Soil Water Balance (SWB) Model and Applications in the Twin Cities Metropolitan Area

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Overview

- **Need for infiltration and recharge information**
  - Better understand how climate and land use affect infiltration
  - Support regional groundwater flow modeling
- **Overview of the Soil Water Balance (SWB) model**
  - Code developed by U.S.G.S. and Wisconsin Geological and Natural History Survey
- **Application to the Twin Cities Metropolitan Area**
  - Inputs
  - Results
  - Sensitivity

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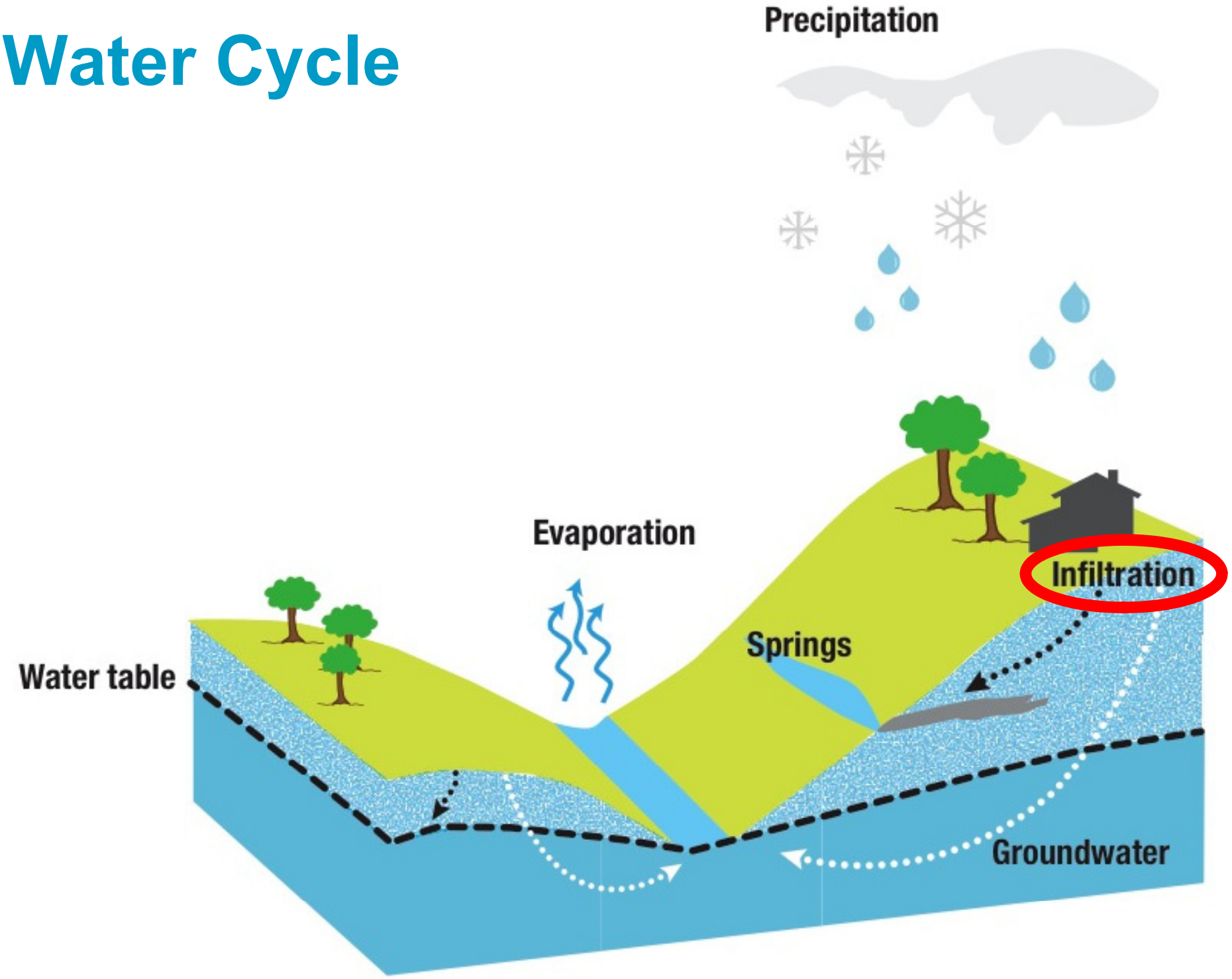
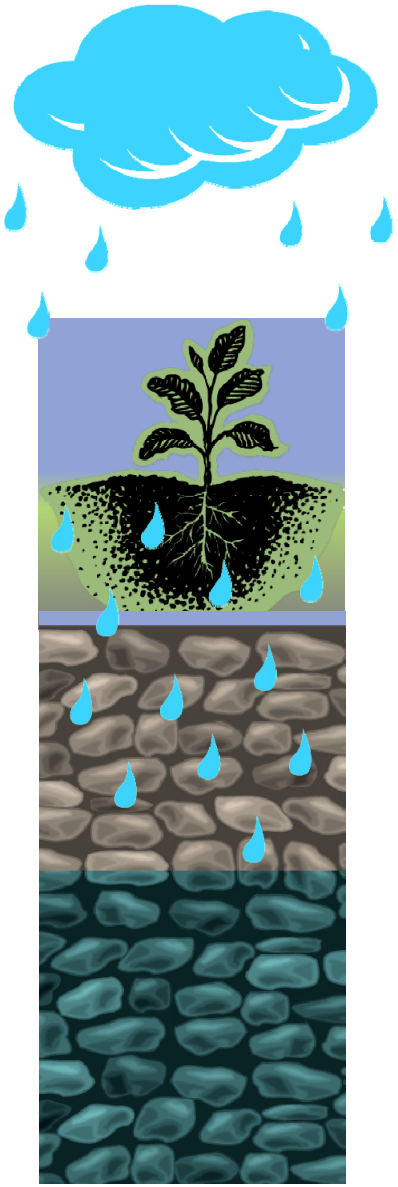
Water Cycle


Precipitation
Evaporation
Infiltration
Springs
Water table
Groundwater



Precipitation

Infiltration

Shallow

Aquifer Recharge

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Metro Water Supplies Over Half of Minnesota's Population

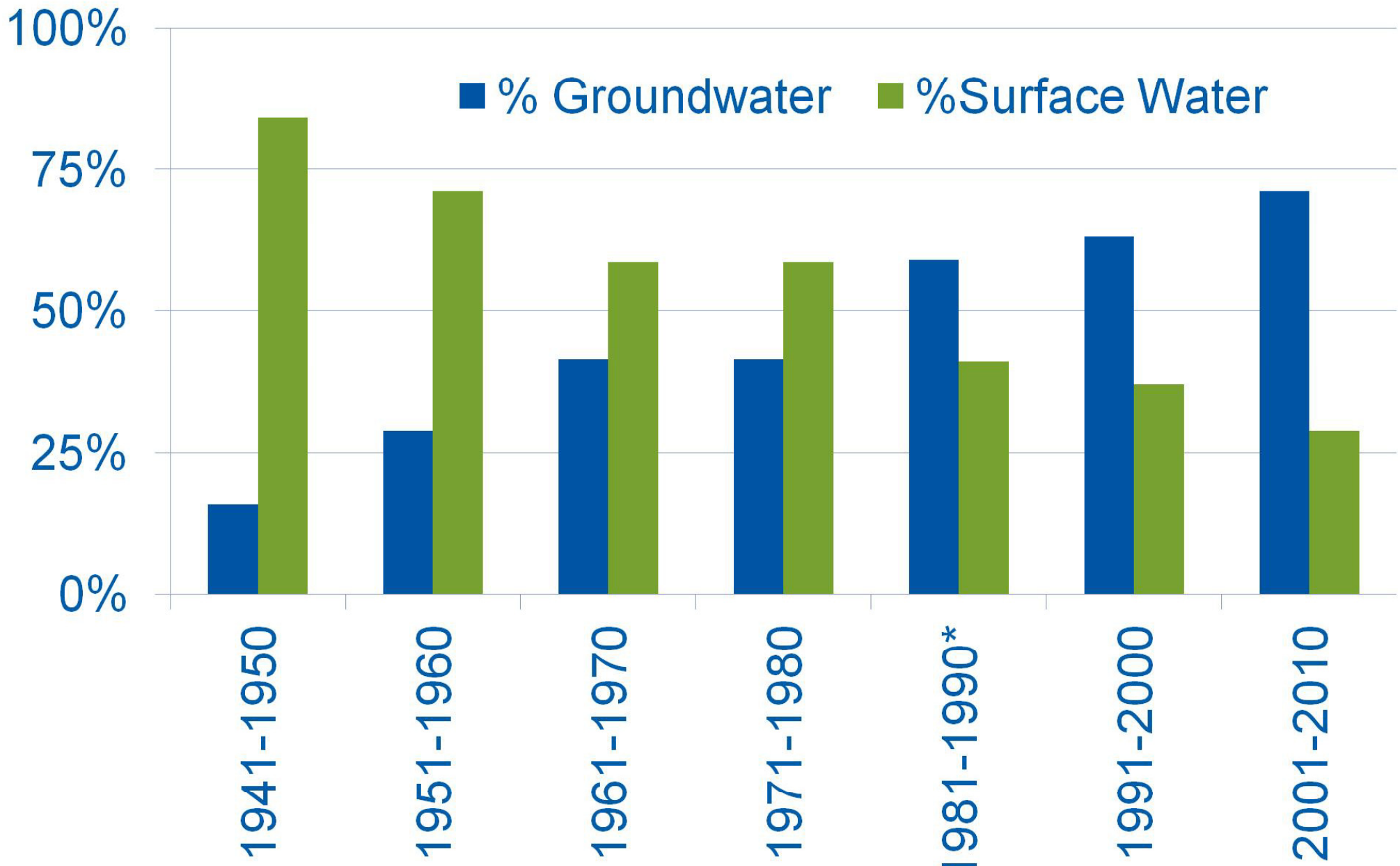
Groundwater: 70 %

- Municipal wells
- Private wells

Surface Water: 30 %

- St Paul and Minneapolis
- Intakes from Mississippi River

Municipal Water Use in Seven-County Twin Cities Metropolitan Area, Minnesota



Council Role in Water Supply Planning

2005 MN Stat., Sec. 473.1565

"Carry out planning activities addressing the water supply needs of the metropolitan area"

Twin Cities Metropolitan Area Master Water Supply Plan

"Ensure a sustainable water supply for current and future generations."

