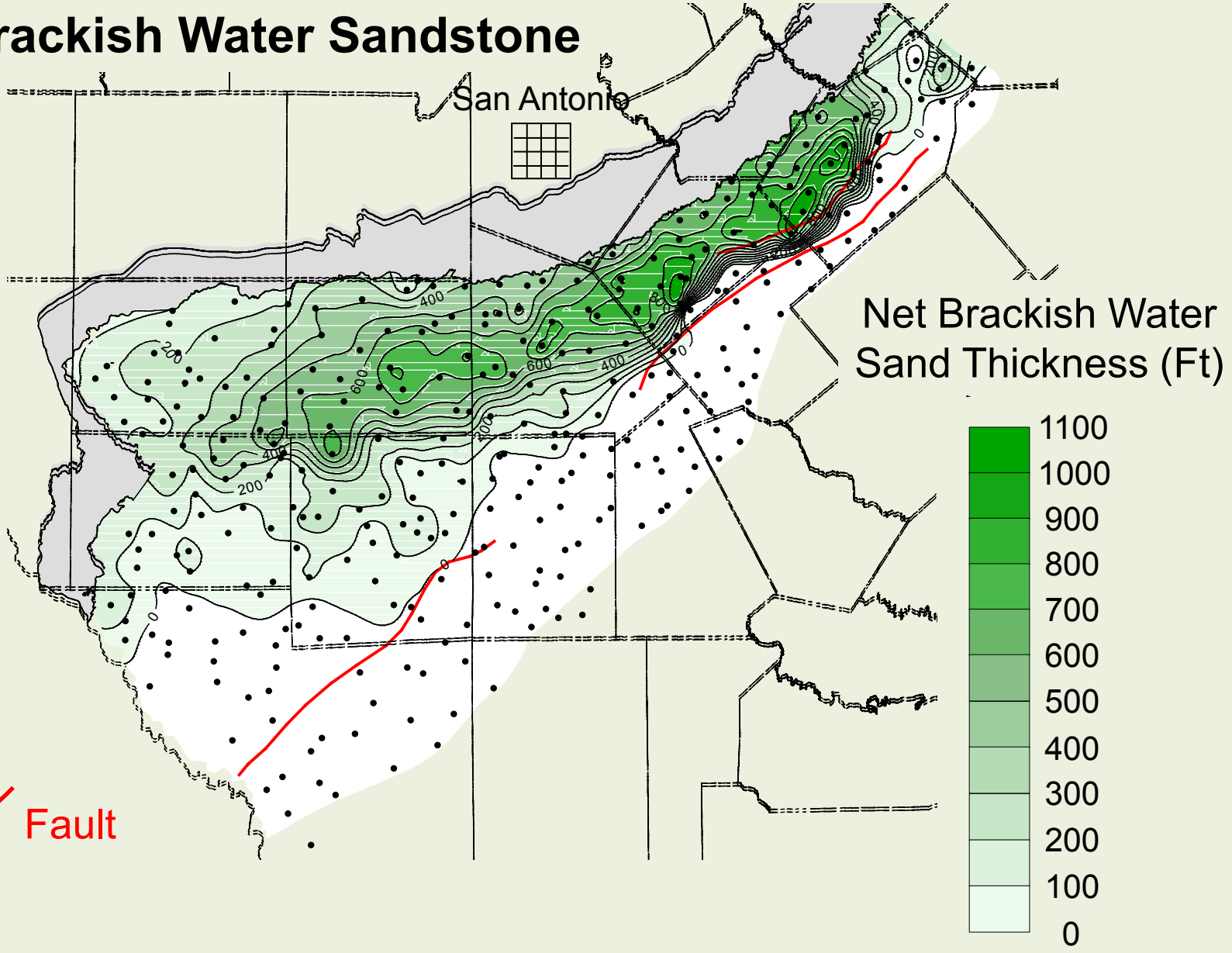
Carrizo-Upper Wilcox
Net Freshwater Sandstone



