Overview of USGS report "Simulation of Groundwater Flow in the Silurian Aquifer, Eastern Iowa, 2020-2045"

Jude Thomas (presenting)

USGS Central Midwest Water Science Center

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U.S. Department of the Interior
U.S. Geological Survey

Outline

- Purpose & Scope
- Model Advantages
- Conceptual Model
- Steady State and Transient Model
- Water Balance Evaluation
- Future Drawdowns and Predictive Results

Figure 13. Solution features in Devonian-age limestone near Coralville Dam.

From Tucci, Patrick and McKay, Robert, 2006, Hydrogeology and simulation of ground-water flow in the Silurian-Devonian aquifer system, Johnson County, Iowa: U.S. Geological Survey, Scientific Investigations Report 2005–5266, 73 p.

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Purpose and Scope of this effort

- To describe the conceptual and numerical groundwater flow models for the Silurian aquifer
- Construct and calibrate steady-state and transient numerical models
- Forecast the effects of estimated future water use through the year 2045
- Model is useful for assessing the sustainability of the Silurian aquifer and assisting communities with decision making and planning for long-term water supplies

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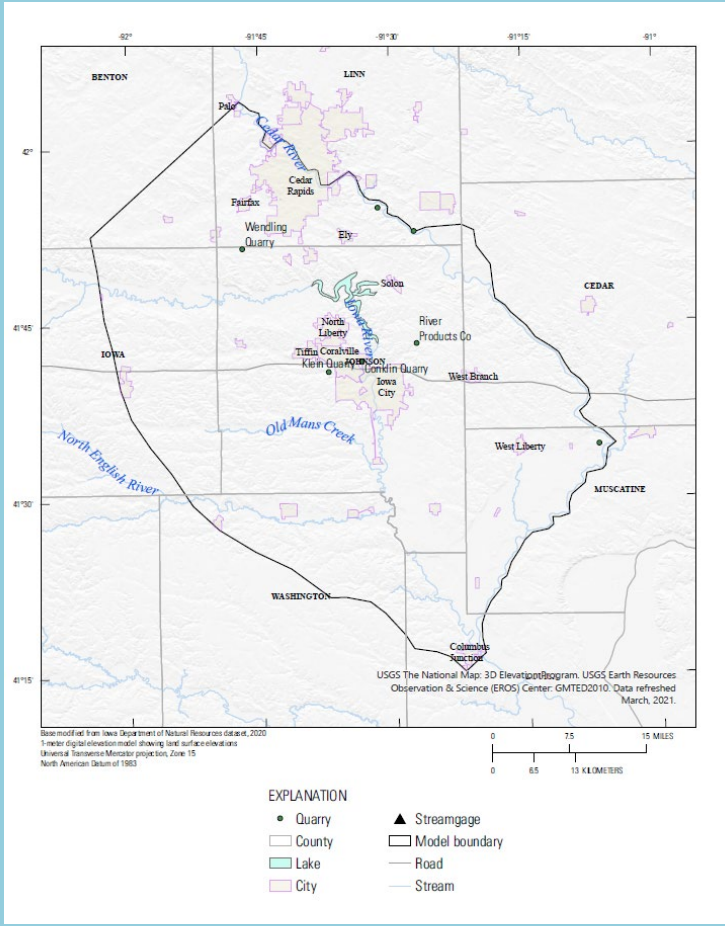
Numerical Model Advantages

- Continued population growth has increased water use in model area by over 25% since the USGS 2006 Silurian model.
- Understand how droughts place additional stress on the area’s water supply, including the Silurian aquifer.
- Model predictions run for the next 20 years based on projected increases in use and variable climate (dry/wet)
- Groundwater models allow for water inputs and outputs to be quantified and scenarios run at different time periods to understand changes to groundwater

Conceptual Model

Model Boundary based on hydrologic and topographic features

- Model area is ~4100 square kilometers in east-central Iowa
- Boundary delineated along Cedar River to the NE/E/SE including small portion of the Cedar River watershed (NE)
- Boundary NW of Cedar Rapids at Palo USGS gage, and SE boundary in Louisa County at Columbus Junction gage.
- Western/Southwestern boundary is topographic high located a reasonable distance from pumping activities in the area of interest.



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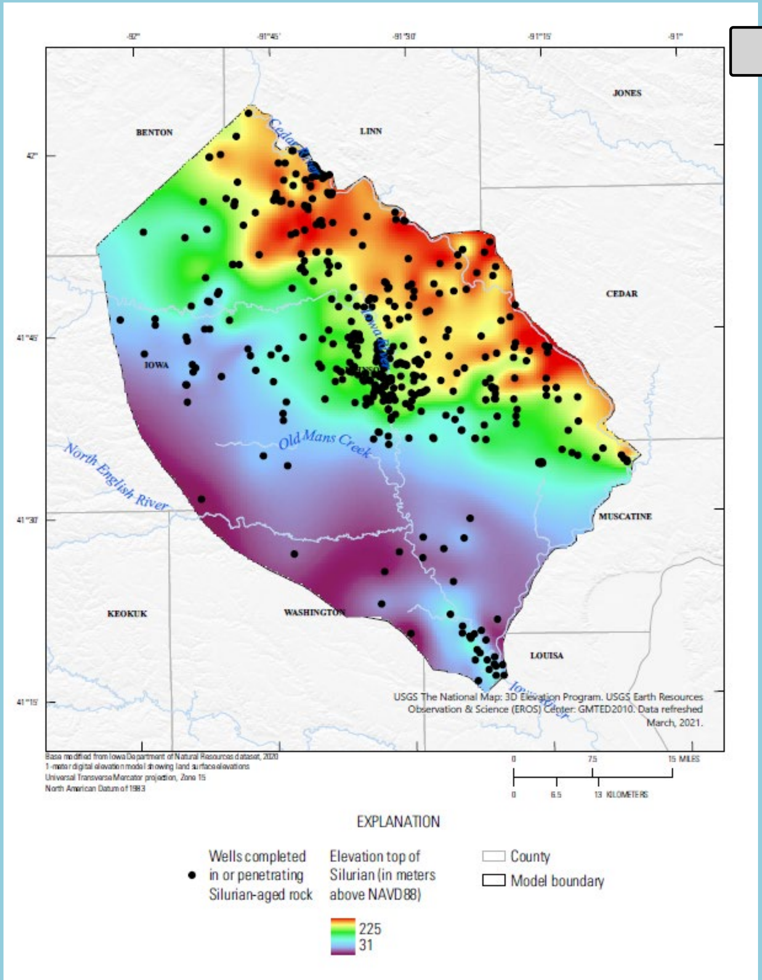
Model Boundaries from 2024 USGS Draft Report

Conceptual Model

Hydrogeologic Surfaces

Conceptual model includes the following surfaces (resulting in 5 layers):

