Hydrogeochemical Evaluation of the Texas Gulf Coast Aquifer System and Implications for Developing Groundwater Availability Models

Presented to:
TEXAS GROUNDWATER PROTECTION COMMITTEE (TGPC)
Fiscal Year 2014, Second Quarter Meeting
Wednesday, January 15, 2014
Texas Commission on Environmental Quality (TCEQ)

Presented by:
Steve Young
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Topics

- Project Overview
- Introduction to the Gulf Coast Aquifer System
- Areal Snapshots of Water Quality
- Vertical Cross Sections of Water Quality
- Estimate of Groundwater Age
- Groundwater Flow Modeling
- Upward migration of formation water along growth faults
- Summary of Findings

Project Overview

Project Overview

- Objective

  -use geochemical data to identify relationships relevant for evaluating the conceptual flow model for the Gulf Coast Aquifer System (**GCAS**)

  --identify potential data gaps in geochemical data and obtain additional measurements to help fill the gap

- Method/Approach

  - construct maps consist of areal plots and vertical cross-sections of ions, ion ratios, hydrogeochemical facies, stable isotopes, and groundwater ages based on ^{14}C.

  - develop transects through the Gulf Coast and Aquifer and focus sampling on a representative cross section for GMA 14, GMA 15, and GMA 16

  - analyze these maps to identify lines of lines of evidence for groundwater mixing, flow paths, and ages

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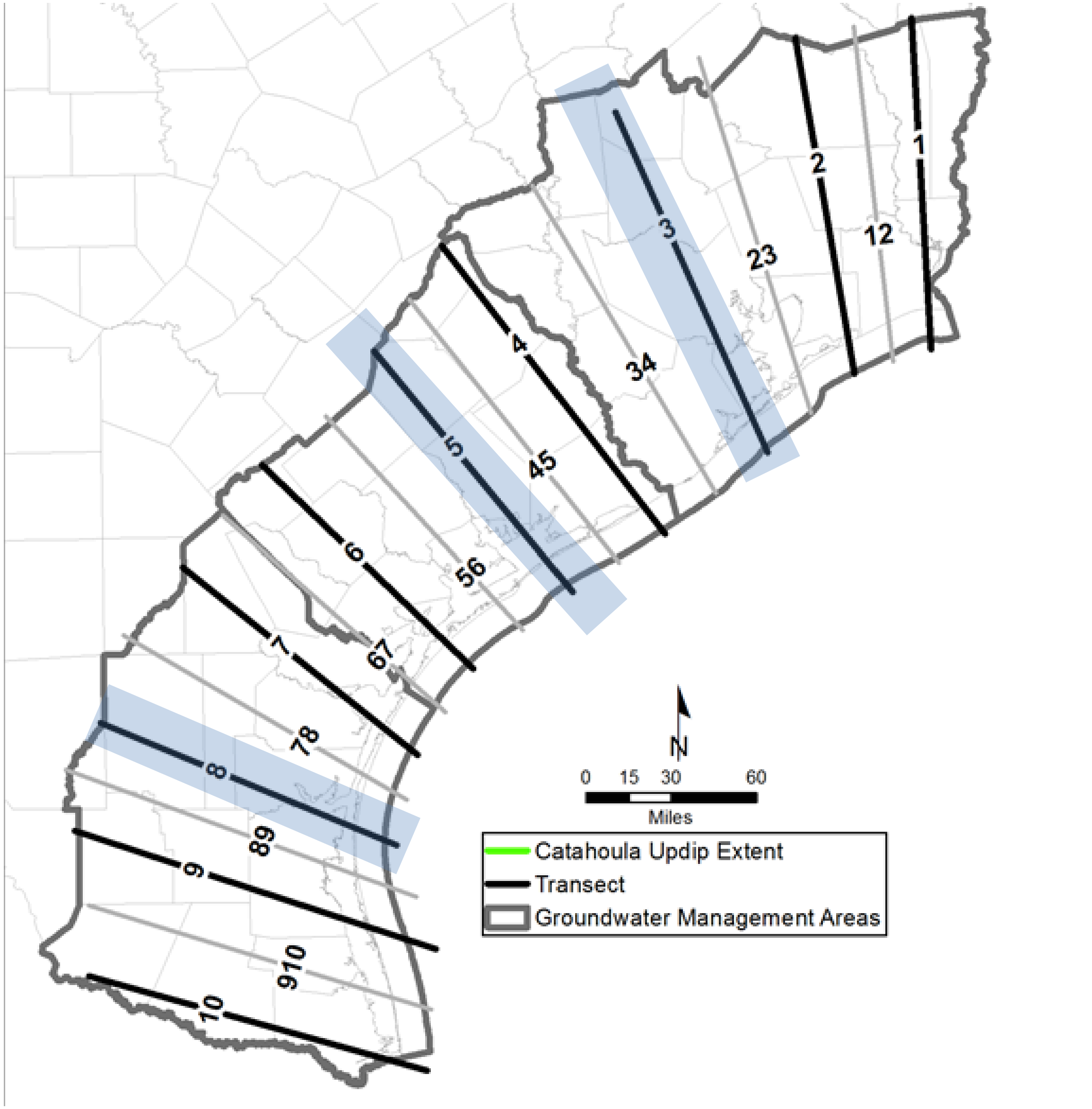
Nineteen Transects



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Project Team

- INTERA
  - -Steve Young
  - -James Pinkard
- Tetra Tech
  - - Randy Basset
- Baer Engineering
  - - Michael Johnson
- Consultant
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- TWDB Contract Manager
  - - Cindy Ridgeway
- Financial Assistance
  - - Lone Star GCD (Montgomery County)
- Assistance with Identifying and Sampling Wells
  - -USGS (Houston Office); Lone Star GCD, Harris-Galveston Subsidence District,
  - -Bluebonnet GCD, Texana GCD, Brush County GCD, Duval County GCD,

Introduction to the Gulf Coast Aquifer System

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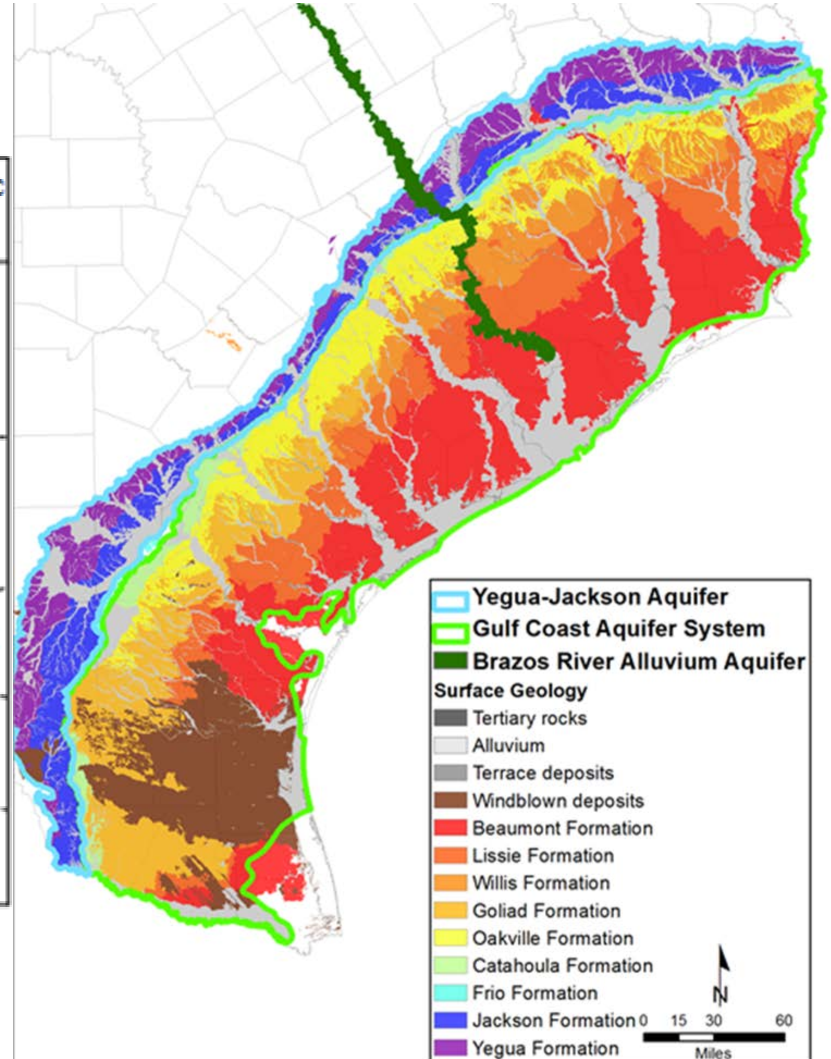
Aquifers and Geological Formations

ERA	Epoch		Est. Age (M.Y)	Geologic Unit	Hydrogeologic Unit
Cenozoic	Pleistocene		0.7	Beaumont	CHICOT AQUIFER
			1.6	Lissie	
	Pliocene		3.8	Willis	
	Miocene	Late	11.2	Upper Goliad	EVANGELINE AQUIFER
			14.5	Lower Goliad	
		Middle	17.8	Upper Lagarto	
				Middle Lagarto	BURKEVILLE
		Early		Lower Lagarto	JASPER AQUIFER
			24.2	Oakville	
	Oligocene		32	Frio	CATAHOULA
			34	Vicksburg	



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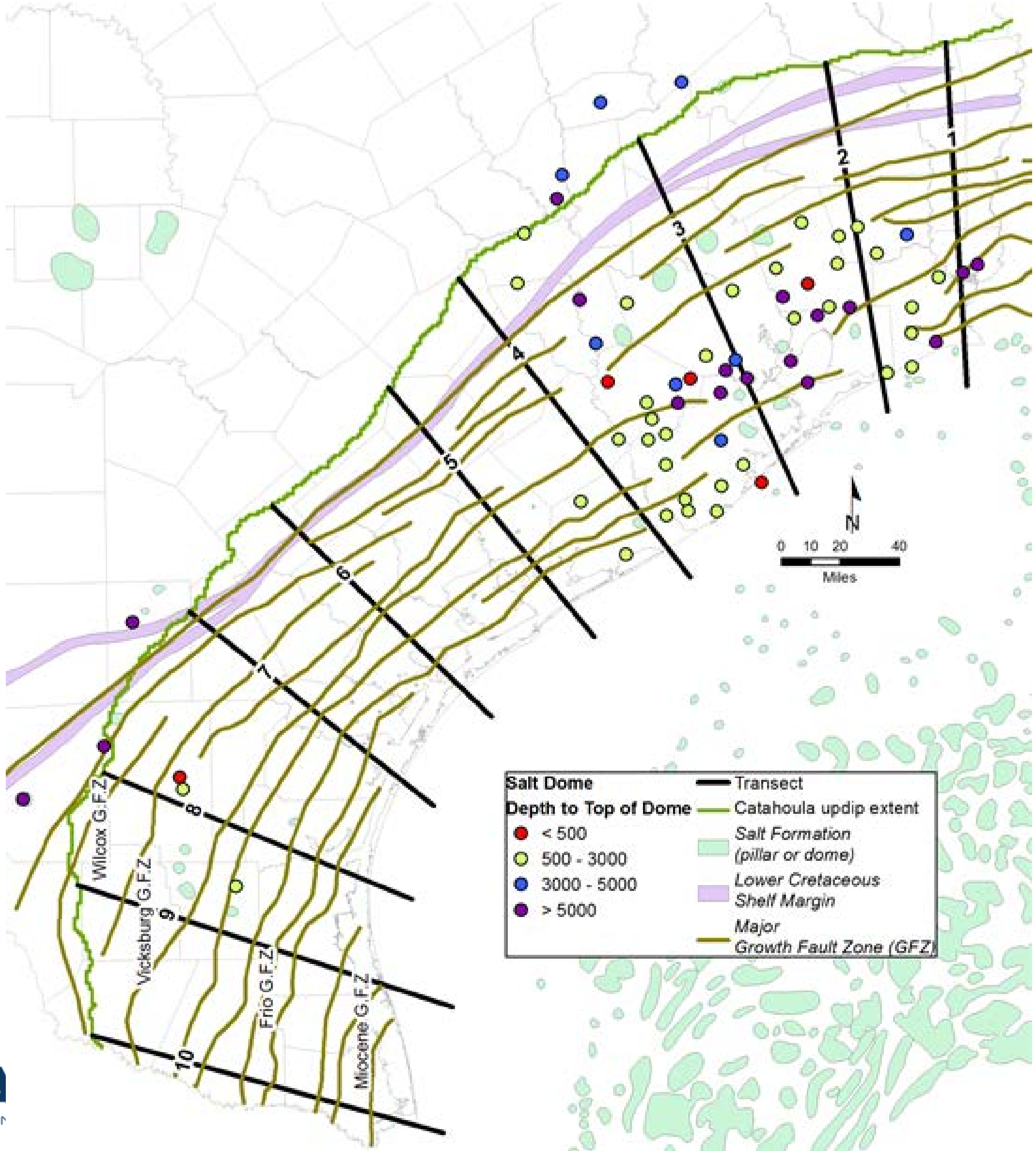
Salt Domes and Growth Faults



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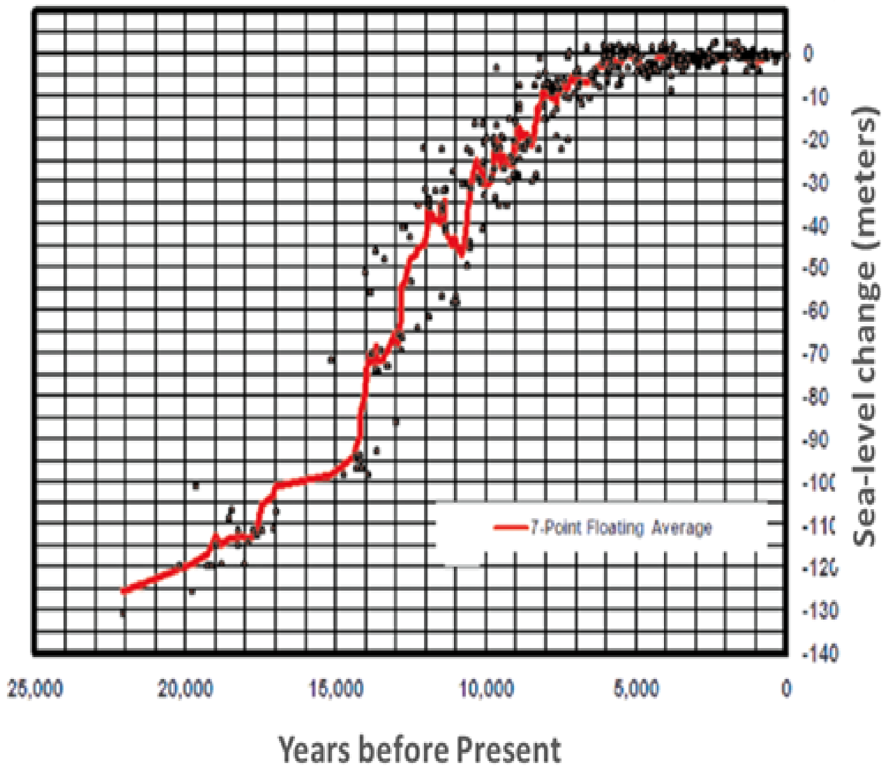
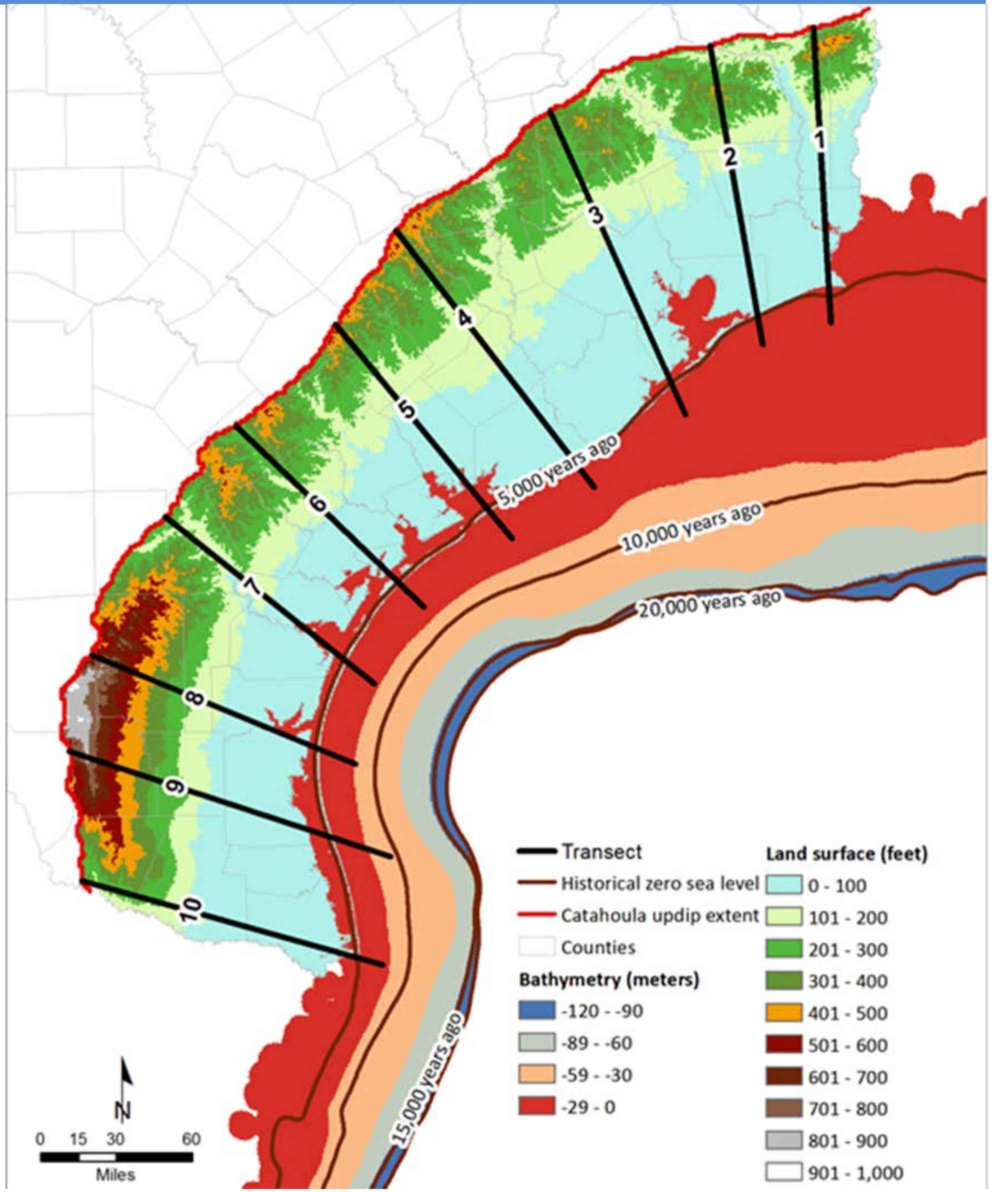
Sea Level Change