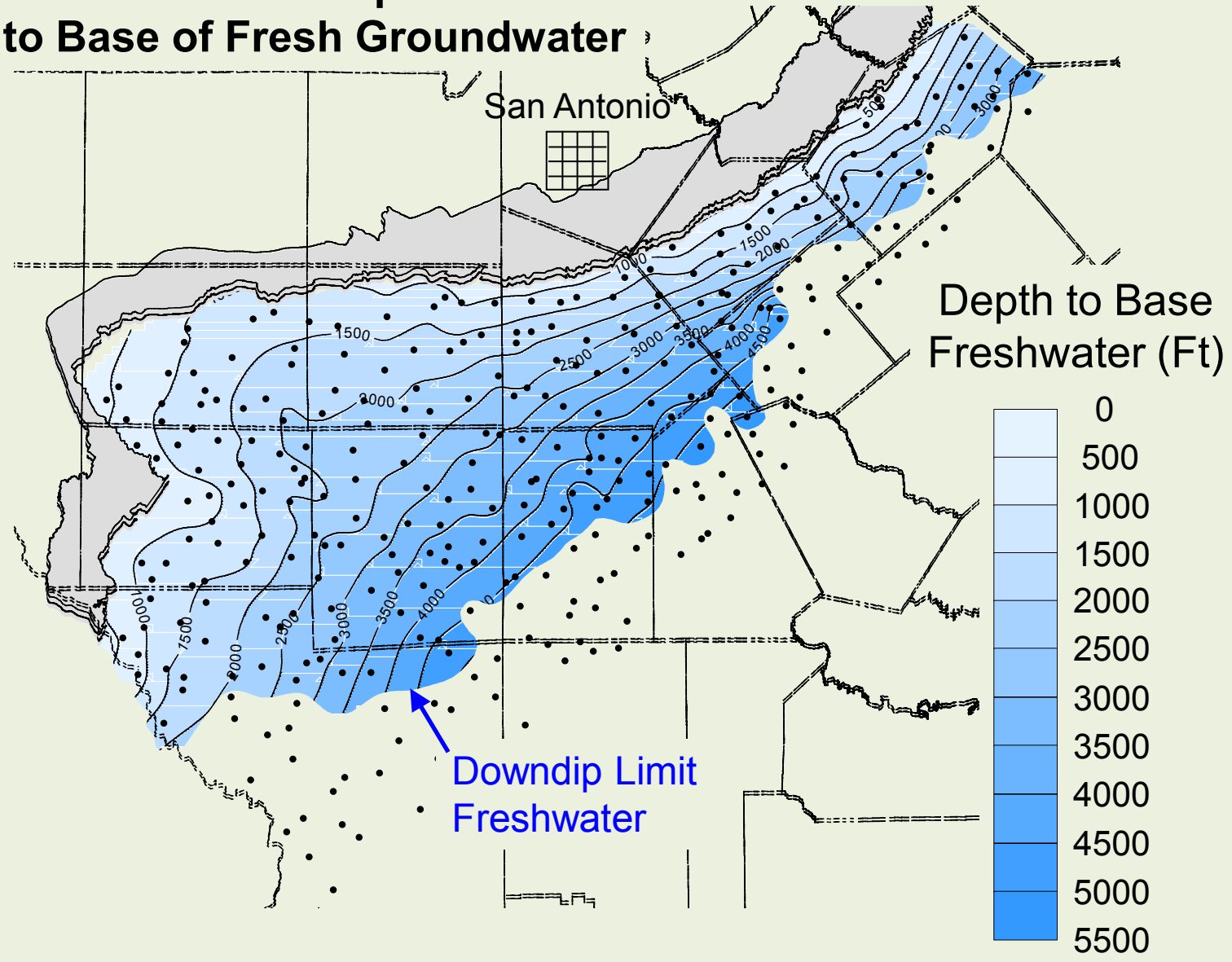
Carrizo-Upper Wilcox
Net Brackish Water Sandstone