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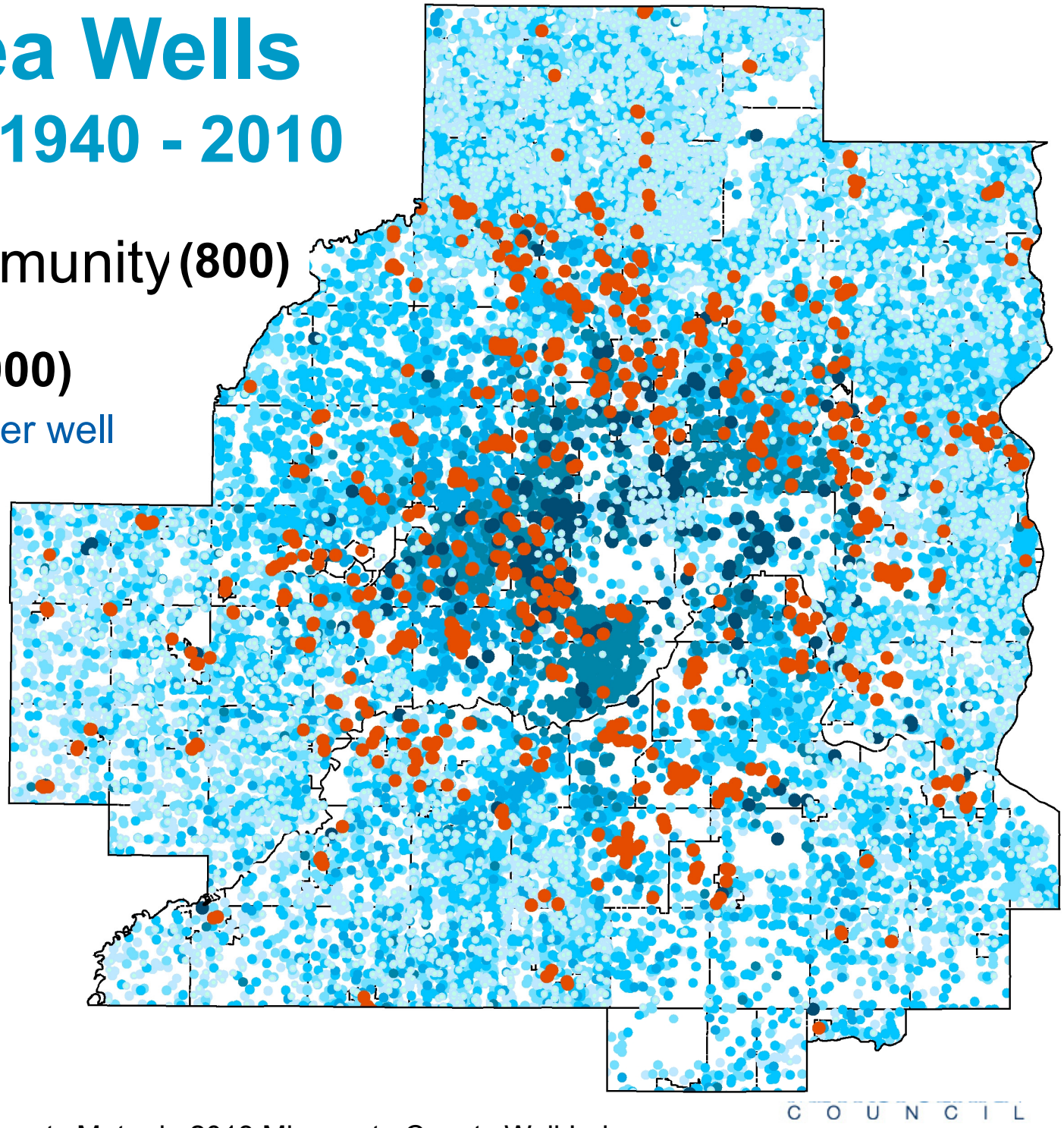
Metro Area Wells
Drilled from 1940 - 2010

- Public Community **(800)**
- Private **(60,000)**
  Darker blue = older well



1940-2010 data reported for 7-County Metro in 2013 Minnesota County Well Index

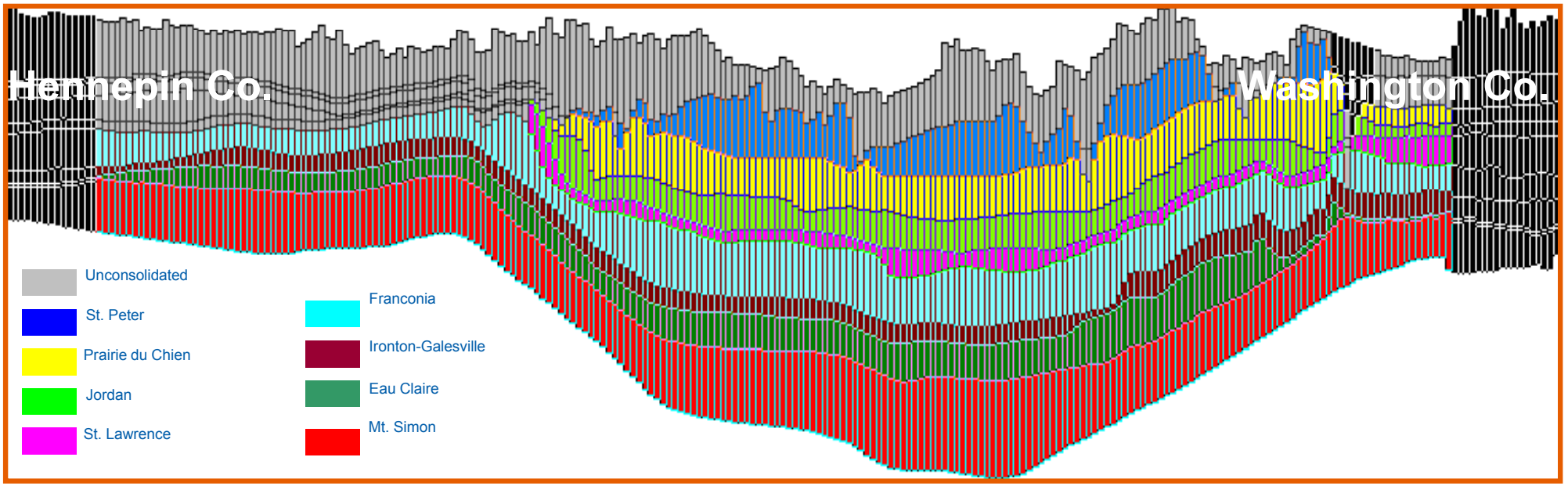
Regional Groundwater Model: Metro Model 2 → 3

Recharge

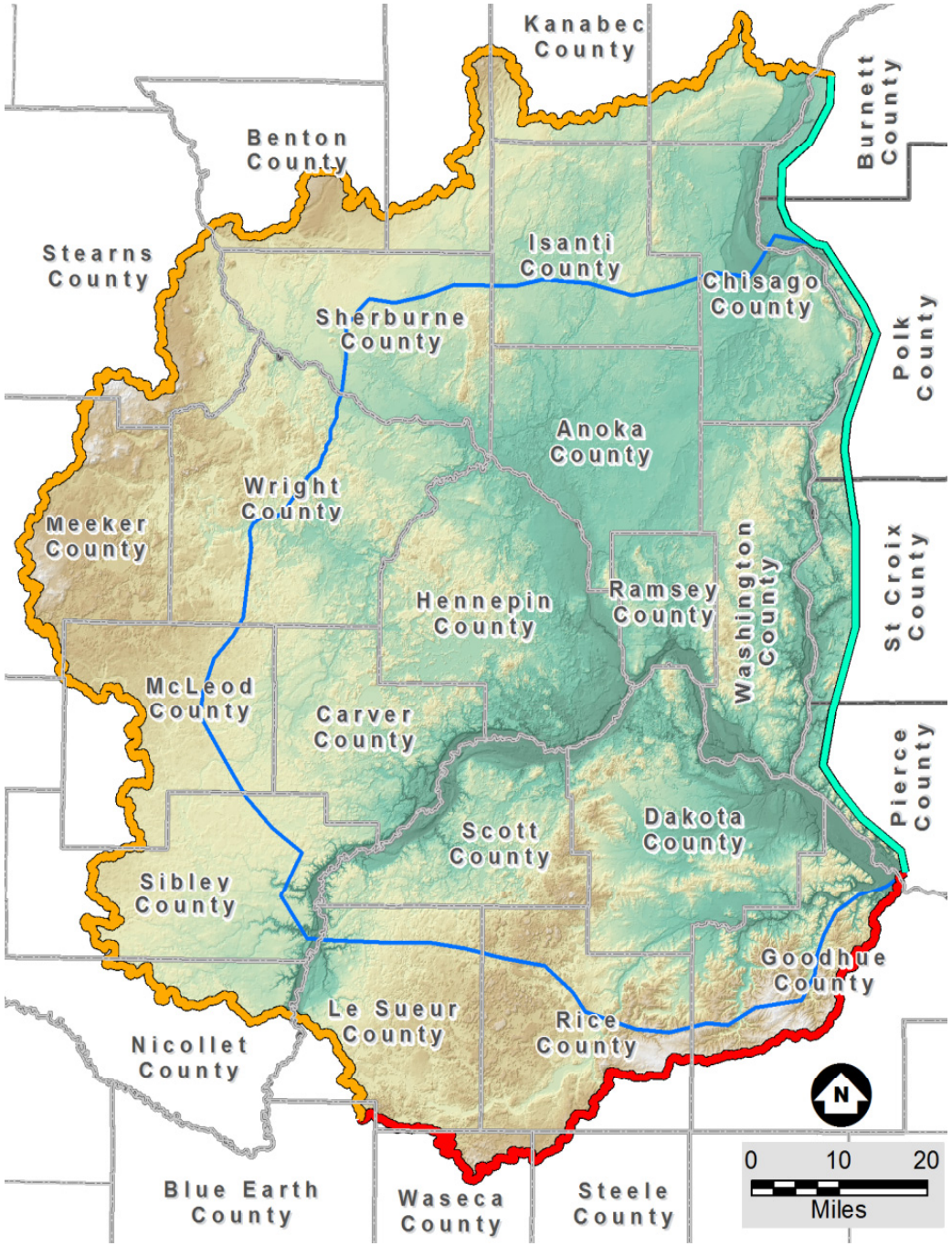
IN

Pumping & Baseflow

OUT



Expanded Metro Model Domain



Constant Head

General Head

No Flow

Metro Model 2 Boundary

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Met Council Project Objectives

1. Evaluate how infiltration varies through time across the eleven-county metropolitan area
2. Create an input for Metro Model 3
3. Be compatible with the statewide recharge project going on by USGS and MPCA