1. Ground Surface (LiDar)
2. Top of Devonian (Geosam Points)
3. Top of Kenwood Shale (arbitrary 10 ft)
4. Top of Silurian (Geosam Points)
5. Top of Maquoketa (Geosam points) where the base of the model is 50 meters below top of Maquoketa



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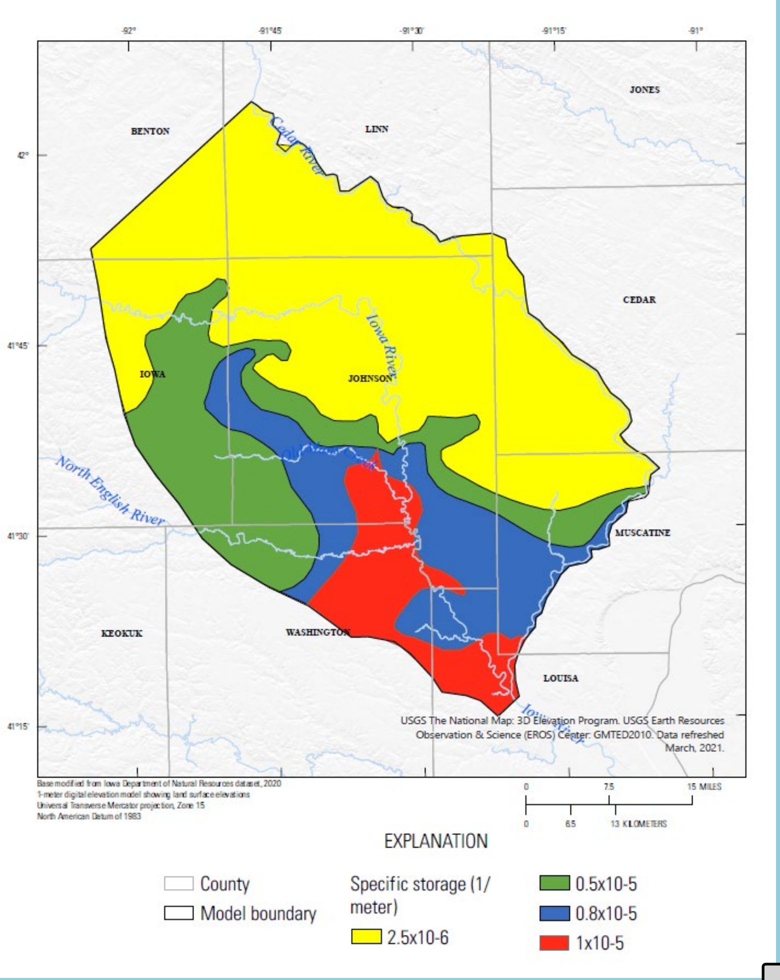
Conceptual Model

Aquifer Parameters

- Aquifer parameters derived from 27 aquifer pump tests within the model boundaries, 22 in Johnson County
  - Hydraulic conductivity
  - Storativity
  - Transmissivity
- Specific storage distribution was estimated using pump test results and aquifer thickness allowing for spatial variability



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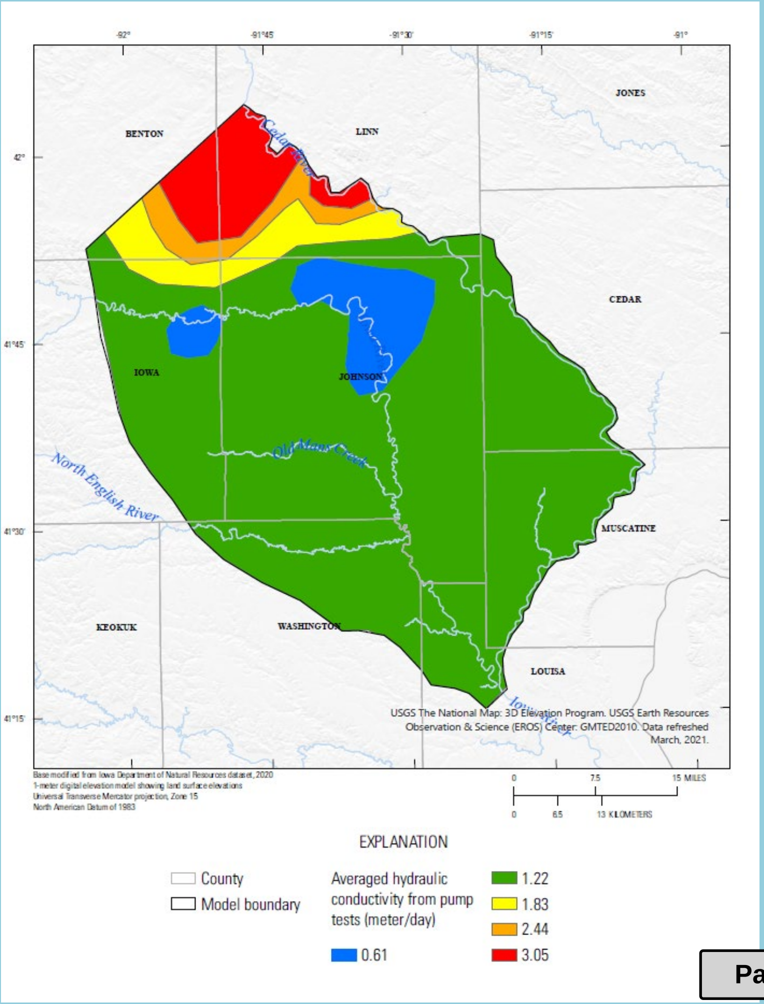
Conceptual Model

Aquifer Parameters

- Used Kriging interpolation for hydraulic conductivity distribution
- Hydraulic conductivity distributions were the starting point for model input



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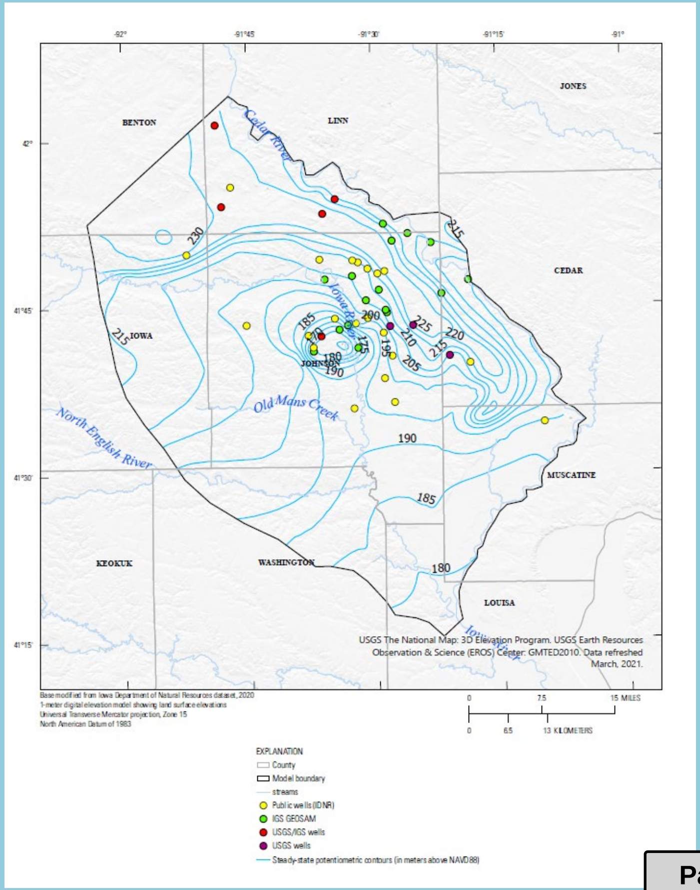
Potentiometric Surface (Groundwater Elevation) Silurian Aquifer

