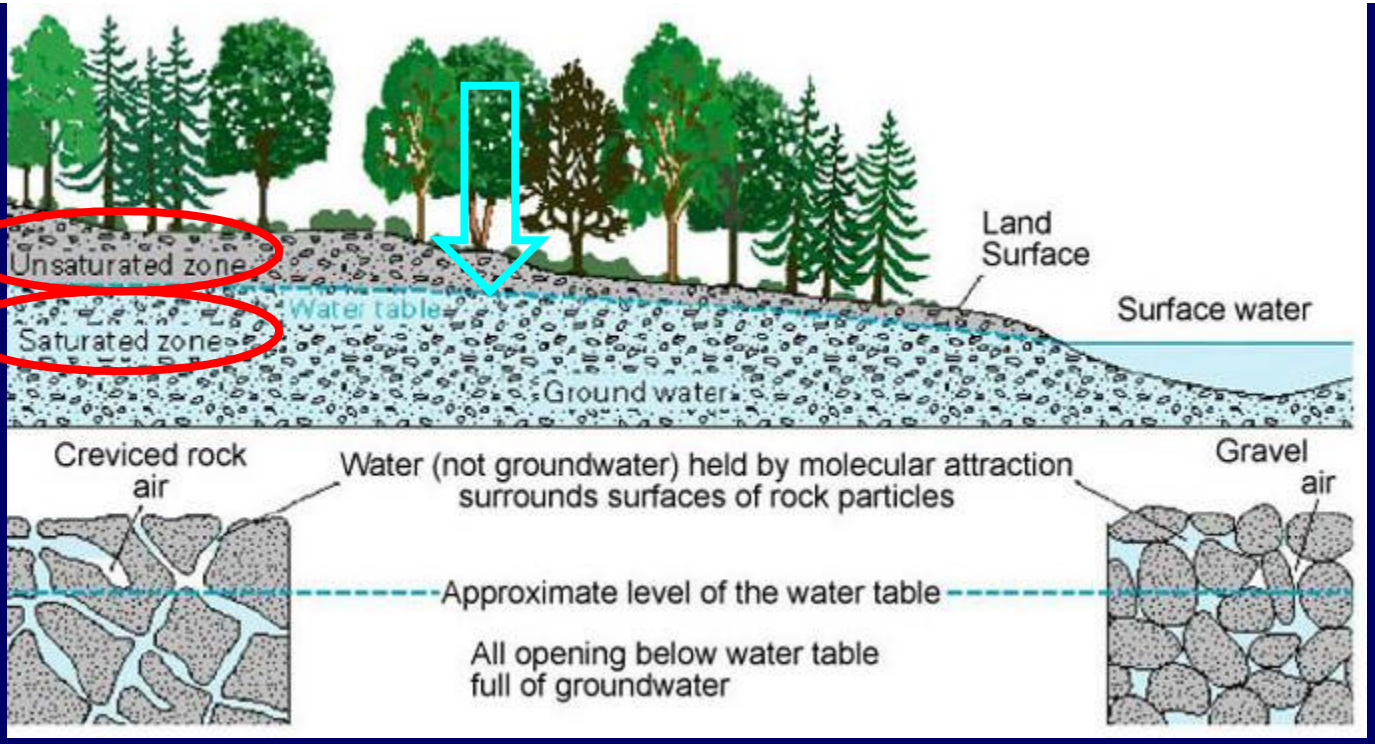
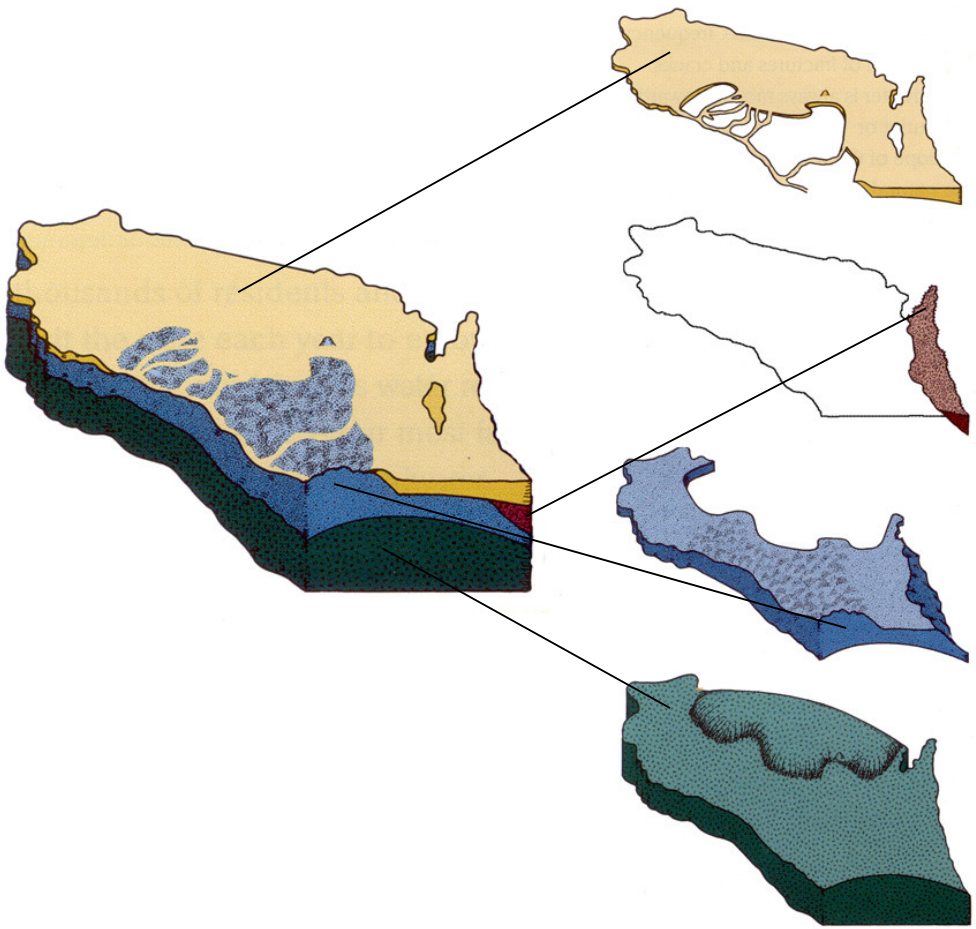


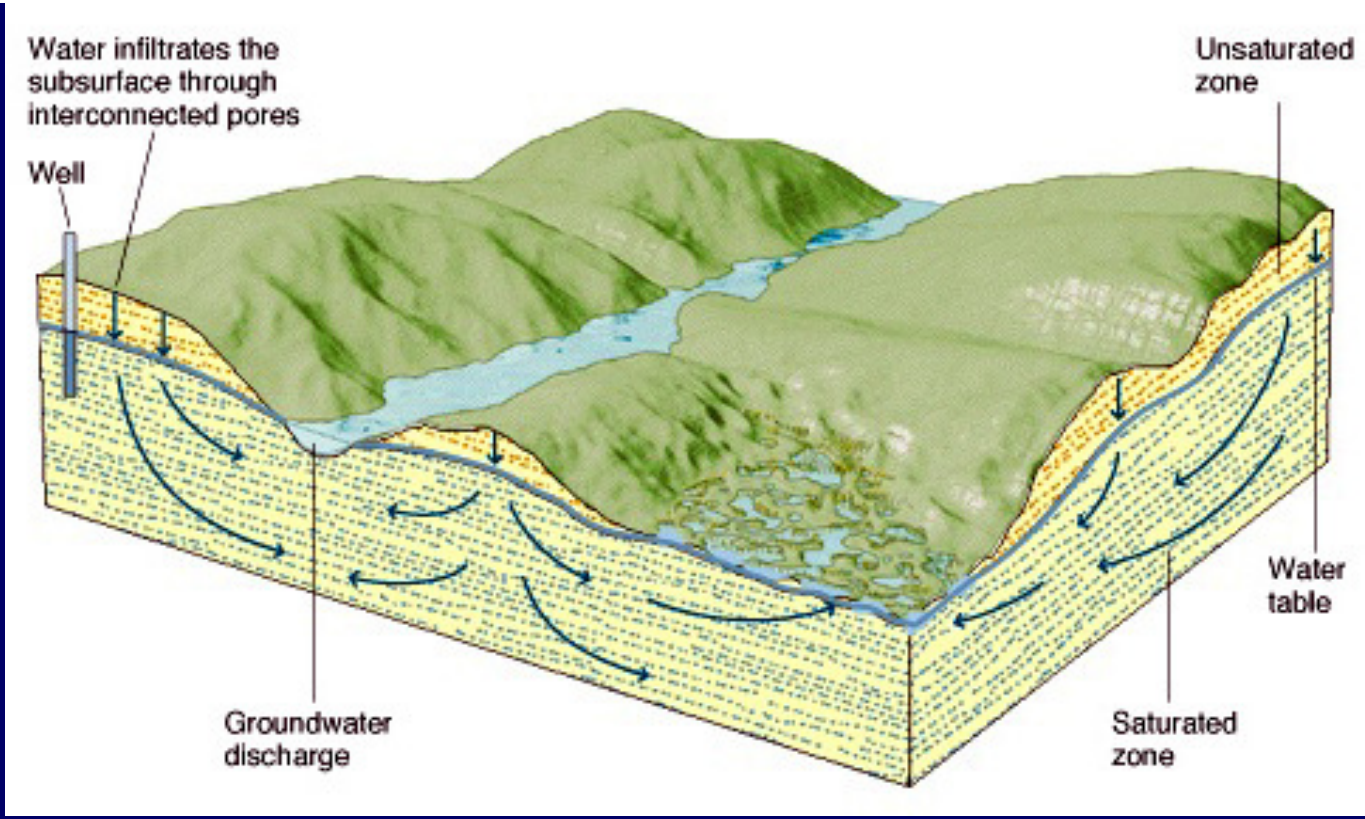
- Aquifer – a geologic unit that can store and transmit usable quantities of water to a well
- Water table is boundary between the unsaturated and saturated zones
  - Unsaturated zone - pores spaces contain both air and water
  - Saturated zone - pores spaces are filled with water
- Groundwater Recharge -- water that seeps past the root zone and makes it to the water table (top of the saturated zone)

Wisconsin Aquifers



- Sand & gravel aquifer
- Silurian dolomite aquifer
- Sandstone & dolomite aquifer
- Crystalline bedrock aquifer

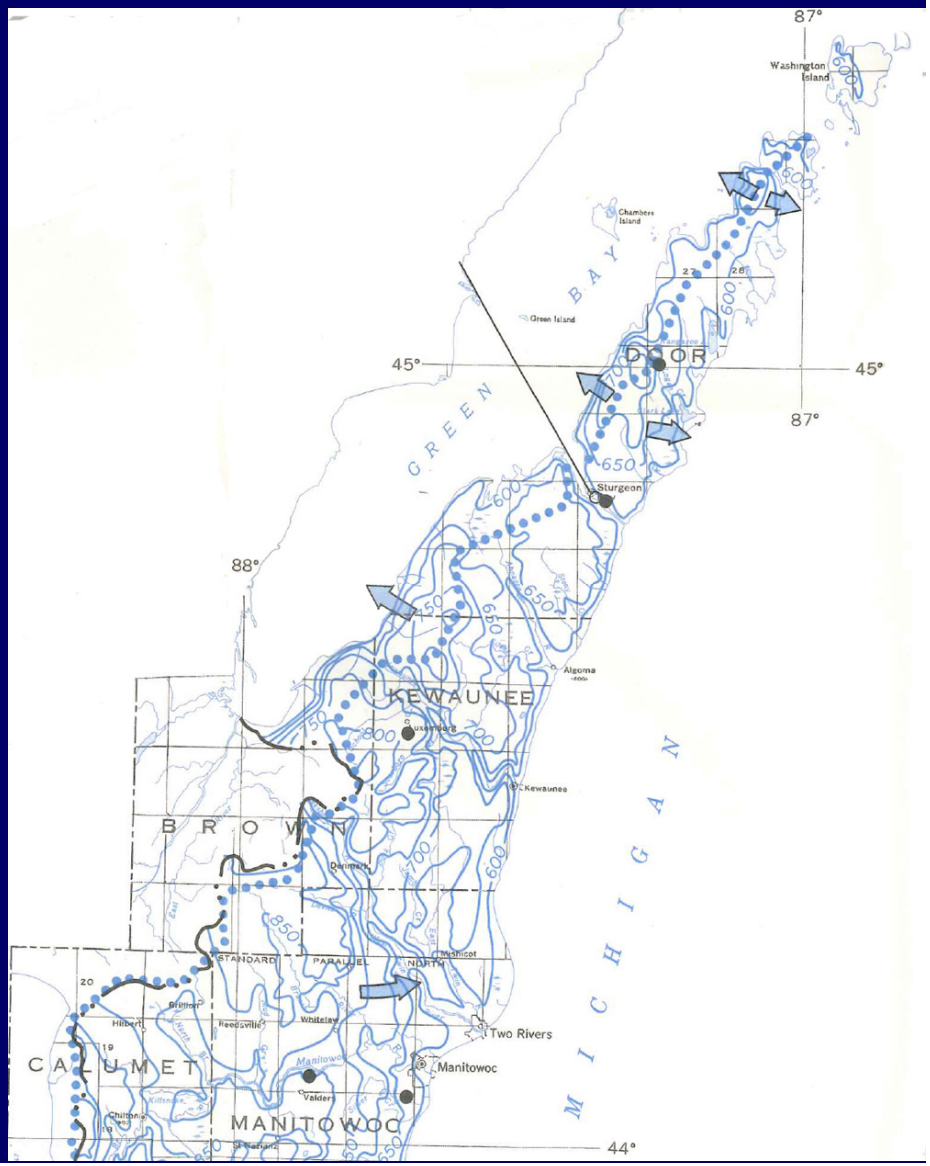
Image from DNR Magazine supplement: Groundwater Wisconsin's Buried Treasure



- Groundwater flow is from areas of higher hydraulic head to areas of lower hydraulic head.
- Recharge area -- area where precipitation infiltrates and moves into the groundwater flow system. Groundwater flow is generally downward in these areas.
- Discharge area -- area where water exits the aquifer. In this diagram streams and lakes are the discharge areas.

