# Toward Better Simulation of Ecohydrology: Forecasting Pumping Effects to Fens

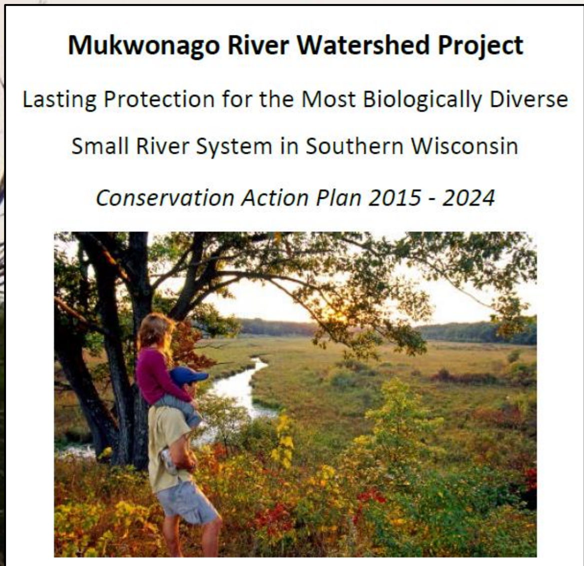
USGS
Randy Hunt
Daniel Feinstein

UW Extension
Wisconsin Geological and Natural History Survey
Dave Hart

The Nature Conservancy
Protecting nature. Preserving life.
Sarah Gatzke

Photo from: www.nature.org

Photo from: dnr.wi.gov


**Mukwonago River Watershed Project**

Lasting Protection for the Most Biologically Diverse Small River System in Southern Wisconsin

*Conservation Action Plan 2015 - 2024*

"Reduce future land-use and water-use impacts on the aquatic resources of the Mukwonago River Watershed" with the objective to strike a sustainable balance between the water needs of people and natural systems in the watershed, using science-based solutions".

- Model the Mukwonago watershed's groundwater
- Develop a decision support tool
- Explore future and cumulative impacts of groundwater withdrawals and policies on groundwater-dependent systems.

# Need a quantitative tool suitable for decision-support

## Forecasting effects on fens from:

1. **Groundwater pumping from high capacity wells**

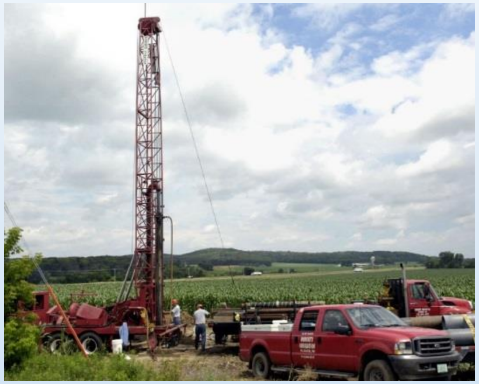
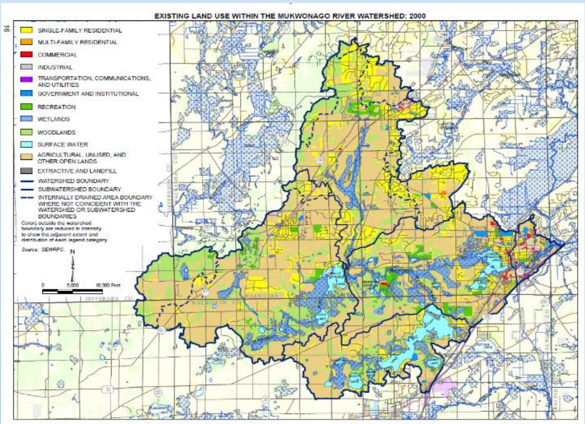
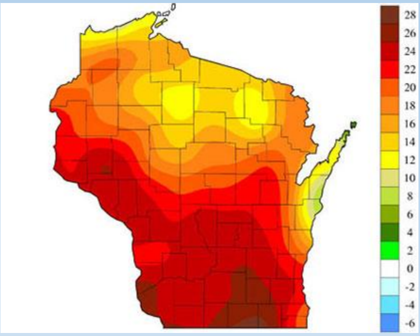