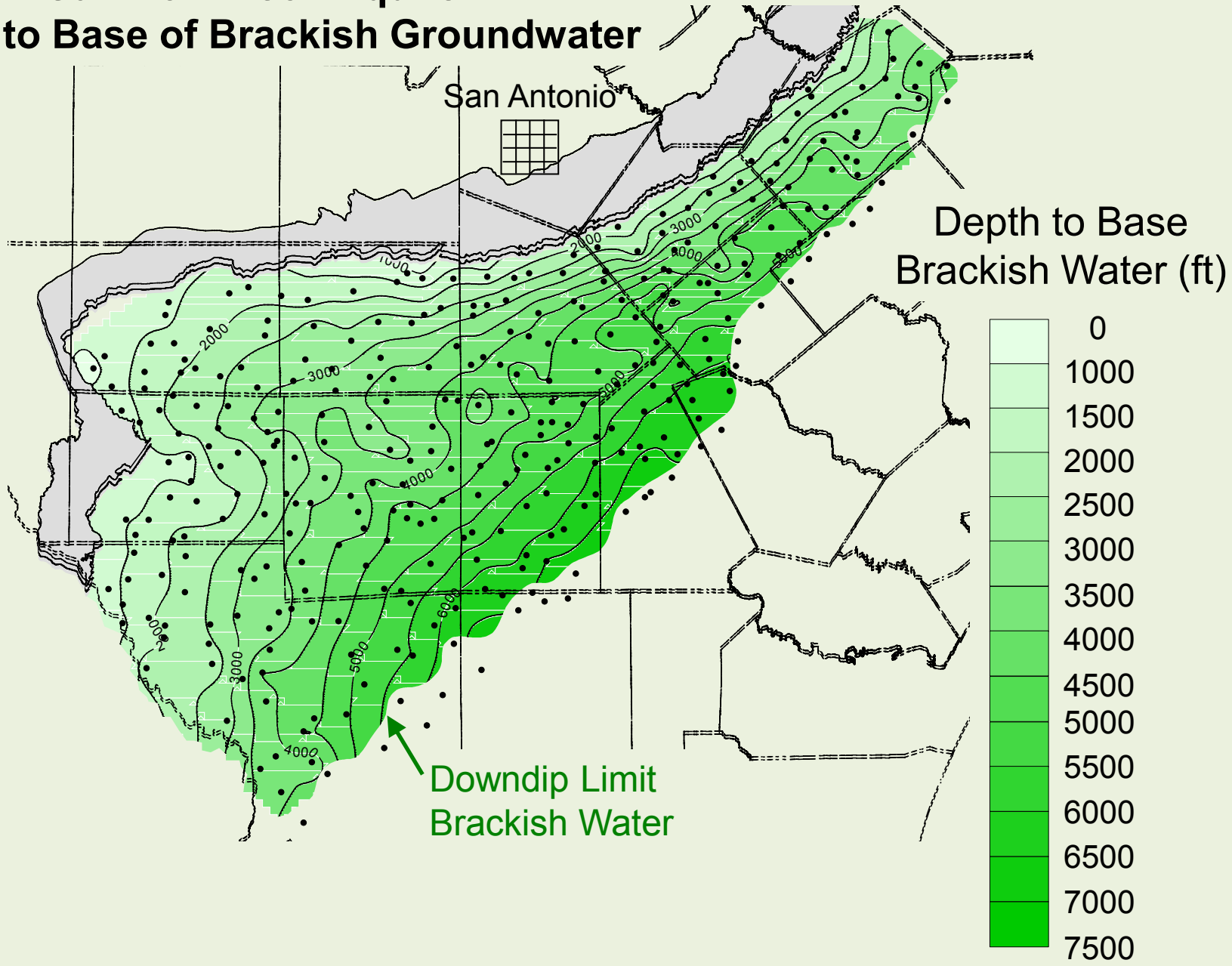
Lower Wilcox
Net Brackish Water Sandstone