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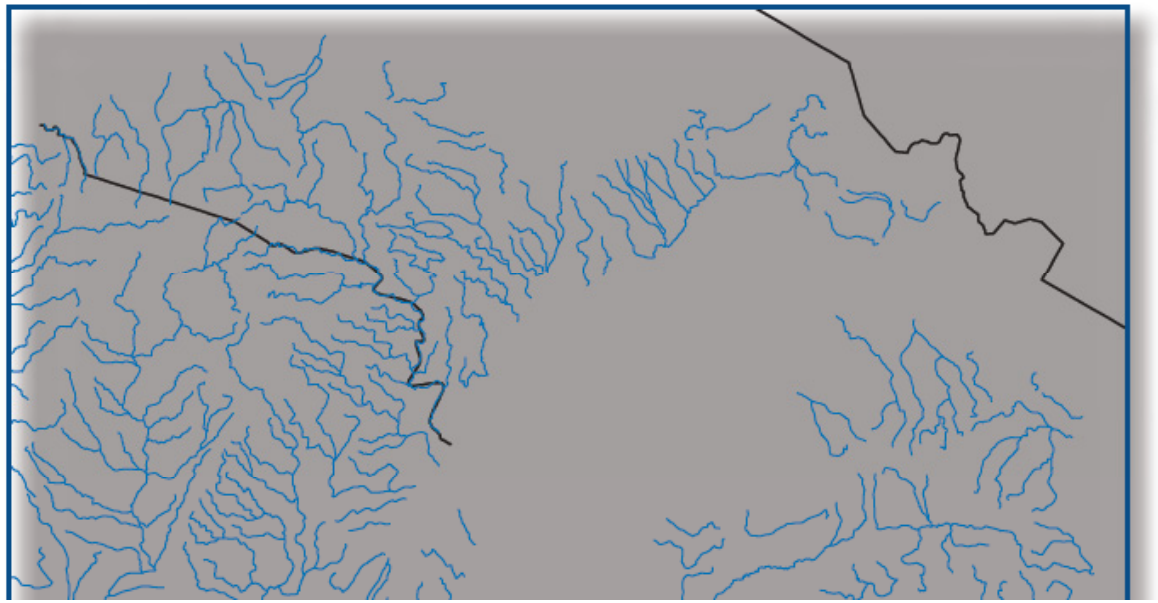
USGS
science for a changing world

Groundwater Resources Program

SWB—A Modified Thornthwaite-Mather Soil-Water-Balance Code for Estimating Groundwater Recharge



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References

- Westenbroek, S.M., Kelson, V.A., Dripps, W.R., Hunt, R.J., and Bradbury, K.R., 2010, SWB – A modified Thornthwaite-Mather Soil-Water-Balance code for estimating groundwater recharge: U.S. Geological Survey Techniques and Methods 6-A31, 60 p.

- Doherty, J., 2004, PEST – Model-independent parameter estimation user manual (5th ed.): Brisbane, Australia, Watermark Numerical Computing, [336] p.

- Healy, R.W. and Cook, P.G., 2002, Using groundwater levels to estimate recharge: Hydrogeology Journal, v. 10, p. 91-109.

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Project Team

- Metropolitan Council
- Barr Engineering Co.
- Supported by Clean Water Fund

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Approach

- **Collect data**
  - 11-county metro area (12,635 square miles)
  - Changing land use data
  - Spatially variable climate input from 1988-2011
- **Run model**
  - Monthly and annual results
  - 90m x 90m grid cells
- **Understand limitations**
  - Consistency with other methods
  - Parameter sensitivity and uncertainty assessment

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Our Approach

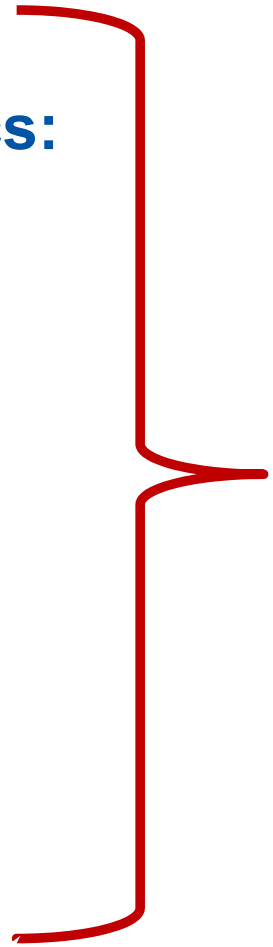
Climate Data

Landscape Characteristics:

- Land Use
- Hydrologic Soil Type
- Flow Direction
- Available Water Capacity

Soil and Land Use Look-Up Table

Soil-Water Retention Table

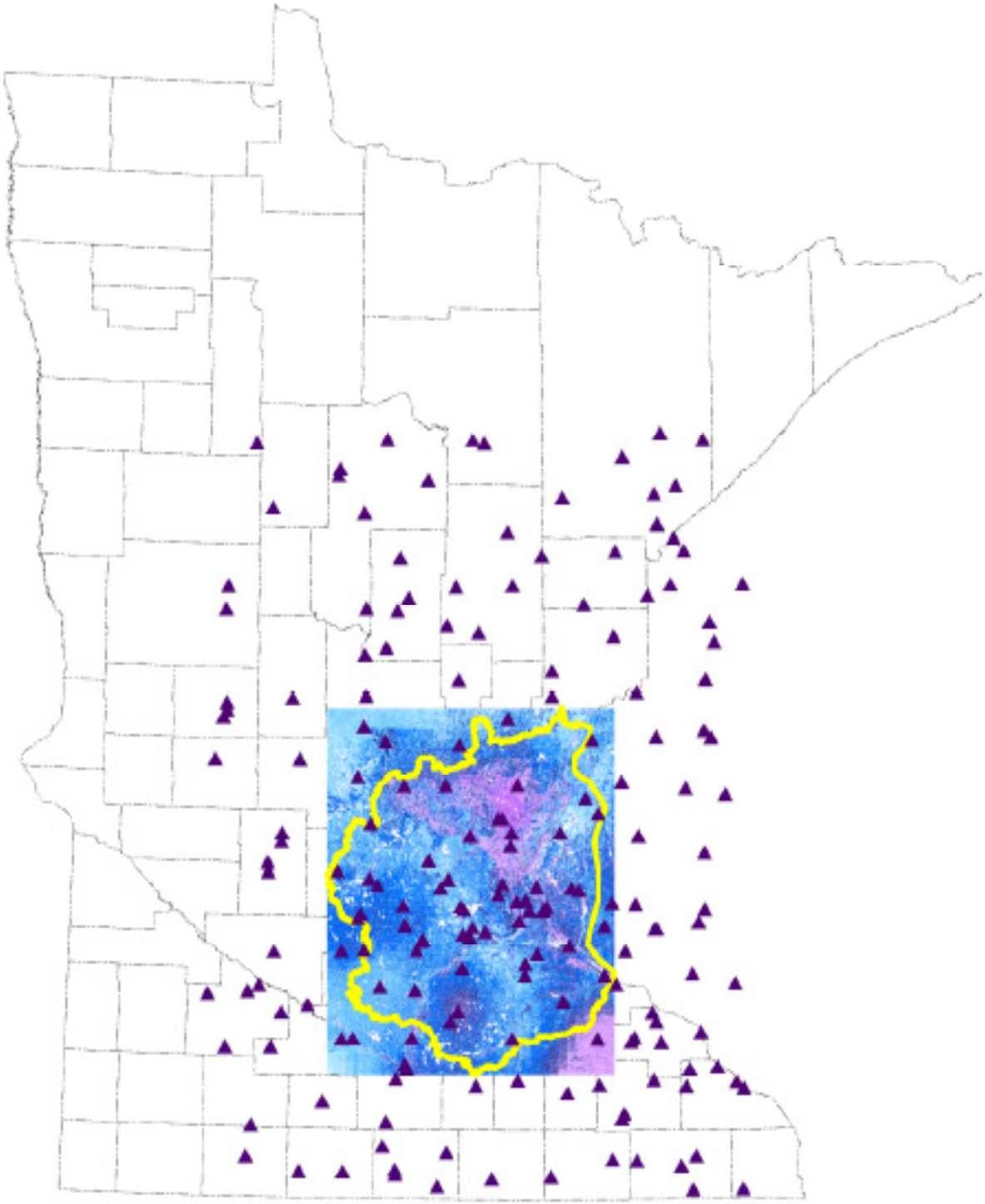


Soil Water Balance Code

Infiltration to Groundwater

Climate Input

- Global Historical Climatology Network
- 191 stations with data from 1988-2011
- Daily precipitation, min and max temperature
- Interpolated across model domain



