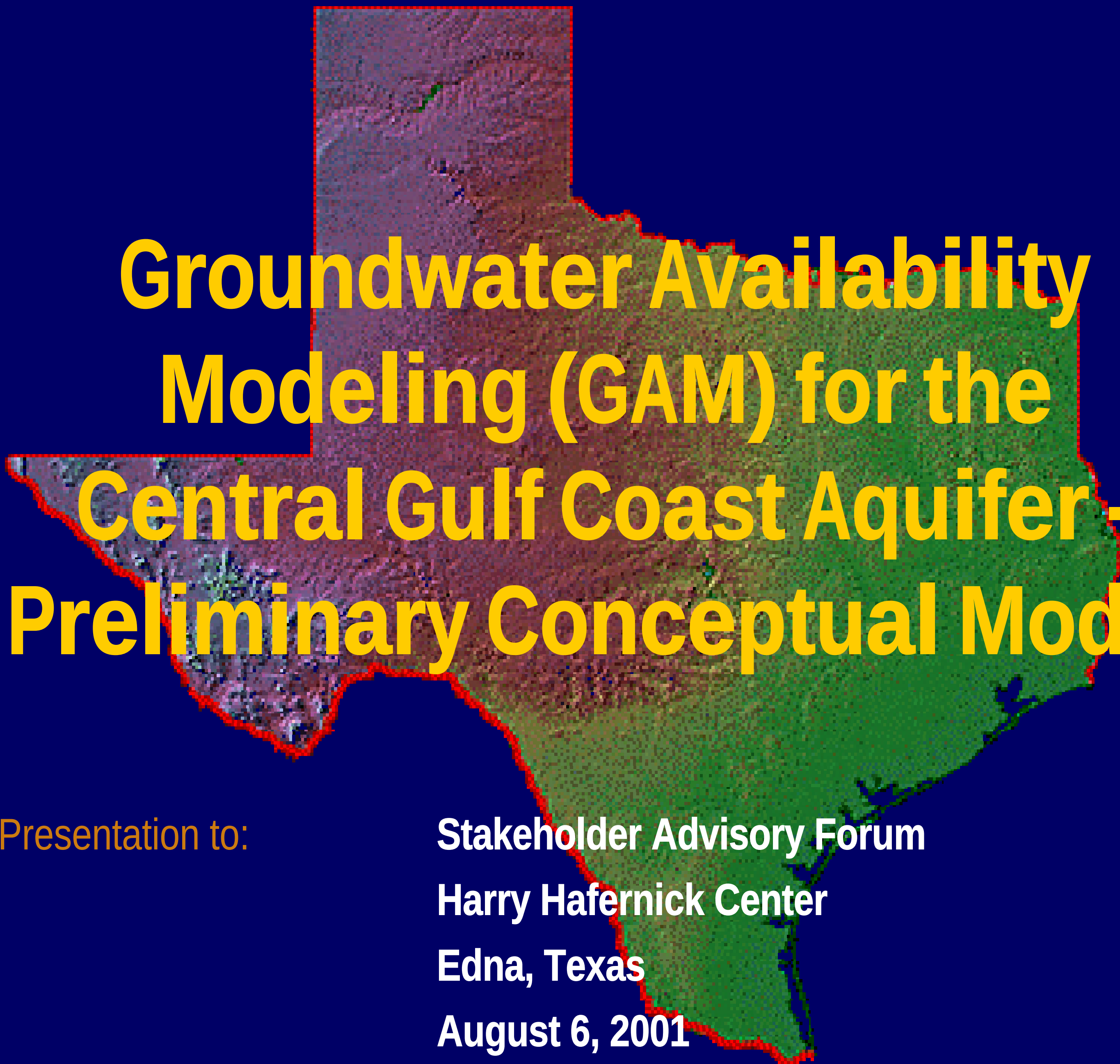
Waterstone

Environmental Hydrology and Engineering Inc.



Groundwater Availability Modeling (GAM) for the Central Gulf Coast Aquifer - Preliminary Conceptual Model

A Presentation to:

Stakeholder Advisory Forum
Harry Hafernick Center
Edna, Texas
August 6, 2001

Presentation Topics

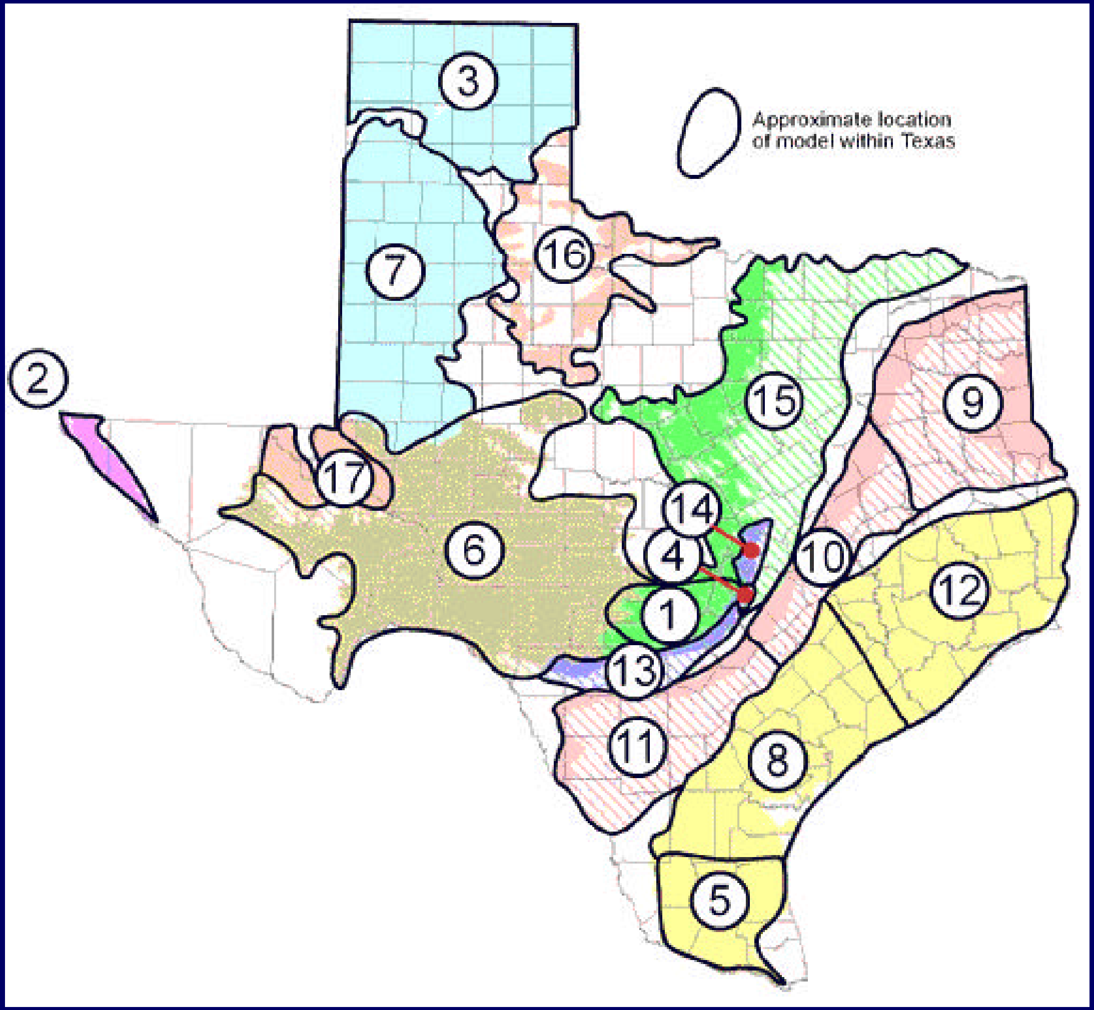
- Review of GAM Objectives
- Conceptual Model of Groundwater Flow for Central Gulf Coast GAM
- GAM Schedule

GAM Objectives

- Include substantial Stakeholder input
- Create standardized, publicly available numerical groundwater flow models with supporting data
- Provide information on groundwater availability through 2050 for normal and drought-of-record conditions
- Provide strategic water-management tools for regional water planning

GAM Regions

- **Ongoing:**
  - Carrizo-Wilcox (9-11)
  - Ogallala south (7)
  - Gulf Coast central (8)
  - Gulf Coast north (12)
  - Lower Rio Grande (5)
  - Edwards Trinity (6)
- **Completed:**
  - Trinity HC (1)
  - Hueco Bolson (2)
  - Ogallala north (3)
  - Edwards - BS (4)

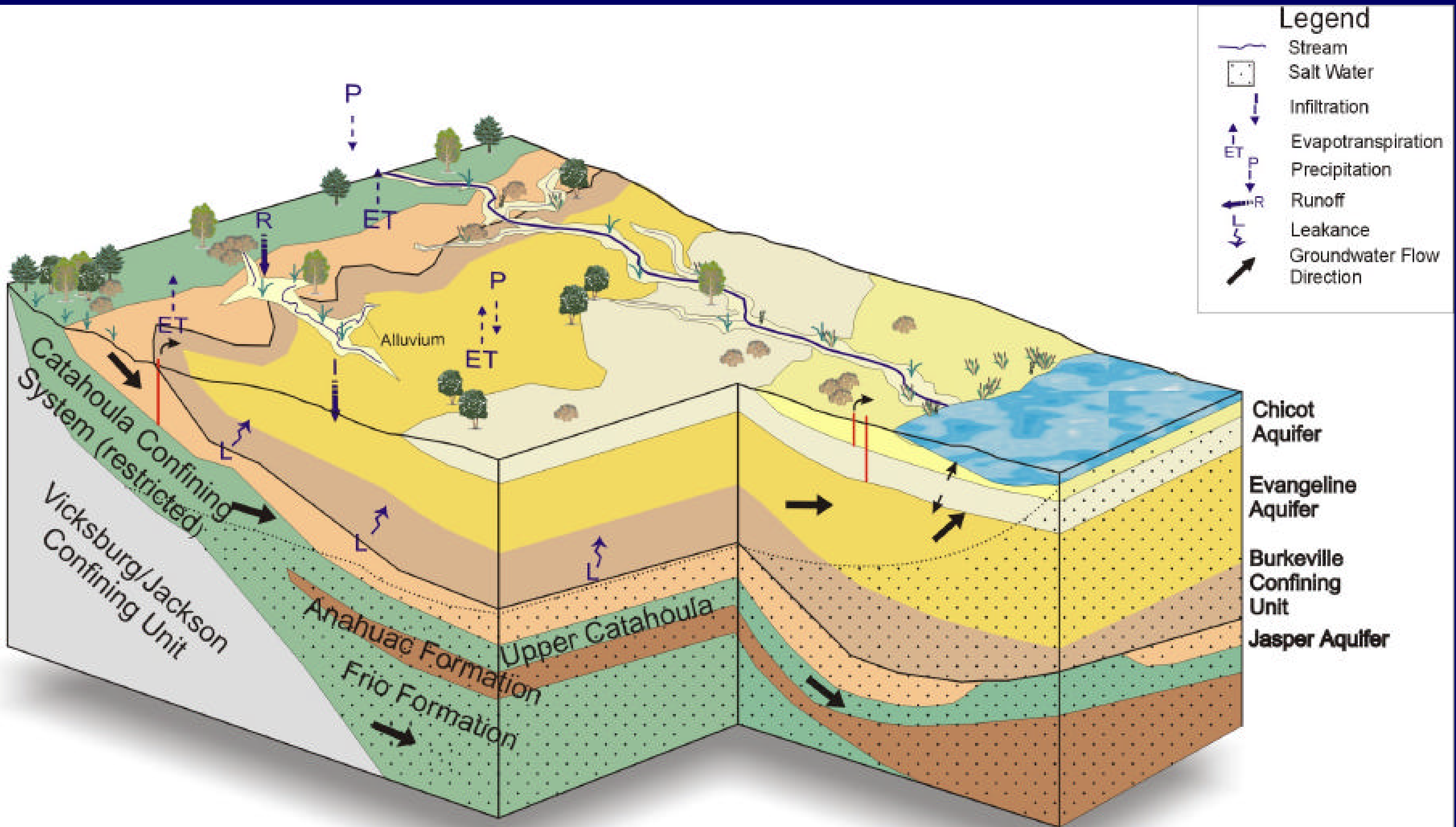


http://www.twdb.state.tx.us/gam

Conceptual Model Topics

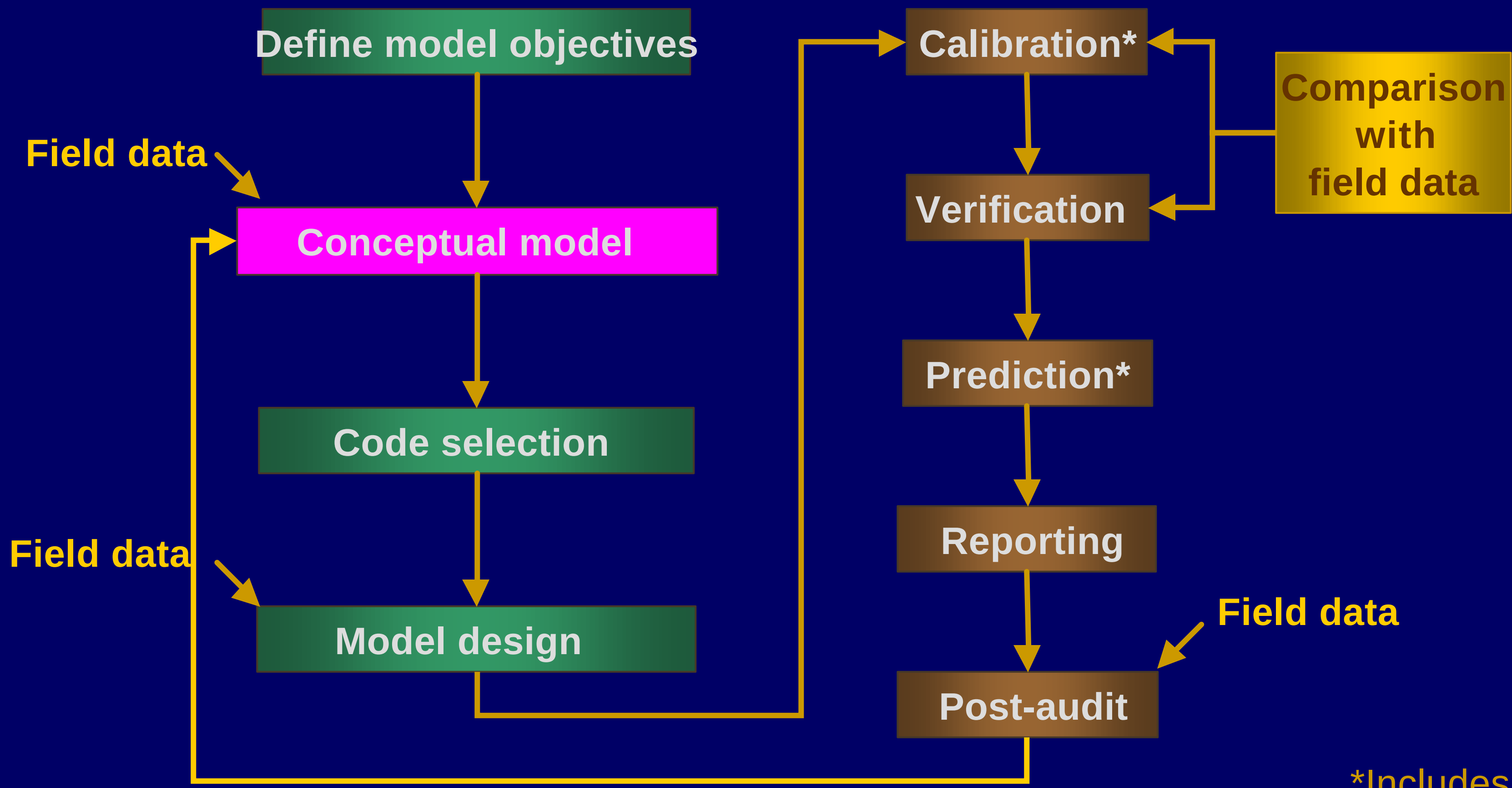
- Schematic Diagram of Aquifer System
- Model Region and Boundaries
- Geology/Hydrostratigraphy
- Structure
- Water Levels & Regional Groundwater Flow
- Hydraulic Properties
- Recharge
- Discharge
- Water Quality
- Subsidence