Carrizo-Wilcox Aquifer
Depth to Base of Fresh Groundwater



Carrizo-Wilcox Aquifer
Depth to Base of Brackish Groundwater

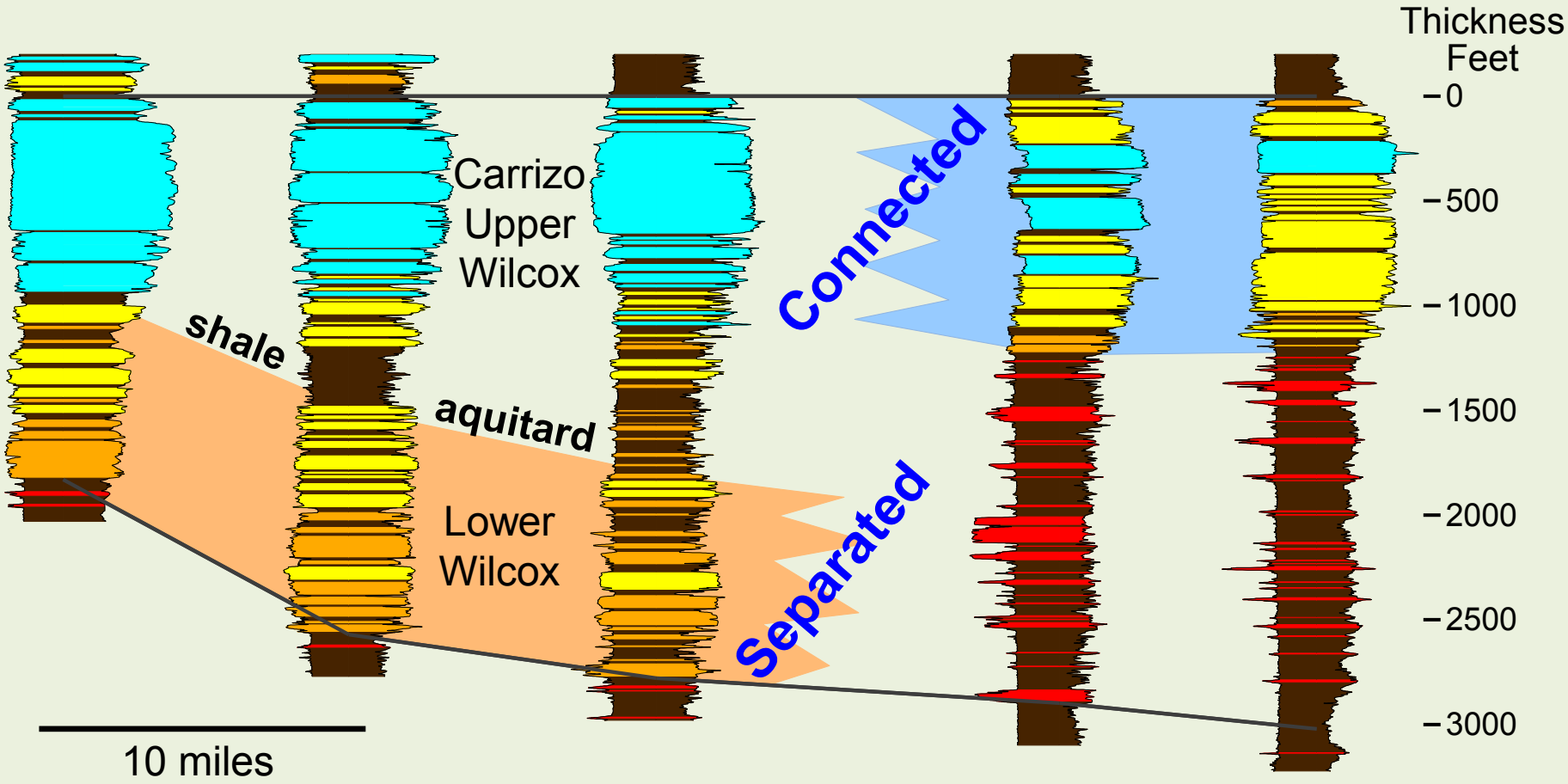


ESTIMATING BRACKISH GROUNDWATER RESOURCES

Hydraulic Connectivity – protecting the freshwater resource by distinguishing flow systems

