Minnesota

Conceptual Drinking Water Supply Plan: Groundwater Modeling Discussion

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3M PFC Settlement Subgroup 1 Meeting

February 19, 2020

Agenda

- ❑   Overview

- ❑   Model Construction

- ❑   Preliminary scenario results discussion and examples

  - ❑   Sub-Regional (multiple large groundwater well fields)
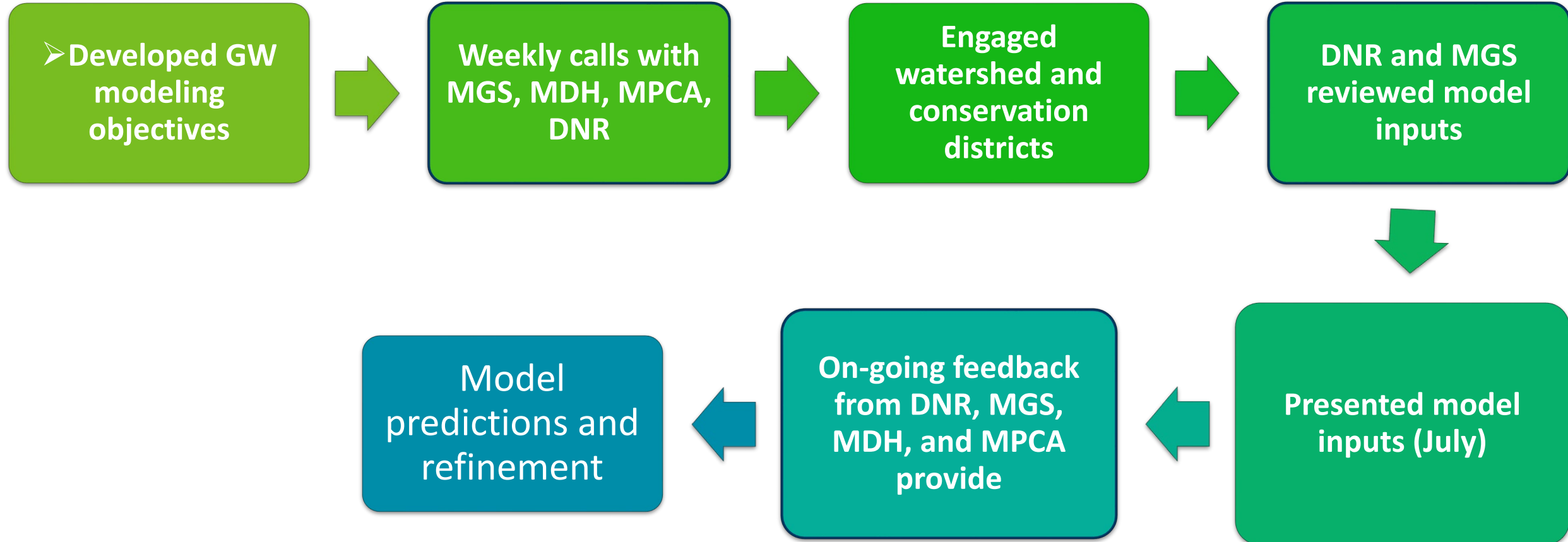
  - ❑   Community-Specific

- ❑   Next Steps

❑ Parking Lot

❑ Sticky notes

- Groundwater is the primary source of drinking water for the East Metro Area

- Water distribution

  - 8 communities with public water systems and 1 community connected to St. Paul Regional Water Services

  - Over 6,000 private wells across all 14 communities

- Water demand

  - Washington County population is expected to grow

  - 2040 maximum daily water demand: 52 million gallons per day

Overview - groundwater model collaboration

➤ **Developed GW modeling objectives** → **Weekly calls with MGS, MDH, MPCA, DNR** → **Engaged watershed and conservation districts** → **DNR and MGS reviewed model inputs**

↓

Model predictions and refinement ← **On-going feedback from DNR, MGS, MDH, and MPCA provide** ← **Presented model inputs (July)**

| What the Model <u>DOES</u>	What the Model <u>DOES NOT</u> do
Predicts groundwater elevations and gradients under steady state conditions	Does not predict groundwater elevations and gradients under transient conditions (time varying)
Simulates drawdown of pumping wells (municipal, irrigation, pollution containment, etc.)	Does not simulate drawdown under transient conditions (time varying)
Conservatively simulates transport of PFAS compounds using particle tracking and flow paths - What current and/or future wells could be impacted?	Does not predict groundwater concentrations of PFAS compounds
Simulates groundwater flow across faults and allows layers to pinch out	Does not account for any unknown sources of PFAS, and does not evaluate specific PFAS compounds

Model Construction

Basic Assumptions

- Data used for model construction provided by many sources

- Geology and model layers based on bedrock and Quaternary rasters obtained from MGS

- Based on bulk hydraulic parameters across East Metro Area

- Model calibrated to average groundwater elevations over a 3-year period (2016-2018)

- Scenario evaluations are simulated under steady-state conditions

- Areas of non-municipal wells with HI>0.5 used as known areas of impact

Differences From Previous Models

- Quaternary deposits are now represented by top 5 layers in the model (where present)

- Model constructed using Unstructured Grids

  - Off-set of beds from faults explicitly represented

  - Pinching out layers
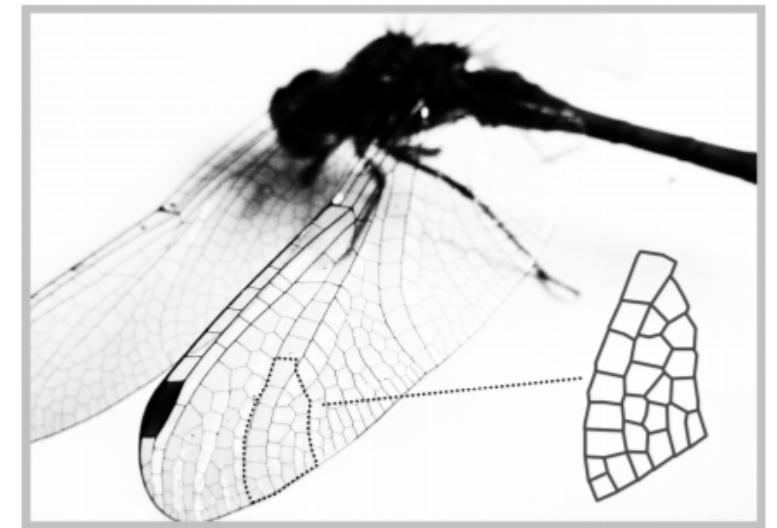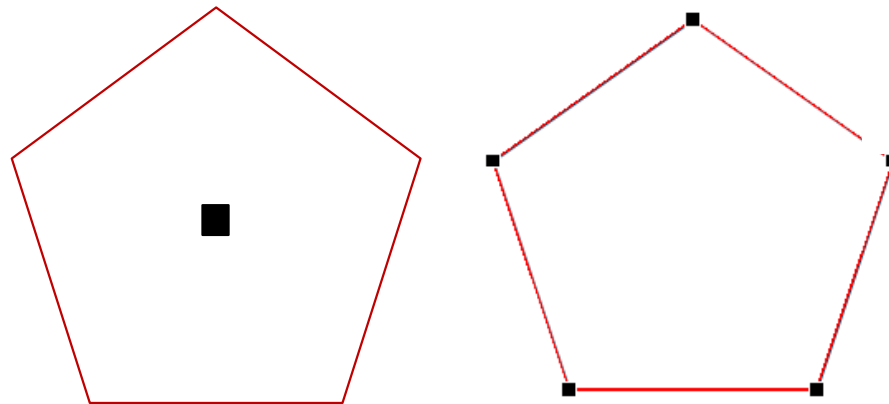
Unstructured Voronoi grids in nature as seen on a dragonfly wing.
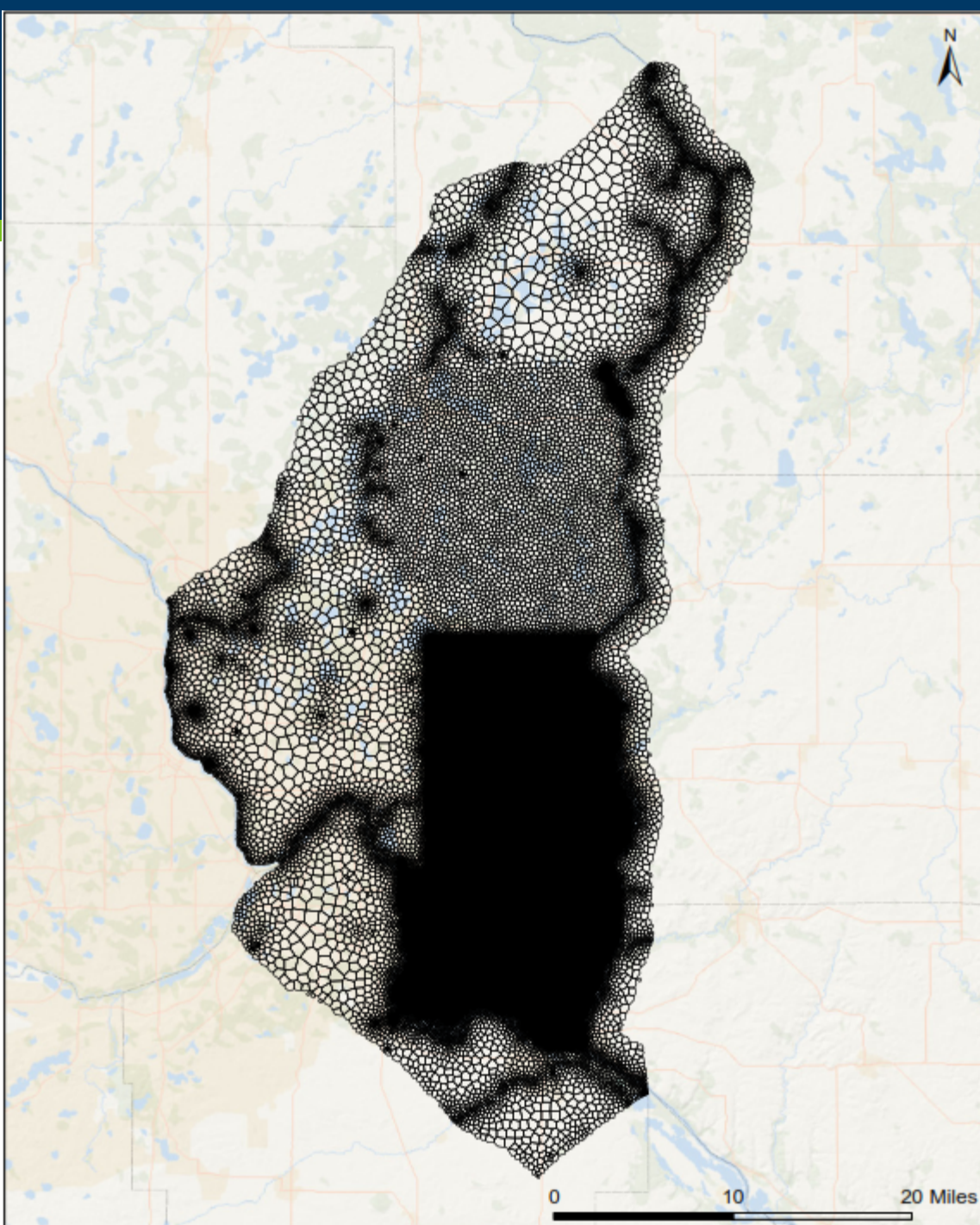Image source: DOI: 10.21858/msr.19.10

