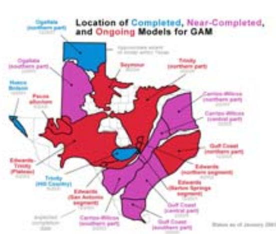
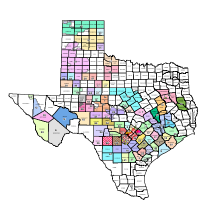
5th Stakeholder Advisory Forum
West Texas Igneous and Bolson GAM

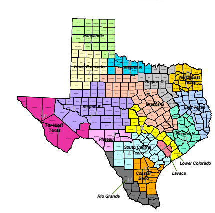
March 25, 2004

Groundwater Availability Modeling

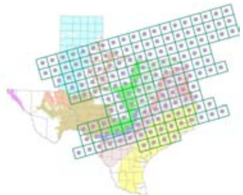




Contract Manager

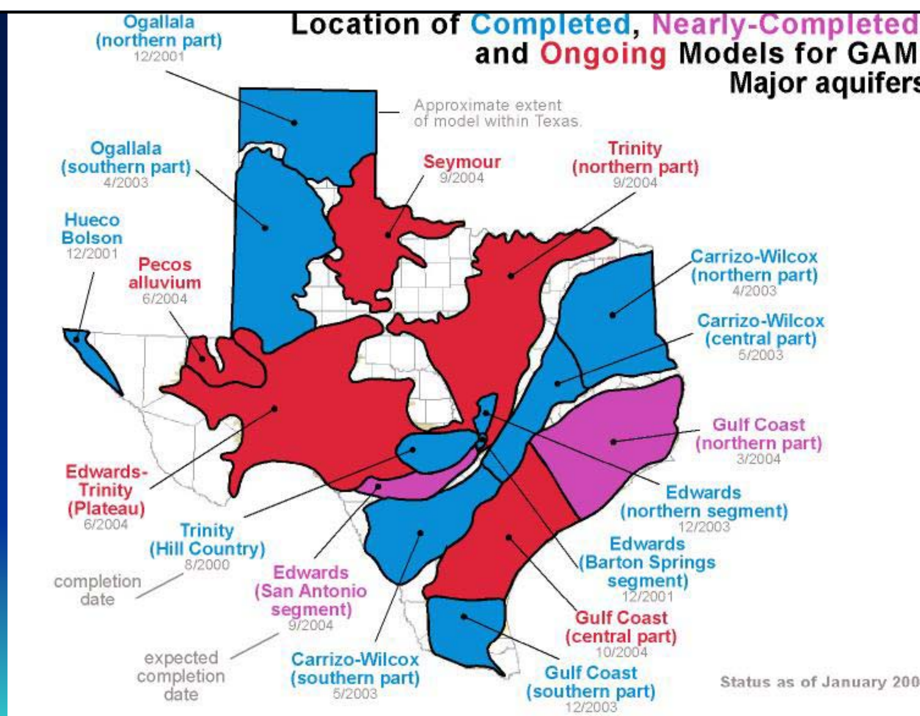


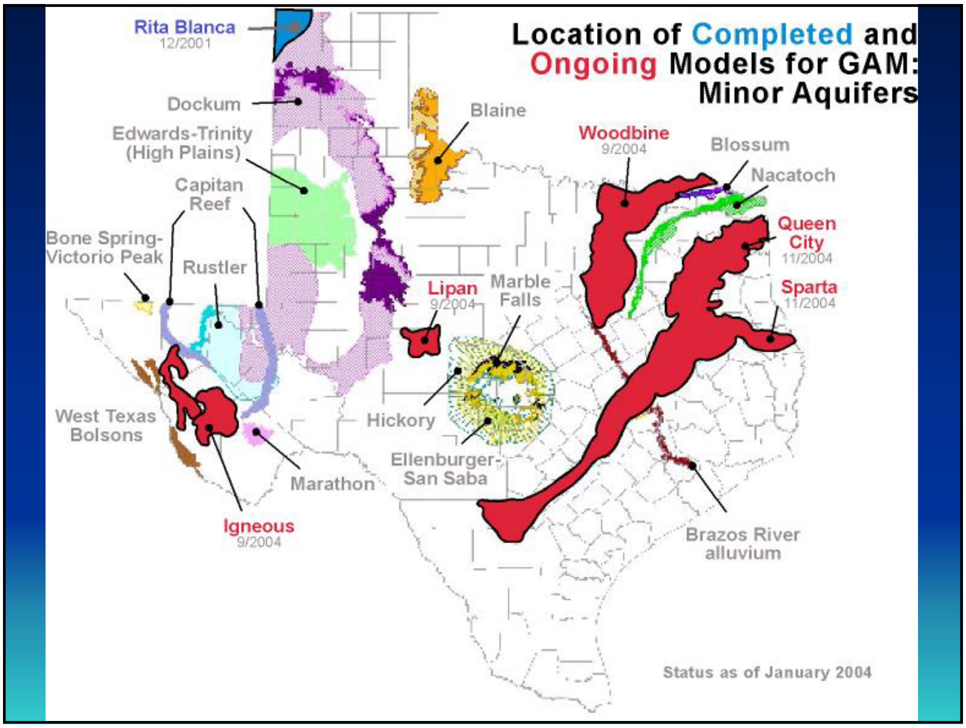
- Texas Water Development Board



GAM

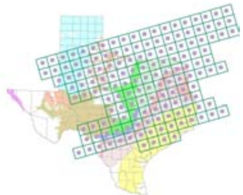
- Purpose: to develop the best possible groundwater availability model with the available time and money.
- Public process: you get to see how the model is put together.
- Freely available: standardized, thoroughly documented, and available over the internet.
- Living tools: periodically updated.





What is groundwater availability?

- …the amount of groundwater available for use.
- The State does not decide how much groundwater is available for use: GCDs and RWPGs decide
- A GAM is a tool that can be used to assess groundwater availability once GCDs and RWPGs decide how to define groundwater availability.

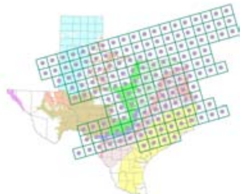


Do we have to use GAM?

- Water Code & TWDB rules require that GCDs use GAM information. Other information can be used in conjunction with GAM information.
- TWDB rules require that RWPGs use GAM information unless there is better site specific information available

How do we use GAM?

- The model itself
  - predict water levels and flows in response to pumping and drought
  - effects of well fields
- Data in the model
  - water in storage
  - recharge estimates
  - hydraulic properties
- GCDs and RWPGs can request runs



Living tools

- GCDs, RWPGs, TWDB, and others collect new information on aquifer
- This information can enhance the current GAMs
- TWDB plans to update GAMs every five years with new info
- Please share information and ideas with TWDB on aquifers and GAMs

Participating in the GAM process

- SAF meetings
  - hear about progress on the model
  - comment on model assumptions
  - offer information (timing is important!)
- Report review
  - Deadline for comments on the IBGAM is **April 9, 2004**. The final draft report is posted at: http://www.twdb.state.tx.us/gam/bol_ig/bol_ig.htm
- Contact TWDB (Robert Mace or Ted Angle)

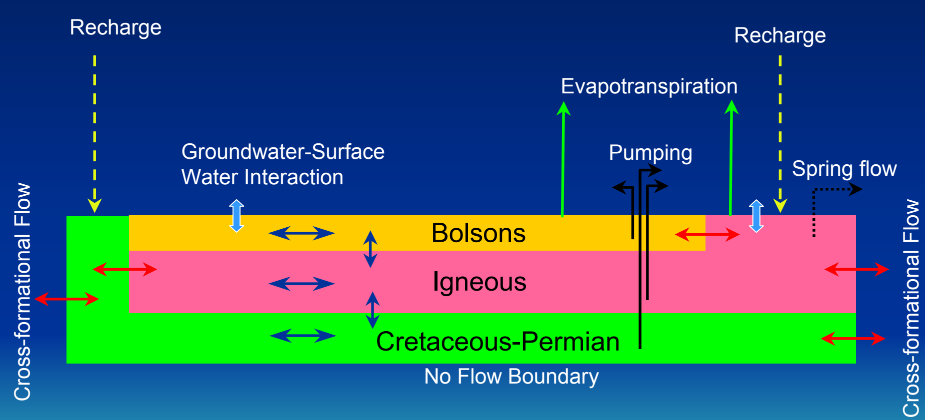
Comments:

Ted Angle
(512)936-2387
tangle@twdb.state.tx.us
www.twdb.state.tx.us/gam

TEXAS WATER DEVELOPMENT BOARD

Conceptual model

Conceptual Block Diagram



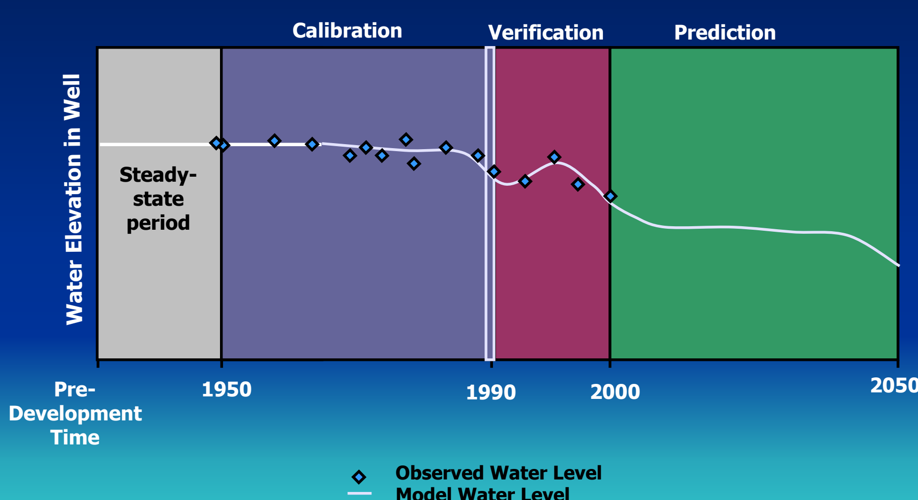
Responses to Public Comments regarding Conceptual Model

- **Wells** in the flats may be completed in both Bolson and igneous aquifers.
- **Volcaniclastic units** were included in the Bolson aquifer thickness because these units are unconsolidated, and have hydraulic conductivity more similar to Bolson than the igneous.
- **Zonation** - Although there are three layers in the model, aerial zonation was used to further refine hydraulic properties based on geology, hydraulic conductivity data, and water level responses.
- **Hydraulic conductivity** refers to the ability of an aquifer material to transmit water.
- **Water level maps** were developed according to the methodology in Appendix A, which relied on water levels measured around 2000. Apparent water level decreases between 1950 and 1980 were caused by differences in the contour interval on those maps.

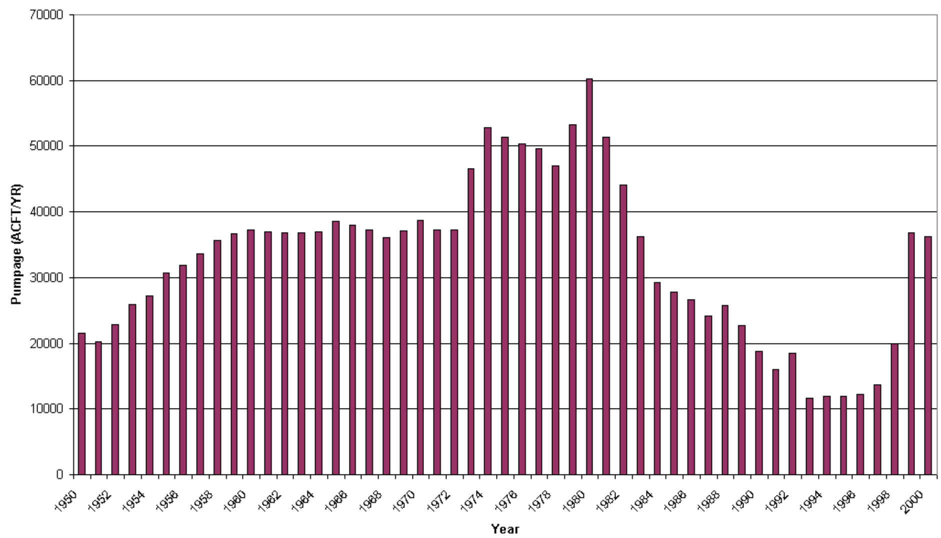
Simulation Periods

Time Period	# Stress Periods	Length (years)
pre-1950: steady state period prior to major pumping	1	2738
1950 – 1990: calibration period Focus on 1970-1990 Most significant irrigation pumping	40	1
1990 – 2000: verification period Relatively dry period	10	1

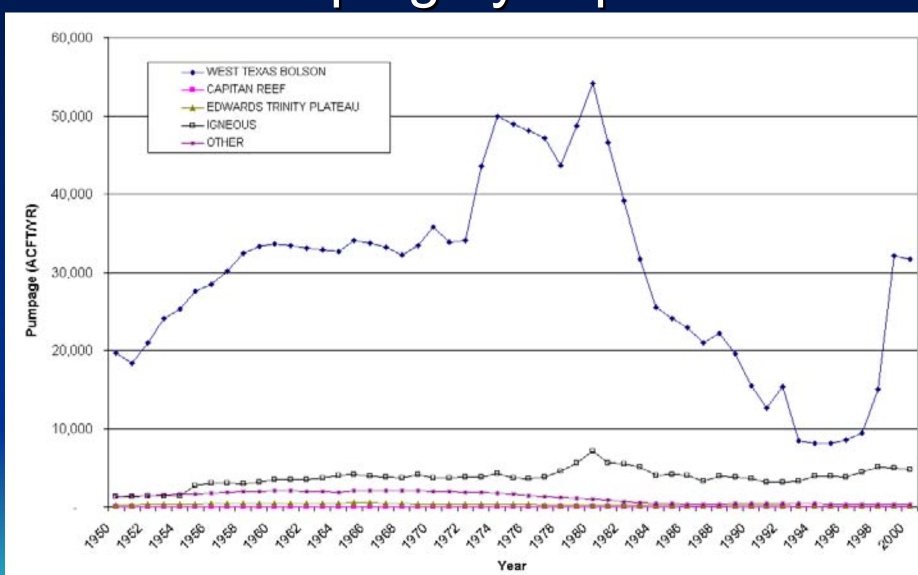
GAM Modeling Periods



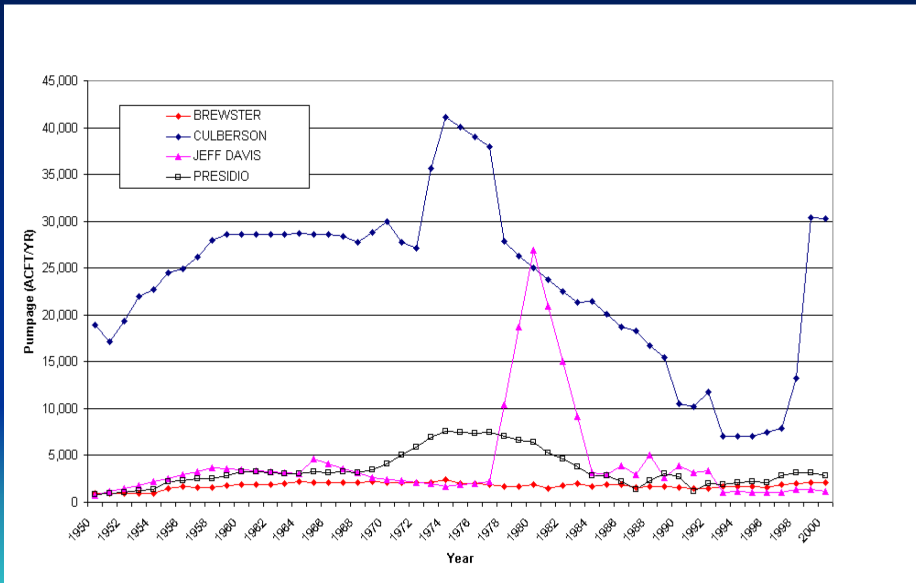
Total Pumping



Pumping by Aquifer

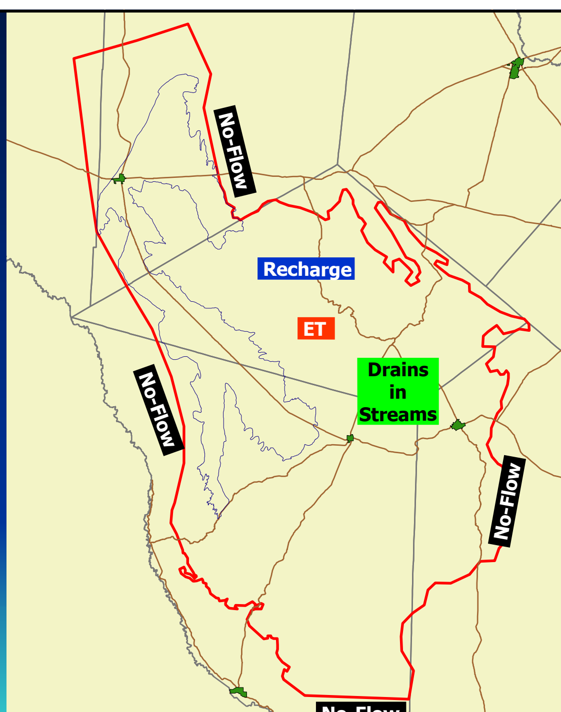


Pumping (by County)