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Areal Snapshots of Water Quality

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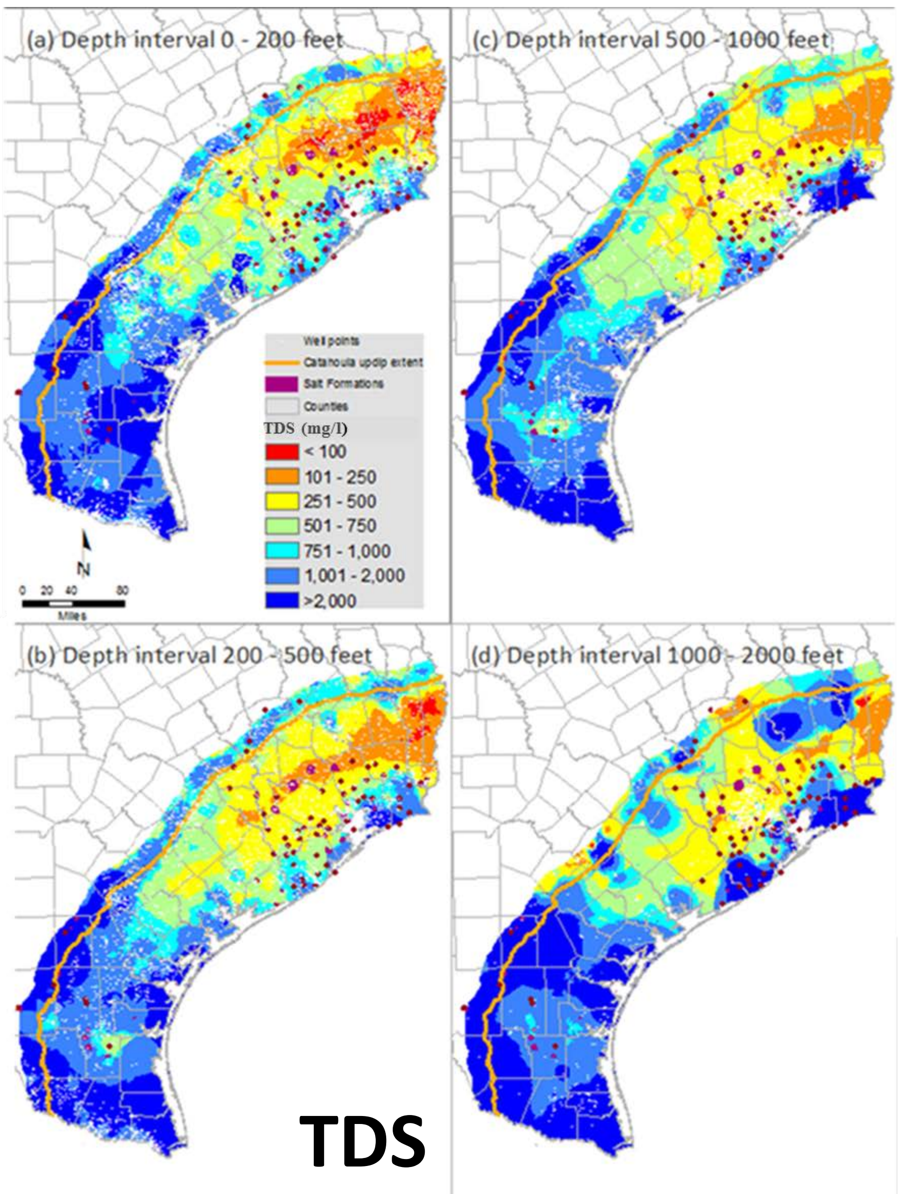
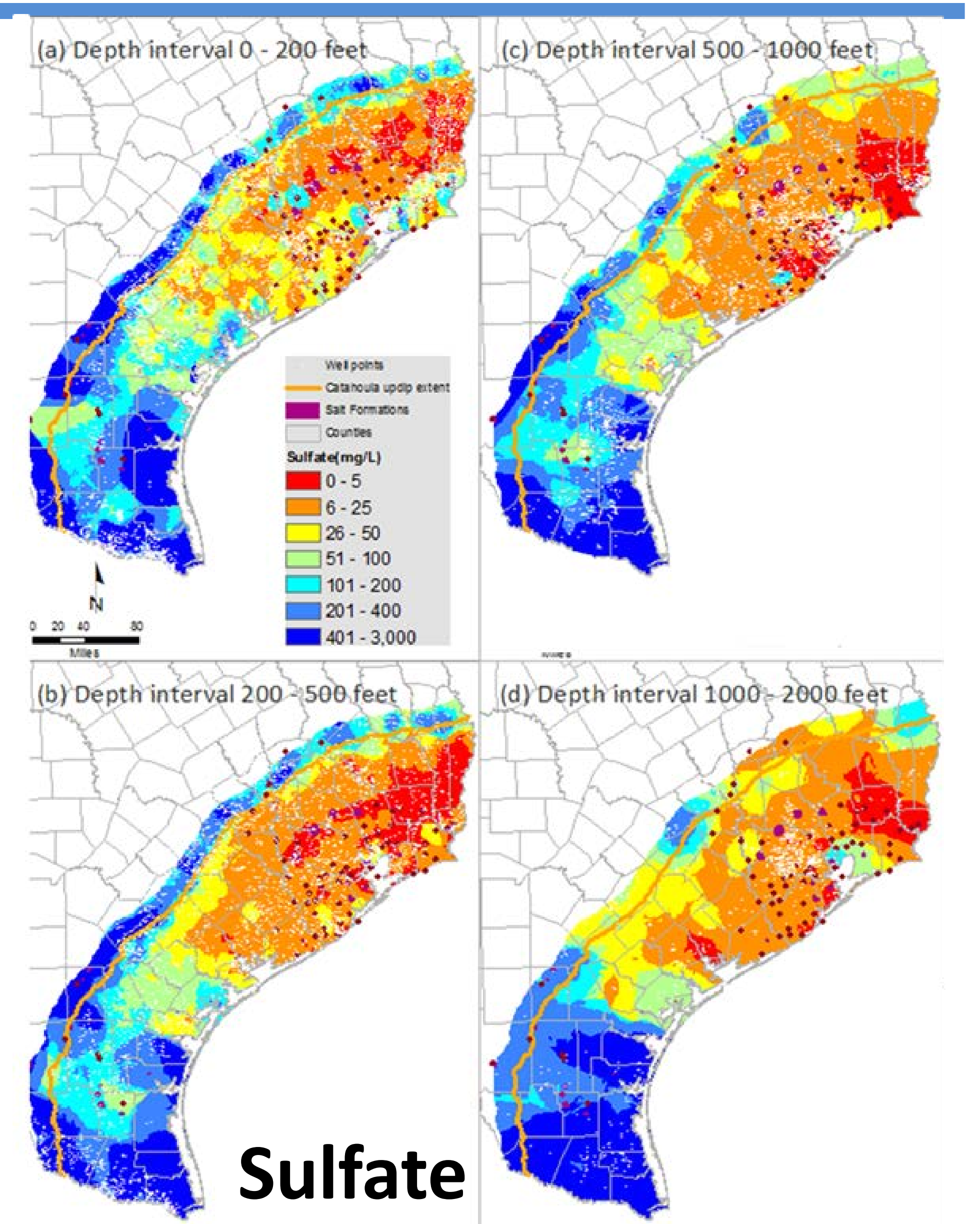
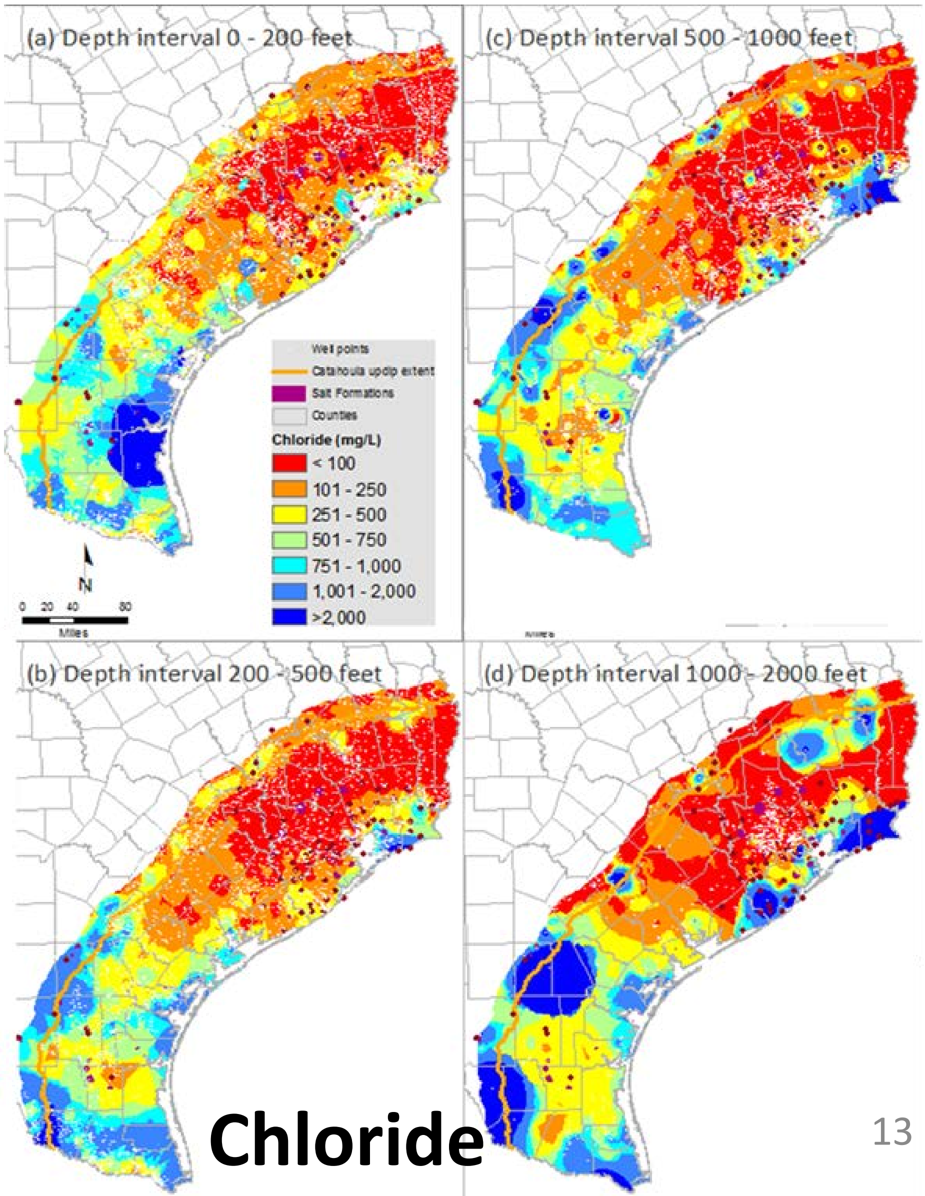
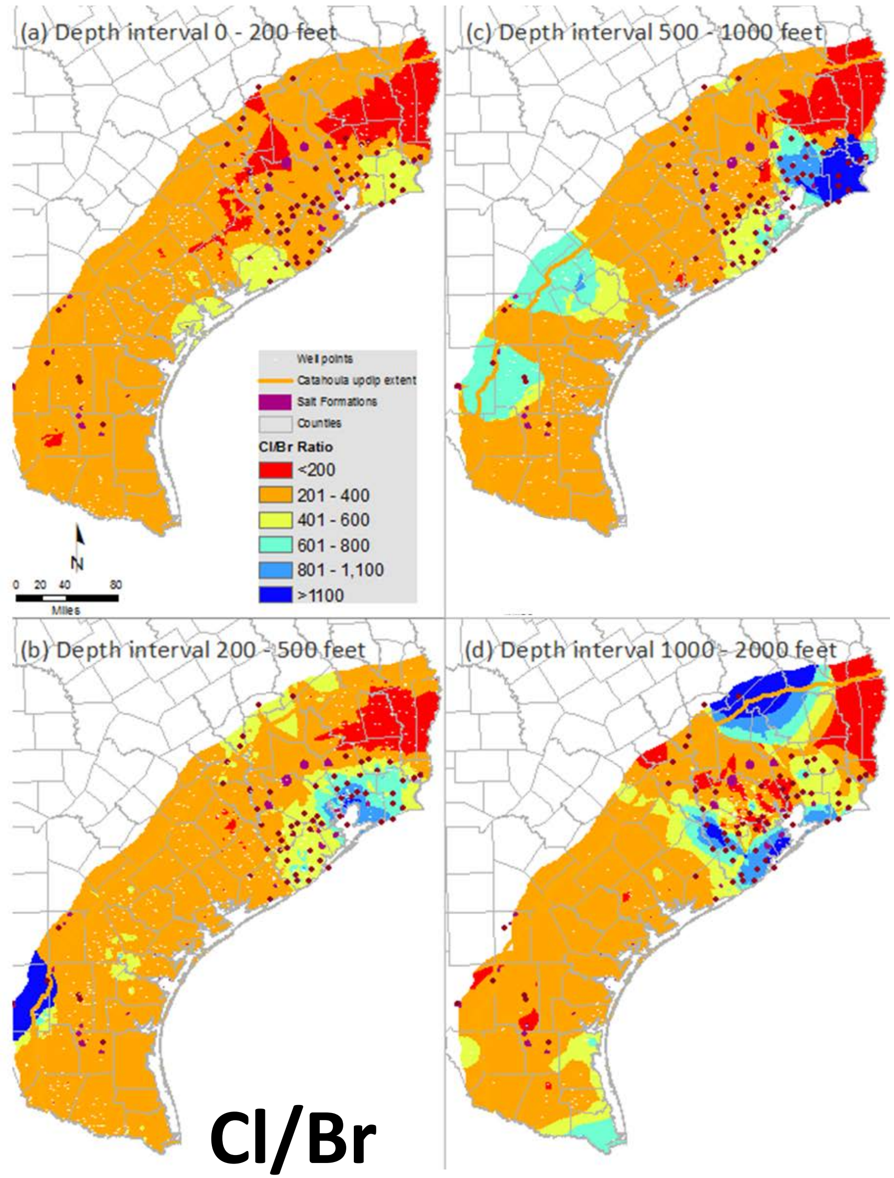
Areal Profiles of TDS and Sulfate





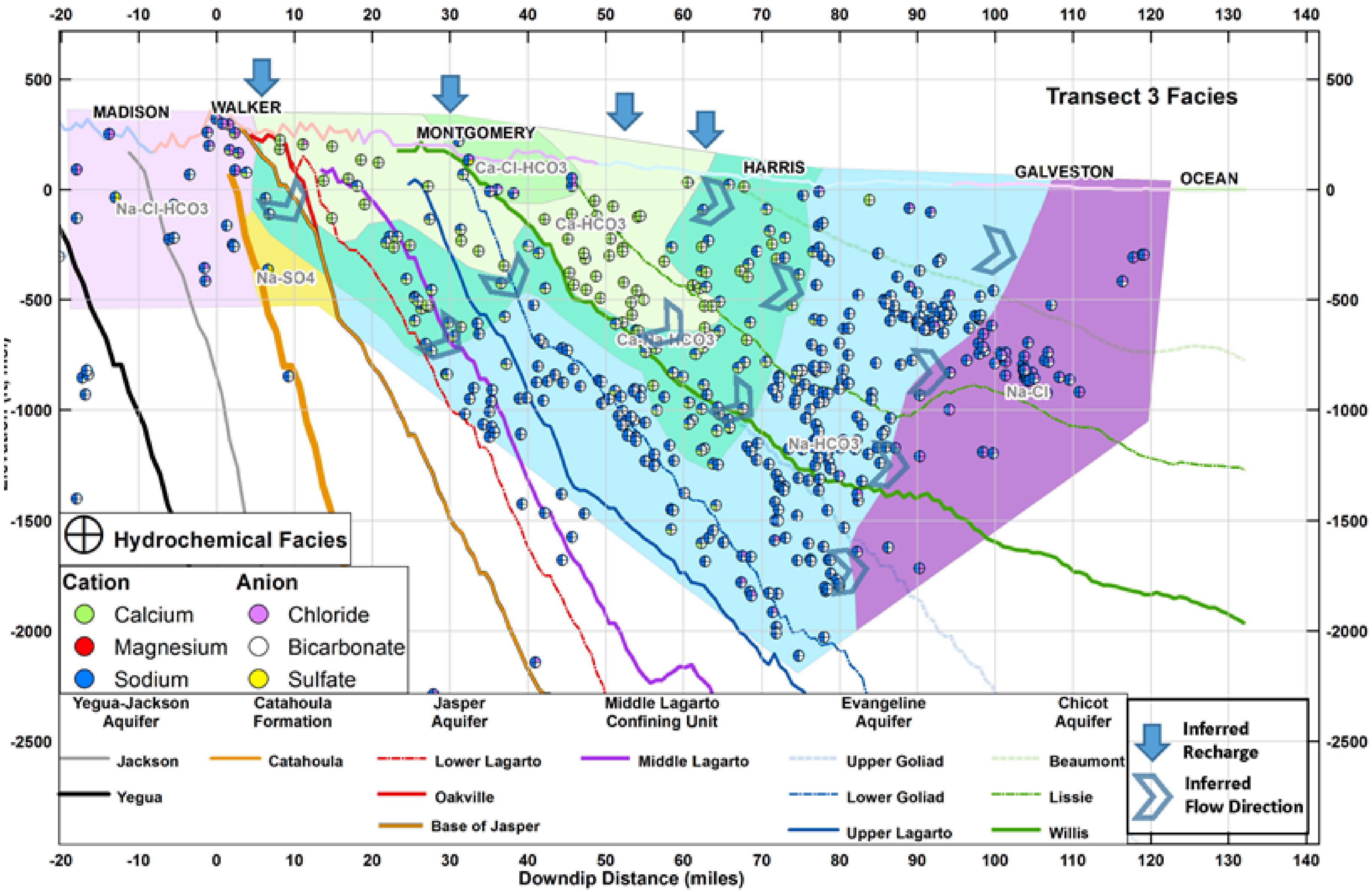
Areal Profiles of Chloride and Cl/Br Ratios



