Use of Coupled Surface-Water/Groundwater Models in Managing Water Resources

Texas Alliance of Groundwater Districts
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Edwards-Trinity Aquifer GAM (Anaya and Jones, 2009)
Edwards-Trinity Aquifer

Edwards-Trinity Aquifer GAM (Anaya and Jones, 2009)
Edwards-Trinity Aquifer Regional-Scale GAM

Figure 7-2. Boundary conditions for layer 1 used within model.
The Problem

Regional-scale models not capable of replicating local-scale hydraulic features
Related Studies Provide Insight on Modeling Watersheds Independently

- Distinct Watersheds
- Refined Grid

Edwards Aquifer FEM (Fratesi et al., 2014)
Edwards-Trinity Aquifer
Major Watersheds Act Separately
Southern Edwards Plateau

- Schleicher County
- Sutton County
- Val Verde County

Edwards Plateau

Unconfined ↔ Partially Confined ↔ Confined

No Communication Between Watersheds ↔ Communication Between Watersheds
Edwards-Trinity Aquifer
Major Watersheds Act Separately
Devils River Watershed

Drains southward off Edwards Plateau

Watershed can be treated as a separate hydraulic entity

Devils River watershed has features that make it difficult to model SW-GW regimes.
Conceptualization of the Devils River Watershed
Flow is as groundwater upstream where river beds are dry...and as surface water downstream...
How is this much water conveyed through this desert landscape?
Consider the Presence of 1,000 gpm Wells Along Rivers in the Upper Devils River (Near Juno)

River channel has lots of water…

…but, table lands are dry

Where is this water coming from?
All high capacity wells in the Devils River watershed are located along major river channels.

Supported by a review of over 2,200 wells in the TWDB database.

There are 752 wells with measured capacity in the TWDB database.

High capacity water wells are only located near river channels.
Data Support This Observation

Distance From River Channel Versus Well Capacity

Virtually all wells with capacity of 500 gpm are within 1.5 miles of a river.
Rain Water Is Focused into River Beds and Acts as a Mild Acid That Dissolves the Limestone

The preferential flow paths that are formed may be a "pipe", but it is more likely the flow paths are simply zones of enhanced permeability

Woodruff and Abbott, 1970s, 1980s
How is Groundwater Flow in the Devils River Watershed Conceptualized?
Pipes in a sponge
What other evidence is available to support this conceptualization? 2013-2017
Subsurface Geophysical Imaging
Subsurface Characterization

Pole-dipole electrical resistivity survey was conducted to image the floodplains to characterize the conduit/matrix hydraulics.
Devils River above Dolan Falls

Potential Conduit
Dye Tracer Test
Supporting Proof of Preferential Flow Channels in River Channels

Dye tracer tests in Sonora confirm the presence of preferential flow in Devils River channel

Groundwater will flow at most a few 10s of feet/yr in a porous media aquifer such as the Carrizo-Wilcox

Preliminary results from the Sonora tracer test suggests groundwater travels a half to one mile a day in the “pipes” associated with Devils River
Gain/Loss Measurements
Devils River is Mostly Gaining

2006 – TCEQ
2013 – Jeff Bennett/NPS; Marcus Gary/EAA; Ron Green/SwRI; Kevin Urbanczyk/Sul Ross; students
Groundwater Chemistry
Groundwater Chemistry Indication of Conduit Location
Devils River Watershed Conceptual Model – 2014 (Green et al., 2014)
Rivers:
1. High conductivity zones
2. Discrete elements
3. Fluid transfer boundary conditions (allows springs to self locate)
Limitations in a Groundwater-Flow Only Model (FEFLOW)

Model did not adequately reflect baseflow under low-flow or drought conditions.
Integrated models are available, but not well developed, particularly for challenging environments such as semi-arid karstic watersheds.
Hydraulic couplings are more complex than just SW $\leftrightarrow$ GW
Regulatory Challenges in Surface-Water vs. Groundwater Modeling