- Used as input head estimates for steady state model
- Based on steady state and/or normal climatic conditions.
- Groundwater level data from multiple available sources (USGS, IGS, IDNR).
- Used as input head estimates in steady state model.



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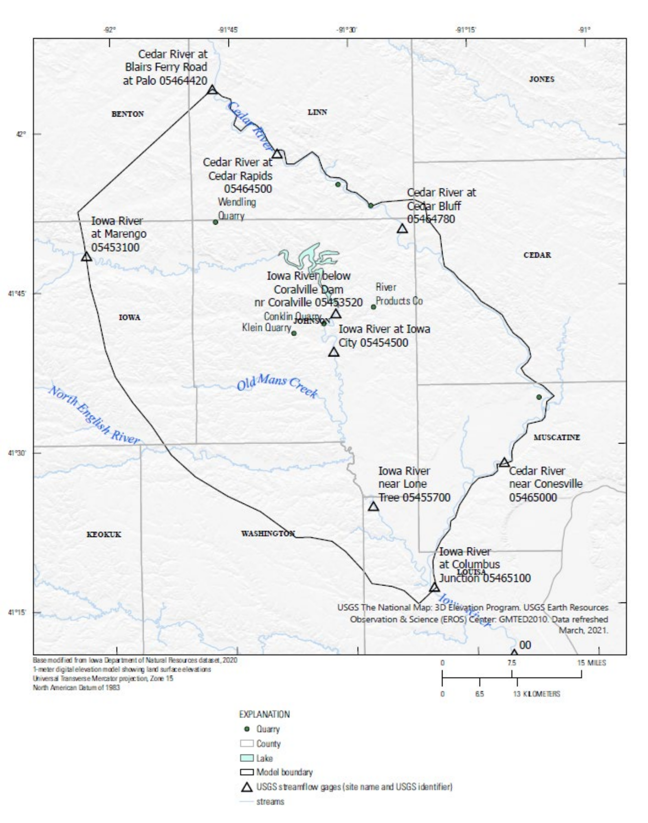
Conceptual Model

Boundary Conditions

- River boundaries based on USGS gages and regression analyses
- Constant head boundary (red line) based on potentiometric map
- General head boundaries based on lake elevations, and quarry sump elevations.



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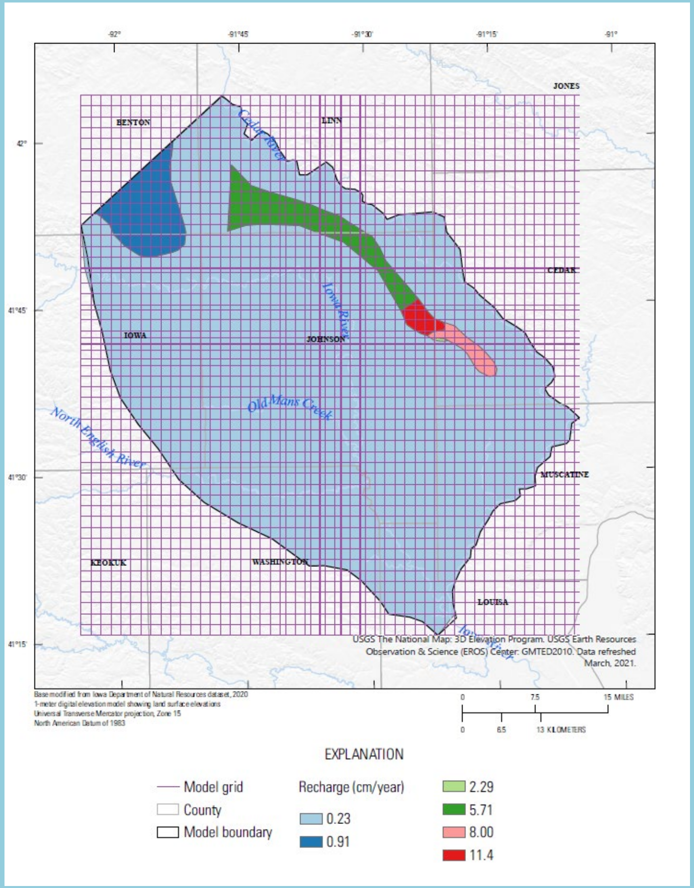
Conceptual Model

Net Recharge

- Recharge values adapted from previously published values and adjusted based on geology (depth to Silurian aquifer) and matching model output to observed water levels
- Model grid from steady state was refined for transient model to allow for more detail in areas of interest (around pumping centers)



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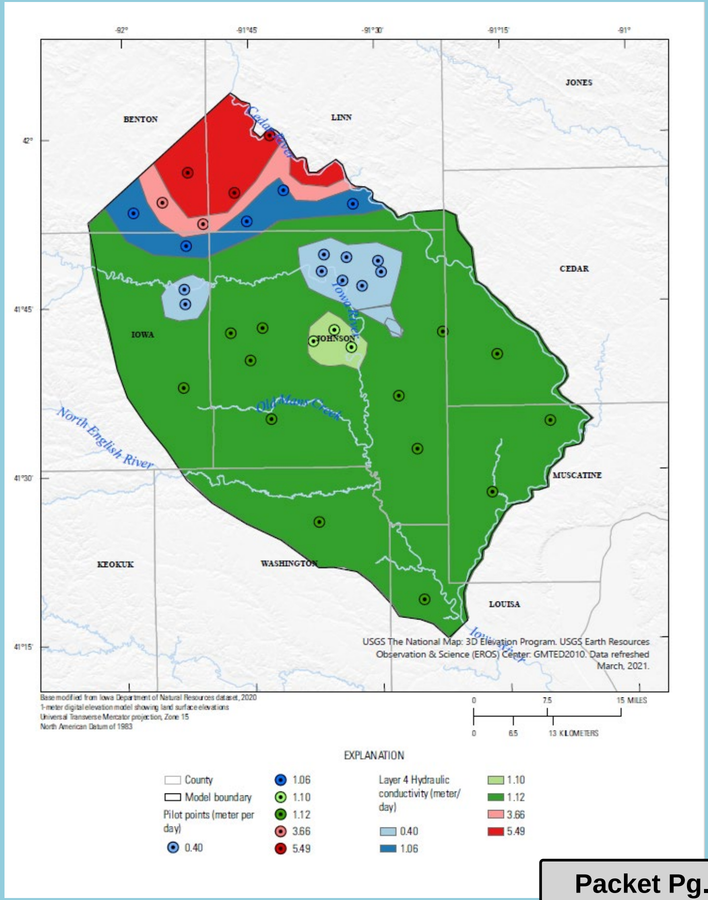
Steps in modeling

