Updating the Barton Springs Groundwater Availability Model

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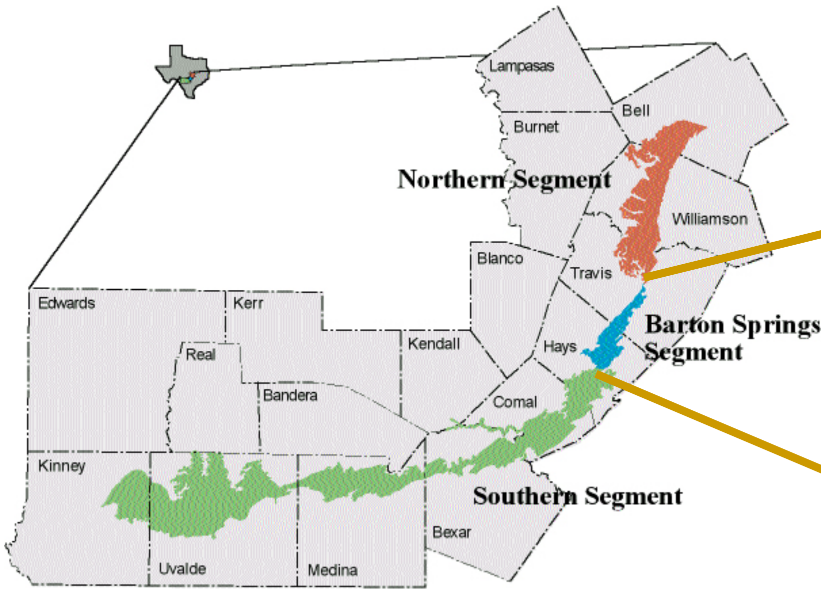
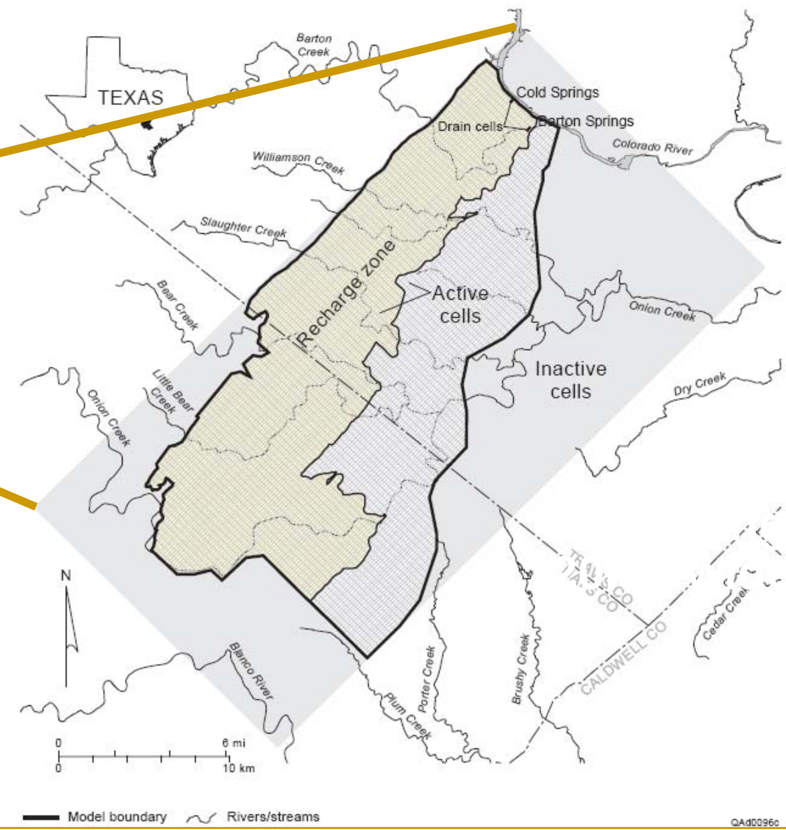
Outline

- Barton Springs segment GAM update project
- MODFLOW-DCM
- Barton Springs segment model
- Preliminary plans for this project

Barton Springs Segment
Edwards Aquifer





(Scanlon et al., 2003; BSEACD,2003)

Scanlon et al., 2001, *Groundwater availability of the Barton Springs segment of the Edwards Aquifer, Texas: Numerical simulations through 2050.*

Barton Springs Segment GAM Update Motivation

- Initial Barton Springs Segment GAM (Scanlon et al., 2001) calibrated to normal spring flow conditions
- BSEACD developed alternative model, calibrated to low spring flow conditions
- Matching both normal and low spring flow using standard MODFLOW was not achieved
- Instigated interest in exploring innovative karst modeling technology

GAM Update Project Timeline

- TWDB issued RFQ in summer of 2007
- “Research grants for improvements and updates to existing groundwater availability models with matching fund contributions”
- SwRI was approached by BSEACD to respond to the RFQ
- SwRI teamed with BSEACD to submit a proposal to TWDB in September 2007
- Contract finalized on March 31, 2008
- Terms: 12 months, jointly funded by TWDB & BSEACD

GAM Update Project Objectives

- Develop the conceptual model
- Define the model architecture
- Calibrate the model
- Conduct sensitivity analysis

GAM Update Project Tasks

- Task 1: Develop an Improved and Updated Barton Springs GAM Model.
- Task 2: Fulfill the TWDB GAM Requirements
- Task 3. Identify the Transient Calibration Period
- Task 4. Prepare Documentation
- Task 5. Conduct an Outreach and Technical Transfer Program
- Task 6. Prepare Status Reports and Final Report

GAM Update Project Deliverables

Deliverable	Date
Kickoff Meeting	April 25, 2008
1st Stakeholders Advisory Forum	May 28, 2008
2nd Stakeholders Advisory Forum	December 15, 2008
Draft Final Report	January 30, 2009
Final Project Report Presentation	February 16, 2009
Final Report	March 31, 2009

Background: Karst Modeling Initiative

- Phase 1
  - Funded by EAA, SWFWMD, AwwaRF
  - December 2003 – December 2004
- Phase 2
  - Funded by EAA, SWFWMD
  - In-kind contribution from BSEACD
  - August 2005 – January 2007

Evaluate existing modeling tools for karst aquifers.

Develop new computational tools as needed.

Focus on distributed parameter models and water supply applications.