Schematic Diagram of Flow System



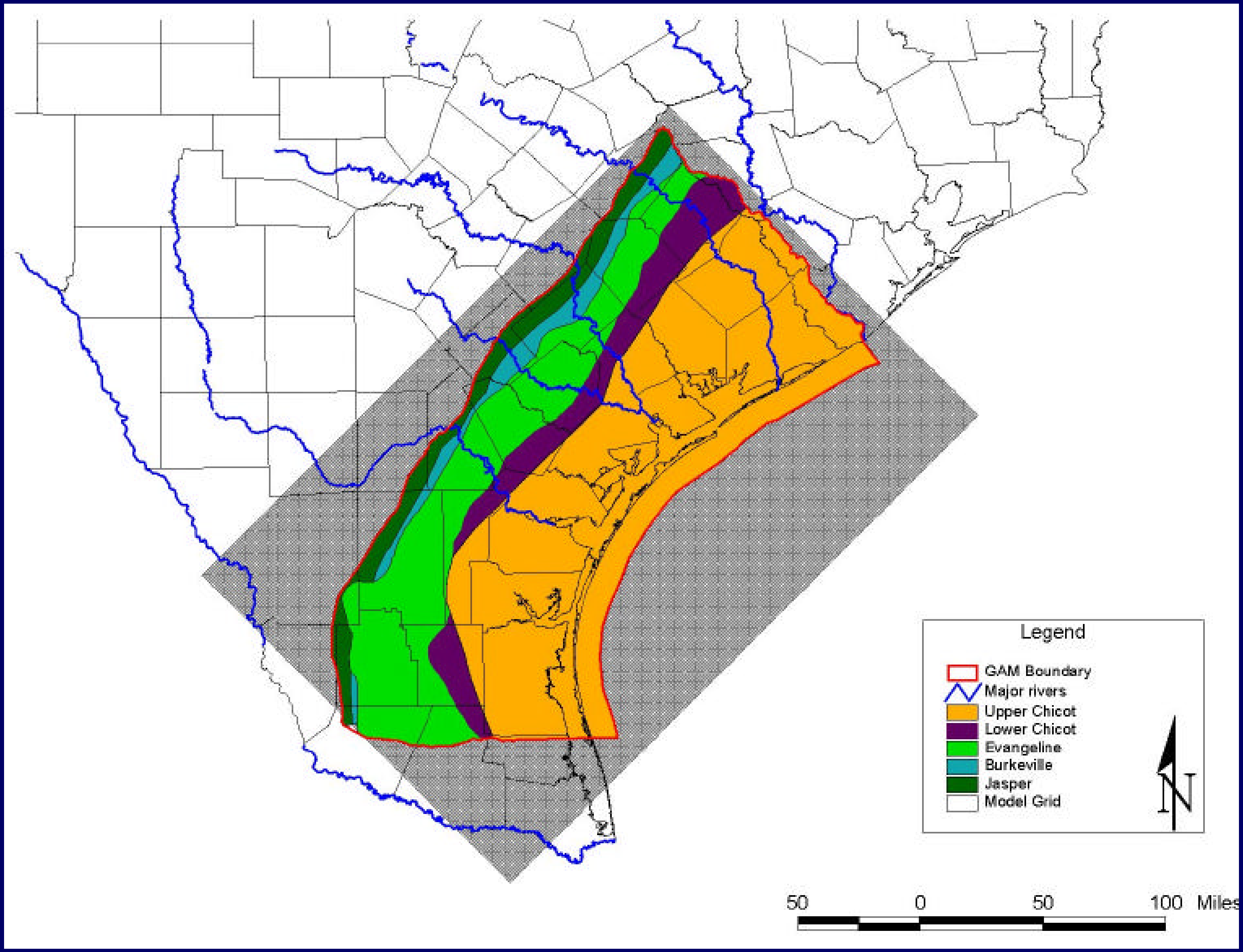
Geology adapted from Baker (1979, 1986)

Groundwater Modeling Steps

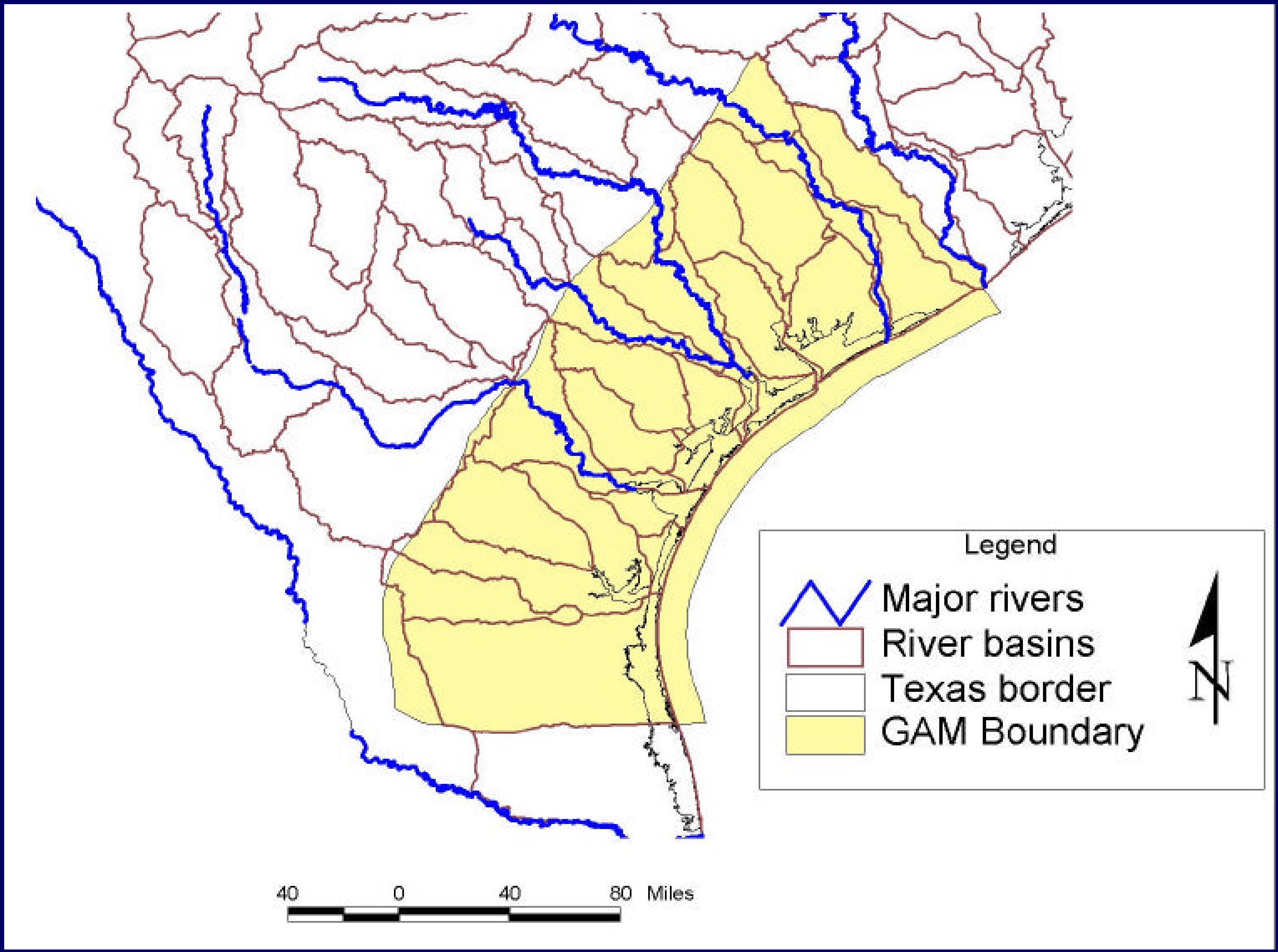


*Includes sensitivity analysis

Numerical Model Grid



Model Region/Boundaries



Geologic Formations

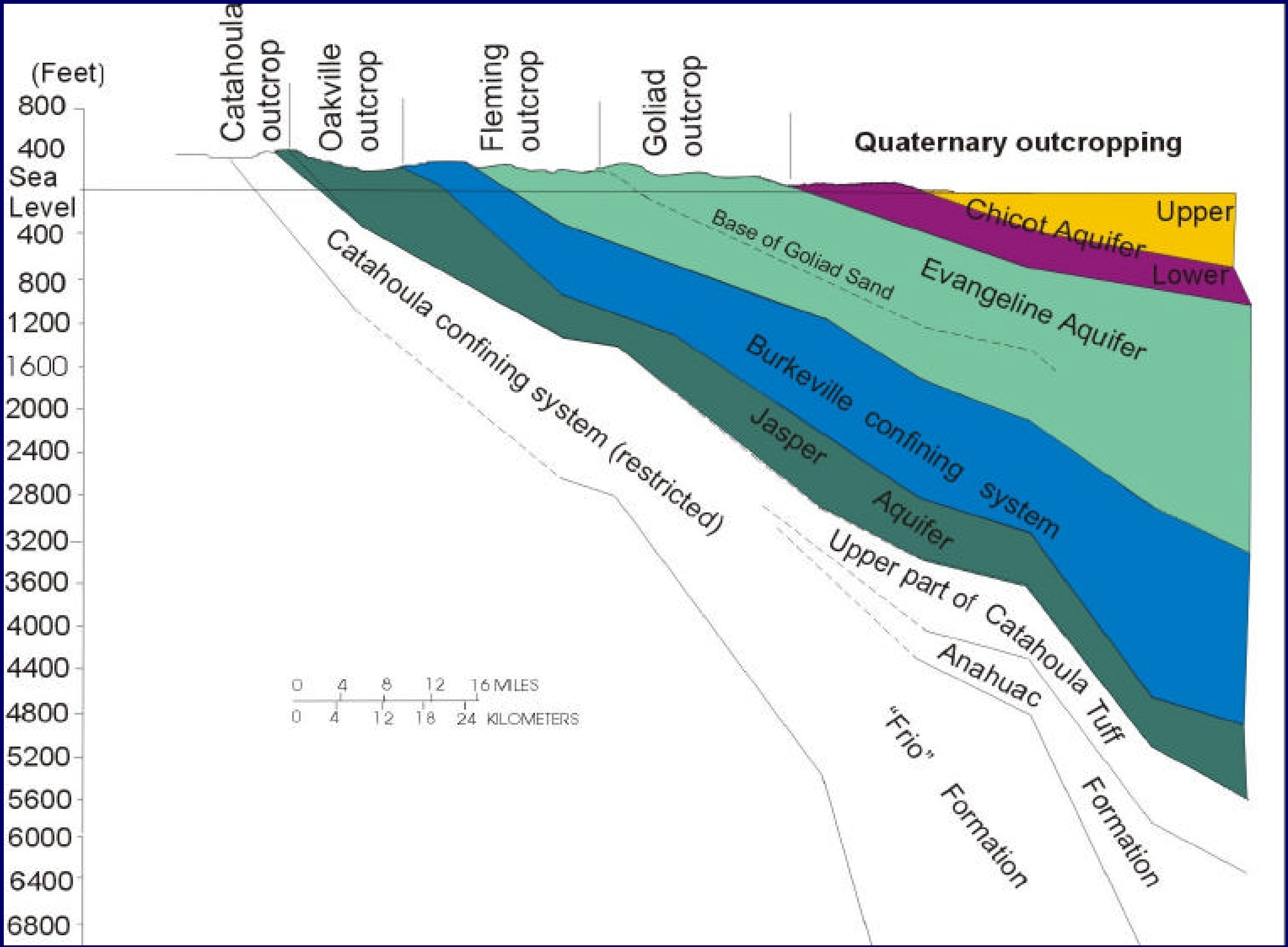
System	Series	Stratigraphic Units Baker (1979)	Hydrogeologic Units Baker (1979)	Hydrogeologic Units Carr, et al. (1985)	Hydrogeologic Units Ryder (1988)	Hydrogeologic Units TAMU-CC(2000)
Quaternary	Holocene	Alluvium	Chicot Aquifer	Upper Chicot Aquifer	Holocene-Upper Pleistocene Permeable Zone	Upper Chicot Aquifer
	Pleistocene	Beaumont Clay				
		Montgomery Fm.				
		Bentley Fm.		Lower Chicot Aquifer	Lower Pleistocene-Upper Pliocene Permeable Zone	Lower Chicot Aquifer
		Willis Sand				
Tertiary	Pliocene	Goliad Sand	Evangeline Aquifer	Evangeline Aquifer	Lower Pilocene-Upper Miocene Permeable Zone	Evangeline Aquifer
	Miocene	Fleming Fm.	Burkeville Confining Unit	Burkeville Confining Unit	Middle Miocene Confining Unit	Lagarto Confining Unit
		Oakville Sandstone	Jasper Aquifer			Jasper Aquifer
		Catahoula Tuff	Catahoula Confining System		Middle Miocene Permeable	
	Oligocene	Anahuac Fm.			Lower Miocene-Upper Oligocene Confining Unit	
		Frio Fm.			Lower Miocene-Upper Oligocene Permeable Unit	

Adapted from TAMU-CC (2000)

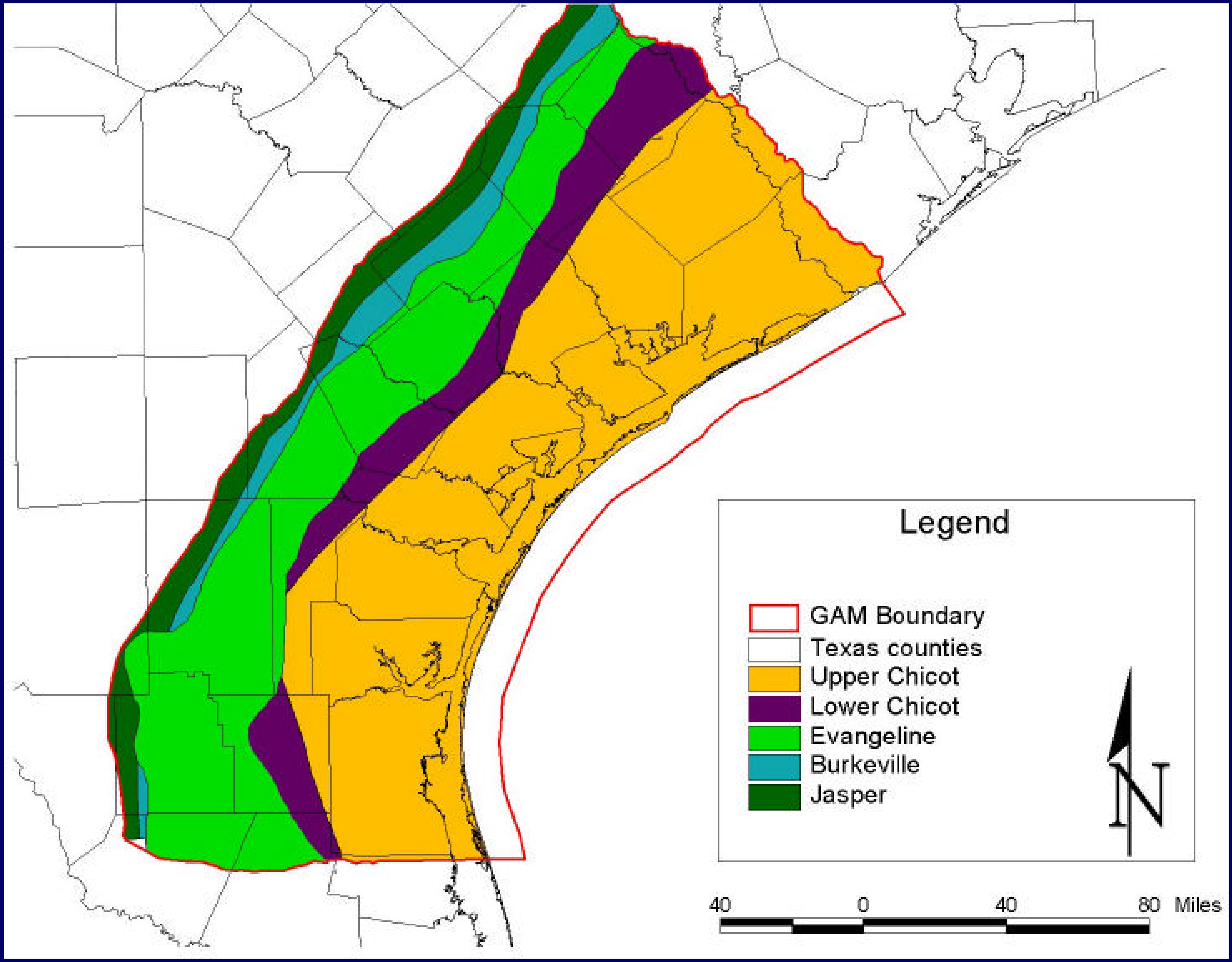
Modeled Formations

<table>
<tr><th>Stratigraphic Units</th><th colspan="2">Hydrogeologic Units</th><th rowspan="2">Model Layer</th></tr>
<tr><th>Baker (1979)</th><th>Baker (1979)</th><th>Carr, et al. (1985)</th></tr>
<tr><td>Alluvium</td><td rowspan="5">Chicot Aquifer</td><td rowspan="3">Upper Chicot Aquifer</td><td rowspan="3">1</td></tr>
<tr><td>Beaumont Clay</td></tr>
<tr><td>Montgomery Fm.</td></tr>
<tr><td>Bentley Fm.</td><td rowspan="2">Lower Chicot Aquifer</td><td rowspan="2">2</td></tr>
<tr><td>Willis Sand</td></tr>
<tr><td>Goliad Sand</td><td>Evangeline Aquifer</td><td>Evangeline Aquifer</td><td>3</td></tr>
<tr><td>Fleming Fm.</td><td>Burkeville Confining Unit</td><td>Burkeville Confining Unit</td><td>4</td></tr>
<tr><td>Oakville Sandstone</td><td>Jasper Aquifer</td><td rowspan="2"></td><td rowspan="2">5</td></tr>
<tr><td>Catahoula Tuff</td><td>Catahoula Confining System</td></tr>
</table>