Conceptual > Steady State > Transient

1. Take the conceptual model information and put it into MODFLOW to create a numeric model (all the inputs define how water moves in and out of the model area)
2. The model is then first run as steady state which assumes:
    - inflow = outflow
    - no time-dependent changes in aquifer storage
    - no changes in the direction and velocity of water movement.
3. The transient model is the steady state model BUT we are now allowed to:
    - Vary water inflows and outflows in response to changes in climate or water-use patterns (drought/flood/increased pumping scenarios)
    - Changes result in increases or decreases in aquifer storage and changes in the direction and velocity of groundwater flow.

Steady State Model and Parameter Estimation (PEST) and Pilot Points

- PEST used to adjust hydraulic conductivity (K) to match observation data
- Pilot points were distributed across model area where parameters are allowed to vary at each pilot point
- The rest of the grid is then interpolated by kriging



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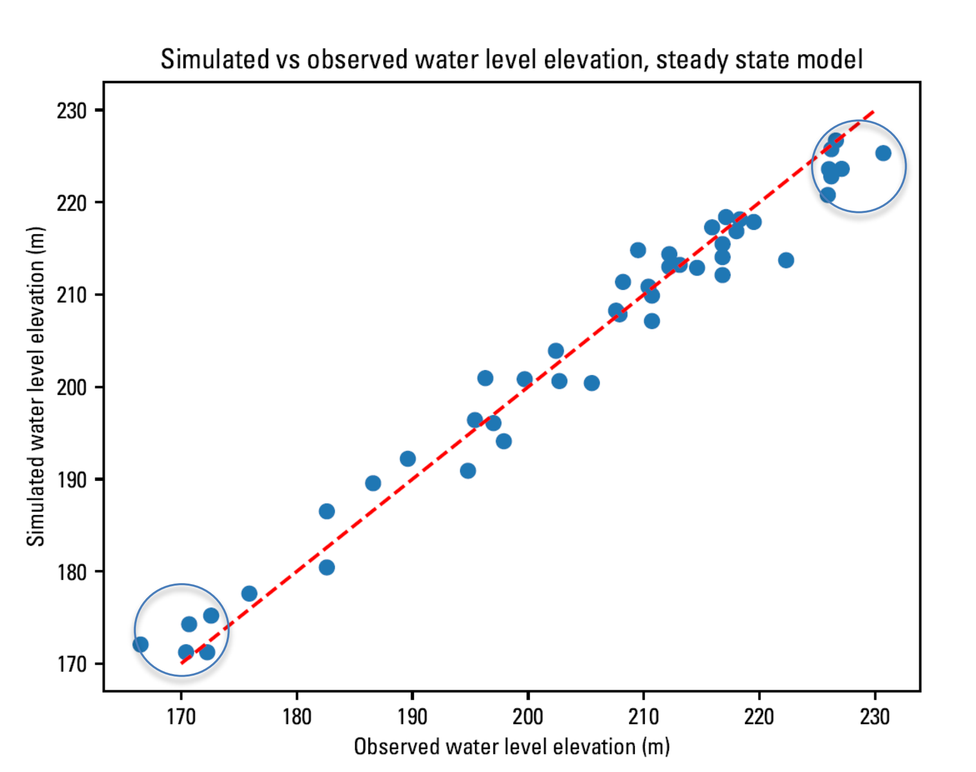
Steady State Model Results

- Elevations from observation wells (static)
- Generally good fit
- Model slightly under predicts at the high and over predicts at the low end (circled areas)



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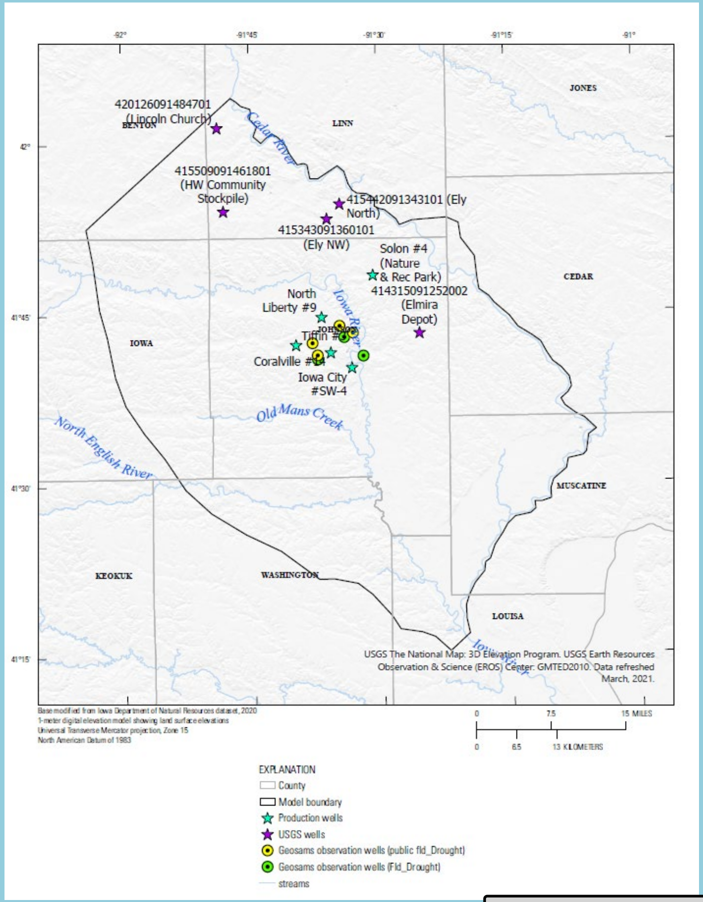
Transient Model

- Transient model included time series pumping and groundwater level data from the cities of Coralville, Iowa City, North Liberty, Solon, and Tiffin.
- Some of data was provided in daily timesteps, while some was available as monthly or yearly timesteps