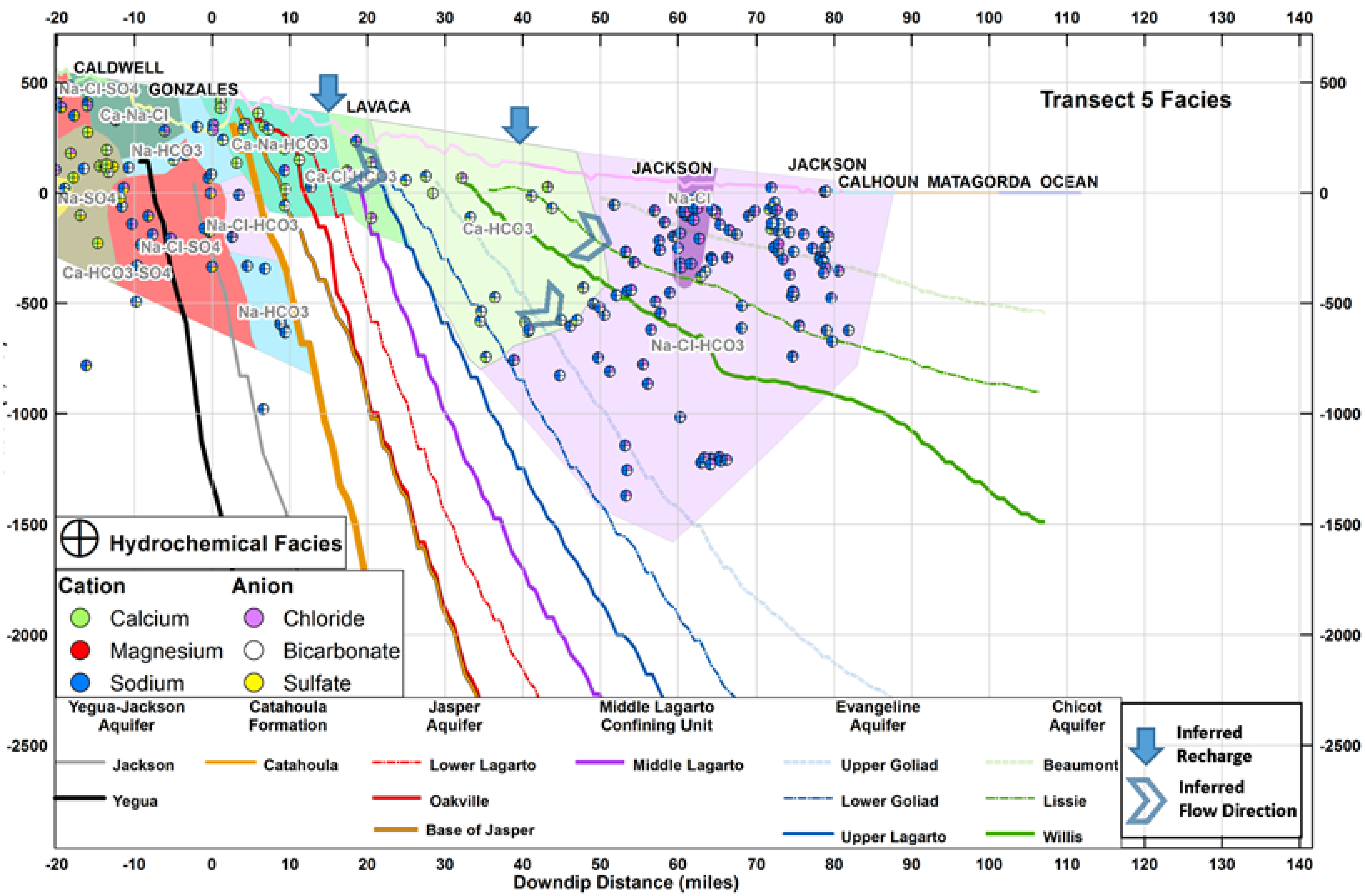


Vertical Cross Sections of Water Quality

Hydrogeochemical Facies at Transect 3 (GMA 14)



Hydrogeochemical Facies at Transect 5 (GMA 15)



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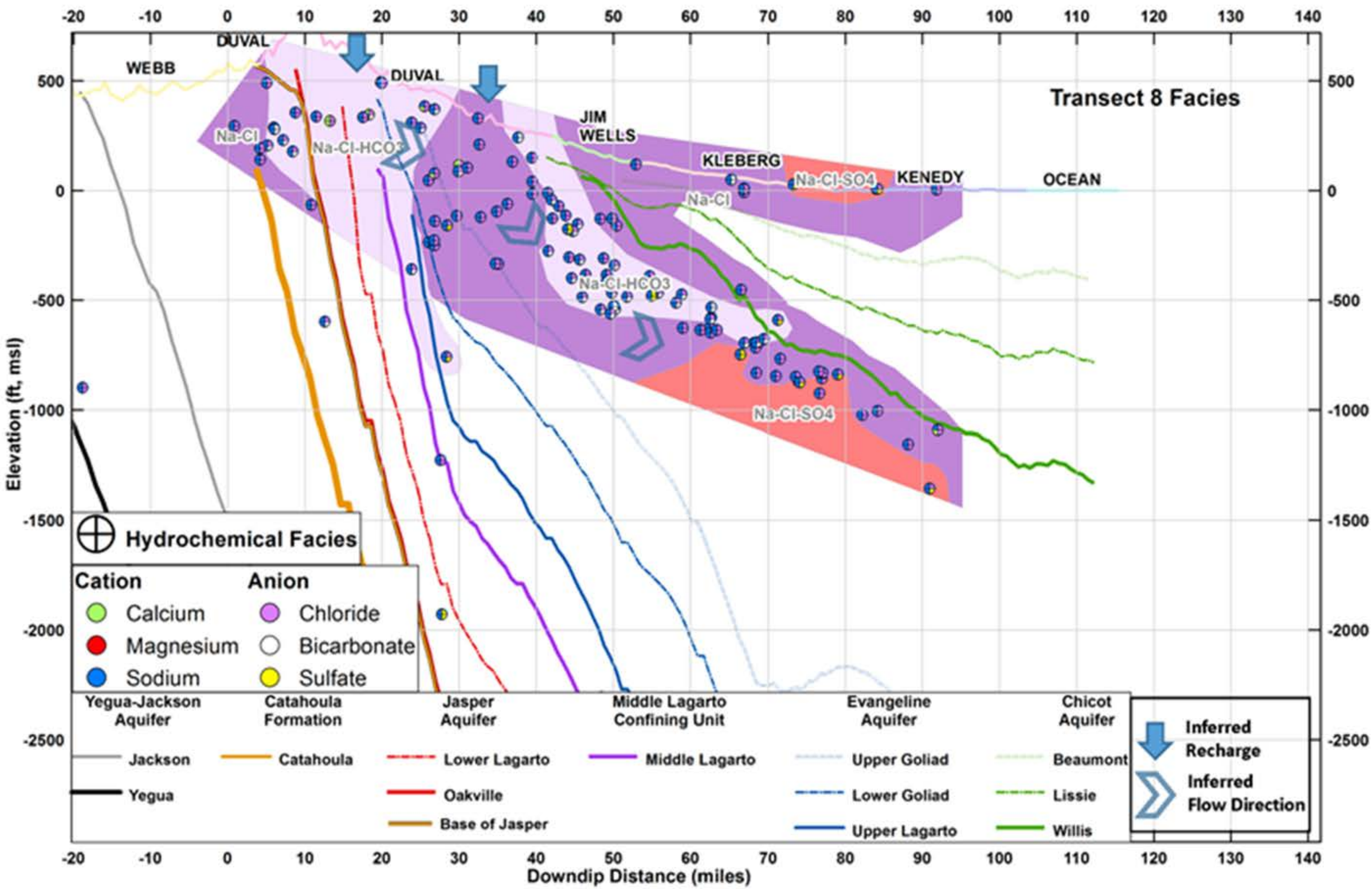
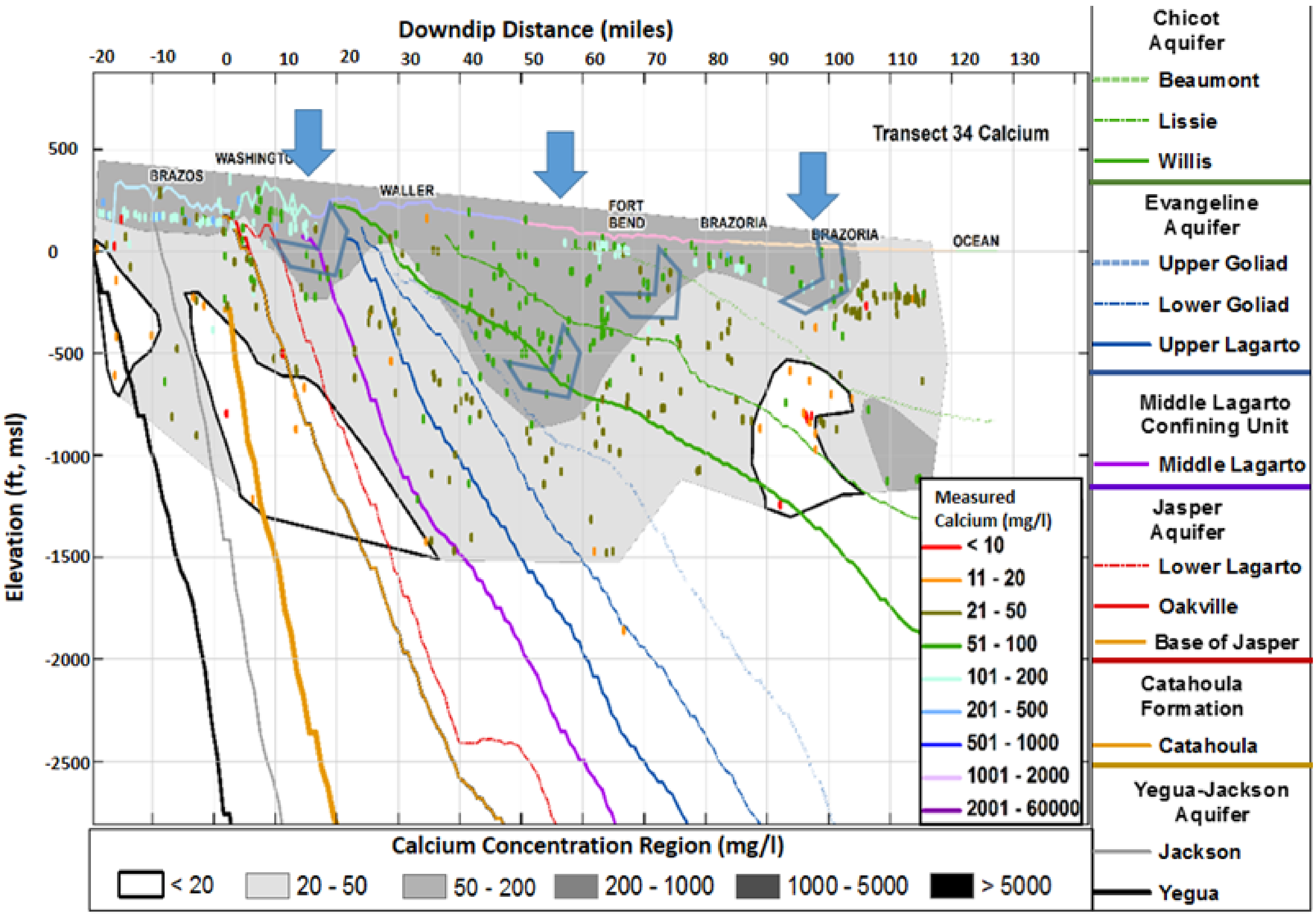
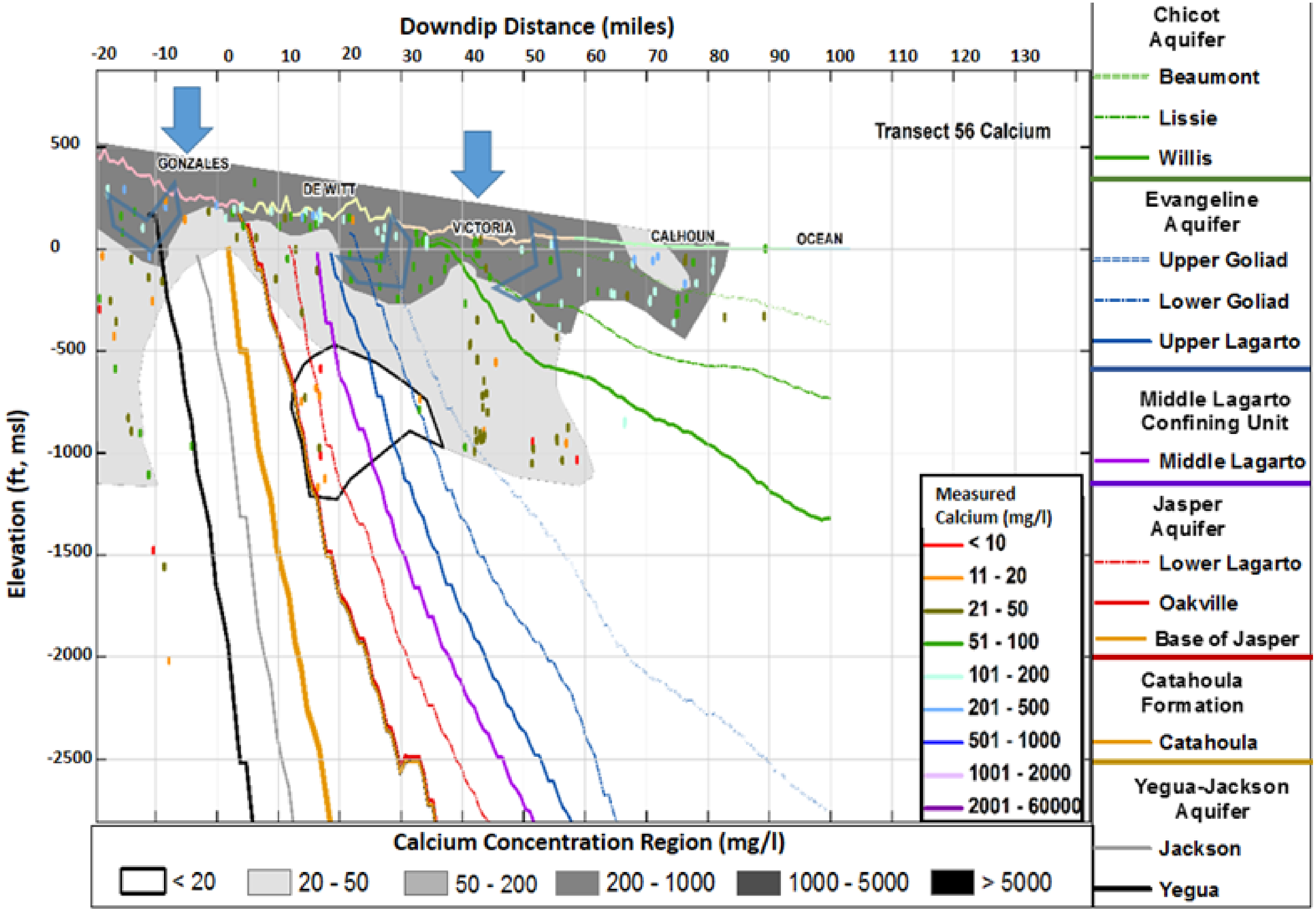
Hydrogeochemical Facies at Transect 8 (GMA 16)



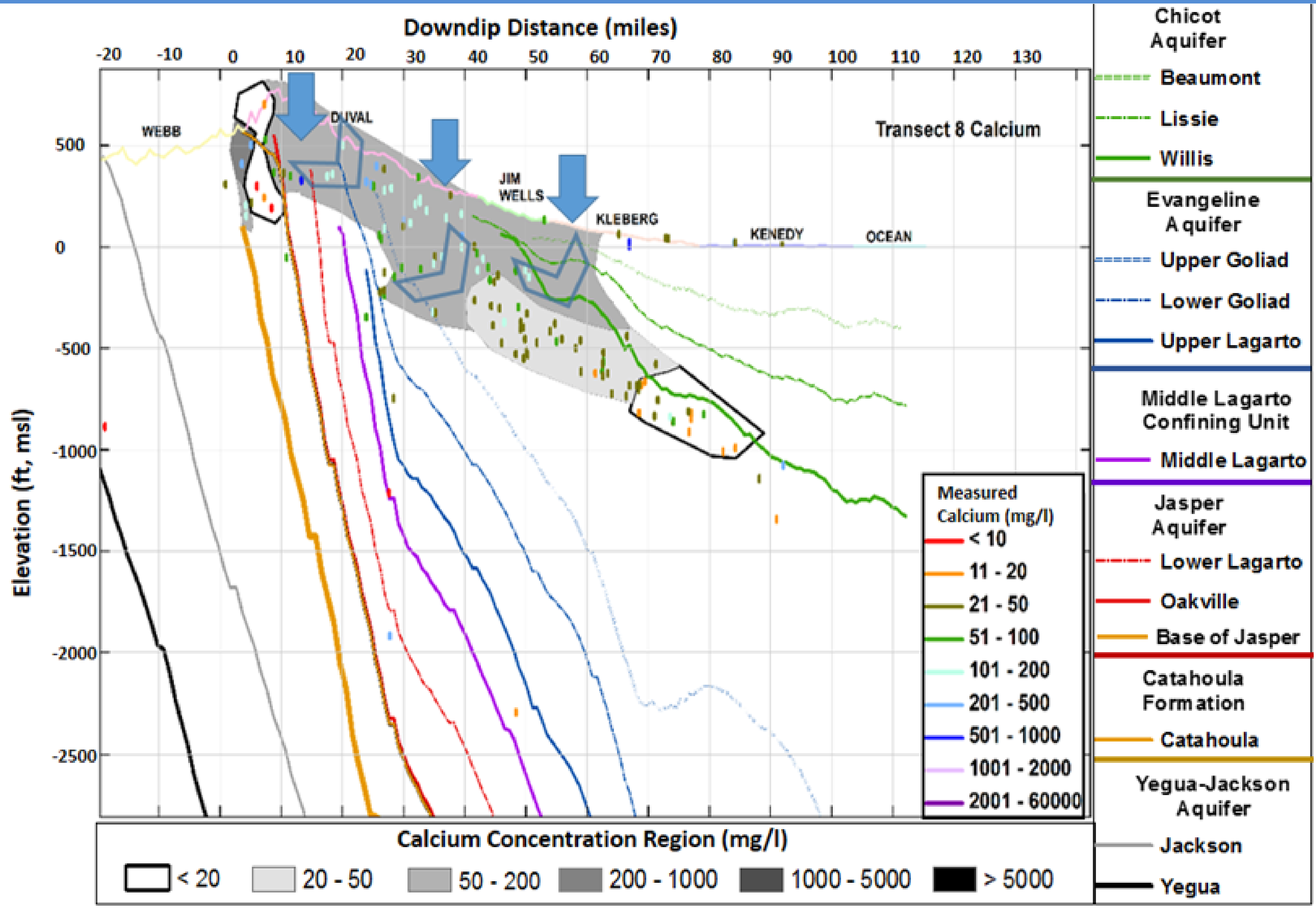
Calcium Concentrations at Transect 34 (GMA 14)