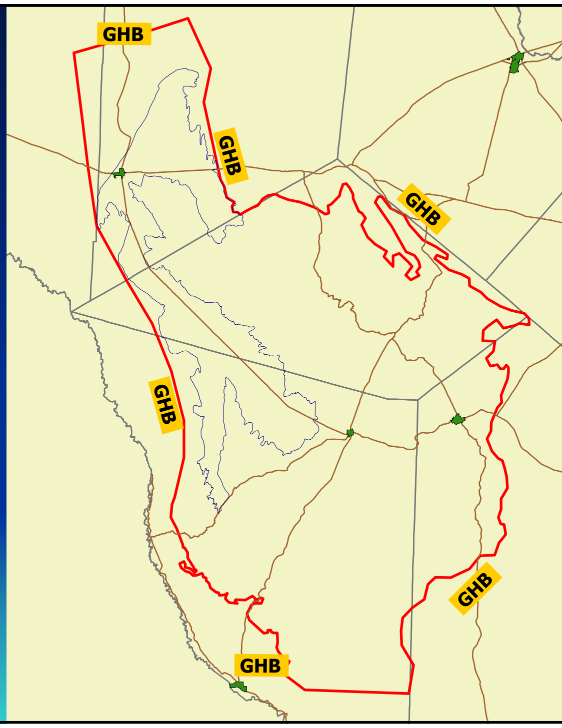
Model Architecture

Layer 1 Boundary Conditions



Layer 2 Boundary Conditions

Layer 3 Boundary Conditions

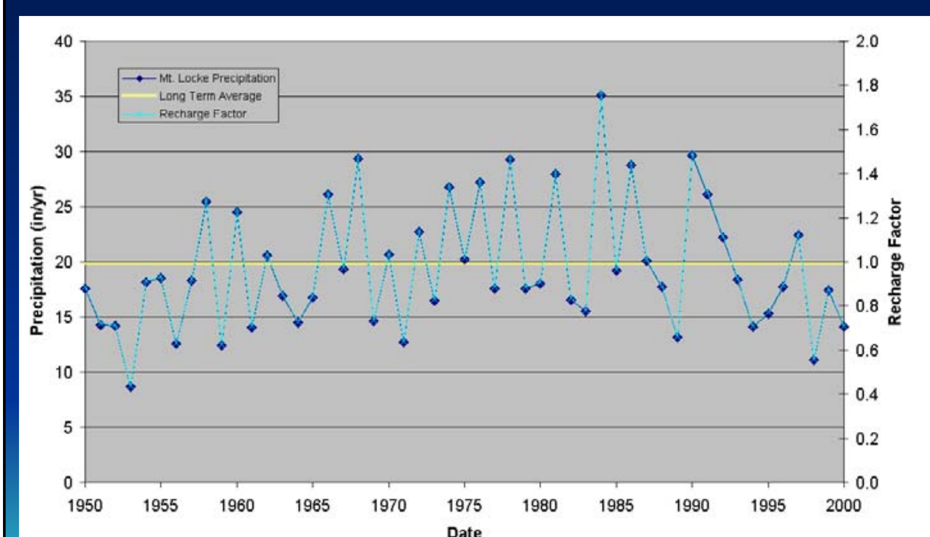


Calibration and Verification

Evapotranspiration

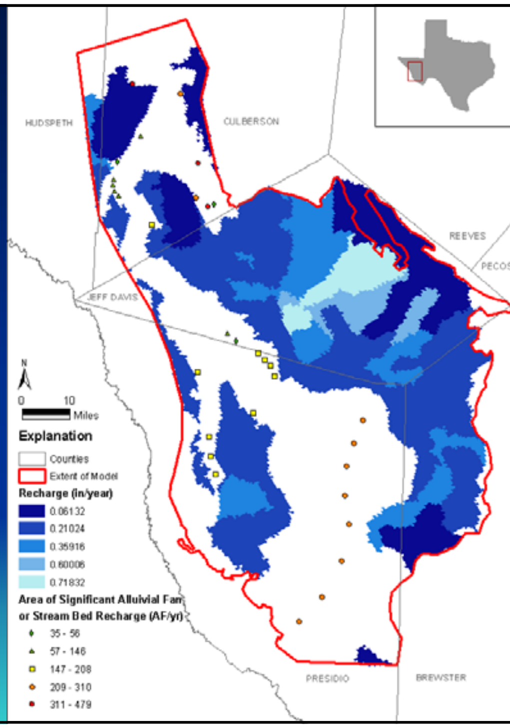
- 10 in/year maximum
- Extinction depth= 10 ft

Transient Recharge Factor
Based on Mt. Locke Precipitation Variation



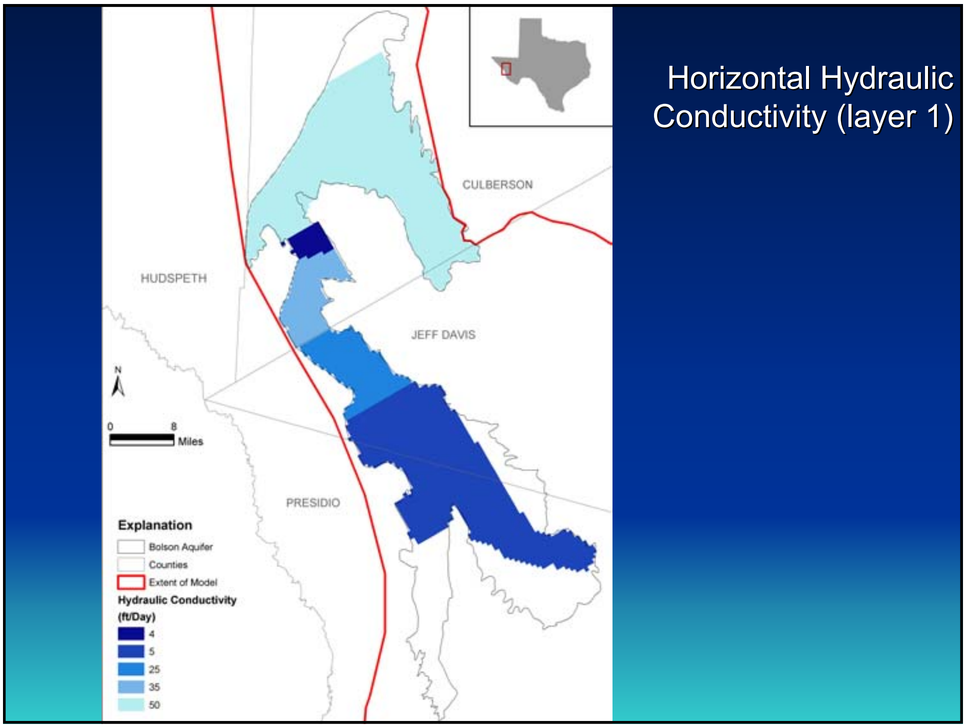
Final Distribution of Steady-State Recharge

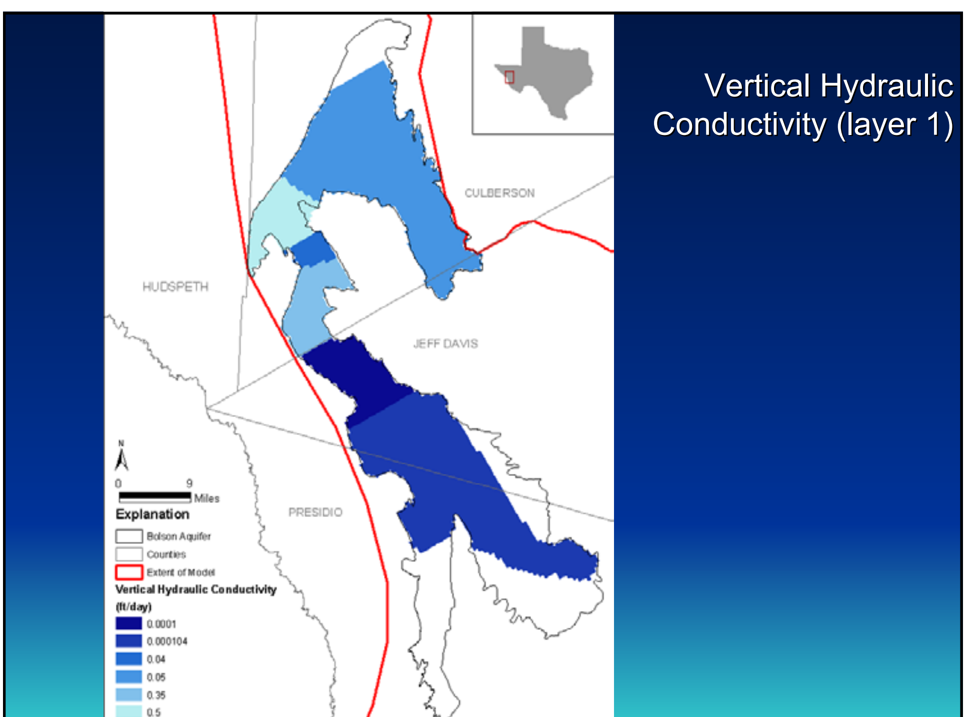
(60% of Original Runoff Redistribution Estimate)



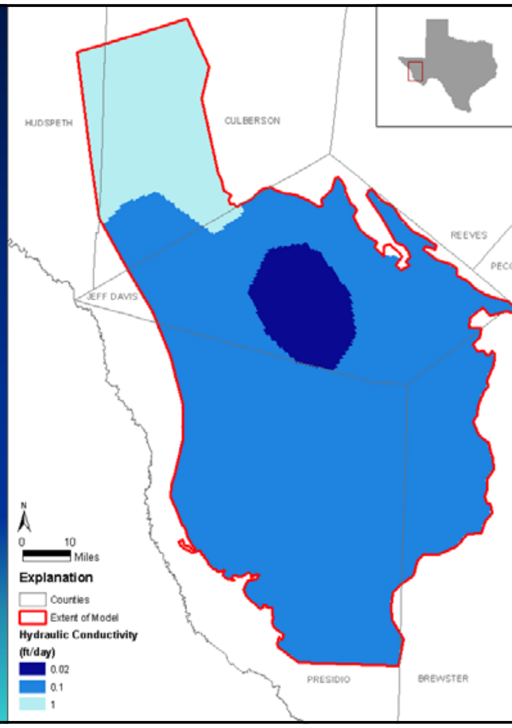
Hydraulic Properties

Layer	Kx (ft/day)	Kz (ft/day)	specific yield	storativity
1	4 - 50	0.0001 - 0.35	0.06	-
2	0.2 - 1	0.00008 - 0.1	0.01	3e-5
3	0.1 - 1	0.0001 - 0.1	0.01	3e-5

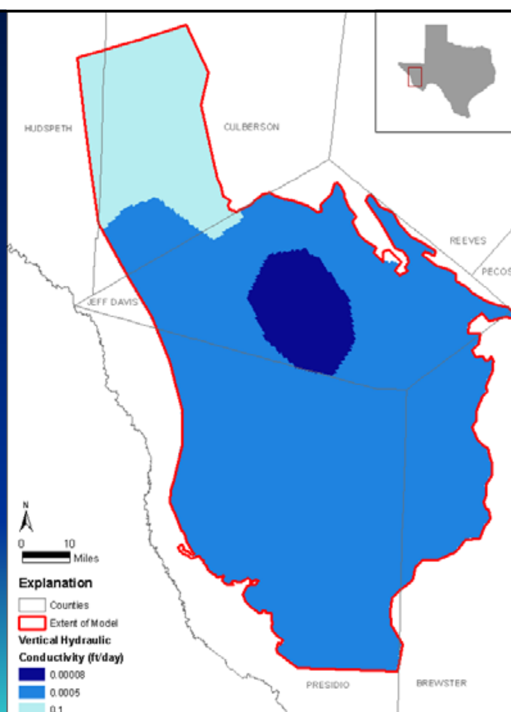

Horizontal Hydraulic Conductivity (layer 1)
CULBERSON
HUDSPETH
JEFF DAVIS
PRESIDIO
N
0
8
Miles
Explanation
Bolson Aquifer
Counties
Extent of Model
Hydraulic Conductivity (ft/Day)
4
5
25
35
50


Vertical Hydraulic Conductivity (layer 1)
CULBERSON
HUDSPETH
JEFF DAVIS
PRESIDIO
N
0
9
Miles
Explanation
Bolson Aquifer
Counties
Extent of Model
Vertical Hydraulic Conductivity (ft/day)
0.0001
0.000104
0.04
0.05
0.35
0.5

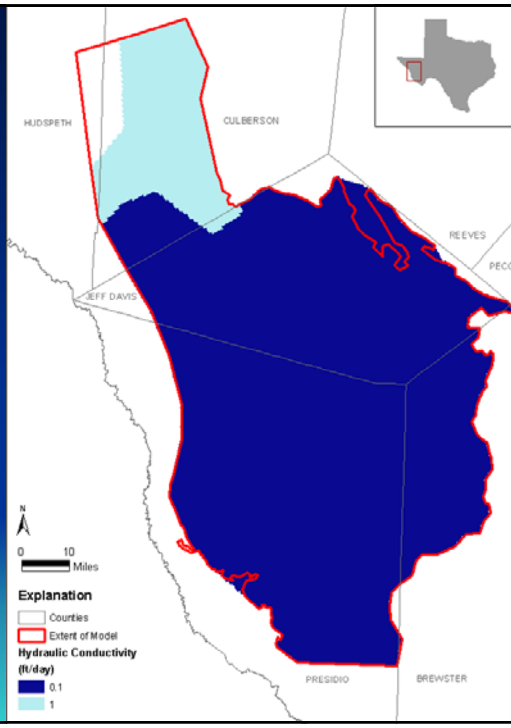
Horizontal Hydraulic Conductivity (layer 2)



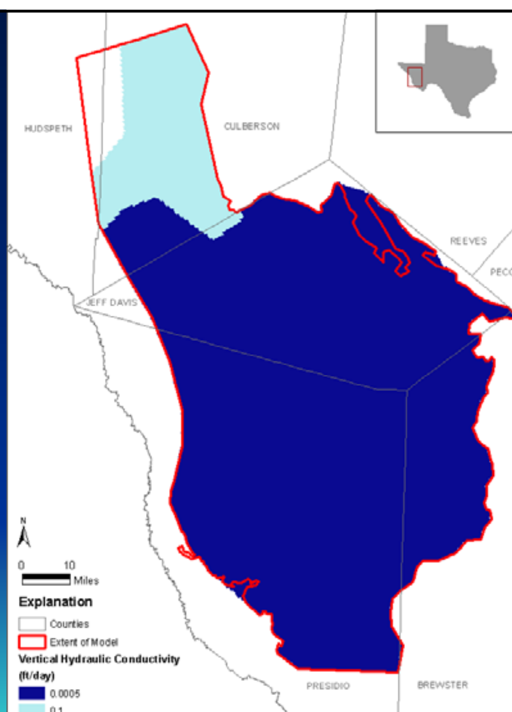
Vertical Hydraulic Conductivity (layer 2)



Horizontal Hydraulic Conductivity (layer 3)



Vertical Hydraulic Conductivity (layer 3)



Responses to Public Comments regarding Model Calibration

- Igneous hydraulic conductivity - Vertical variation in hydraulic conductivity within the igneous aquifer below the Bolsons is dealt with by assuming that the volcaniclastics are a part of the Bolson layer. In areas where the igneous units outcrop, it is assumed that the entire thickness of the igneous can be appropriately simulated with one layer. Any vertical variation in hydraulic conductivity is averaged over the layer (about 40 layers as 1). Horizontal permeability in the Igneous aquifer is 200-250 times greater than vertical hydraulic conductivity. This is appropriate because of the lack of vertical connection between layers of igneous deposits.
- Recharge - The general applicability of the runoff-redistribution method is based on other modeling studies that have been completed in the southwest and documented in the literature. Consistent with these publications, the estimated recharge was reduced to 60% of the original value determined from the method.
- Historical Pumping - On average, about 81% of groundwater use is for irrigation between the 1980-2000. However, the area and volume of groundwater used for irrigation did change between 1980 and 2000.