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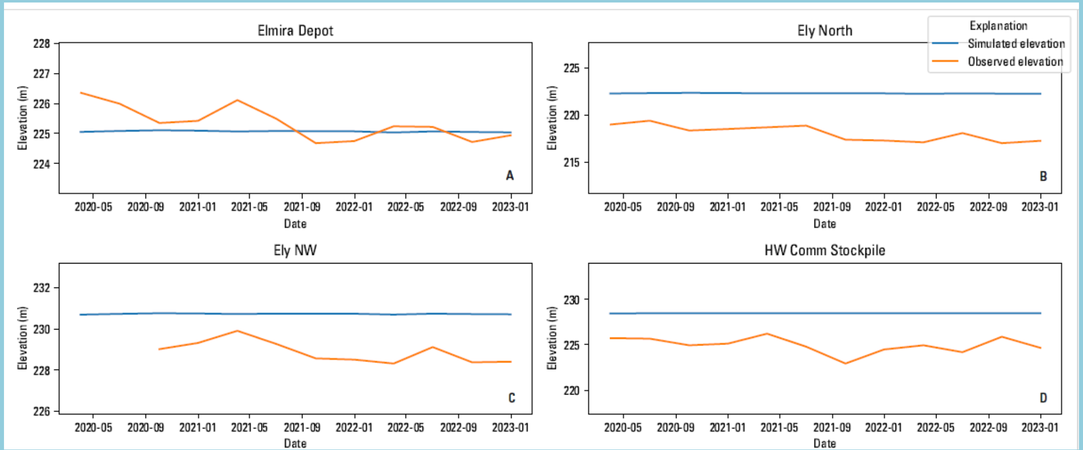
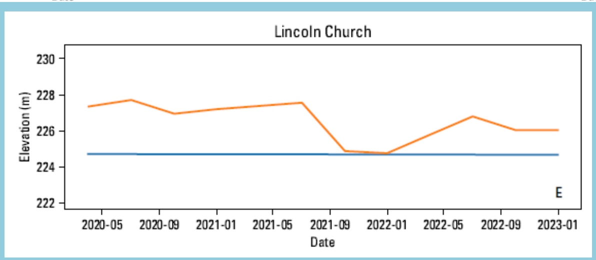
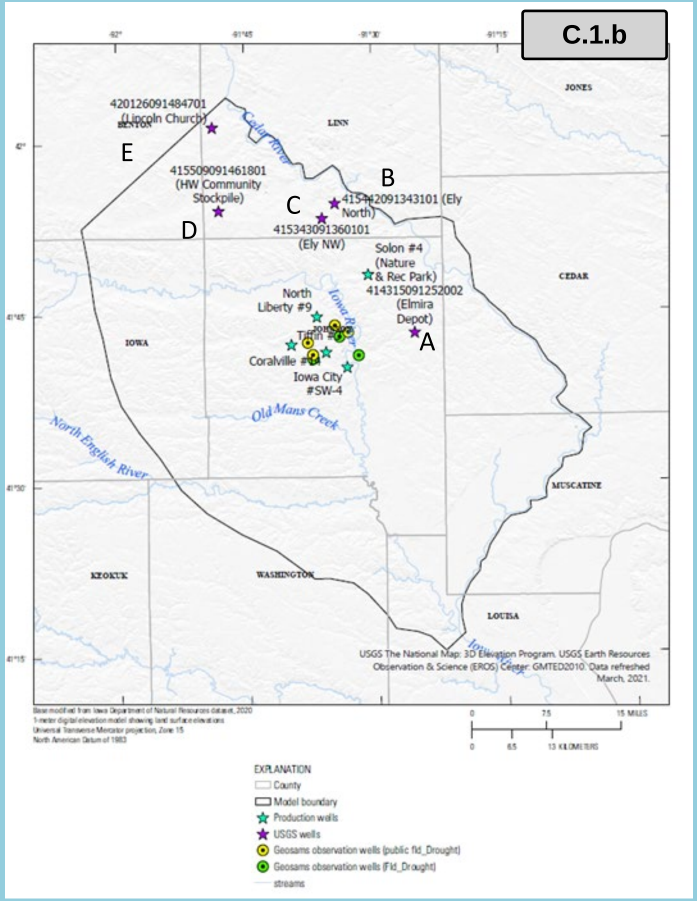
Transient Model Results

- Hydrographs of simulated and observed water level elevations at
- Observation wells (A-E)
  - Generally over predicts water level but within a few meters of observed







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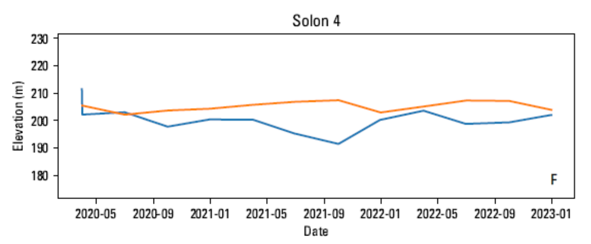
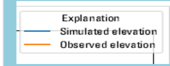
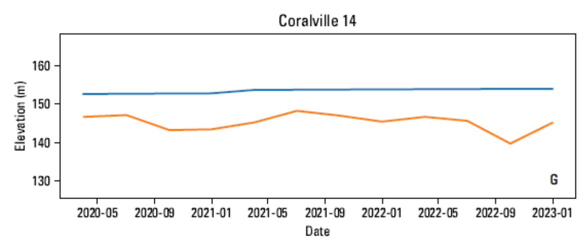
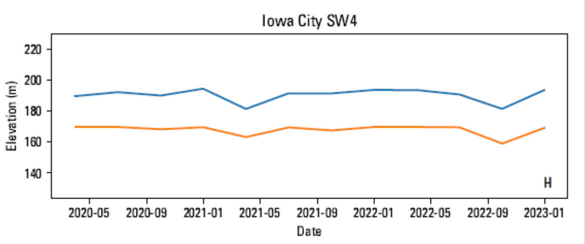
Transient Model Results

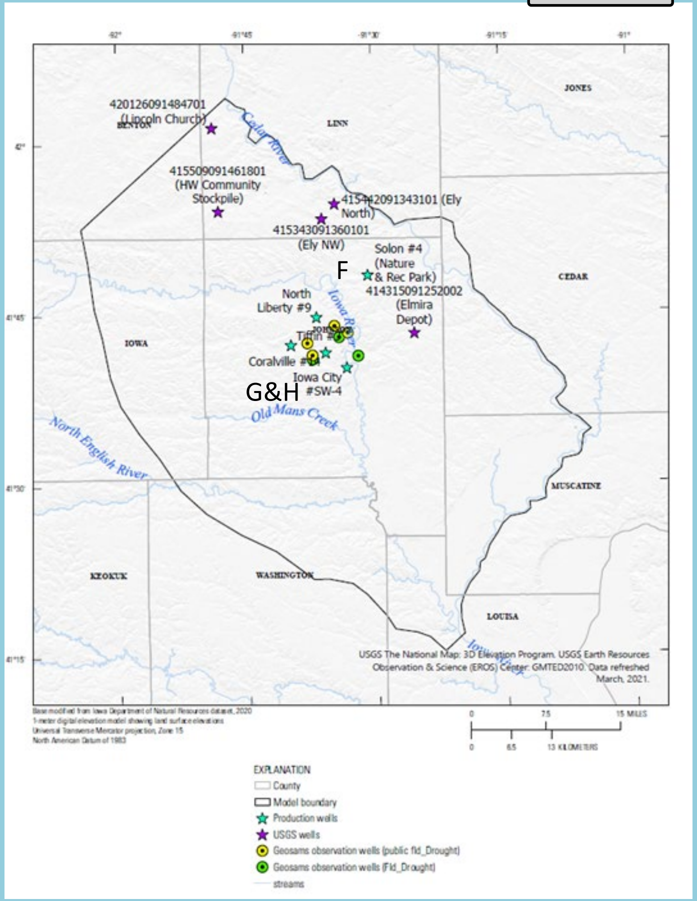
- Pumping wells (F-H)
  - Over/under predict water level
  - Frequency of water level and pumping data effects model's ability to capture variations over time