Calcium Concentrations at Transect 56 (GMA 15)



Calcium Concentrations at Transect 8 (GMA 16)

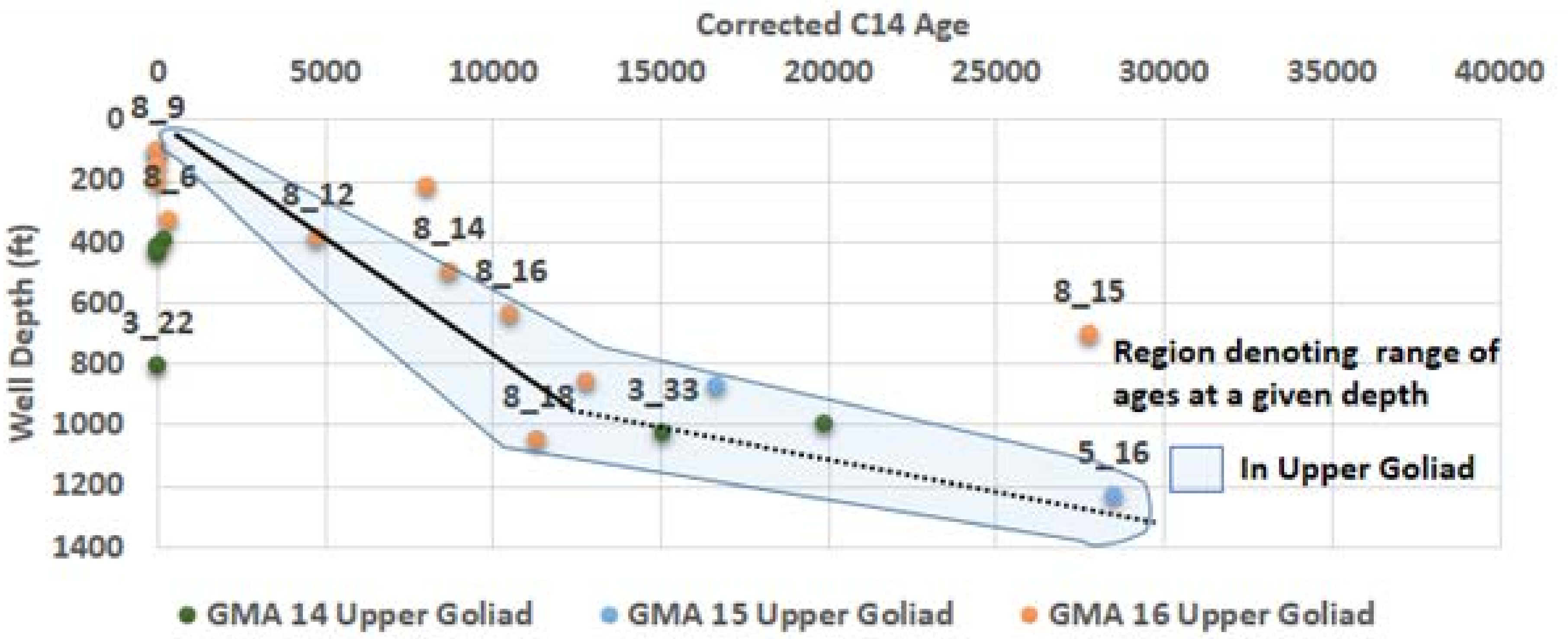


Estimate of

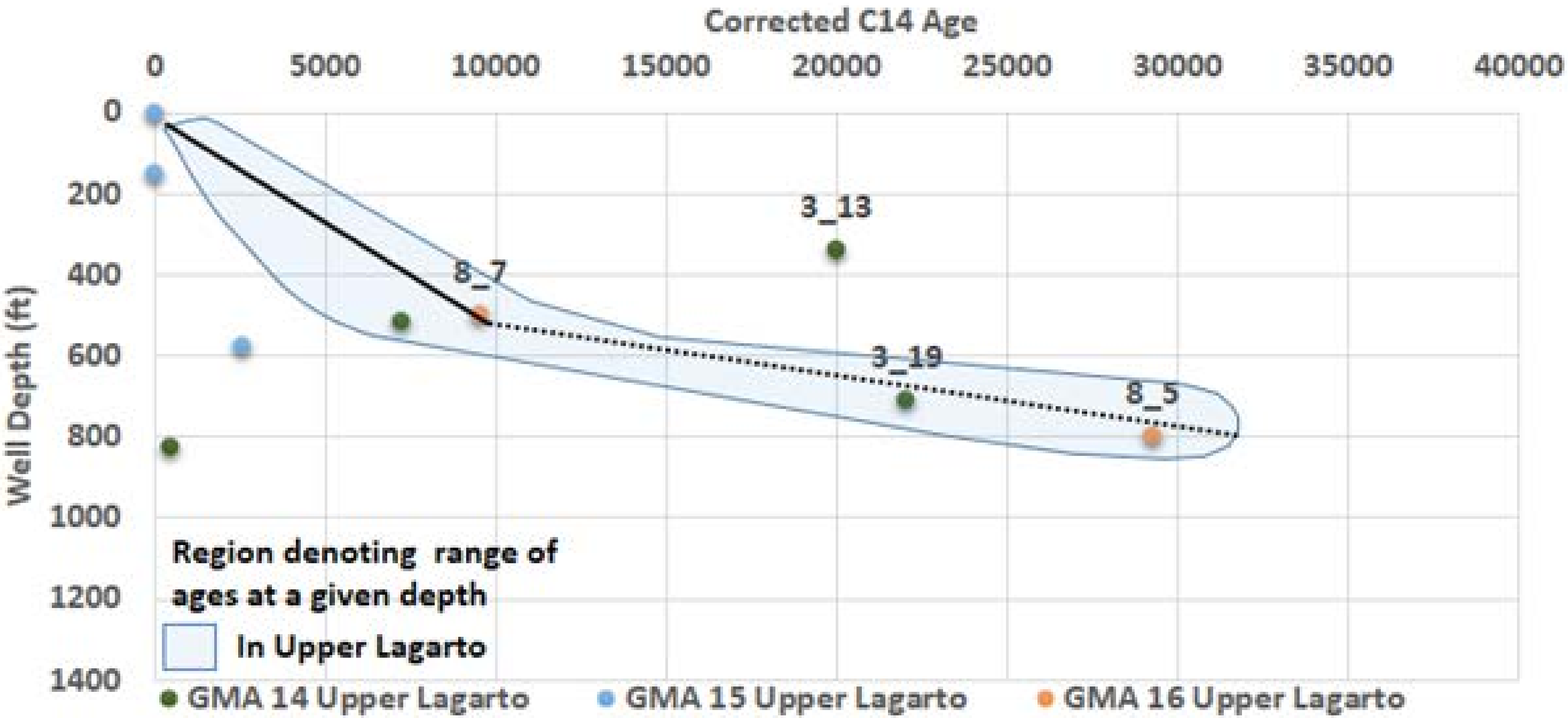
Groundwater Age

^{14}C Age (YBP) versus for Base of Chicot

^{14}C Age (YBP) versus for Top of Evangeline



^{14}C Age (YBP) versus for Base of Evangeline



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Comparison of Groundwater Age Calculated from Field Data and Modeling Results

Source of Depth Estimate			Estimated Depth Range where Groundwater has an Age of 10,000 ybp					
			Lissie		Willis		Upper Goliad	
			Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit
^{14}C Measurements Corrected			300	600	400	800	600	1100
LCRB Model	Transect 34	GMA 14	250	600	600	850	900	1100
LCRB Model	Transect 45	GMA 15	250	650	600	800	800	1400
Northern Gulf Coast Aquifer System GAM	Transect 34	GMA 14	(1)	(1)	(1)	(1)	(1)	(1)
Northern Gulf Coast Aquifer System GAM	Transect 45	GMA 15	250	650	600	800	200	300
Central Gulf Coast Aquifer System GAM	Transect 45	GMA 15	400	500	400	700	700	800
Central Gulf Coast Aquifer System GAM	Transect 8	GMA 16	(1)	(1)	(1)	(1)	(1)	(1)
GMA 16 AGM	Transect 8	GMA 16	(1)	(1)	(1)	(1)	100	600

(1) Groundwater in formation is significantly older than 10,000 ybp.

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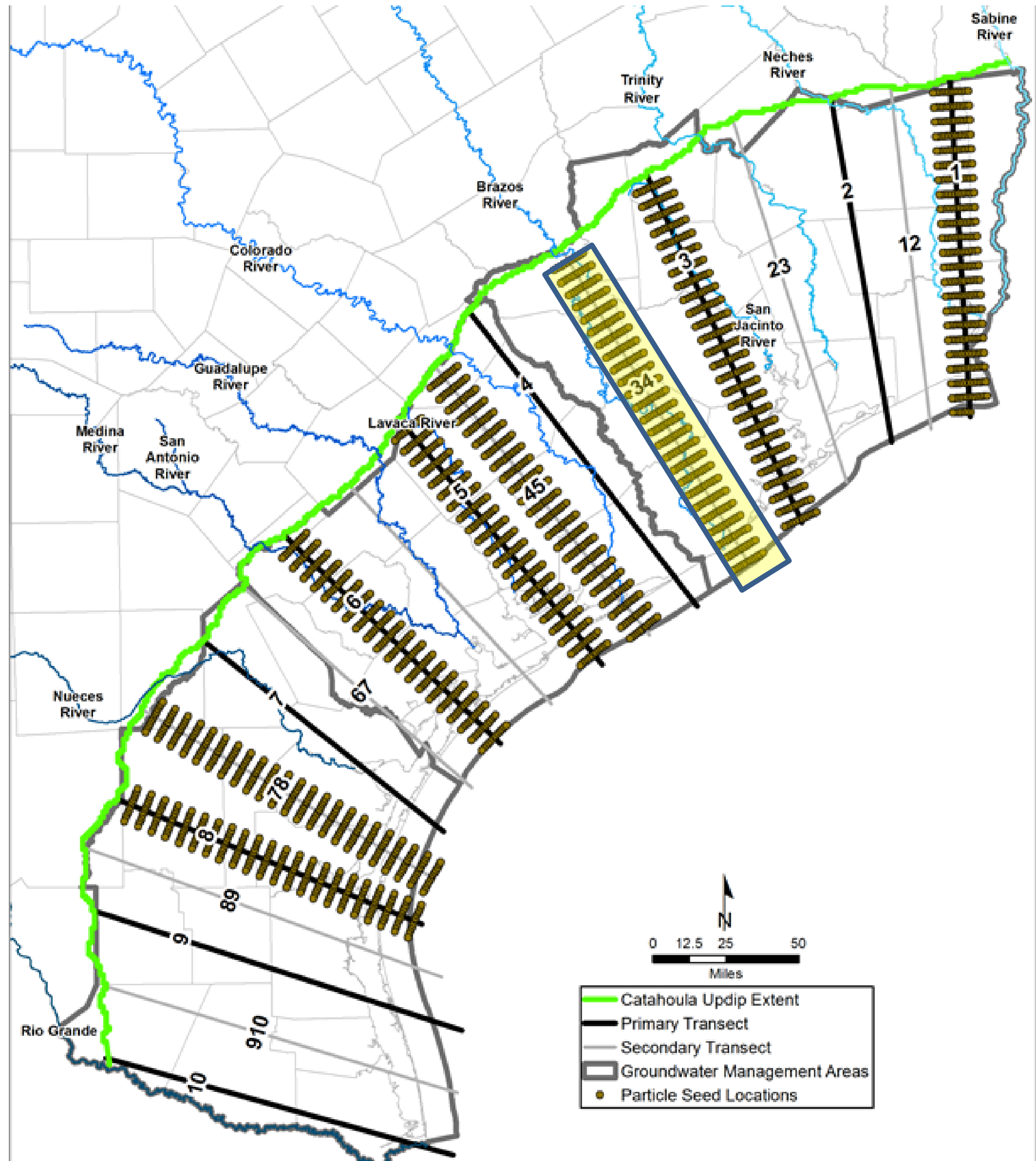
Groundwater Flow Modeling

Reverse Particle Tracking To Estimate Groundwater Age

- Initial particles locations located along transects based at fixed elevations per 100 ft increments
- Particles are back-track using a models pre-development water level conditions
- Time for particle to reach its recharge source at surface is the estimated age of groundwater



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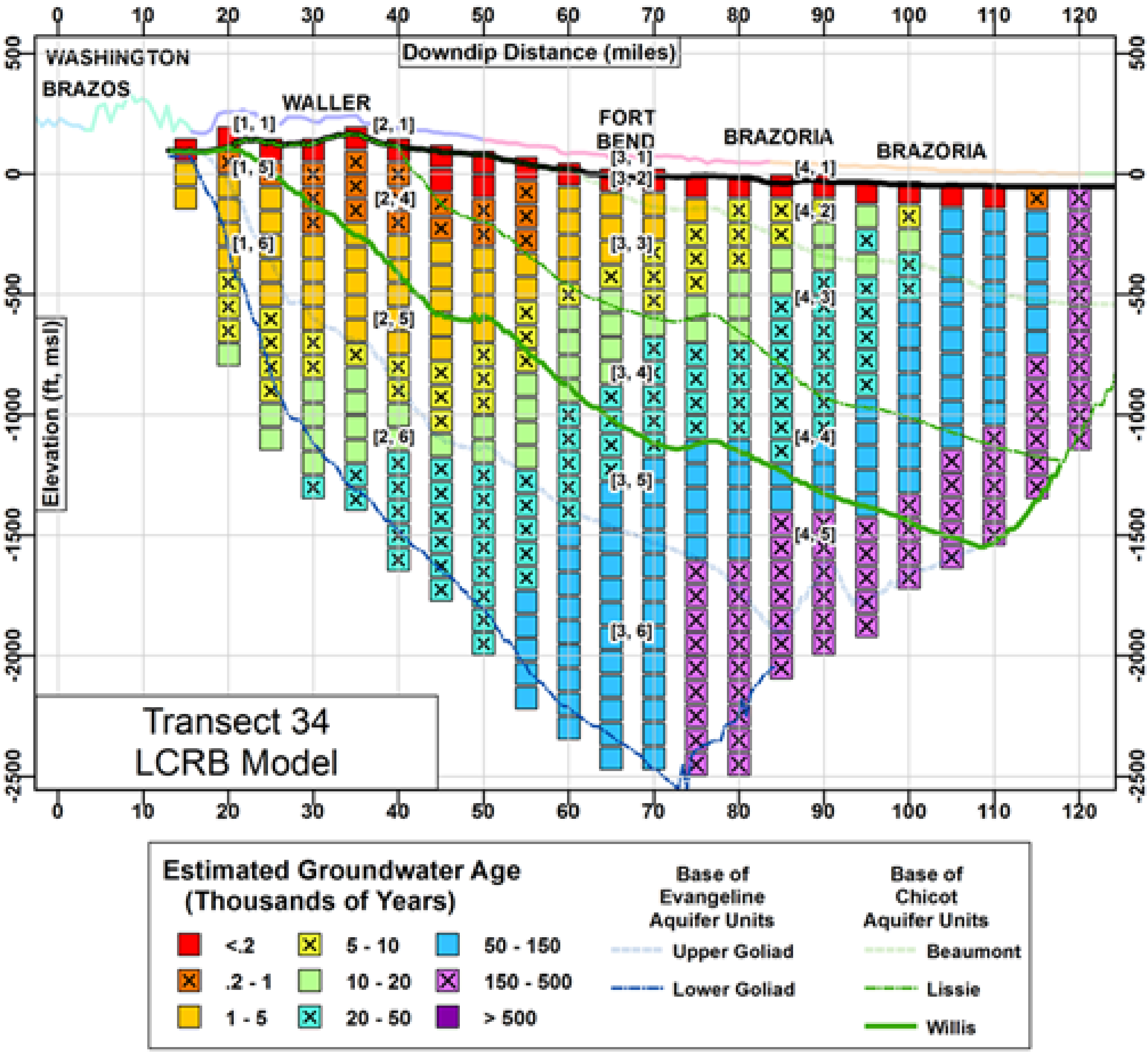
Reverse Particle Tracking To Estimate Groundwater Age