Photo from: journaltimes.com

2. **Land use change and changes to groundwater recharge**



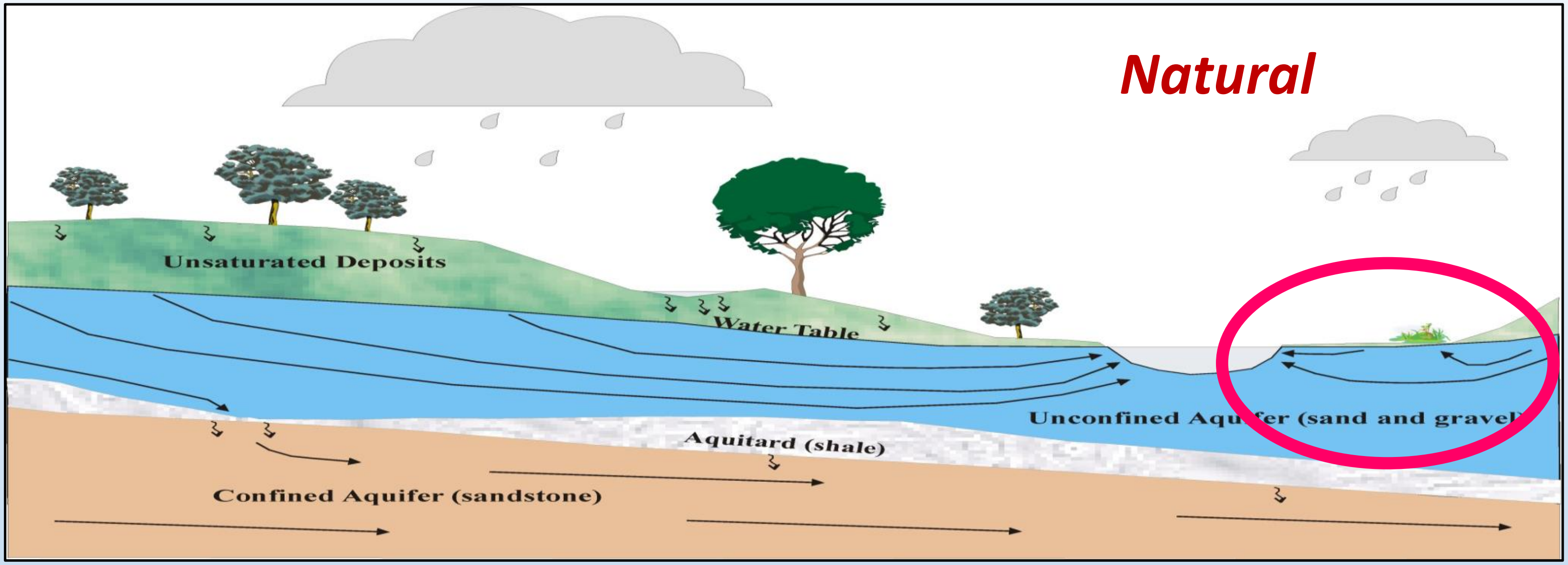

3. **Climate change**

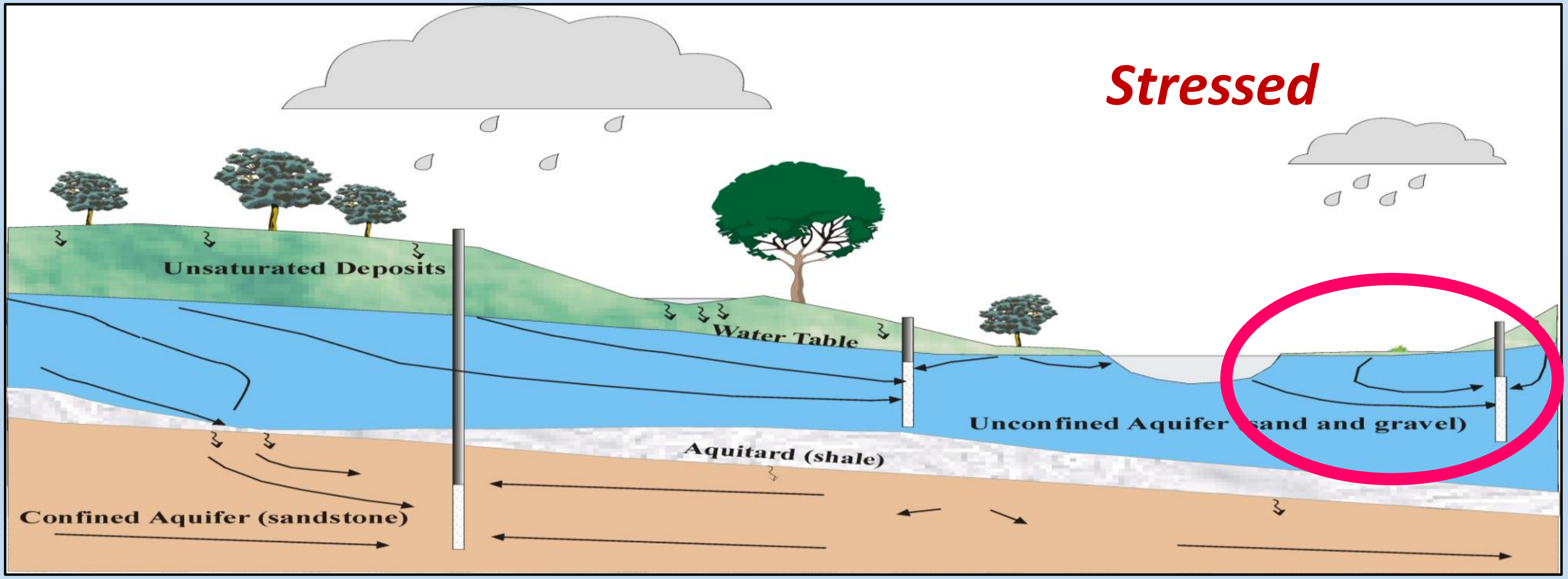



**Projected Change in the Frequency of 90°F Days Per Year from 1980 to 2055**

WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

# Components of Groundwater Flow System needed:



# Decision-support: Jurisdictional Wetlands

**Wetlands are defined using the vegetation, soils, and hydrology, where the last is often the most contentious. Why?**

**Hydrophytes and hydric soils integrate time, so their presence = meeting the wetland criteria**

**Hydrology is a snapshot measurement, does not integrate time**

**What to do: Simplify during rule making**

***Wetland hydrology = "sufficient root zone saturation" to cause establishment of hydrophytes and hydric soils***

# Decision-support: Jurisdictional Wetlands (cont.)

## Simplifying further, "*sufficient root zone saturation*" is where:

**root zone saturation** = water table within 12" of land surface (recognizing the effect of the capillary fringe)

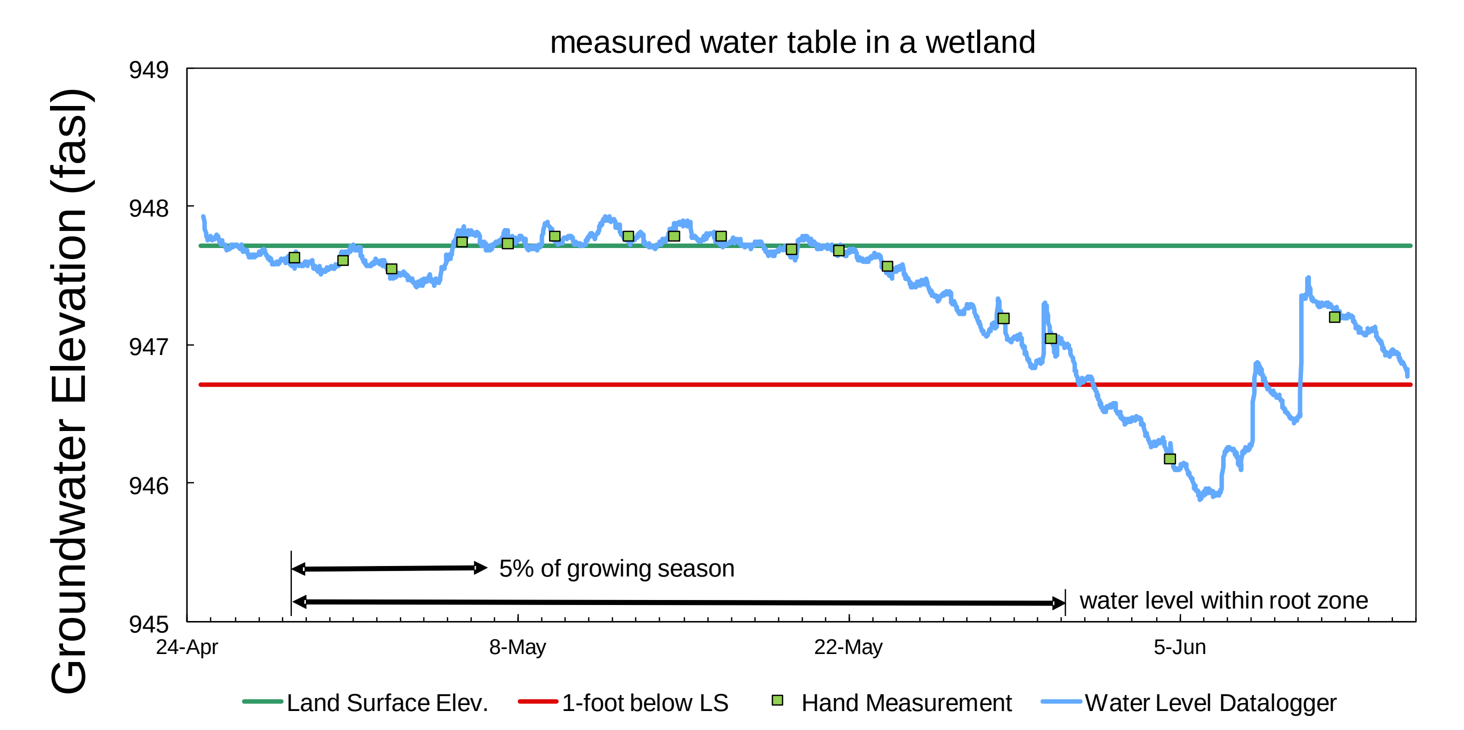
**sufficient** = continually during at least 5% of the growing season for most years