Summary of Karst Modeling Initiative

- MODFLOW-DCM Version 2.0
  - Turbulence model with transition between laminar and turbulent regimes
  - New Newton-Raphson solver
  - Robust fix to MODFLOW dry cell problem
- Barton springs conduit model (with help from BSEACD) and calibrated in steady state and transient
- Implemented initial version of model for Santa Fe Sink/Rise system (Florida karst aquifer)
- Presented results
  - USGS Karst Interest Group Meeting
  - NGWA Groundwater Expo
  - GSA Annual Meeting (invited)

MODFLOW-DCM Version 2.0

- Classical dual conductivity framework
  - Continuum or discrete network representation for conduit
  - Continuum representation for diffuse system
  - Exchanges linear (confined) or nonlinear (unconfined)
- Current version limited to 2 ½ dimensions
  - One layer for conduit, one for matrix
  - Top and bottom of each layer specified by user
- Confined or unconfined (convertible)
  - New algorithm for drying cells
- Turbulent or laminar flow in conduit system
- Legacy data honored
- A MODFLOW variant, not a package

DCM input parameters

- Conduit conductivity
  - Effective grid-scale property
  - Implicitly incorporates geometrical properties
  - Input for laminar conditions
- Critical gradient for onset of turbulence
- Conduit storage parameters
- Conduit-matrix exchange term
  - Depends on matrix conductivity and conduit surface area
  - Implicitly incorporates geometrical properties
  - Input for filled conduit – calculated for partially filled conduit

Treatment of dry cells

- Dry cells lead to convergence failures in MODFLOW
- Conduits amplify the pre-existing problem
- DCM algorithm
  - Water level not allowed to drop below cell bottom elevation
  - Dry cell remains active in calculation
  - Upstream weighting of branch conductance prevents flow from a dry cell but allows flow to a dry cell
- New Newton-Raphson solver improves convergence
- Modified WELL package ramps down pumping as cell dries out (or use MNW, multinode well package)
- Journal article in review by Ground Water

MODFLOW-DCM Summary

- New simulation technology makes more realistic models possible
  - Straightforward representation of conduits
  - Better representation of multiple timescales
  - Turbulent flow
- Accepts data in standard MODFLOW input
  - Reuse input files from existing model
- Dry cell numerical problems fixed
  - Removes major obstacle for applications
  - Technology spinoff with more general applications

MODFLOW-DCM Modeling of Barton Springs Segment





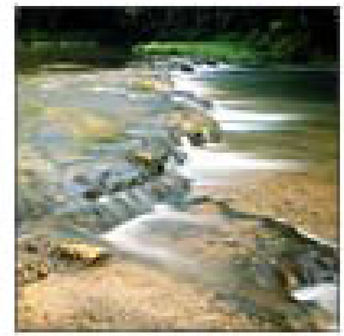
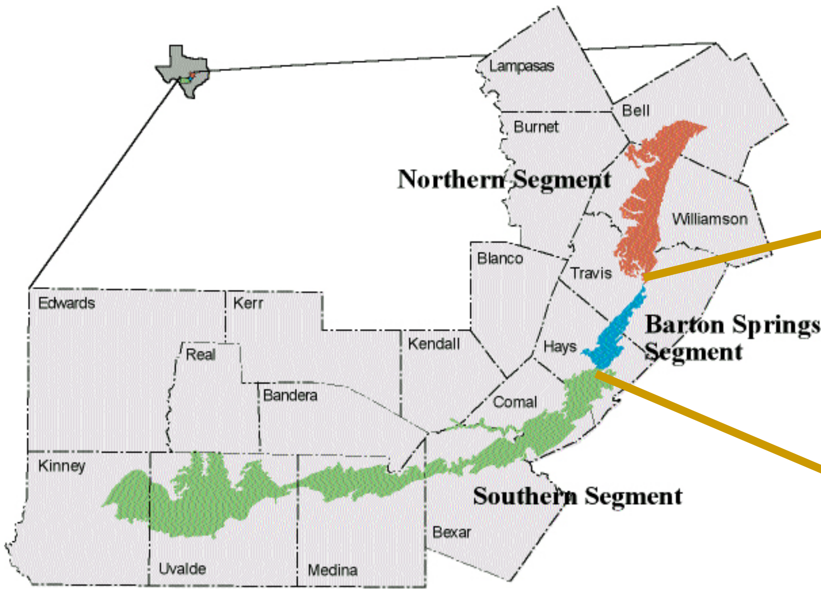


Image Source
http://www.ci.austin.tx.us/parks/bartonsprings.htm

Barton Springs Segment
Edwards Aquifer



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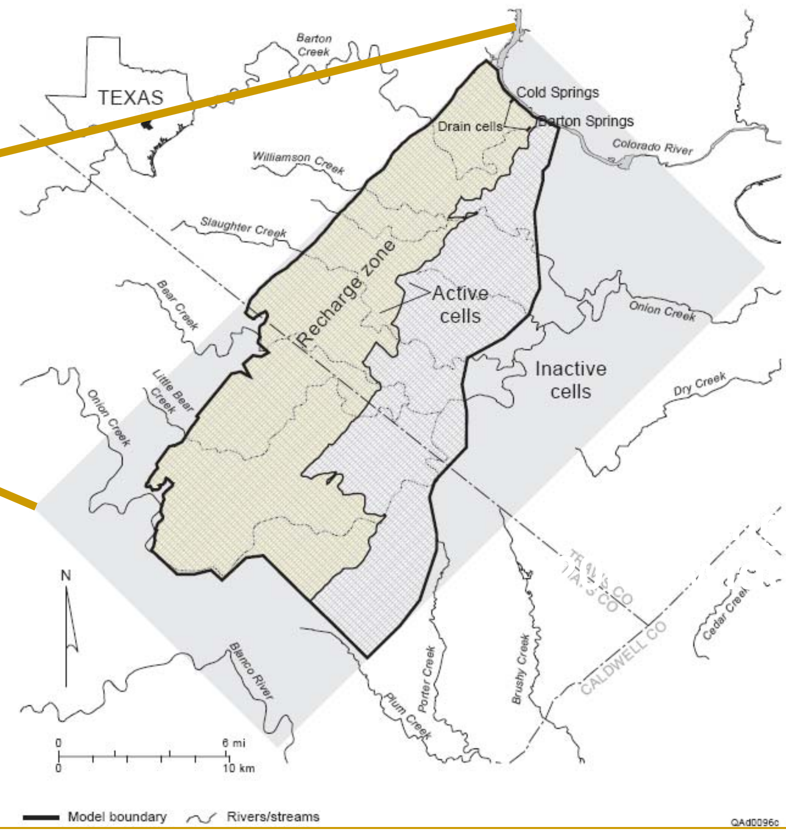