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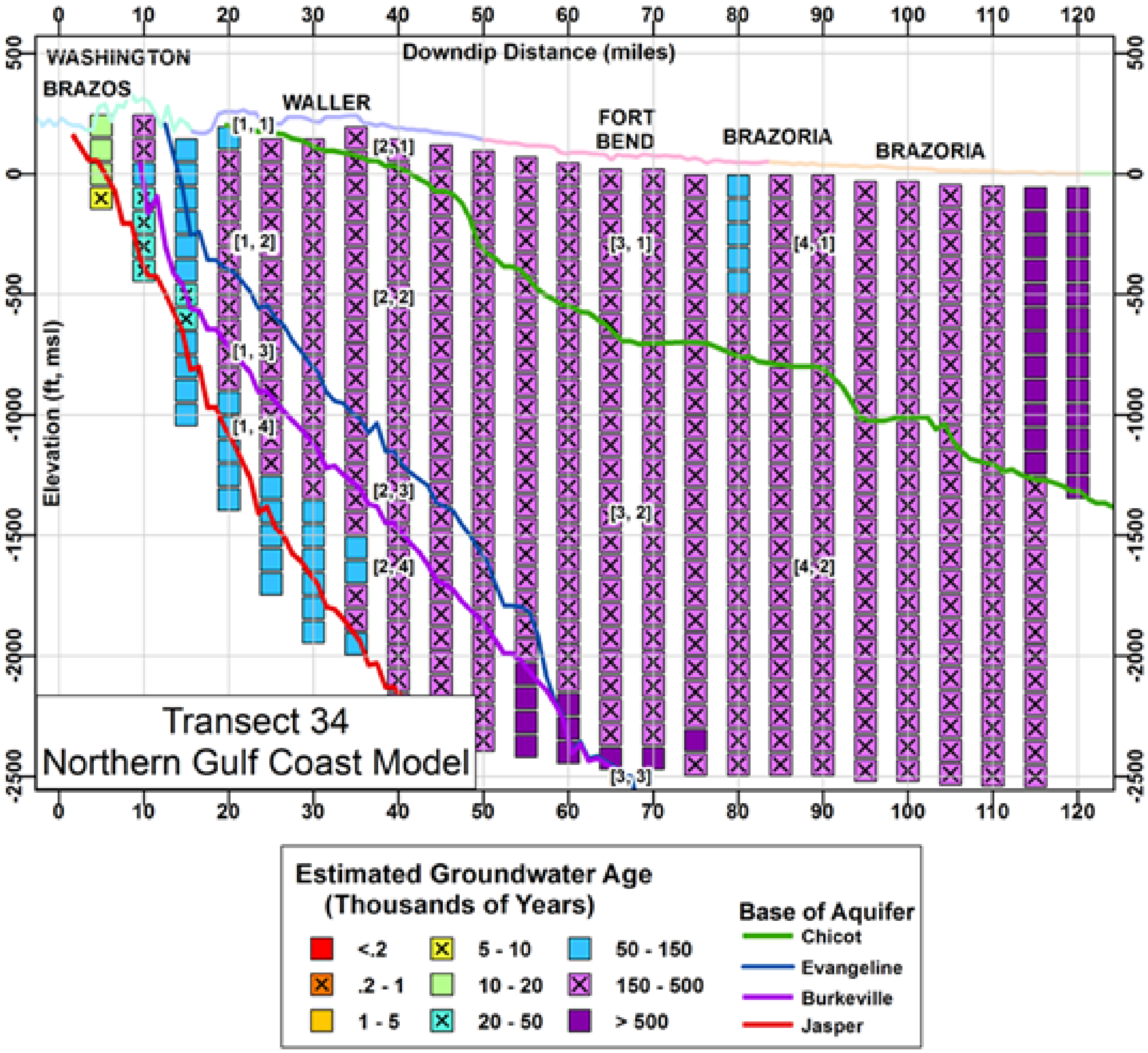
Reverse Particle Tracking To Estimate Groundwater Age



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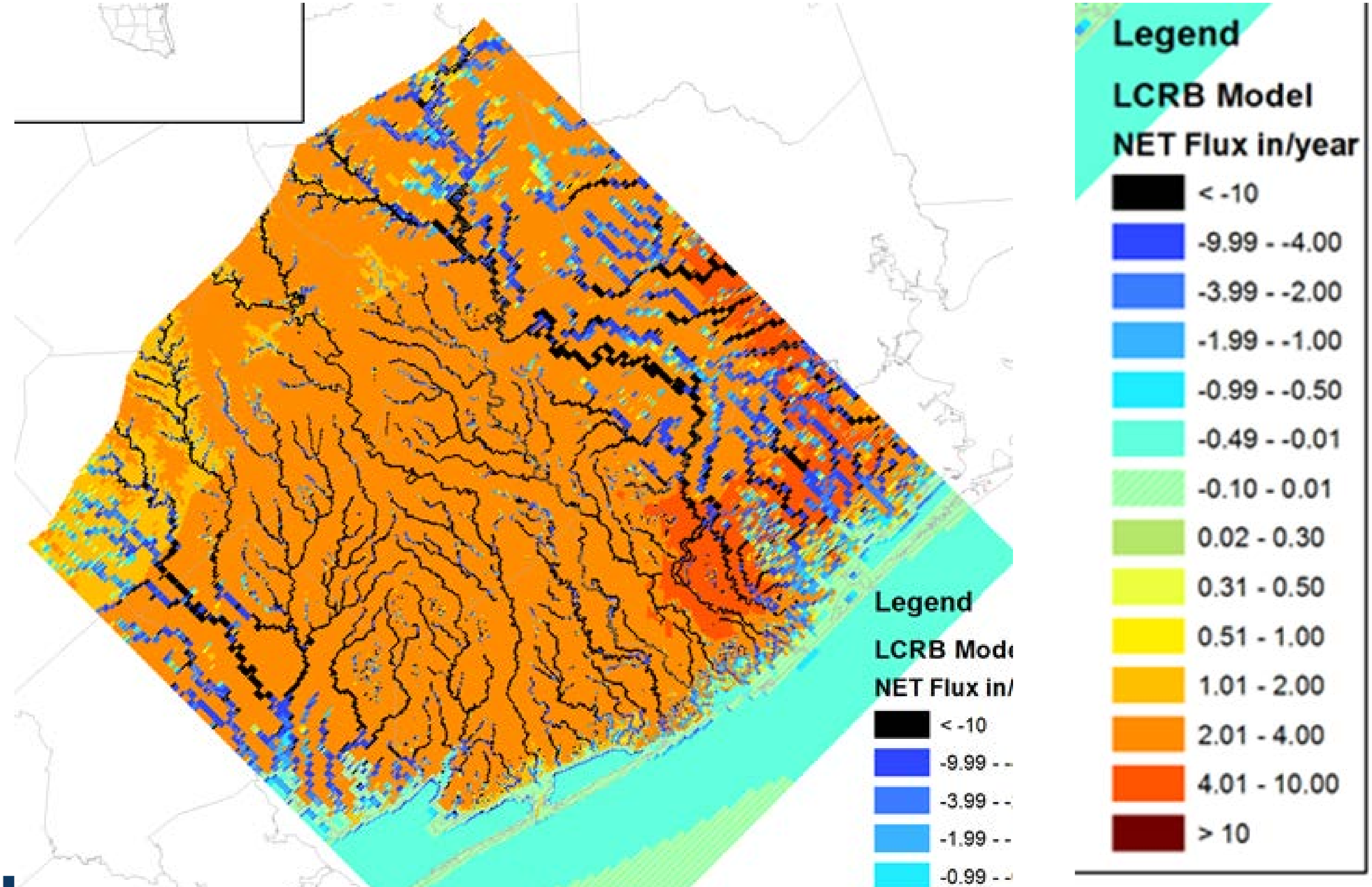
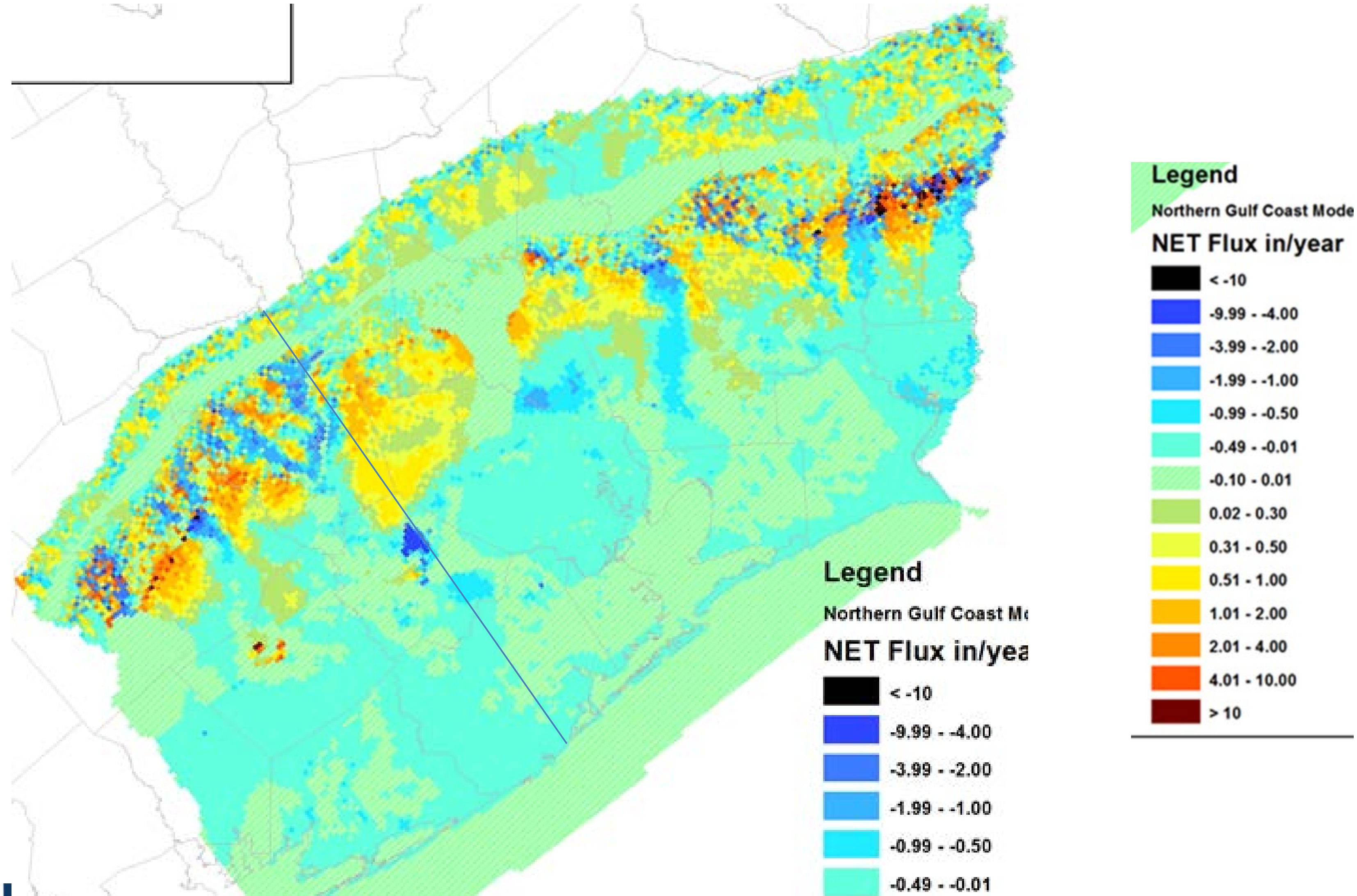
Recharge and Discharge Fluxes at Ground Surface for Predevelopment Conditions for LCRB Model



Recharge and Discharge Fluxes at Ground Surface for Predevelopment Conditions for Northern Gulf Coast GAM



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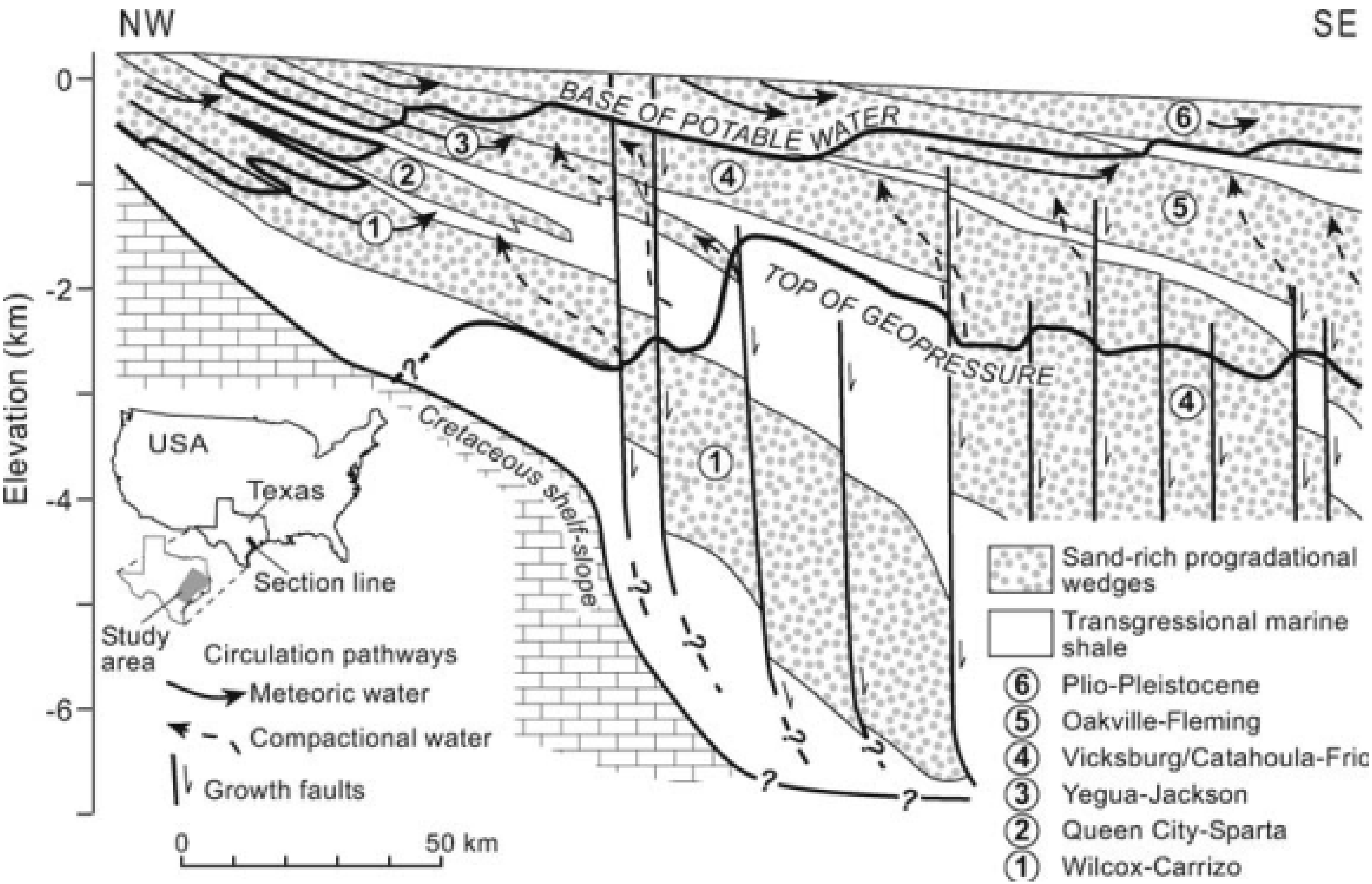
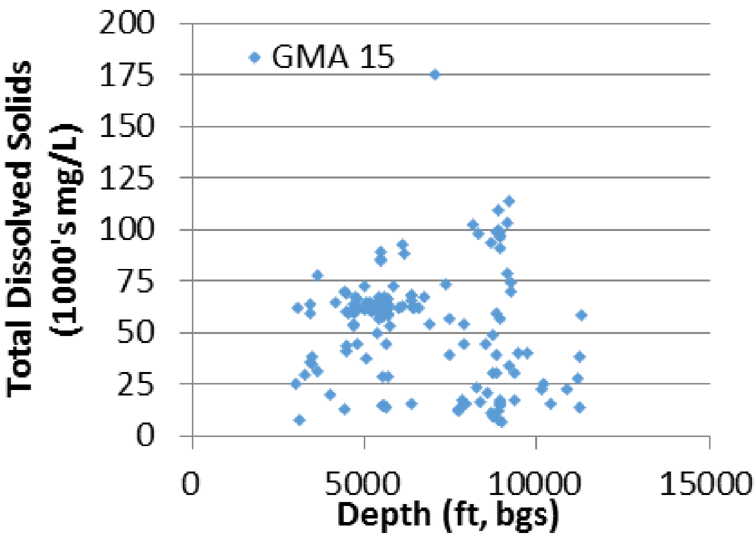
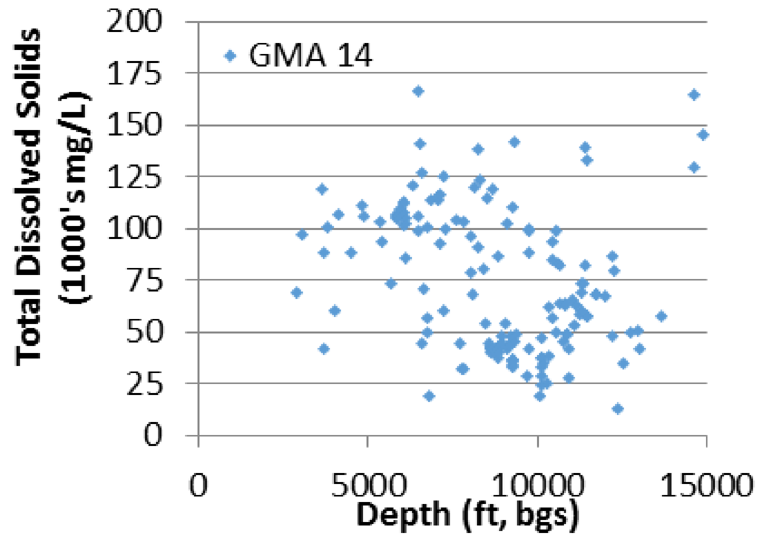
Upward Migration of Formation Water Along Growth Faults