# Decision-support: Jurisdictional Wetlands (cont.)

## Simplifying further, "*sufficient root zone saturation*" is where:

**root zone saturation** = water table within 12" of land surface (recognizing the effect of the capillary fringe)

**sufficient** = continually during at least 5% of the growing season for most years

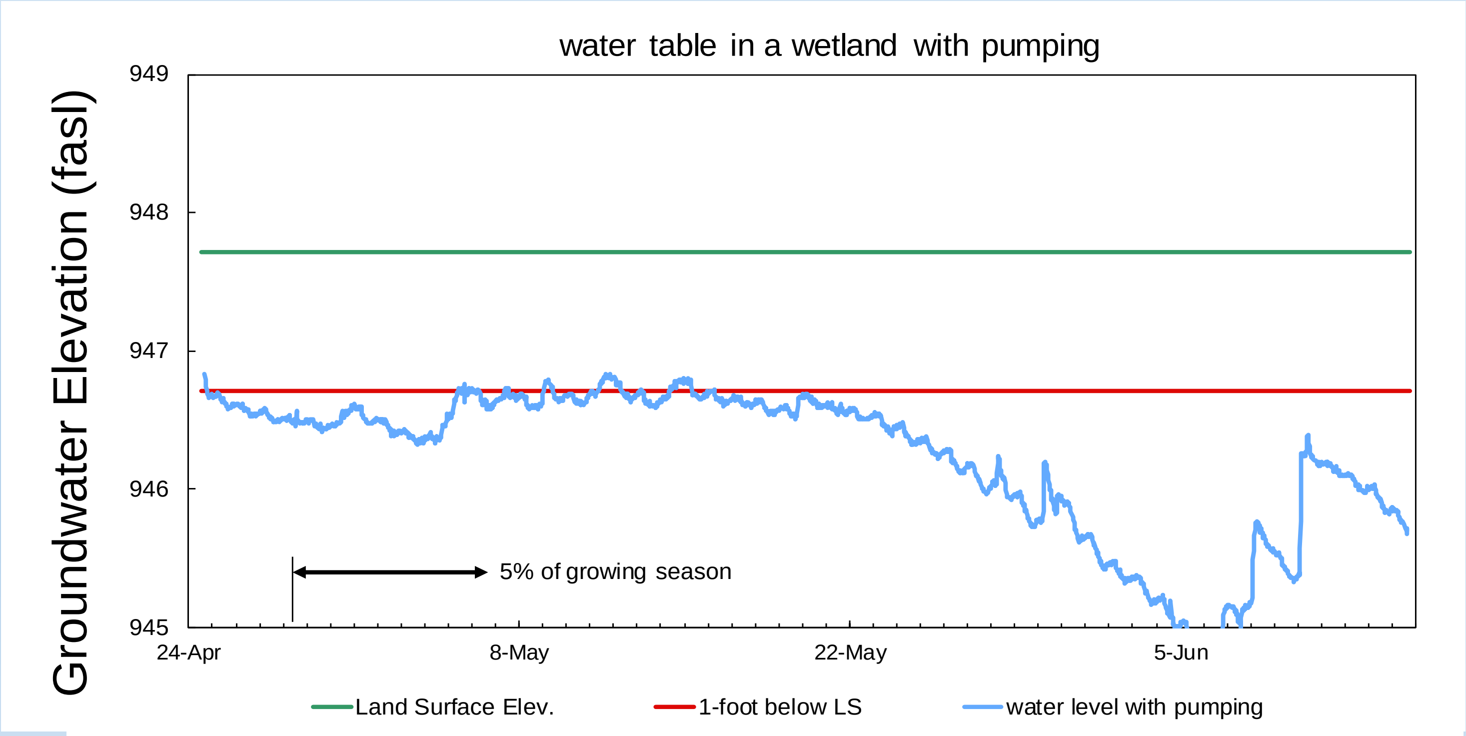


# Decision-support: Jurisdictional Wetlands (cont.)

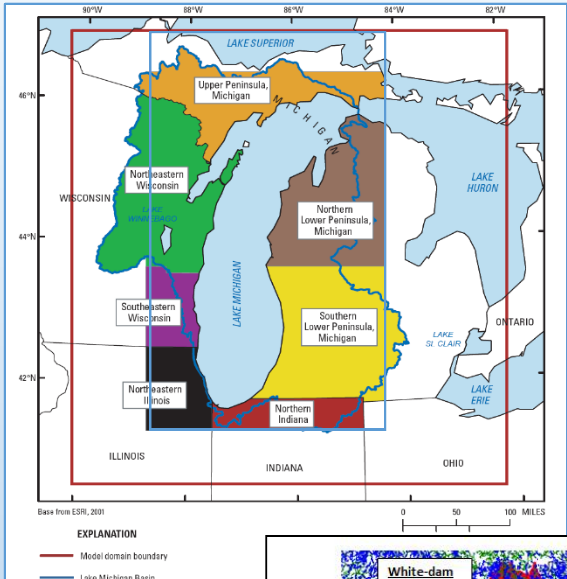
## Simplifying further, "*sufficient root zone saturation*" is where:

**root zone saturation** = water table within 12" of land surface (recognizing the effect of the capillary fringe)

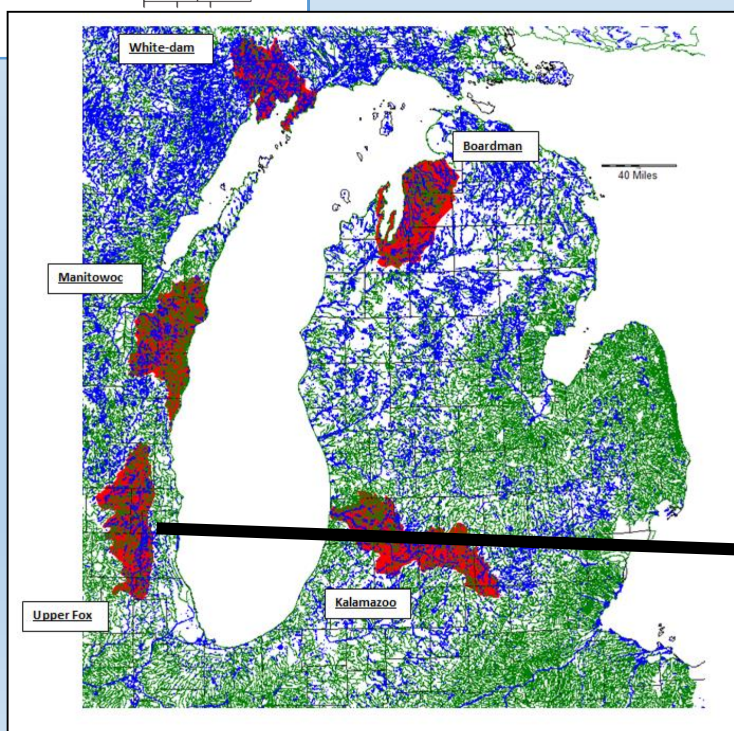
**sufficient** = continually during at least 5% of the growing season for most years