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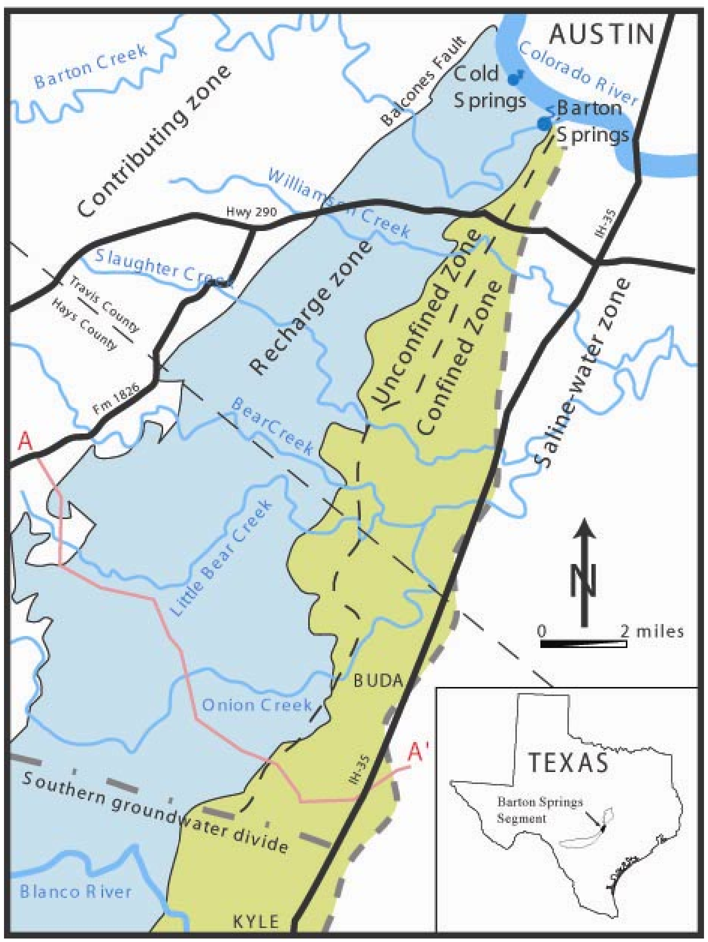
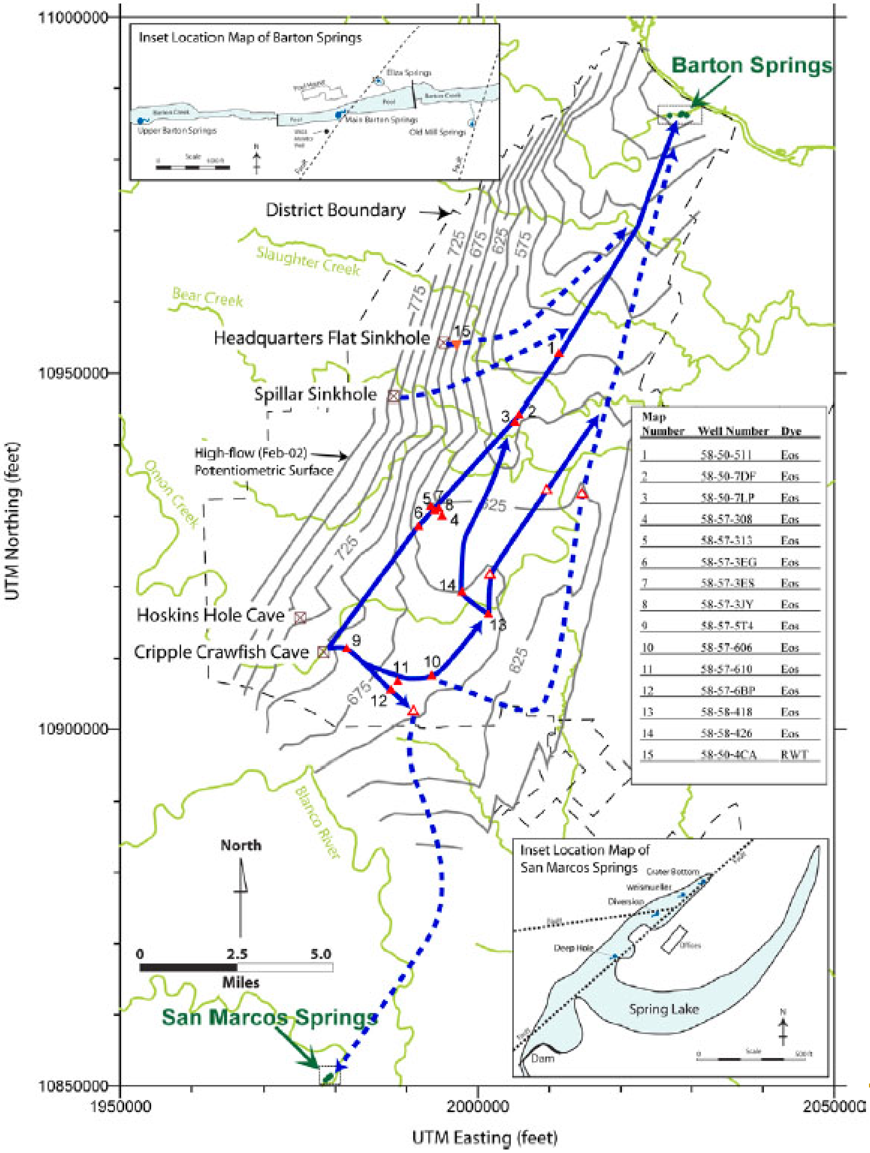
Model for Barton Springs segment of Edwards Aquifer

- Started with existing GAM
- Added conduit layer
  - Conduit locations provided by BSEACD (dye tracing, sediment in wells, troughs)
  - Conduit recharge concentrated in small number of known features
  - Conduit elevations coincide with top of Kirshberg member
  - Conduits are 20 feet thick
- Recalibrate