Land Use

USGS

– *2006*

Met Council

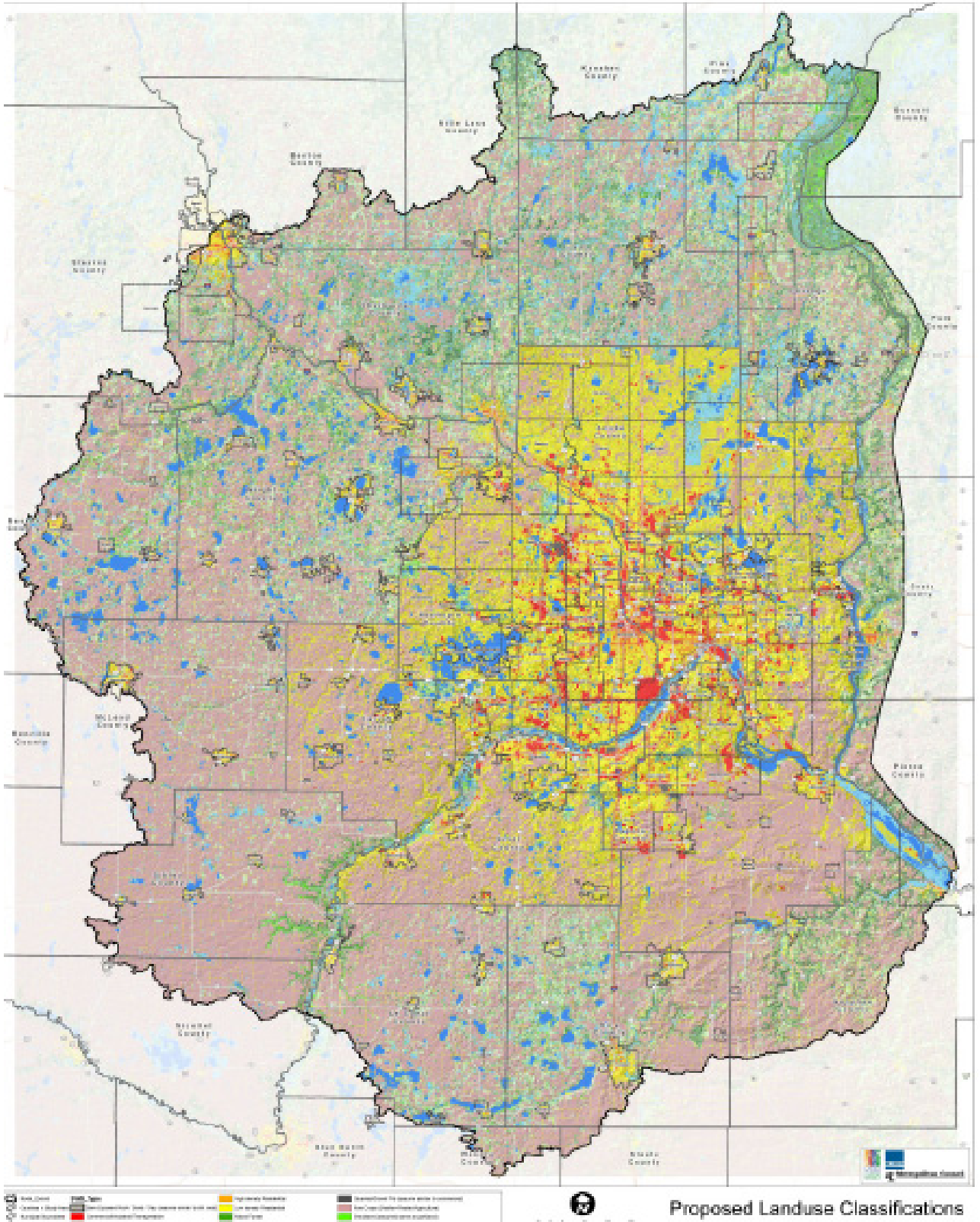
–*1990*

–*1997*

–*2000*

–*2005*

–*2010*



Changing Land Use

Met Council Land Use Data Year	Years of SWB Simulation Input
1990	1988-1993
1997	1994-1998
2000	1999-2002
2005	2003-2007
2010	2008-2011

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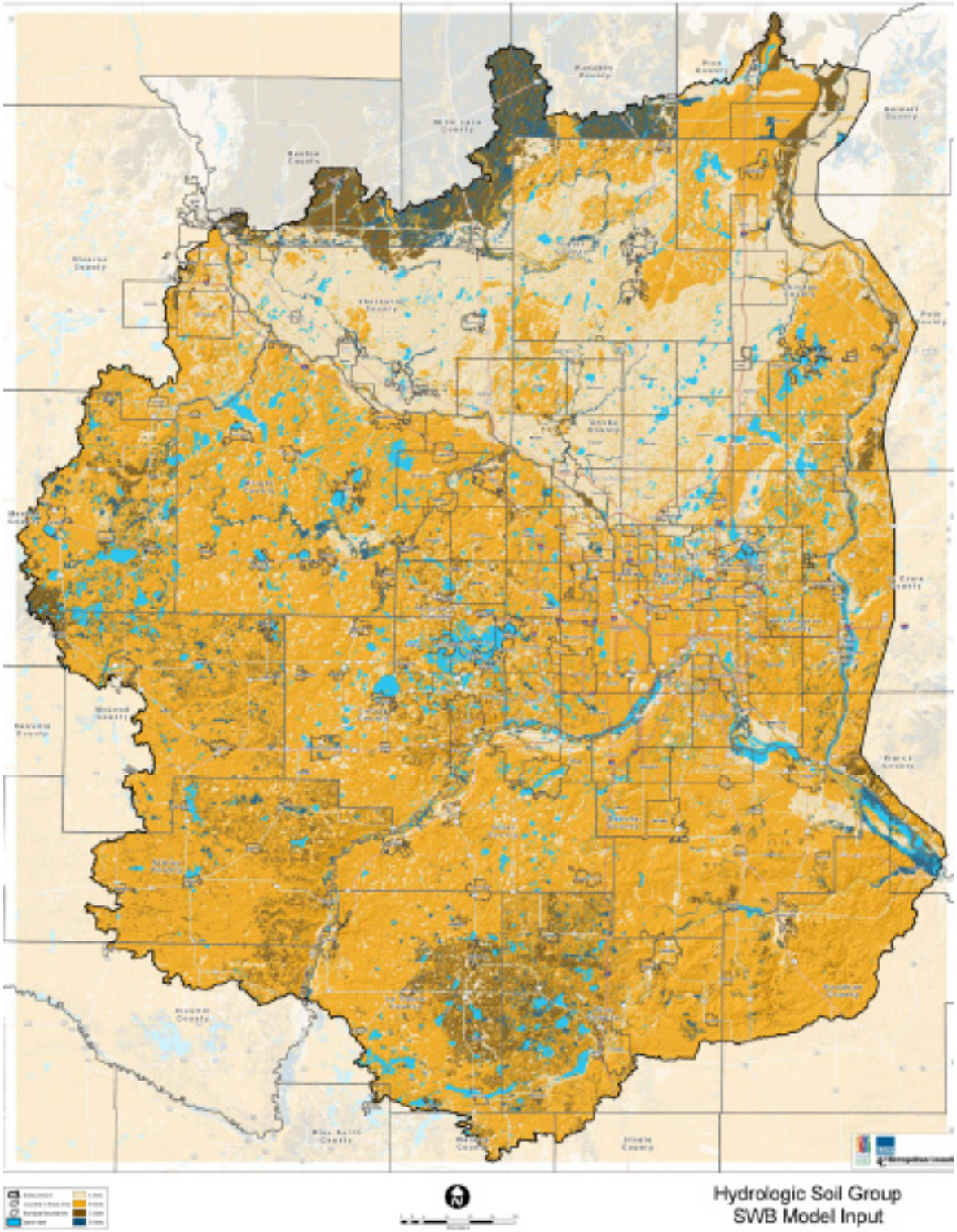
Soil

- USDA-NRCS Soil Survey Geographic Database
- Soil Hydrologic Class (A-D)



Soil & Land Use Look-Up Table

		CURVE NUMBER				MAX RECHARGE (in/day)				ROOT ZONE DEPTH (ft)			
code	SWB Description	A	B	C	D	A	B	C	D	A	B	C	D
11	Openwater	100	100	100	100	9	5.5	2.4	0.7	0	0	0	0
21	LowdenRes	54	70	80	85	9	5.5	2.4	0.7	1.67	2.08	1.33	0.83
22	HidenyRes	77	85	90	92	9	5.5	2.4	0.7	1.11	1.39	0.89	0.55
23	Comm/Ind/Tran	89	92	94	95	9	5.5	2.4	0.7	0.74	0.93	0.59	0.37
31	BareRock/Sand	89	92	94	95	9	5.5	2.4	0.7	0.5	0.5	0.5	0.5
32	Quarries/Pits	89	92	94	95	9	5.5	2.4	0.7	0.5	0.5	0.5	0.5
41	DeciduousForest	36	60	73	79	9	5.5	2.4	0.7	6.66	6.66	5.33	3.9
42	EvergreenForest	36	60	73	79	9	5.5	2.4	0.7	6.66	6.66	5.33	3.9
43	MixedForest	36	60	73	79	9	5.5	2.4	0.7	6.66	6.66	5.33	3.9
51	Shrubland	39	61	74	80	9	5.5	2.4	0.7	3.33	4.17	3.33	2.22
71	Grass/Herbs	39	62	74	85	9	5.5	2.4	0.7	3.33	4.17	3.33	2.22
81	Pastures	39	61	74	80	9	5.5	2.4	0.7	3.33	4.17	3.33	2.22
82	Row Crops	67	78	85	89	9	5.5	2.4	0.7	1.67	2.08	1.33	0.83
85	Urban/RecGrass	39	61	74	80	9	5.5	2.4	0.7	3.33	4.17	3.33	2.22
92	Wetlands	60	60	60	60	9	5.5	2.4	0.7	1.67	2.08	1.33	0.83

Available Water Capacity

- Natural Resource Conservation Service SSURGO data for all areas except a small portion of Pine County
- Natural Resources Conservation Service STATSCO data used in part of Pine County

Available soil water capacity * Root Zone Depth= Maximum Soil Water Capacity

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Flow Direction

- National Elevation Dataset – USGS topographic data
- Stream lines – USGS National Hydrography dataset