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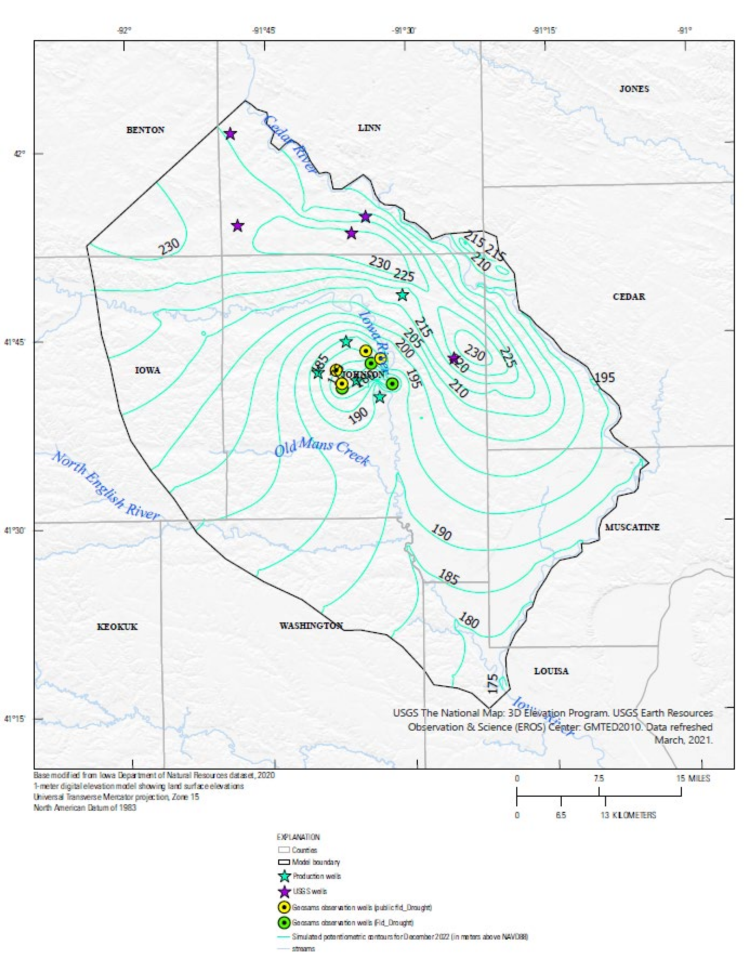
Transient Model Output: Simulated water table for Oct. through Dec. 2022



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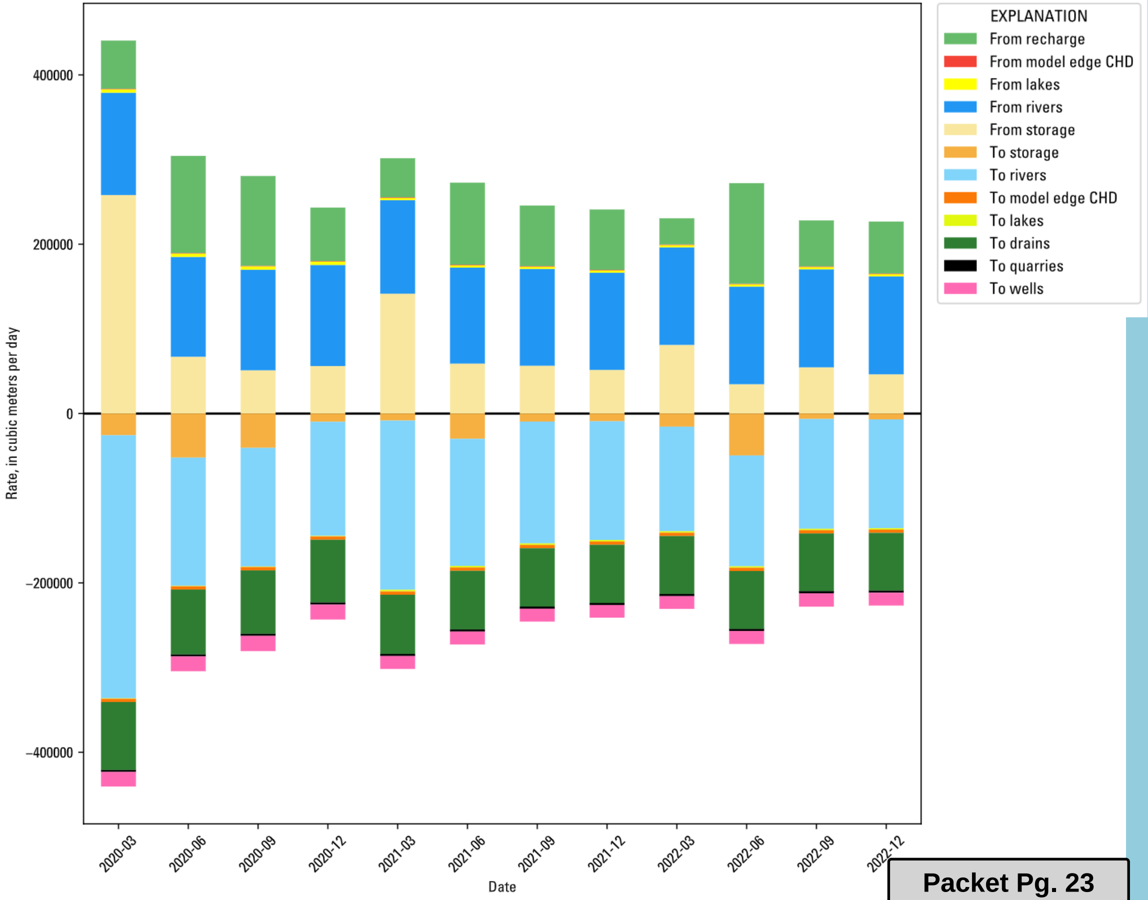
Transient 2020 to 2022 Water Balance

- Recharge from precipitation provides much of the inflow into the aquifer.
- Wells, voids and fractures (drains), and quarries represent outflow from the aquifer.
- Aquifer is providing more baseflow to the rivers likely due to the dry conditions.
- Storage from and to the model area is generally decreasing over this period and may be related to drought/dry conditions.