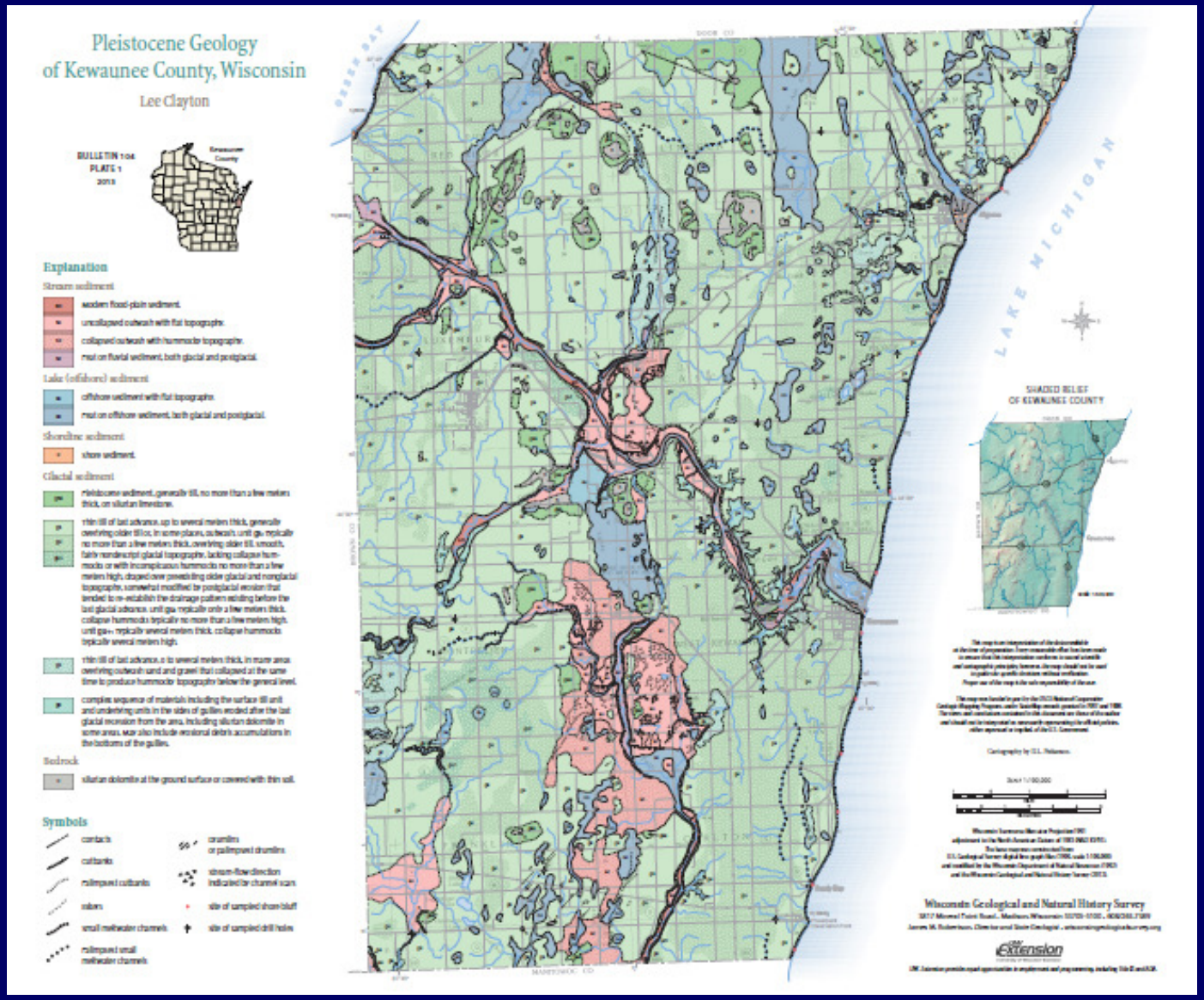
Flow Patterns in the Dolomite Aquifer

- Regional divide between flow to Lake Michigan and flow to Fox Valley
- Groundwater discharge to surrounding surface water features
- Long flow paths
- Vertical flow through relatively uniform aquifer



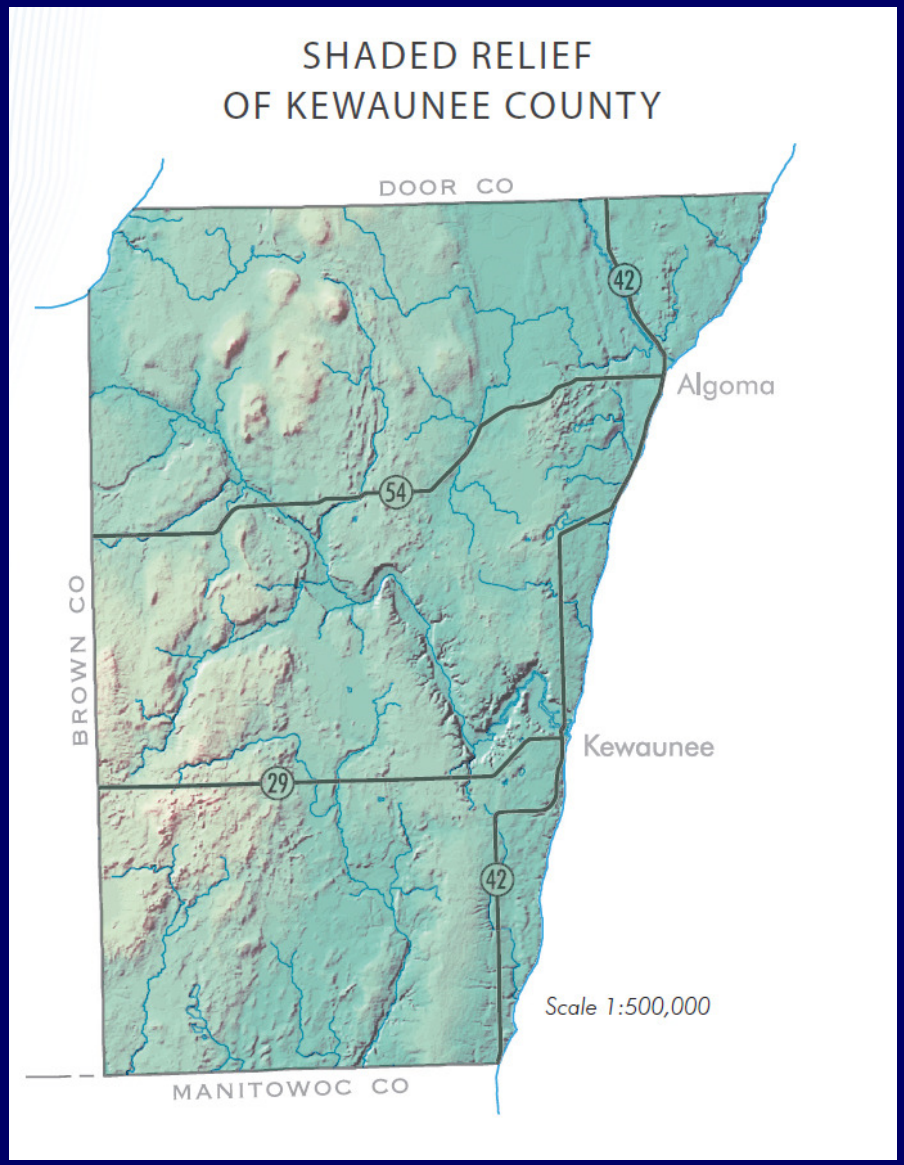
USGS Hydrologic Atlas HA432
Water Resources of Wisconsin, Lake Michigan Basin