Cross Section



Preliminary Geologic Outcrops



Hydrostratigraphic Structure: Data Sources

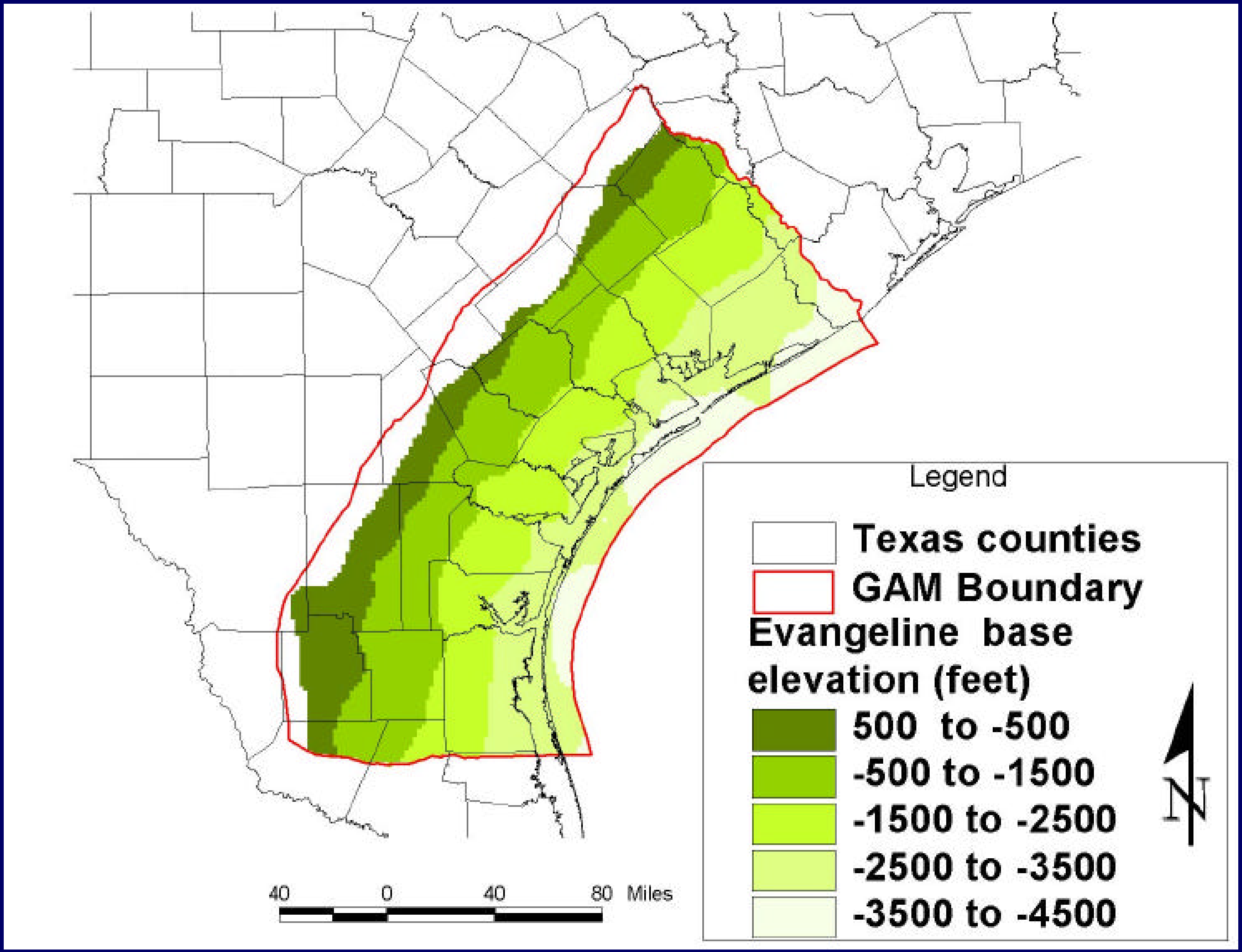
	Baker (1979)	Carr et al. (1985)	Chowdhury (2001)
Chicot	♦	♦	♦
Evangeline	♦	♦	♦
Burkeville	♦		♦
Jasper	♦		♦

Note: Chicot was further divided into Upper & Lower units based on Ryder (1988).

Hydrostratigraphic Structure

- ➲ Baker (1979)—TWDB Report 236
  - 7 cross sections defining all 5 hydrostratigraphic layers
- ➲ Carr et al. (1985)—TWDB Report 289
  - Detailed contour maps define base of Chicot and Evangeline
  - About 400 electric logs used to define contours
- ➲ Chowdhury (in progress)—Southern Gulf Coast GAM
  - Model overlap with SGC GAM
  - Used Baker (1979), Carr et al. (1985) and about 50 additional borehole electric logs
- ➲ TAMU—CC
  - Used their subdivision of Upper Chicot

HSU Structure – Evangeline



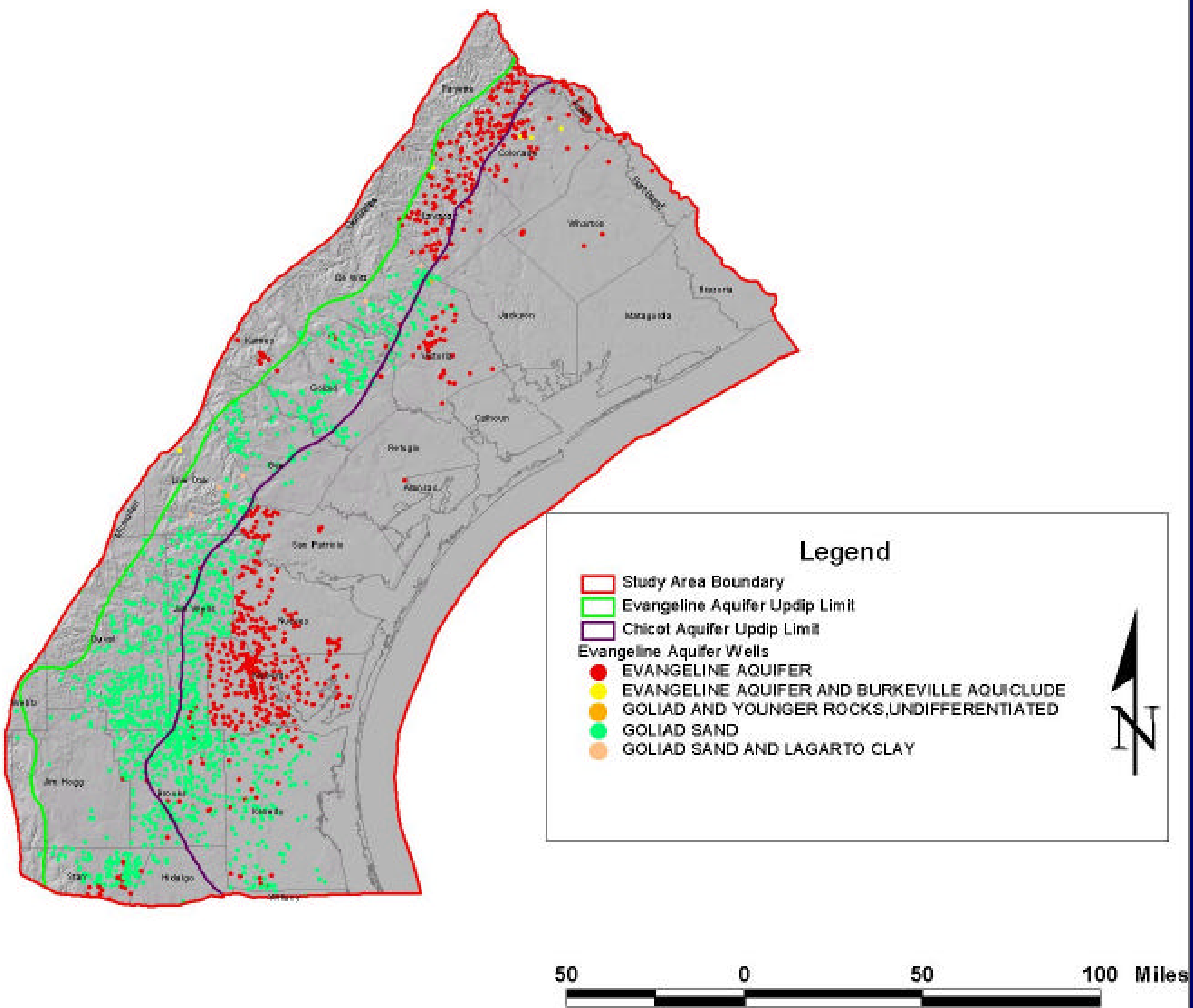
Water Levels & Regional GW Flow

- ➲Develop water level maps
  - – Predevelopment water levels for model initialization
  - – 1980 - 1990 water levels for calibration
  - – 1990 - 2000 water levels for verification
- ➲Hydrographs for calibration
- ➲Evaluate cross-formational flow