# Why MODFLOW? Leveraging existing regional models

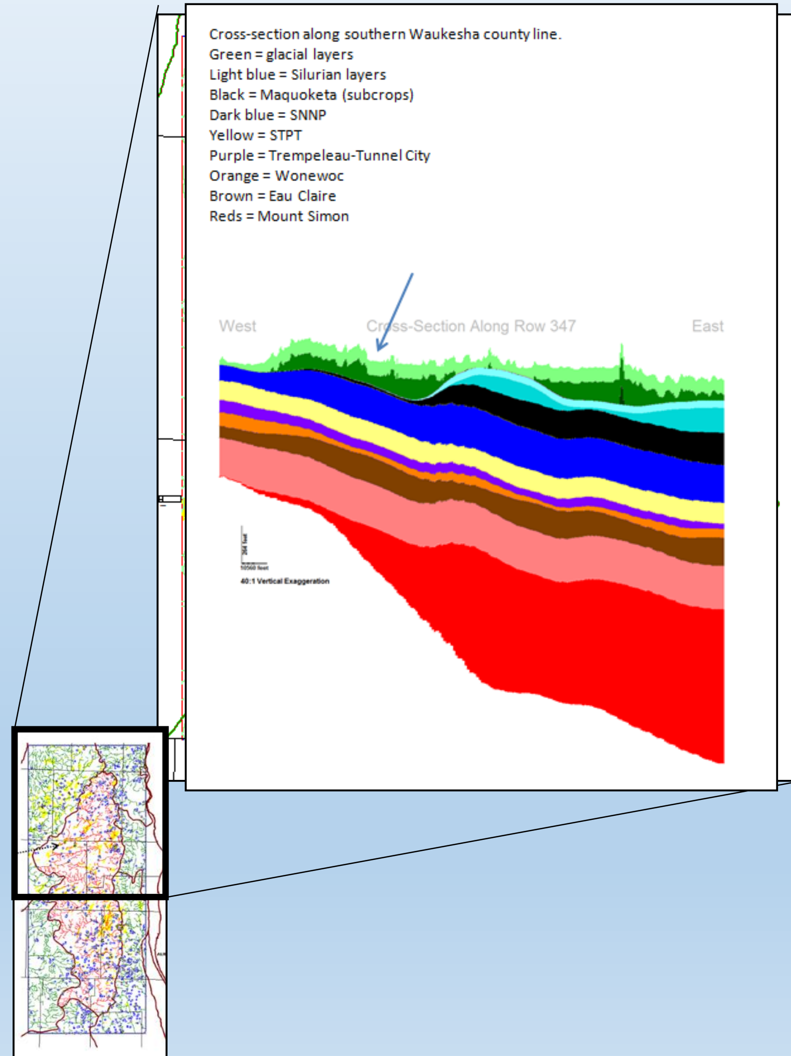



**Lake Michigan Basin Parent Model**




**Inset Child Model**

**Inset Grandchild Model**



# Why MODFLOW? Unsaturated Zone Flow (UZF) Package can simulate distribution of fen water flows

- Lateral gw flow in and out of water table cell
- Upward gw flow to water table cell

- Infiltration through root zone
- Recharge across water table
- Rejected recharge when water table at land surface
- Route overland runoff to streams and lakes

- Seepage across fen water table to land surface

ground water

Importance of Unsaturated Zone Flow for Simulating Recharge in a Humid Climate

by Randall J. Hunt[1], David E. Prudic[2], John F. Walker[3], and Mary P. Anderson[4]

Abstract

Transient recharge to the water table is often not well understood or quantified. Two approaches for simulating transient recharge in a ground water flow model were investigated using the Trout Lake watershed in north-central Wisconsin: (1) a traditional approach of adding recharge directly to the water table and (2) routing the same volume of water through an unsaturated zone column to the water table. Areas with thin (less than 1 m) unsaturated zones showed little difference in timing of recharge between the two approaches; when water was routed through the unsaturated zone, however, less recharge was delivered to the water table and more discharge occurred to the surface because recharge direction and magnitude changed when the water table rose to the land surface. Areas with a thick (15 to 26 m) unsaturated zone were characterized by multimonth lags between infiltration and recharge, and, in some cases, wetting fronts from precipitation events during the fall overtook and mixed with infiltration from the previous spring snowmelt. Thus, in thicker unsaturated zones, the volume of water infiltrated was properly simulated using the traditional approach, but the timing was different from simulations that included unsaturated zone flow. Routing of rejected recharge and ground water discharge at land surface to surface water features also provided a better simulation of the observed flow regime in a stream at the basin outlet.

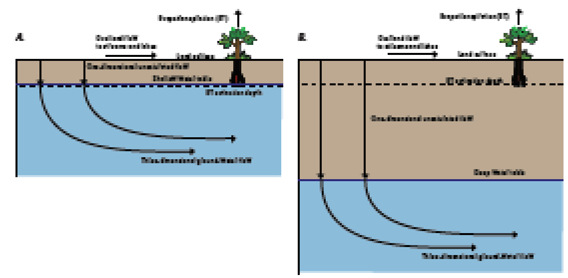
(Hunt et al. 2008)

USGS

A Product of the Ground-Water Resources Program

Documentation of the Unsaturated-Zone Flow (UZF1) Package for Modeling Unsaturated Flow Between the Land Surface and the Water Table with MODFLOW-2005