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1988-2011 Results

Average Infiltration

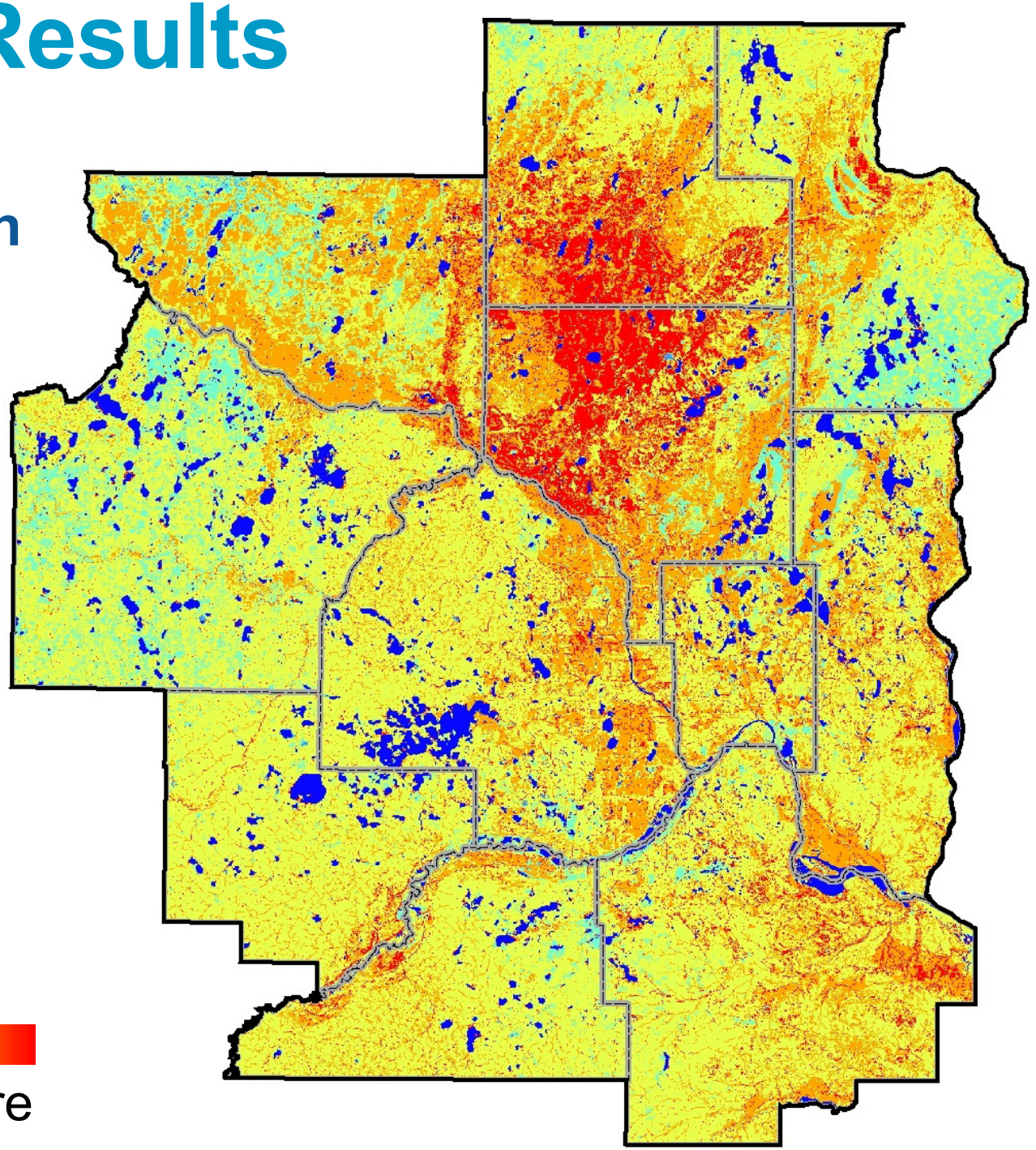
8.2 inches/year

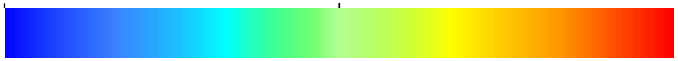
Maximum (2002)

13 inches/year

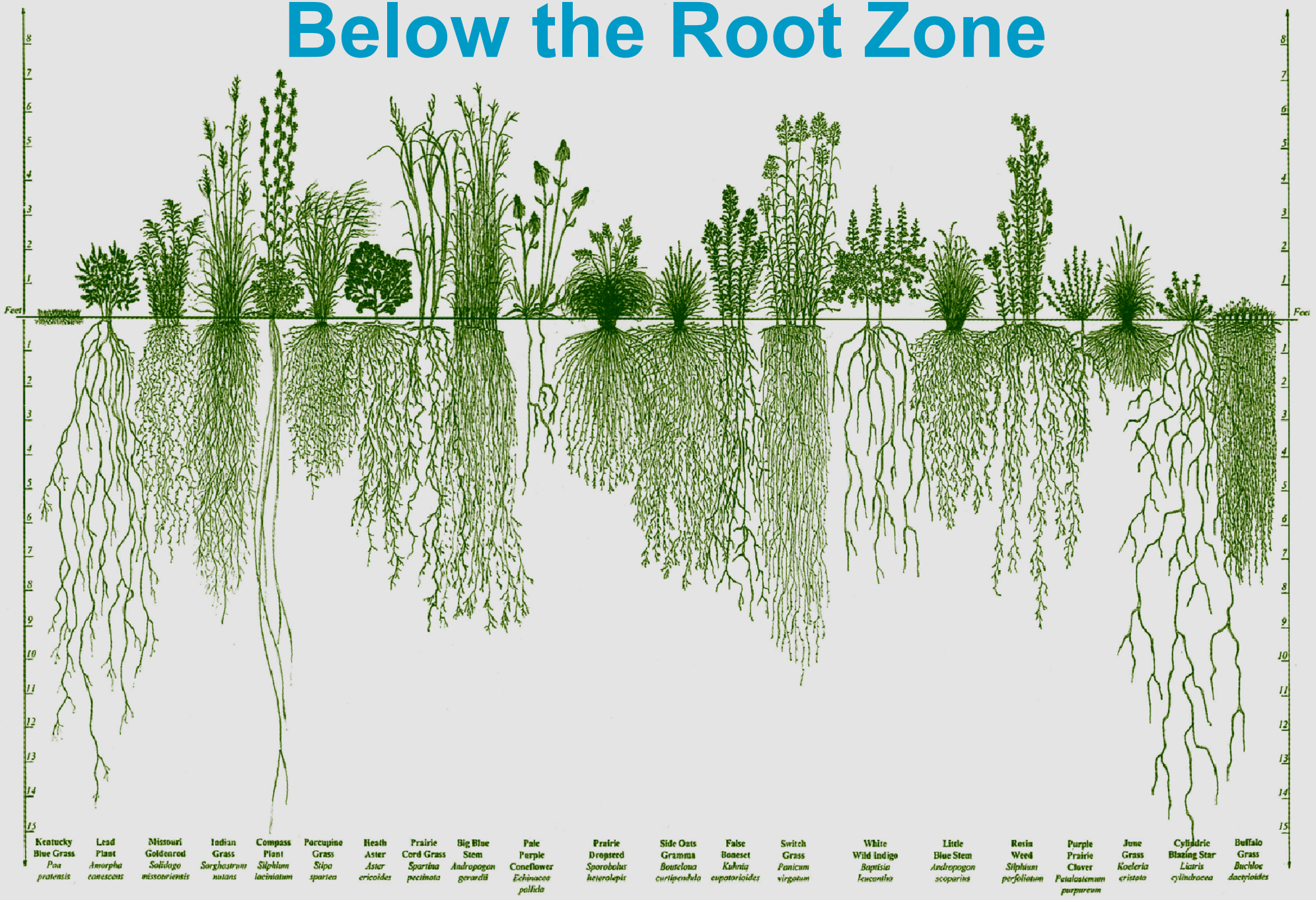
Minimum (2000)