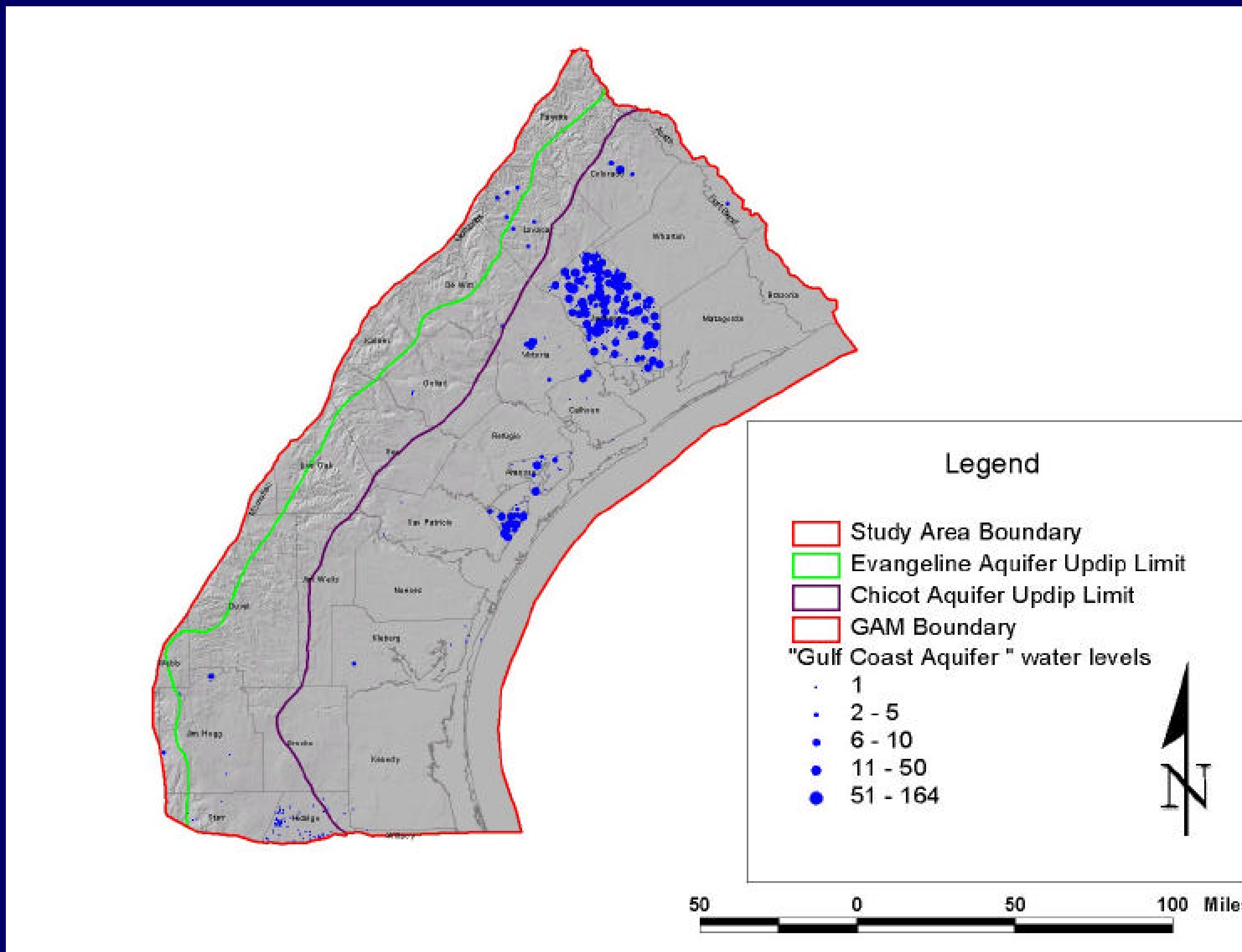
Water-Level Data Sources

- TWDB Groundwater Database
- USGS Reports
- TWDB and predecessor reports

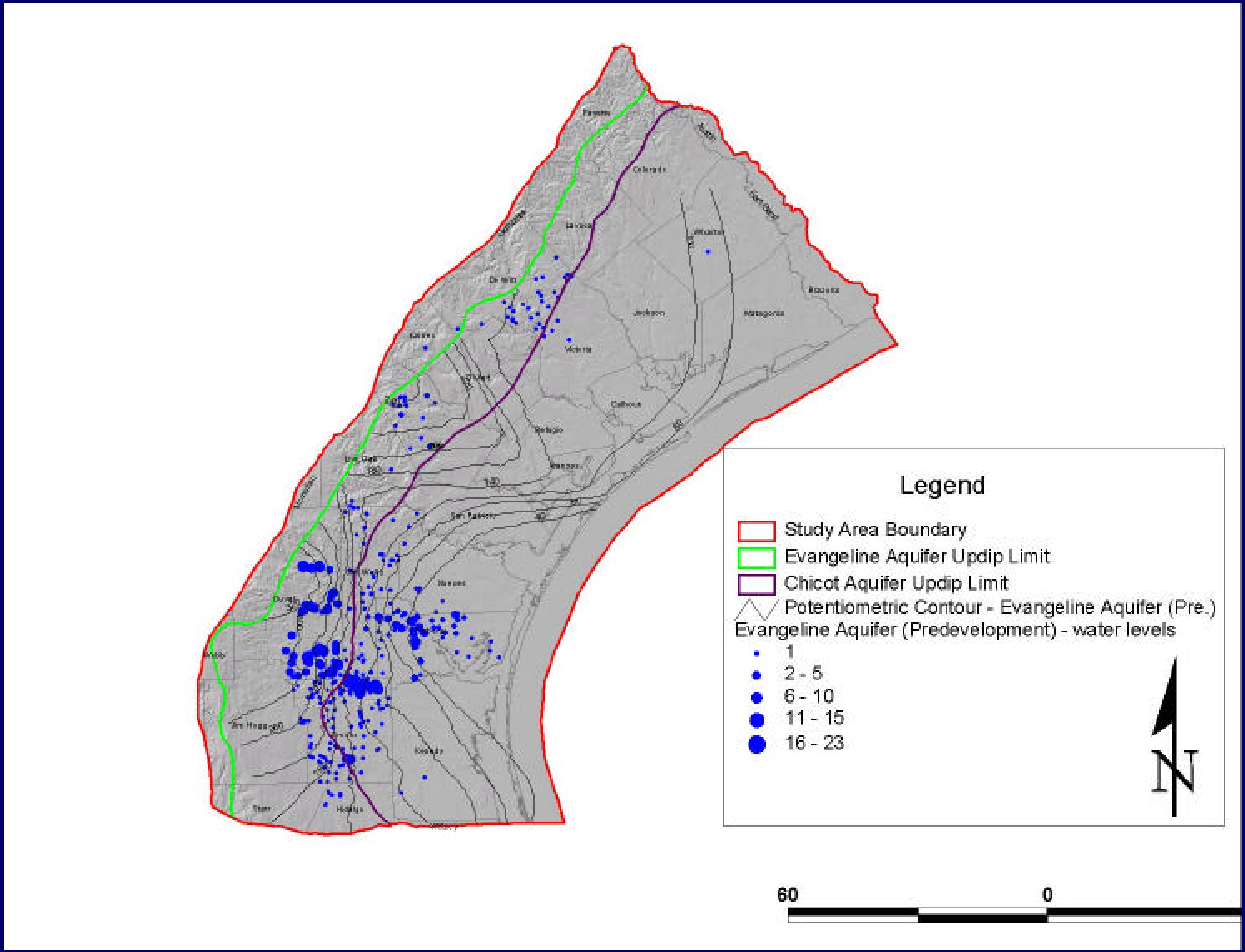
Evangeline Aquifer Wells



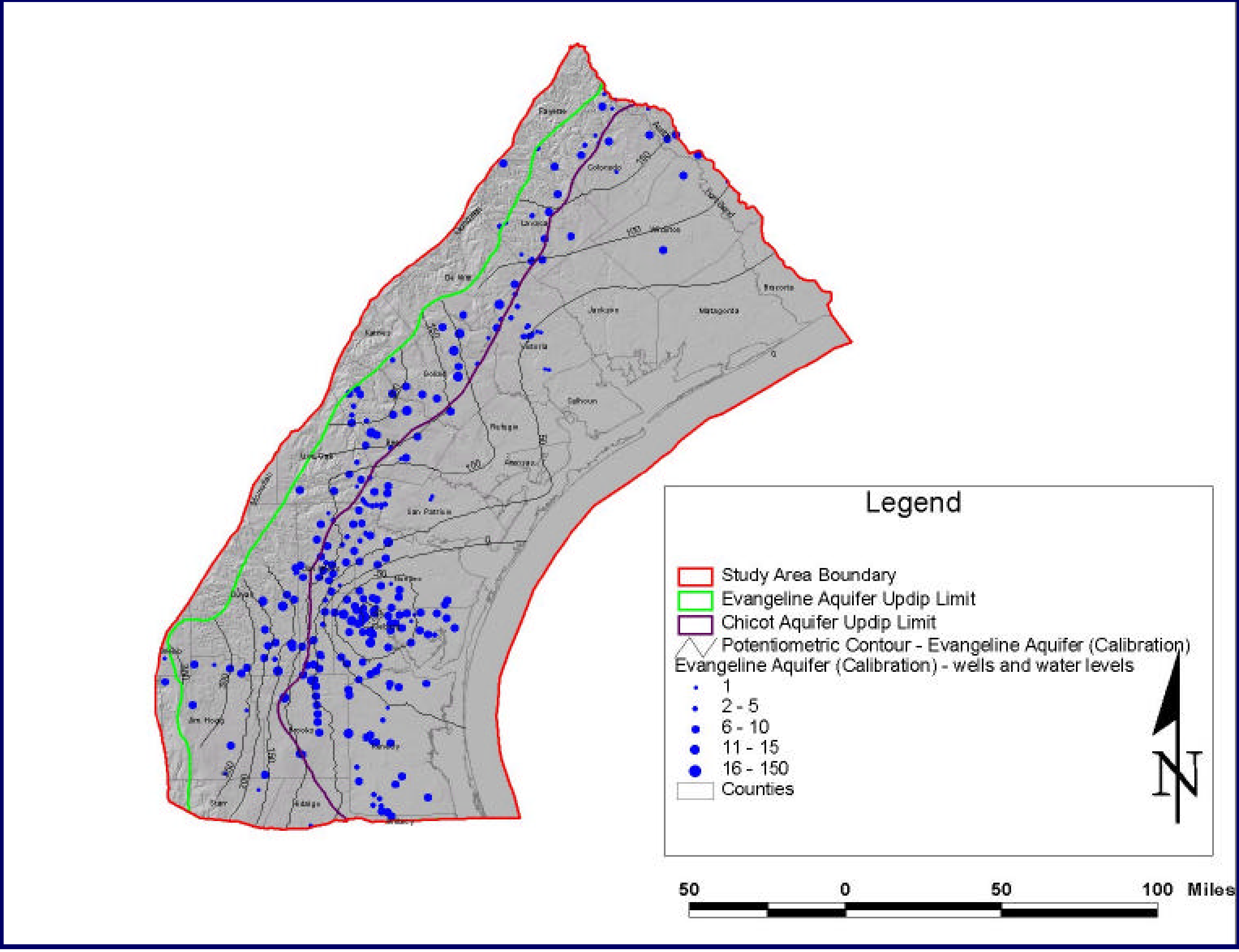
Anomalous Data: Gulf Coast Aquifer Wells?



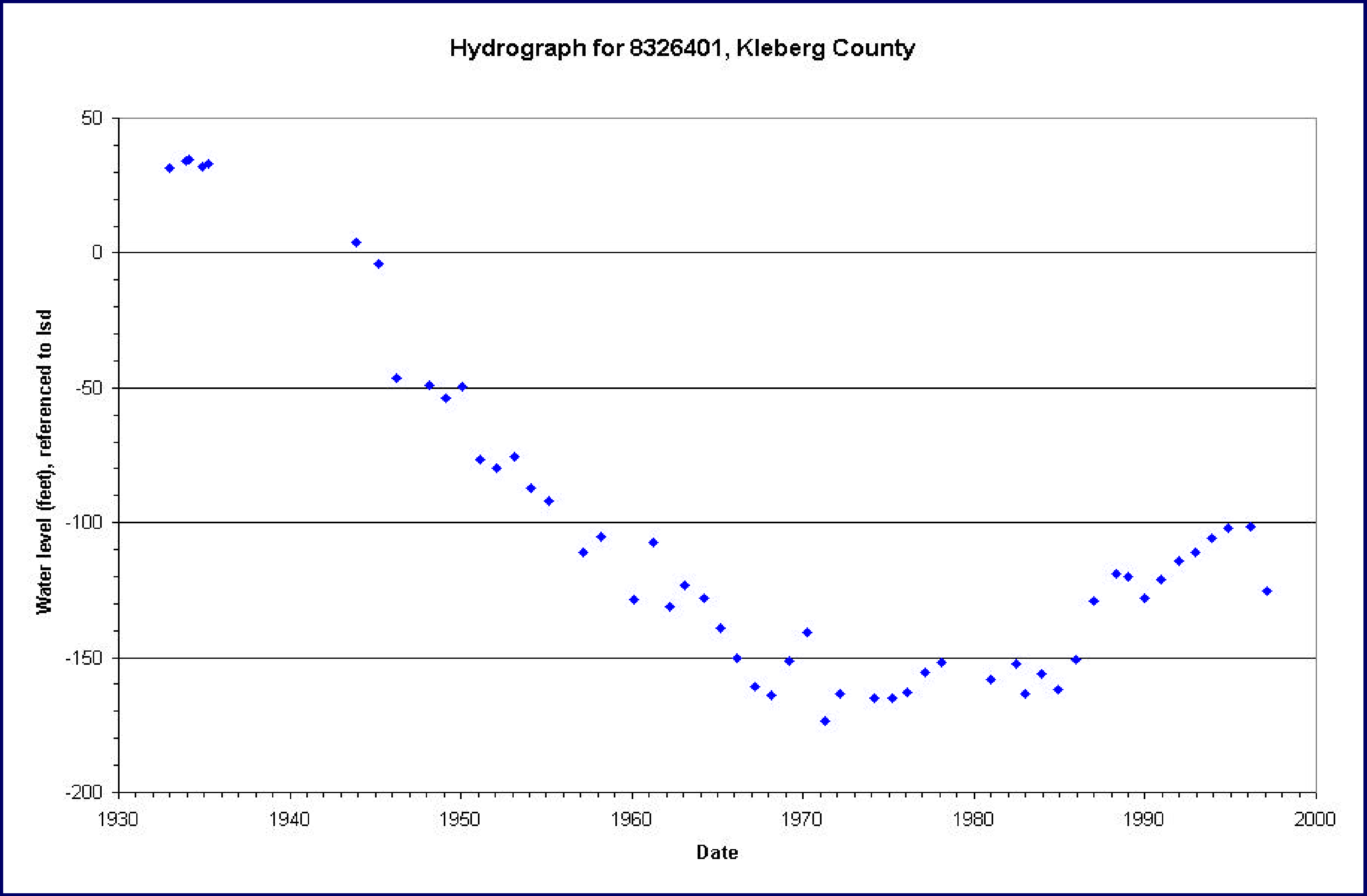
Evangeline Aquifer Predevelopment



Evangeline Aquifer Calibration 1980-1990



Evangeline Aquifer – Kleberg Co.



Water-Level Data Analysis

- All data are *not* equal
  - The only situation worse than no data is bad data
- Evaluate and analyze anomalous water-level measurements
  - Prioritized based upon rank assigned from moving neighborhood
  - Special attention to predevelopment water levels in highly developed areas such as municipalities
  - Utilize spatial data and point data
  - Attribute (flag) each measurement

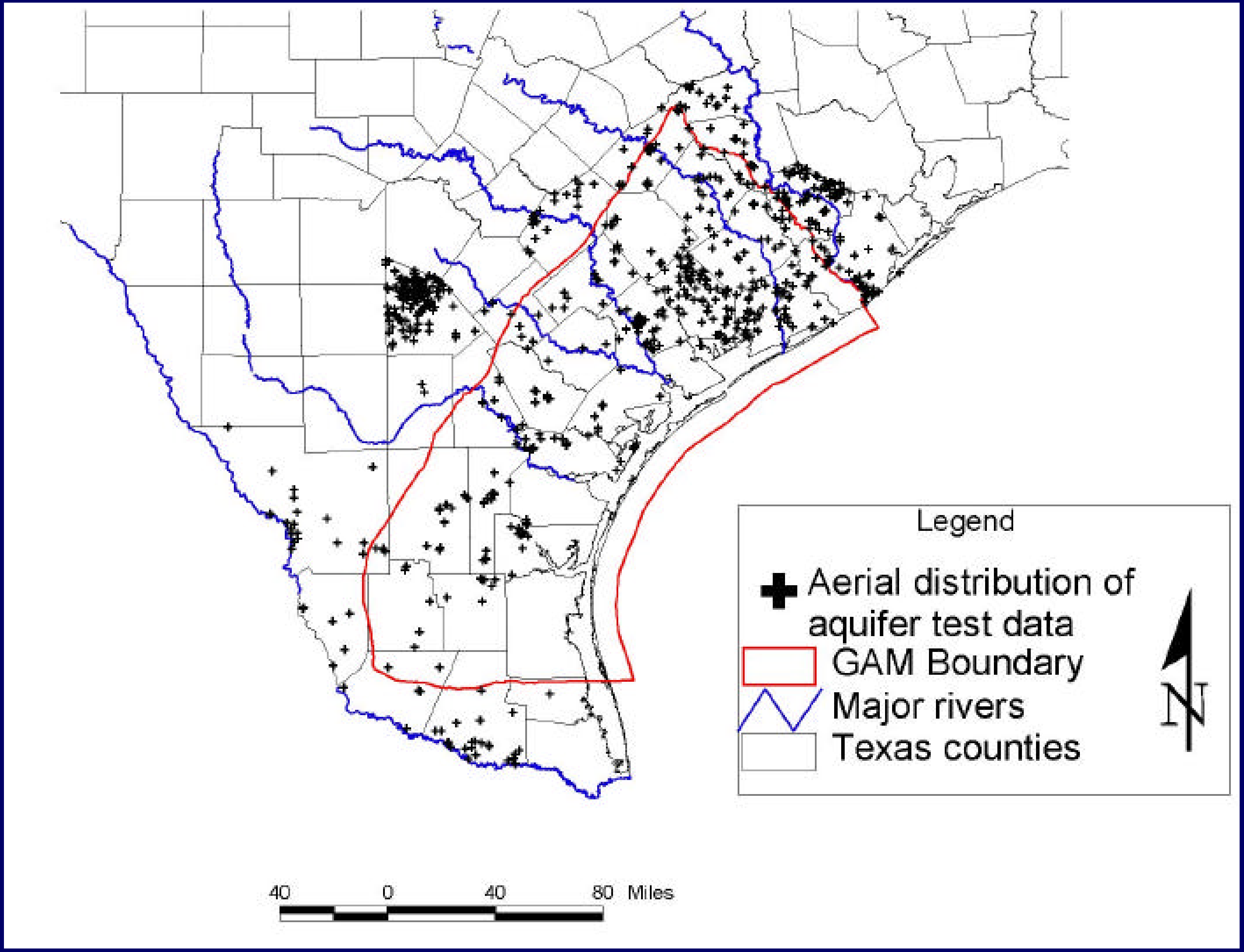
Aquifer Hydraulic Properties

- Properties related to aquifer's ability to transmit and store groundwater
  - Hydraulic conductivity (K)
  - Storativity (S)
  - Specific Yield (S_y)

Data Sources and Approach

- Data sources:
  - Myers 1969 – TWDB aquifer test summary report
  - County groundwater reports
  - TWDB online database of specific capacity results
- Coordinates used where provided, otherwise reconciled with TWDB well database
- Contoured information not used since underlying data is unknown
- Grouped by aquifer and analyzed

Areal Distribution of Aquifer Property Data



Data Status

Data Type	Acquired	Formatted	Processed
Specific Capacity (K)	Yes	Yes	No
Aquifer Tests (K, S)	Yes	Yes	Yes
Net or % sand	Yes	Yes	Yes

Preliminary Summary of Results from Aquifer Tests

	Layer	# Data	Average	Range
S	Chicot	21	9.1E-04	4.6E-5 - 4.0E-03
	Evangeline	30	3.3E-04	1.8E-05 - 1.0E-03
	Burkeville	4	6.0E-03	1.3E-04 - 1.0E-02
	Jasper	6	3.7E-03	7.0E-05- 1.8E-02
K (ft/d)	Chicot	116	51	2.3 - 623
	Evangeline	77	19	0.4 - 131
	Burkeville (outcrop)	16	35	2 - 120
	Jasper	12	11	0.8 - 36

Hydraulic Conductivity Data Review

- Potential errors in assignment to proper model layers
  - To be evaluated during calibration
  - QC screened interval against layering geometry in GIS
- Data represent horizontal hydraulic conductivity, no vertical hydraulic conductivity reported
- Burkeville data scarce since not usually a water source
- Derived K data is a starting point—calibrate to final K