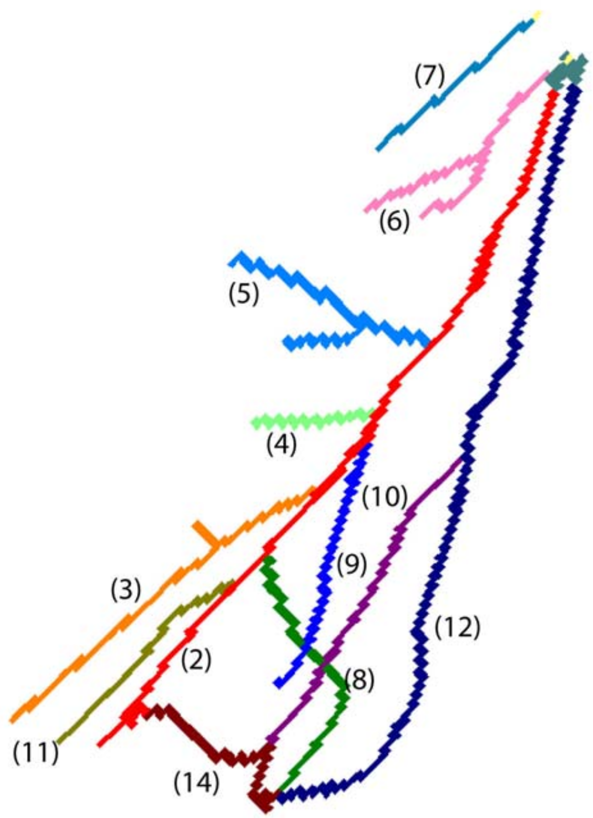
Dye Trace Map

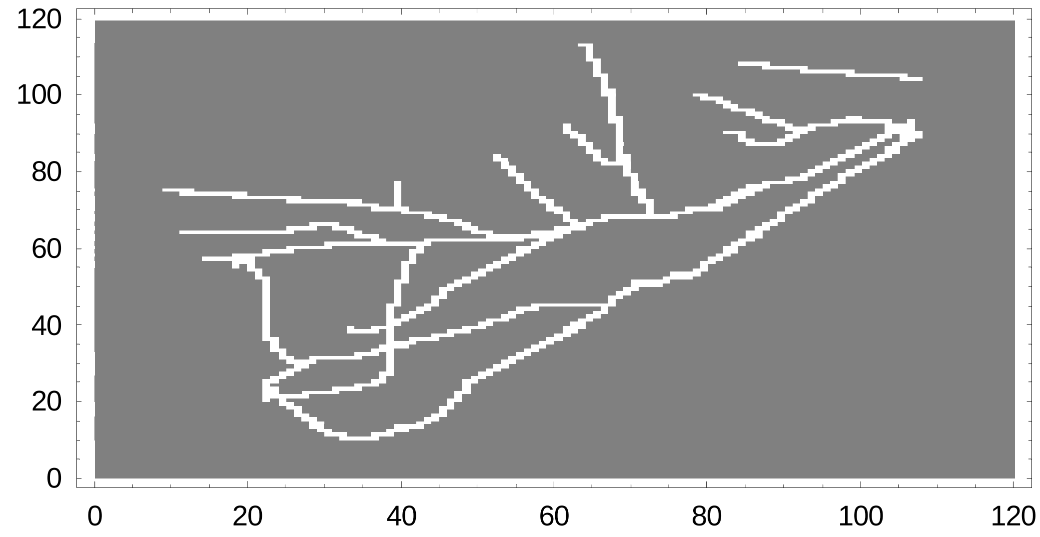


Source: http://www.ci.austin.tx.us/watershed/dyetrace.htm

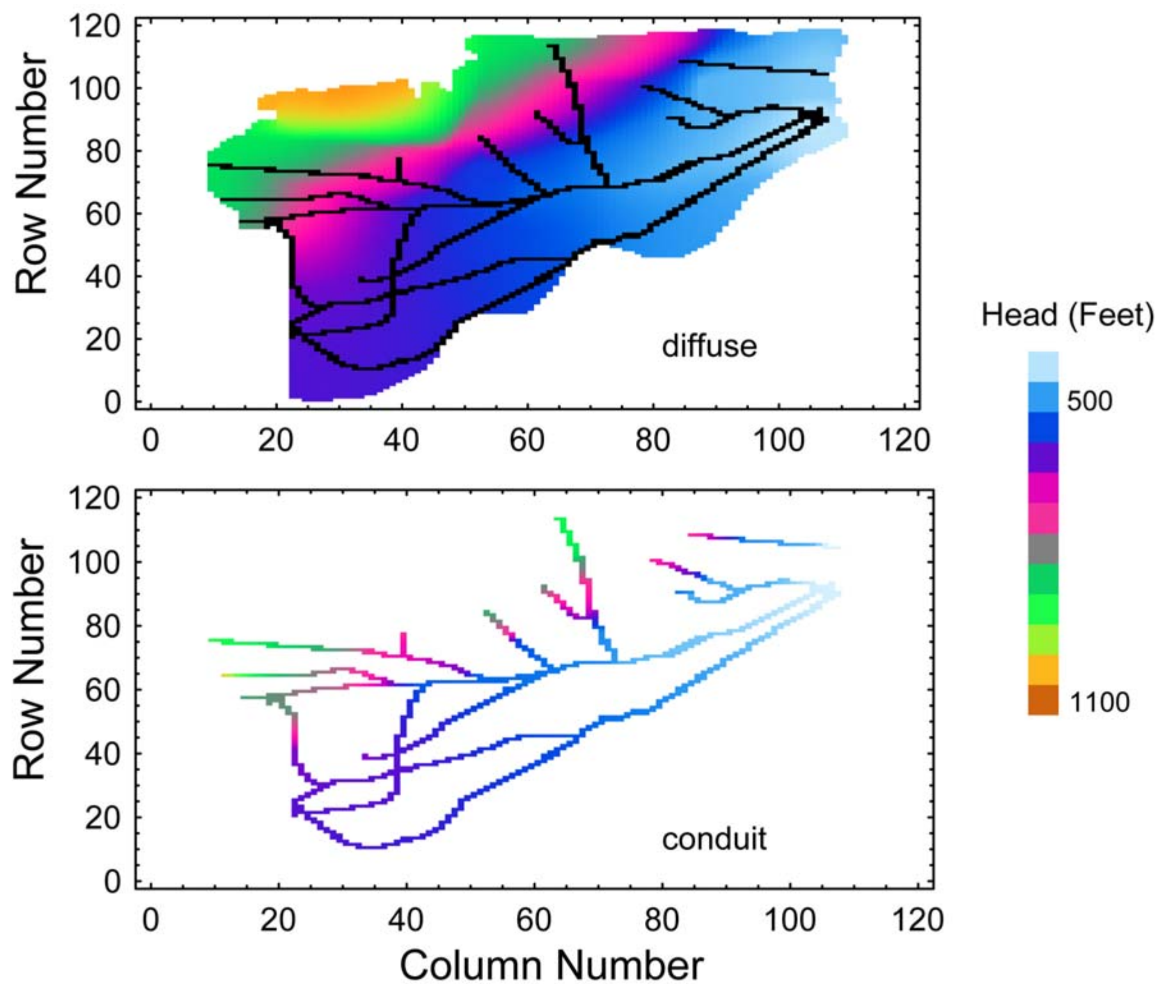
Source: Hauwert et al. (2001)