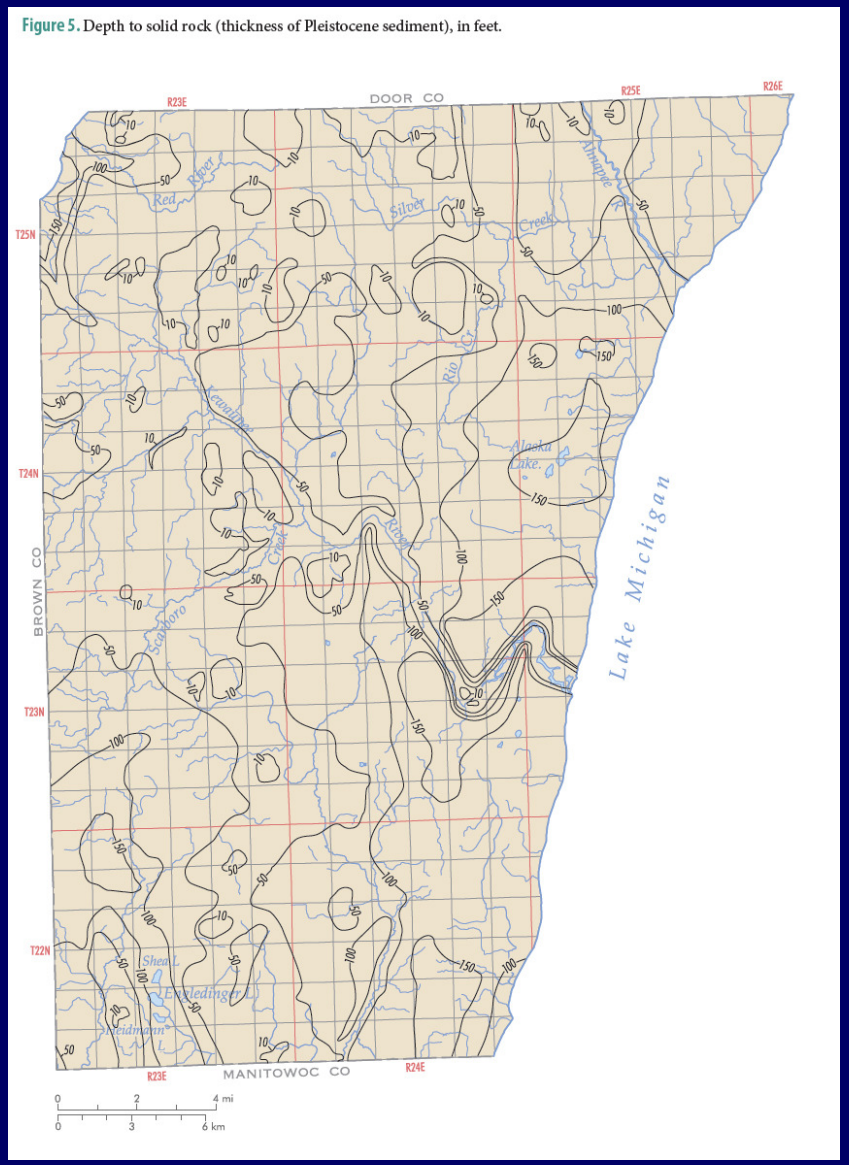
Kewaunee County Geology



Glacial sediment of varying thickness over dolomite bedrock

Kewaunee County Geology

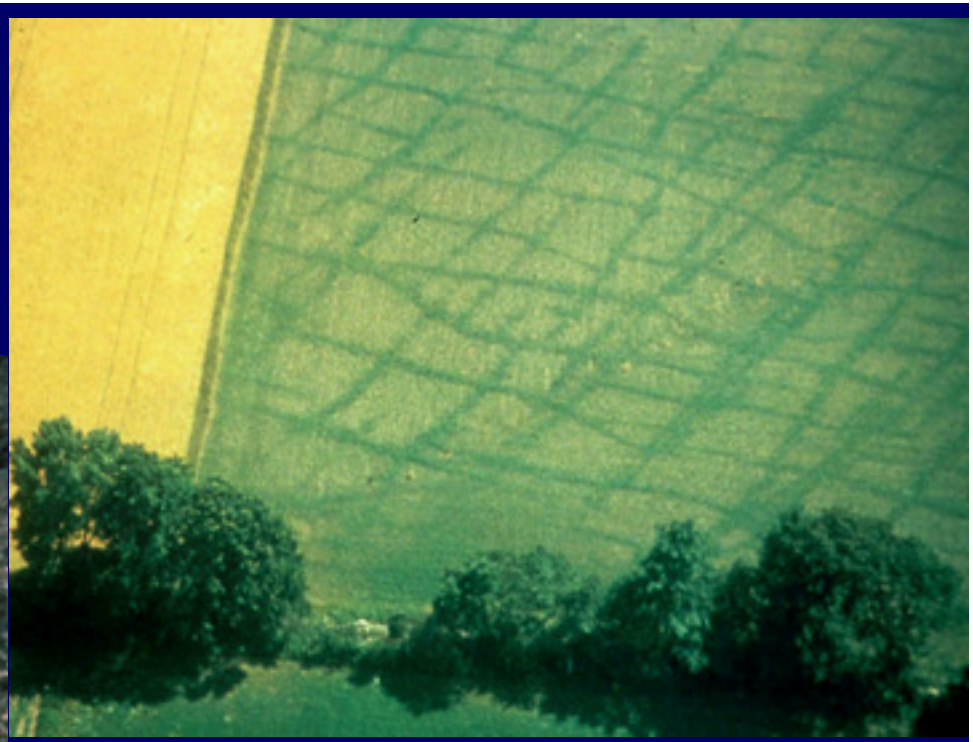




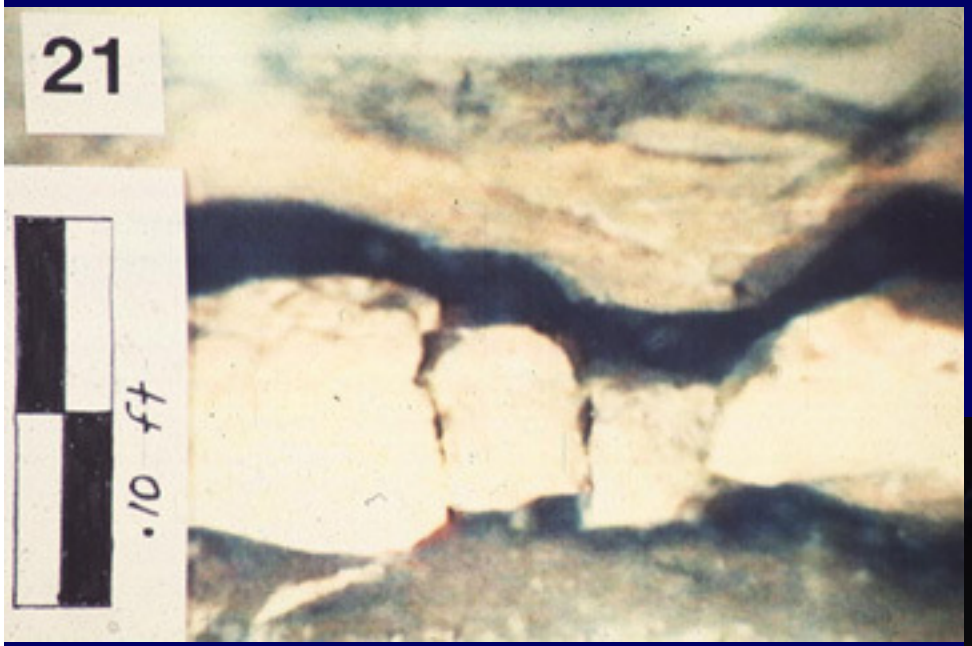
Glacial sediment of varying thickness over dolomite bedrock

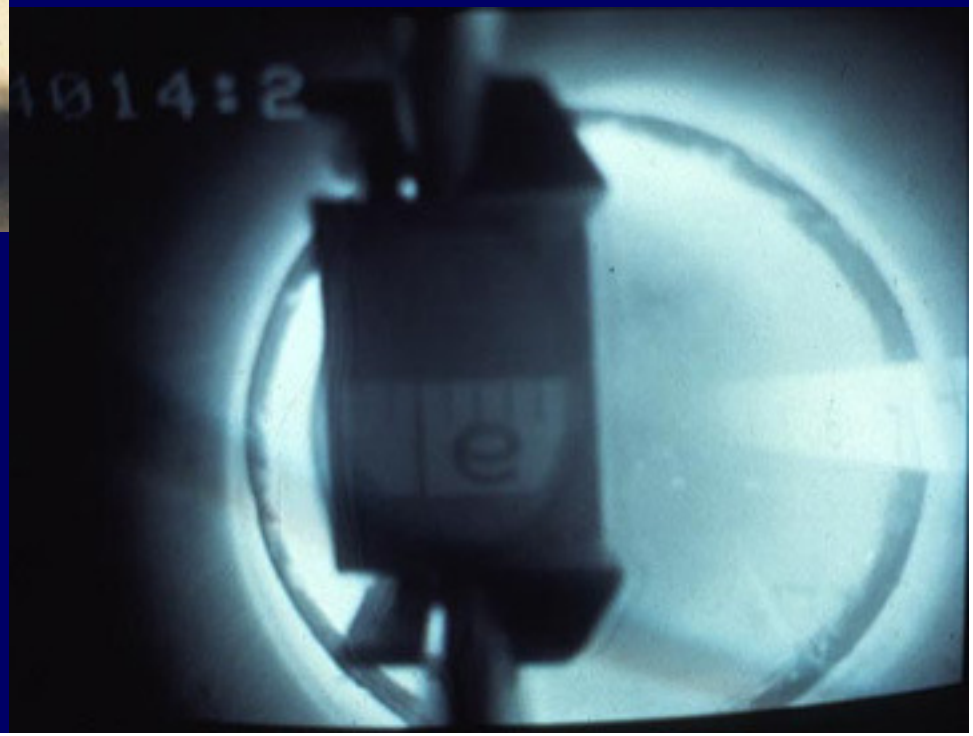
Kewaunee County Geology

Silurian Dolomite Aquifer

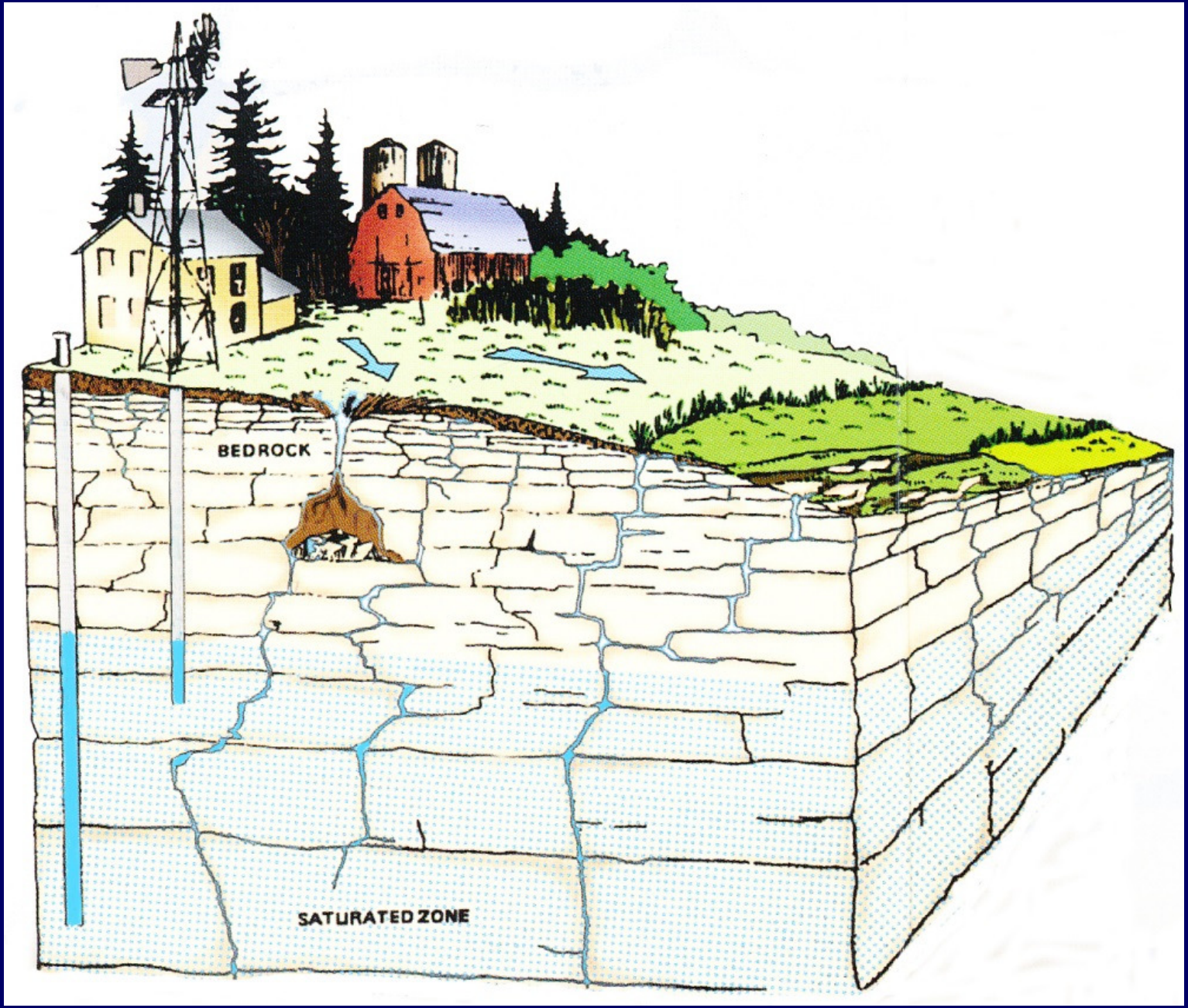


Bedding-plane Fractures





Pictures of fractures intersecting boreholes



From Door County Soil & Water brochure: *Protect the Water You Drink*

Flow Characteristics of Silurian Dolomite Aquifer

- Dense and ubiquitous fracture network
  - little surface runoff
  - water easily infiltrates to subsurface
- Recharge
  - exceedingly rapid
  - carries surface contaminants to the water table
- Flow within the aquifer occurs primarily along bedding plane fractures
- Flow rates vary from 10's to 100's of ft/day

Water Cycle

- Processes
  - Evaporation
  - Transpiration
  - Precipitation
  - Infiltration
  - Groundwater flow
  - Overland flow
  - Stream runoff