Model construction
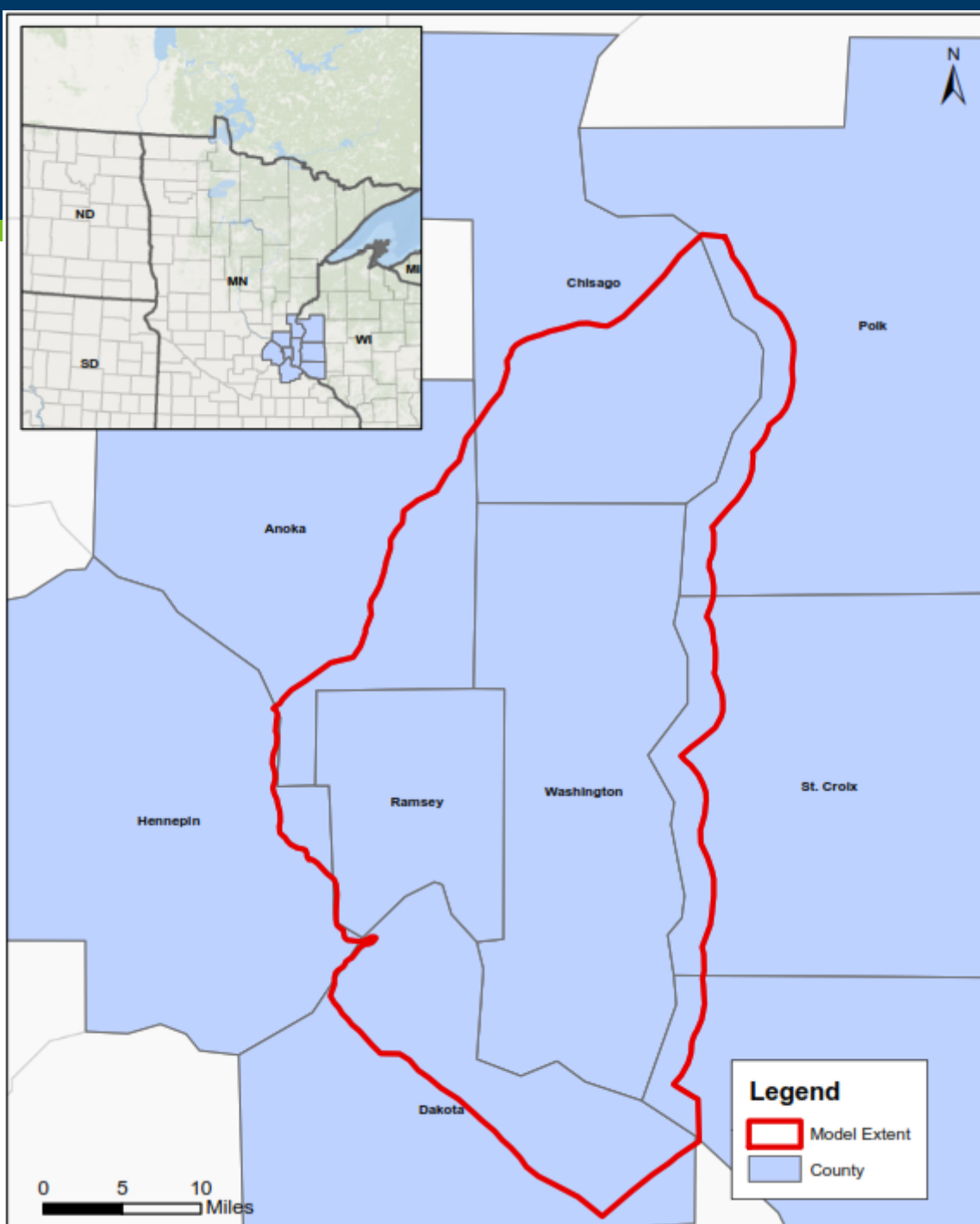
Model domain

- 1,194 Square Miles

- Centered on Washington County

- Generally Bounded by St. Croix, Mississippi, and Minnesota Rivers

Model construction

Model grid

- Previous models are typically finite difference grid models

- This model is **Unstructured Grid (USG)**

  - Matches reality better

  - Local refinement

  - Publicly available model code

Model construction

Model layers and geologic representation

- 18 layers

- Every major aquifer represented

- Some aquifers broken up further

	Quaternary sediments
	shallow bedrock
	Glenwood/Platteville
	St. Peter Sandstone
	lower St. Peter confining unit
	Prairie Du Chien (Shakopee)
	Prairie Du Chien (Oneota)
	Jordan Sandstone
	St. Lawrence formation
	Tunnel City (Mazomanie)
	Tunnel City (Lone Rock)
	Wonewoc Sandstone
	Eau Claire Formation
	Mt. Simon Sandstone

Model construction

Data	Source
Precipitation data	DNR (2019a)
Historic and current pumping volumes	DNR (2019b)
Lake bathymetry data	DNR (2019c)
Groundwater elevations	DNR (2019d), MDH (2019)
Surface water elevations	DNR (2019e)
DNR Northeast Metro Lakes Groundwater-Flow model files	DNR (2019f)
3-meter digital elevation model (DEM)	DNR (2019g)
Recharge and run-off estimates from 1990s through 2018	DNR (2019h)
Land use map	Minnesota IT Services (2019)
Surface water boundaries	U.S. Geological Survey (2019a)
U.S. Geological Survey (USGS) Northeast Metro Lakes Groundwater-Flow model files	U.S. Geological Survey (2019b)
Geologic maps	Minnesota Geological Survey (multiple sources)
Hydraulic conductivity	Runkel et al. (2003), Tipping et al. (2010), MNDNR (2019j)
Well construction details	MDH (2019)
Baseflow measurements	Jones et al. (2017)
Metro Model 3	Metropolitan Council (2019)
Groundwater sample data	MPCA (2019a)
PFAS source areas	MPCA (2019b)

Cross-sections

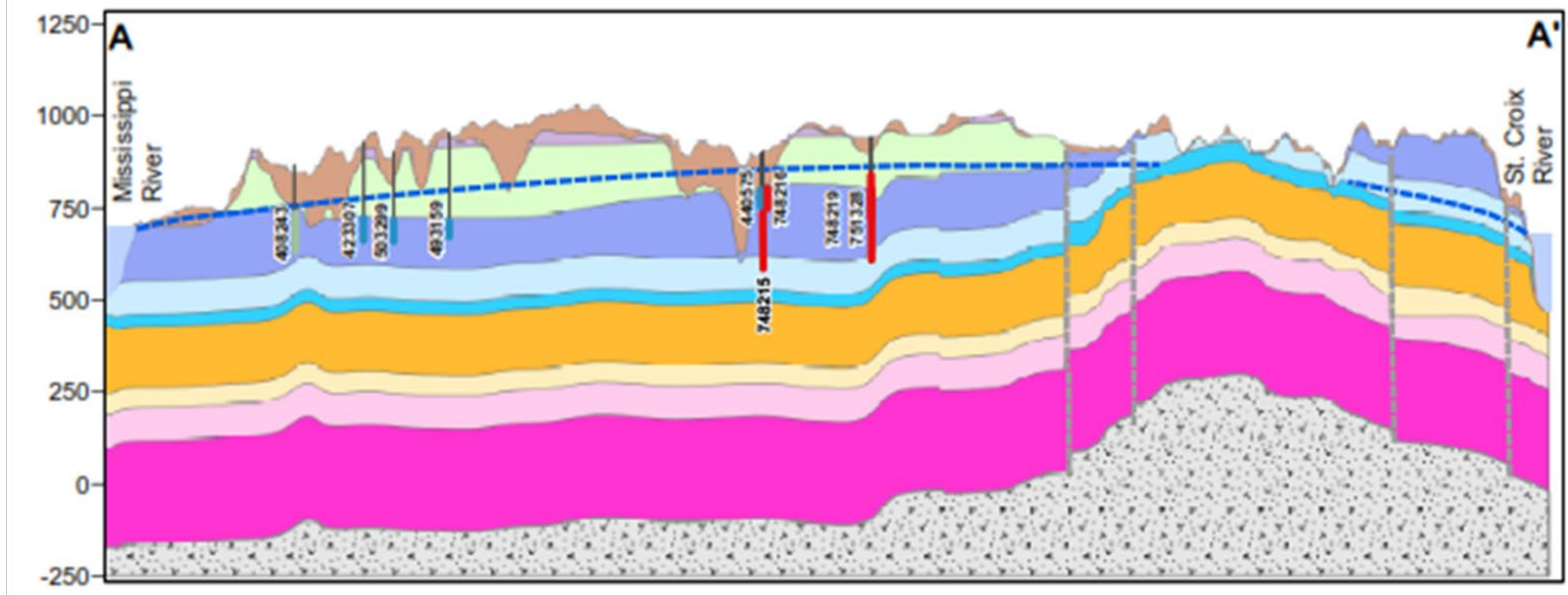- One N-S cross-sections

- Two E-W cross-sections

- One oblique cross-section (diagonal)