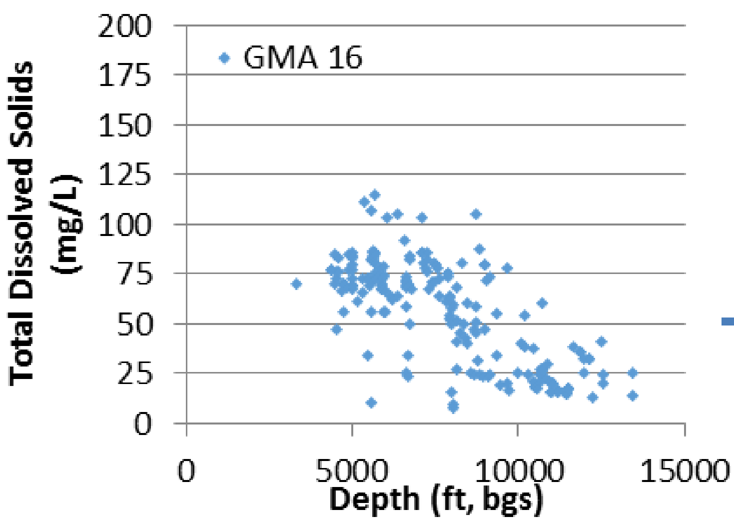
Meteoric and Compactional Circulation Pathways(from Dutton and others, 2006)

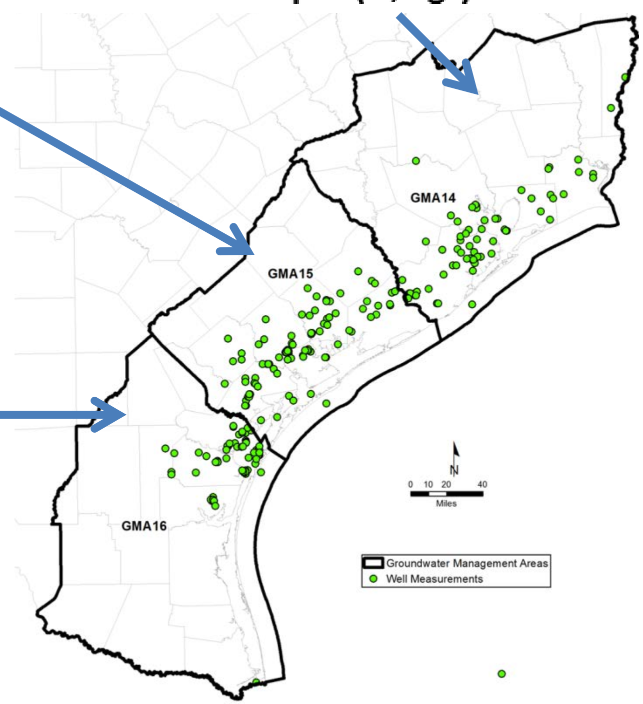


Elevated TDS in Formation Water in Catahoula

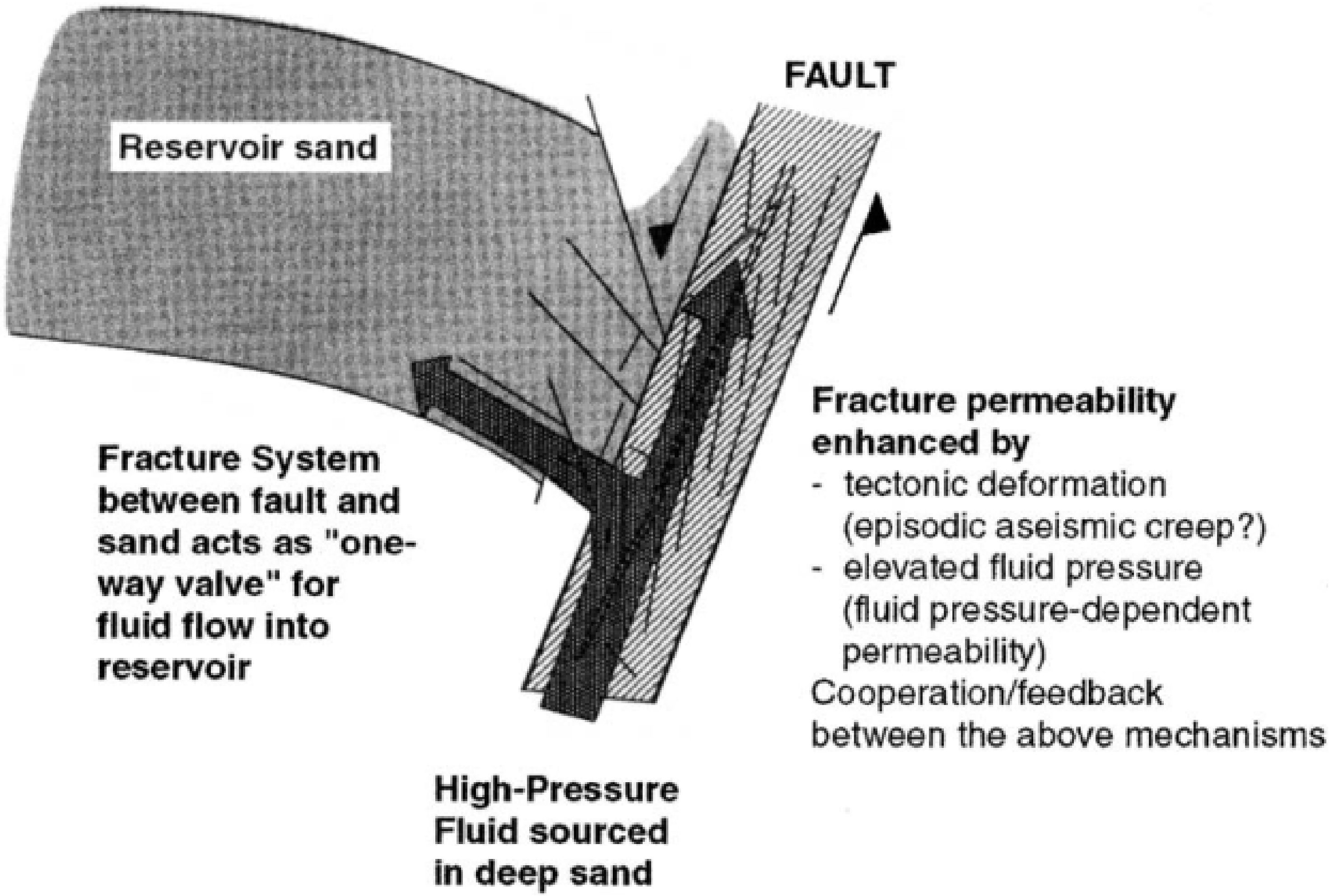








Mechanism for Upswelling of Brine Along Growth Faults(from Kuecher and others, 2001)



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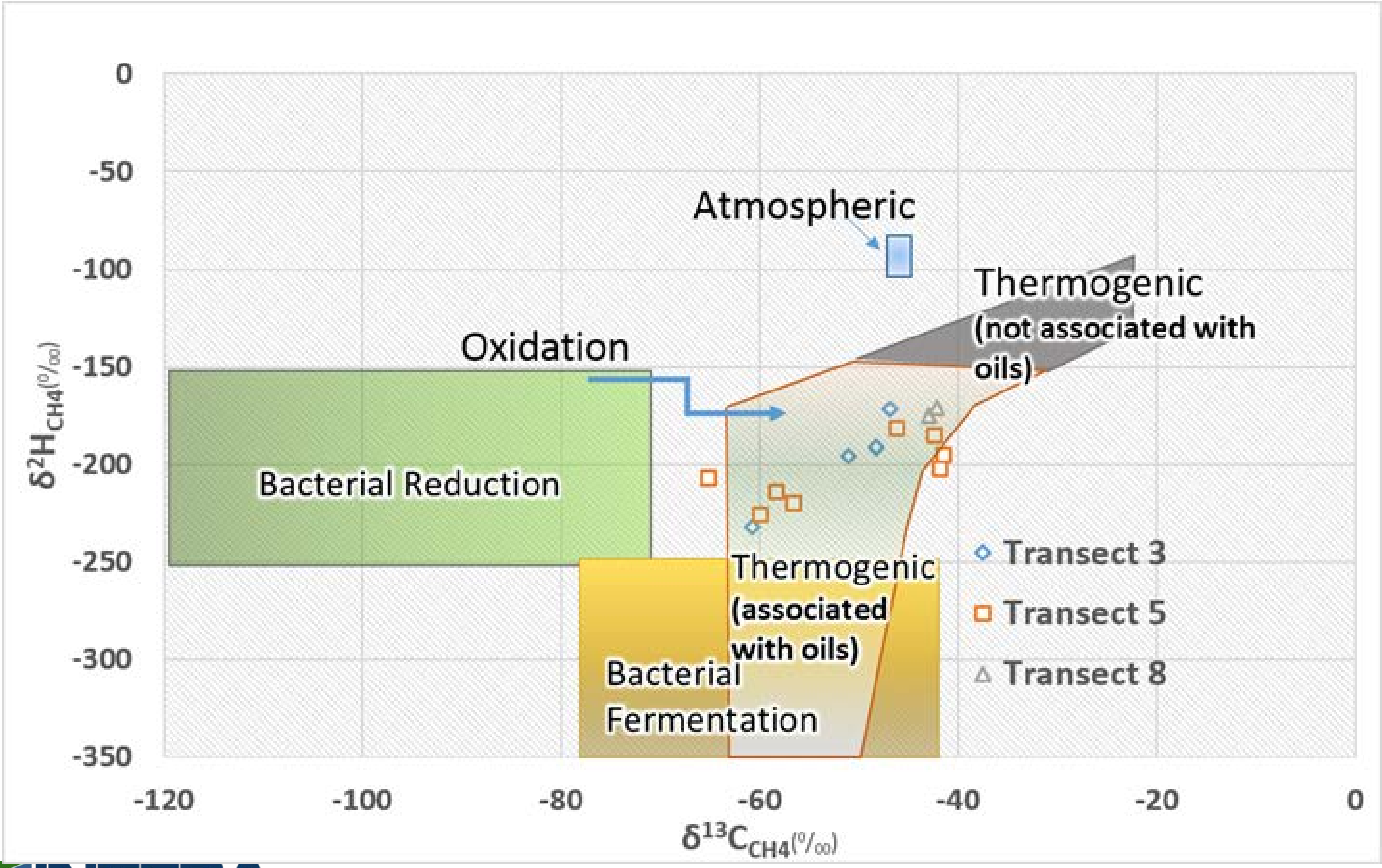
Evidence of Upswelling: Origin of Methane



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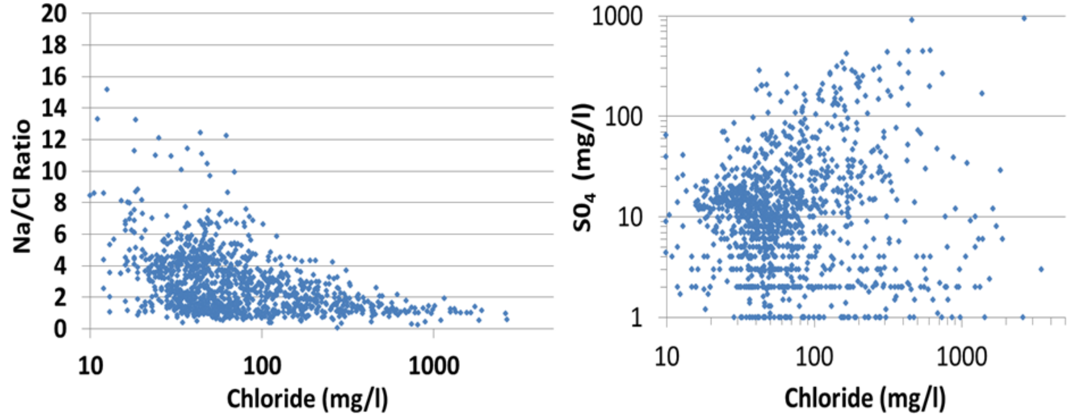
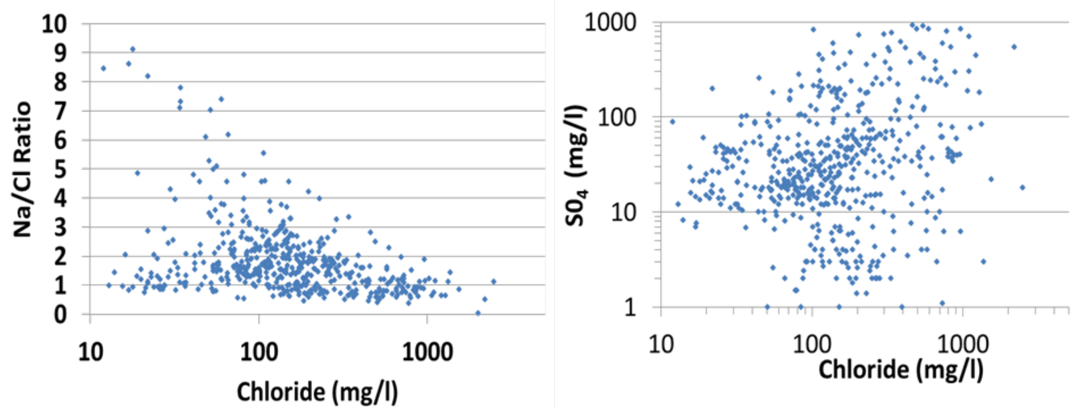
Lines of Evidence for Upswelling of Formation Water Contribution to Elevated TDS Concentrations

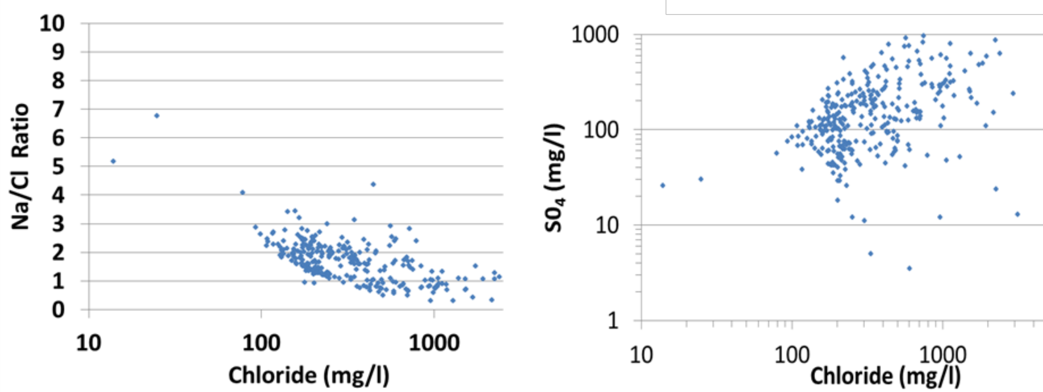
Transects 3 & 34



Transects 5 & 56



Transects 8 and 89



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Summary of Findings

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Geochemical Analyses

Analyses Method and/or Map	Insight
Tabulated and plotted depth-average geochemical values for the Gulf Coast Aquifer System Region	Notable differences in the geochemistry of GMA 14, 15, and 16. These differences attributed to differences in climate, distribution of salt domes, and stratigraphy
Plots of hydrogeochemical facies, chloride values, and sand and salinity profiles along vertical cross-sections	Direction of groundwater flow and evidence of recharge, mixing, and "preferred-flow" region within or between aquifers
Analysis of carbon and isotope of gases such as carbon dioxide and methane	Evidence of movement along growth faults

Geochemical Analyses

Analyses Method and/or Map	Insight
Analysis of the hydropressure and brine concentrations in the Catahoula and deeper deposits	Evidence that a source of the increased total dissolved solids (TDS) near the coast is upswelling of brine
Analysis of stable isotopes of oxygen and hydrogen	Evidence of meteoric water
Analysis of carbon stable and radioactive isotopes	Estimate of groundwater age

Conceptual Flow Model

- The up-dip boundary for the regional Gulf Coast Aquifer System flow should be the Catahoula Formation outcrop;

- The downdip boundary for the regional Gulf Coast Aquifer System flow should allow groundwater to discharge across a large area of the ocean bottom;

- The numerical representation of the regional groundwater flow system should be constrained by estimates of groundwater age calculated from ^{14}C measurements;

- A conceptual water budget should be developed and be guided by recharge estimates by Scanlon and others (2012) after appropriate uncertainty estimates have been developed;

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Conceptual Flow Model (con’t)

- Proper conceptualization and representation of groundwater mixing and flow paths requires vertical layering smaller than the thicknesses of the major aquifers; and the utility and accuracy of the GAMs could be improved is model layers represented the geological formations that comprised the Chicot, Evangeline, and Jasper Aquifers,

- General head boundaries do not accurately model recharge to an aquifer and should not be used for that purpose in any future GAMs for the Gulf Coast Aquifer System,

- A continuous, low permeability “Burkeville” Confining Unit does not exist up dip at the outcrop; and