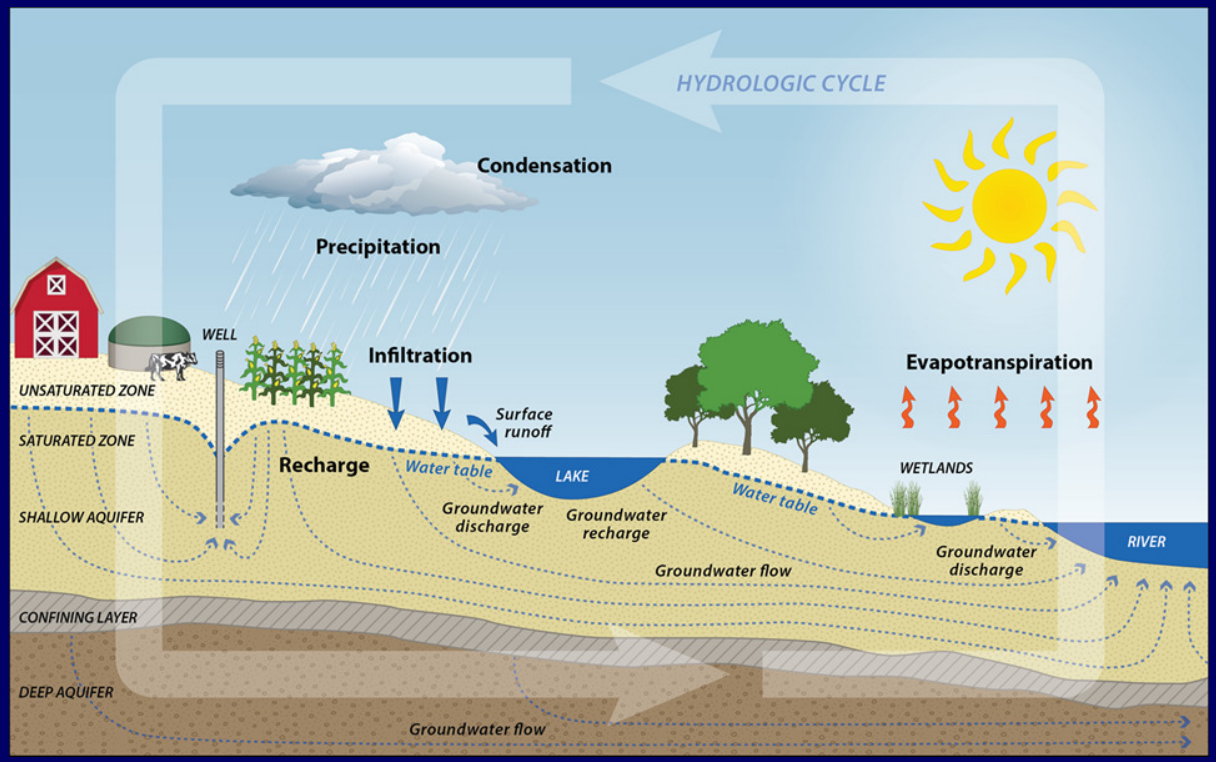
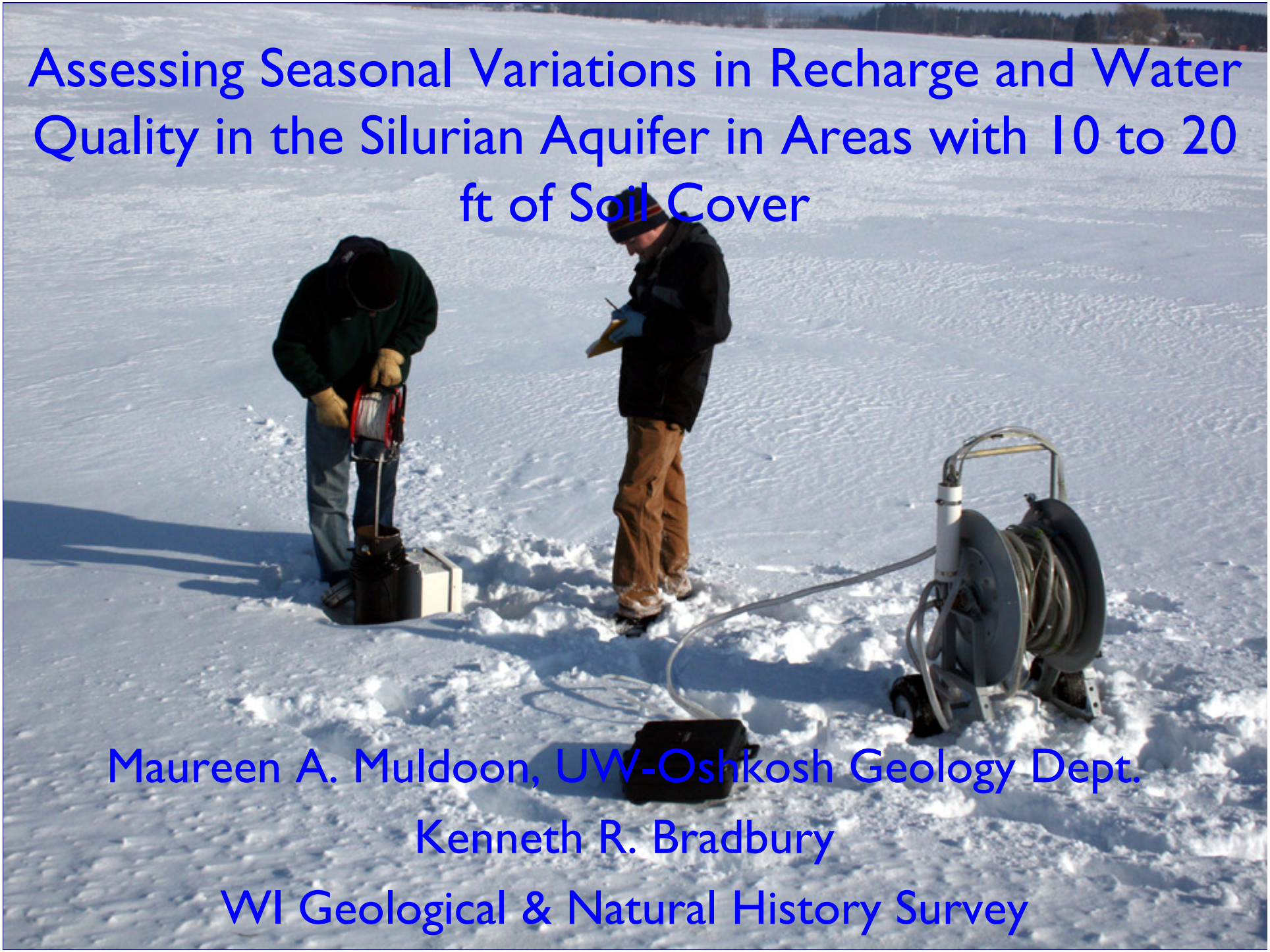


Figure from WI Geological and Natural History Survey

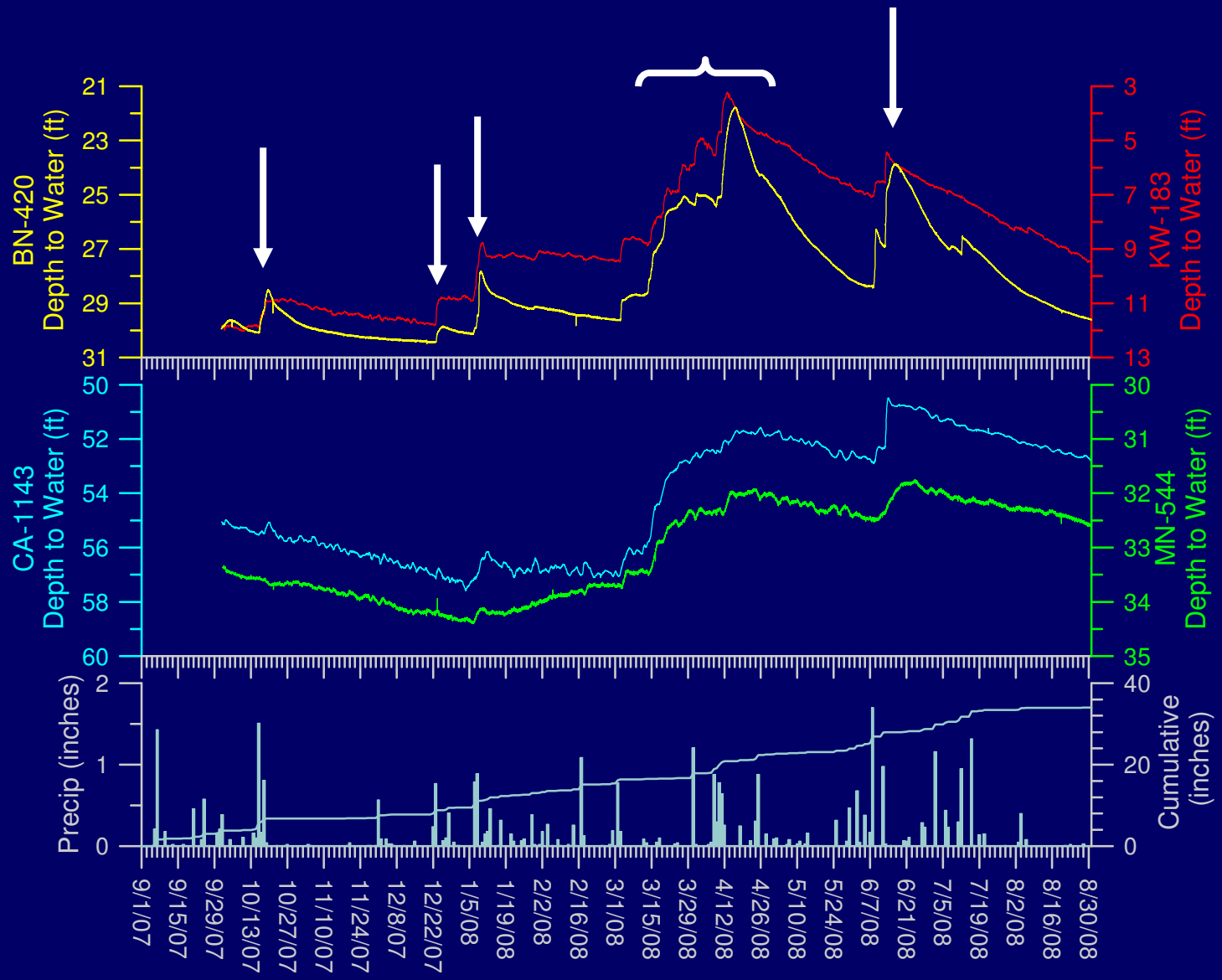
- Indictors of recharge
  - Water level in well rises
  - Change in water temperature or chemistry

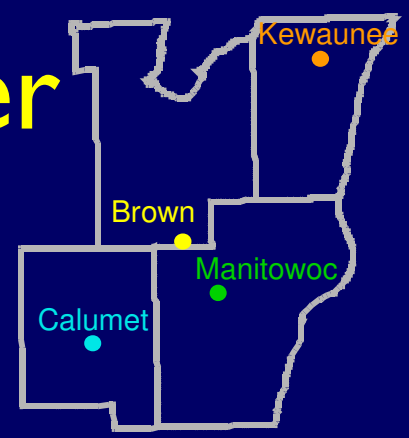
Assessing Seasonal Variations in Recharge and Water Quality in the Silurian Aquifer in Areas with 10 to 20 ft of Soil Cover

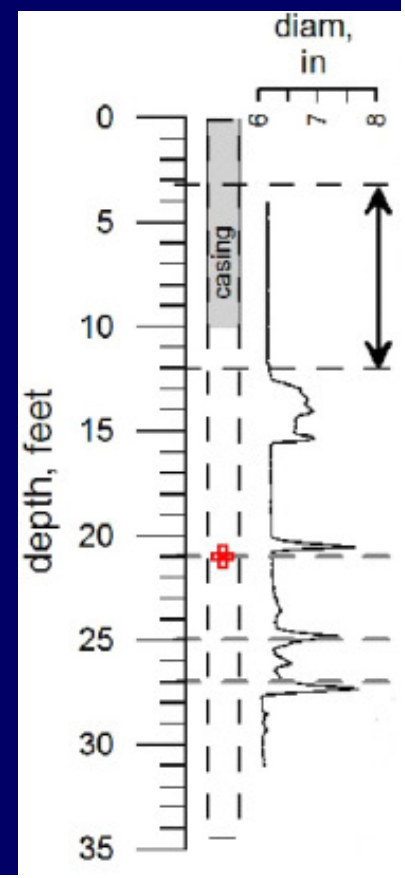


Maureen A. Muldoon, UW-Oshkosh Geology Dept.
Kenneth R. Bradbury
WI Geological & Natural History Survey

Recharge to the Silurian Aquifer







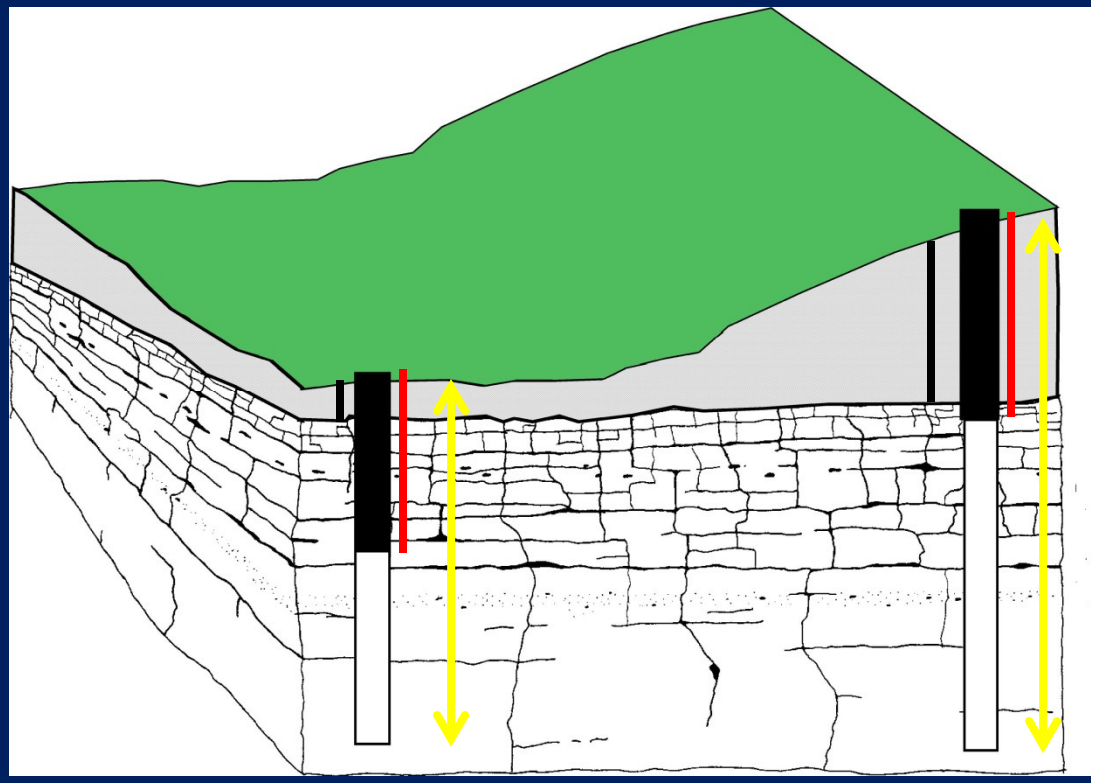
Recharge to the Silurian Aquifer

- Studies in NE WI demonstrate that recharge reaches the aquifer within 1 to 2 days, even with sediment thicknesses up to 18 ft and depth to water > 50 ft
- Review of Midwestern and national literature suggests that cohesive soils frequently contain fractures and macropores to significant depths
- Photo from Dodge County: Manure through 15+ feet of clay via cracks and pathways