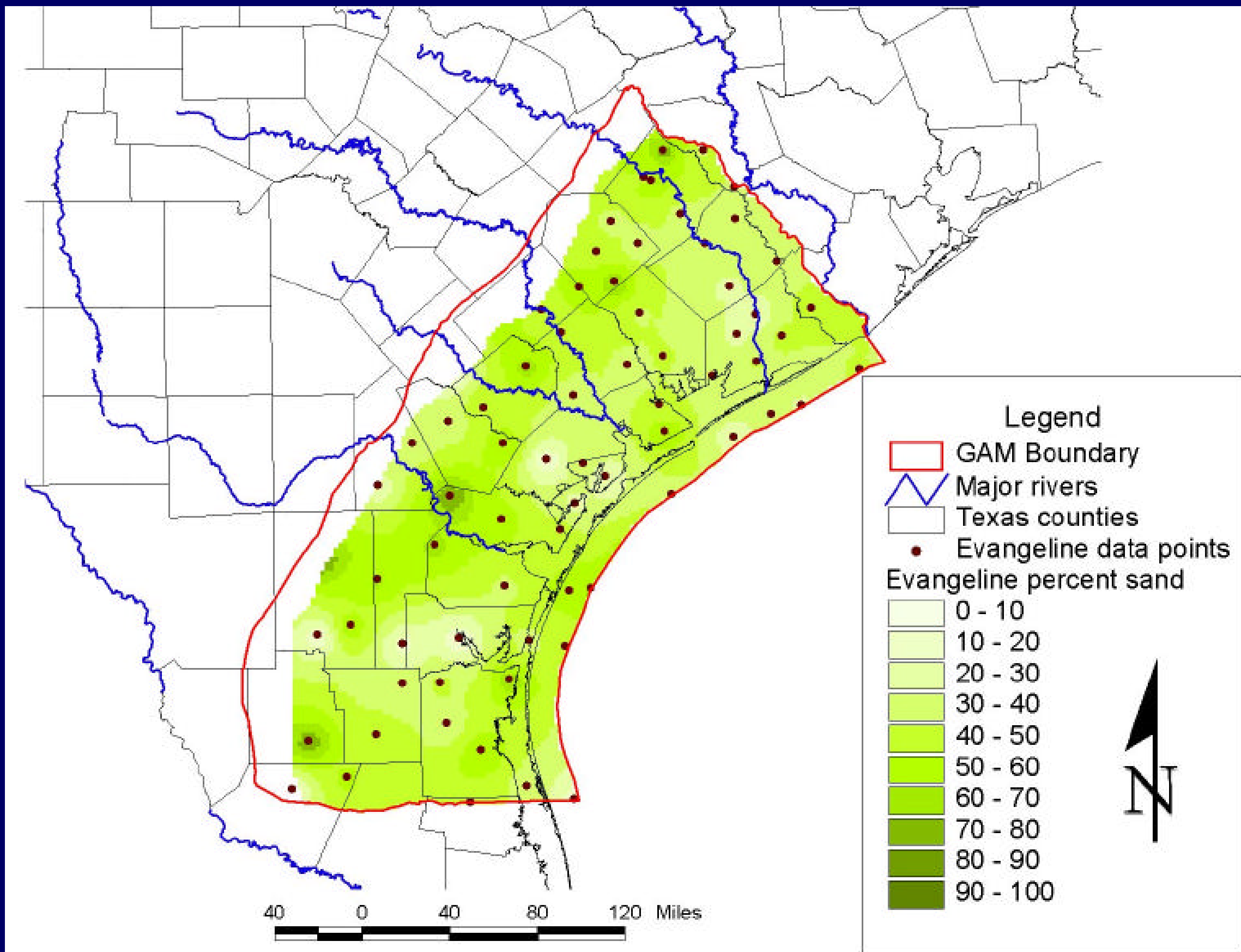
Storativity Data Review

- Potential error in assignment to proper model layers
  - To be evaluated during calibration
  - QC screened interval against layering geometry in GIS
- Specific storage will be estimated from pumping test data
- Specific yield data
  - Can be reasonably estimated for these types of materials

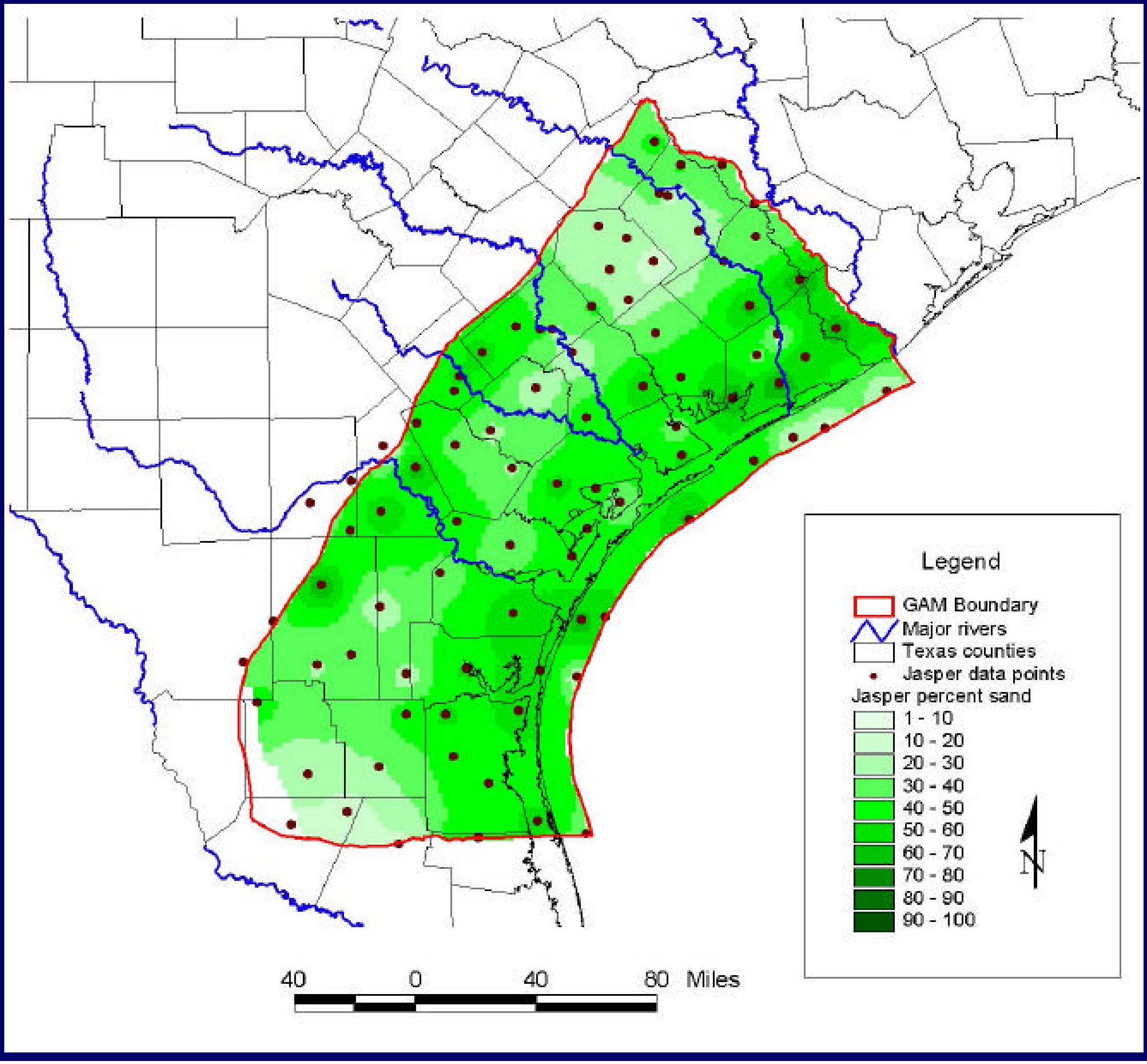
Sand Percent

- ➲ Aquifer deposits are derived from streams and deltas
  - ➲ Sandier parts represent channels
- ➲ Sandier parts have higher ability to transmit groundwater (hydraulic conductivity)
- ➲ In other Texas aquifer systems it is possible to relate hydraulic conductivity to amount of sand to provide extra information about the aquifer
- ➲ Obtained Wilson and Hosman (1988) analysis of geophysical well logs for sand percent

Evangeline Sand Percentage



Jasper Sand Percentage



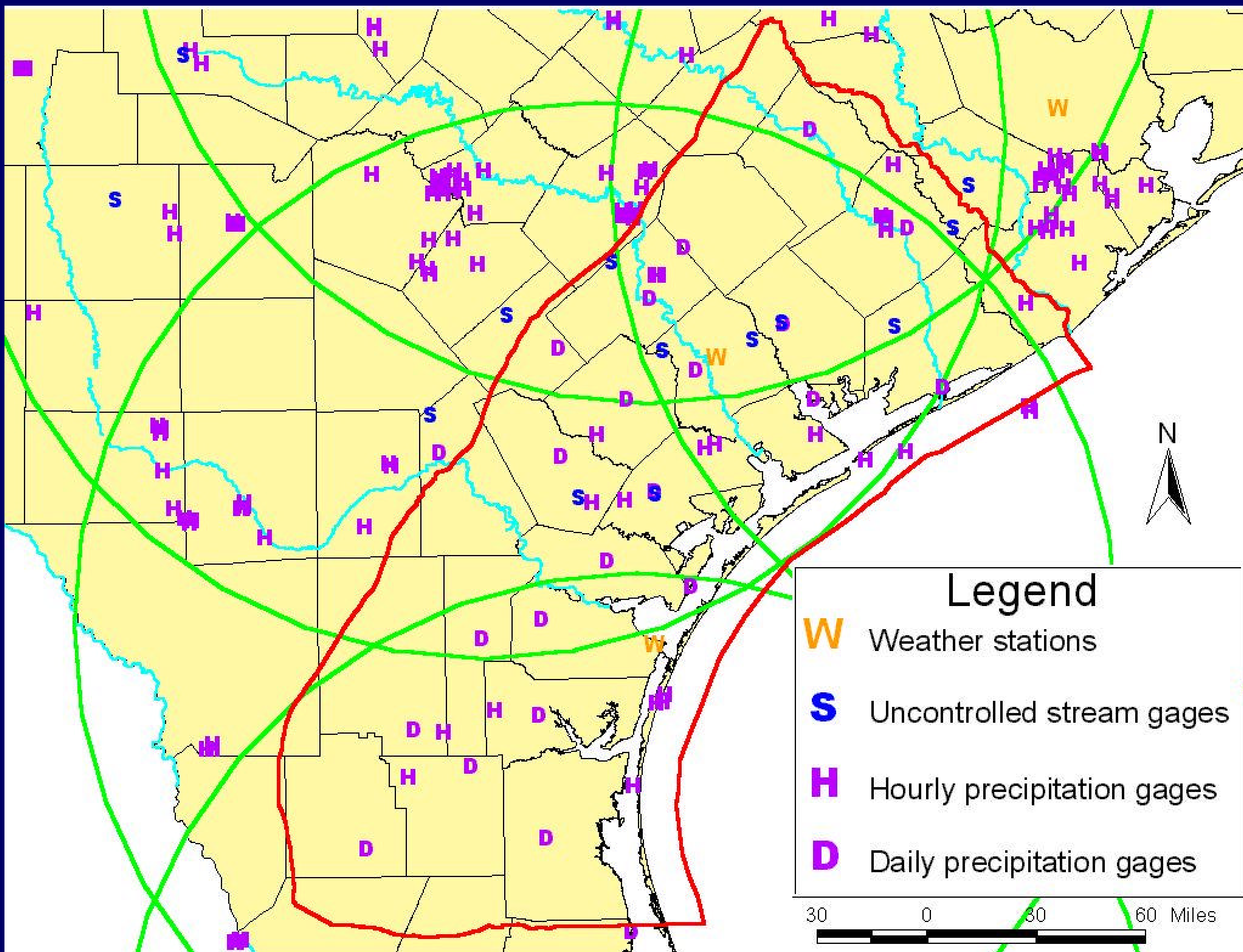
Data Use in Calibration

- Use sand percentage to establish areas of similar properties
- Use test data to establish initial K, S, and Sy
- Calibrate vertical hydraulic conductivity (no test data)

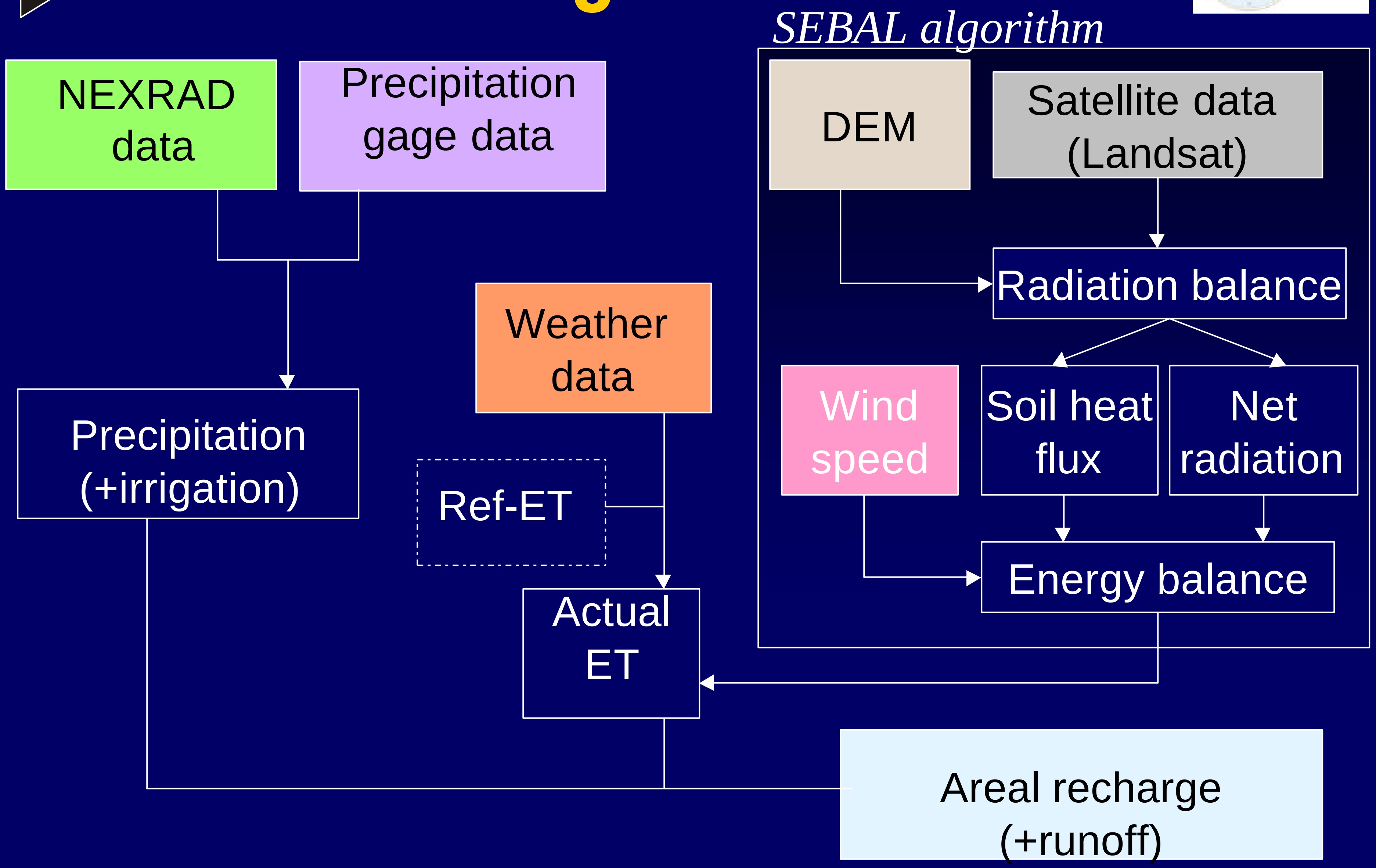
Recharge

- ➲ Infiltration
  - – Precipitation
  - – Temperature
  - – Evaporation and ET
  - – Irrigation/Crop Use
- ➲ SW/GW interaction