Calibration Targets

- 1670 head measurements in 365 wells

Layer	Steady-state	Calibration & Verification	Total
Bolson	53	1193	1246
Igneous	1	423 *	424
Cretaceous	0	0	0
Total	54	1616	1670

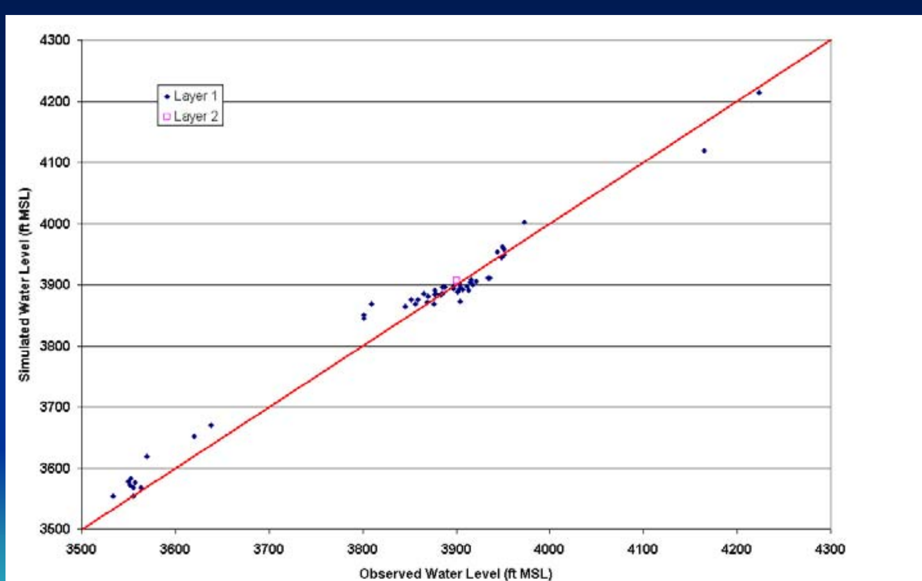
* - Included 245 geographically distributed measurements from 2000-2001

Calibration Statistics

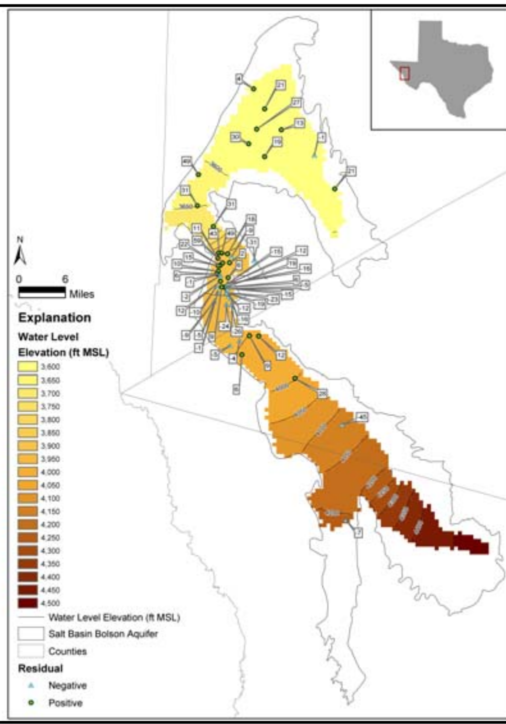
Steady-State (1950)

Layer	Count	Mean Error	Mean Absolute Error	Residual Standard Deviation (RMS)	RMS/ Range
		(feet)	(feet)	(feet)	
Bolson	53	6	17	21	0.03
Igneous	1	7	7	-	-
Cretaceous	0	-	-	-	-
All Layers	54	6	17	21	0.03

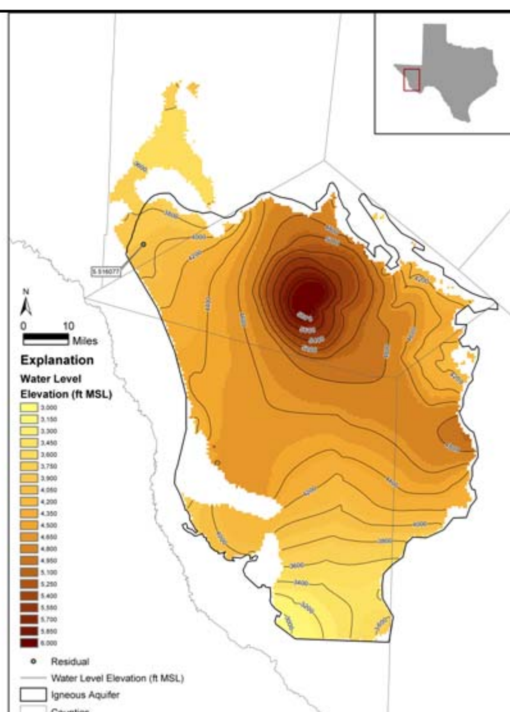
Crossplot of Steady-State Heads

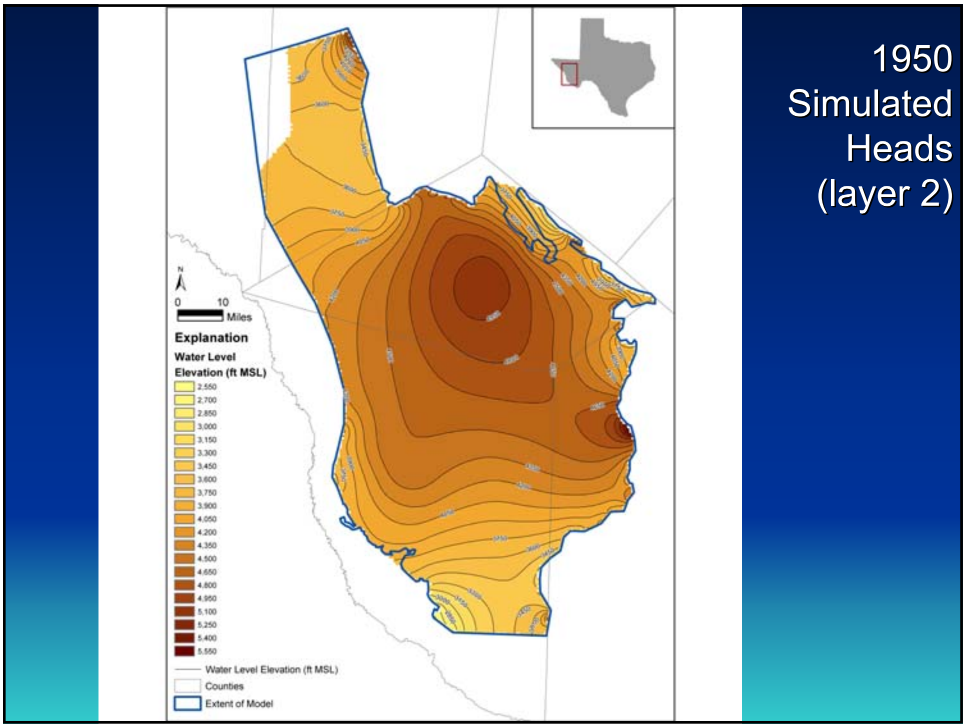


1950 Simulated Heads (layer 1)

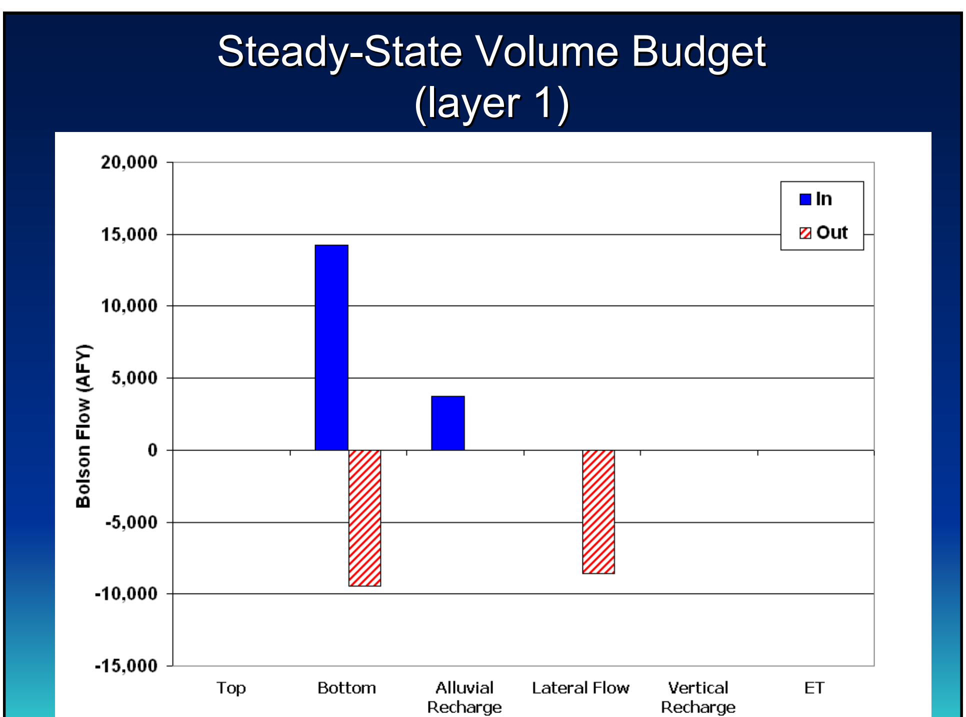


1950 Simulated Heads (layer 2)

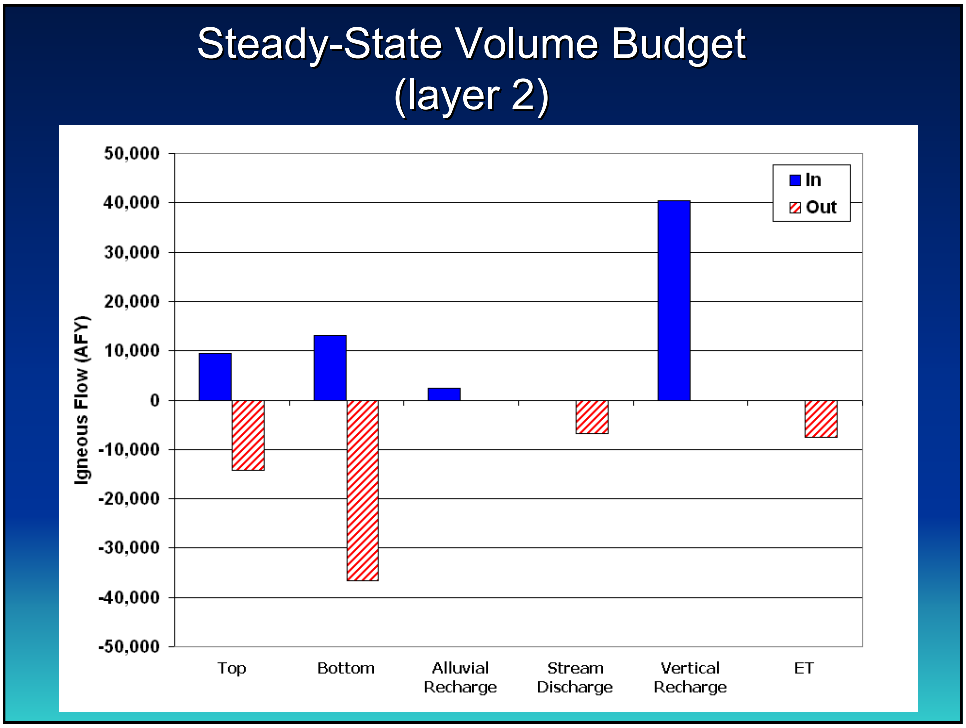


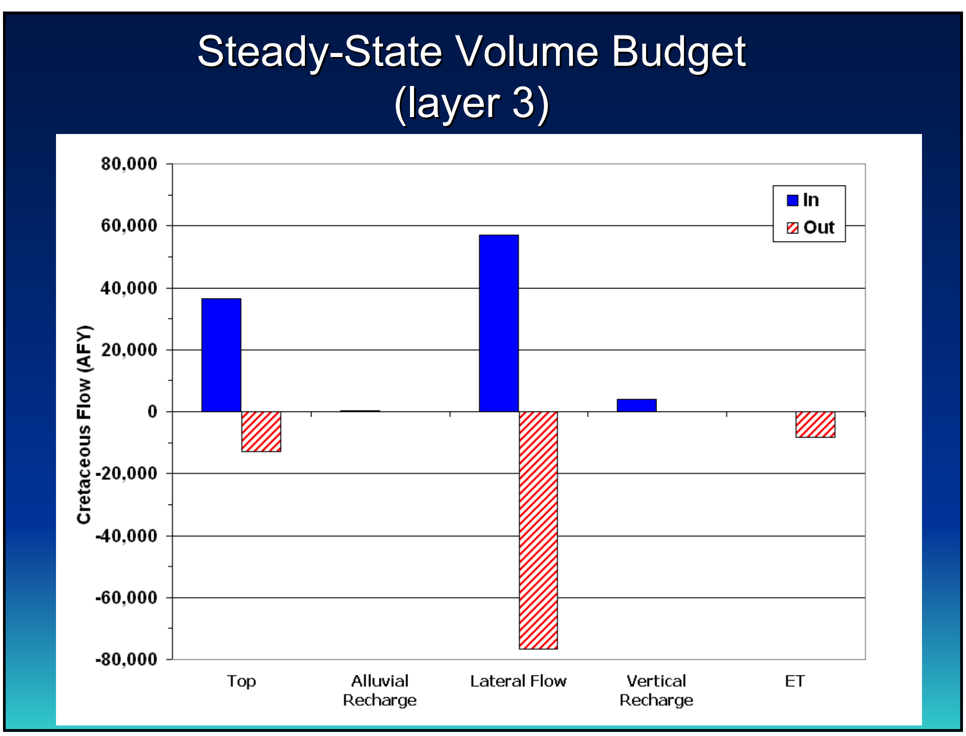


1950 Simulated Heads (layer 2)
0
10
Miles
Explanation
Water Level Elevation (ft MSL)
2,550
2,700
2,850
3,000
3,150
3,300
3,450
3,600
3,750
3,900
4,050
4,200
4,350
4,500
4,650
4,800
4,950
5,100
5,250
5,400
5,550
Water Level Elevation (ft MSL)
Counties
Extent of Model

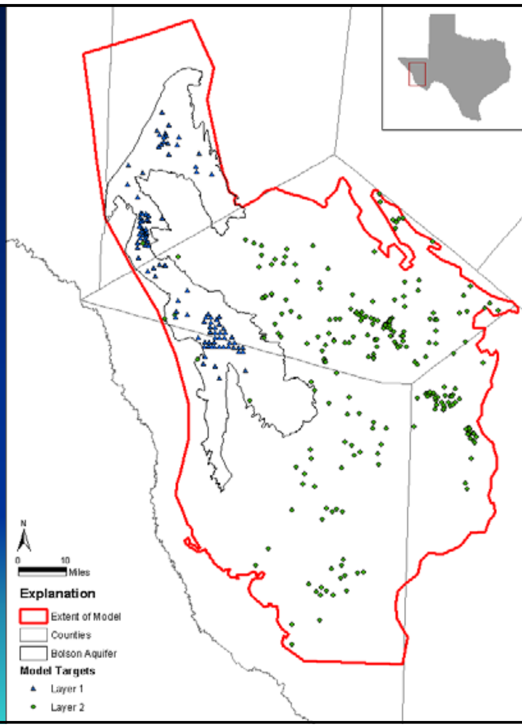


Steady-State Volume Budget (layer 1)
Bolson Flow (AFY)
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
In
Out
Top
Bottom
Alluvial Recharge
Lateral Flow
Vertical Recharge
ET


Steady-State Volume Budget
(layer 2)
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
Igneous Flow (AFY)
In
Out
Top
Bottom
Alluvial Recharge
Stream Discharge
Vertical Recharge
ET


Steady-State Volume Budget
(layer 3)
80,000
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
Cretaceous Flow (AFY)
In
Out
Top
Alluvial Recharge
Lateral Flow
Vertical Recharge
ET

Calibration Wells

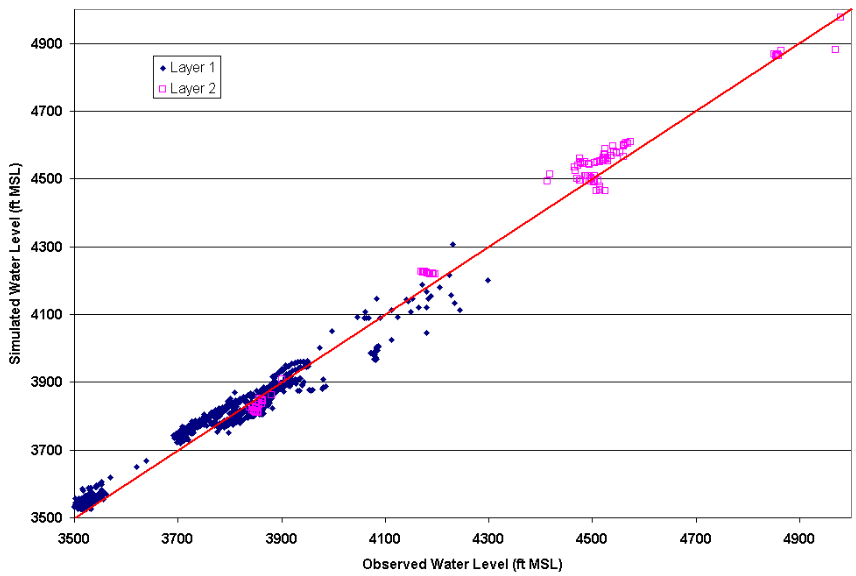


Calibration Statistics

(1951-1990)

Layer	Count	Mean Error	Mean Absolute Error	Residual Standard Deviation (RMS)	RMS/ Range
		(feet)	(feet)	(feet)	
Bolson	895	-10	27	35	0.04
Igneous	122	17	35	35	0.03
Cretaceous	0	-	-	-	-
All Layers	1017	7	28	34	0.02

Crossplot of heads during calibration period (1950-1990)