Photo from Fred Madison

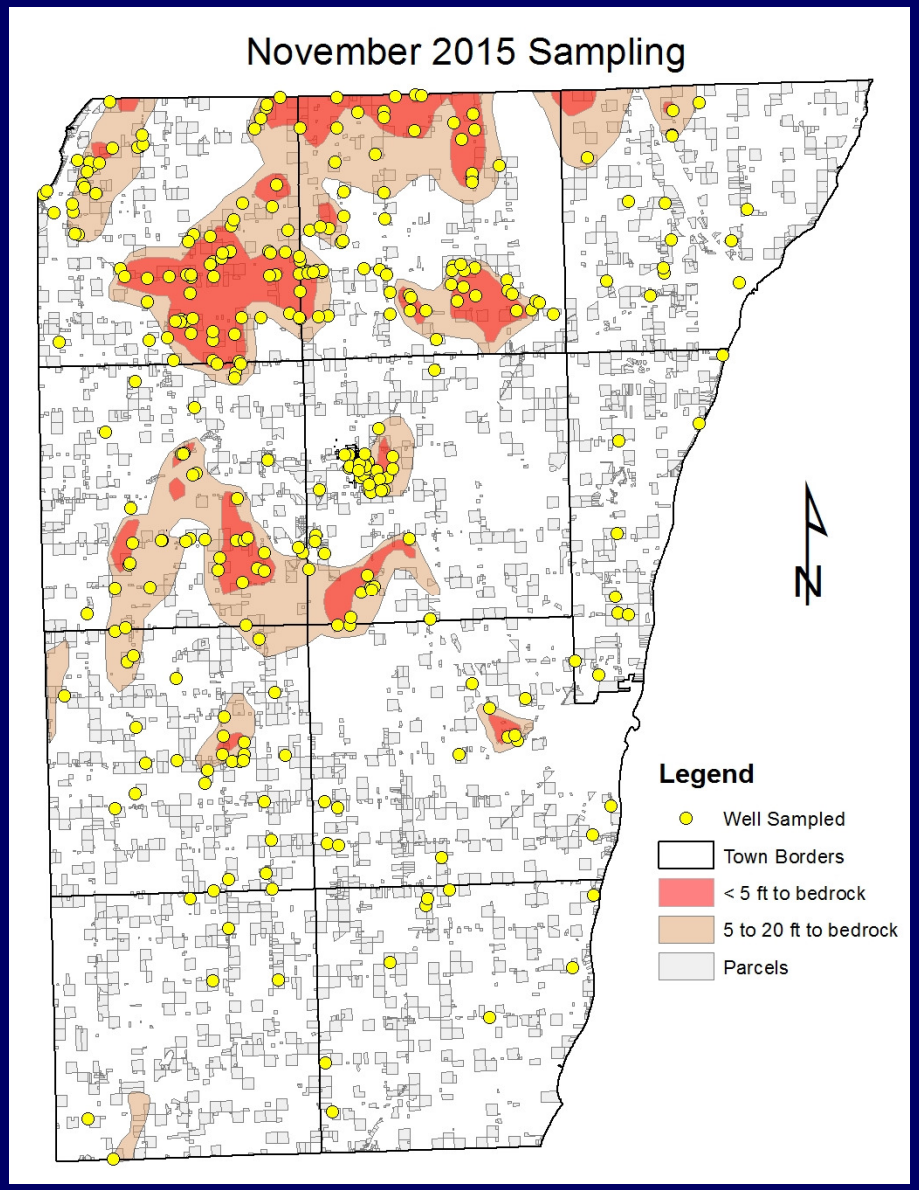
How is Your Well Constructed?

- Depth to rock
- Casing Depth
- Total Depth



Objective 1

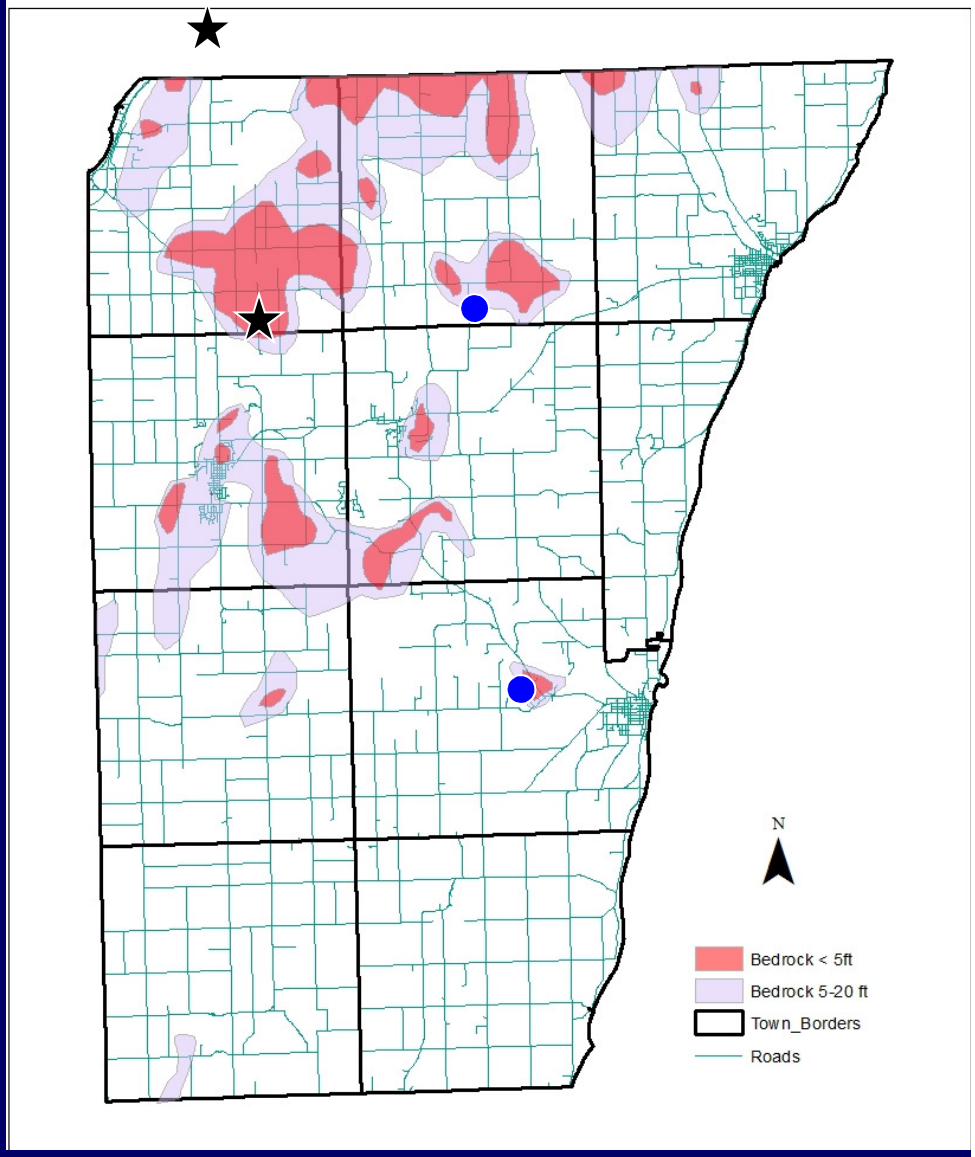
- County-wide randomized sampling of private wells stratified by depth-to-bedrock: <5 ft , 5-20 ft, > 20 ft
- Participation rate ~50%
- November 2015
  - Recharge period
  - 327 samples
- Second county-wide sampling in July 2016
  - Non-recharge period
  - 400 samples



Arc Map coverages from D. Bonness

Objective 3 -- Methods

- Measure recharge indicators at two non-pumping monitoring wells
- Use automated samplers at two domestic wells to collect samples during recharge events
- Analyze by qPCR for microbial targets:
  - 1) human-specific microbes
  - 2) bovine-specific microbes
  - 3) Non-specific microbes found in fecal wastes



Methods – Monitoring Wells

- Existing Well KW183
  - Installed 2008
  - Depth to rock 7 ft
  - WL, fluid T & Cond, pH, CDOM, turbidity

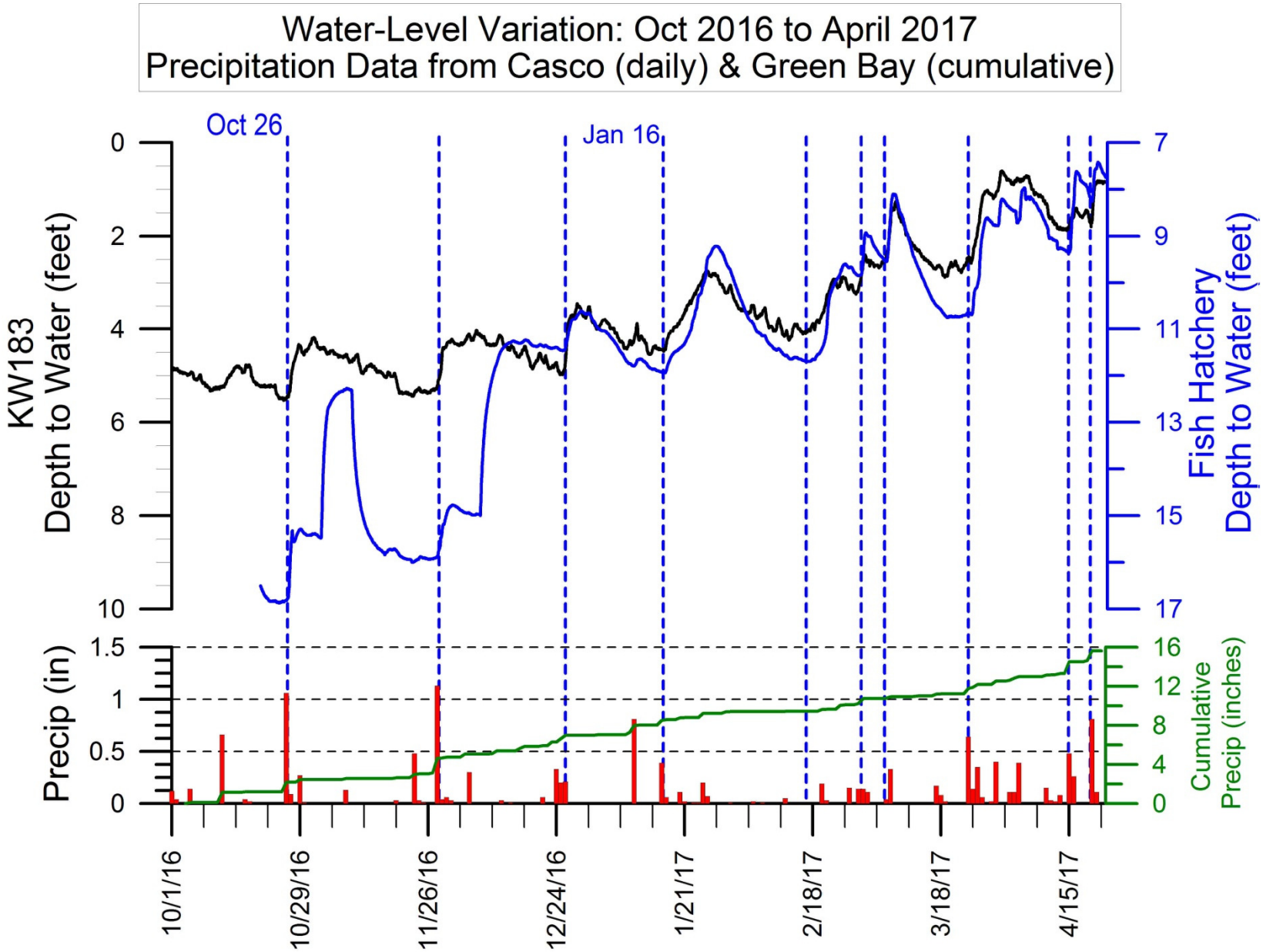
- New well at Fish Hatchery
  - Installed Aug 2016
  - Depth to rock 11.5 ft
  - WL, fluid T & Cond
  - Are 2 high-capacity wells at the hatchery