- One Groundwater Model cross-section

Quaternary
Decorah Shale
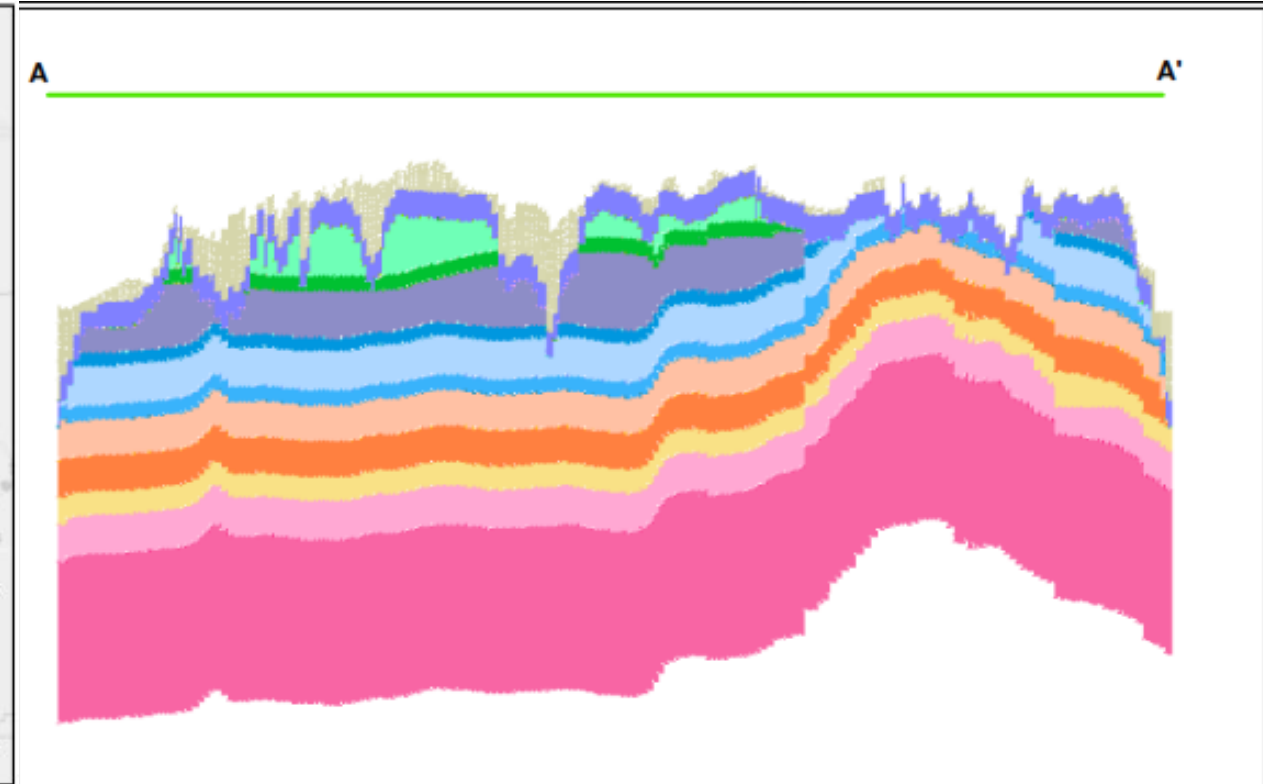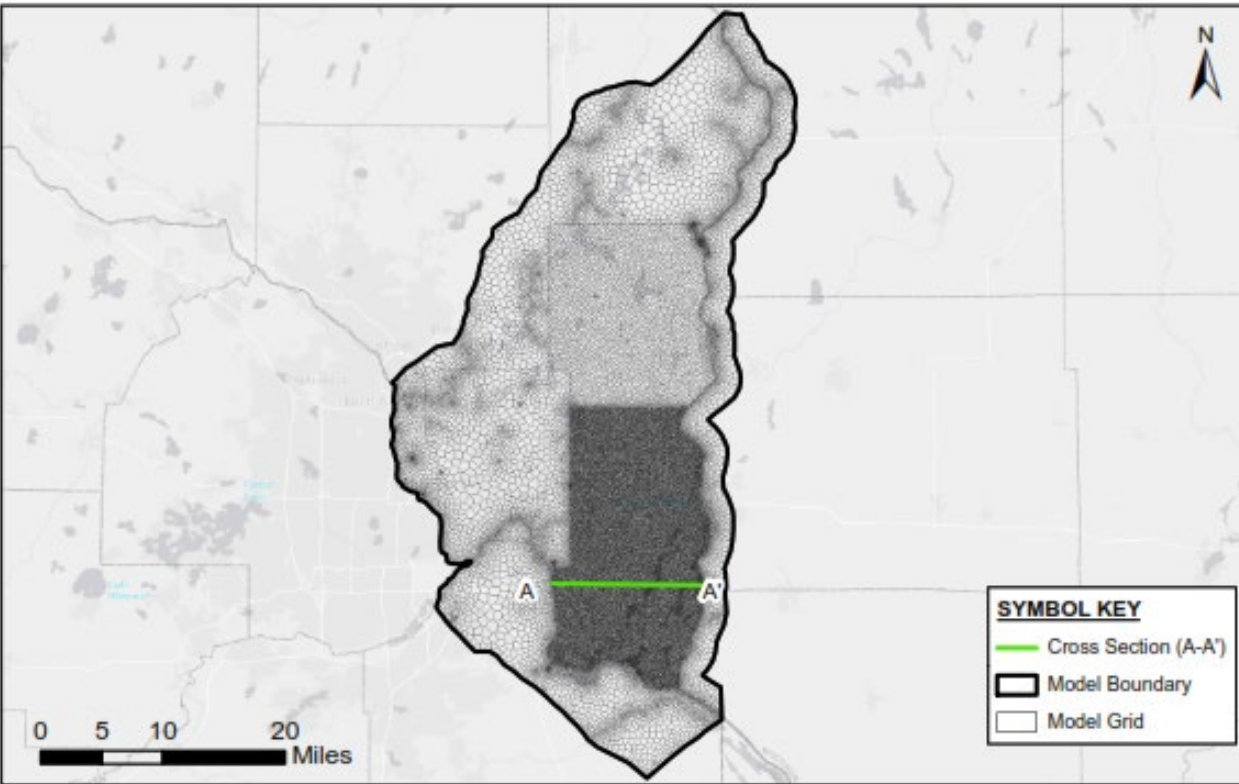Glenwood_Platteville Formations
St. Peter Sandstone
Prairie Du Chien Group
Jordan Sandstone
St. Lawrence Formation
Tunnel City Group
Wonewoc Sandstone
Eau Claire Formation
Mt. Simon Sandstone
PreCambrian
Potentiometric Surface (St. Peter - Praire Du Chien - Jordan Aquifers)
Fault
Well (colored according to health index)
531446 Unique Well Number

Bedrock Hydraulic Parameters

- Hydraulic conductivity – one of more sensitive parameters in the model

- Conductivity measurements are real-world reported values

- Vertical K range:
  - 10^{-7} m/d (aquitards like the Eau Claire Fm.) to
  - 1.2 m/d (aquifers like the deep Jordan Fm.)

- Horizontal K range:
  - 10^{-5} m/d (Eau Claire Fm.) to
  - 50 m/d (Prairie du Chien Fm.)

SYMBOL KEY

☐ Model Boundary

Mean Annual Recharge (in)

- 0-2
- 2-4
- 4-6
- 6-8
- 8-10
- 10-12
- 12-14
- 14-16
- 16-18
- 18-20
- >20

Applied Recharge

- Collaboration with DNR

- One of more sensitive parameters in the model

- Average of soil water balance (SWB) model output for time frame 2016-2018

- Rivers and lakes assigned zero recharge

- Areas outside of SWB assigned a recharge of 6 inches
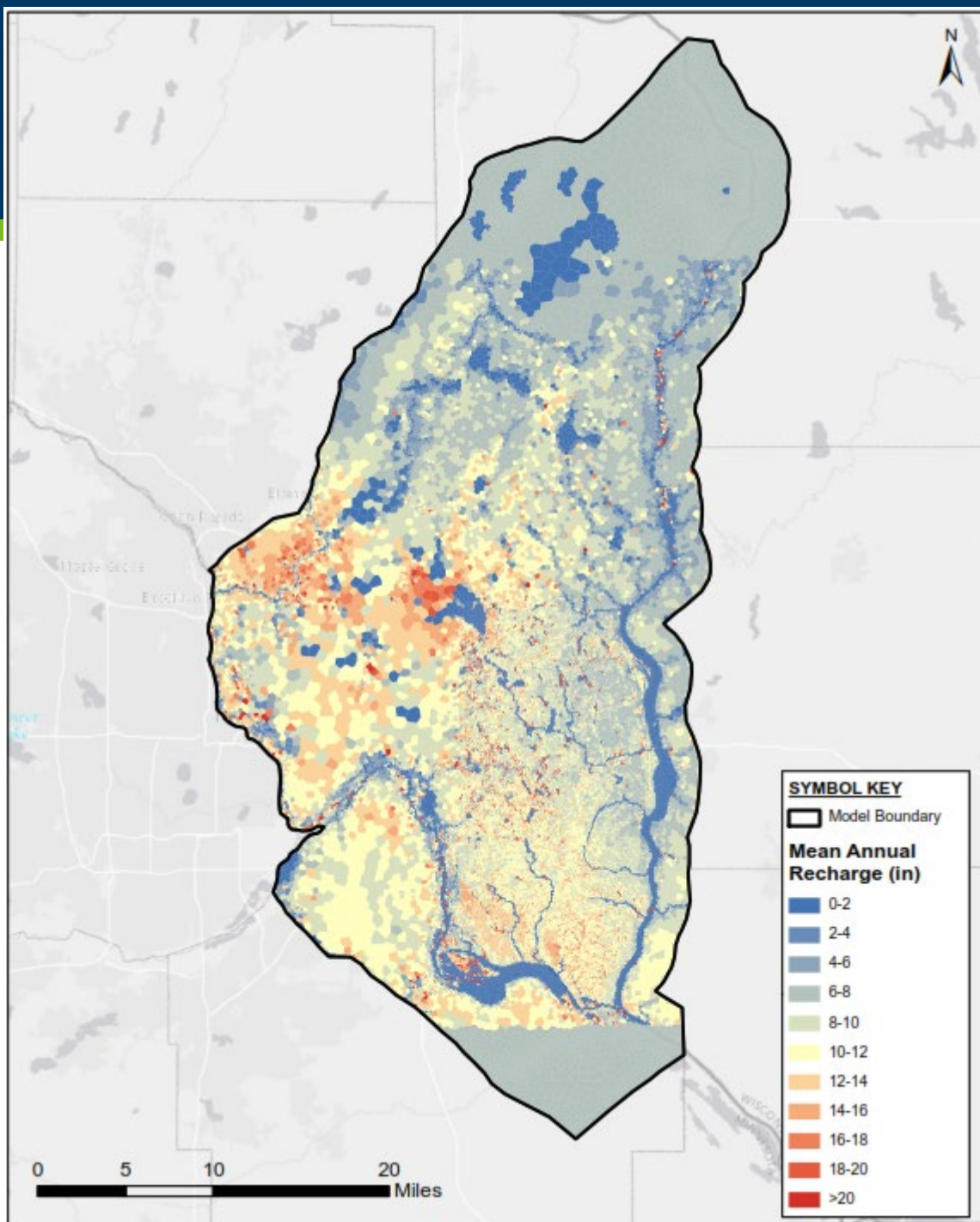
Groundwater calibration

- Model simulated groundwater elevations compared to average measured groundwater elevations from 2016 – 2018