Conduit network



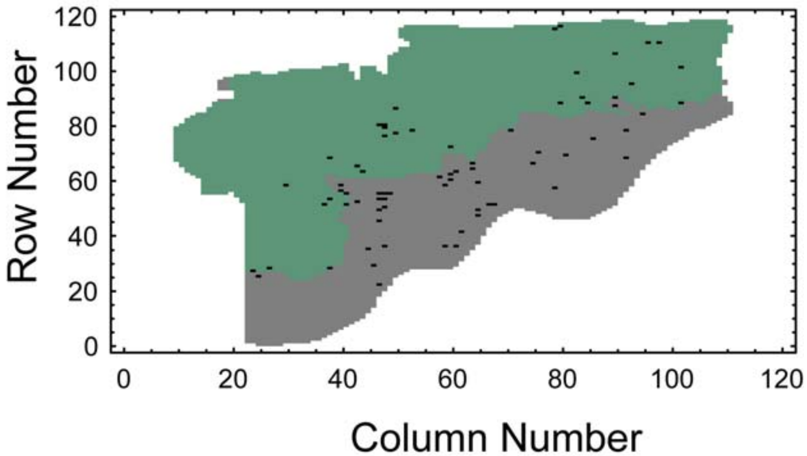


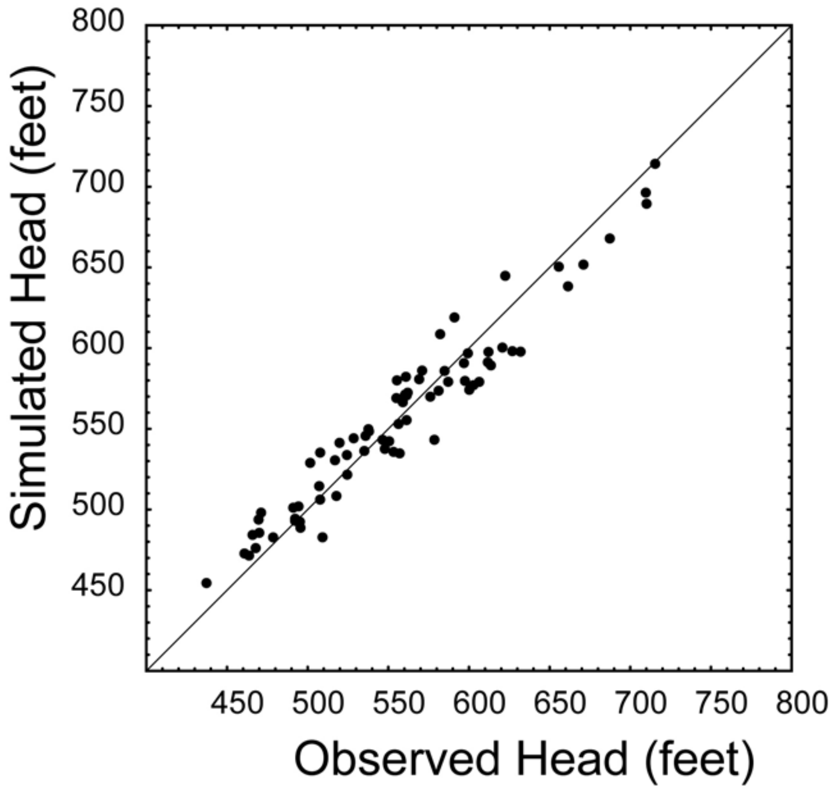
Simulated heads



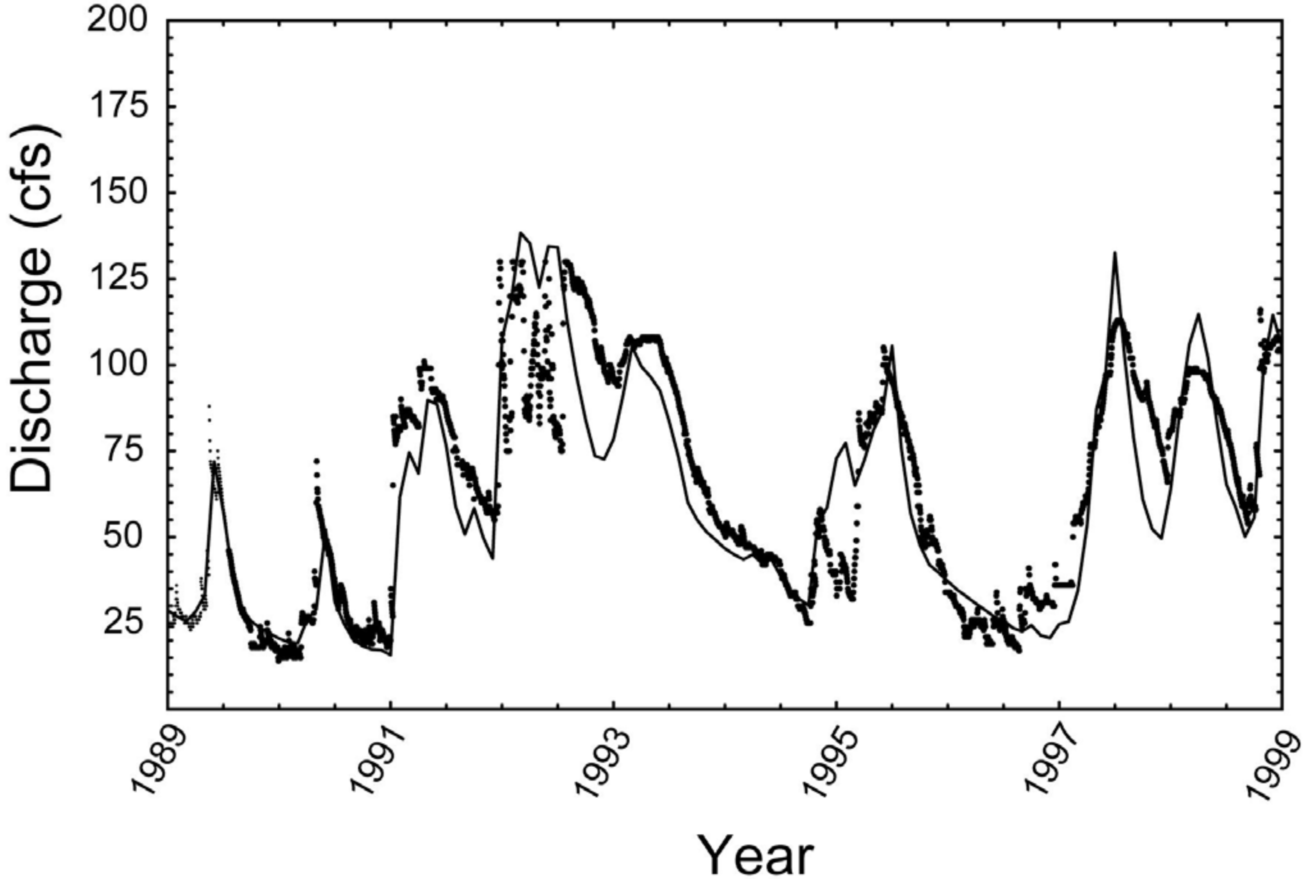
Comparison with observed head

- Head range in the observation set: 278 feet
- RMS residual: 18 feet or 6%
- RMS residual <10% considered calibrated by Texas state (GAM) rules