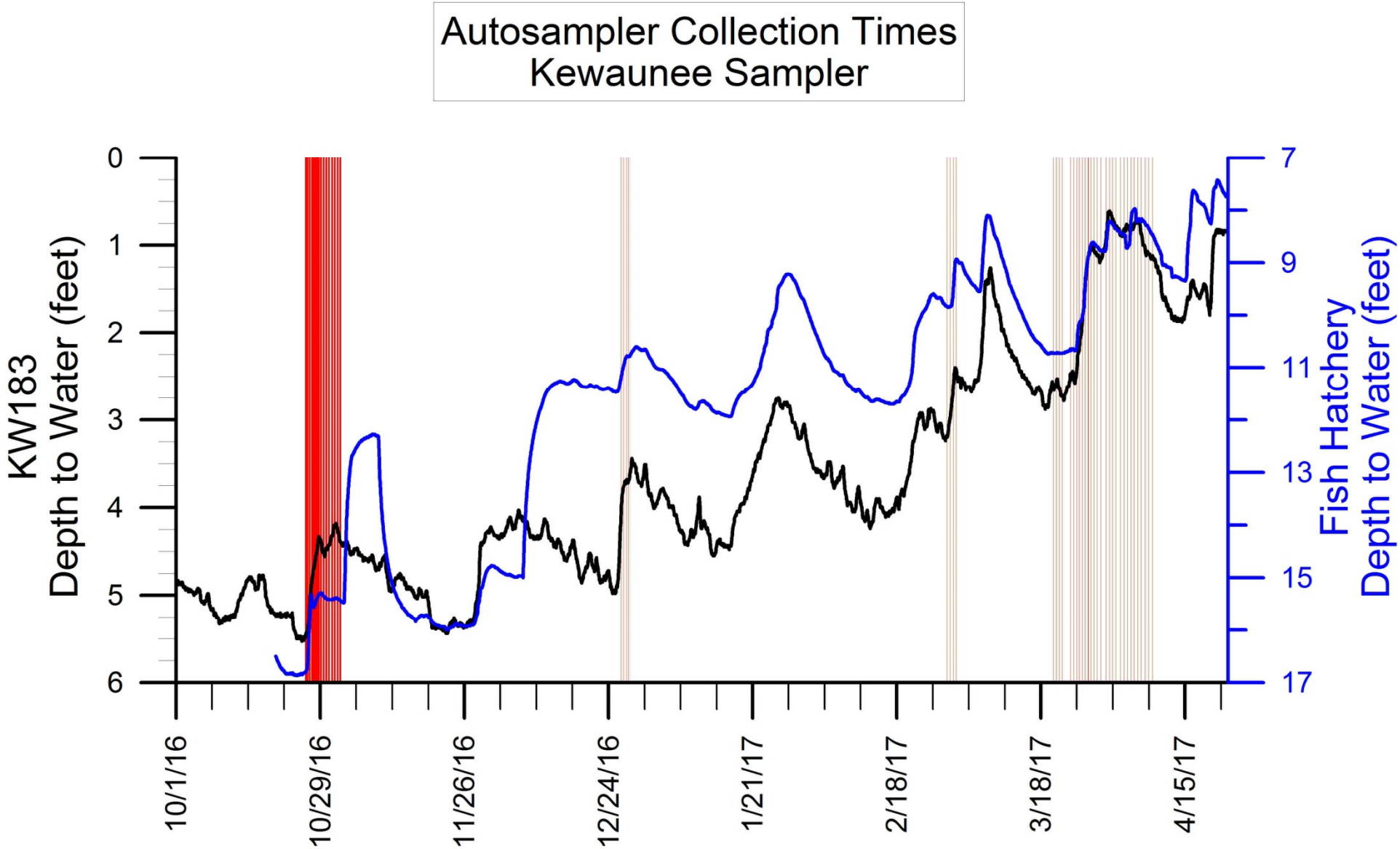
Methods: Auto-samplers

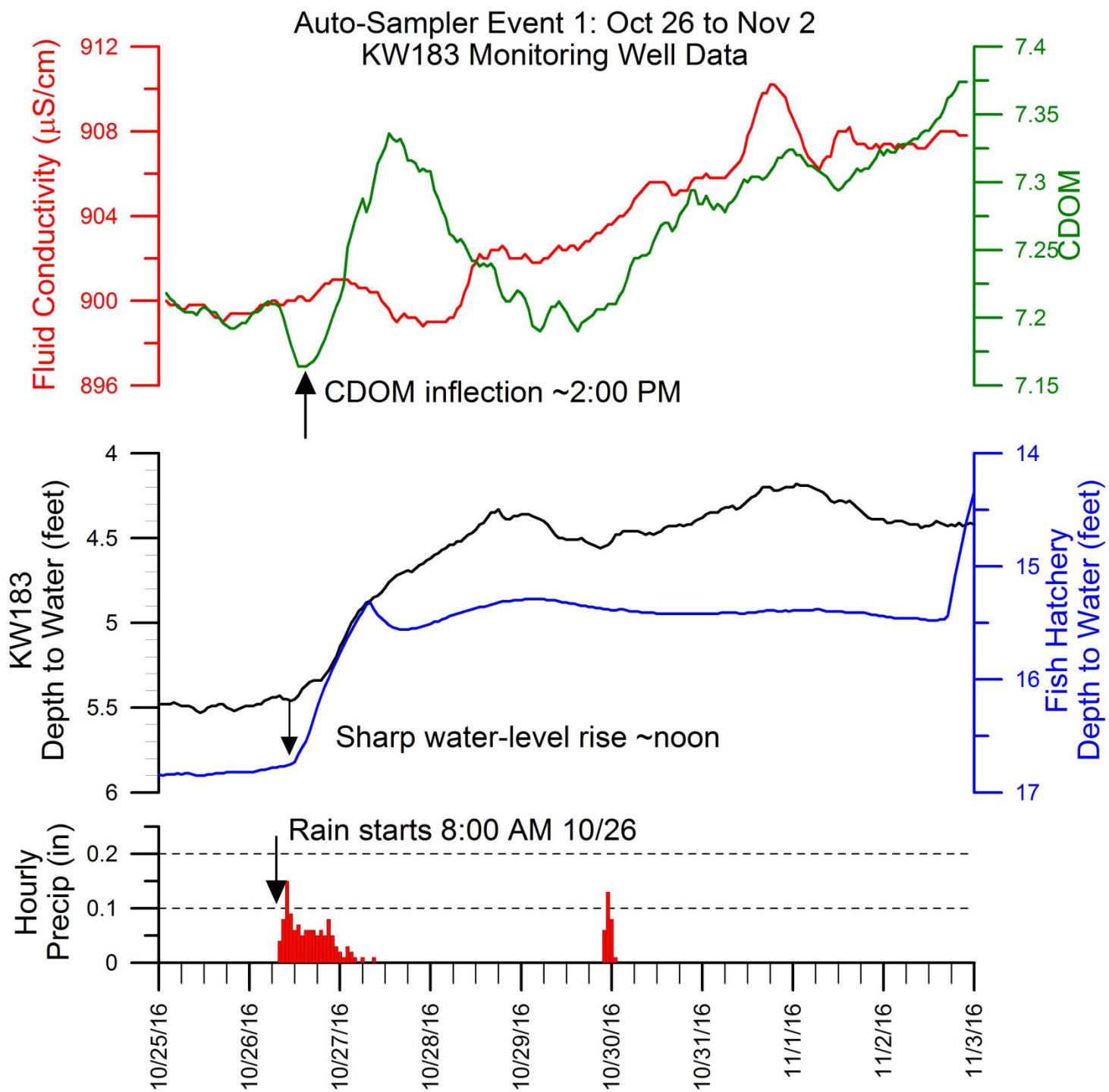
- Placement
  - Wells with known water quality concerns
  - Engaged homeowners
  - First sampler installed in Kewaunee in mid-October 2016. New well 300-ft deep, cased to 200 ft (4 filters)
  - Second sampler installed in Door County in mid-January 2017. Old well, 43-ft deep, cased to 29 ft. (8 filters)
- Water Chemistry
  - Fluid temperature & conductivity
  - Nitrate & chloride
  - pH & FDOM

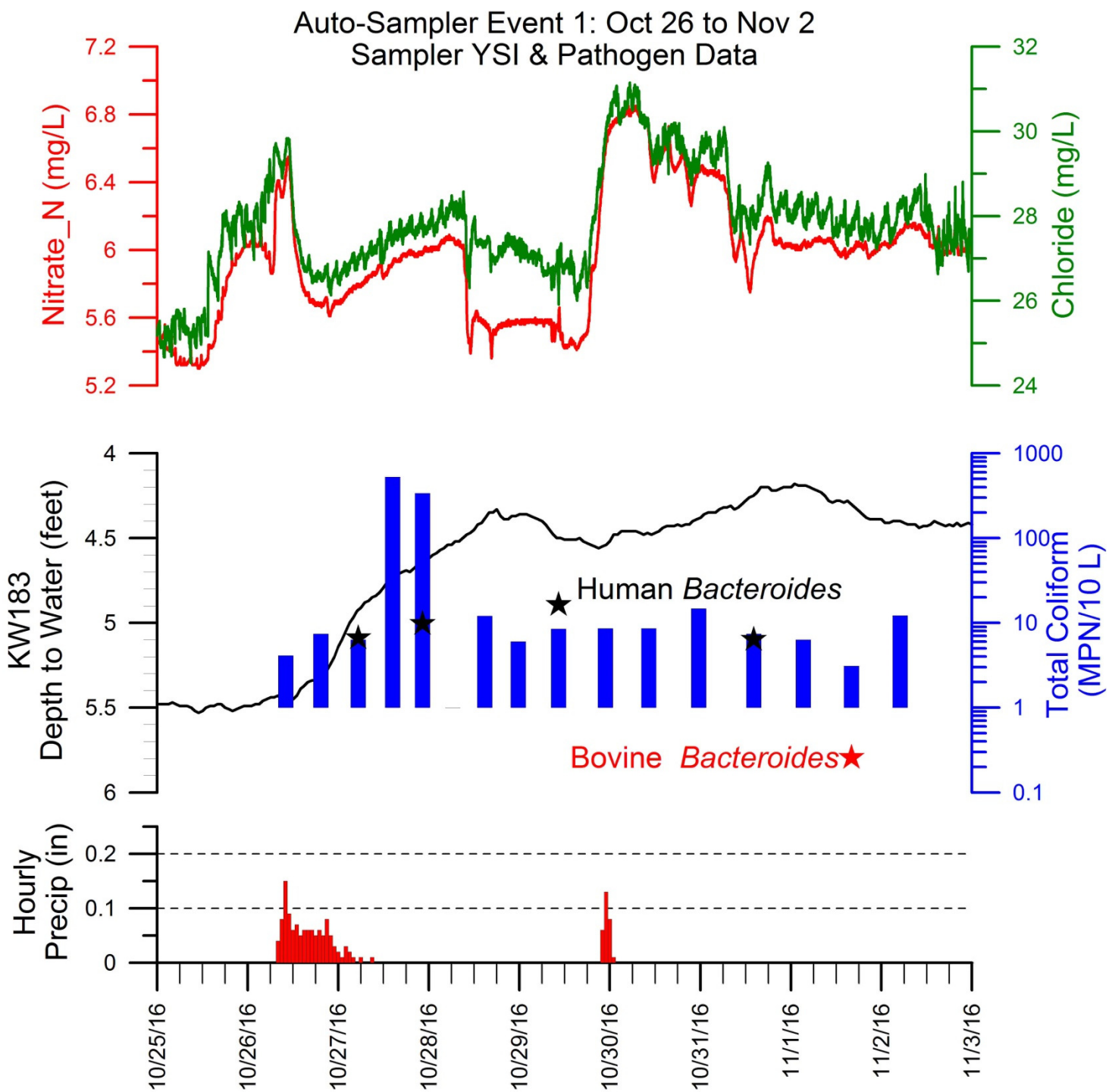
- Can initiate sampler remotely
  - Run 600+ liters through hemodialysis filter