- Calibration Statistics

  - Number of Observations = 79

  - Residual Mean (m)   = -2.50

  - Residual Sum of Squares   = 3050

  - Scaled Root Mean Square Error   = 0.070
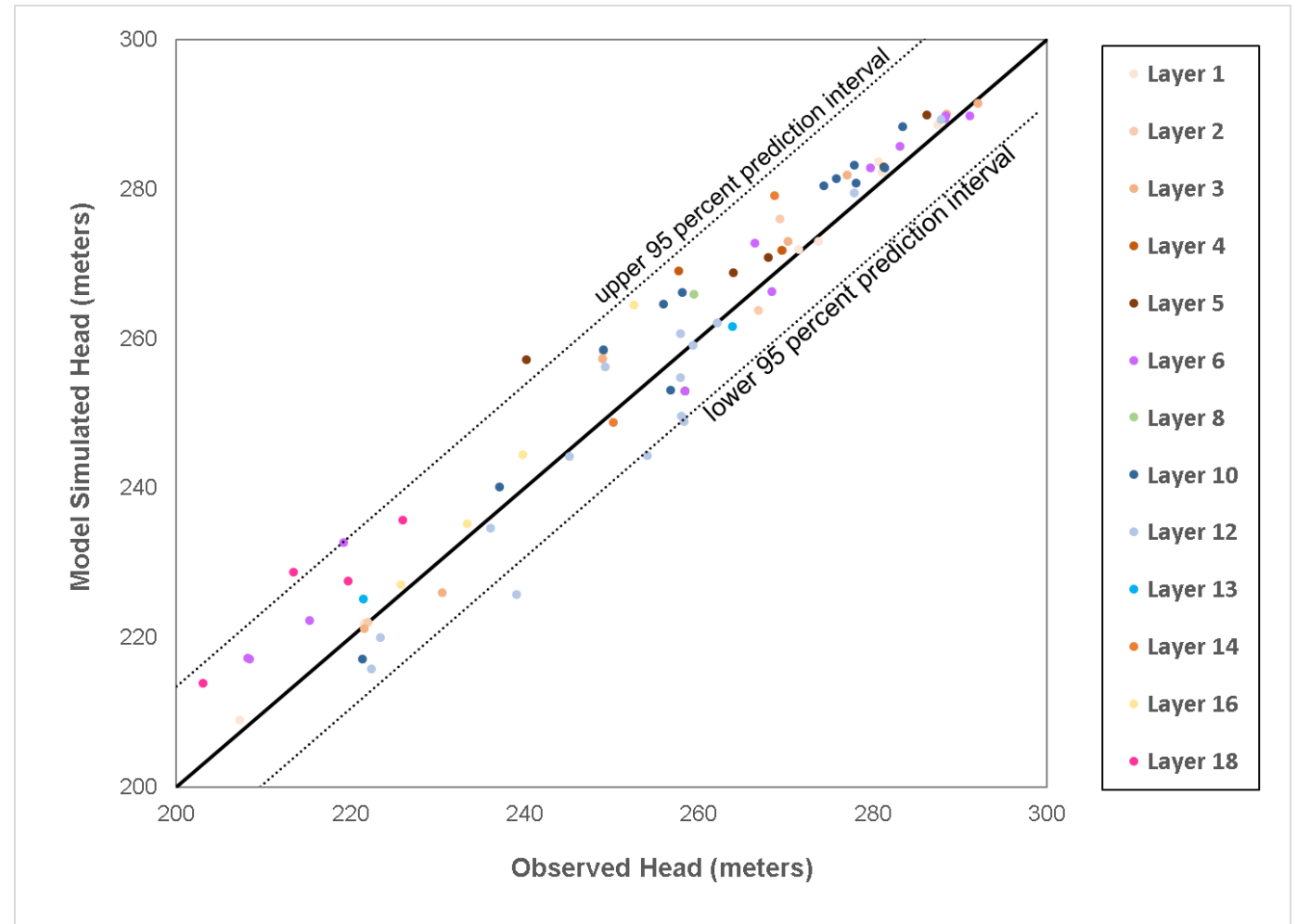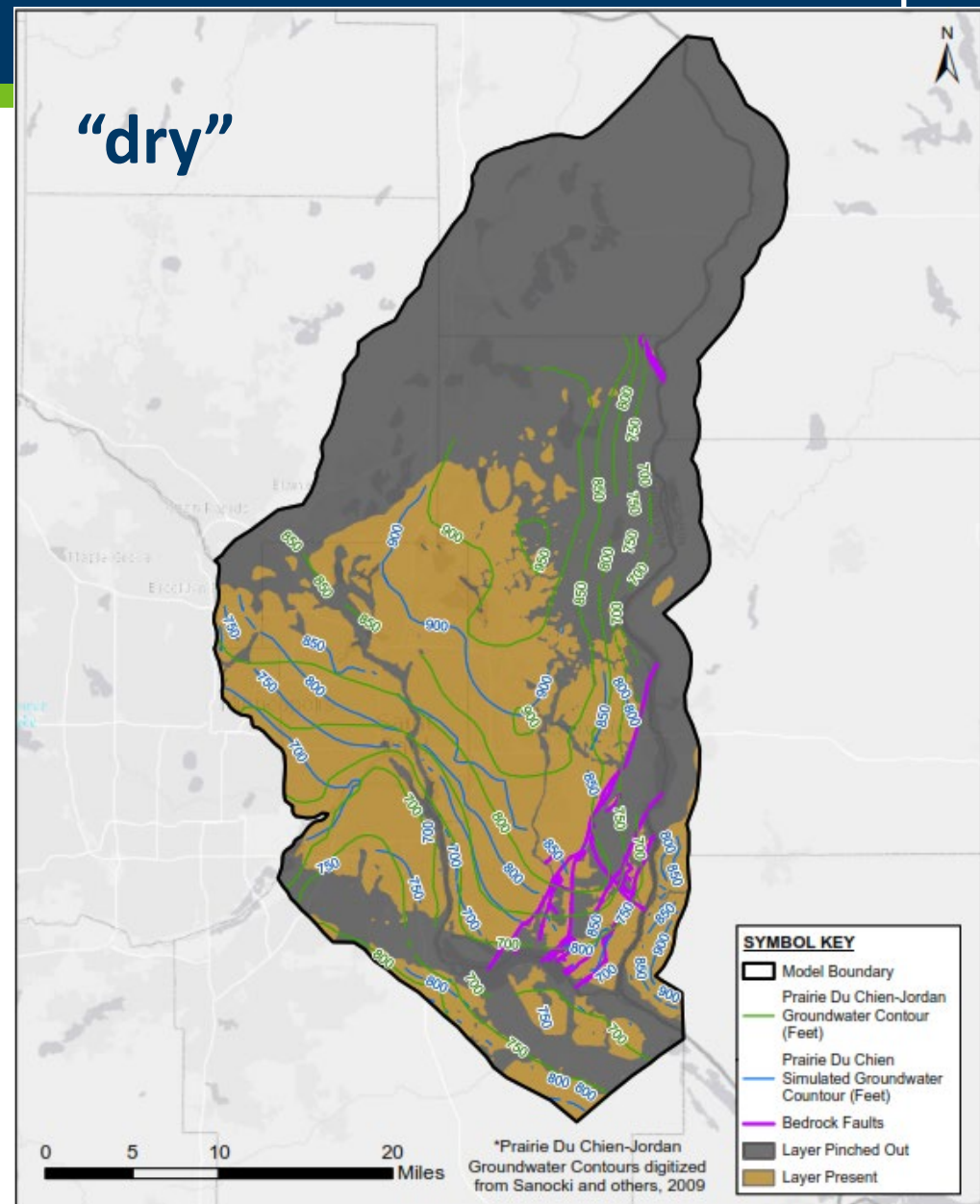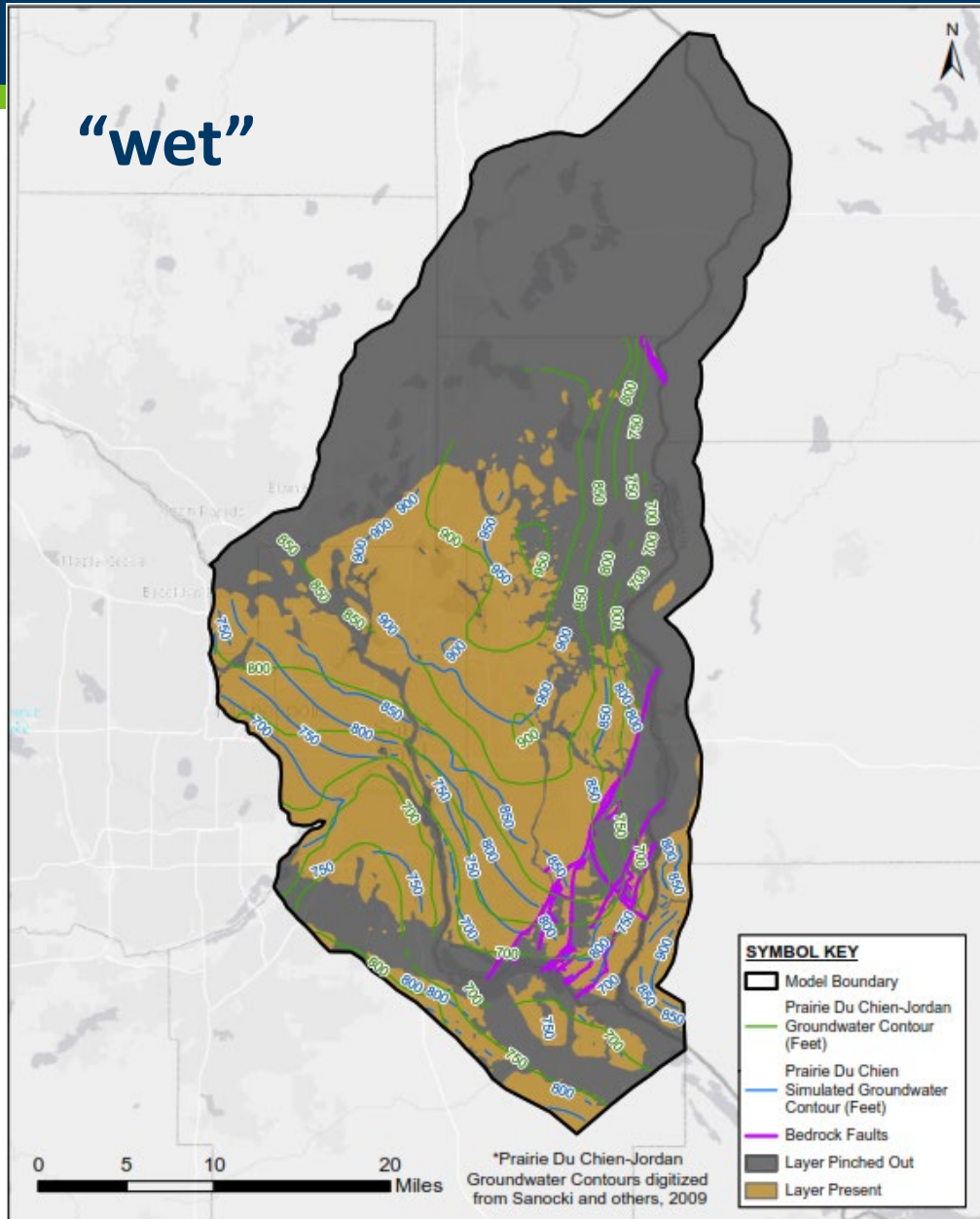
Calibration - Flow Field