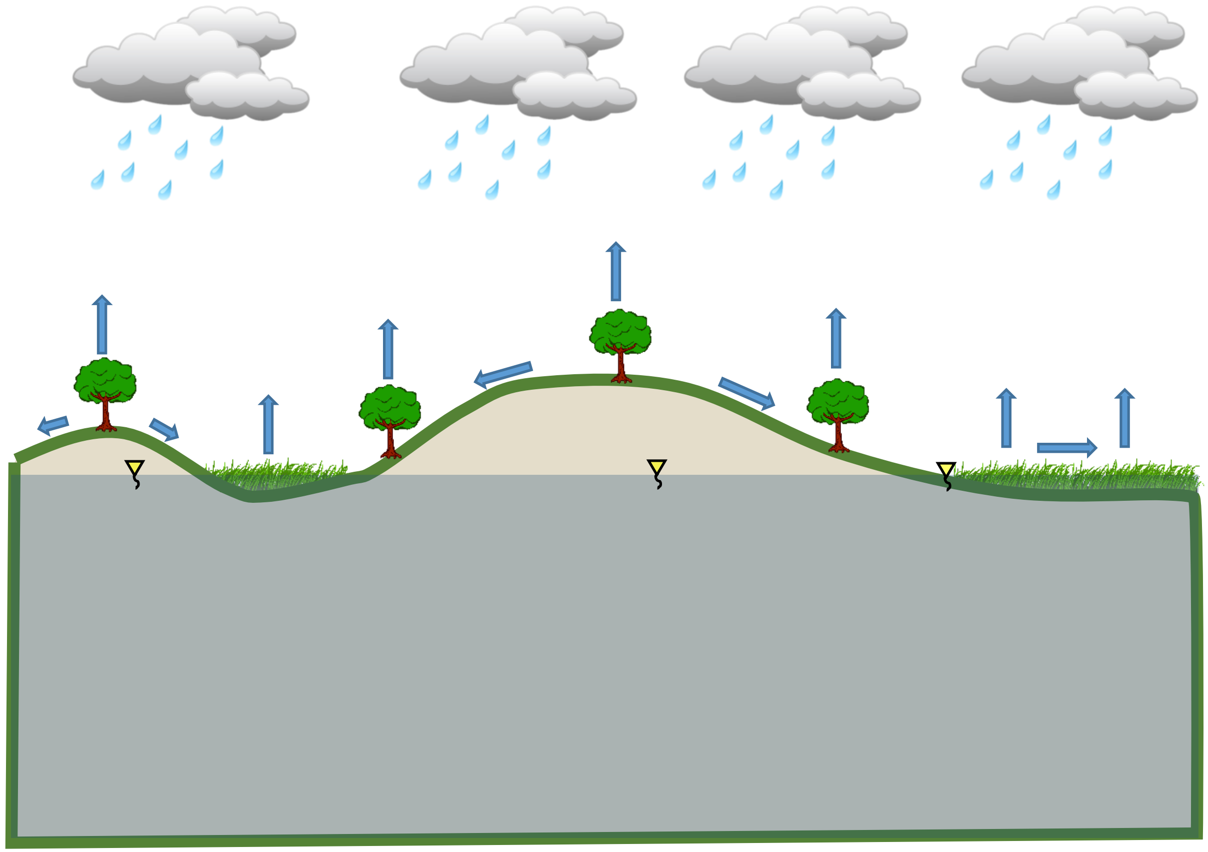
Chapter 19 of
Section A, Ground Water, of
Book 6, Modeling Techniques



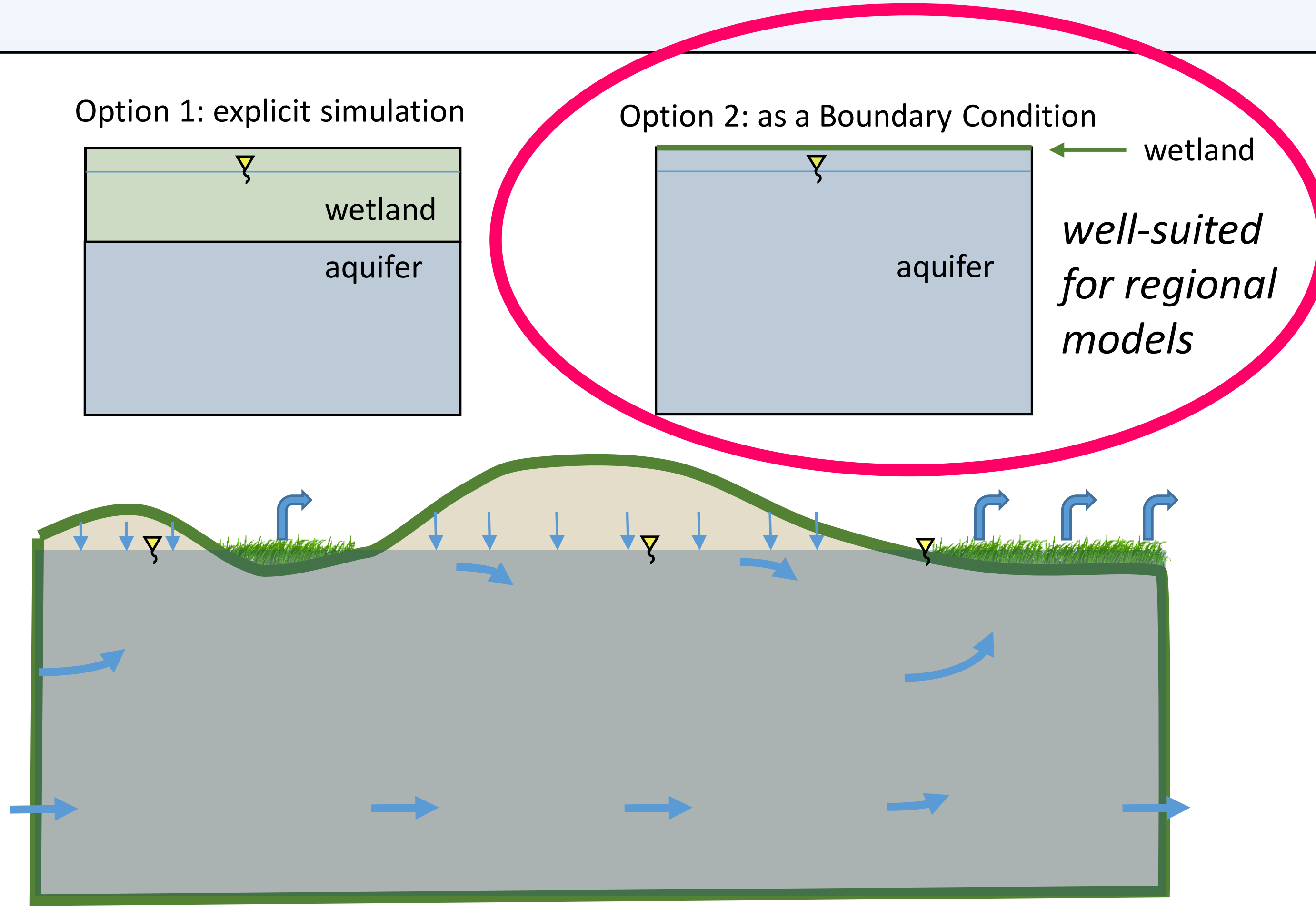
Techniques and Methods 6-A19

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

(Niswonger et al. 2006)