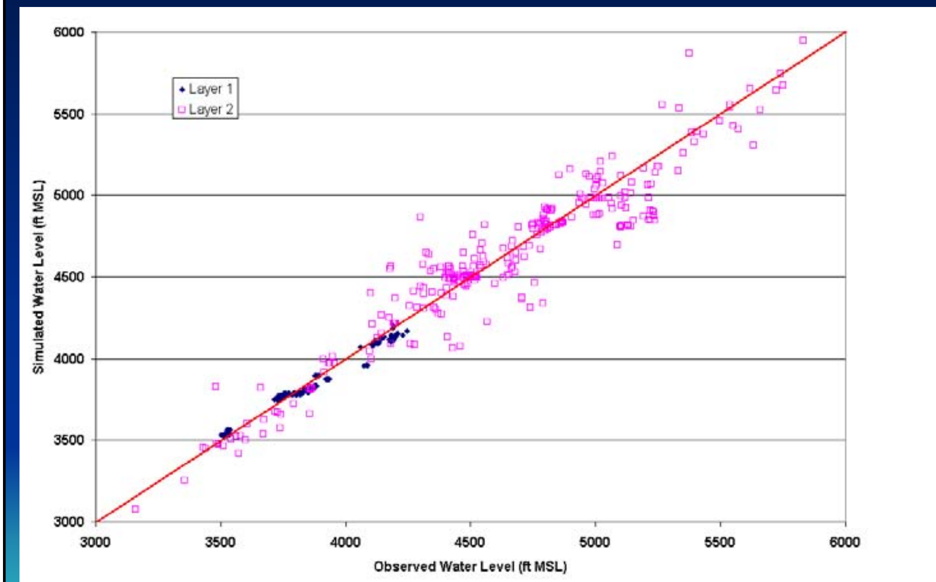


Verification Statistics

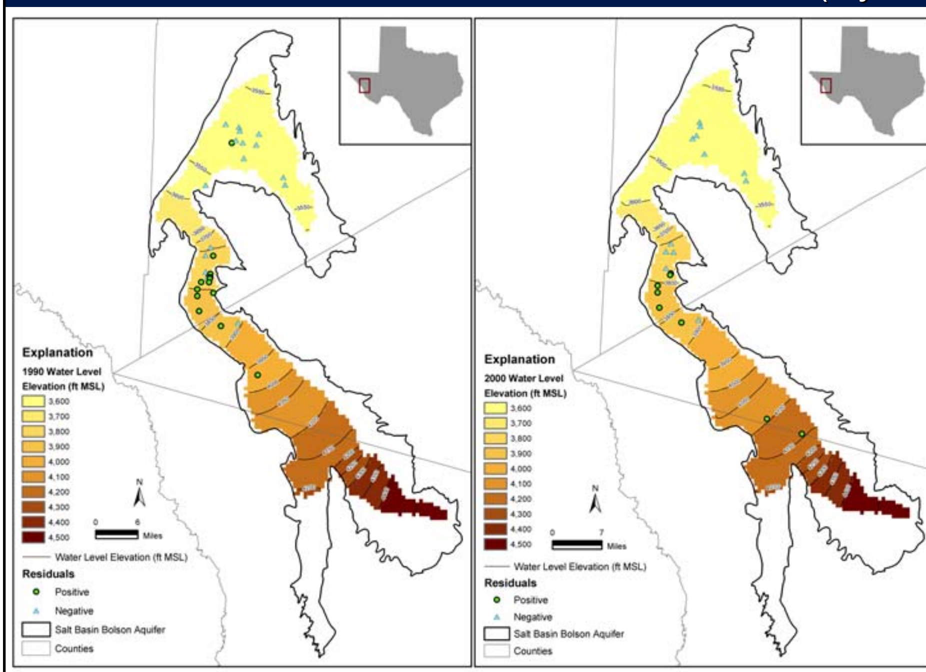
(1991-2000)

Layer	Count	Mean Error	Mean Absolute Error	Residual Standard Deviation (RMS)	RMS/ Range
		(feet)	(feet)	(feet)	
Bolson	298	-15	27	35	0.05
Igneous	301	-15	105	150	0.05
Cretaceous		-	-	-	-
All Layers	599	-15	64	109	0.04

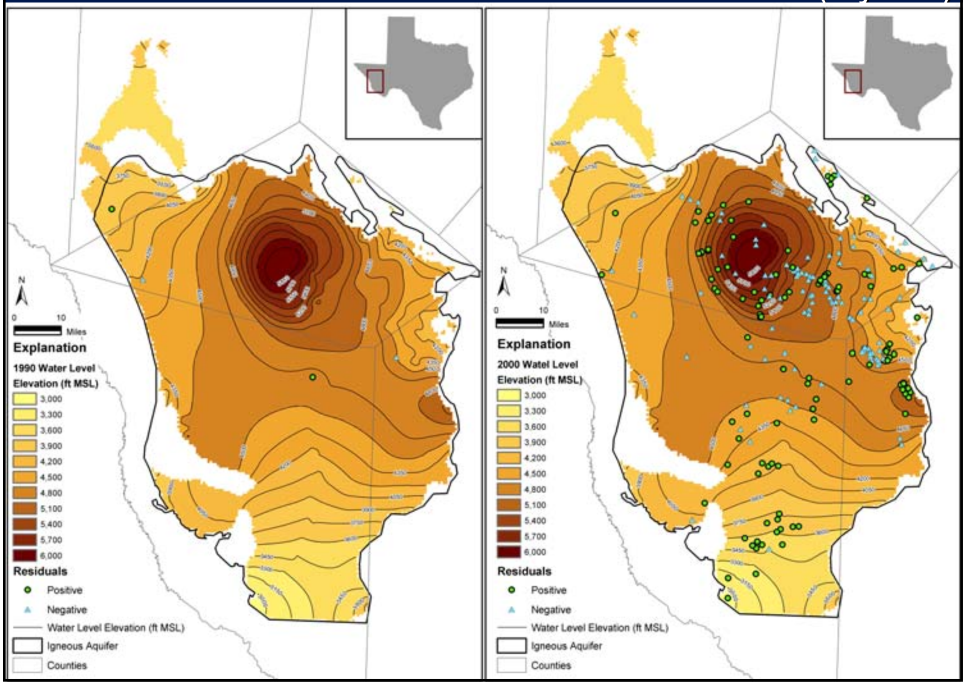
Crossplot of heads during verification period (1990-2000)



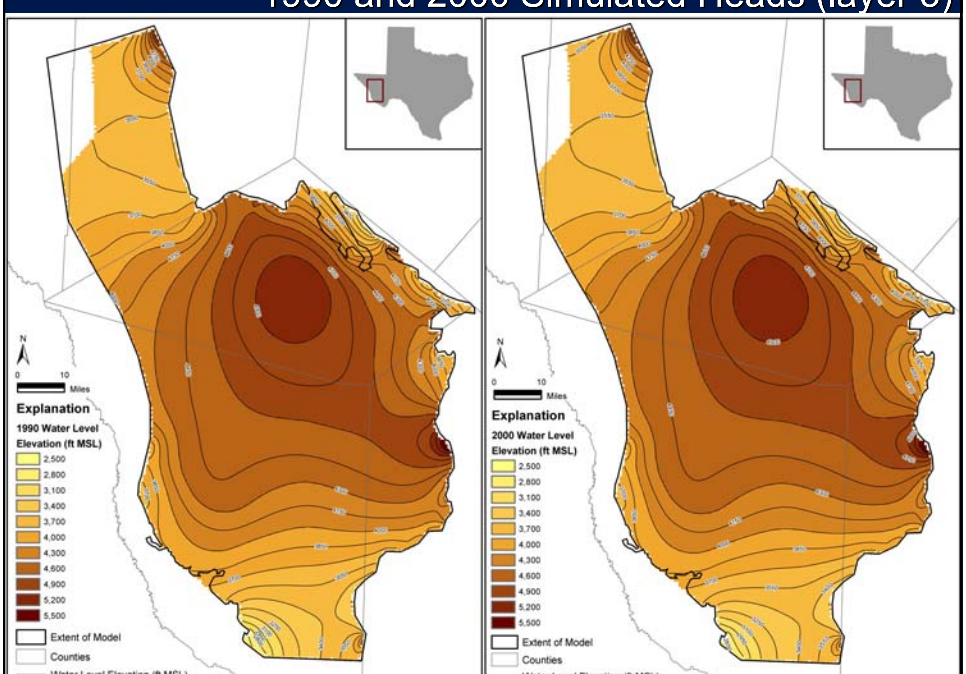
1990 and 2000 Simulated Heads (layer 1)



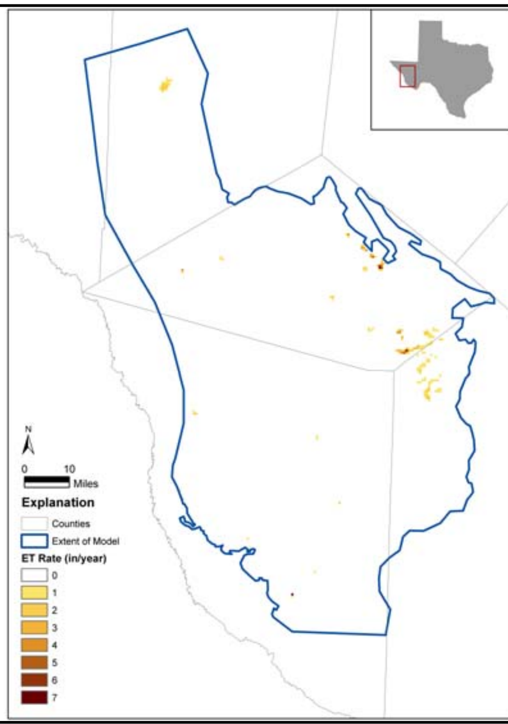
1990 and 2000 Simulated Heads (layer 2)



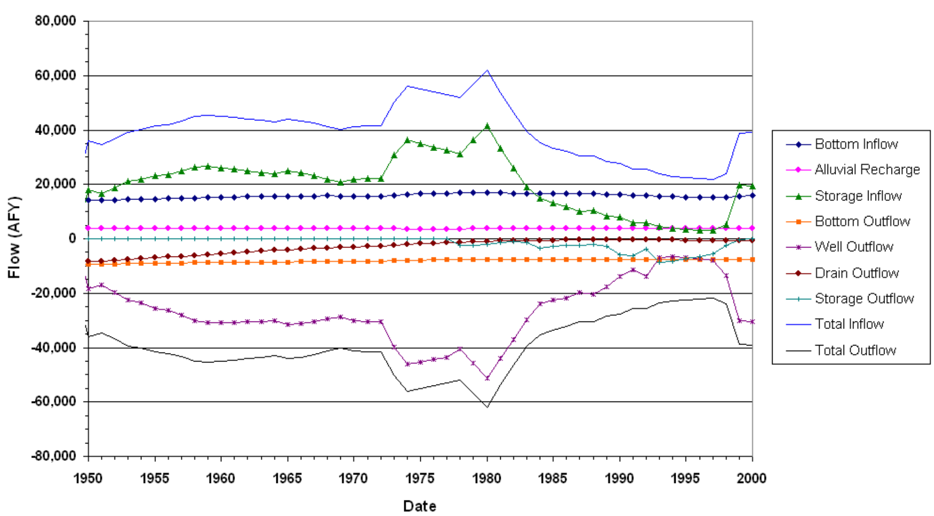
1990 and 2000 Simulated Heads (layer 3)



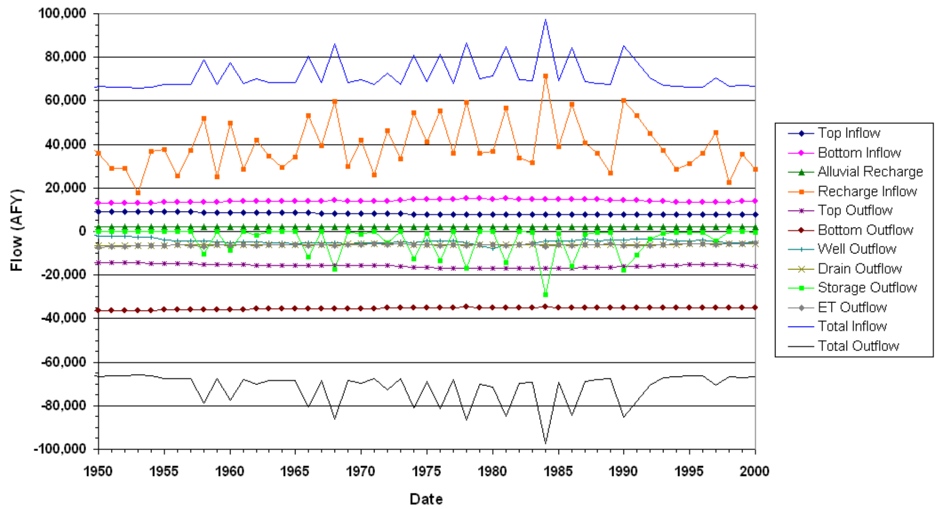
Simulated Steady-State Evapotranspiration from Water Table



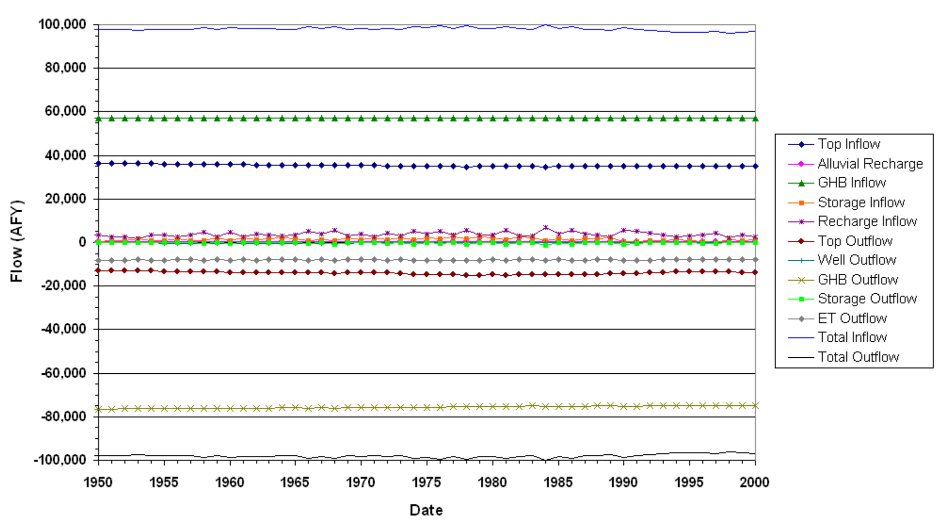
Volumetric Budget (layer 1)



Steady-State Volume Budget
(layer 2)



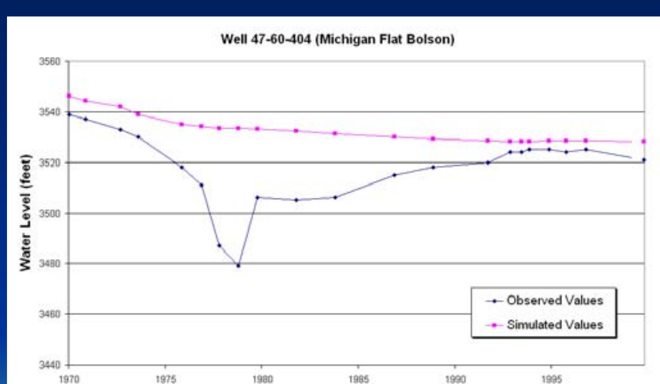
Steady-State Volume Budget
(layer 3)



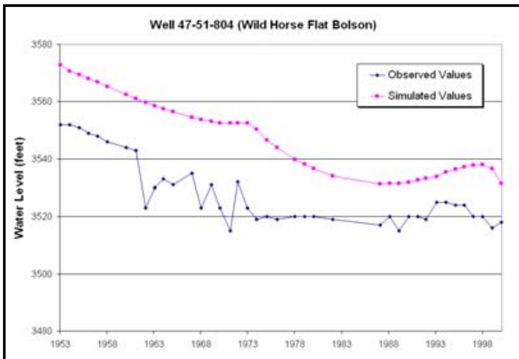
Eastward Flow out of Wild Horse Area

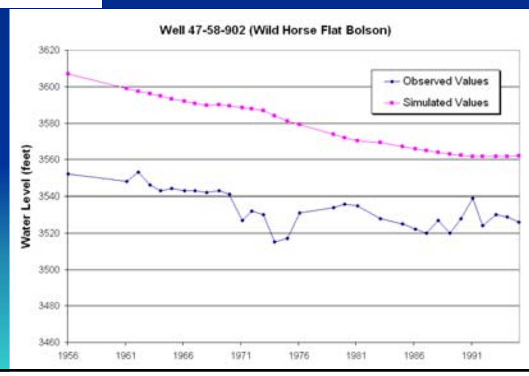
- In Bolson -flow drops from about 2,100 to zero AFY between 1950-1975
- In Cretaceous – flow drops from about 14,000 to 12,000 AFY between 1950-2000