- Confirms flow direction and gradients

- Interpolated vs model simulated groundwater elevation contours

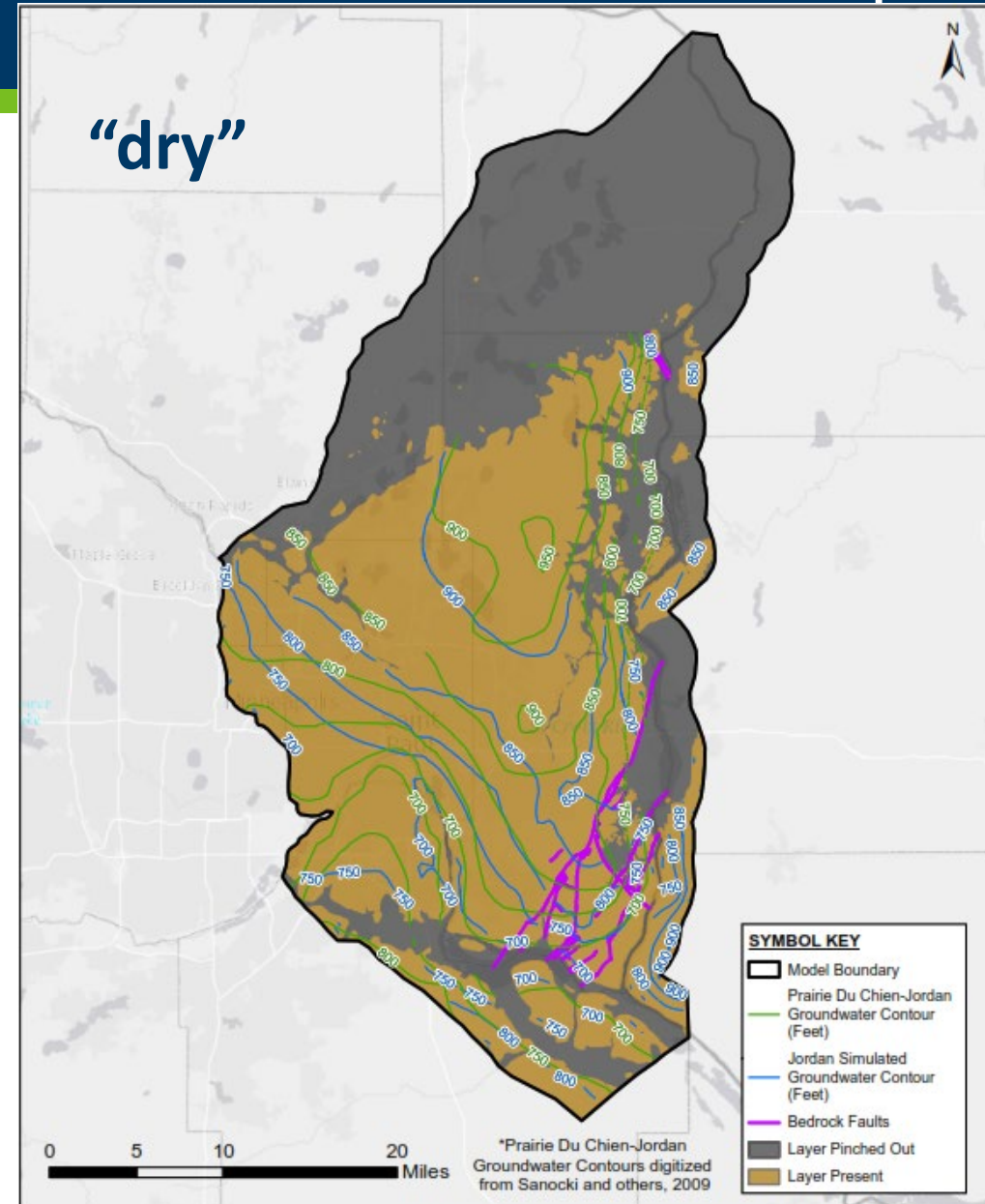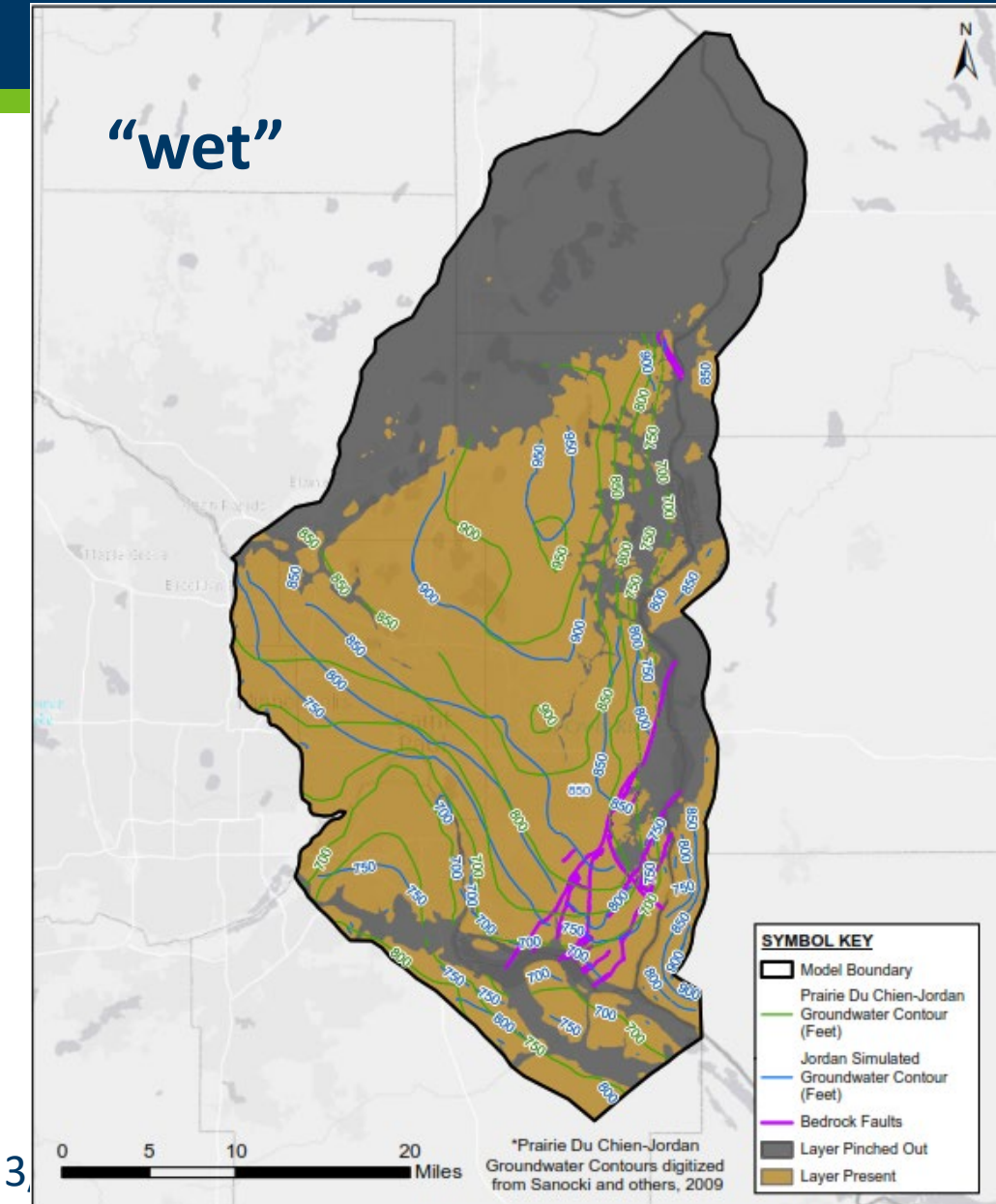 - Prairie du Chien

  - Jordan

Groundwater Calibration Flow Field - Prairie Du Chien aquifer

"wet"

"dry"

SYMBOL KEY

- Model Boundary
- Prairie Du Chien-Jordan Groundwater Contour (Feet)
- Jordan Simulated Groundwater Contour (Feet)
- Bedrock Faults
- Layer Pinched Out
- Layer Present

*Prairie Du Chien-Jordan Groundwater Contours digitized from Sanocki and others, 2009

0 5 10 20 Miles

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Sensitivity analysis

- The model calibration is most sensitive to recharge. Calibration error decreased as recharge is decreased.

- The model calibration is sensitive to K in Quaternary layers (both horizontal and vertical). Model error increased as K decreased.

- The model calibration is sensitive to horizontal K in Shakopee Member of the Prairie du Chien; however, increasing K did not improve the calibration error.

- The model calibration is relatively insensitive to general head boundaries with the exception of the Quaternary layers on the southern boundary where head targets are adjacent to the boundary.

Summary

WHAT WERE THE RESULTS?	WHAT DO THEY MEAN?
✓ Calibration of model is good (7% error, water balance less than 0.1%) ✓ Simulated potentiometric surface closely, matches observed potentiometric surface.	✓ Model should be able to predict groundwater flow and flow paths into the future. ✓ Model can predict groundwater flow and travel times with reasonable confidence.