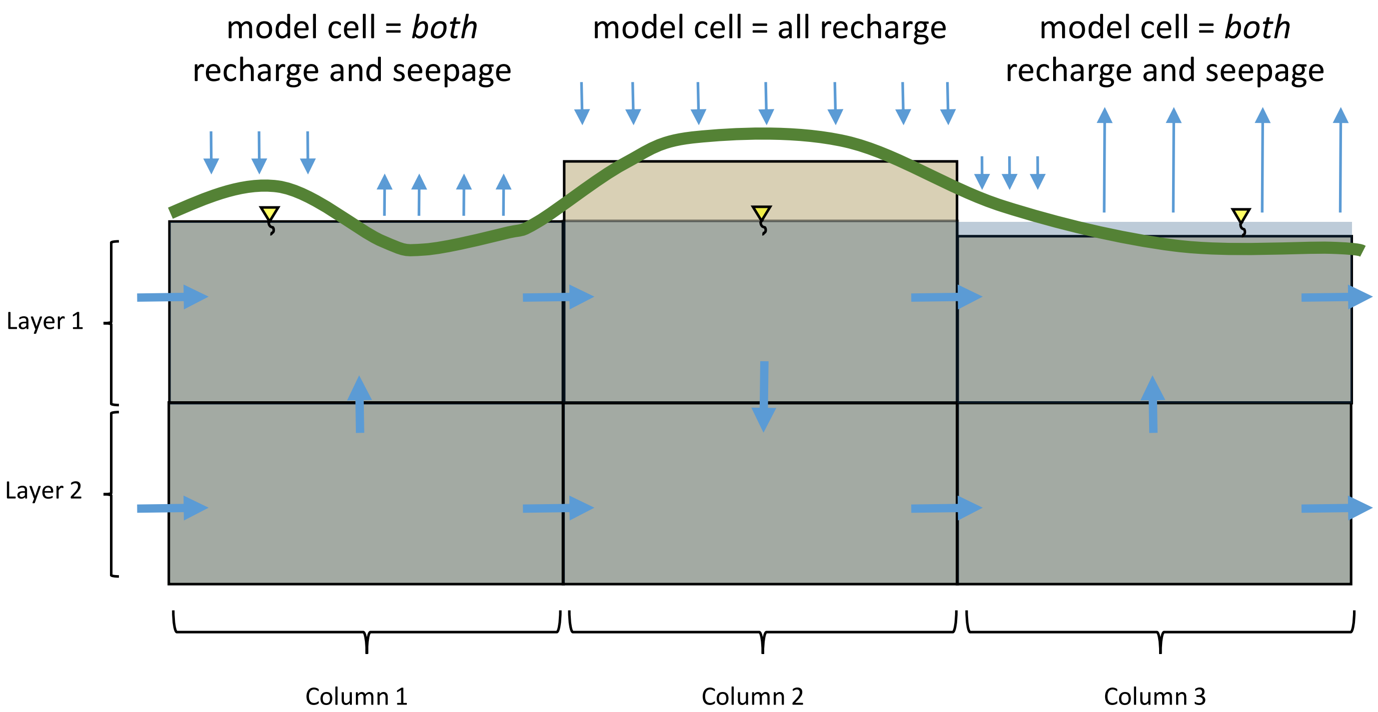


Surface water view of the world

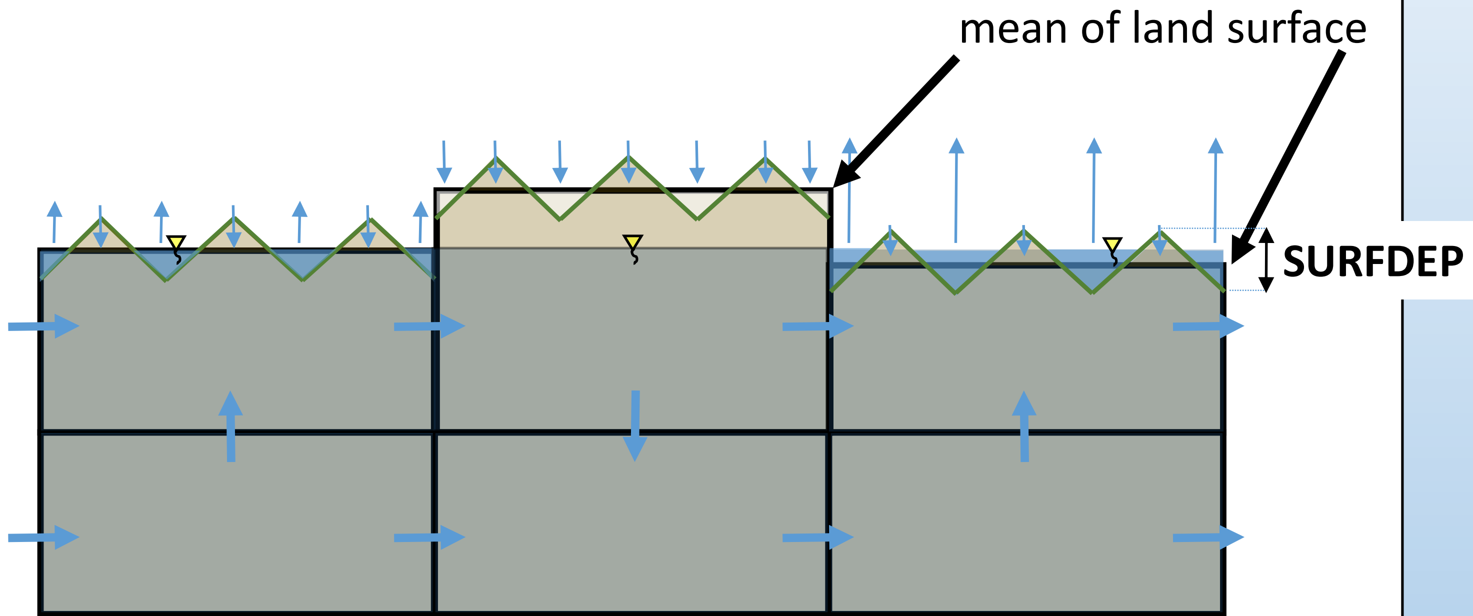



A “fen” view of the world (groundwater system)