Hydrographs Michigan Flat

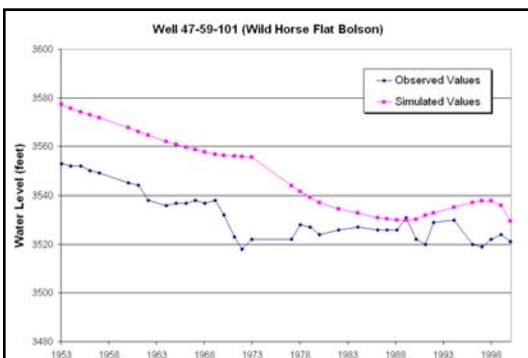


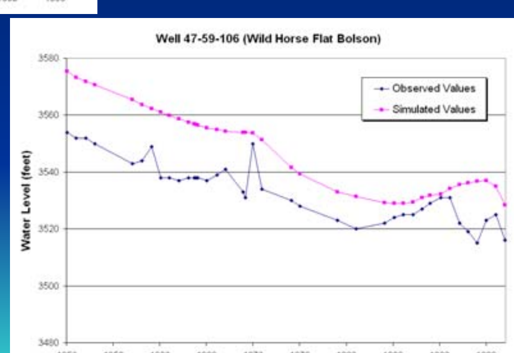
Hydrographs Wild Horse Flat



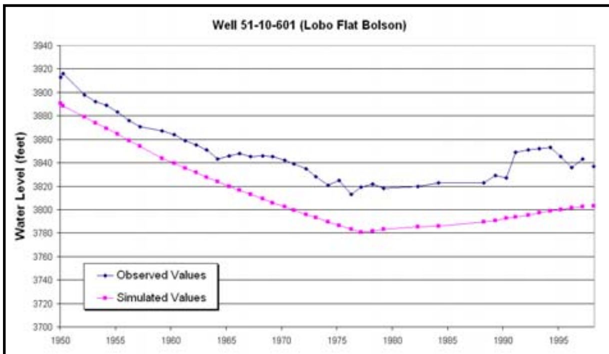


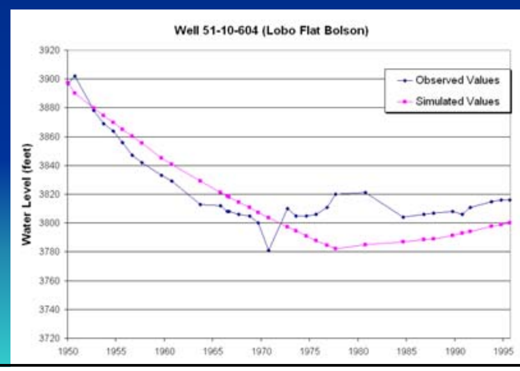
Hydrographs Wild Horse Flat



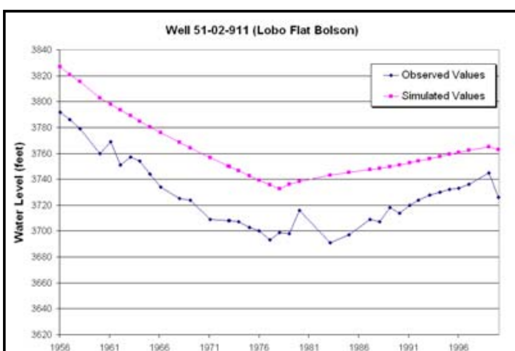


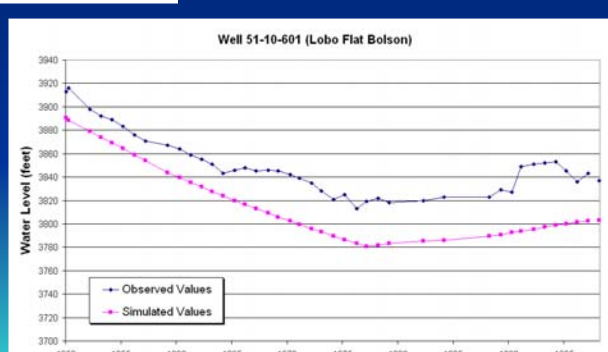
Hydrographs
Lobo Flat



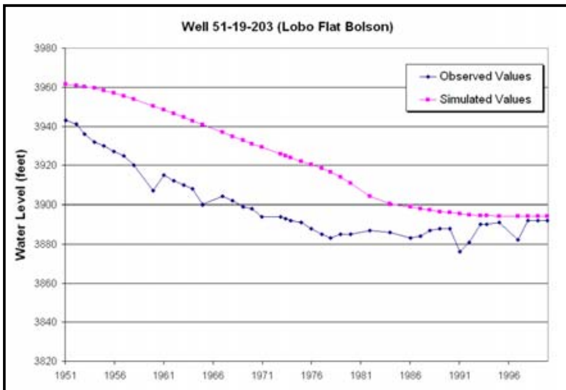


Hydrographs
Lobo Flat

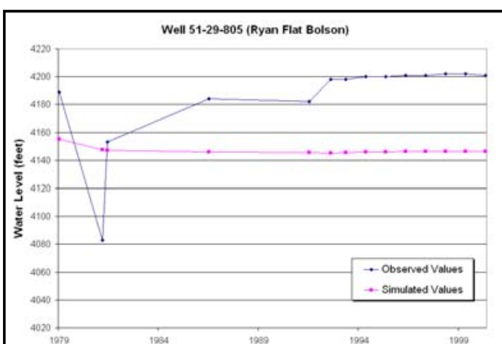




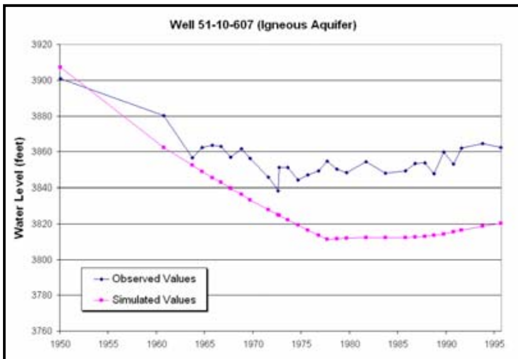
Hydrographs Lobo Flat

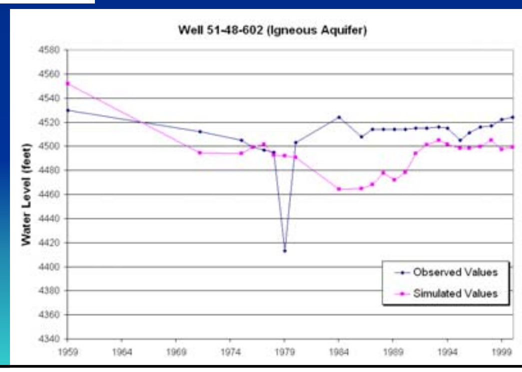


Hydrographs Ryan Flat

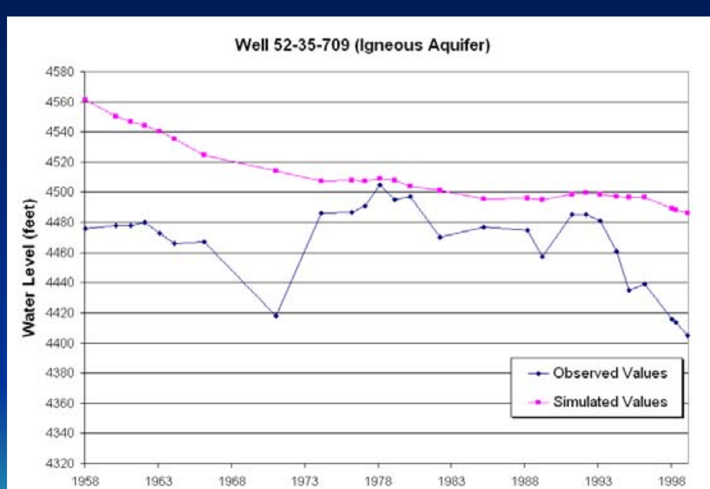


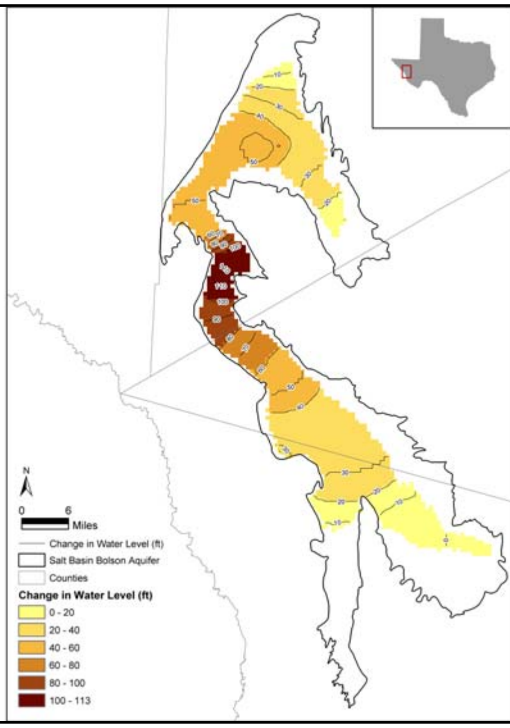
Hydrographs Igneous aquifer



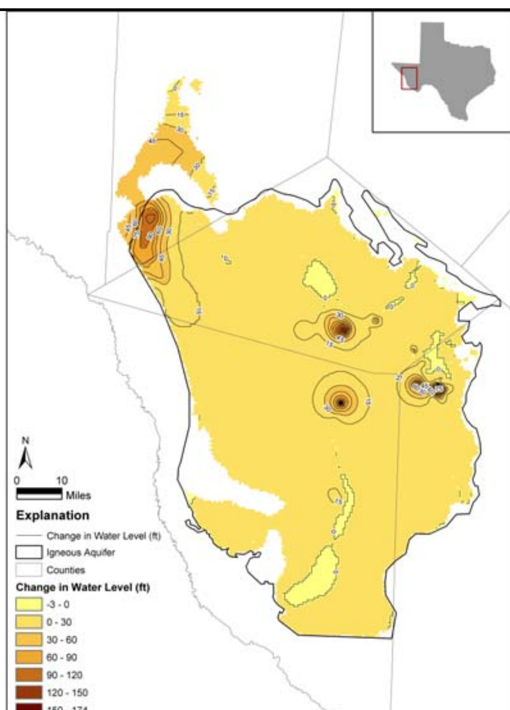


Hydrographs Igneous aquifer

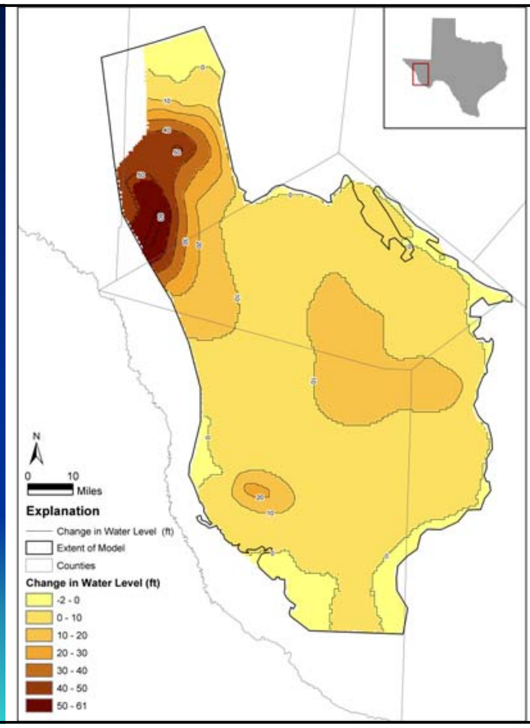




Water Level Change between 1950 and 2000 (Layer 1)

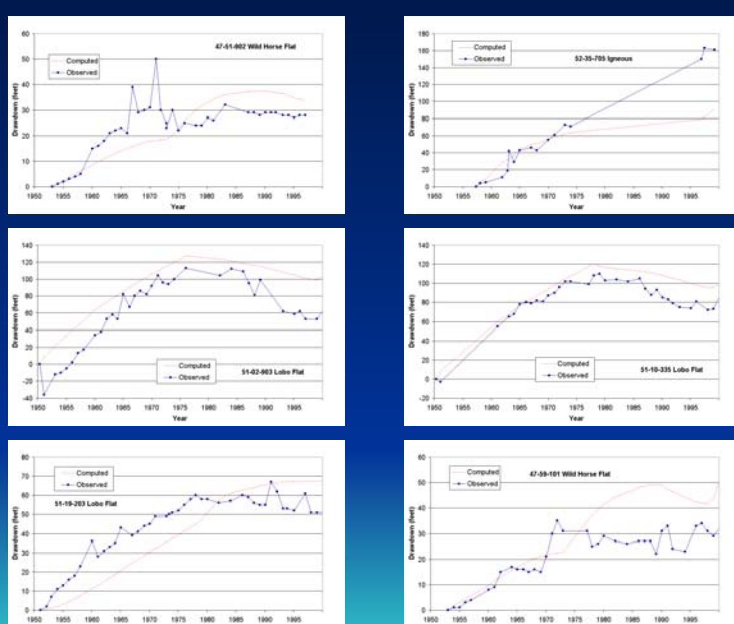


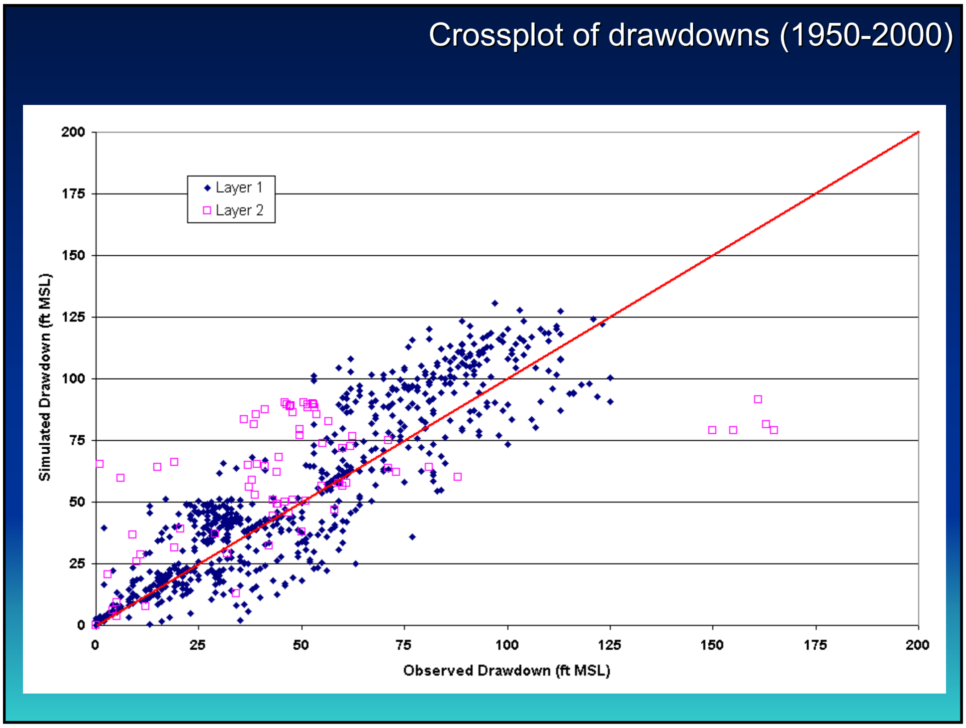
Water Level Change between 1950 and 2000 (Layer 2)



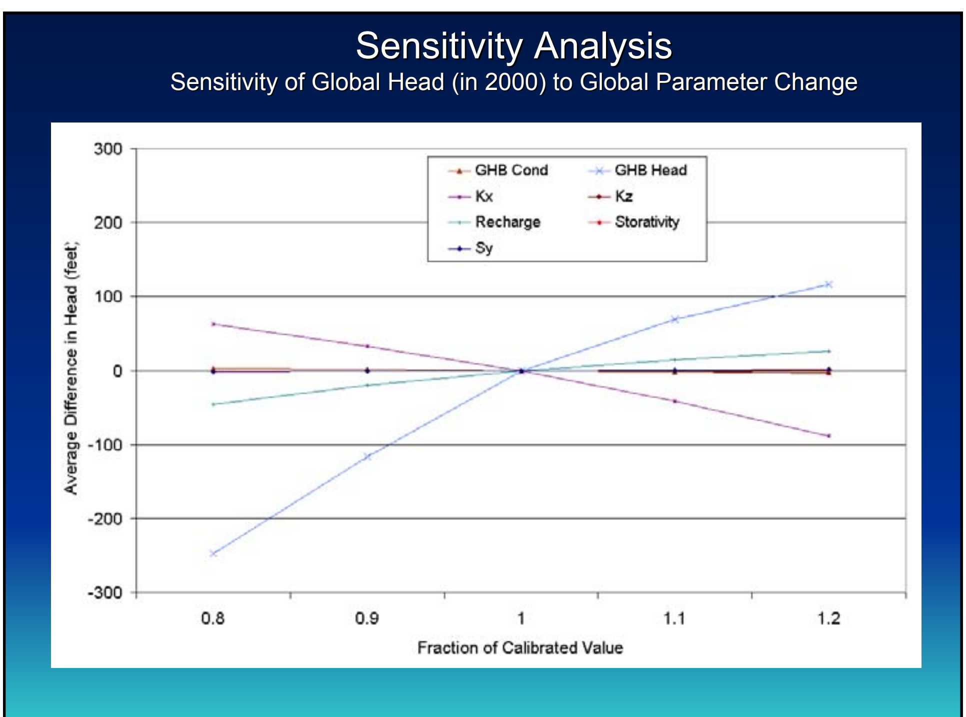
Water Level Change between 1950 and 2000 (Layer 3)