Preliminary scenario results and examples

26 model simulations

Simulate conditions when all municipal wells are turned off

- **Regional**
- One Regional Surface Water Plant
- Two Regional Surface Water Plants
  - Woodbury served by Mississippi Plant
  - Woodbury served by St Croix Plant
- St Paul Regional Water Services

Simulate placement of new municipal wells and well fields across the east metro

- **Regional**
- One Groundwater well field
- Sub-regional (three groundwater well fields)

- **Community-specific and Integrated**
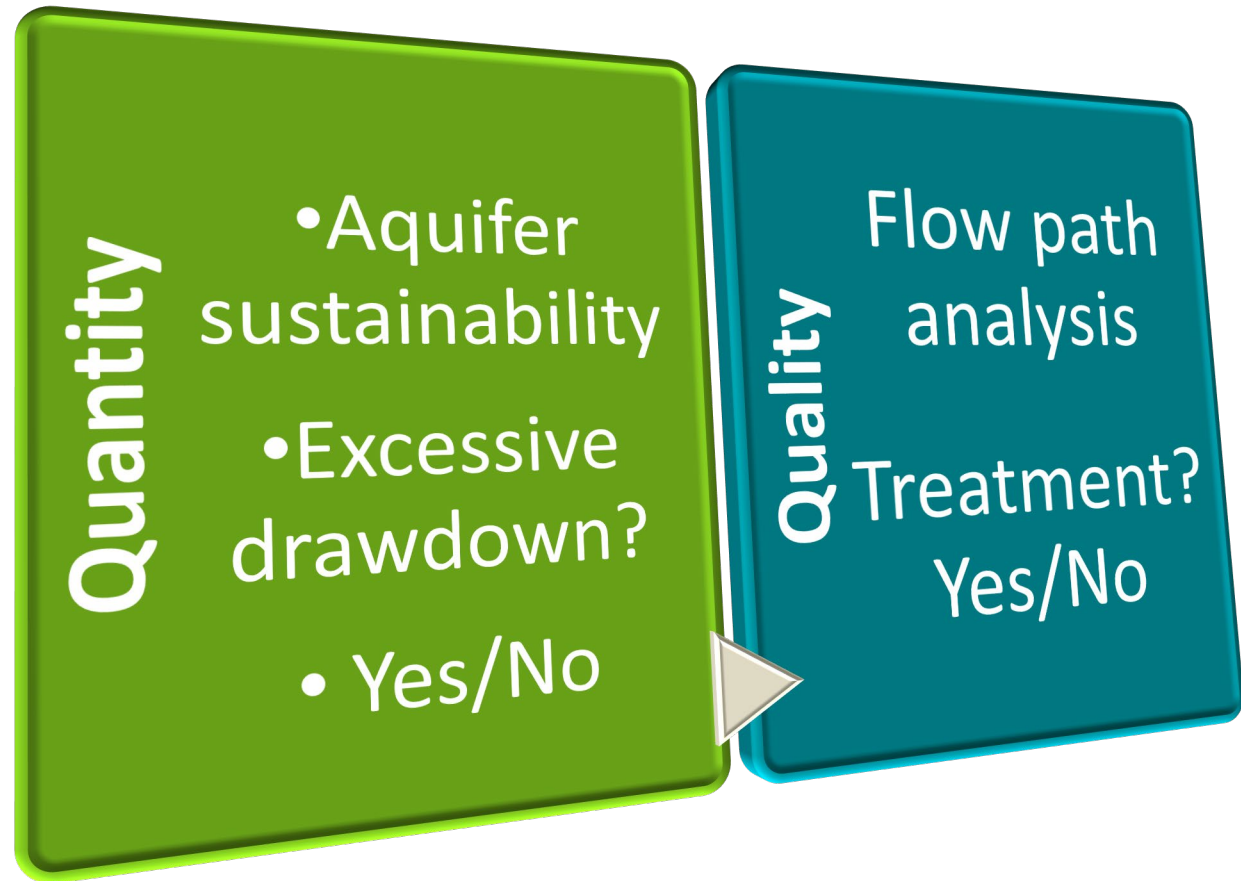- Cottage Grove, Lake Elmo, Lakeland, Oakdale, West Lakeland

Objectives

- Is there enough water?

- Does it require treatment?

Examples

- Sub-Regional Scenario

- Community Specific Scenario

  - Cottage Grove

Quantity
- Aquifer sustainability
- Excessive drawdown?
- Yes/No

Quality
Flow path analysis

Treatment? Yes/No
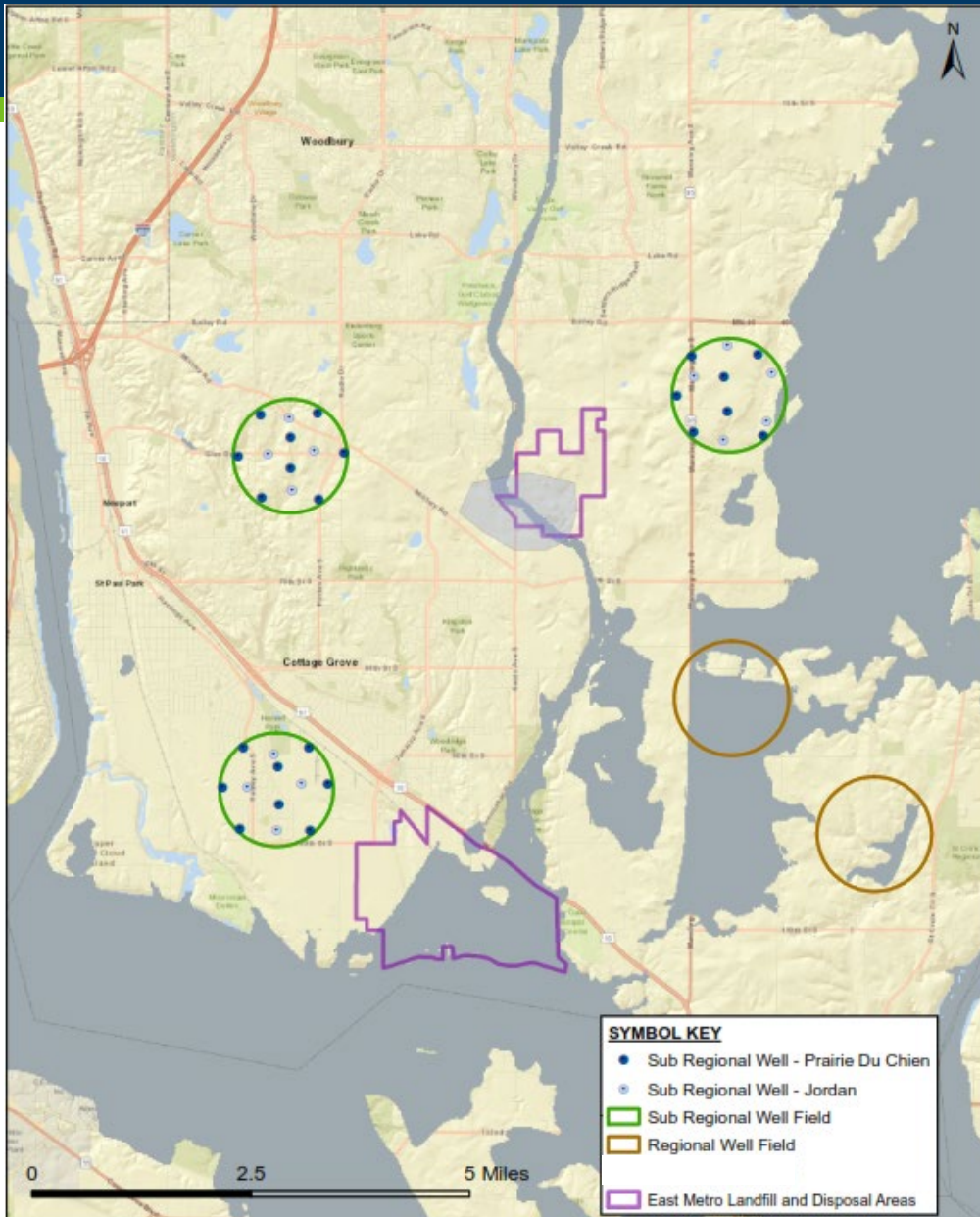
Sub-Regional Scenario

- Steady State condition (inputs not varying with time)

- Municipal pumping wells non-operational (turned off)

- Non-municipal wells remain operational

- Areas of HI>0.5 used to help assess areas of future impacted groundwater

- Three new well fields (18 MGD MDD ea.)

