Introduction To Groundwater Concepts

Important Concepts

Hydrologic Cycle

Aquifers

Hydraulic Conductivity

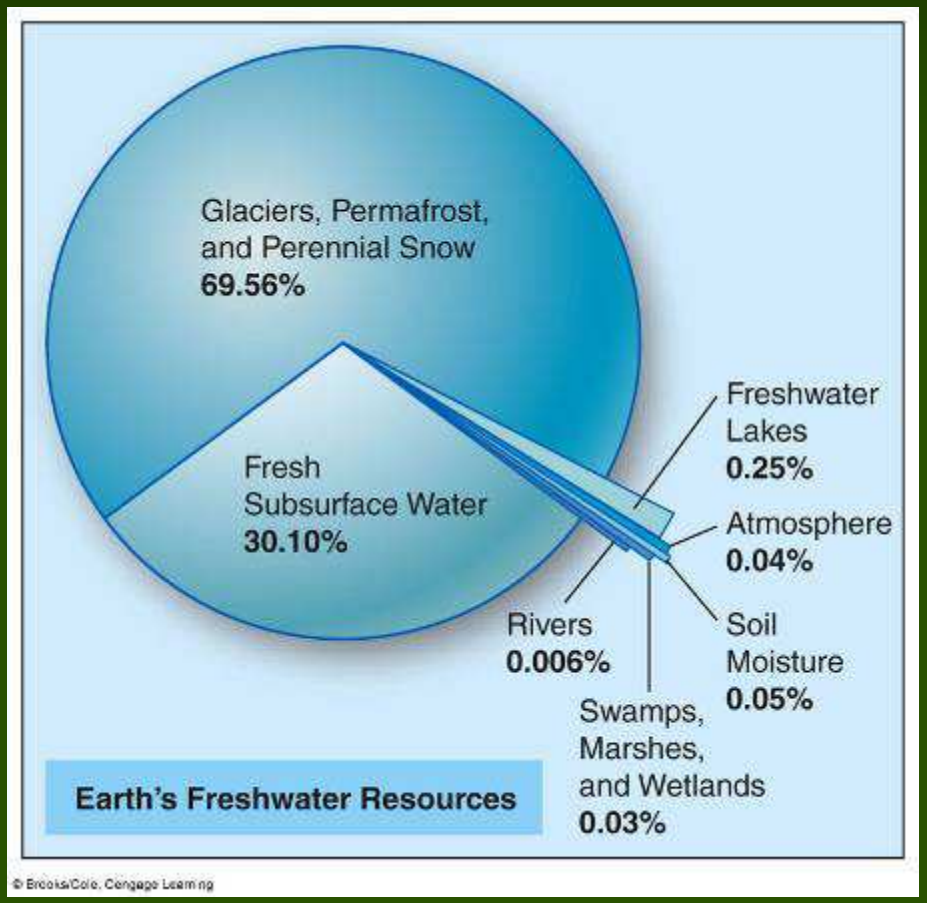
Head

Gradient

Drawdown

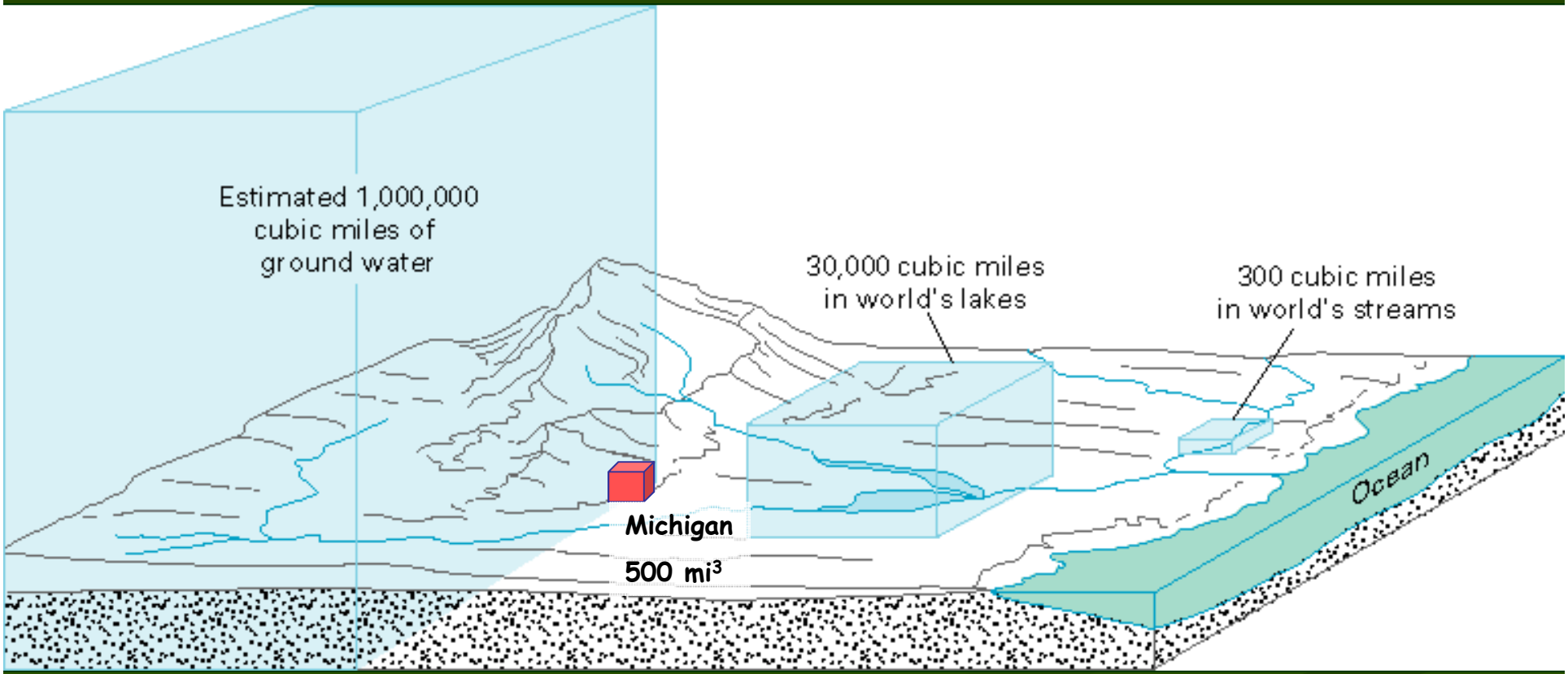
Capture

Earth's Freshwater Resources

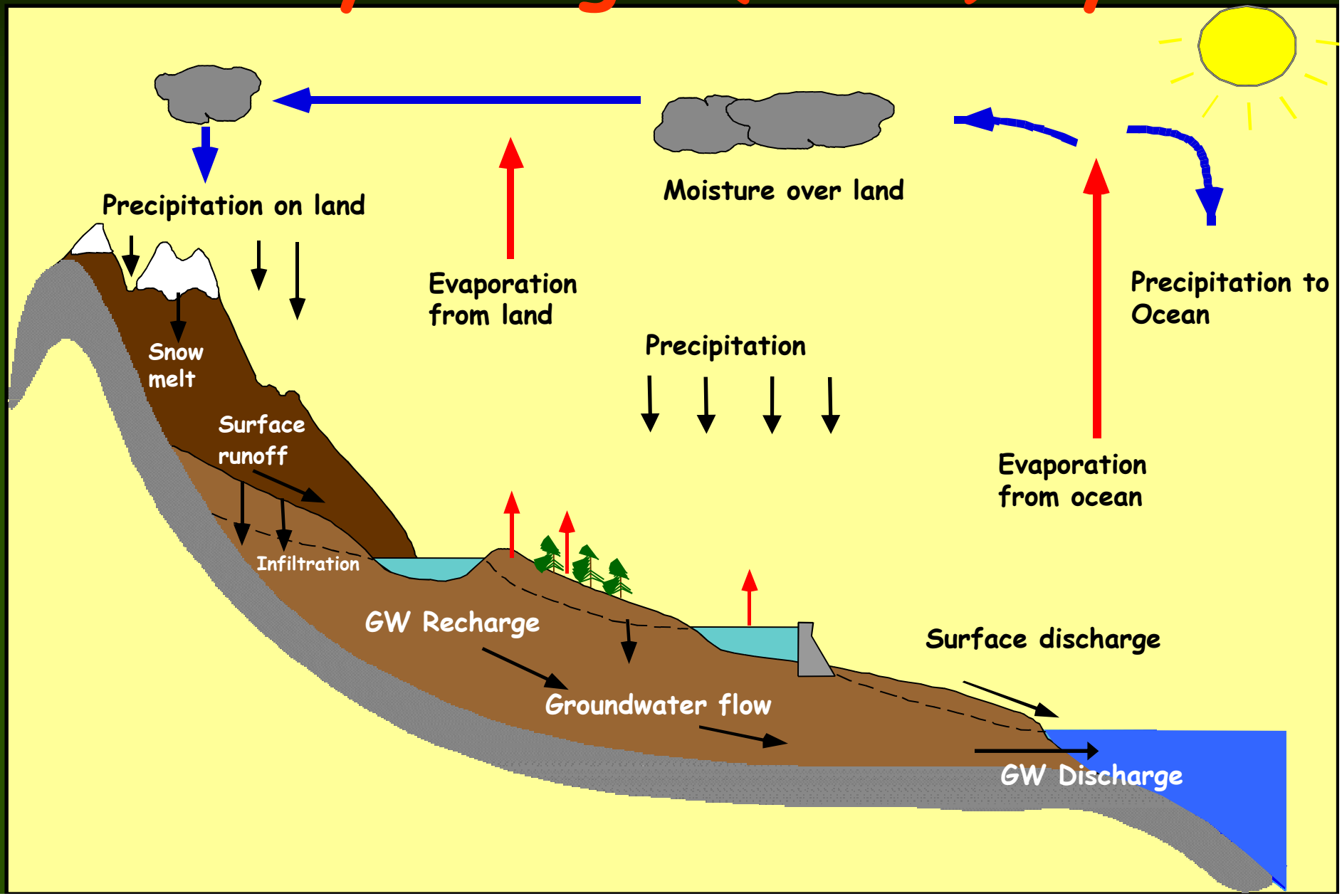


- 97% of Earth's water exists as salt water
- Of the remaining water (3%):
  - 69.6% glaciers, permafrost, and snow
  - 30.1% subsurface water
  - <1% rivers, lakes, swamps, wetlands, atmosphere

Earth's *liquid* fresh water resources



The Hydrologic (Water) Cycle



Experts' shocking revelation:

EARTH'S WATER SUPPLY CAME FROM DINOSAUR PEE

Every drop of water on Earth used to be urine — and 99.9 percent of it was once dinosaur pee-pee!

That's the fascinating finding of U.S. researcher Dr. Milton R. Grillingham, who says animals have drunk and fouled our water supply since life began.

"There's just no getting around it — every drop of water you drink has been drunk before and passed as urine," the New York City scientist told reporters. "And the overwhelming majority of water on the planet has passed through one of the dinosaurs that roamed the Earth millions of years ago.

Dr. Milton R. Grillingham

"When you realize that one pit stop by a brontosaurus could take 50 minutes and fill a small, in-ground swimming pool, that's not too hard to understand."

Dr. Grillingham's research confirms the findings of South African researcher Dr. Robert Johns, who used complex mathematical formulas and computer models to determine that all our water has been drunk before — and that most of it has been drunk many times.

"The dinosaurs did most of the damage early on, but now humans are certainly fouling up their fair share," the Cape Town researcher stated. "The average human being produces one gallon of urine a day and with five billion people on this planet, that can really add up.

"The bottom line is that our water isn't as pure as we like to think."

But experts in the United States say the fact that all our water was once urine doesn't mean it's not safe to drink.