Observed and simulated drawdown (1950-2000)

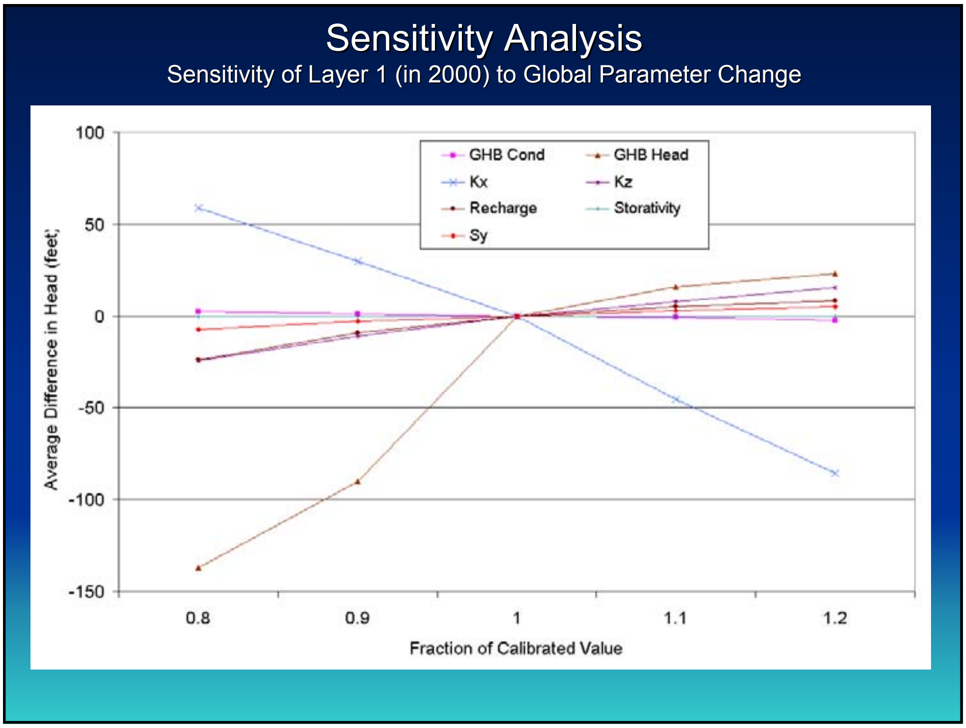


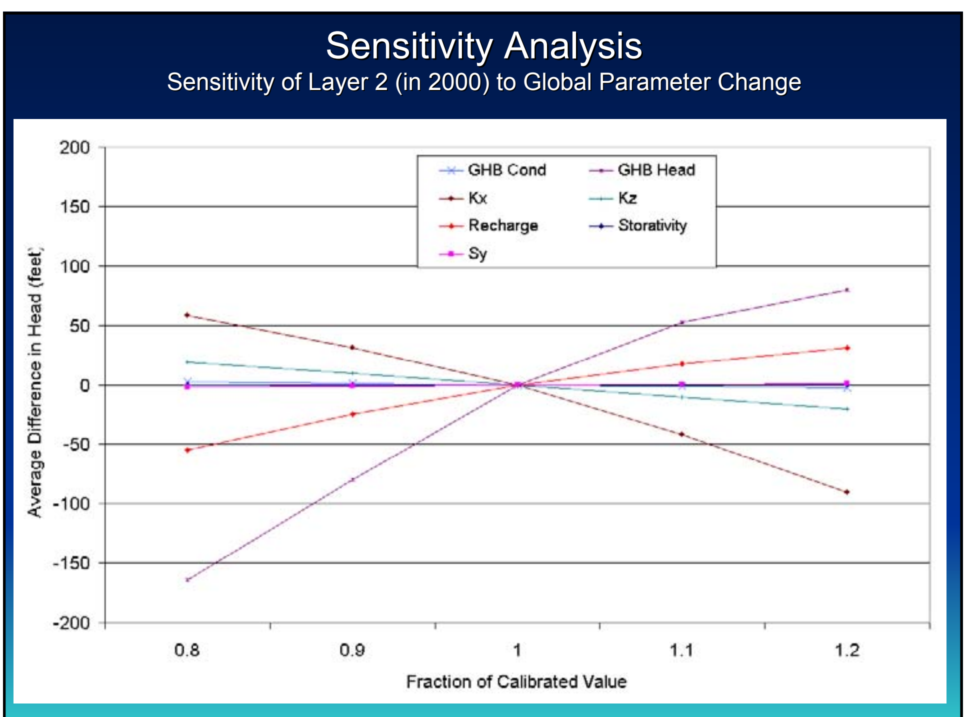


Crossplot of drawdowns (1950-2000)
Layer 1
Layer 2
Simulated Drawdown (ft MSL)
Observed Drawdown (ft MSL)
0
25
50
75
100
125
150
175
200



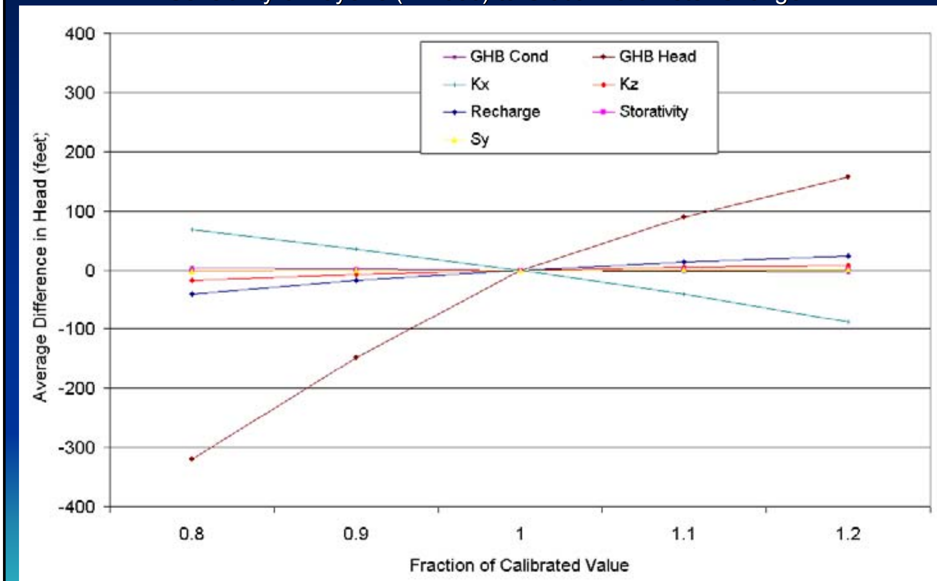
Sensitivity Analysis
Sensitivity of Global Head (in 2000) to Global Parameter Change
GHB Cond
GHB Head
Kx
Kz
Recharge
Storativity
Sy
Average Difference in Head (feet)
Fraction of Calibrated Value
300
200
100
0
-100
-200
-300
0.8
0.9
1
1.1
1.2


Sensitivity Analysis
Sensitivity of Layer 1 (in 2000) to Global Parameter Change
GHB Cond
GHB Head
Kx
Kz
Recharge
Storativity
Sy
100
50
0
-50
-100
-150
Average Difference in Head (feet)
0.8
0.9
1
1.1
1.2
Fraction of Calibrated Value


Sensitivity Analysis
Sensitivity of Layer 2 (in 2000) to Global Parameter Change
GHB Cond
GHB Head
Kx
Kz
Recharge
Storativity
Sy
200
150
100
50
0
-50
-100
-150
-200
Average Difference in Head (feet)
0.8
0.9
1
1.1
1.2
Fraction of Calibrated Value

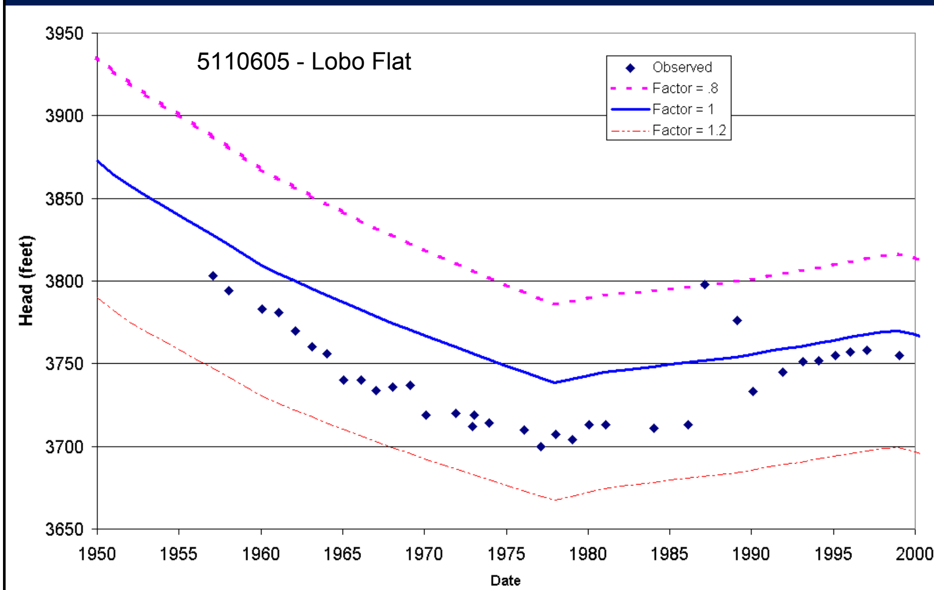
Sensitivity Analysis

Sensitivity of Layer 3 (in 2000) to Global Parameter Change



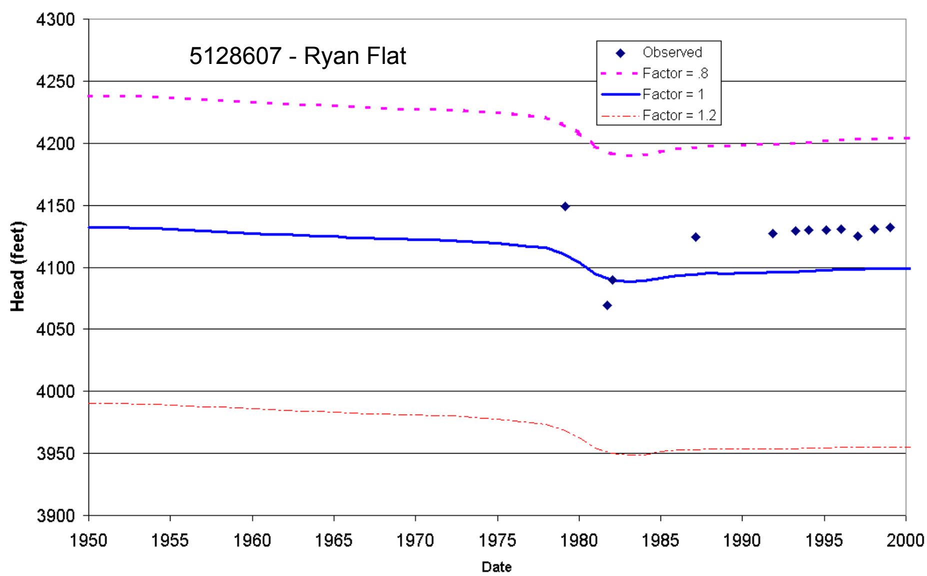
Sensitivity Analysis

Hydrograph Sensitivity to Global Parameter Change



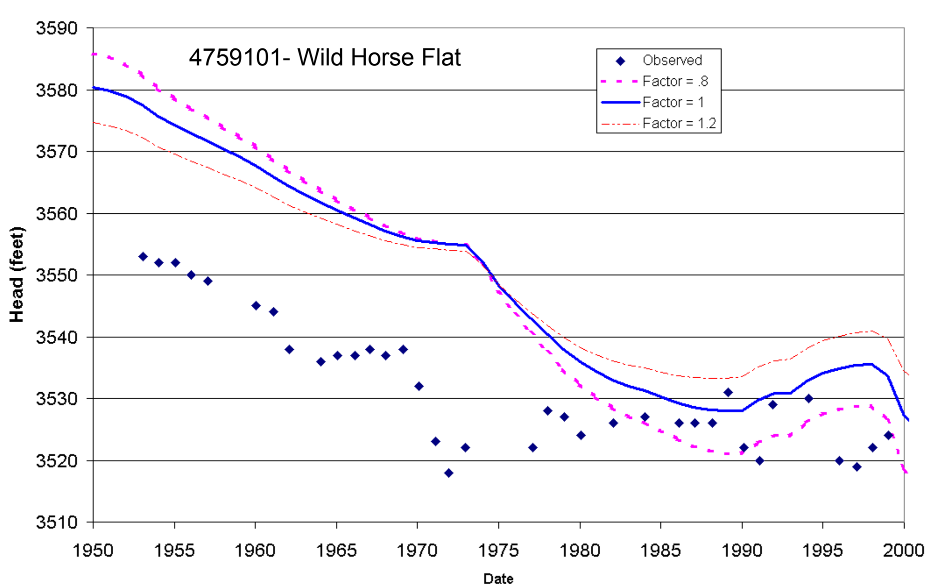
Sensitivity Analysis

Hydrograph Sensitivity to Global Parameter Change



Sensitivity Analysis

Hydrograph Sensitivity to Global Parameter Change



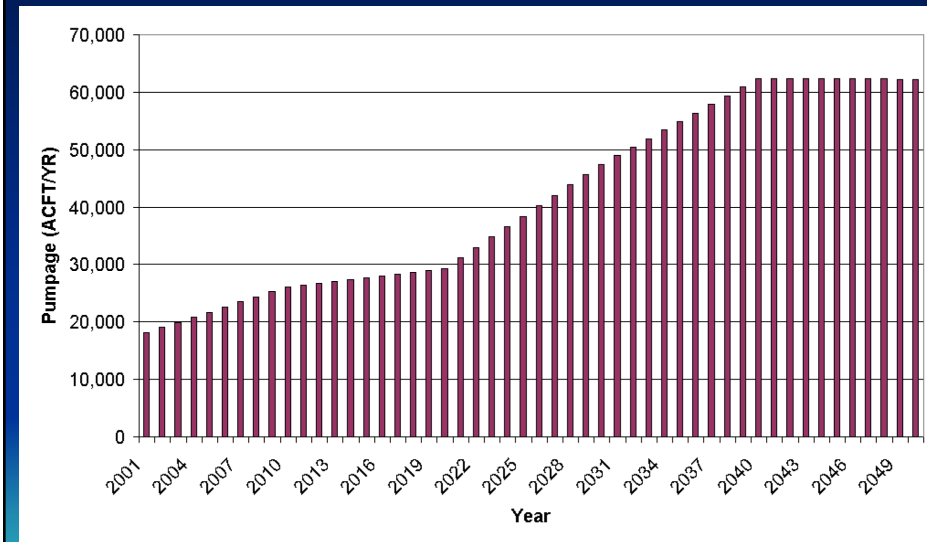
Predictive Simulations

Responses to Public Comments regarding Model Predictions

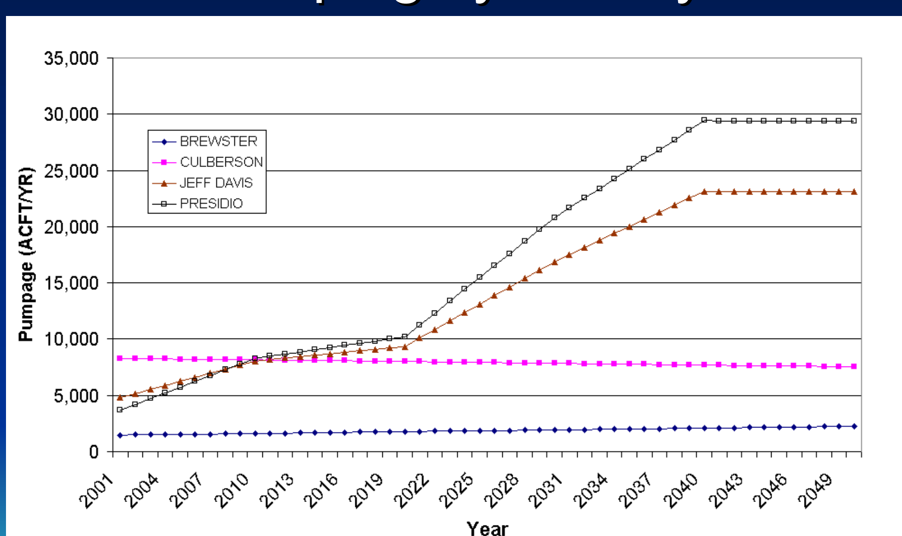
- Culberson Co. - In 2002, the State Water Plan included estimates of future demand in Culberson Co. that were about 1/3 of the current usage. Therefore, water levels generally increase in Culberson Co. during the predictive period. For the final report, another simulation will be completed which will include the recently approved demands from Region E, which are equal to the metered amounts.

- Region E strategy – a tentative strategy was approved by Region E and included in the State Water Plan (SWP) which proposed that El Paso would pump groundwater from Ryan Flat. The existing well field is located in Jeff Davis and Presidio Counties. However, the SWP stated that all the pumping would occur in Jeff Davis Co. Region E has approved a clarification of that strategy which assumes that pumping will occur in both counties, which better represents the intent of the strategy.