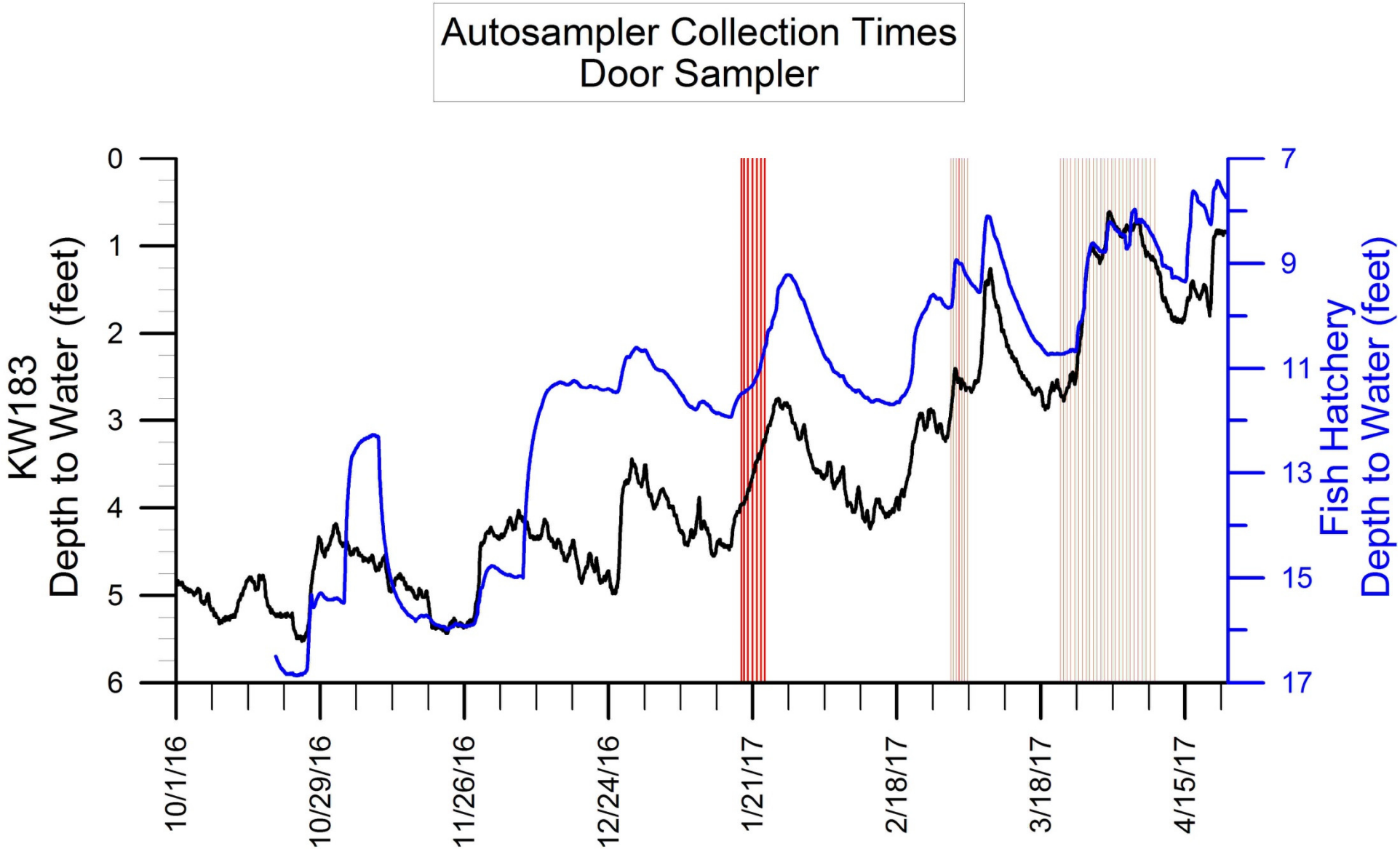
Results – Monitoring Wells

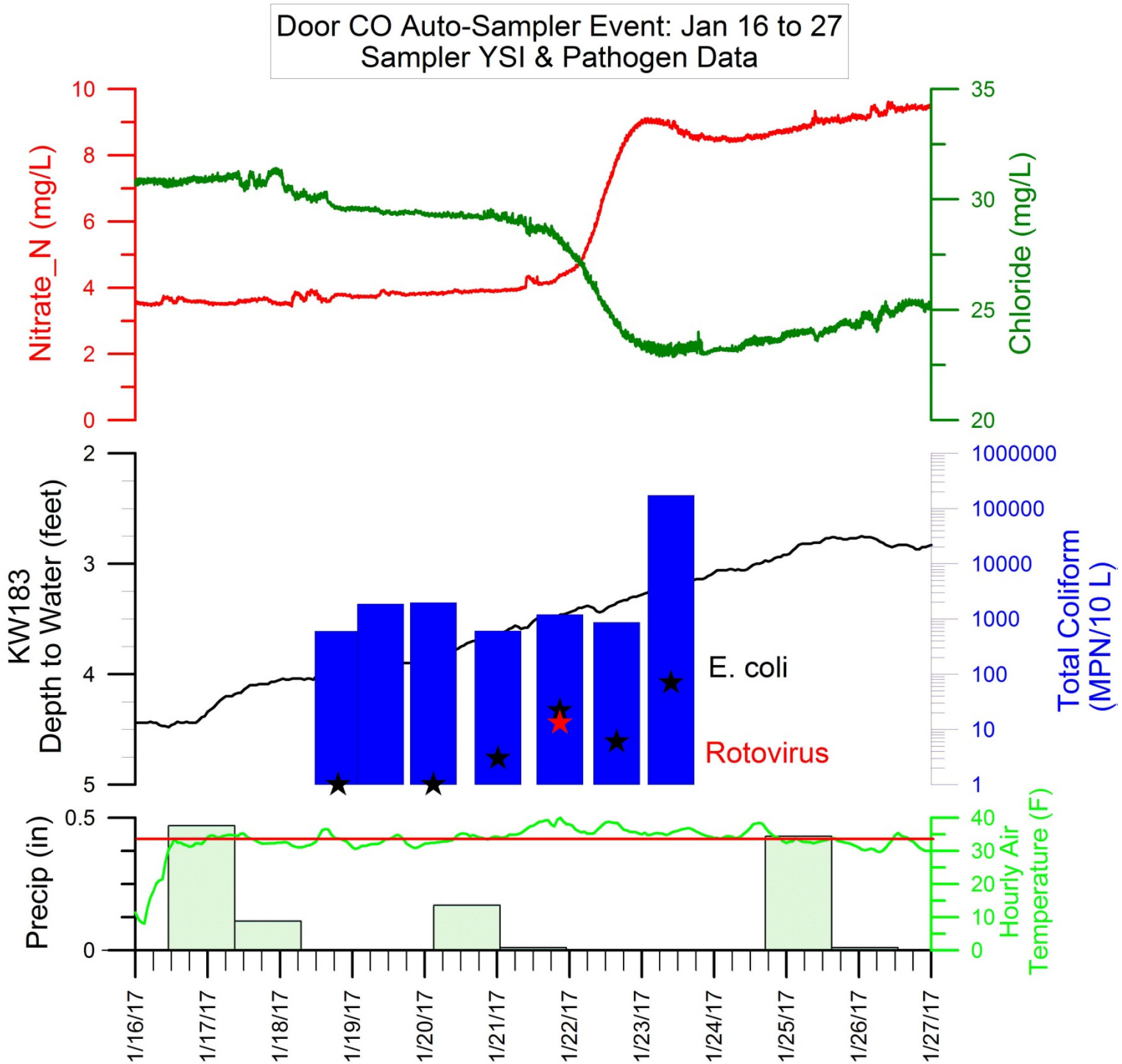



Autosampler Collection Times
Kewaunee Sampler
KW183
Depth to Water (feet)
0
1
2
3
4
5
6
Fish Hatchery
Depth to Water (feet)
7
9
11
13
15
17
10/1/16
10/29/16
11/26/16
12/24/16
1/21/17
2/18/17
3/18/17
4/15/17


Auto-Sampler Event 1: Oct 26 to Nov 2
KW183 Monitoring Well Data
Fluid Conductivity (µS/cm)
912
908
904
900
896
CDOM
7.4
7.35
7.3
7.25
7.2
7.15
CDOM inflection ~2:00 PM
KW183
Depth to Water (feet)
4
4.5
5
5.5
6
Fish Hatchery
Depth to Water (feet)
14
15
16
17
Sharp water-level rise ~noon
Hourly
Precip (in)
0.2
0.1
0
Rain starts 8:00 AM 10/26
10/25/16
10/26/16
10/27/16
10/28/16
10/29/16
10/30/16
10/31/16
11/1/16
11/2/16
11/3/16


Auto-Sampler Event 1: Oct 26 to Nov 2
Sampler YSI & Pathogen Data
Nitrate_N (mg/L)
7.2
6.8
6.4
6
5.6
5.2
Chloride (mg/L)
32
30
28
26
24
KW183
Depth to Water (feet)
4
4.5
5
5.5
6
Total Coliform
(MPN/10 L)
1000
100
10
1
0.1
Human Bacteroides
Bovine Bacteroides
Hourly
Precip (in)
0.2
0.1
0
10/25/16
10/26/16
10/27/16
10/28/16
10/29/16
10/30/16
10/31/16
11/1/16
11/2/16
11/3/16


Autosampler Collection Times
Door Sampler
KW183
Depth to Water (feet)
0
1
2
3
4
5
6
Fish Hatchery
Depth to Water (feet)
7
9
11
13
15
17
10/1/16
10/29/16
11/26/16
12/24/16
1/21/17
2/18/17
3/18/17
4/15/17


Door CO Auto-Sampler Event: Jan 16 to 27
Sampler YSI & Pathogen Data
Nitrate_N (mg/L)
Chloride (mg/L)
KW183
Depth to Water (feet)
Total Coliform
(MPN/10 L)
E. coli
Rotovirus
Precip (in)
Hourly Air
Temperature (F)
1/16/17
1/17/17
1/18/17
1/19/17
1/20/17
1/21/17
1/22/17
1/23/17
1/24/17
1/25/17
1/26/17
1/27/17

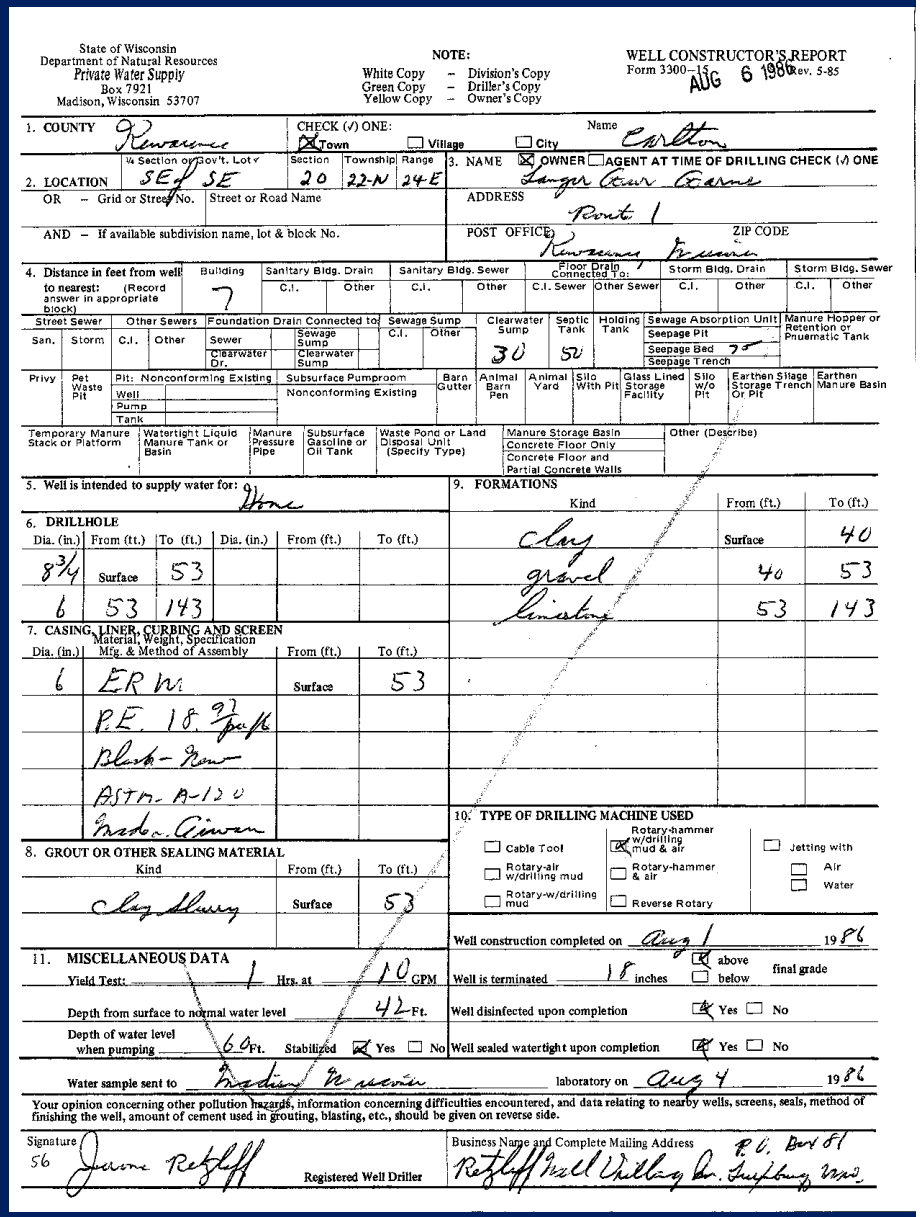
Summary

- Discrete Recharge Events
  - There have been 10 discrete recharge events from mid-Oct 2016 to late April 2017
  - Fall & Spring: > 1.0 inch rain in a 24-hour period
  - Winter: Days with above freezing and small amounts of rain
- Recharge Indicators (in addition to water-level rise)
  - Sharp inflections in fluid conductivity record
  - Sharp inflections in Nitrate-N, Chloride, and Dissolved Organic Matter (CDOM)
- Pathogen Transport
  - Total Coliform shows significant variability across recharge events
  - Have little data on virus transport (presumably due to lack of source term(s) in the vicinity of the auto-samplers)

Well Construction Reports

- Well Constructors' Reports
  - Have been required by the state since 1937
- WI Geological & Natural History Survey has records prior to 1988

  http://geodata.wgnhs.uwex.edu/well-viewer/
- DNR has online data for wells constructed since 1988
- http://dnr.wi.gov/topic/wells/



State of Wisconsin
Department of Natural Resources
Private Water Supply
Box 7921
Madison, Wisconsin 53707

NOTE:
White Copy – Division's Copy
Green Copy – Driller's Copy
Yellow Copy – Owner's Copy

WELL CONSTRUCTOR'S REPORT
Form 3300–15 Rev. 5-85
AUG 6 1986

1. COUNTY Kewaunee
CHECK (✓) ONE: ☒ Town ☐ Village ☐ City
Name Carlton

2. LOCATION ¼ Section or Gov't. Lot ✓ SE of SE
Section 20 Township 22-N Range 24-E
OR – Grid or Street No. Street or Road Name
AND – If available subdivision name, lot & block No.