    - Is capacity available? – Yes/no # gpm

    - Can the aquifer sustain the required pumping rates without excessive drawdown? – yes/no
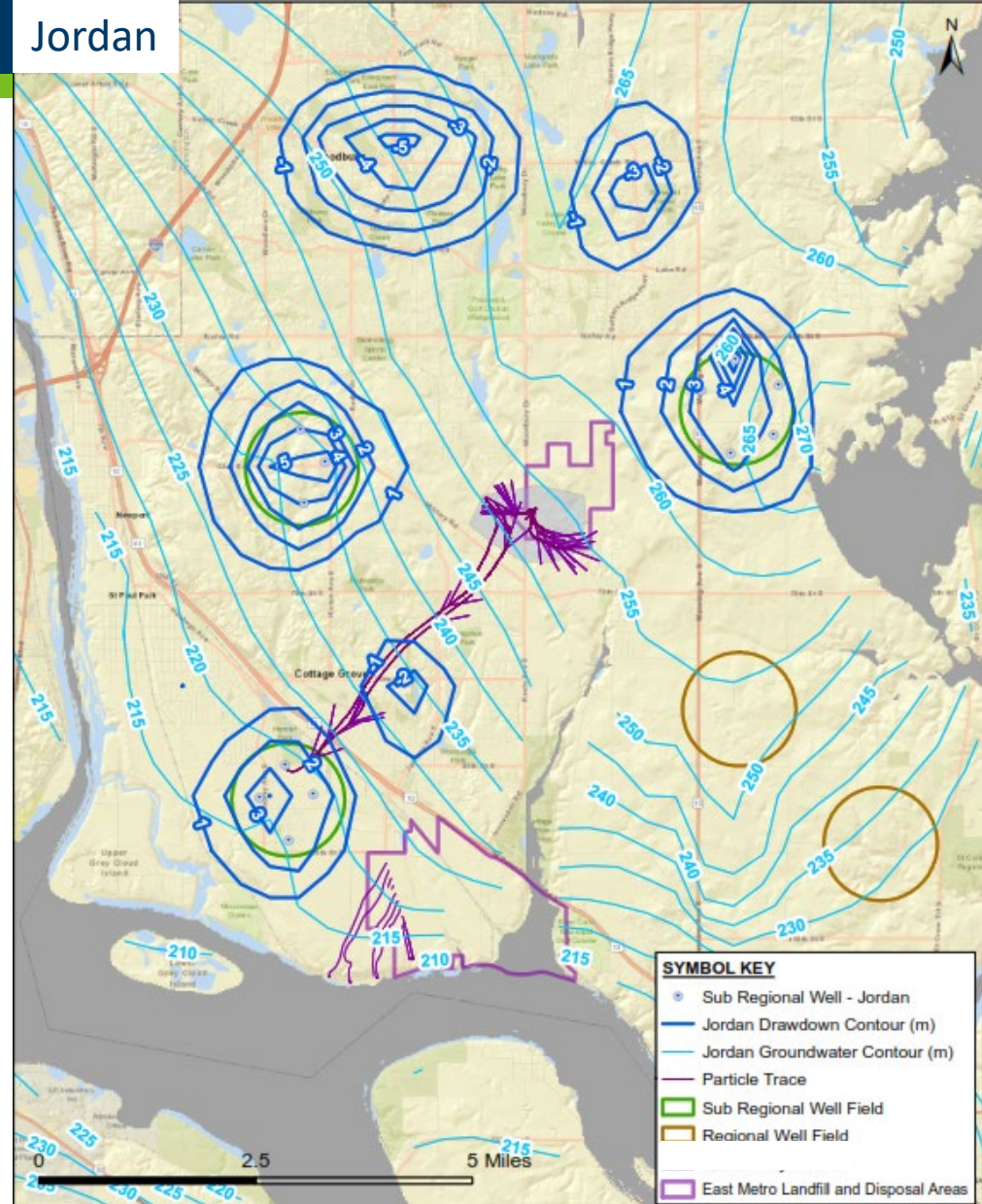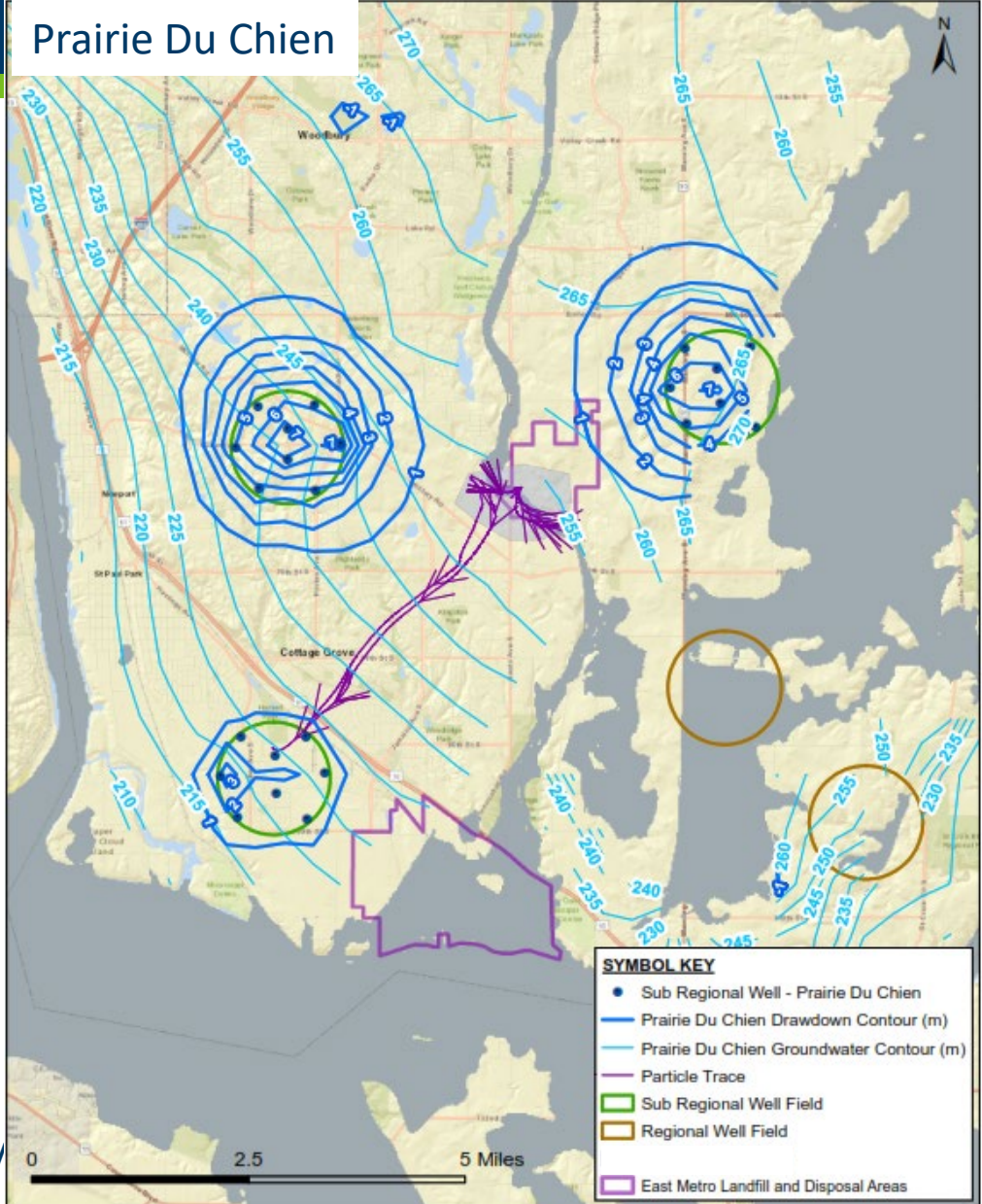
Sub-Regional Scenario

- 36 Production wells

  - 23 wells in the Prairie Du Chien (layer 10)

  - 13 wells in the Jordan (layer 12)

- Total production ADD* was divided equally among all 36 wells (408 gpm each)

- Dry condition applied a 124% increase in demand (506 gpm each) and 66% of recharge
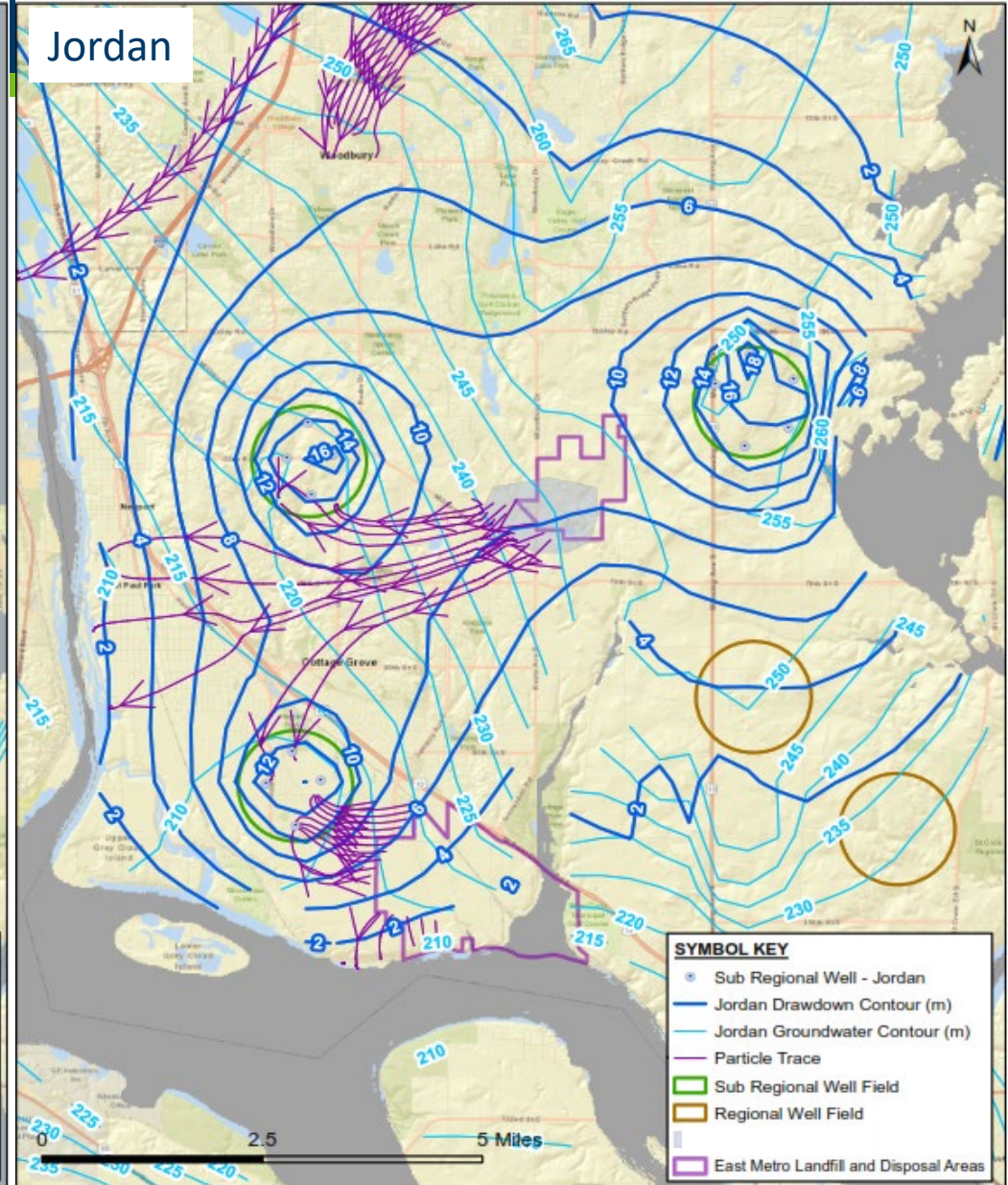
*ADD – average daily demand

SYMBOL KEY

- Sub Regional Well - Prairie Du Chien
- Sub Regional Well - Jordan
- Sub Regional Well Field
- Regional Well Field
- East Metro Landfill and Disposal Areas
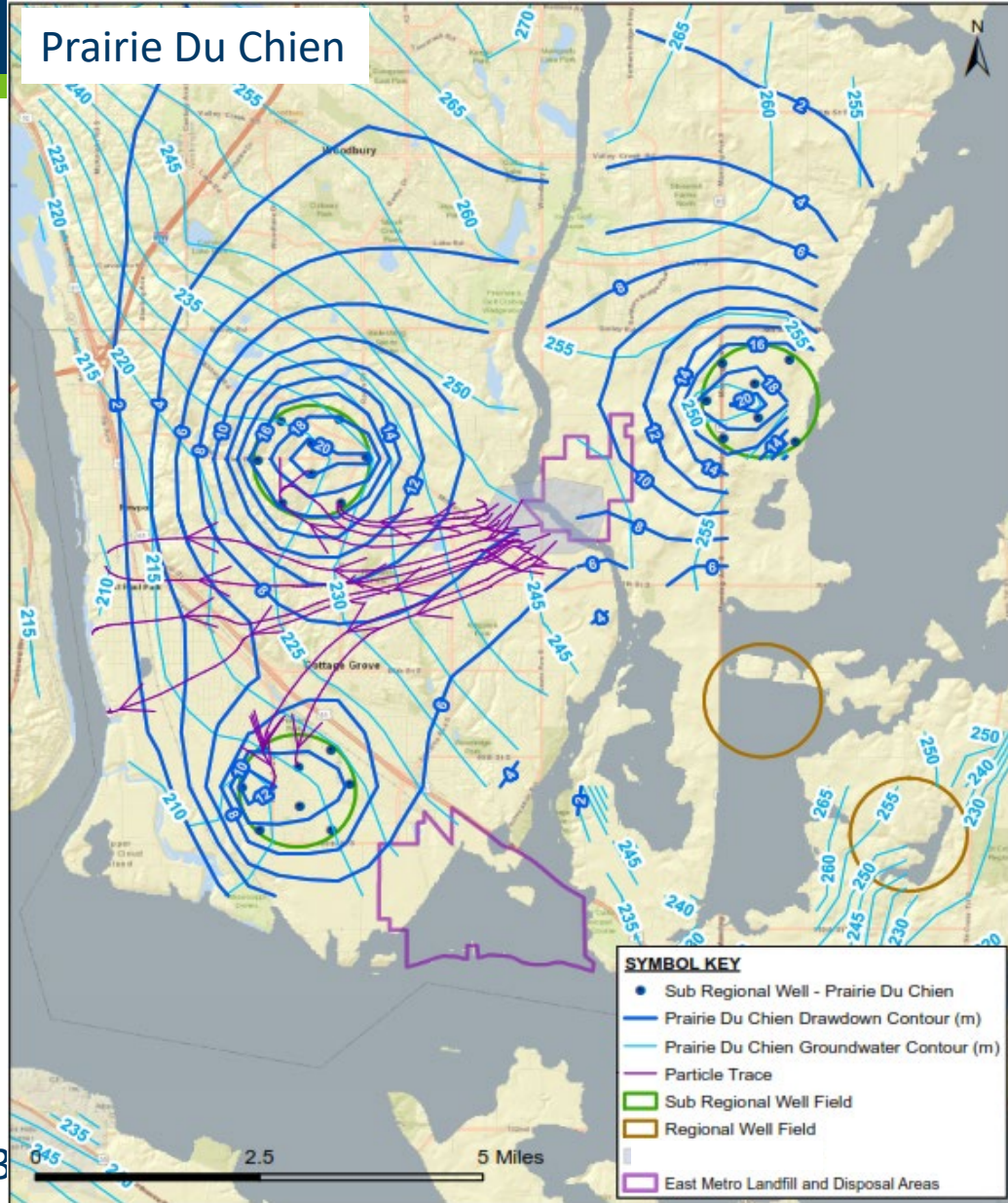
Community-specific scenario example