2.7 inches/year



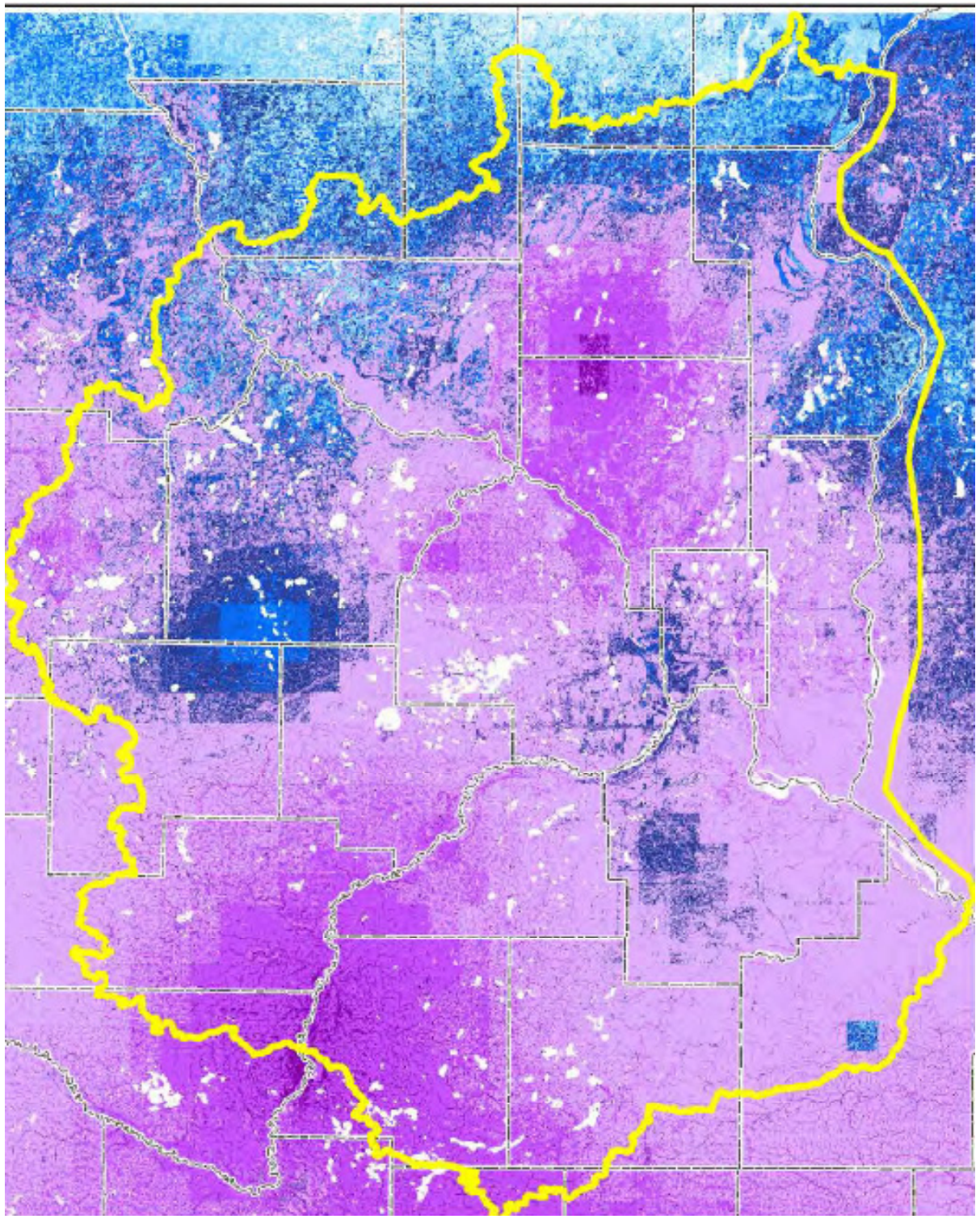


SWB Calculates Infiltration Below the Root Zone

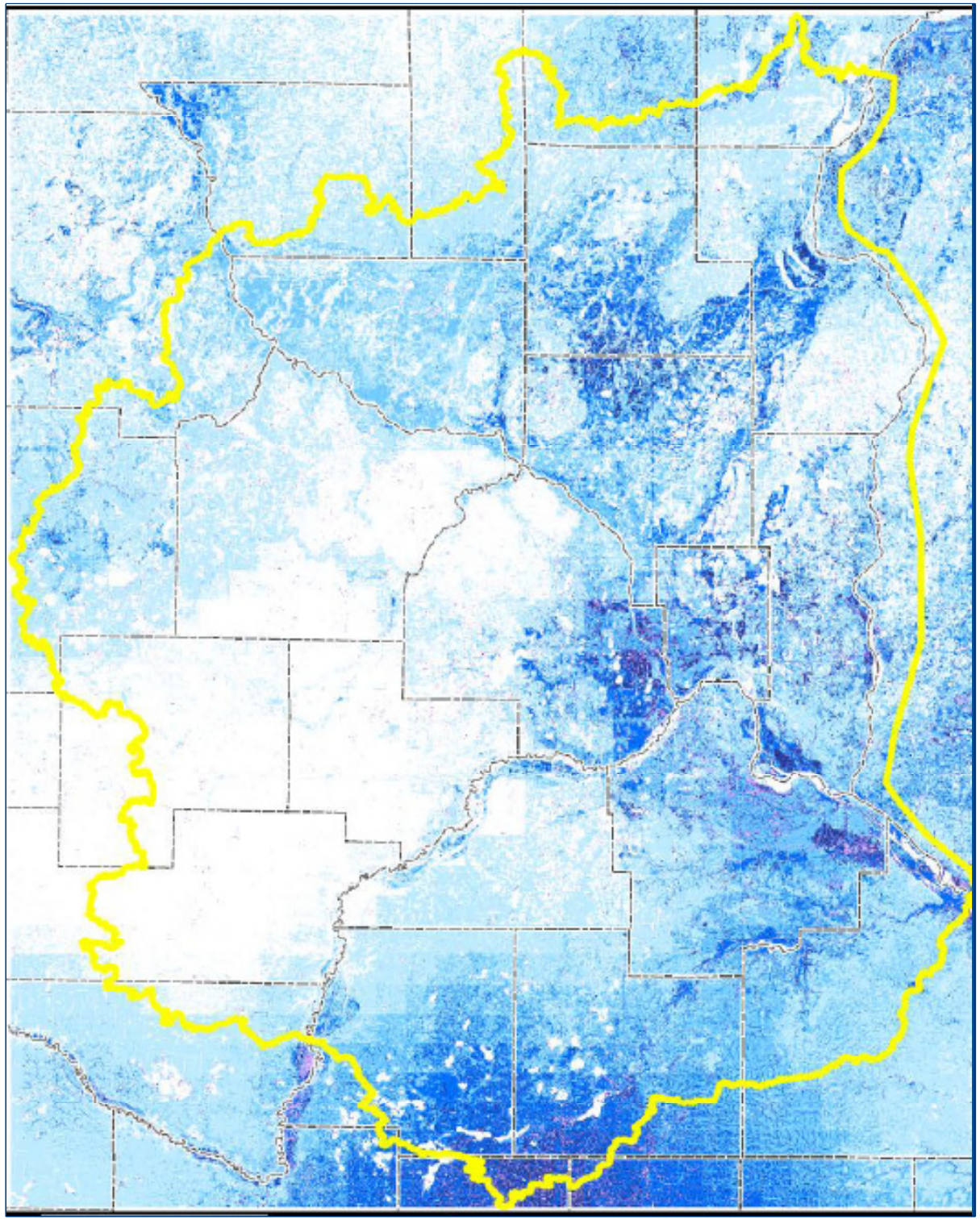


Drawn by Heidi Natura, Conservation Research Institute

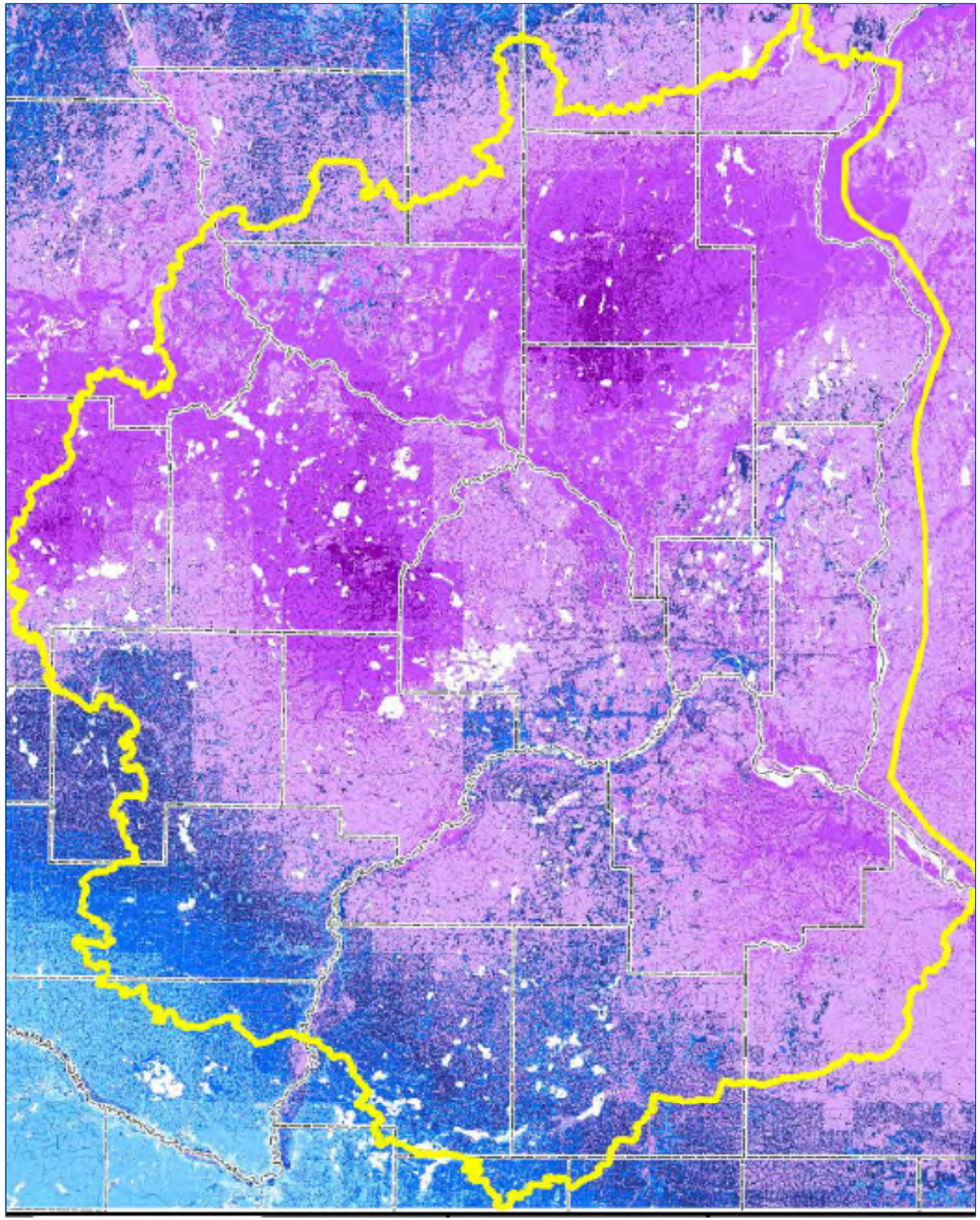
1993



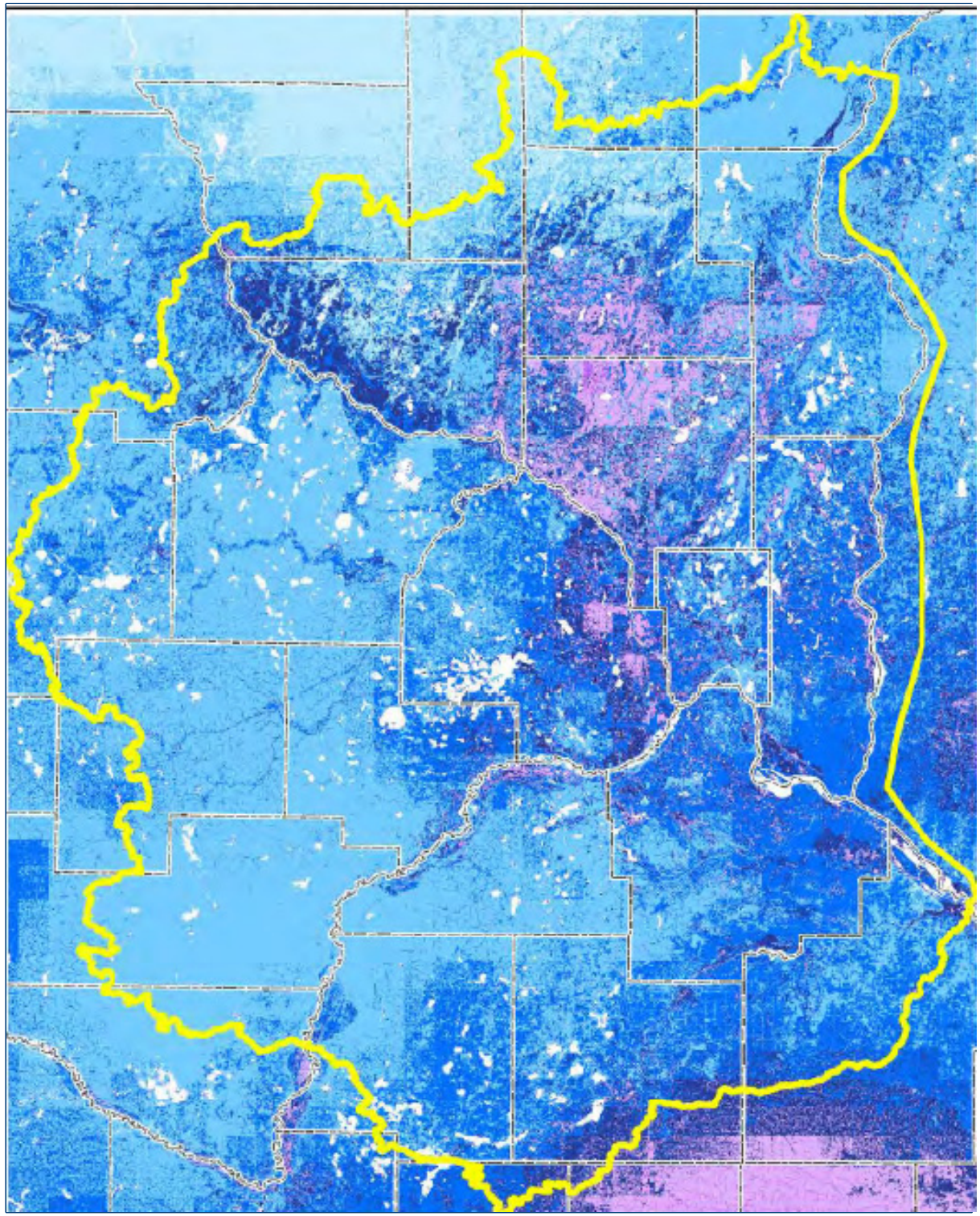
2000
Driest