- Freshwater flow system = freshwater + brackish water in laterally continuous sandstones (connected brackish groundwater)
- Brackish water flow system = brackish water vertically separated from freshwater by shales (separated brackish groundwater)

Carrizo-Wilcox Stratigraphic Cross Section Showing Connected and Separated Brackish Groundwater



VOLUMETRIC ANALYSIS OF GROUNDWATER IN THE CARRIZO-WILCOX AQUIFER IN SOUTH TEXAS

Groundwater volume = sandstone volume * porosity

Sandstone volume = area * thickness (from net sand maps)

Porosity estimated from petrographic studies

Groundwater volume ≠ producible resource

Groundwater volume plus drawdown and storativity are needed to estimate the producible resource

Tasks

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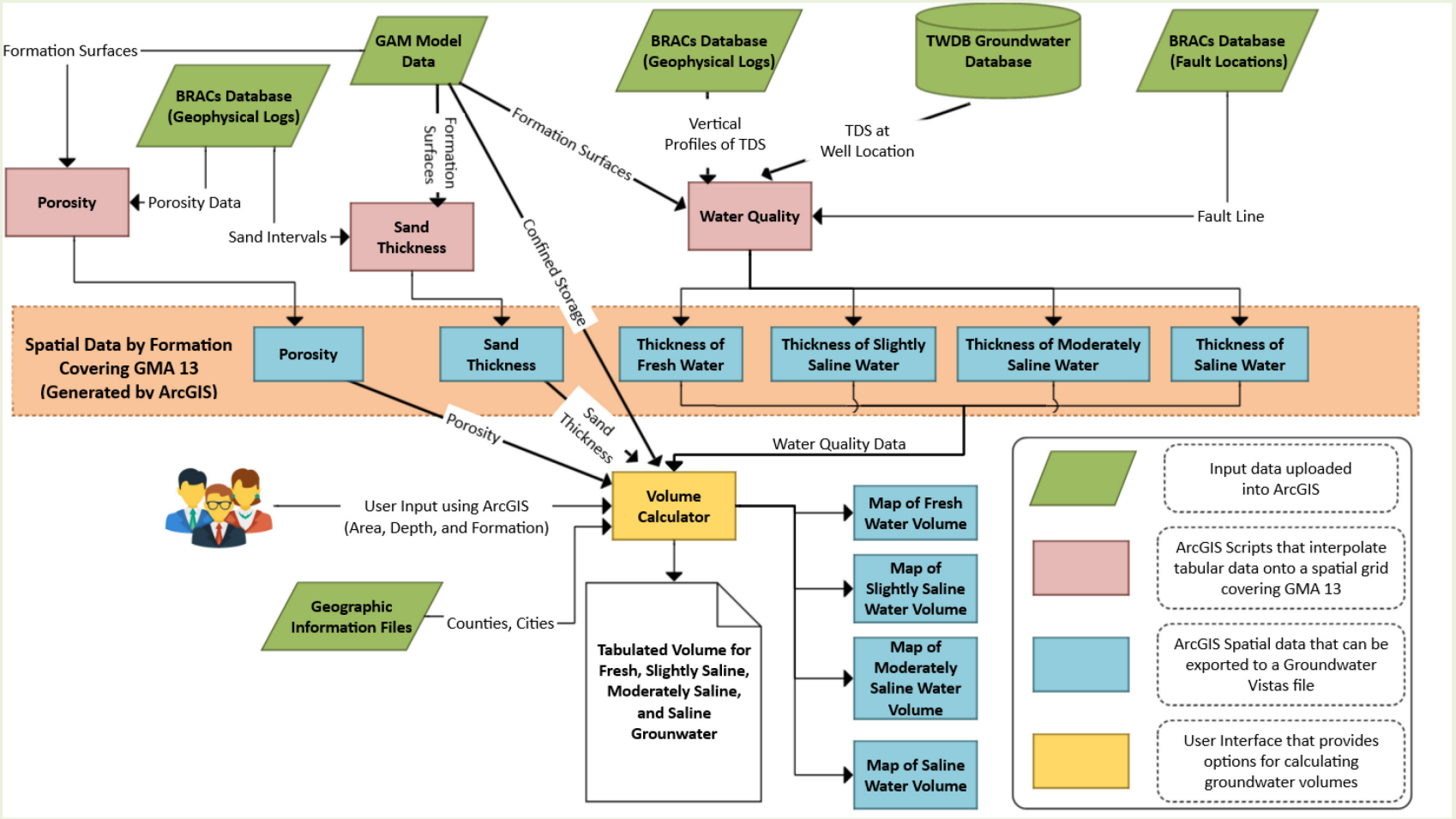
- Task 5. Visualization and groundwater quality