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Future Model Prediction Drawdown in Silurian Aquifer 2022 to 2045

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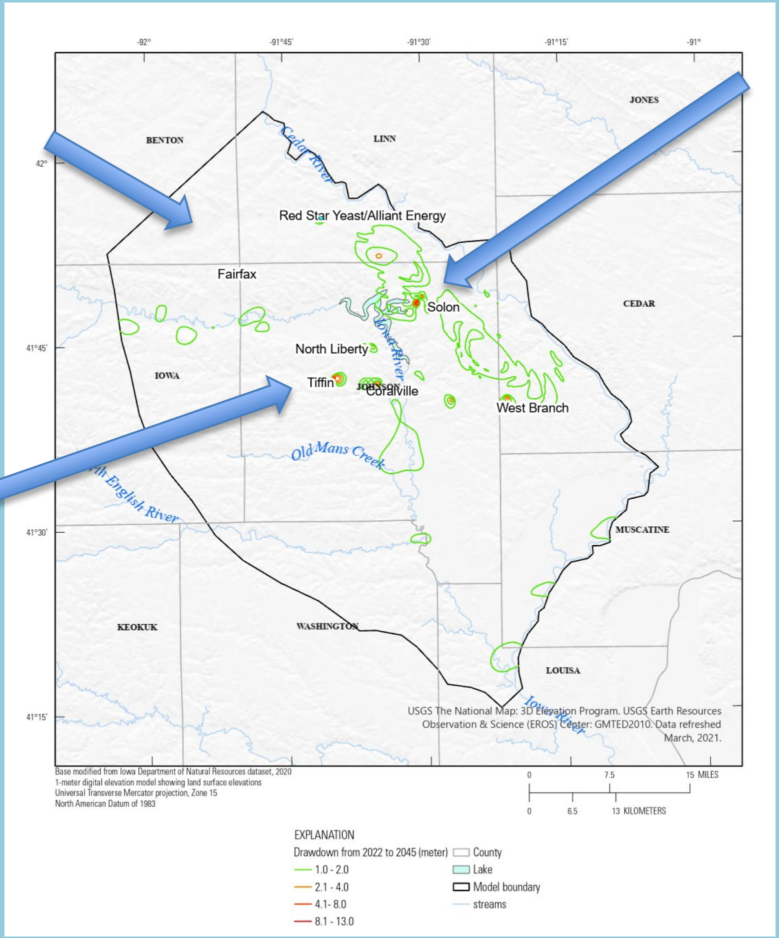
No drawdown in the Silurian in the northern portion of the model area

Drawdown in the Iowa City area of 4 to 13 meters (13 to 43 feet).



Drawdown in the Solon area of 4 to 13 meters (13 to 43 feet)

Drawdowns based on -

- Annual increases in pumping rates between 0 and 5% (information from city staff)
- Assumption of moderate decrease in precipitation associated with periodic drought

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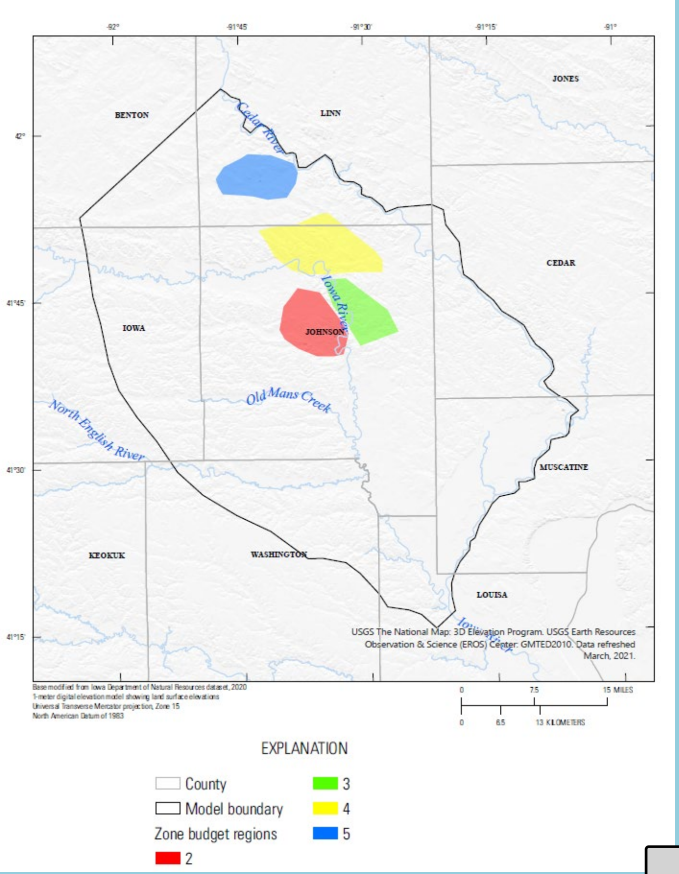
Use of Zone Budgeting in Higher Usage Areas

- Zone 2 is the Iowa City Metro Area
- Zone 3 is the Southern Coralville Reservoir Area
- Zone 4 is the Northern Coralville Reservoir Area including the City of Solon.
- Zone 5 is the Fairfax and Southern Cedar Rapids Industrial Area.
- Zone 1 is the rest of the model area



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Forecast groundwater budget components, Zone 2&3