Questions

Backpocket Slides

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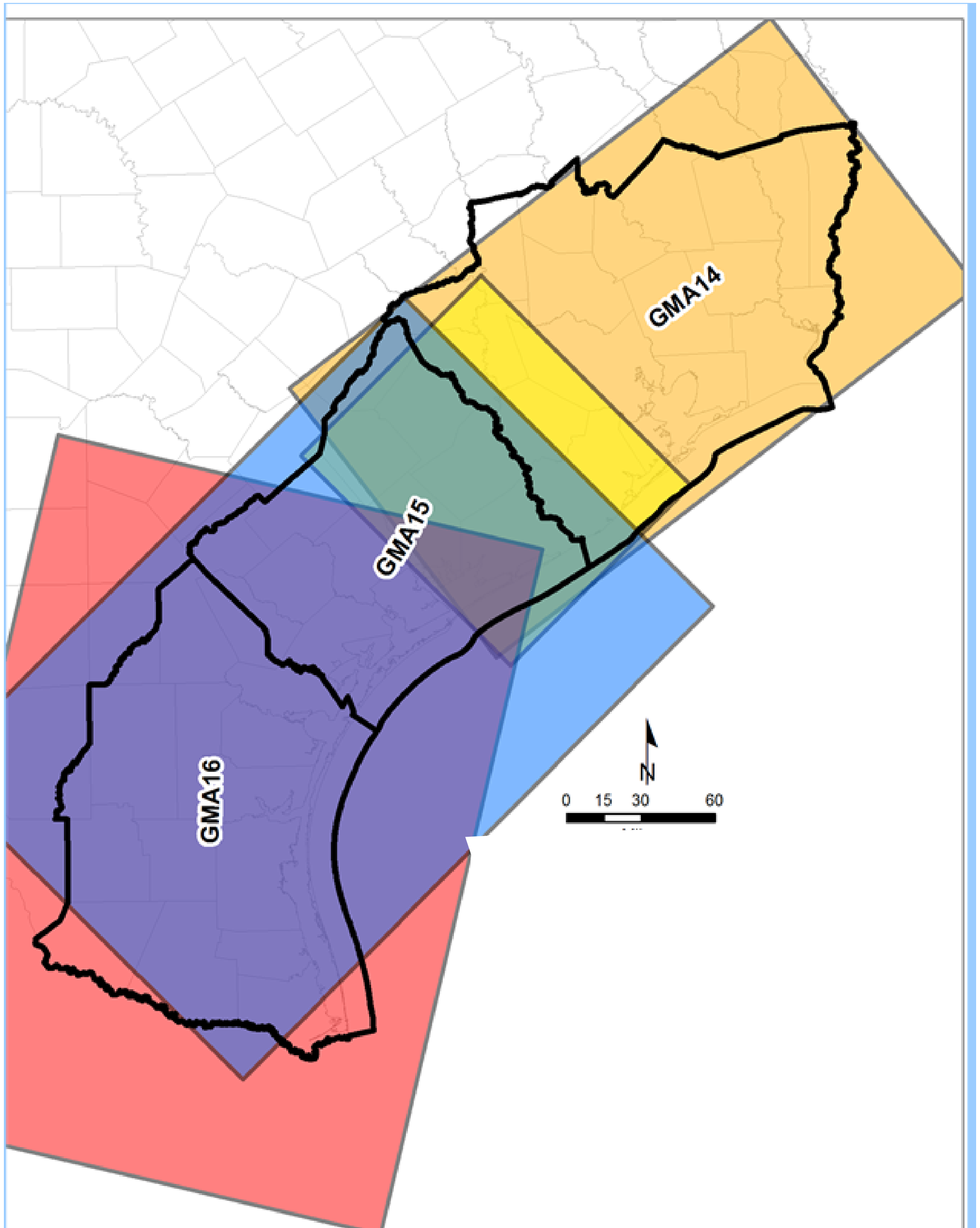
Regional Models for GCAS

- **Northern Gulf Coast Aquifer System GAM**
- **Central Gulf Coast Aquifer System GAM**
- **GMA 16 Alternative Groundwater Model**
- **Lower Colorado River Basin Model**



Comparison of Corrected ^{14}C Age Based on NETPATH Modeling and Pearson Correction

	Soil to Recharge Well to Well 5-1, Well 5-3, Well 5-12, Well 5-13, or Well 5-18				
	5-1	5-3	5-12	5-13	5-18
$^{14}C_{MEAS}$ ybp	8,940	12,280	6,730	9,340	7,220
$^{14}C_{MEAS}$ pmc	32.85	21.67	43.25	31.25	40.69
$^{13}C_{MEAS}$ DIC	-9.3	-7.3	-13.3	-12.9	-10.0
$\delta\,^{34}S$ meas	4.1	10.9	-1.0	8.3	-
Mass Transfer[1]					
calcite	3.77	5.46	2.70	3.59	3.81
$CO_{2(g)}$	2.23	2.25	2.97	3.82	2.87
Ca/Na Ex	1.70	2.89	0.44	1.55	1.86
Mg/Na Ex	-0.18	-0.51	-0.44	-0.50	-0.95
K/Na Ex	-2.43	-4.60	-0.11	0.68	
NaCl	5.53	5.22	3.27	0.85	2.26
gypsum	0.40	0.40	0.11	0.23	0.13
pyrite	0.10	0.05	-	-	-
Computed Values					
$^{14}C_{ADJ}$ (ybp)	1,019	2,456	1,579	4,140	456
$^{14}C_{ADJ}$ (pmc)	37.16	29.17	52.36	51.57	43.00
$\delta\,^{13}C$ DIC calc	-9.3	-7.3	-13.1	-12.9	-10.8
$\delta\,^{34}S$ calc	4.1	10.9	-1.0	8.3	
$^{14}C_{ADJ}$ (ybp)[2]	996	2,391	1,539	4,025	modern

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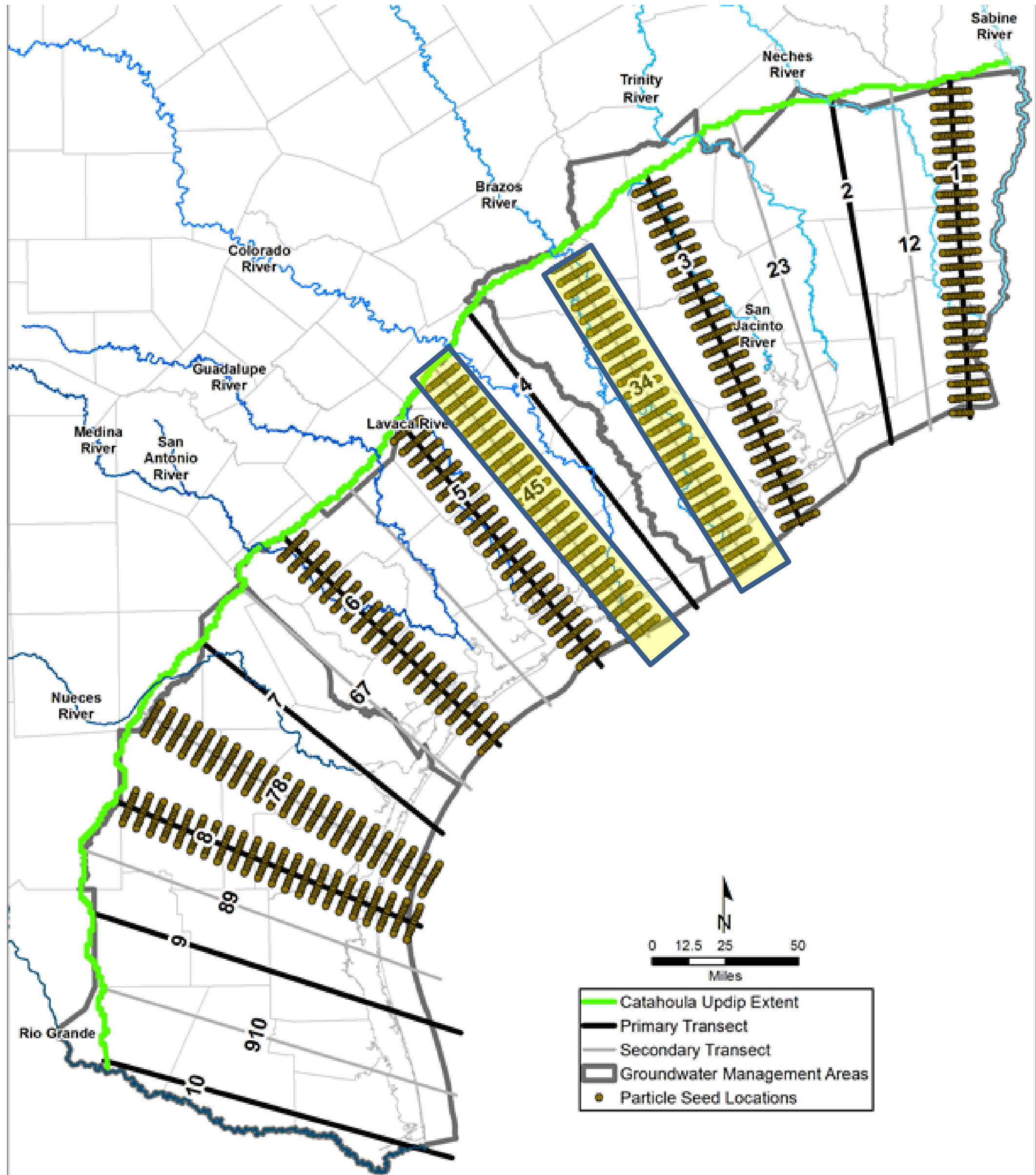
NOTES:
[1] millmoles
[2] Pearson Method

Reverse Particle Tracking To Estimate Groundwater Age

- Initial particles locations located along transects based at fixed elevations per 100 ft increments
- Particles are back-track using a models pre-development water level conditions
- Time for particle to reach its recharge source at surface is the estimated age of groundwater



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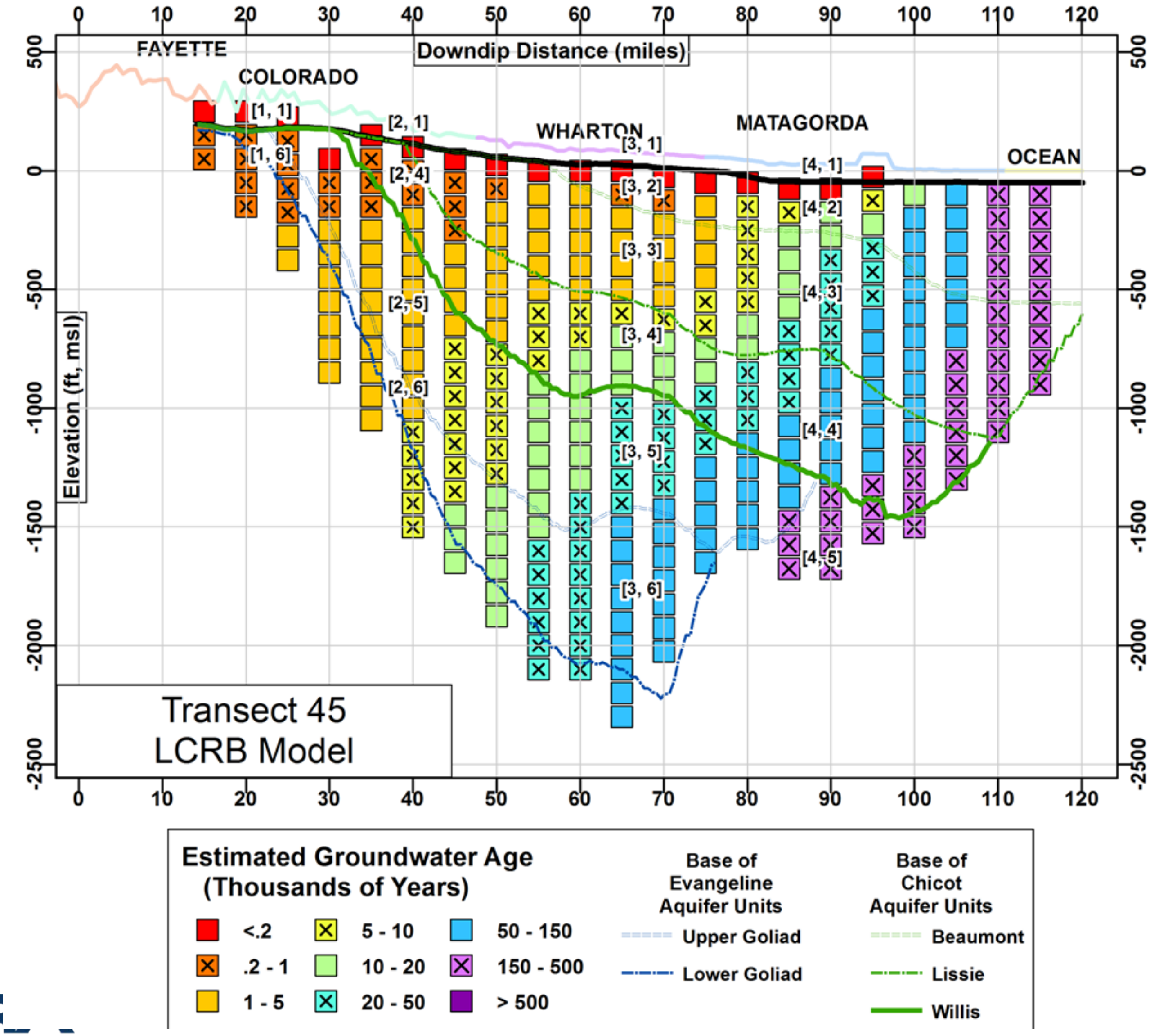
Reverse Particle Tracking To Estimate Groundwater Age



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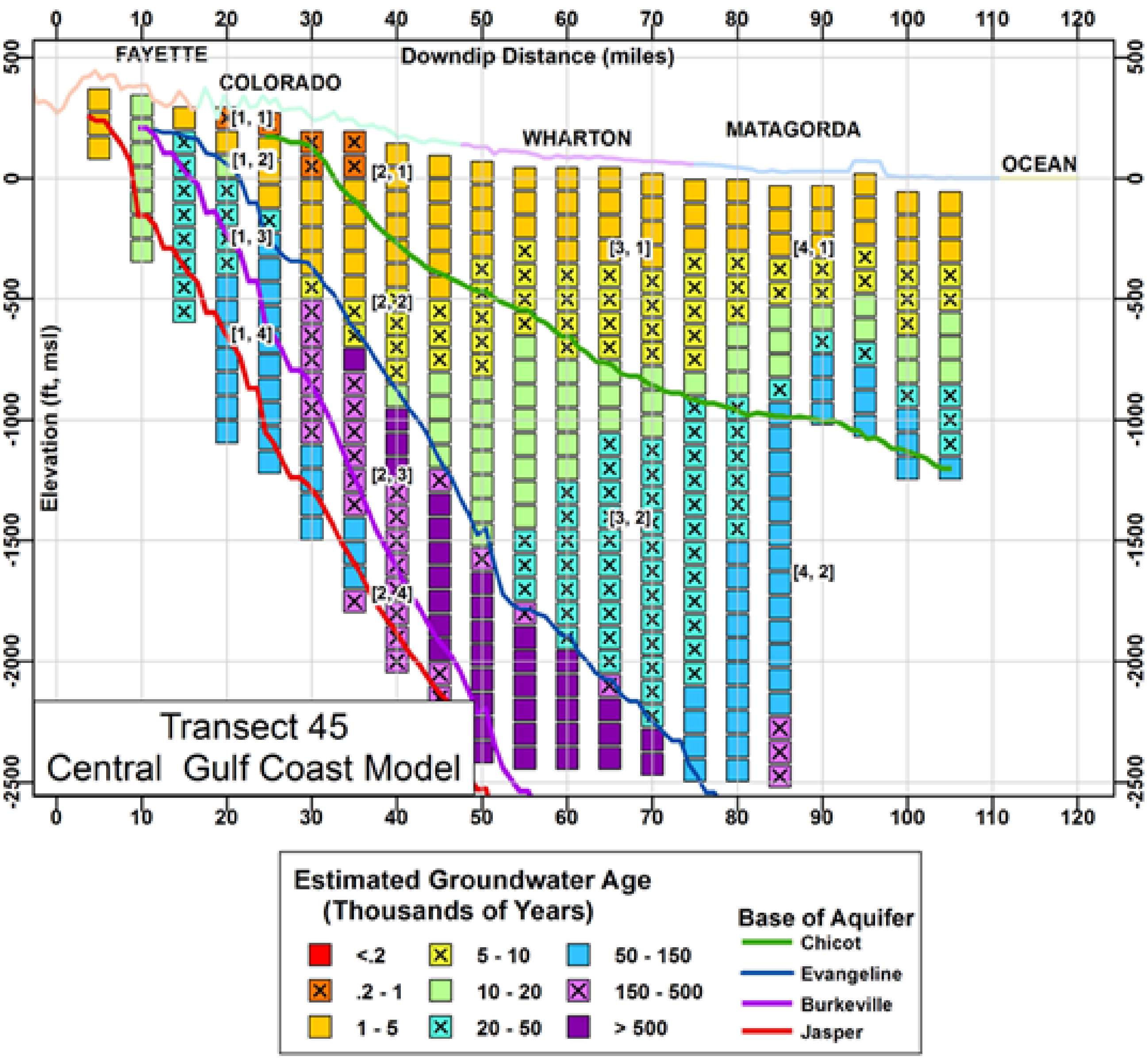
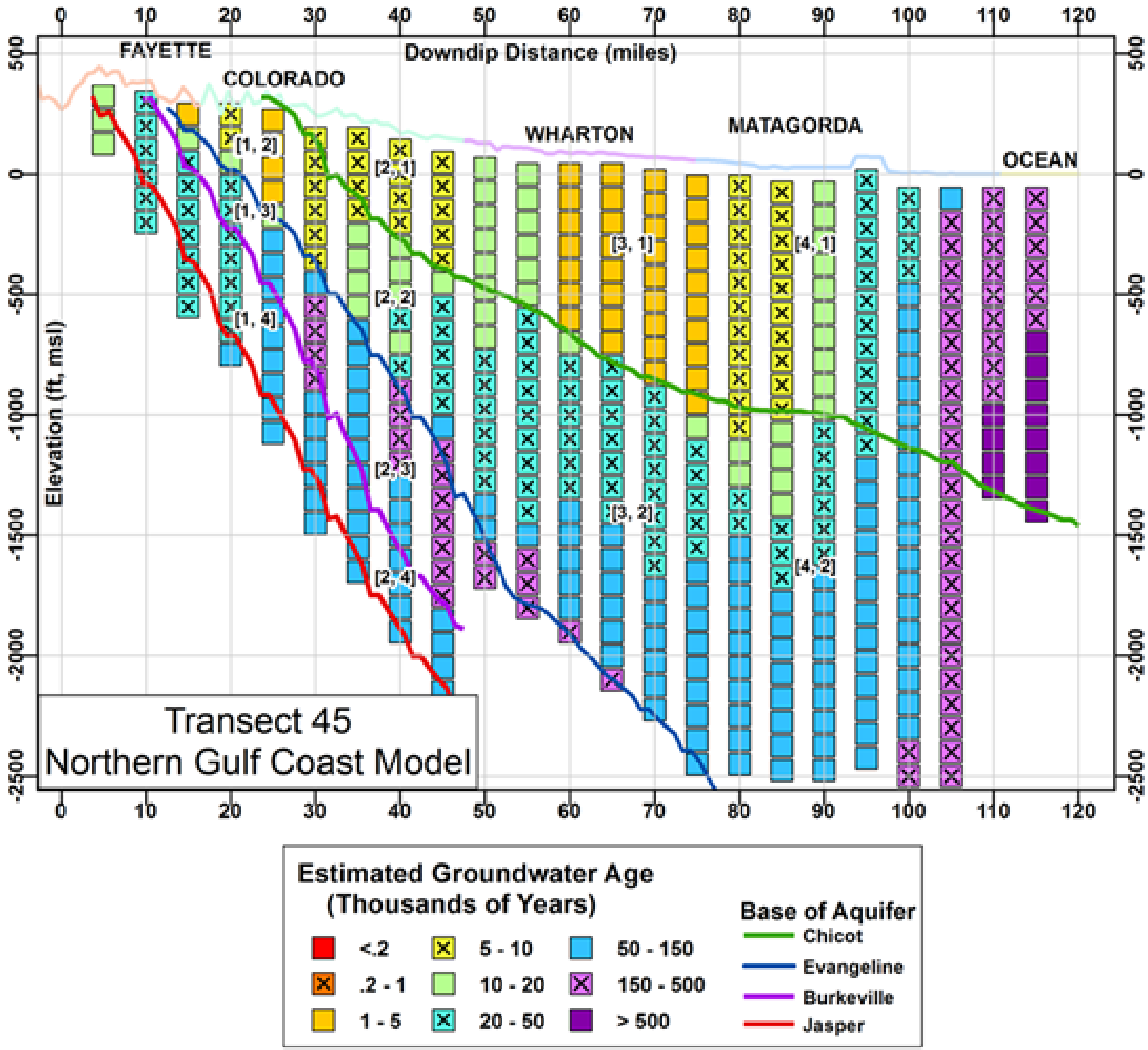
Reverse Particle Tracking To Estimate Groundwater Age