Task 4: GIS based Application to Calculate Volumes of Fresh, Brackish, and Saline Groundwater

- 4.1: Development of a GIS tool to calculate volumes of fresh, brackish, and saline groundwater
- Aquifer properties and model layers from S Queen City Sparta GAM
- Consistent with TWDB TERS calculations
- Export sand thickness, porosities, and groundwater volumes by water quality category

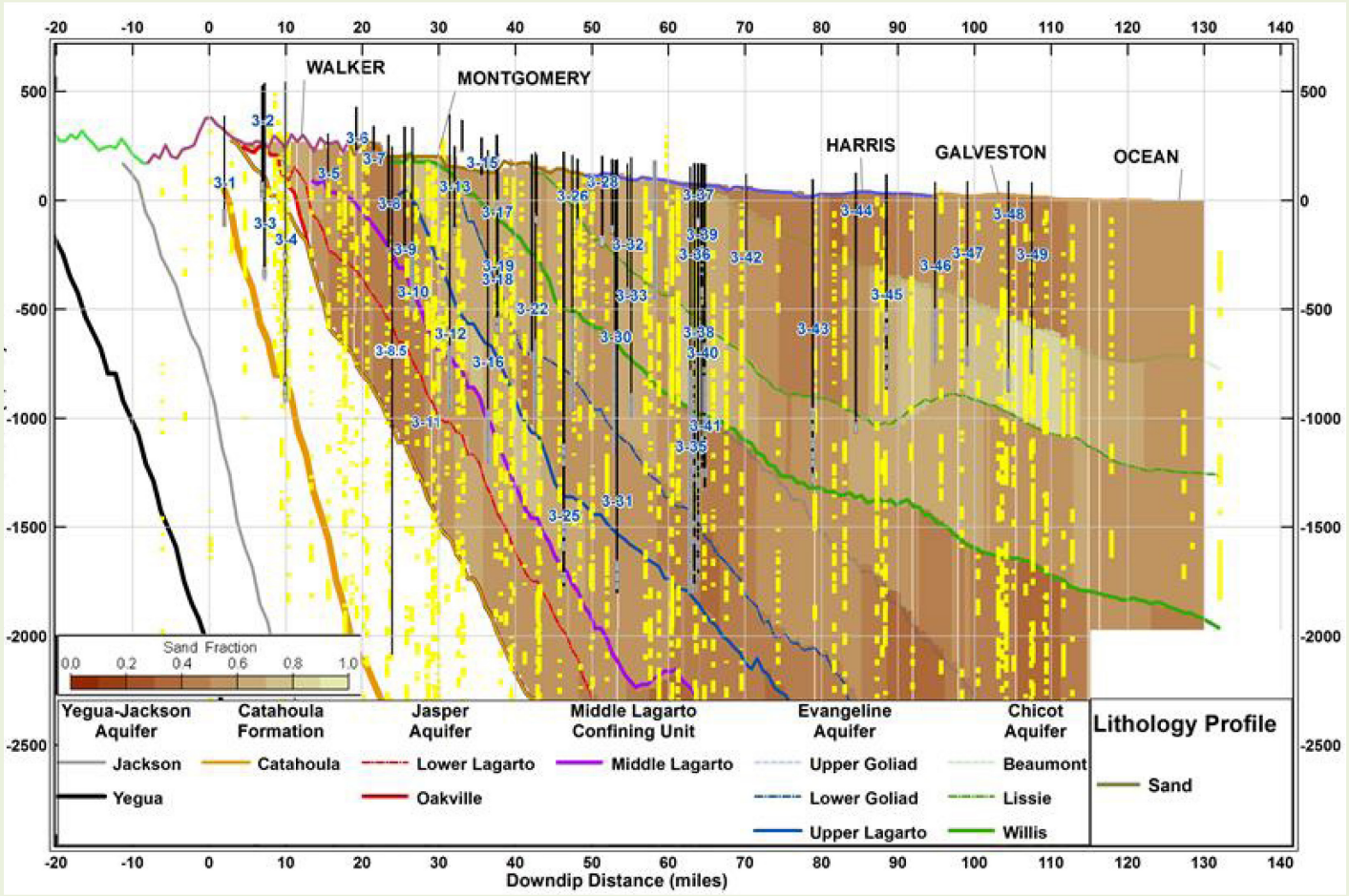
Conceptual Schema for GIS Application to Calculate Groundwater Volumes of Different Qualities