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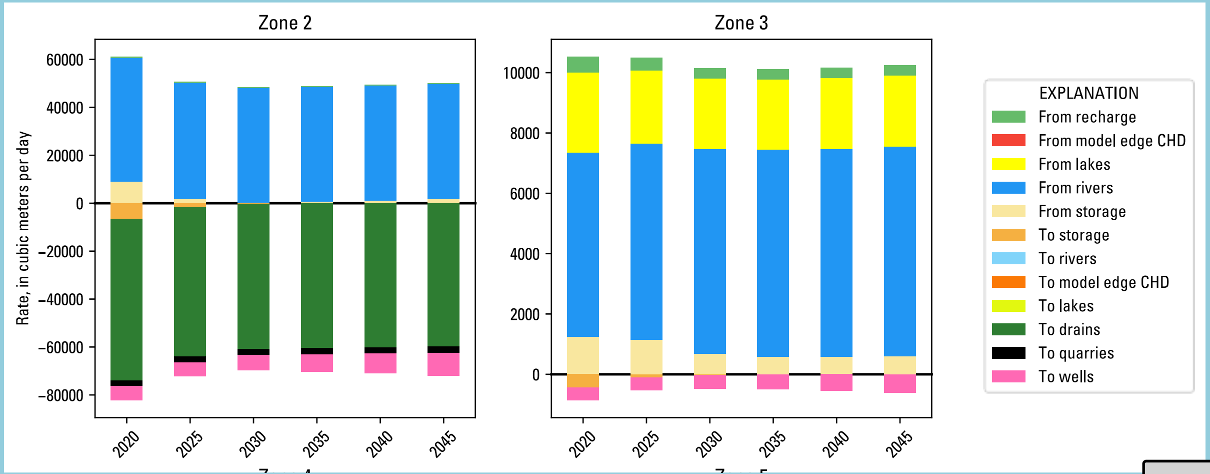
- Zones won't add up to 100% in and out, but exist within the larger model water budget which is balanced
- Each zones water budget shows the primary components of their water budget
- Zone 2 (Iowa City area), the primary components of the water budget in the Silurian aquifer are rivers and drains (water leaving model) where aquifer storage is small in 2030 and continues to decrease from 2030 to 2045.
- Zone 3 (rural areas to the south of the Coralville Reservoir) generally is a source of water in the Silurian aquifer from 2030 to 2045 where rivers and lakes are major components of the water budget.



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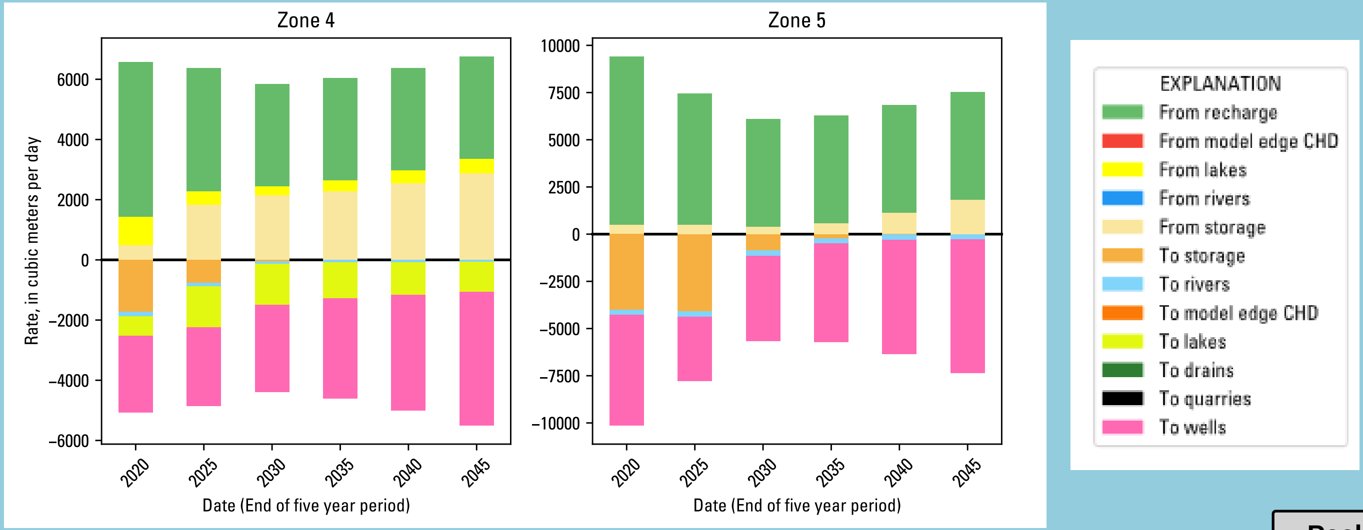
Forecast groundwater budget components, Zone 4&5

- Zone 4 represents the rural areas to the north and east of the Coralville Reservoir and Zone 5 represents the Fairfax and Cedar Rapids area.
- Rivers, quarries, and drains are not major components within these zone water budgets.
- Recharge into the model will be driven by climatic variation while wells withdrawing water from the model are driven by current and projected increases in use
- Zone water budgets show decreases in storage in the Silurian aquifer from 2030 to 2045.



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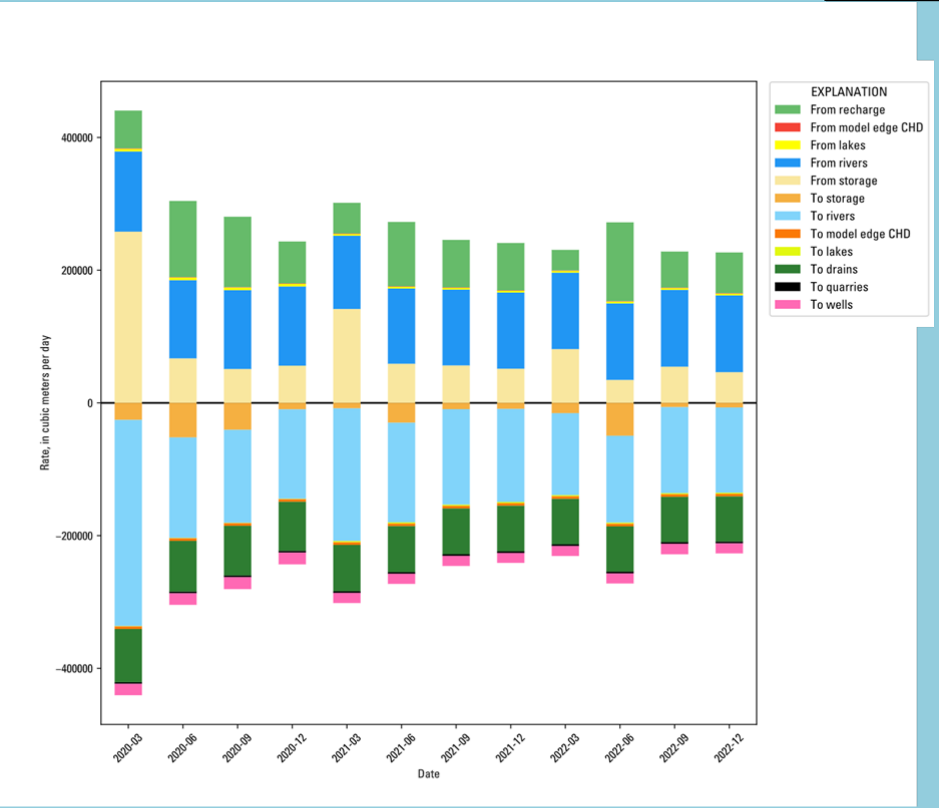
Conclusions

- Simulated drawdowns in the models higher use areas ranged from 1 to 13 meters (3 to 43 feet) from 2022-2045
- The model indicates decreasing storage in the Silurian aquifer from 2020-2045.
- Limited availability of long-term groundwater level data in the Silurian aquifer will continue to represent a challenge to understanding aquifer conditions.



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