Reverse Particle Tracking To Estimate Groundwater Age



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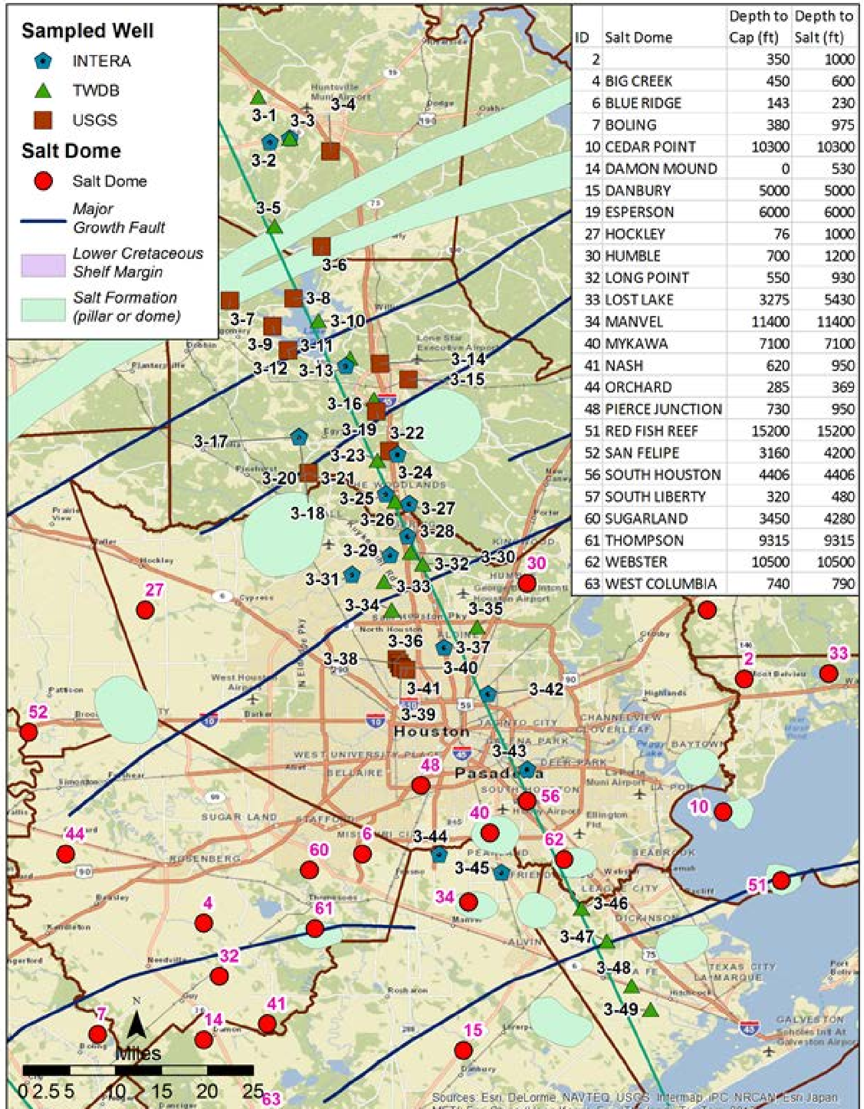
Transect 3 Sample (Aerial View)



ID	Salt Dome	Depth to Cap (ft)	Depth to Salt (ft)
2		350	1000
4	BIG CREEK	450	600
6	BLUE RIDGE	143	230
7	BOLING	380	975
10	CEDAR POINT	10300	10300
14	DAMON MOUND	0	530
15	DANBURY	5000	5000
19	ESPERSON	6000	6000
27	HOCKLEY	76	1000
30	HUMBLE	700	1200
32	LONG POINT	550	930
33	LOST LAKE	3275	5430
34	MANVEL	11400	11400
40	MYKAWA	7100	7100
41	NASH	620	950
44	ORCHARD	285	369
48	PIERCE JUNCTION	730	950
51	RED FISH REEF	15200	15200
52	SAN FELIPE	3160	4200
56	SOUTH HOUSTON	4406	4406
57	SOUTH LIBERTY	320	480
60	SUGARLAND	3450	4280
61	THOMPSON	9315	9315
62	WEBSTER	10500	10500
63	WEST COLUMBIA	740	790

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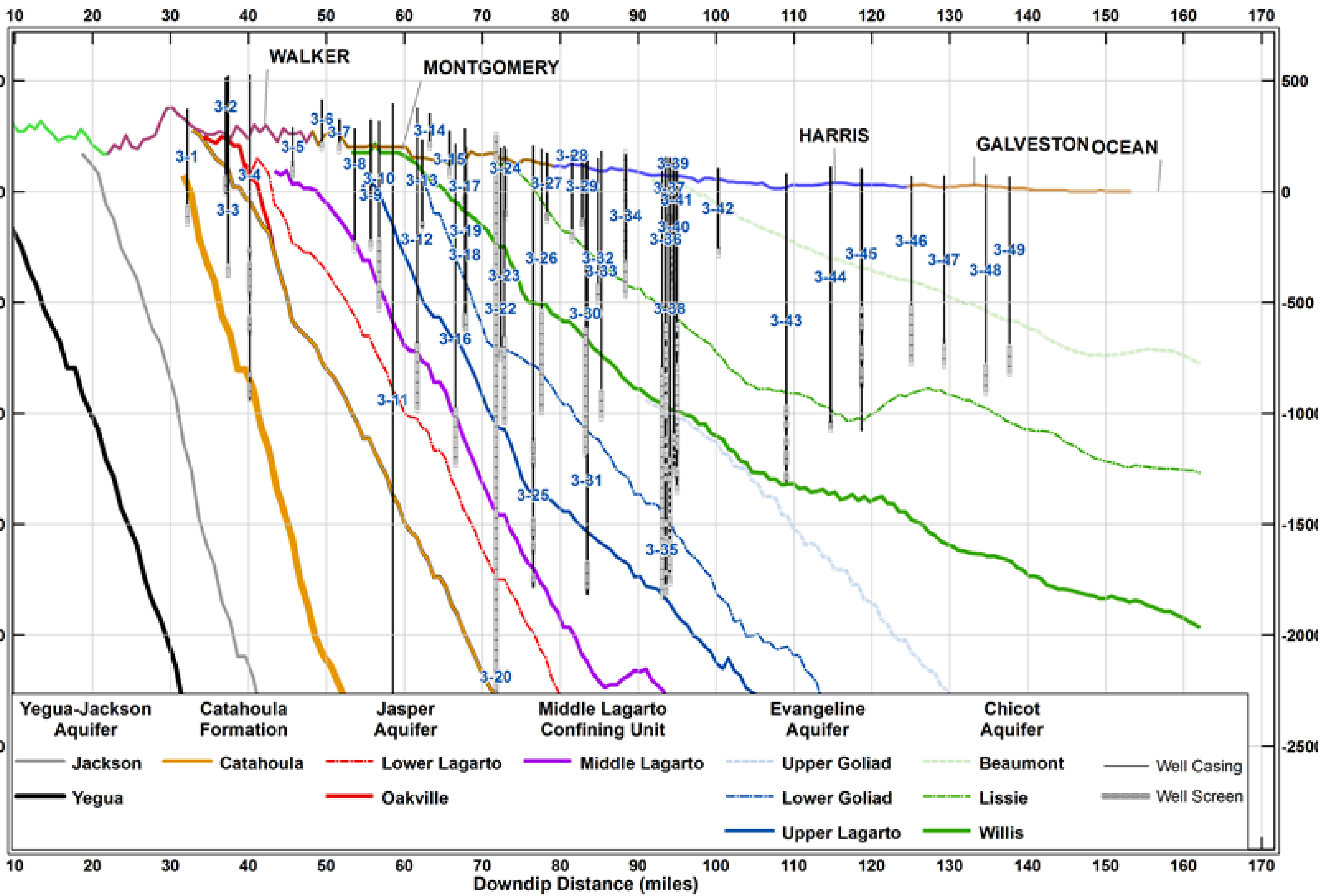
Transect 3 Sample (Cross-section View)



Geochemical Parameters

Sample No.	Analyte	Lab
1	Dissolved Metals (Ca, Mg, Na, K, Fe)	San Antonio Testing
2	TDS	
	Alkalinity	
	pH	
	Specific Conductance	
	Br, Cl, F, SO_4 (dissolved)	
3	Nitrate + Nitrite	
4	H_2S	
	HS	
5	TOC Dissolved	
6	Fixed and hydrocarbon gas composition	Zymax
7	δC13 of C1, C2	
8	δD of C1, C2	
9	δO18 of H20	
10	δD of H20	

Sample No.	Analyte	Lab
11	RSK 175 for C1, C2, C3	Zymax
12	Gas extraction fee	
13	Total Gas for methane, ethane, propane, butane, and pentane(for purpose of identifying thermo versus biogenic carbon sources)	
14	δS34 of SO4	University of Arizona Environmental Lab
15	δO18 of SO4	
16	δC13 of DIC	Beta Analytics
	C-14	

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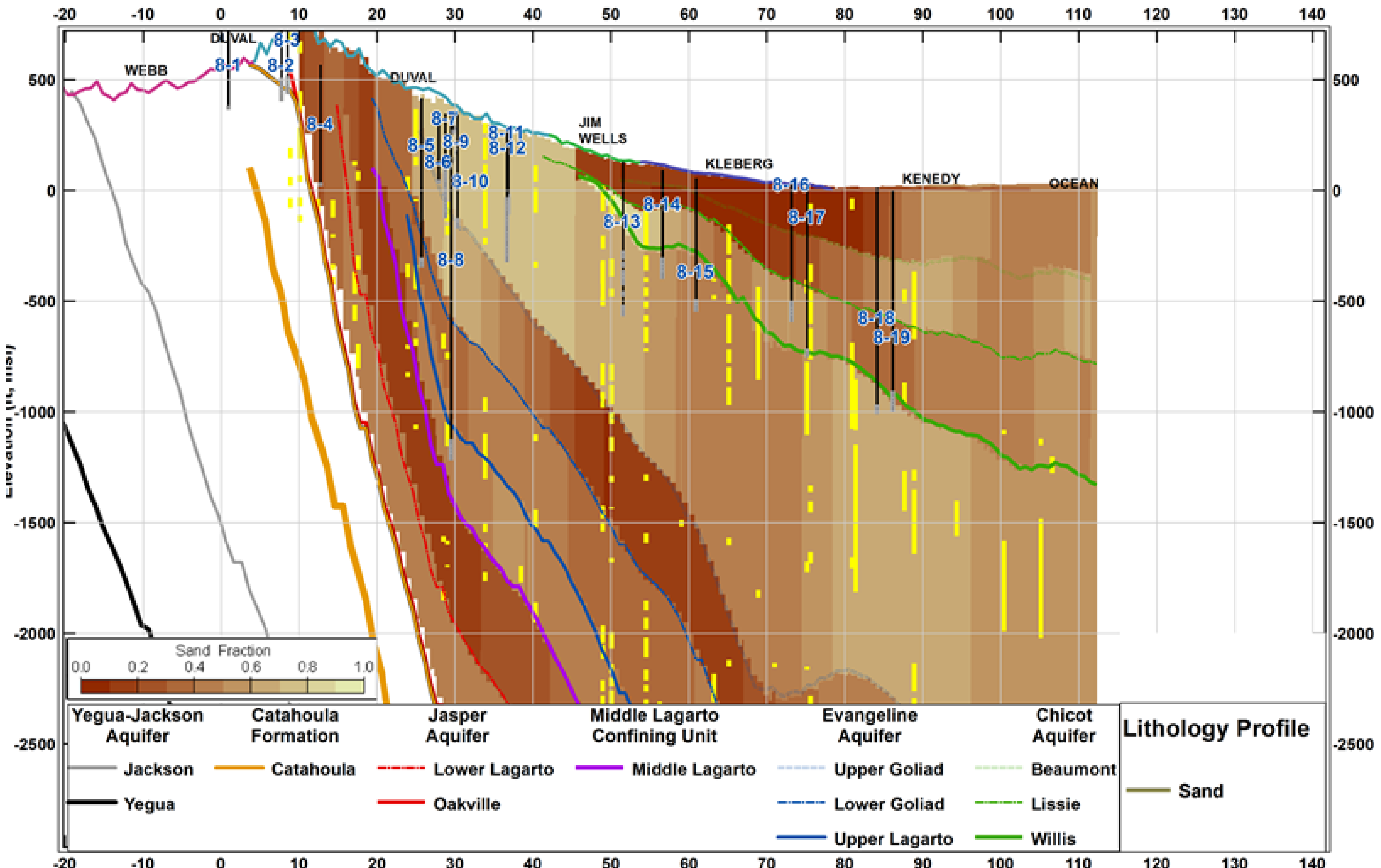
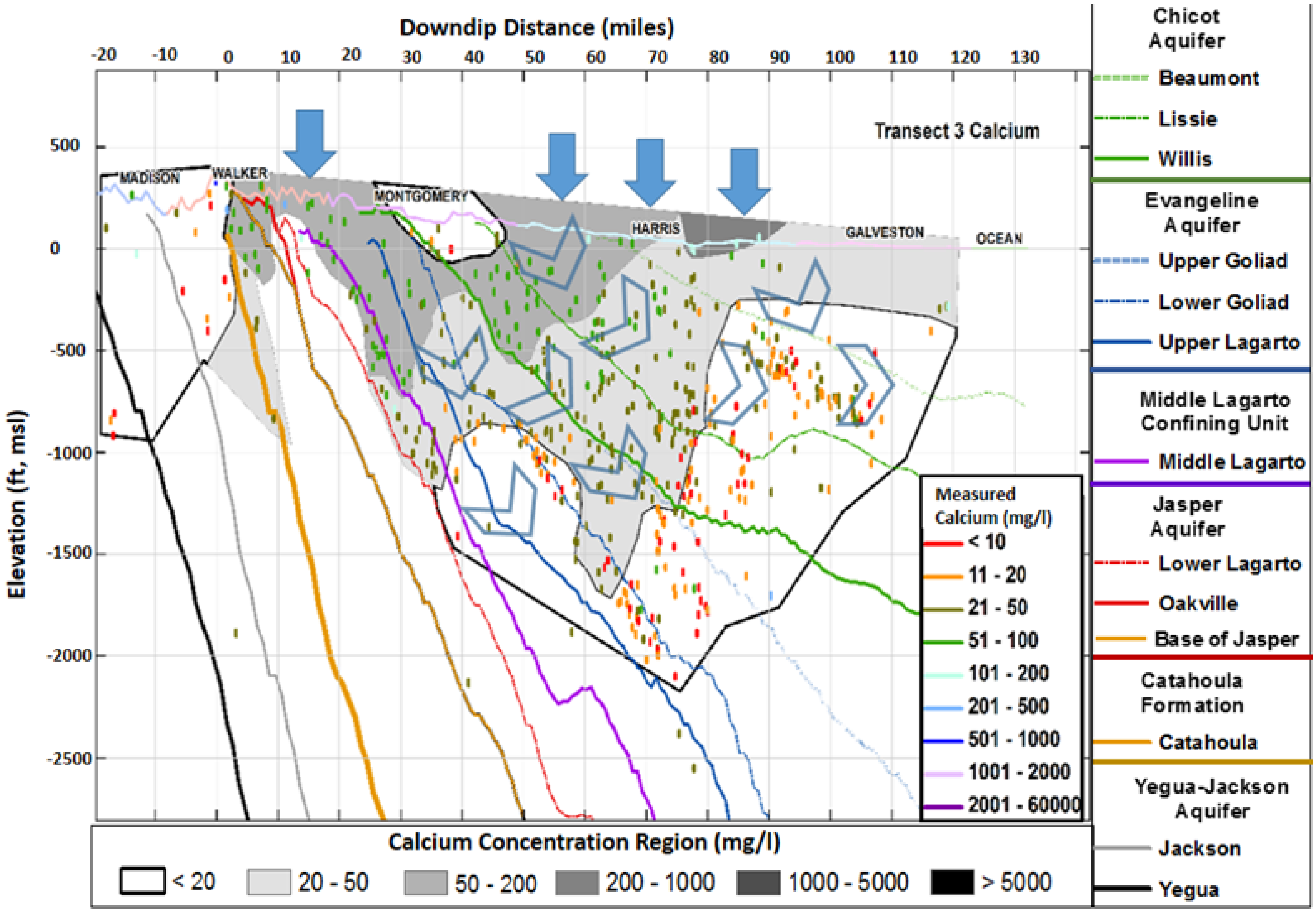
Lithology for Transect 8 (GMA 16)



Calcium Concentrations at Transect 3 (GMA 14)



GEC