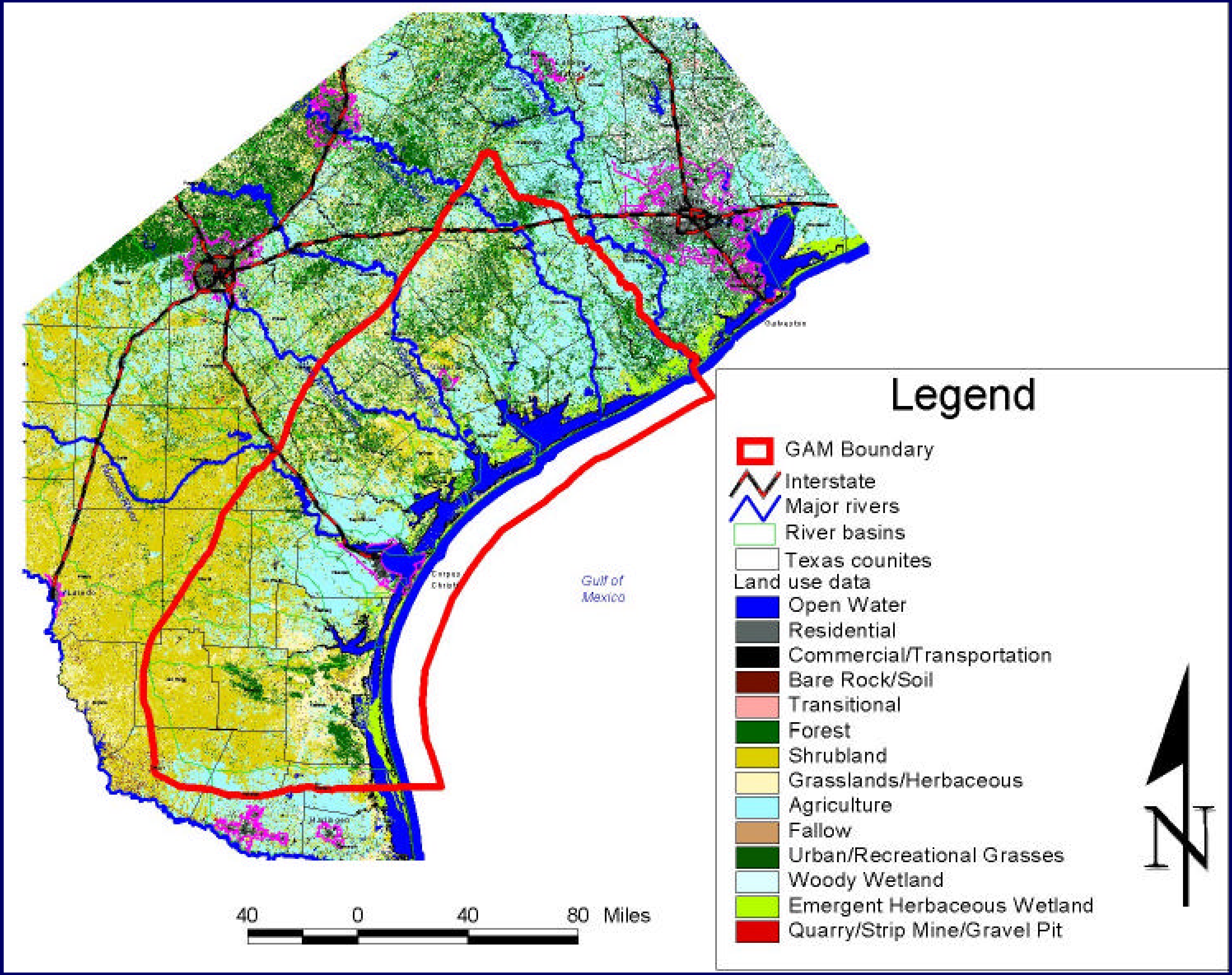
Data Coverage for Recharge Estimation



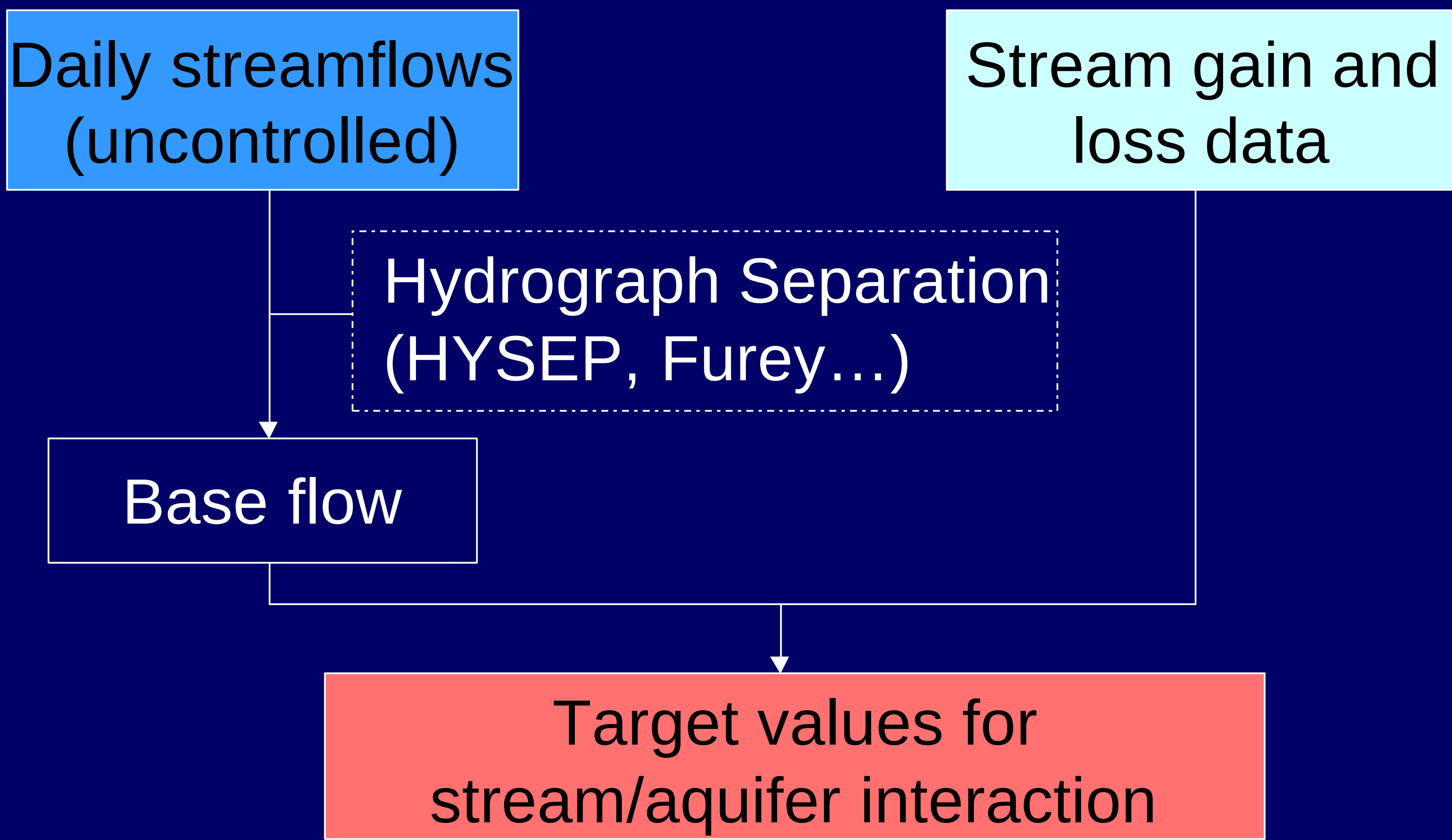
Areal Recharge



Land Use


Galveston
Corpus Christi
Laredo
Gulf of Mexico
Legend
GAM Boundary
Interstate
Major rivers
River basins
Texas counites
Land use data
Open Water
Residential
Commercial/Transportation
Bare Rock/Soil
Transitional
Forest
Shrubland
Grasslands/Herbaceous
Agriculture
Fallow
Urban/Recreational Grasses
Woody Wetland
Emergent Herbaceous Wetland
Quarry/Strip Mine/Gravel Pit
N
40 0 40 80 Miles

Stream/Aquifer Interaction



Presentation of Findings

Data Type	Acquired	Formatted	Processed
Precip.	Yes	Yes	No
NEXRAD	No	No	No
Weather	Yes	Yes	Yes
Stream flow	Yes	Yes	Partial

Infiltration - Current Status

- Current data gaps: NEXRAD data
- Furey algorithm vs. HYSEP program for base flow separation
- Which ET package to use?

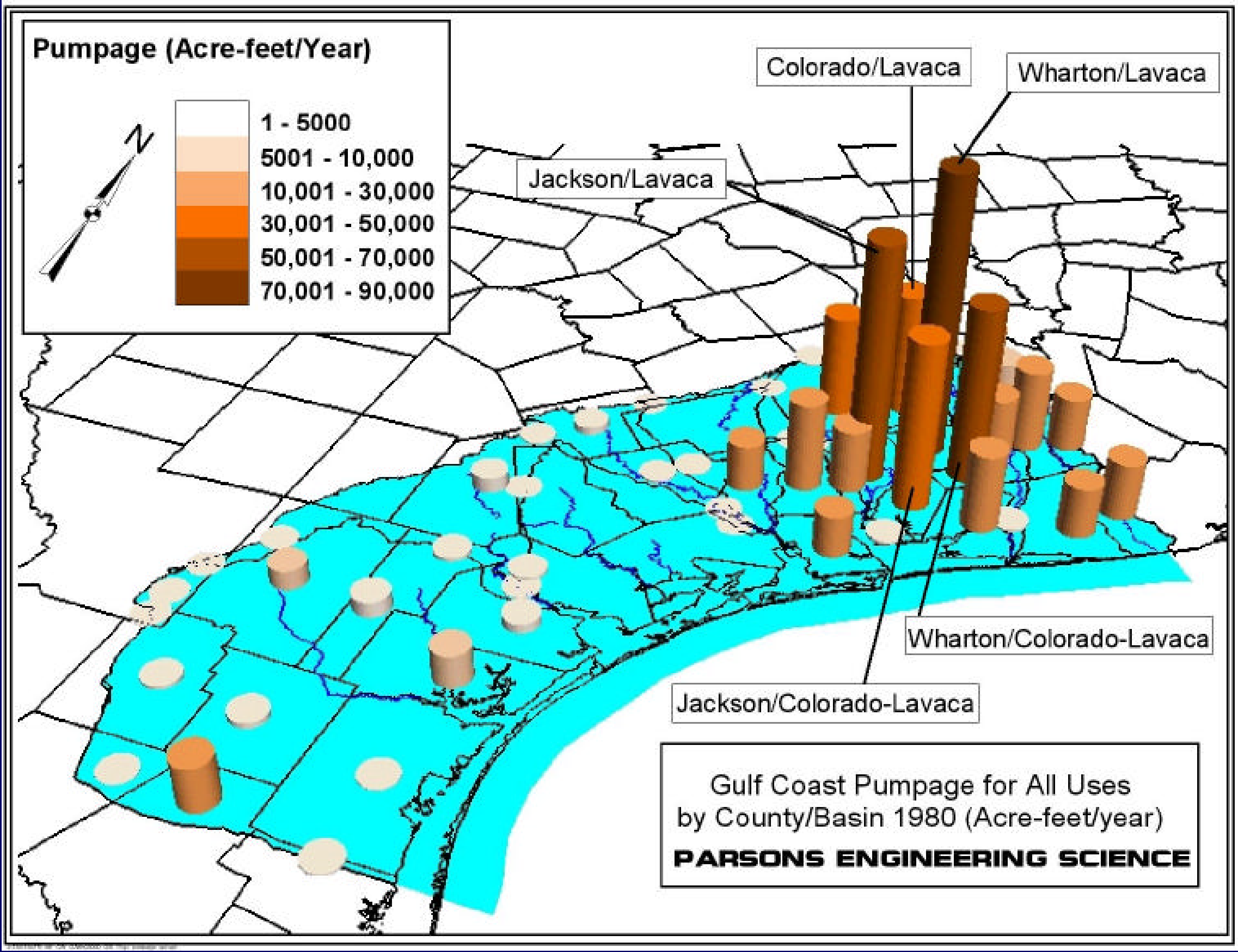
Discharge

- Baseflow to rivers, lakes, springs
  - Parameters and hydrograph calibration targets (WAM & USGS)
  - Streamflow, lake, and drain MODFLOW packages
- Cross-formational flow
- Pumping
  - Historical (pre-development to 2000)
  - Projected

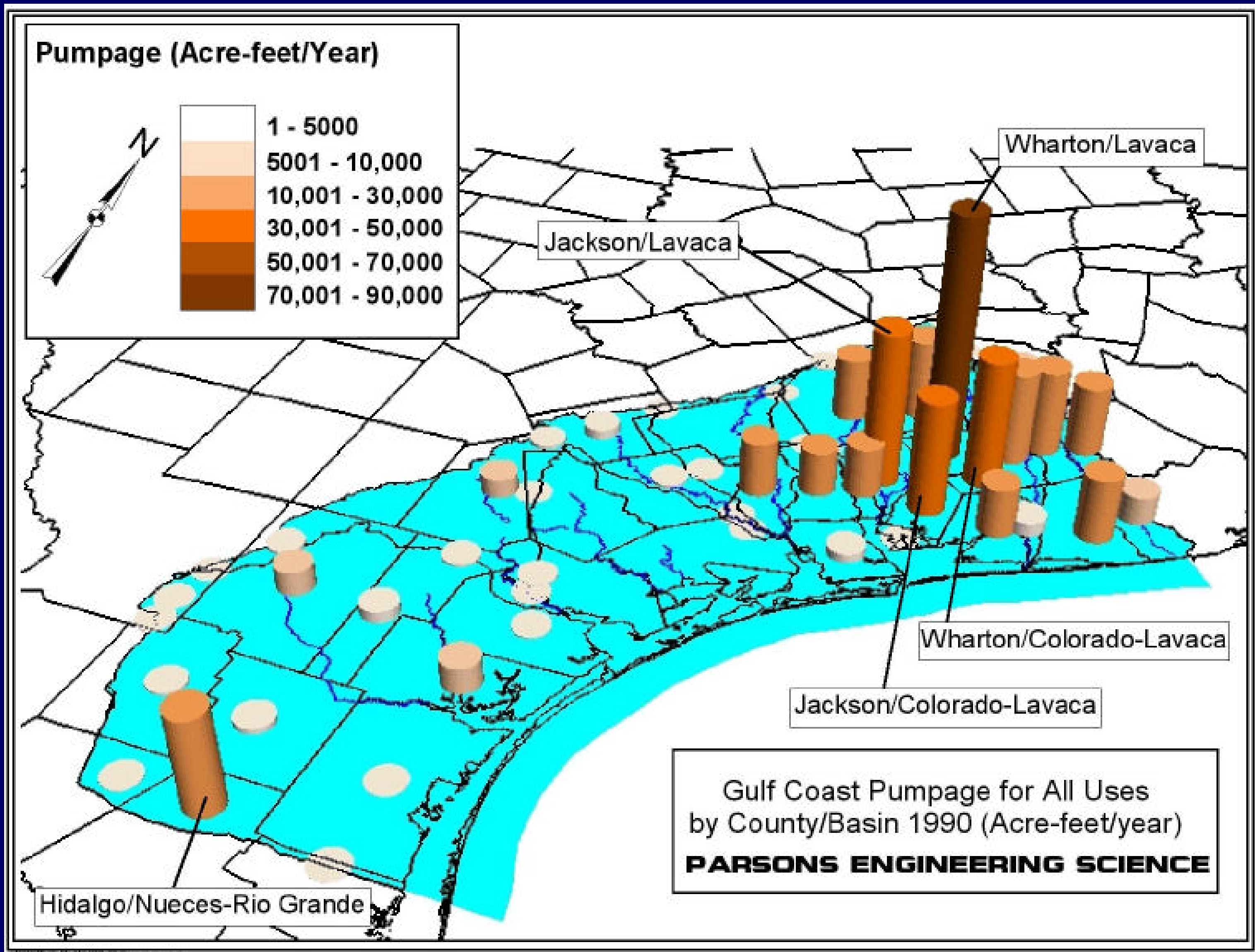
Pumpage Data

- Data sources
  - TWDB, USGS (historical-1980-2000),
  - RWPGs, TAG, GWCDs (predictive, 2000-2050)
- Data gaps
  - GW-use data in TX extends through 1997
- Data analysis
  - Well specific locations for municipal, power, mining and industrial uses
  - Land use distribution for livestock and irrigation uses
  - Population density for rural domestic uses