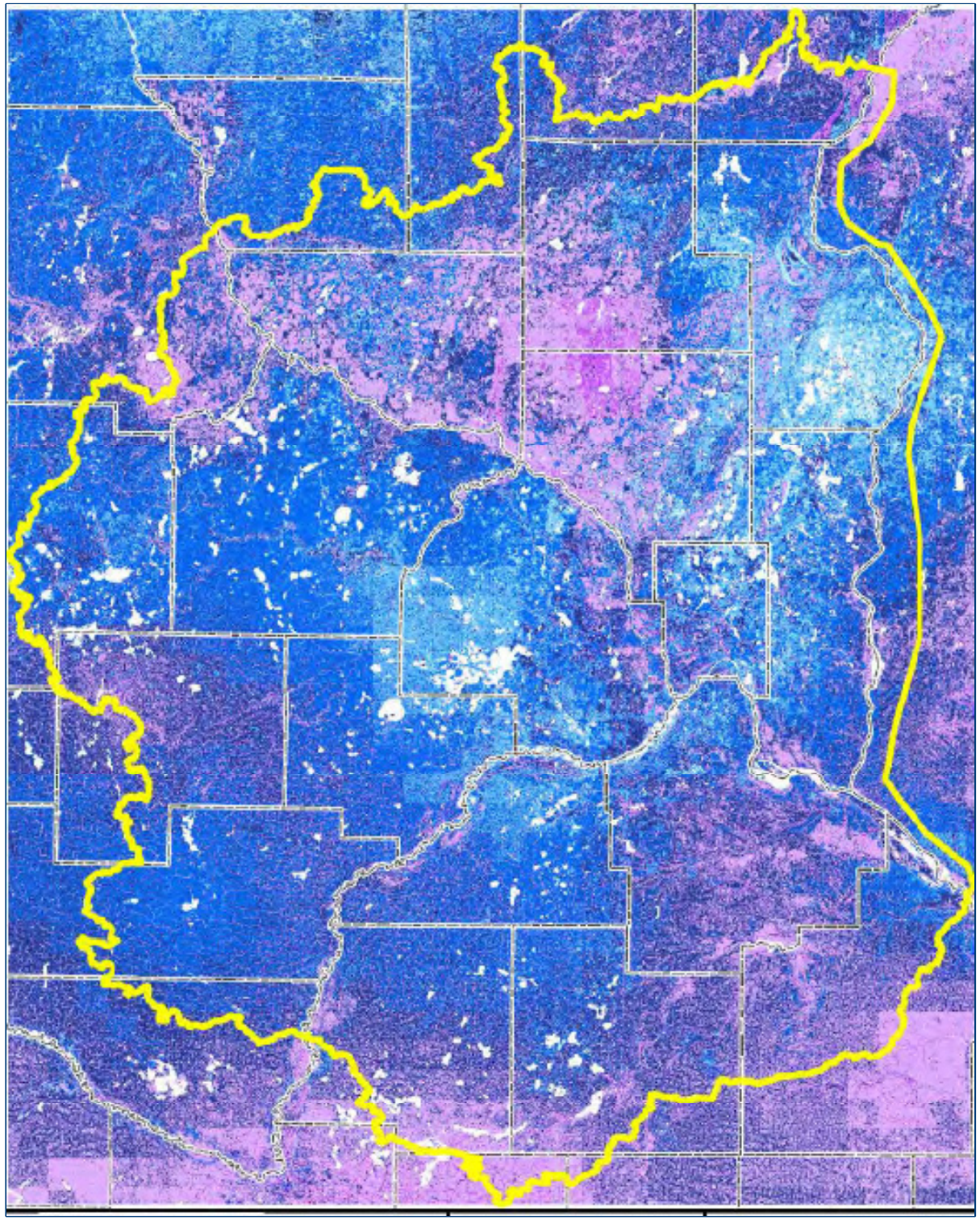
2002
Wettest



2006



2010



How do results compare to other work done to estimate recharge?

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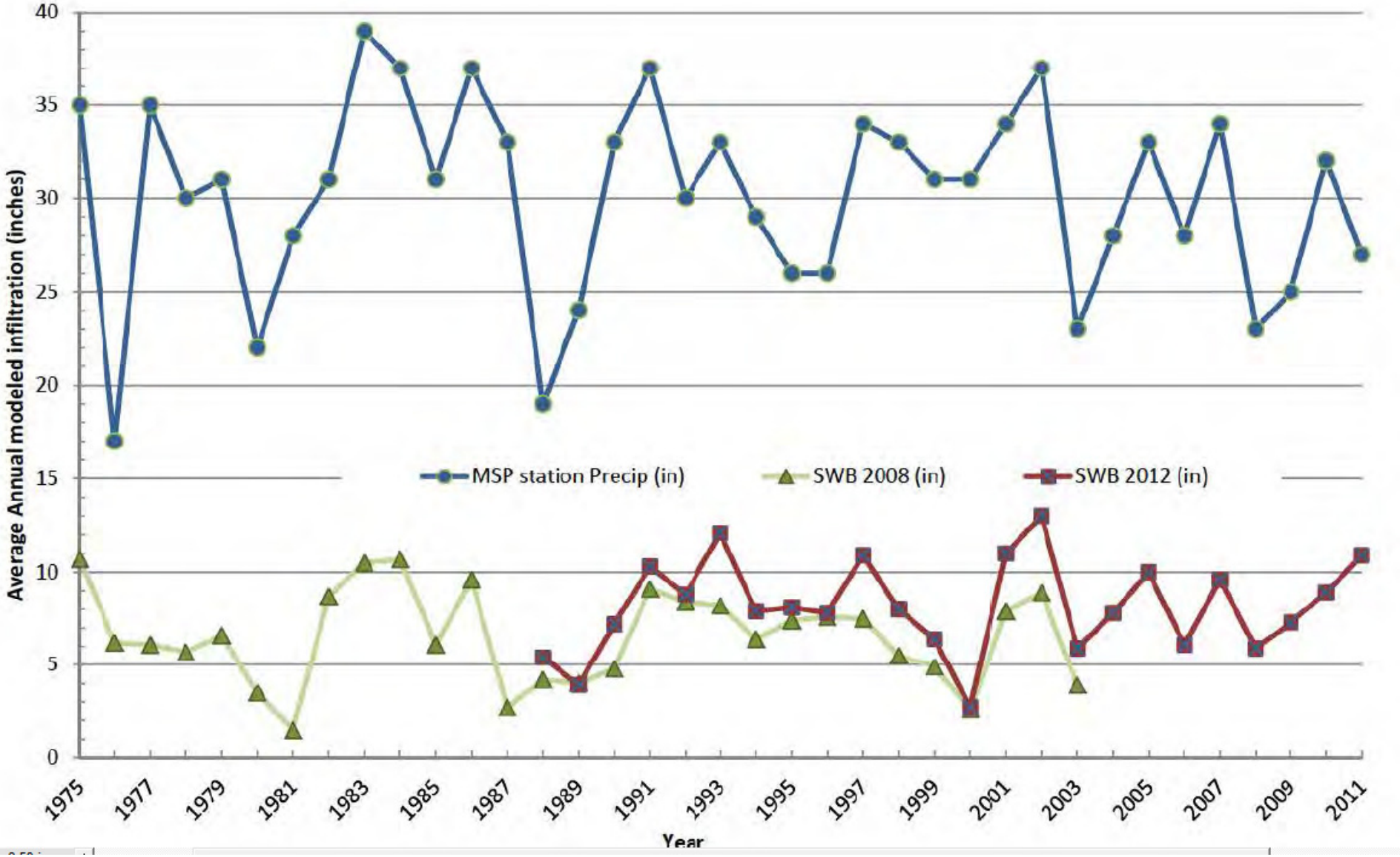
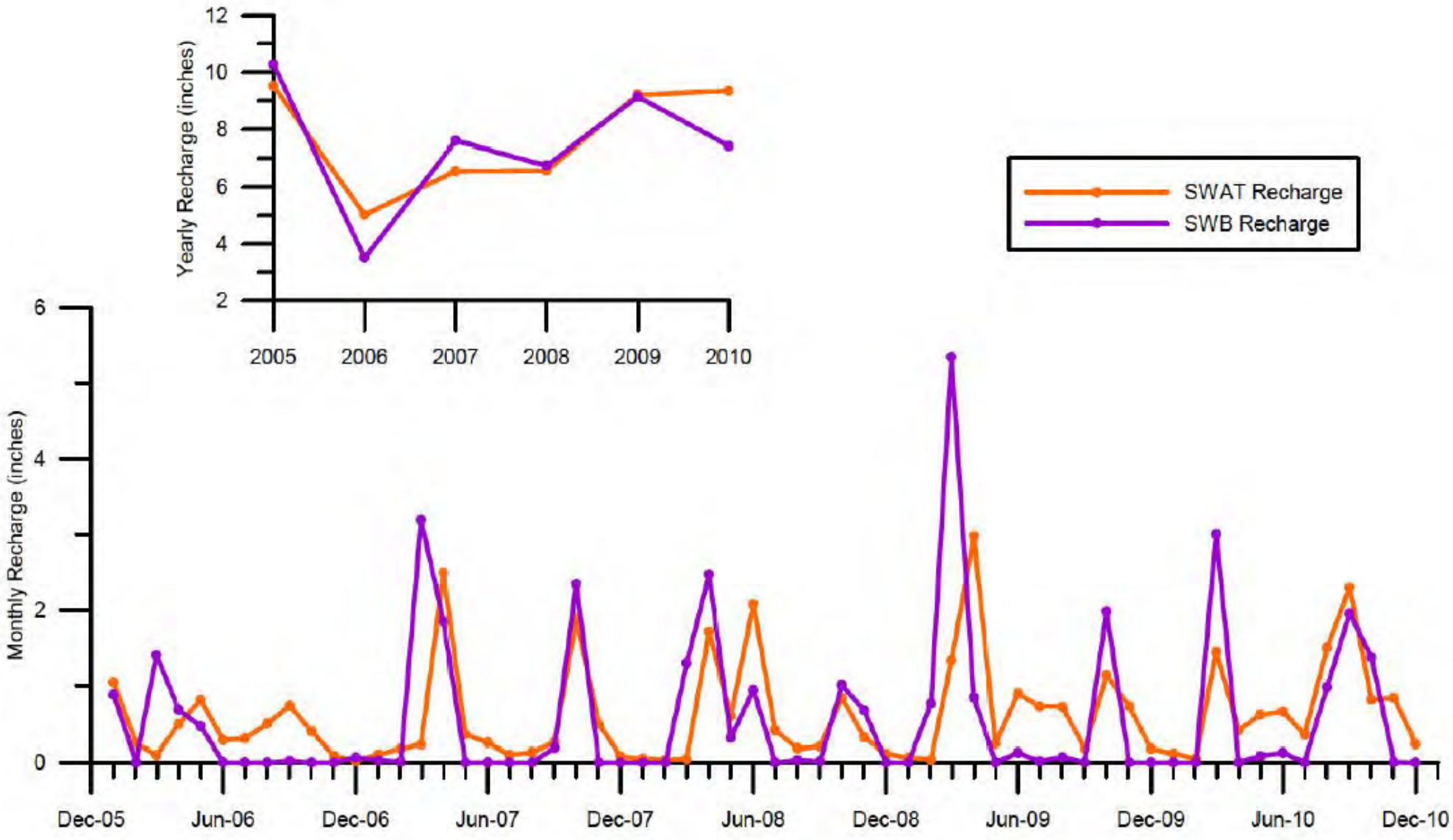
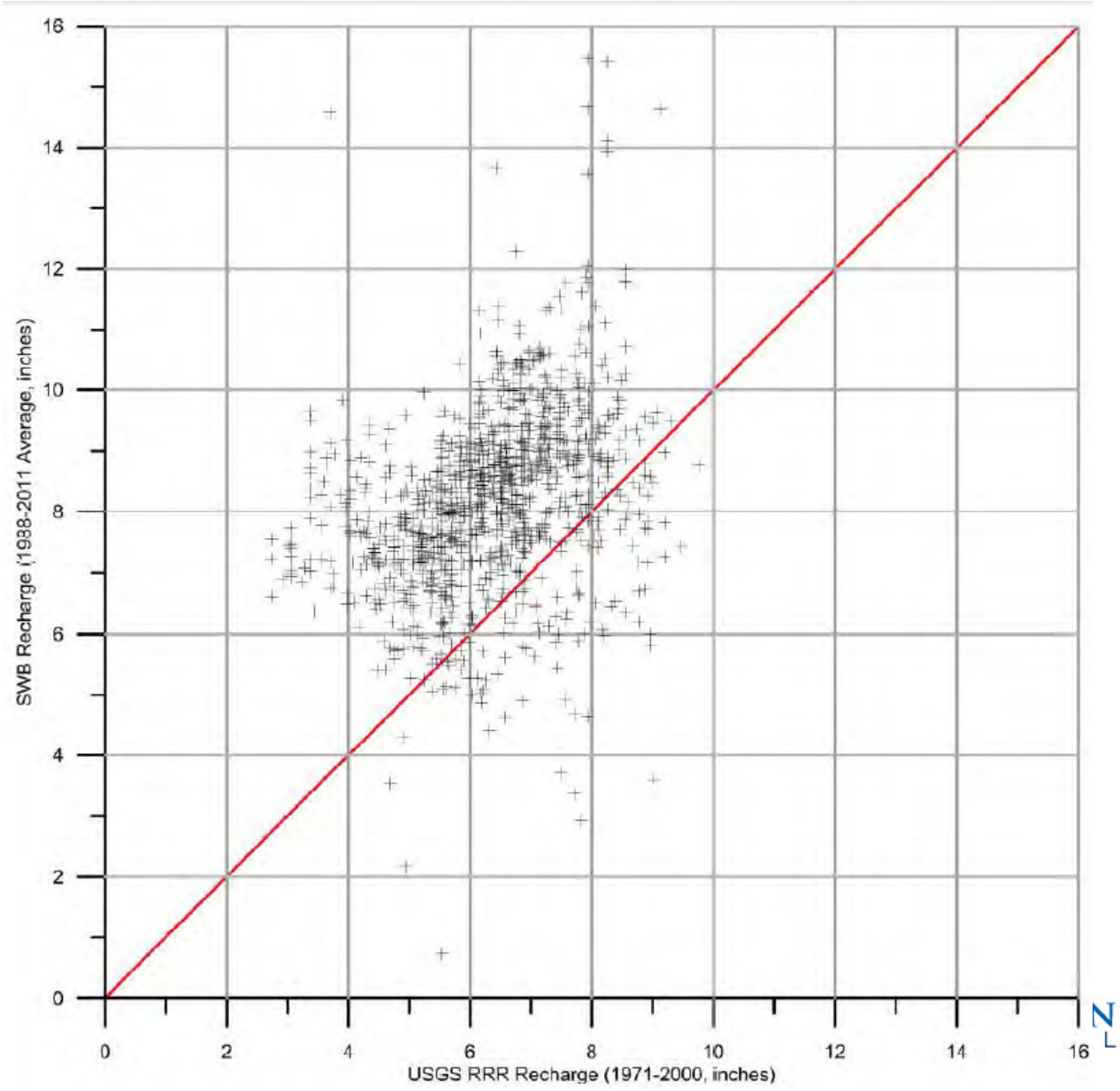
SWB 2008 vs. 2012