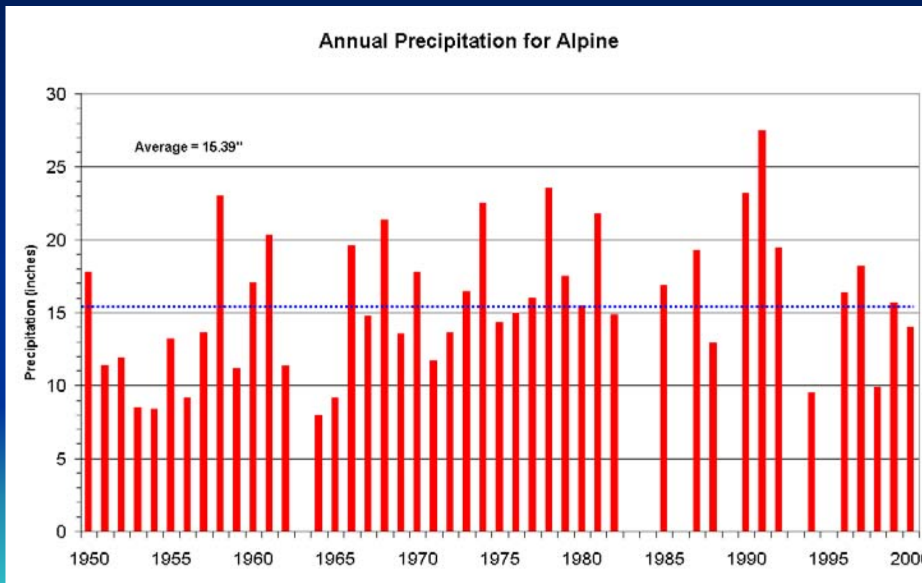
Total Pumping



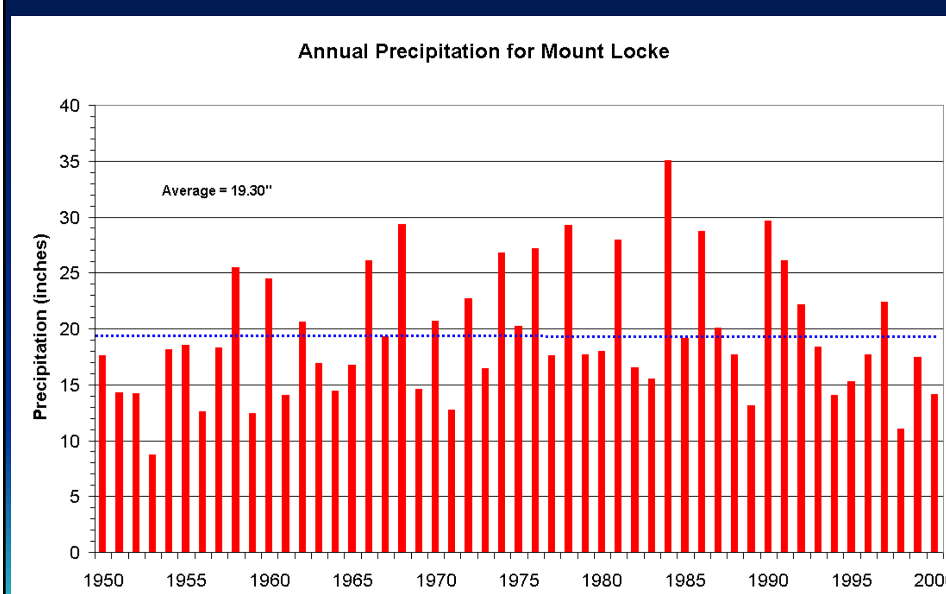
Pumping by County



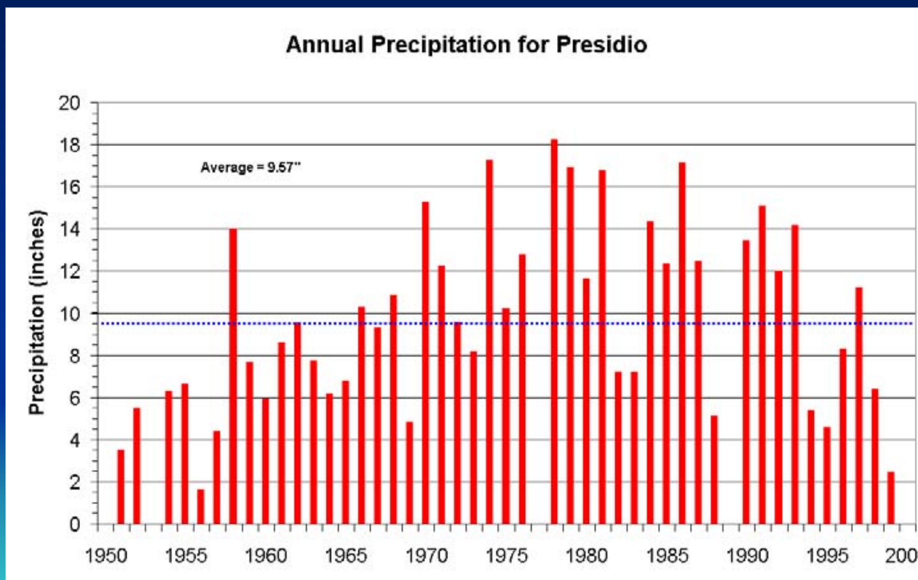
Drought of Record



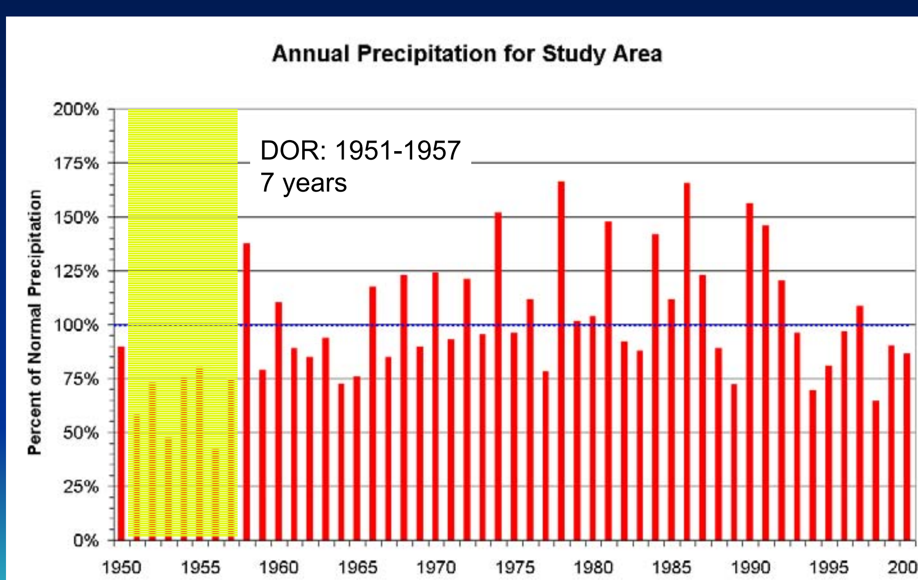
Drought of Record



Drought of Record



Drought of Record



Drought of Record

- DOR = 7 years
- 1951-1957
- Recharge estimates are based to variation in regional precipitation (average from gages in the model area)
- Ranges from 42-80% of normal and averages 64%

Water Level, Saturated Thickness and Drawdown in 2010 - Average Recharge - Bolson

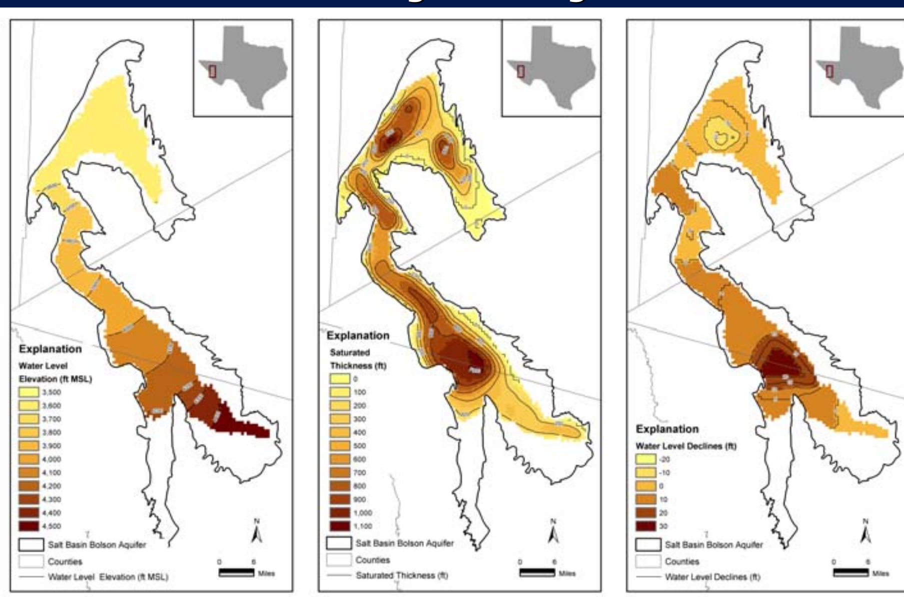


Figure 10.2.1 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2010 Under Average Conditions (Layer 1)

Water Level, Saturated Thickness and Drawdown in 2010 - Average Recharge - Igneous

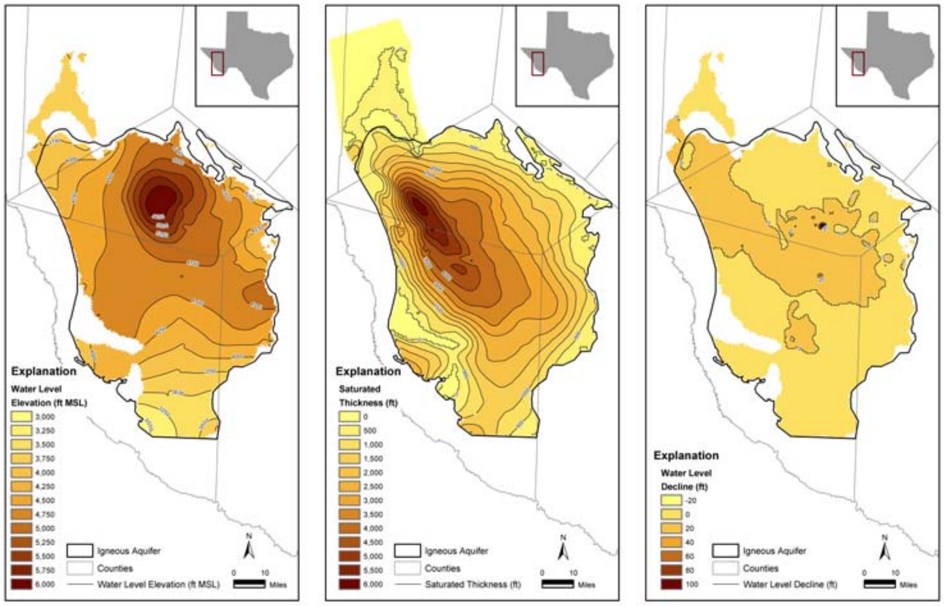


Figure 10.2.2 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2010 Under Average Conditions (Layer 2)

Water Level, Saturated Thickness and Drawdown in 2020 - Average Recharge - Bolson

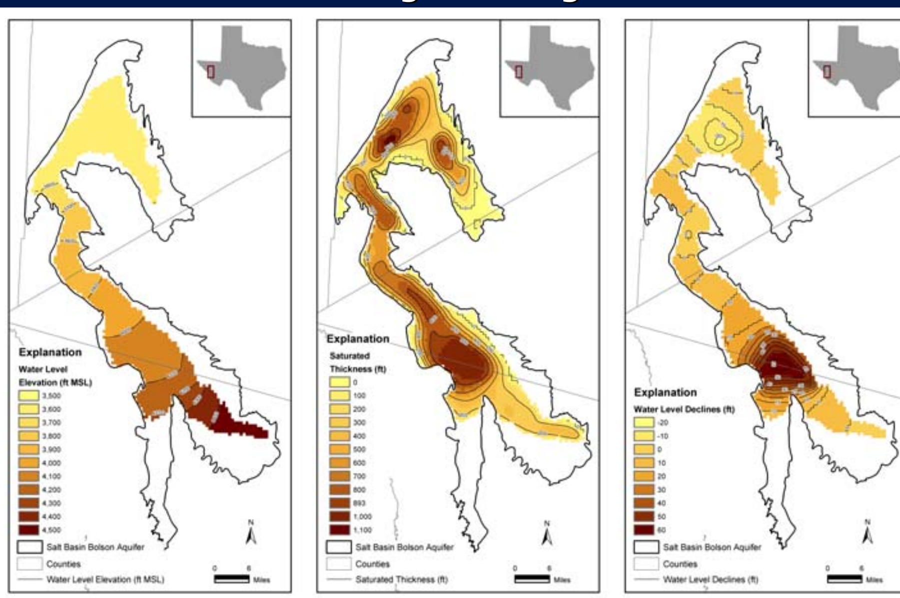


Figure 10.2.3 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2020 Under Average Conditions (Layer 1)

Water Level, Saturated Thickness and Drawdown in 2020 - Average Recharge - Igneous

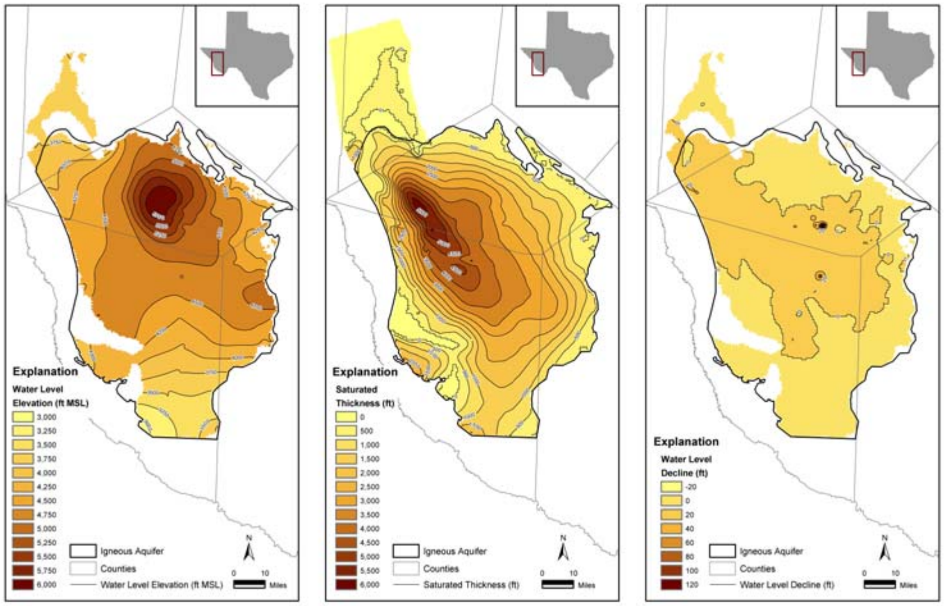


Figure 10.2.4 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2020 Under Average Conditions (Layer 2)

Water Level, Saturated Thickness and Drawdown in 2030 - Average Recharge - Bolson

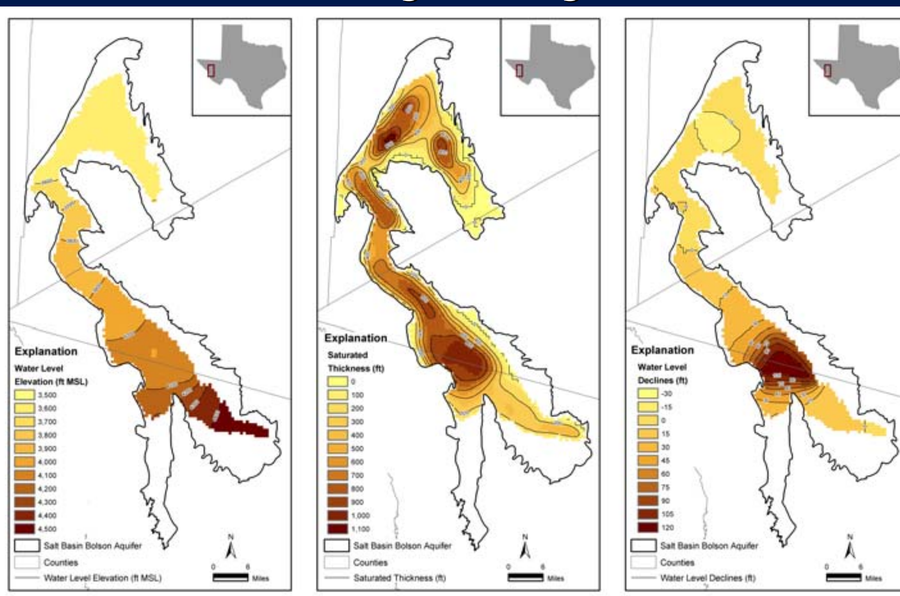


Figure 10.2.5 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2030 Under Average Conditions (Layer 1)

Water Level, Saturated Thickness and Drawdown in 2030 - Average Recharge - Igneous