Surface Water | Groundwater
---|---
Owned by the State | Owned by Land Owners
Governed by TCEQ | Governed by TWDB/GMAs/GCDs
Administered using WAMs | Administered using GAMs

(Winter et al., 1998)
Technical Challenges in Surface-Water vs. Groundwater Modeling

**Surface-Water**
- Event-based or continuous simulation
  - “Total” vs “Incremental” precipitation records
  - “Long term” = 6 months
- Finer granularity
  - Hourly precipitation records
  - 15-minute timesteps

**Groundwater**
- Continuous
  - Incremental precipitation
  - “Long term” = decades
- Coarser granularity
  - One month stress periods

*Fully coupled models are available, but have short time steps and long run times. Answer is not just faster cpu.*
Surface-Water Model
Spatial Variability in Precipitation
NEXRAD Database

SW models – hourly precipitation or less
Our model – Oregon State University PRISM daily precipitation dataset
Ongoing spot comparison with gage stations
Surface-Water Model Calibration

Short-term Independent Precipitation Events

- Precipitation distributed evenly over entire model domain
- Hourly timestep
- Two different loss methods

Six separate models:
- **Large** (~80,000 cfs) discharge event August 1998
- **Moderately large** (~8,000-12,000 cfs) discharge events February 1997 and October 2002
- **Small** (~1,000 cfs) discharge events June 2000, May 2001, and May 2002
Deficit and Constant Loss Method should be appropriate for long-term model.
Surface-Water Model Calibration

Long-Term

2000-2015
Long-Term Calibration 2000-2015

2000-2015

- Actual Discharge
- Model Discharge
- Precipitation

Measured Discharge
  - Green

Measured Discharge
  - Purple

Storm absent in PRISM data
Percolation is Calculated by Surface-Water Model and Imported into the Groundwater Model

Infiltration

Saturated Fraction

March 12, 2004

February 4, 2004

2.4”

1
Groundwater Model Refinement
Two-Layer MODFLOW-USG Model

Edwards Rocks

Trinity Rocks
Mesh refinement at areas where the surface-water flow accumulation has selected stream channels

Sycamore Creek Watershed
Quad-Tree mesh refined along stream centerlines

Significantly reduces mesh density while preserving complexity
Refined Characterization of Devils River Conduit Network
Groundwater Model Performance
Groundwater Model
River Discharge: Pafford Crossing

Flow Cubic Meters/day

Date

9-Feb-99 9-Feb-00 8-Feb-01 9-Feb-02 8-Feb-03 9-Feb-04 8-Feb-05 9-Feb-06 8-Feb-07 9-Feb-08 8-Feb-09 9-Feb-10 8-Feb-11 9-Feb-12 8-Feb-13 9-Feb-14 8-Feb-15 9-Feb-16 8-Feb-17
Groundwater Model Calibration
River Discharge: Pafford Crossing
Groundwater Pumping Scenario

• Well field located near Juno

• Cumulative pumping of 8,000 gpm (12,800 acre-ft/yr)

• What is the effect on baseflow to the Devils River?
Groundwater Pumping Scenario
8,000 gpm at Juno

Flow Cubic Meters/day

Date

With pumping

Without pumping
Self Selecting Spring Locations
Self Selecting Spring Locations

Pre-Development

Current Conditions

With Juno Wellfield
Notable Results

• **Groundwater flow controlled by the morphology** of the area more than the hydraulic properties of the rocks. Model is relatively insensitive to assignment of hydraulic properties.

• Relatively modest pumping in upper Devils River watershed has **shifted live water ~10 miles south**.

• **Groundwater pumping reduces baseflow**, not surge in surface flow.

• **Pumping of groundwater in basin will result in proportional reduction of flow in the Devils River**. Impact is most pronounced during low flow conditions.
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- Lower Pecos River/Devils River Watersheds
  - Field studies – Coypu Foundation (2015-2016)
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