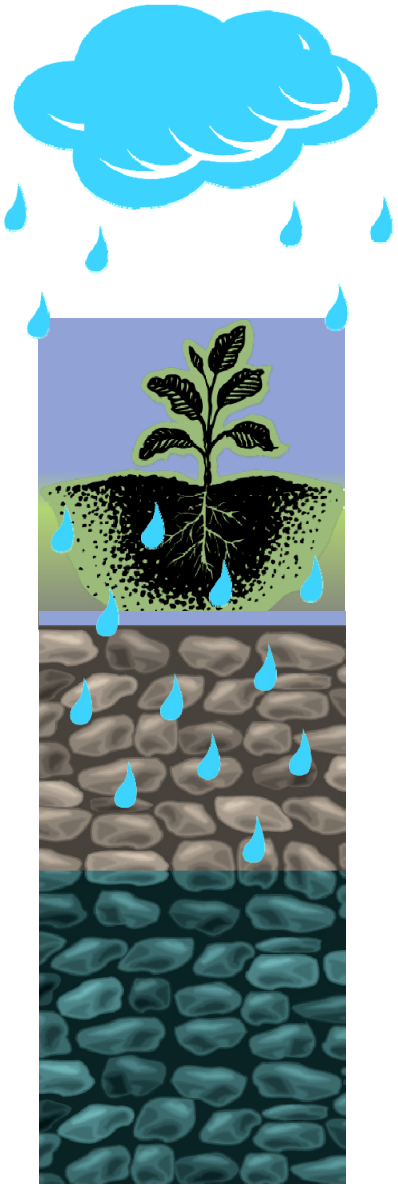


SWB (2012) vs. SWAT: Little Rock Creek



SWB (2012) vs. USGS Regional Regression Recharge Method





Precipitation

Infiltration

Shallow

Aquifer Recharge

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Sensitivity to Parameter Uncertainty

Varied parameters for different land use and soil hydrologic group combinations:

- Maximum Recharge
- Root zone depth
- Curve number

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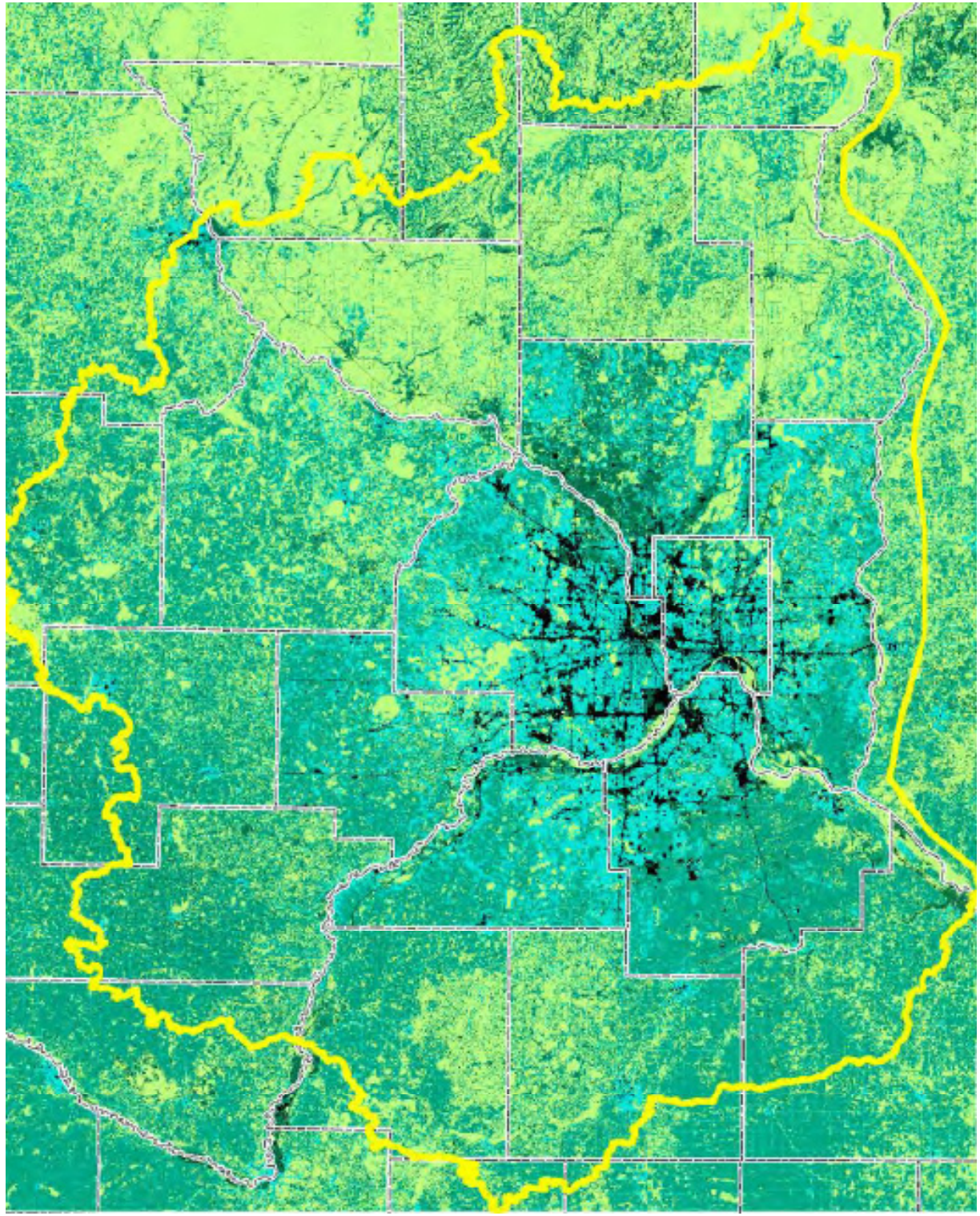
Estimated Uncertainty of SWB Model Infiltration



Challenges & Limitations

- Uncertainty must be acknowledged
- Not for “site” scale - properties used are generalized
- Not for daily estimates – monthly or annual instead

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Successes

- Improves understanding of climate and land use impacts on regional infiltration
- Useful input to regional groundwater model
- Simpler and less time-intensive to apply than a fully-coupled groundwater and surface water model

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