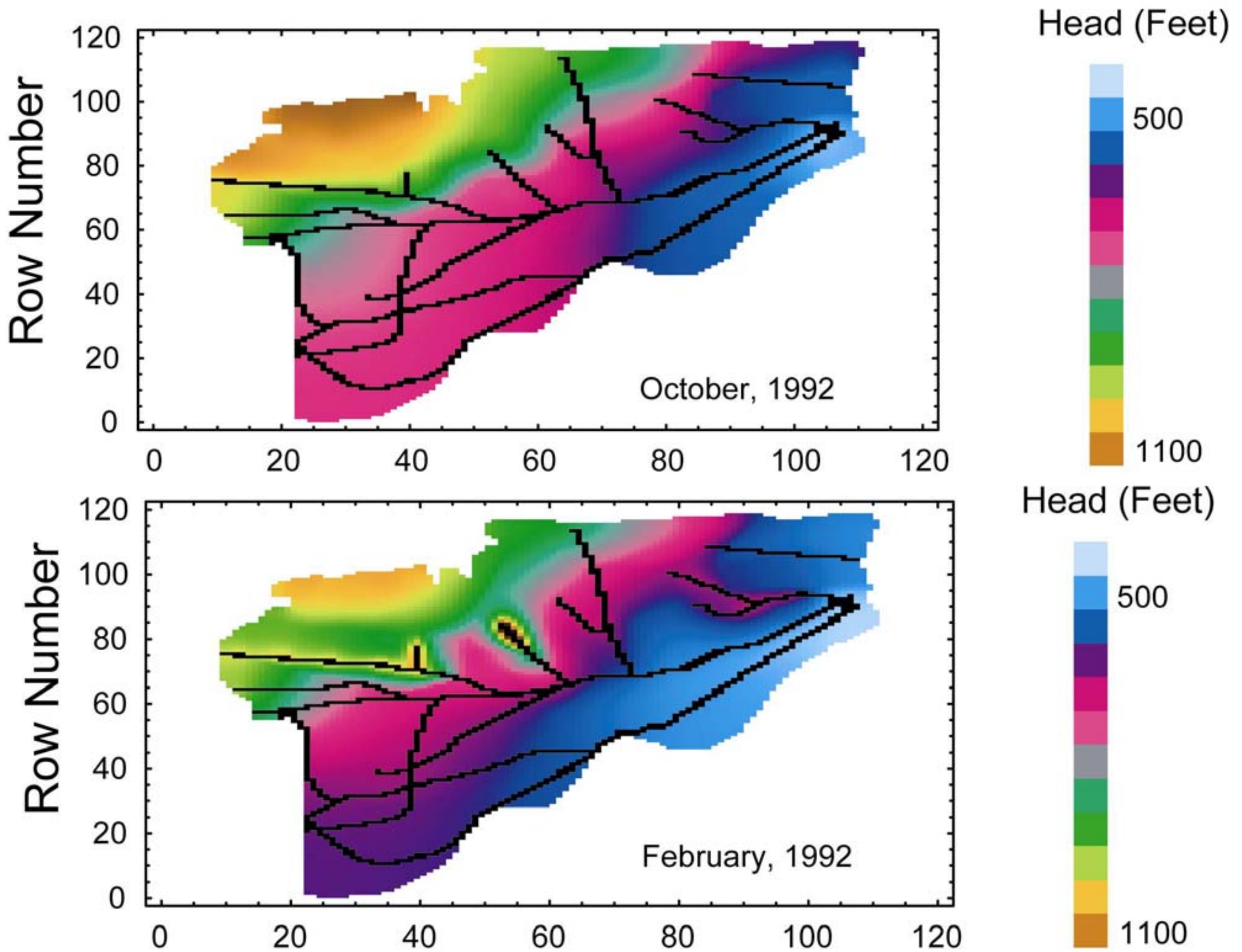




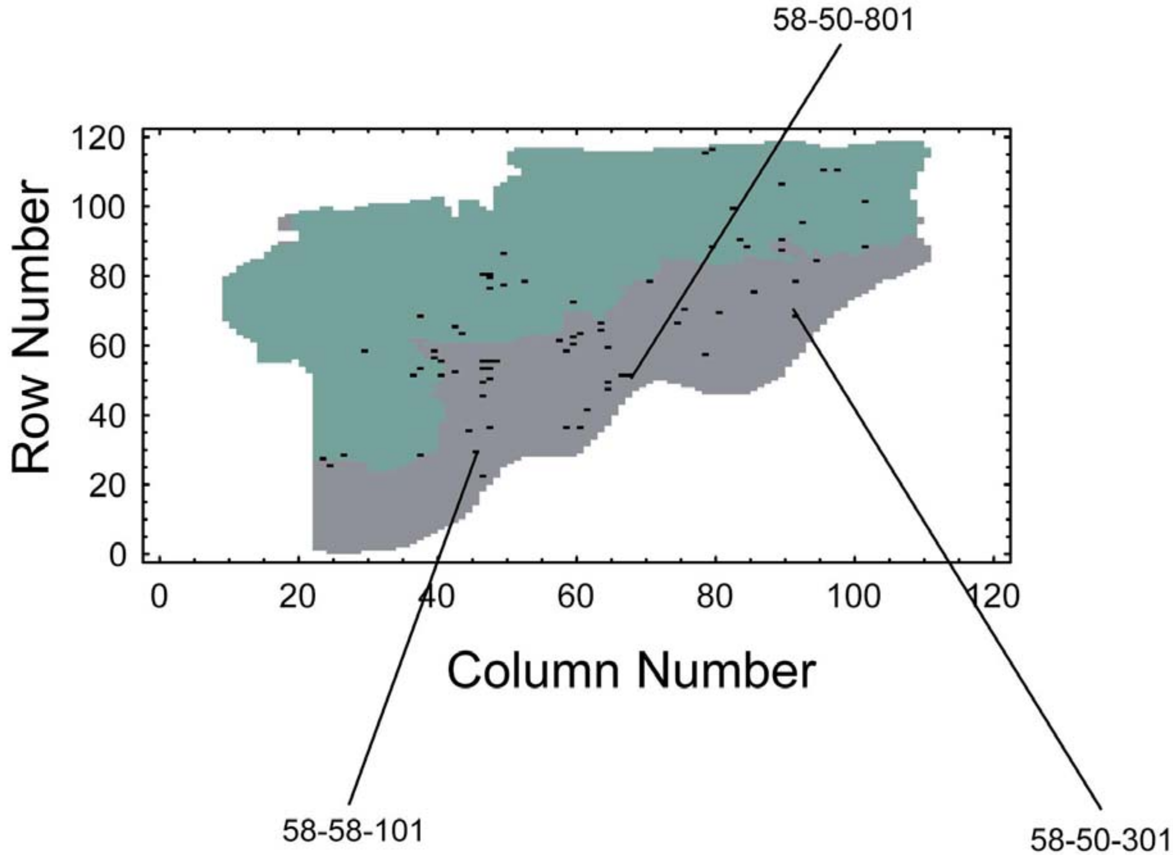
Discharge versus time



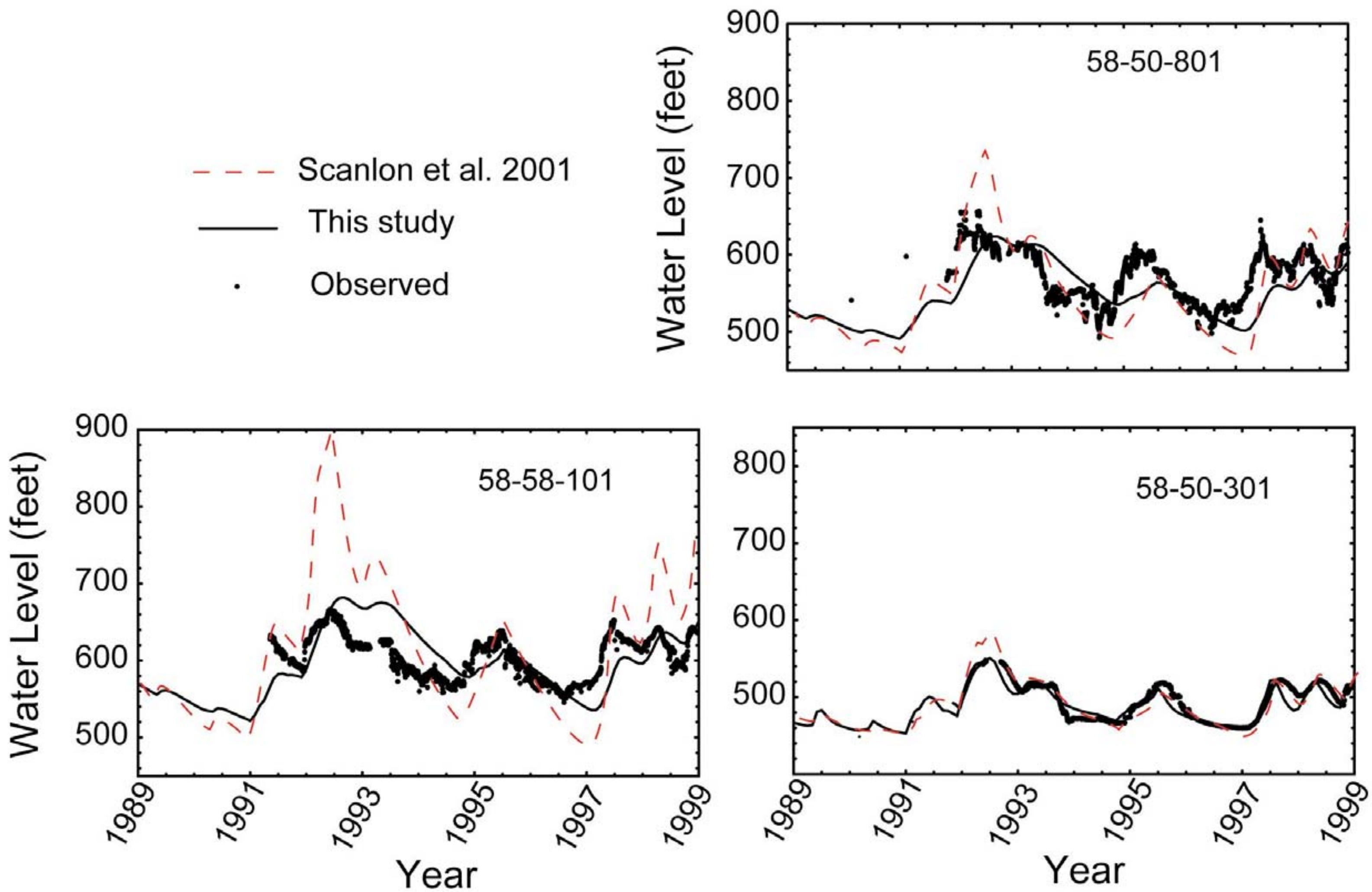
Diffuse System Water Levels



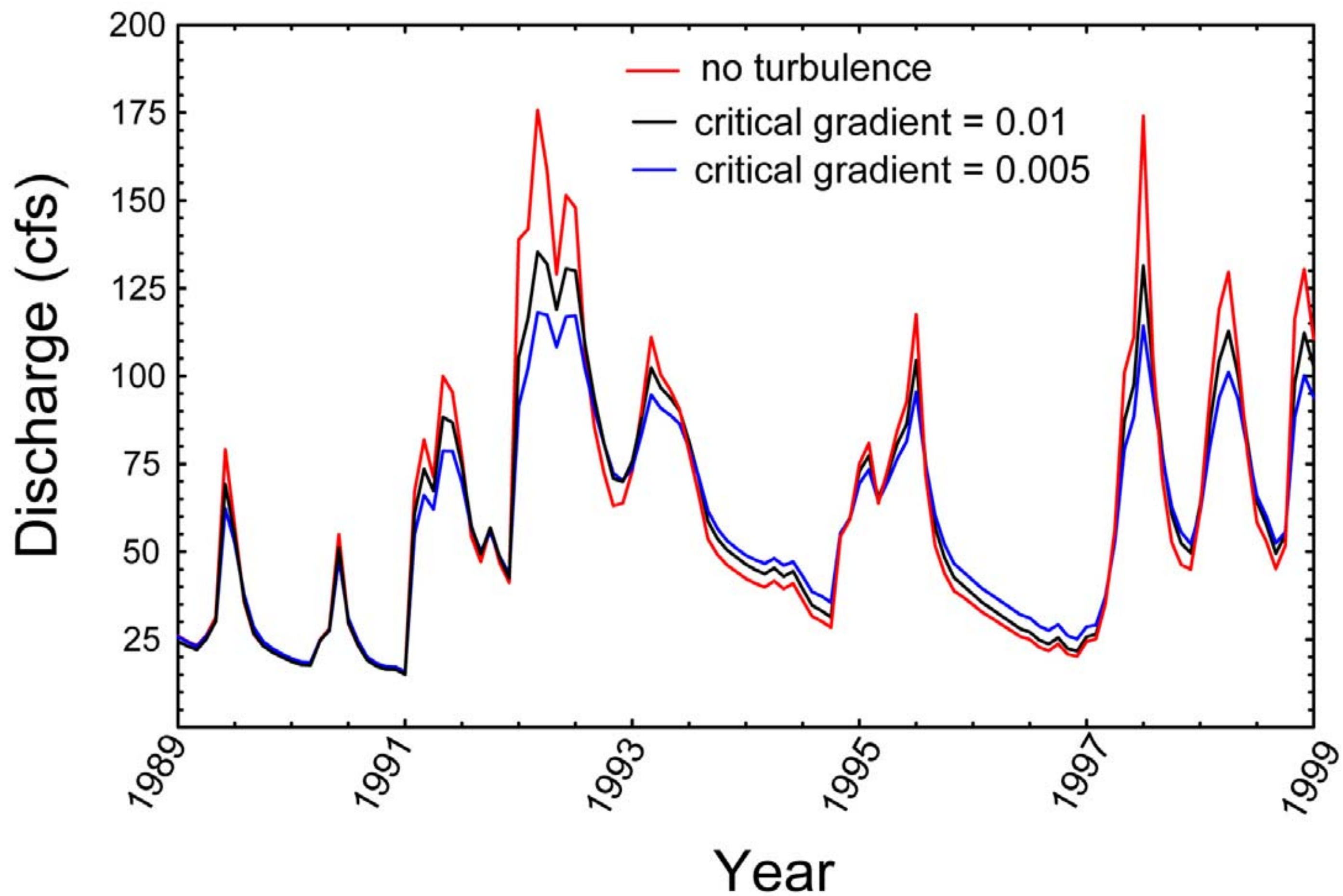
Locations with good transient water-level records



Transient water-level comparisons



Effect of turbulence model



Conclusions: Barton Springs modeling

- Able to achieve calibration in steady state
  - Residual errors similar to previous efforts
  - Not unique
- Transient calibration
  - Discharge match similar to previous efforts
  - Improved match to water level hydrographs
- Simultaneous representation of flashy spring hydrograph and subdued water level hydrographs
- Turbulence model improved match to spring hydrographs
- Able to simulate drought conditions without numerical problems
- Spring discharge during low flow conditions partially controlled by conduit elevation

Planned activities for GAM update project (1)

- Revisit and document DCM input
  - Focused recharge assumptions
  - Recharge rates
  - Conduit network geometry