Task 4: GIS based Application to Calculate Volumes of Fresh, Brackish, and Saline Groundwater

- 4.2: Application of GIS Tool to calculate Fresh, brackish and Saline groundwater volumes in the Queen City, Sparta, and Carrizo-Wilcox Aquifers

Task 5. Visualization of Groundwater Quality Graphical User Interface



Example of visualization of sands from geophysical well logs and well screen locations along a transect int eh Gulf Coast Aquifer from Young et al. (2014)

Deliverables

- Sections detailing all data sources and data analysis methodologies and techniques used in the study
- Net sand and sand percent maps for the Carrizo-Wilcox, Queen City, and Sparta aquifers
- Hydrochemical facies areal maps and cross sections for each aquifer.
- Areal maps of salinity zones for each aquifer
- Vertical cross sections of salinity zones for each aquifer (up to 10)
- Sample visualizations of the salinity zones delineated by the study
- Calculated groundwater volumes (based on porosity, specific yield and storativity) within each salinity category (fresh, brackish and saline) for different regions within the study area as defined by existing boundaries for aquifers, counties, groundwater conservation districts (GCDs), groundwater management area (GMA 13)
- Documentation of all software tools developed for the study.

Project Schedule – Part 1

1.0 Project Management – 24 months

- 1.1 Status reports – monthly
- 1.2 TWDB review meetings – 3 total
- 1.3 Stakeholder/TWDB interaction – ongoing
- 1.3 Stakeholder advisory forum meetings – 3 total

2.0 Water Quality – 8 months

- 2.1 Data sources
- 2.2 Groundwater quality characterization
- 2.3 Suitability for desalination or hydro-fracturing

3.0 Geophysical log interpretation – 22 months

- 3.1 Evaluation and selection of logs
- 3.2a Interpretation of groundwater salinity Carrizo-Wilcox
- 3.3a Groundwater salinity mapping Carrizo-Wilcox

} 9 months

- 3.2b Interpretation of groundwater salinity Queen City-Sparta
- 3.3b Groundwater salinity mapping Queen City-Sparta