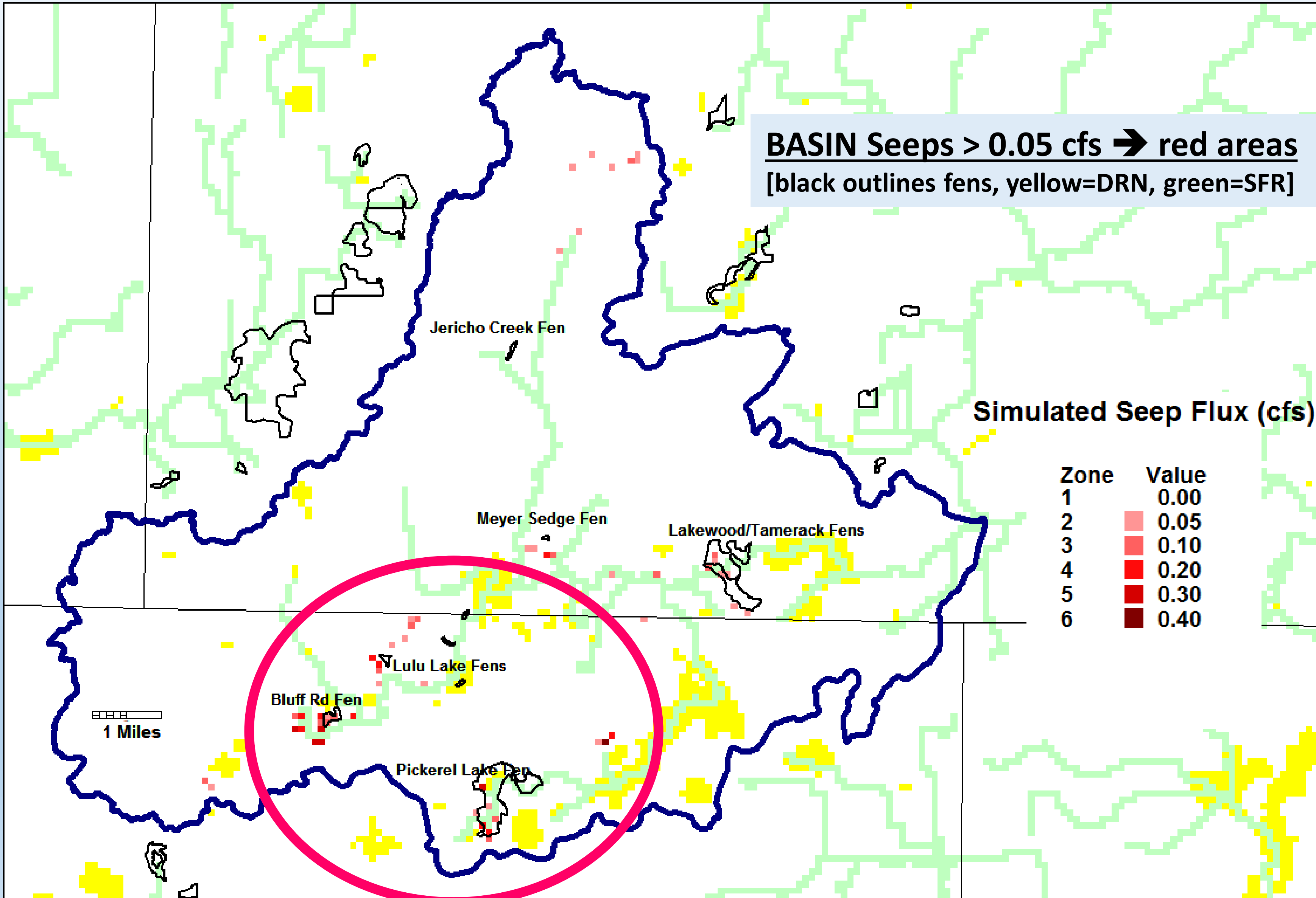
# The fen view of the world simplified with a MODFLOW grid



MODFLOW’s UZF Package accounts for recharge ***and*** seepage in a single cell with the variable **SURFDEP**, which accounts for **SURF**ace **DEP**ressions



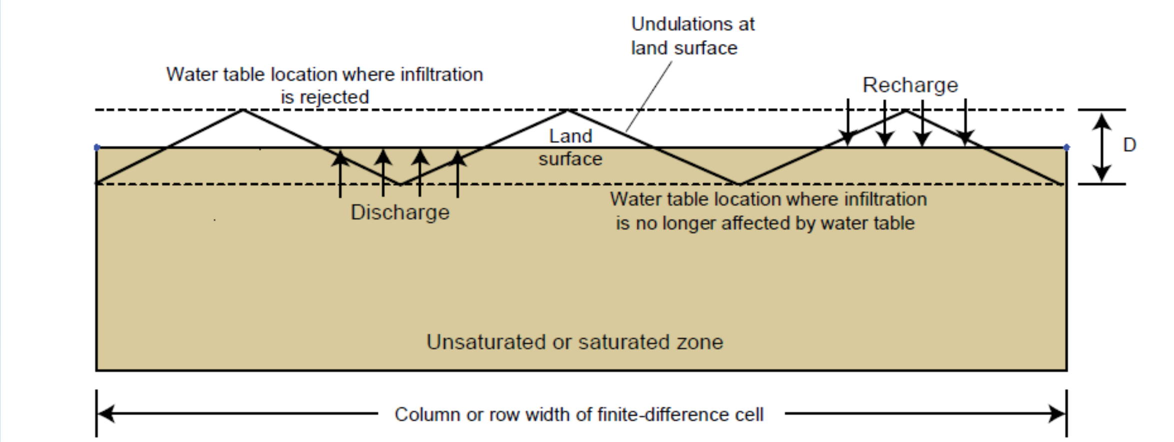
# Comparison of Model Seep Locations to Mapped Fens and Springs



**For our application: <u>Mean</u> land surface from 30m DEM for 500' x 500' cell worked best** (influences # of fen cells and rate of seepage)

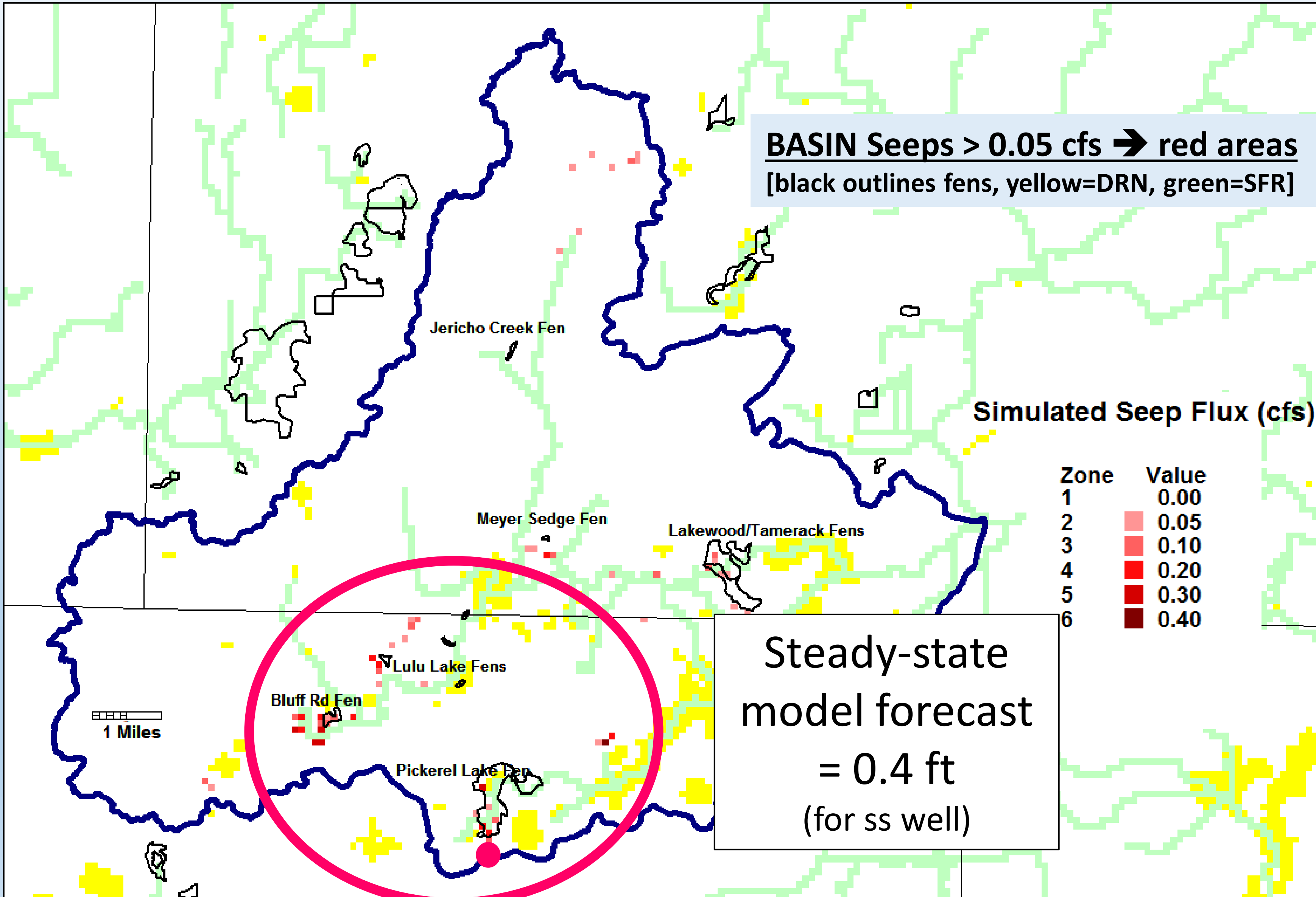
**Simulated seep flow is only moderately sensitive to assumed undulation depth SURFDEP (D)**