  - Conduit elevation
  - Conduit hydraulic properties
  - Conduit/diffuse exchange parameter
  - Diffuse system parameters
  - Boundary conditions
- Recalibrate as necessary
  - PEST or hand calibration
  - Goal is one model for drought and normal conditions

Planned activities for GAM update project (2)

- Sensitivity analyses
  - Recharge rates and distribution
  - Conduit elevation
  - Conduit hydraulic properties
  - Conduit/diffuse exchange parameter
  - Selected diffuse system parameters
  - Turbulence parameter
- Document and archive

Barton Springs Segment of the Edwards Aquifer GAM
1st Stakeholder Advisory Forum
May 28, 2008
Austin, Texas

Name	Affiliation
William Amy	U.S. Fish and Wildlife
Marius Jigmond	Texas Water Development Board
Cindy Ridgeway	Texas Water Development Board
Dan Opdyke	Texas Parks and Wildlife Department
Brian Smith	Barton Springs/Edwards Aquifer Conservation District
Ned Troshanov	Edwards Aquifer Authority
Al Liu	Edwards Aquifer Authority
Nico Hauwert	City of Austin
Ron Green	Southwest Research Institute
Scott Painter	Southwest Research Institute
Ian Jones	Texas Water Development Board

Barton Springs Segment of the Edwards Aquifer GAM
1st Stakeholder Advisory Forum
Comments and Responses
May 28, 2008
Austin, Texas

Questions and Answers:

Has particle tracking been used to evaluate travel times through the aquifer? *Particle tracking is not currently part of MODFLOW-DCM but can be included in a revised version.*

What is the certainty of mapping and incorporating all major conduits in the model? *The Barton Springs segment of the Edwards Aquifer is a limited system that has been well characterized. It possible to miss some major conduits but this would detected because missing major conduits is likely to impact the ability to calibrate the model.*

What criteria is used to model specific conduits? How will modeling conduits improve the model over the use of a diffuse flow model? *MODFLOW-DCM simulates the effects of conduits, not individual conduits. Modeling conduits produces a better match to stream hydrographs. The original MODFLOW has difficulty calibrating to both hydraulic heads and spring discharge.*