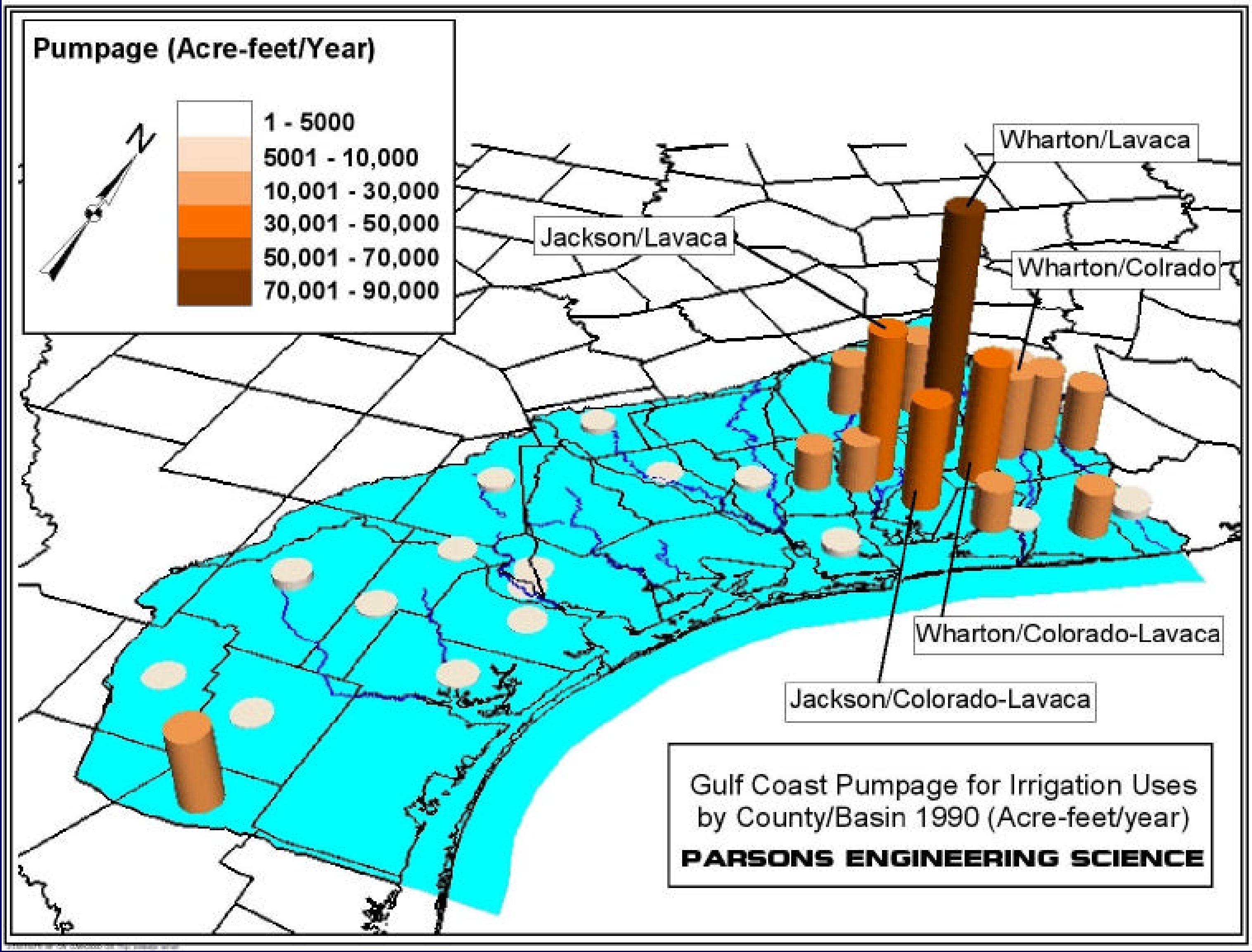
Pumpage by County (1980) – All Uses



Pumpage by County (1990) – All Uses



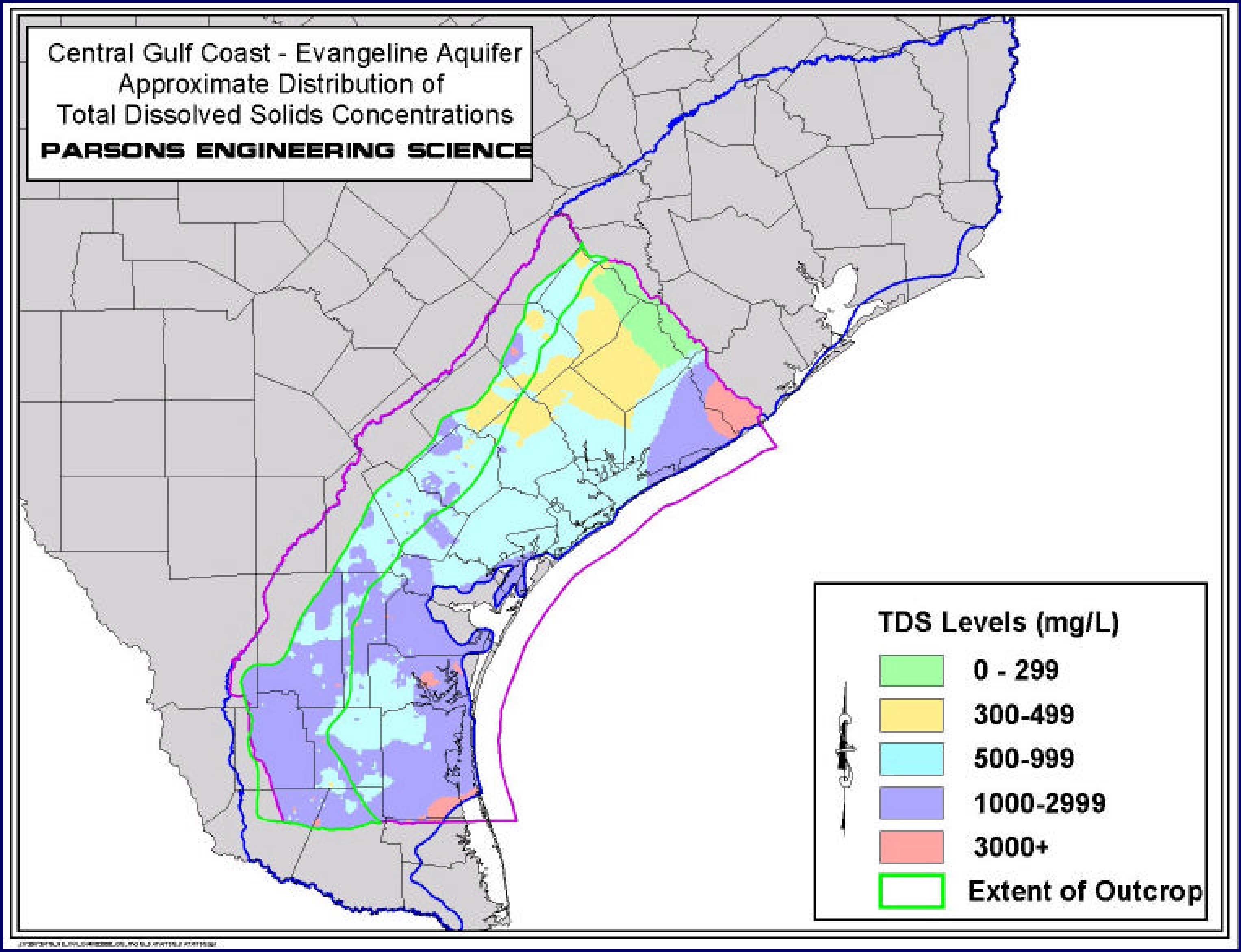
Pumpage by County (1990) – Irrigation



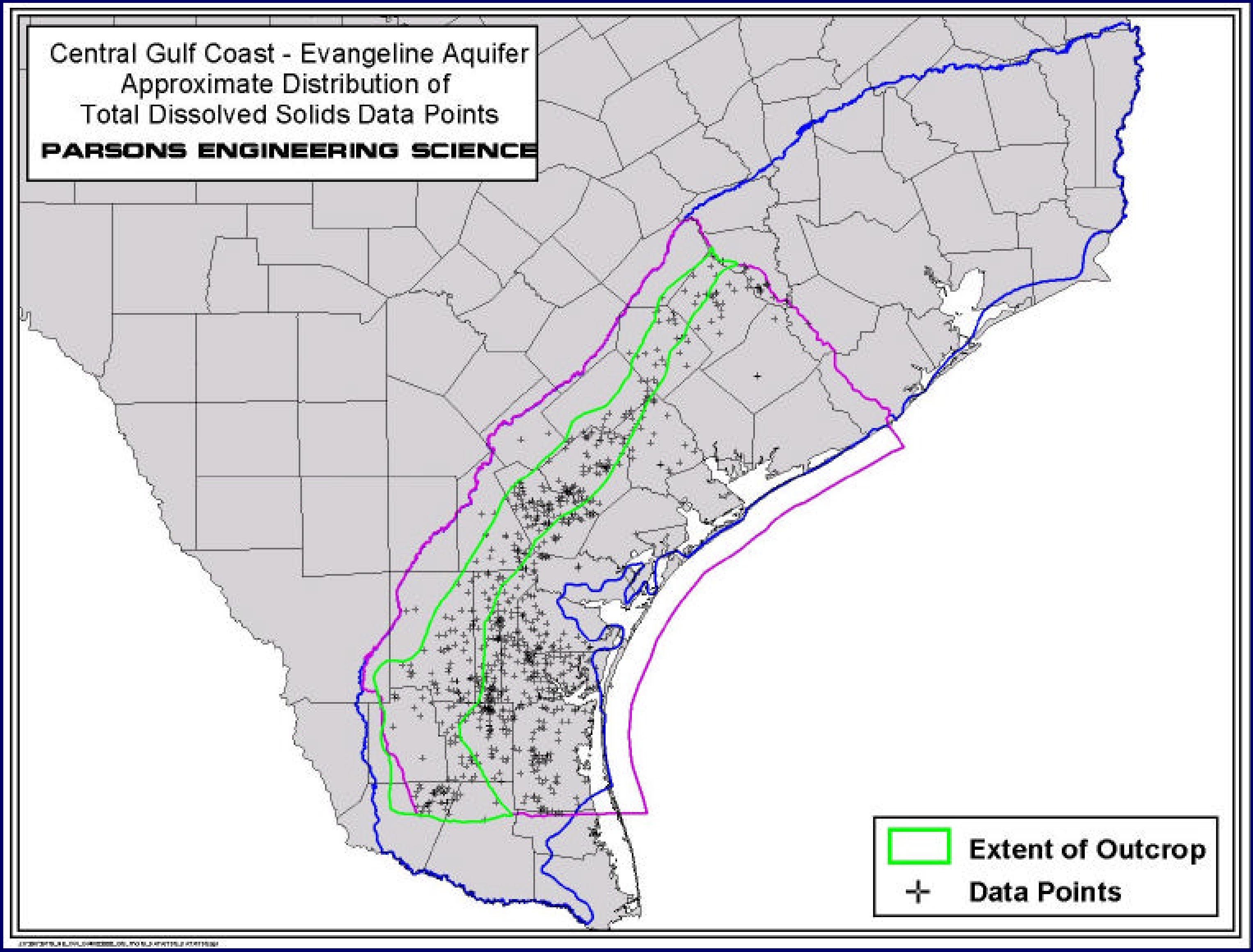
Water Quality Data

- ➲ Approach
  - – Develop water quality distributions for TDS and another constituent of interest
- ➲ Data sources
  - – TWDB, TNRCC (1944-2000)
  - – Reports from Bureau of Economic Geology