| Undulation Depth | Total Basin Seepage (cfs) | #Seep Cells>0.05 cfs |
|---|---|---|
| ±0.5 ft | 8.0 | 49 |
| ±1.0 ft | 8.9 | 51 |
| ±1.5 ft | 9.9 | 55 |




**(Niswonger et al. 2006)**

# Scenario Testing: Adding a well pumping 140 gpm 1000’ south of Pickerel Fen



# Decision-support: Jurisdictional Wetlands and Transience

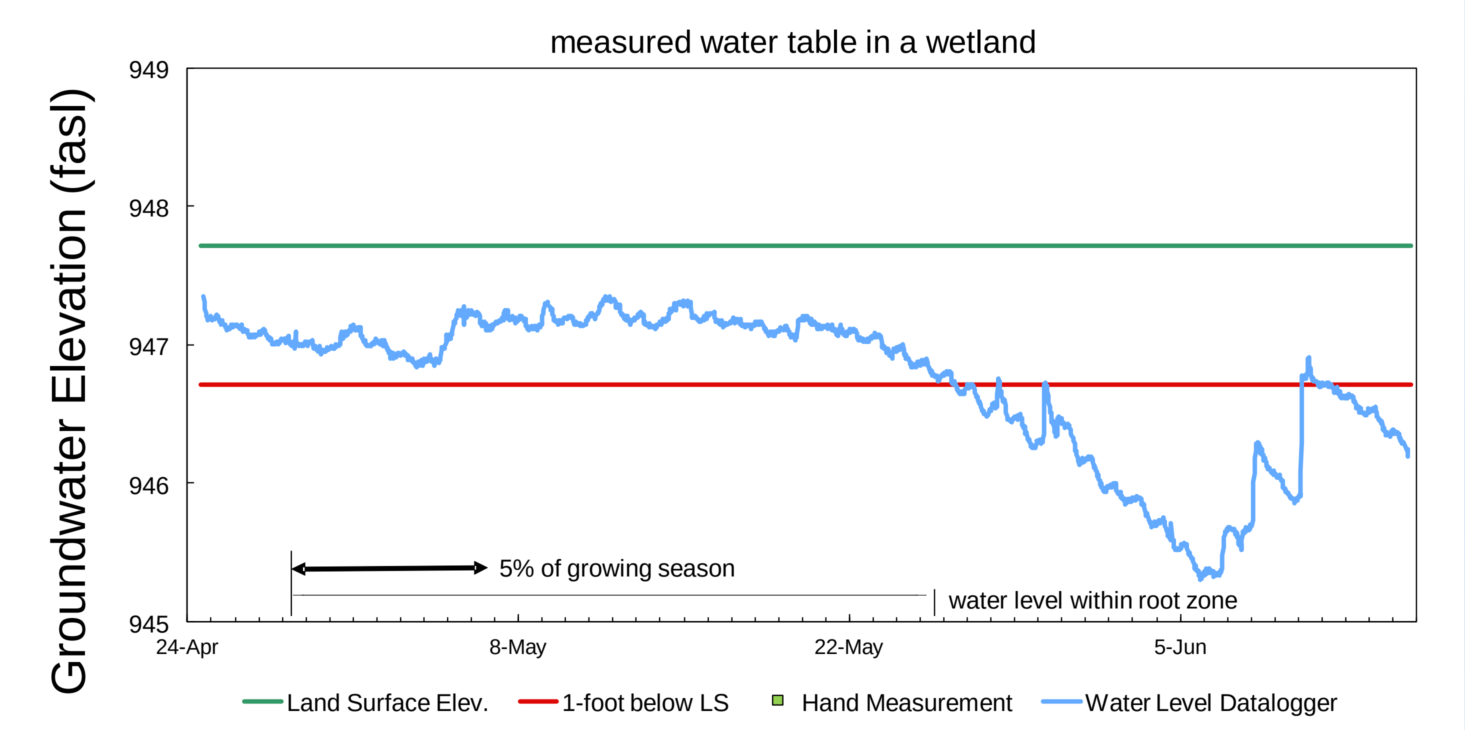
## Recall "*sufficient root zone saturation*" where:

**root zone saturation** = water table within 12" of land surface

**sufficient** = continually during at least 5% of the growing season *for most years*

***Is steady-state (average pumping) the correct approach?***
***What if the pumping well was placed elsewhere?***

***Future work: Transient modeling and fen "depletion" mapping***



# Summary (& take-home points for application):

1) **Simply adding UZF to a regional model provided representative simulation of areas with fen groundwater seepage.** It is not necessary to "rig" the model by specifying explicit hydrologic boundary conditions or fen location/properties/processes.

2) **Results are driven by land surface elevations in low-lying areas – and topography is well known.** Simulations did not need complexity of peat layers, fractured bedrock layers, gravel beds, and vertical structures giving rise to preferential flow paths.

3) **Fens and high-capacity pumping depend on the larger-scale groundwater system, thus we need regional representation of groundwater.** Better to simplify intra-wetland processes and retain good simulation of regional groundwater flow for fen-drawdown type forecasts.