3. NAME ☒ OWNER ☐ AGENT AT TIME OF DRILLING CHECK (✓) ONE
Langer Gear Garms
ADDRESS Route 1
POST OFFICE Kewaunee Wisconsin ZIP CODE

4. Distance in feet from well to nearest: (Record answer in appropriate block)
Building 7 | Sanitary Bldg. Drain C.I. Other | Sanitary Bldg. Sewer C.I. Other | Floor Drain Connected To: C.I. Sewer Other Sewer | Storm Bldg. Drain C.I. Other | Storm Bldg. Sewer C.I. Other
Street Sewer San. Storm | Other Sewers C.I. Other | Foundation Drain Connected to: Sewer Clearwater Dr. Sewage Sump Clearwater Sump | Sewage Sump C.I. Other | Clearwater Sump 30 | Septic Tank 50 | Holding Tank | Sewage Absorption Unit Seepage Pit Seepage Bed 75 Seepage Trench | Manure Hopper or Retention or Pnuematic Tank
Privy | Pet Waste Pit | Pit: Nonconforming Existing Well Pump Tank | Subsurface Pumproom Nonconforming Existing | Barn Gutter | Animal Barn Pen | Animal Yard | Silo With Pit | Glass Lined Storage Facility | Silo w/o Pit | Earthen Silage Storage Trench Or Pit | Earthen Manure Basin
Temporary Manure Stack or Platform | Watertight Liquid Manure Tank or Basin | Manure Pressure Pipe | Subsurface Gasoline or Oil Tank | Waste Pond or Land Disposal Unit (Specify Type) | Manure Storage Basin Concrete Floor Only Concrete Floor and Partial Concrete Walls | Other (Describe)

5. Well is intended to supply water for: Home

6. DRILLHOLE

Dia. (in.)	From (ft.)	To (ft.)	Dia. (in.)	From (ft.)	To (ft.)
8 3/4	Surface	53			
6	53	143			

7. CASING, LINER, CURBING AND SCREEN

Dia. (in.)	Material, Weight, Specification Mfg. & Method of Assembly	From (ft.)	To (ft.)
6	ERW	Surface	53
	P.E. 18.97 per ft		
	Black – New		
	ASTM-A-120		
	Madison Airway		

8. GROUT OR OTHER SEALING MATERIAL

Kind	From (ft.)	To (ft.)
Clay Slurry	Surface	53

9. FORMATIONS

Kind	From (ft.)	To (ft.)
Clay	Surface	40
gravel	40	53
limestone	53	143

10. TYPE OF DRILLING MACHINE USED
☐ Cable Tool ☒ Rotary-hammer w/drilling mud & air ☐ Jetting with ☐ Air ☐ Water
☐ Rotary-air w/drilling mud ☐ Rotary-hammer & air
☐ Rotary-w/drilling mud ☐ Reverse Rotary

Well construction completed on Aug 1 1986

11. MISCELLANEOUS DATA
Yield Test: 1 Hrs. at 10 GPM
Depth from surface to normal water level 42 Ft.
Depth of water level when pumping 60 Ft. Stabilized ☒ Yes ☐ No
Well is terminated 18 inches ☒ above ☐ below final grade
Well disinfected upon completion ☒ Yes ☐ No
Well sealed watertight upon completion ☒ Yes ☐ No

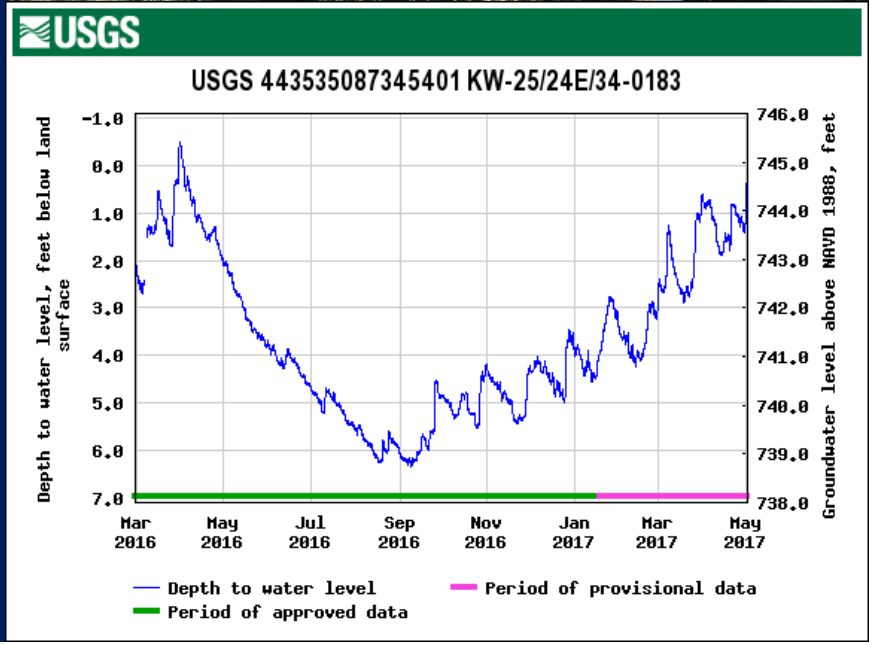
Water sample sent to Madison Wisconsin laboratory on Aug 4 1986

Your opinion concerning other pollution hazards, information concerning difficulties encountered, and data relating to nearby wells, screens, seals, method of finishing the well, amount of cement used in grouting, blasting, etc., should be given on reverse side.

Signature 56 Jerome Retzloff Registered Well Driller
Business Name and Complete Mailing Address Retzloff Well Drilling Inc. P.O. Box 81 Luxemburg Wis.

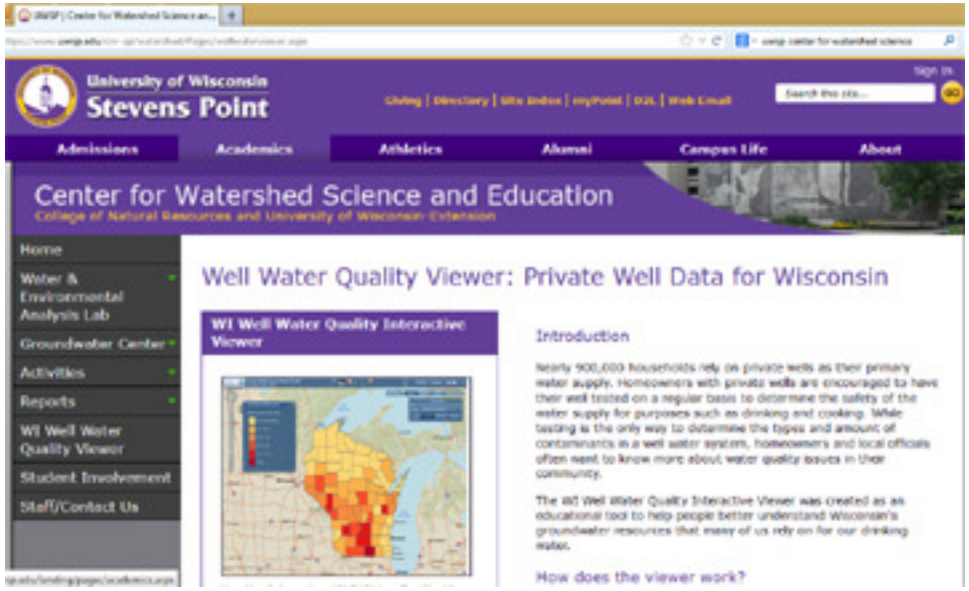
Water Levels in the Aquifer

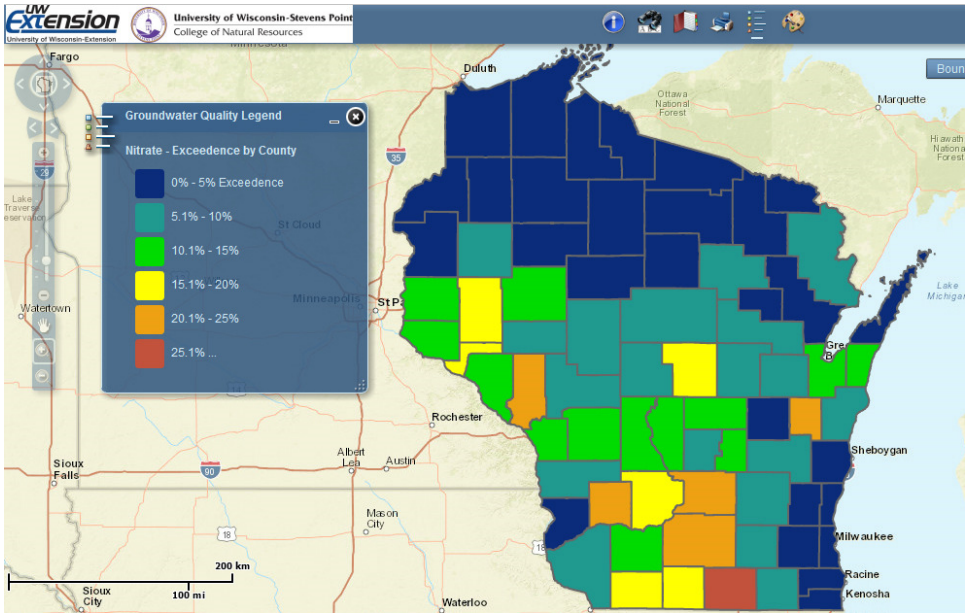
- The monitoring well used in our study is now part of the permanent USGS/WGNHS monitoring well network.
- Search for USGS Groundwater Watch Wisconsin
  - Click on the well in Kewaunee and you can see entire record
  - To look in more detail, click on current/historical observations
- Direct link
  - https://nwis.waterdata.usgs.gov/nwis/uv?site_no=443535087345401



Private Well Data

- UW Stevens Point Center for Watershed Science
  - Interactive program that allows you to view groundwater quality data at a variety of scales
  - Example percent of wells that exceed the standard for nitrate-N at county scale

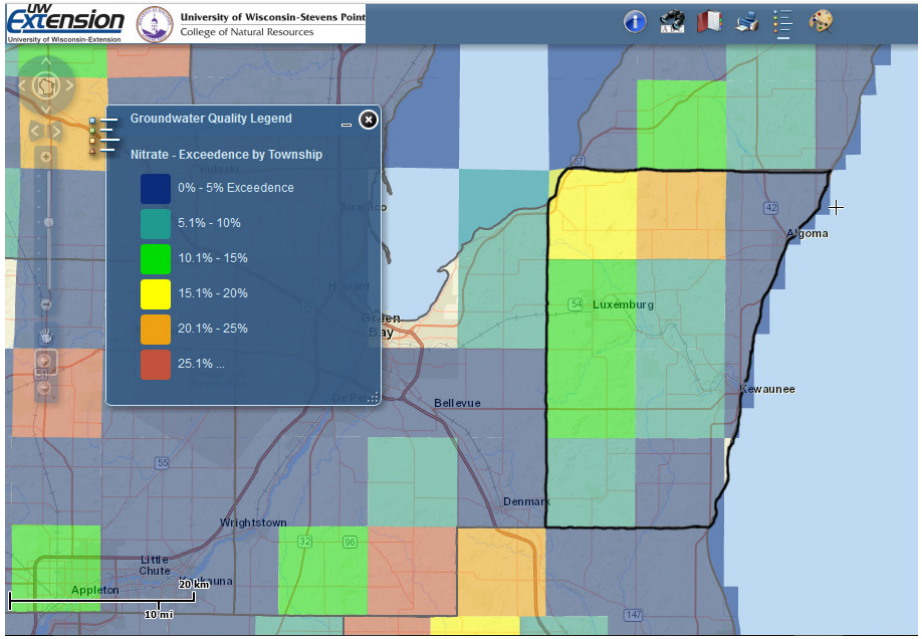




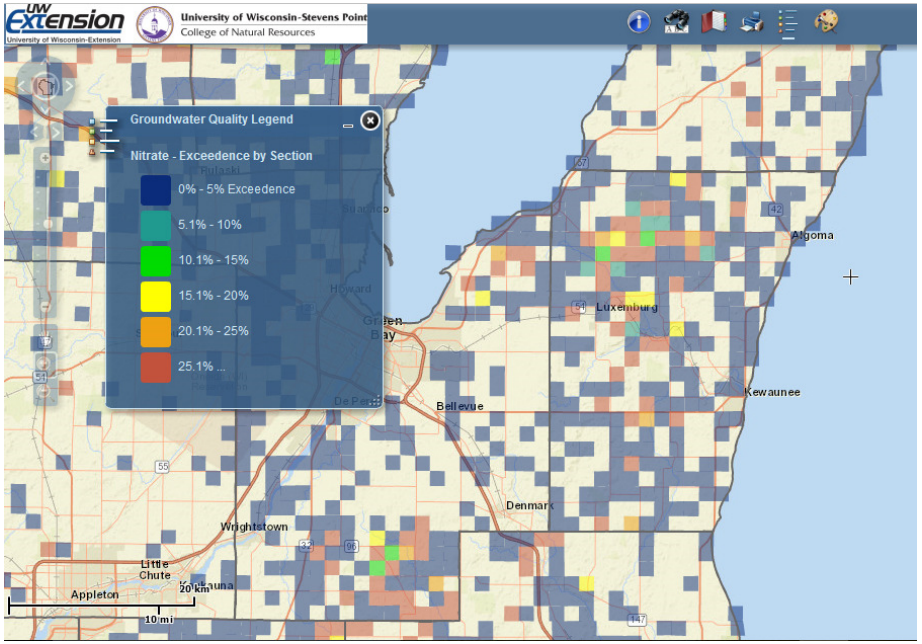
https://www.uwsp.edu/cnr-ap/watershed/Pages/wellwaterviewer.aspx

Private Well Data

- Township Scale



- Section Scale



Percent of wells exceeding the drinking water standard for Nitrate-N