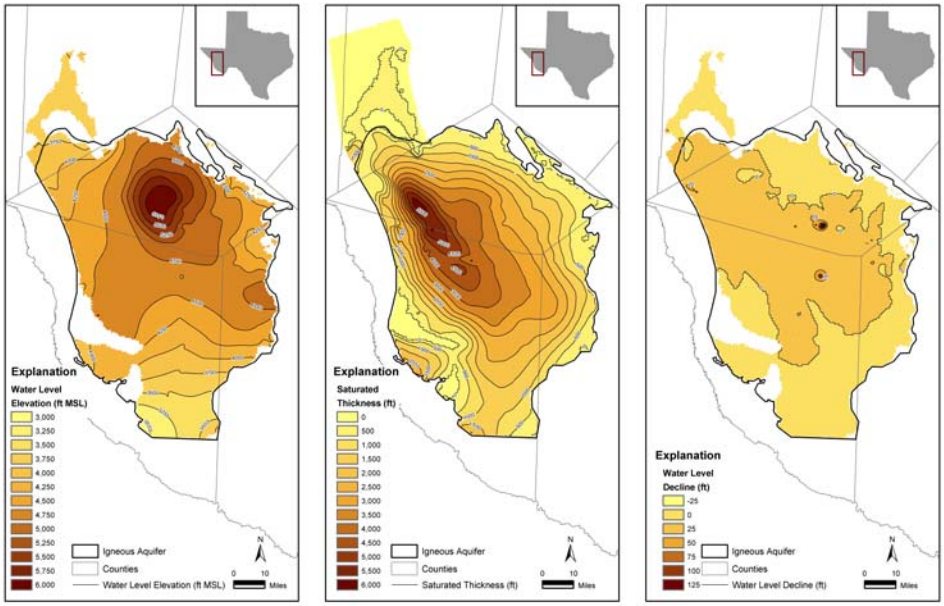


Figure 10.2.6 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2030 Under Average Conditions (Layer 2)

Water Level, Saturated Thickness and Drawdown in 2040 - Average Recharge - Bolson

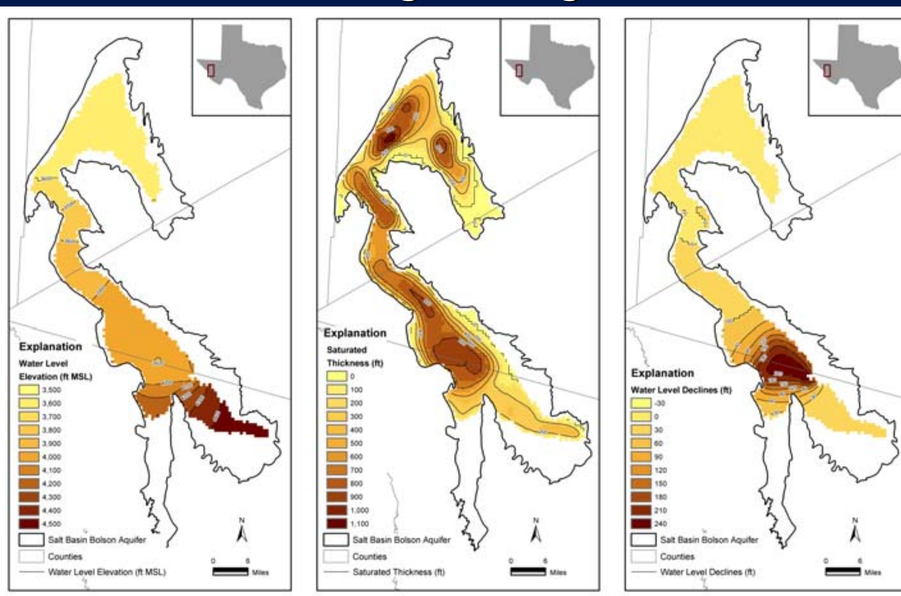


Figure 10.2.7 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2040 Under Average Conditions (Layer 1)

Water Level, Saturated Thickness and Drawdown in 2040 - Average Recharge - Igneous

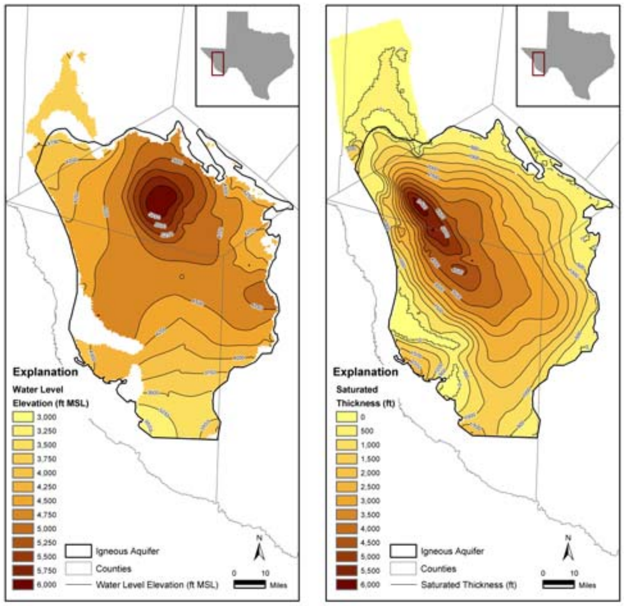


Figure 10.2.8 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2040 Under Average Conditions (Layer 2)

Water Level, Saturated Thickness and Drawdown in 2050 - Average Recharge - Bolson

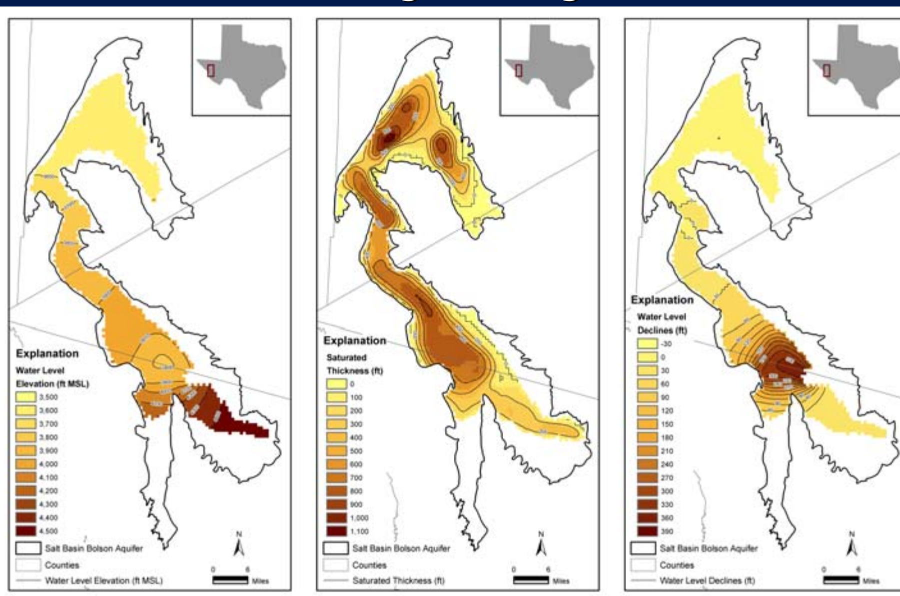


Figure 10.2.9 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2050 Under Average Conditions (Layer 1)

Water Level, Saturated Thickness and Drawdown in 2050 - Average Recharge - Igneous

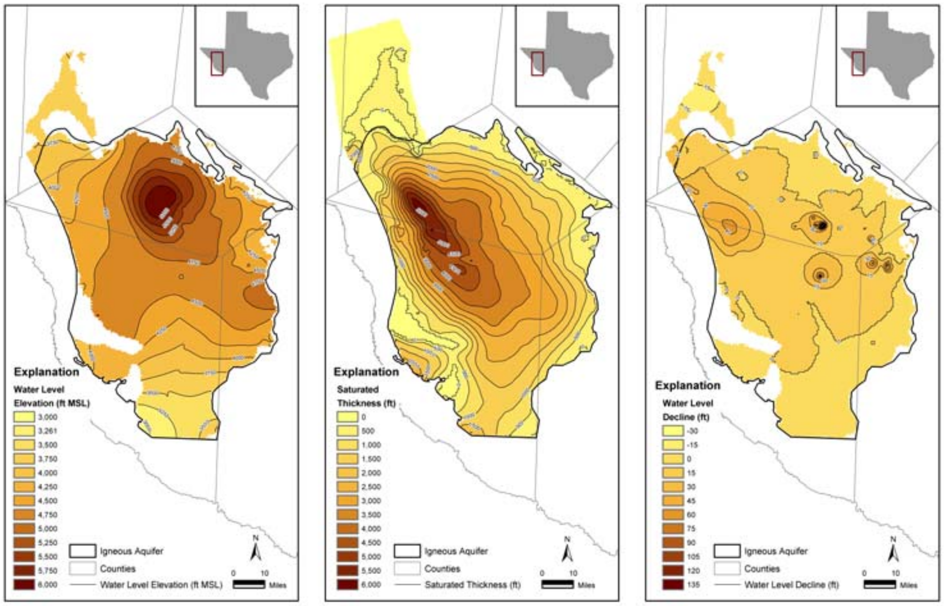


Figure 10.2.10 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2050 Under Average Conditions (Layer 2)

Water Level, Saturated Thickness and Drawdown in 2050 - Average Recharge – Layer 3

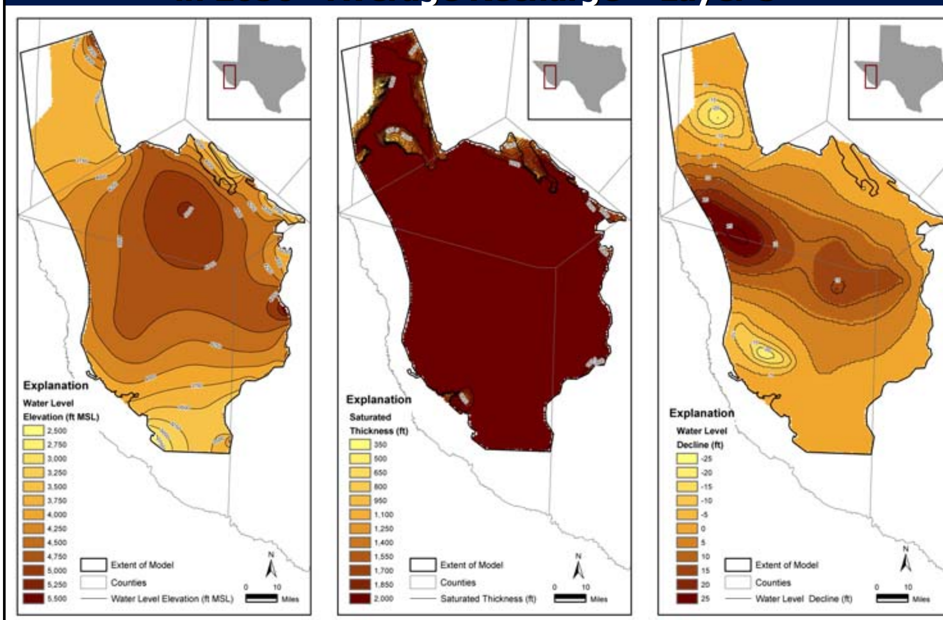
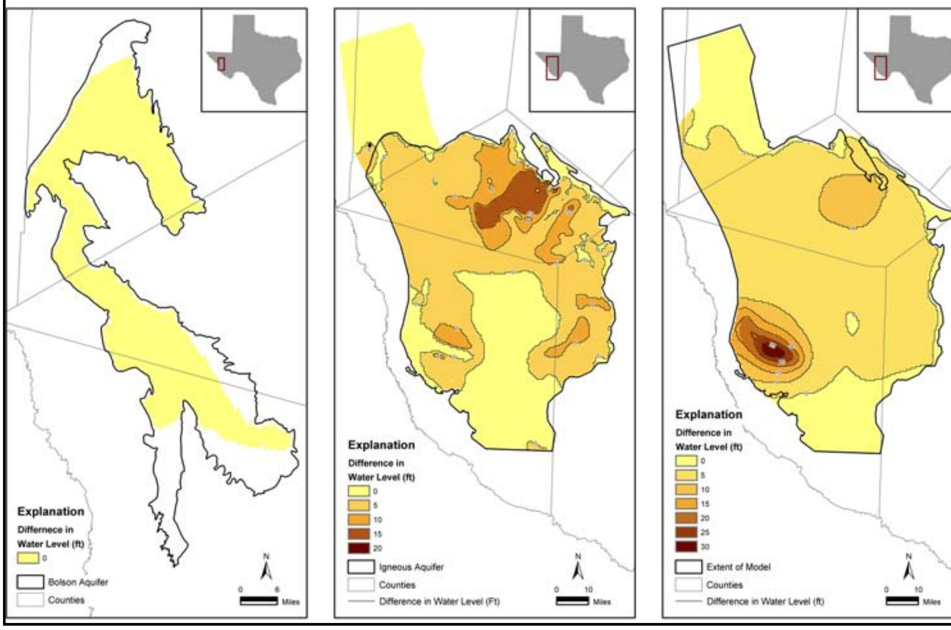
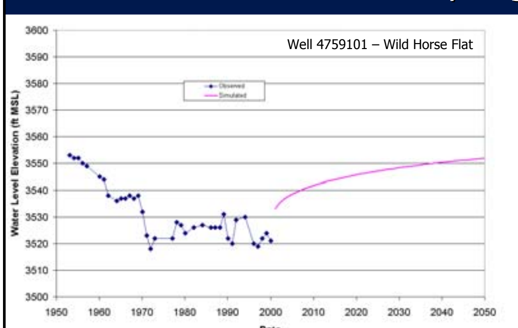


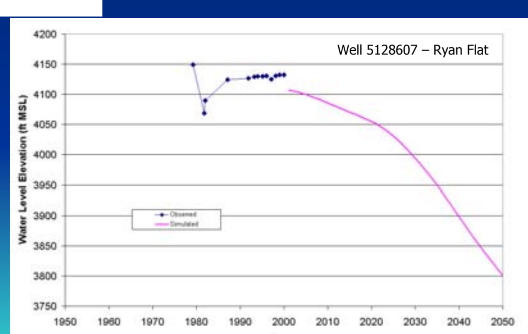
Figure 10.2.11 - Simulated Water Levels, Saturated Thickness, and Water Level Declines in 2050 Under Average Conditions (Layer 3)

Difference in Heads in 2050
Average versus DOR



Observed and Simulated Hydrographs (Average Recharge)





Model Limitations

- Supporting Data
  - Igneous hydrogeology, hydraulic properties, fractures, heterogeneity, connection to Bolson
  - Bolson pumping data
- Limiting Assumptions
  - Continuous porous media model
  - "Lumped-layer" conceptualization
- Limits of Applicability
  - Igneous simulations
  - Stream-aquifer interactions

Conclusions

- Model meets GAM calibration/verification requirements
- Model is a good tool for RWP efforts
- Good tool to assess regional Bolson drawdown from proposed pumping
- Probably not a good tool for detailed Igneous evaluations


Thanks!
Any Questions ?

5th Stakeholder Advisory Forum
March 25th, 2004
West Texas Igneous and Bolson GAM
List of Attendees

Name	Affiliation
James Beach	LBG-Guyton Associates
John Ashworth	LBG-Guyton Associates
Zhuping Sheng	TAMU
Van Robinson	self
Bill Hutchison	El Paso Water Utilities
Steve Finch	John Shomaker & Associates
Dave Hall	Public of El Paso
Kevin Urbanczyk	SRSU
Janet Adams	Jeff Davis UWCD
Gorden Bell	Guadalupe Mtns. N. Park
Mike Mecke	TAMU Extension Service
James W. Word	SRSU
Robert R. Flores	TWDB
Pam Tarelle	SWS
Gordon Wells	Freese & Nichols
Simone Kiel	Freese & Nichols
Jeff Bennett	National Park Service, Big Bend
Juan D. Gomez	CH2MHill

QUESTIONS AND ANSWERS
West Texas Igneous and Bolson GAM
SAF Meeting 5 – March 25, 2004
Alpine, Texas

Question: Was the 60% recharge rate varied over the modeled area?
Answer: No, the 60% rate was not varied spatially.

Comment: You should discuss dispersion of horizontal hydraulic conductivity in Layer 2 as shown in Figure 4.2.7. Also explain that Ts are the factor that influences the model results.
Answer: We recognize that the hydraulic conductivity numbers are different than those estimated from specific capacity and pumping tests. However, these values were necessary to maintain heads at the desired elevation.

Question: Why doesn't the decline in the Alpine well field show up earlier in time?
Answer: The drawdown illustration starts in the base year 2000 and shows water level declines from that year forward. We will check what assumptions were made for that pumping demand for the final report.

Question: Why do you simulate the Drought-of-Record only in the final decade?
Answer: It was a requirement of the GAM process.

Question: How did you distribute vertical pumpage in Ryan Flat?
Answer: Projected demand for the Bolson aquifer is applied to Layer 1 only.

Question: Can you ask for different input criteria when requesting a TWDB GAM run?
Answer: Yes.

Question: How quickly can we expect to get results back from a requested GAM run?
Answer (Ted Angle): Model run requests will be processed in the order that they are received. Results should be available within approximately two weeks of date the run is initiated. NOTE: TWDB will send a letter of acknowledgement within two weeks of receipt of your request. TWDB staff should be able to complete requests within three months. However, estimated GAM run completion dates may be modified depending on priority requests.