} 9 months

Project Schedule – Part 2

4.0 GIS Application – 11 months

- 4.1 GIS tool development
- 4.2 Application of GIS tool

5.0 Visualization – 16 months

- 5.1 GIS visualization – spatial
- 5.2 GIS visualization – cross sections

Data Requests

- Geophysical logs (SP, gamma ray, resistivity, density, etc.) and collocated groundwater quality to calibrate the logs
- Groundwater production data from wells with Total Dissolved Solids > 1,000 mg/L
- Locations, well depths, and screen intervals for proposed brackish groundwater desalination wells
- Groundwater well locations and construction details
- Historic depth to water data
- Historic groundwater quality data (e.g., Total Dissolved Solids, Chloride, …)
- Historic groundwater pumping data

The kickoff Stakeholder Advisory Forum for the GMA 13 Brackish Groundwater Mapping project funded by the Texas Water Development Board (TWDB) was held on Thursday, November 19th, 2015 at 10:30 AM CST at the Evergreen Underground Water Conservation District office located at 110 Wyoming Boulevard, Pleasanton, Texas 78064.

The primary objective of this Stakeholder Advisory Forum is the presentation and discussion of the Brackish Groundwater Mapping effort for the Carrizo-Wilcox, Queen City, and Sparta aquifers, mainly in GMA 13. The meeting began with an introduction to the Groundwater Availability Modeling Program, the project and the project team by Dr. Ian Jones, TWDB contract manager. After the TWDB introduction, Dr. Scott Hamlin with the Bureau of Economic Geology and Dr. Steve Young with INTERA Inc. gave a presentation on the project objectives and proposed methods, project schedule, and a request for data. This was followed by questions and comments from the stakeholders.

The following is a summary of the questions asked and responses.

How are you handling connections between fresh and saline parts of the respective aquifers?

Through evaluation of occurrence of clay aquitards that act as barriers to flow.

Will water quality shapefiles from GIS be available?

Yes.

How will project deliverables be tied to the Groundwater Availability Models?

Project deliverables will be designed to be uploaded into Groundwater Vistas.

Will the Groundwater Availability Models be updated using project deliverables upon project completion?

Not right away. A Gulf Coast Aquifer salinity model currently underway will be used as a test case for future model updates using groundwater salinity.

Will it be required that there be a Modeled Available Groundwater (MAG) for each groundwater salinity?

No. Such changes will be up to the Texas Legislature to decide.

Have you reached out to the oil and gas industry for data?

Yes, the BEG has met with South Texas Energy and Economic Roundtable (STEER).

Have you reached out to the Railroad Commission?

Yes.

Are oil and gas companies required to submit logs to the Railroad Commission?

Yes, but not water quality data.

Is a request for feedback by Sanjeev Kalaswad related to this project?

No, it is related House Bill 30 work being done by the Innovative Water Technologies section.

Participant	Affiliation
Ian Jones	Texas Water Development Board
Steve Young	INTERA
Scott Hamlin	Bureau of Economic Geology
Robert Reedy	Bureau of Economic Geology
Kelley Vickers	Guadalupe County Groundwater Conservation District
Bill Klemt	Guadalupe County Groundwater Conservation District
Natalie Ballew	Texas Water Development Board
Steven Siebert	San Antonio Water System
Richard Dent	San Antonio Water System
Bill Hutchison	Consultant
Humberto Romos	Canyon Regional Water Autority
John Meyer	Texas Water Development Board
Shirley Wade	Texas Water Development Board
Pete Spicer	ConocoPhillips
Carmen Cernosek	Texas Water Development Board
Thomas Burley	U.S. Geological Survey
James Bene	RWH Associates
Graham Moore	Hays Caldwell Public Utility Agency
Mary Nienkamp	University of Southern California/EOG Resources
Ronald Green	Southwest Research Institute
Paul Bertetti	Southwest Research Institute
James Beach	LBG-Guyton
Larry Fox	Evergreen Underground Water Conservation District
Jay Troell	Evergreen Underground Water Conservation District
Russell Labus	Evergreen Underground Water Conservation District
Cindy Ridgeway	Texas Water Development Board
Chris McFarlane	Evergreen Underground Water Conservation District