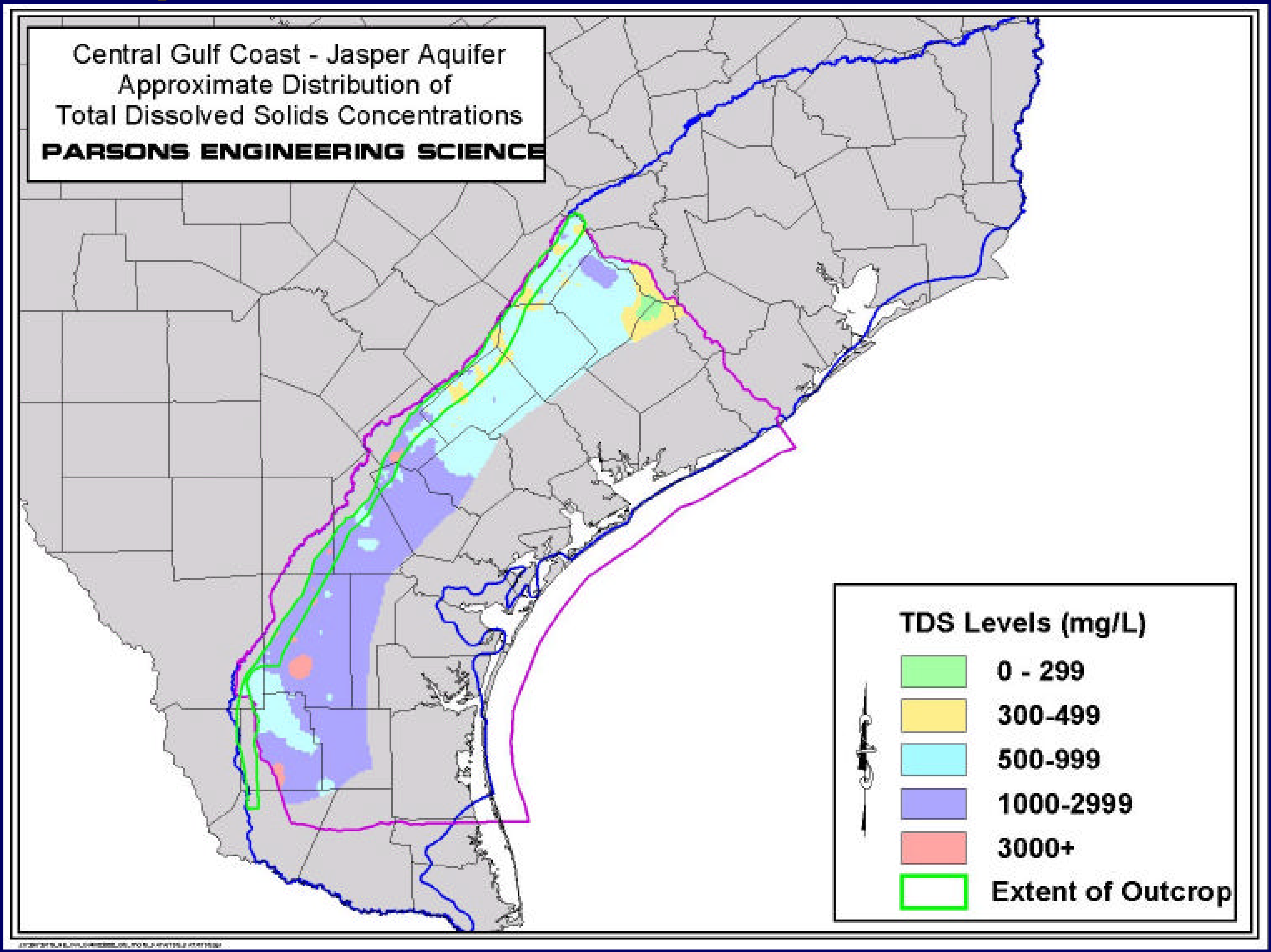
Evangeline TDS



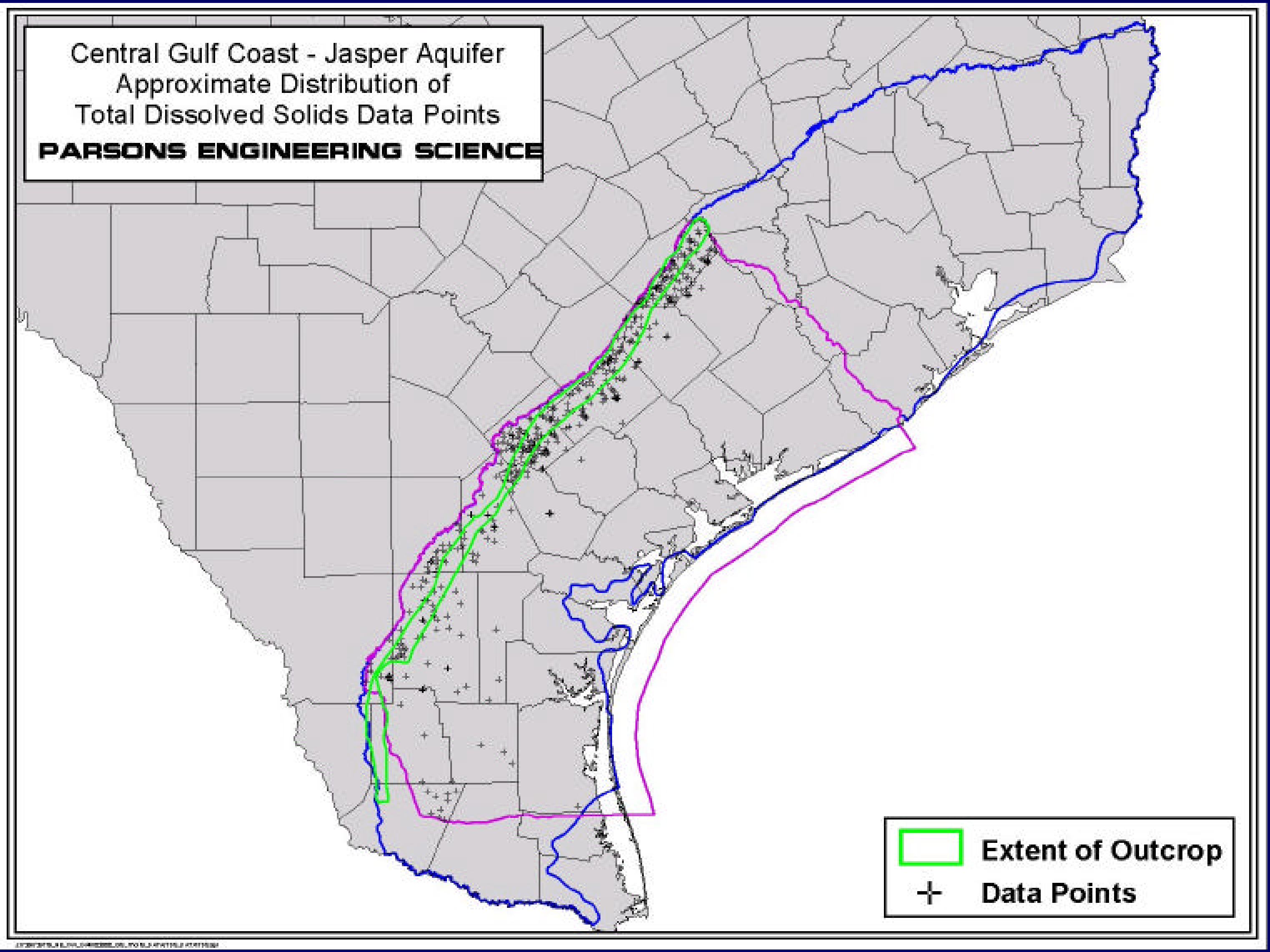
Evangeline TDS Data Locations



Jasper TDS


Central Gulf Coast - Jasper Aquifer
Approximate Distribution of
Total Dissolved Solids Concentrations
PARSONS ENGINEERING SCIENCE
TDS Levels (mg/L)
0 - 299
300-499
500-999
1000-2999
3000+
Extent of Outcrop

Jasper TDS Data Locations



Land Subsidence

- Dropping groundwater levels reduces pore pressures causing compaction in clays and silts
- Subsidence caused by over pumping and compaction
- Houston is a notable Gulf Coast example
  - Up to 1 ft of compaction per 100 ft of water level decline
  - Up to 20% of water released from storage this way
- Subsidence believed to have occurred in SE Jackson and W Matagorda counties as long ago as 1941-1951

Land Subsidence (cont.)

- ➲ Not required under GAM
- ➲ Neglecting it may make model difficult to calibrate (will have to evaluate during process)
- ➲ However, given all other uncertainties we may not be able to distinguish subsidence effects
- ➲ Sensitivity analysis on effects may be performed

- Monthly Reports
- Quarterly Stakeholder Advisory Forum (SAF) meeting

Year	Project quarter	Major milestone	Technical meetings with TWDB	TWDB major tasks
2010	Feb	Start		
		Assemble SAF		Assemble SAF
			Overview of Project	
		Intro SAF Meeting		
	May			Introduce GAM to RWPG's
			Preliminary conceptual model presentation	
	Aug		8/6	
			8/23	TWDB review of conceptual model
	Nov			
			Review of steady-state calibration	

Monthly Reports

Quarterly Stakeholder Advisory Forum (SAF) meeting

Project quarter	Major milestone	Technical meetings with TWDB	TWDB major tasks
2002 Feb			
		Review of transient calibration	
May			
		Review of predictions	
Aug			
	Draft Report		
Nov			Review report
	Review comments	Review of draft report	
	SAF model training	TWDB model training	
Feb	Final deliverables		Post to Web

CENTRAL GULF COAST GAM STAKEHOLDERS ATTENDENCE LIST

SECOND QUARTERLY MEETING

HELD

AUGUST 6, 2001 IN EDNA, TEXAS

Name		Affiliation
Larry H. Akers		Evergreen U.W.C.D.
Jim Naismith		San Patricio M.W.D
Don Roach		San Patricio M.W.D
Thomas D. Hill		Guadalupe_Blanco River Authority
Lonnie Stewart		Live Oak U.W.C.D.
Richard Chapin		TCC-Dow
Tom Michael		Subsidence Dist
Leroy Sebaste		Post Oak G.C.D.
Robert K. Gabysch		Subsidence Dist
Bob Piduns		Post Oak G.C.D.
John Britsschilk	X	Region "P" board
Billy Mann		Bay City Water Dist
Harrison Stafford II		Jackson County
Haskell Simon		Matagorda G.C.D.
Wayne Schirhart		Guadalupe_Blanco River Authority
Chad Kinsfather		LNRA
Jack Harris		Brazoria county
Bob and Lois Weiss		Lavaca G.C.D.
Ronnie Hernandez		San Antonio River Authority
Jerry Pearce		De-Go-La R.C. & D.
Greg Carter		CPL
Steve Robinson		Vinson & Elkins
Bill Norris		NRS Engrs
Patrick Brzozowski	X	LNRA

James Dodson		NRA -Coastal Bend Div
Steve Musich		TNRCC
Jack C Nelson		LNRA
Frank Samuel Jr	X	Wharton County
	X	**= Unable to confidently decipher name**

Questions & Responses from
Second Stakeholder Advisory Forum
Central Gulf Coast GAM
held
August 6, 2001
Harry Hafernick Center, Lake Texana

Introduction

The second Stakeholder Advisory Forum (SAF) for the Central Gulf Coast Groundwater Availability Model (GAM) was held on August 6th at the Harry Hafernick Center on Lake Texana near Edna. The presentation included a review of the GAM Project Team and GAM Objectives and Expectations, and a presentation of the Conceptual Model of Groundwater Flow in the Central Gulf Coast Aquifer. The presentation material is posted at the TWDB GAM website at:
http://www.twdb.state.tx.us/gam/glfc_c/SAF2_GC-c.pdf

Meeting Questions & Responses: (not necessarily listed in the order in which they were asked or discussed)

1. Because the area where the meeting is being held is near the edge of the model region, will it be addressed? What is northernmost county included?

Response: Because of the model overlap that is defined as a requirement by the TWDB, the Edna region will be included in both the Central Gulf Coast GAM and the Northern Gulf Coast GAM (USGS). The Central Gulf Coast GAM extends east to the western part of Austin, Fort Bend, and Brazoria County. The Northern Gulf Coast GAM extends west to include most of Lavaca and Jackson Counties and a small part of Calhoun County. While the local area (Edna) is located near the western boundary of the Northern Gulf Coast GAM, it is a large distance from the eastern model boundary of the Central Gulf Coast GAM.

2. What are examples of field data that are used at the conceptual model stage of the project?

Response: Examples of field data that are evaluated in developing the conceptual model include: geologic logs, water levels, aquifer tests, stream gage levels, precipitation, temperature, evaporation, historical pumpage, water-quality parameters, etc.

3. What version of MODFLOW will be used?

Response: The TWDB has prescribed that MODFLOW-96 (Harbaugh and McDonald, 1996, USGS Open-File Report 96-485) must be used for all GAMs.

4. The geology in the model region is a complex alluvial system that is not consistent throughout the study area. The problem is that it does not represent well as layers.

Response: Yes we are aware of this fact and realize that there is uncertainty in subdividing it into model layers. The complex depositional environment (different river stages, fluvial deltas, etc.) contributes to this complexity and the difficulty in representing it in model layers.

5. Are the Baker (1979) and Carr et al. (1985) reports available?

Response: A listing of all TWDB reports is located at the TWDB website at: http://www.twdb.state.tx.us/publications/publications.htm.
Baker (1979, TWDB Report 236) is available at the TWDB website at: *http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/GWreports.htm#236*. Note that Figure 1 is not included in this online version. Copies of these reports are available for a fee through TWDB's TNRIS office at *http://www.tnris.state.tx.us/ordering.htm* or 512-463-8337.

6. How many cross sections are included in Baker?

Response: There are 12 cross sections for the entire Gulf Coast in Baker (1979). Within our model region there are five cross sections perpendicular to the Gulf coast and one cross section parallel to the coast.

7. At any location, the Evangeline may consist of 5 or 6 sand units interbedded with clay lenses. How will this be modeled?

Response: A regional scale model is being developed with properties input on a 1-mile by 1-mile grid scale areally and one layer vertically for the Evangeline. This modeling scale does not allow simulation of these individual sand and clay units within the Evangeline. Because the sand and clay units are not considered continuous over very large distances, they are lumped together to represent one aquifer unit consistent with the hydrostratigraphic interpretations of Baker (1979) and Carr et al. (1985). This is a model limitation. Modeling regionally at a smaller scale vertically is impractical because the necessary data are not available.

8. What does the Evangeline predevelopment water-level map show?

Response: This map is intended to show the distribution of hydraulic head or water-level elevation in the Evangeline Aquifer prior to development by pumping. The water-level elevation is calculated as the elevation of the top of the well minus the depth to water measured from the top of the well. Flow directions in the aquifer can be determined based on differences in water-level elevation in different wells. Water-level data from the early 1900s were used where possible in developing this map.

9. Did we look at Taylor for predevelopment data?

Response: Yes. (Full reference is: Taylor, T.U., 1907. Underground Waters of Coastal Plain of Texas. USGS Water-Supply and Irrigation Paper No. 190.)

10. What is the source of data and why are they sparse in areas? Are you using TWDB well information? General discussion of TWDB database.

Response: The principal source of well data is the TWDB website. We need additional information in areas of data gaps. [Please contact either Waterstone or TWDB if you are aware of measurements not currently listed in the TNRCC or TWDB database, especially early measurements.] Some wells may be plugged and no longer visible from surface. Some wells do not have proper locations. Advances in technology (GPS units) and methodologies of historically locating wells spatially (using topographic maps) were discussed. Also screen intervals, well depths and how they may change depending on driller and the driller's report were discussed.

11. Will some data be ignored or eliminated?

Response: We may if the data are so uncertain that they cannot be properly assigned.

12. Have you done a frequency analysis on hydraulic property data? This should be included in final report.

Response: Various types of statistical analyses will be performed when the aquifer property database is completed and documented. These analyses will be documented in the final report.

13. What are K and QC?

Response: K refers to hydraulic conductivity, which is a measure of the ability of the geologic unit to transmit water. QC is quality control.

14. Have you looked at oil field logs?

Response: Open discussion. The cost to acquire data from oil companies is not available in the project budget. A quote of $600/mile was received from a seismic broker. If stakeholders can assist in this process, it would be appreciated. It is believed that hydrostratigraphic interpretations included in Baker (1979), Carr et al. (1985), and various reports from the USGS Regional Aquifer Systems (RASA) investigations have utilized some oil field logs in their research.

15. Have you looked at uranium mines? A stakeholder thought they were required to conduct geophysical surveys for TNRCC.

Response: [Steve Musick – TNRCC] stated they have some electric logs and pump test information in their files [not digital and does not cover a large area, mostly located around Evangeline outcrop in western portion of study area].

16. How are we going to use physical properties (e.g., sand percentages)?

Response: We will attempt to correlate K and sand percentage to assist in mapping the distribution of K during model calibration. We will try to look at directional K properties relative to depositional environment.

17. Open discussion of model scale. GWCDs appear to want a "micro" answer and model is more "macro" in scale. The model may not be able to answer all questions or concerns.

Response: The model can answer some questions but one needs to be aware of the model's limitations. This model will include averaging of properties at a 1-mile by 1-mile scale. We need to be aware of the spatial limitations. The model will not be able to answer if a neighbor's well will impact someone. The model may be on a larger scale than required to address some questions. An option is to "telescope" the model and put in finer detail at a later date (beyond scope of current GAM project).

18. Open discussion of problems with well completions. Some wells are screened in wrong intervals or are poorly developed. Specific capacity may increase substantially after well-development activities.

19. Will the interbed storage package in MODFLOW be used? Is the scope for Northern Gulf Coast GAM and Central Gulf Coast GAMs the same except for use of the interbed storage package? Why are model areas not using same options and how it will impact the overlapping area?

Open discussion of using interbed storage package: We discussed that the subsidence package was not completed when the scope for the Central Gulf Coast GAM was defined. According to a Harris-Galveston Subsidence District representative, the package appears to have correctly forecasted subsidence in the Houston area. It is important to have data to correlate/calibrate the results against. Subsidence has been studied in the Houston area and a useful database collected over a long time period has been developed. Very limited subsidence data is available within the Central Gulf Coast GAM region as compared with the Houston region. We do not know the importance of subsidence on the Central Gulf Coast model region. We will include scoping or approximate calculations on the magnitude of the impact of subsidence on water budgets. All models are required to calibrate within a particular range. Both models are using the same geologic structure in the overlap area and are using publicly available data for developing model inputs. Therefore both models should provide somewhat similar results, with the exception of the use of the interbed storage package. The Northern Gulf Coast model should include most of the key areas experiencing subsidence (it extends west to include most of Lavaca and Jackson Counties and a small part of Calhoun County).

20. What is the TWDB's commitment to the groundwater districts?

Response: The TWDB is tasked with completing models of the major aquifers in the next couple of years. The TWDB has been tasked to model the minor aquifers but has not received the funds to do so. Waterstone will provide a training session to the stakeholders at the end of the Central Gulf Coast modeling project so that stakeholders can use the model themselves. The TWDB will assist the GWCDs as time, staff, and funds permit. In the meantime, it is important for the districts to get familiar with their resources and where additional research and/or data are needed. Modeling efforts [and groundwater management] can only be improved with better data.

21. Can we identify type of data and where needed, and contact names for persons who have data available?

Response: The types of data that are being compiled and evaluated for the model have been outlined in the presentation including key data sources. (Note: the presentation is provided on the TWDB website). If anyone has data that they feel would supplement the presented data, they are welcomed to provide it. Data for model areas that currently show sparse data would be useful. Examples of data that are needed include predevelopment water levels. Contact persons include Cindy Ridgeway at the TWDB (512-936-2386) and Patrick Williamson at Waterstone (303-444-1000).