- Steady State condition (inputs not varying with time)

- Municipal pumping wells operational (turned on)

- Non-municipal wells remain operational

- Areas of HI>0.5 used help assess future impacts
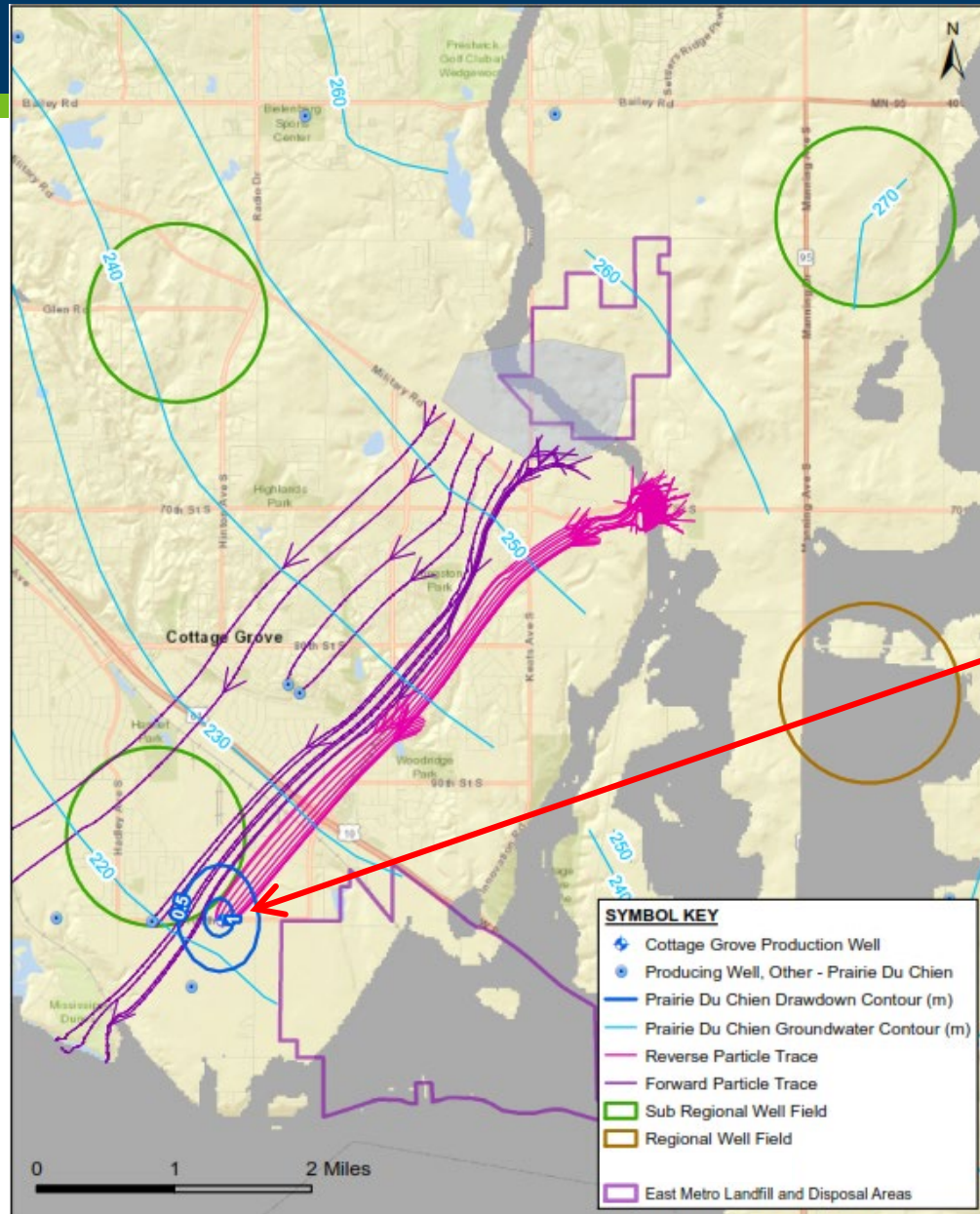
Community-specific scenario example

- Cottage Grove reverse and forward particle flow paths (wet condition)

- Single new well at 400 gpm ADD

- 1.5 m of drawdown predicted

SYMBOL KEY

⚡ Cottage Grove Production Well

⊙ Producing Well, Other - Prairie Du Chien

— Prairie Du Chien Drawdown Contour (m)

— Prairie Du Chien Groundwater Contour (m)

— Reverse Particle Trace

— Forward Particle Trace

▢ Sub Regional Well Field

▢ Regional Well Field

▢ East Metro Landfill and Disposal Areas
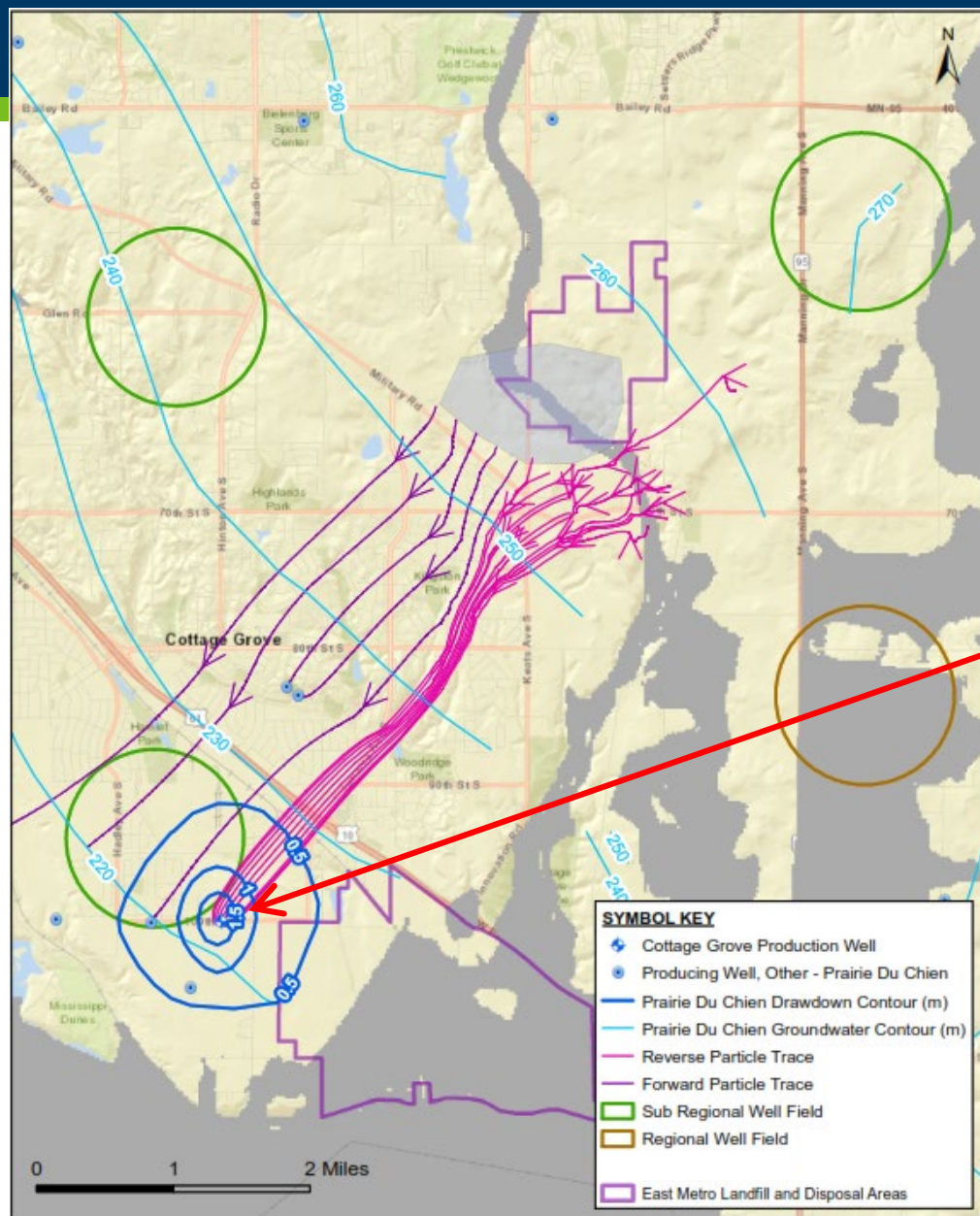
0   1   2 Miles

Preliminary scenario results

Community-specific scenario example

- Cottage Grove reverse and forward particle flow paths (dry condition)

- Single new well at 522 gpm ADD

- 2.0 m of drawdown predicted

SYMBOL KEY

- ⚡ Cottage Grove Production Well
- ⊙ Producing Well, Other - Prairie Du Chien
- —— Prairie Du Chien Drawdown Contour (m)
- —— Prairie Du Chien Groundwater Contour (m)
- —— Reverse Particle Trace
- —— Forward Particle Trace
- ◯ Sub Regional Well Field
- ◯ Regional Well Field
- ▭ East Metro Landfill and Disposal Areas

0   1   2 Miles

In summary

- Model calibrated to average conditions over 2016-2018 (wet period)

- Predicts flow of groundwater, including in areas of faults

- Predicts quantity - drawdown of new wells under CDWSP scenarios

- Predicts quality - potential PFAS migration from areas of known contamination

- 1-on-1 with LGUs to discuss results

- Refine existing scenarios as needed

  - Calibrate flow path timestamps

  - Address buried bedrock valley

  - Additional future demands

- Potentially model new scenarios

Questions

Thank you!

Jim Feild, PG and Konrad Quast, PG

Groundwater Modeling Team

Wood Environment & Infrastructure Solutions, Inc.

MINNESOTA POLLUTION CONTROL AGENCY