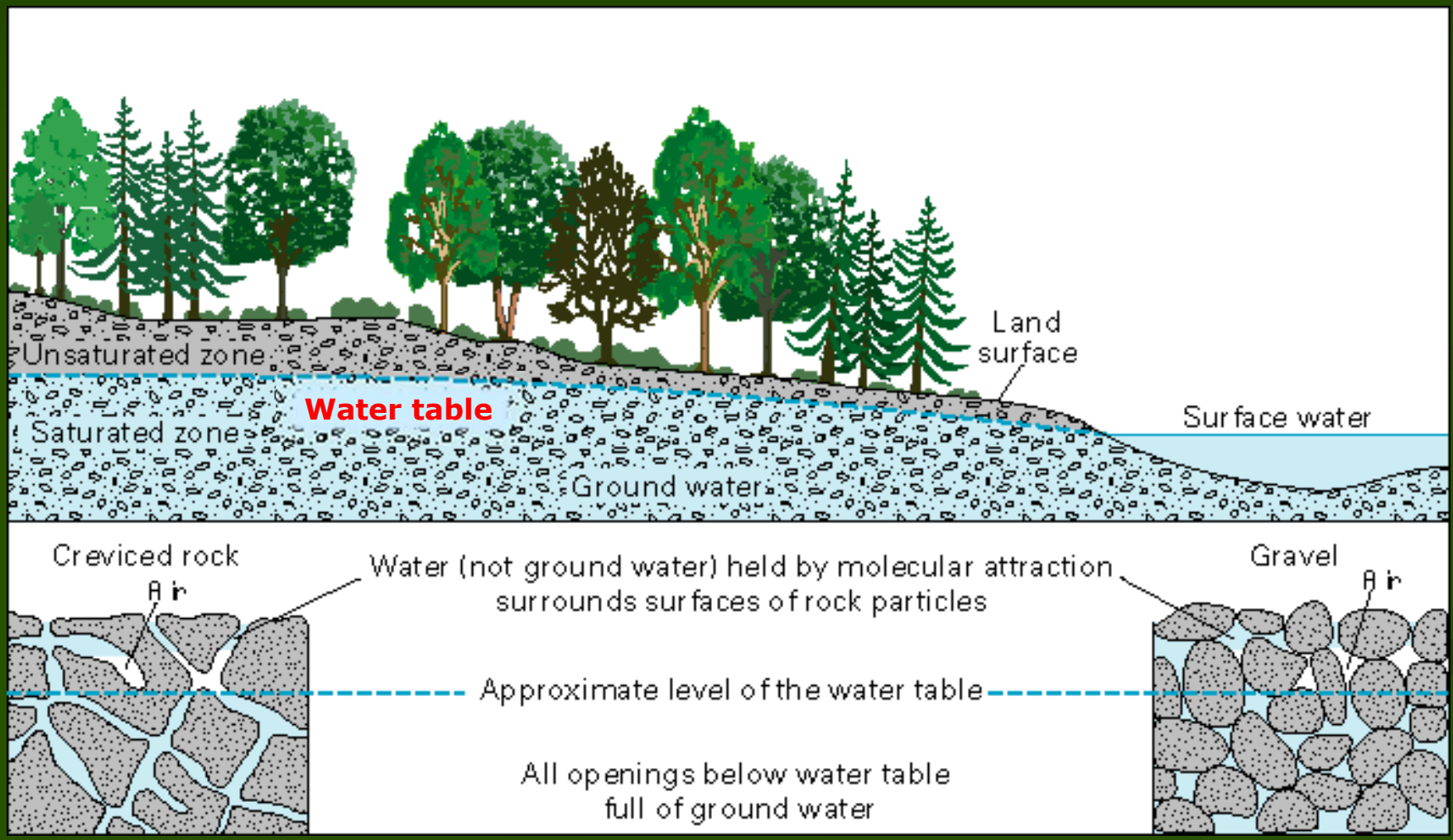
"People in more backward countries might have reason to worry, but in this country our water supply is tested regularly and for the most part has been found safe — whether it was once dinosaur urine or not," said one American health official.

Water Resources

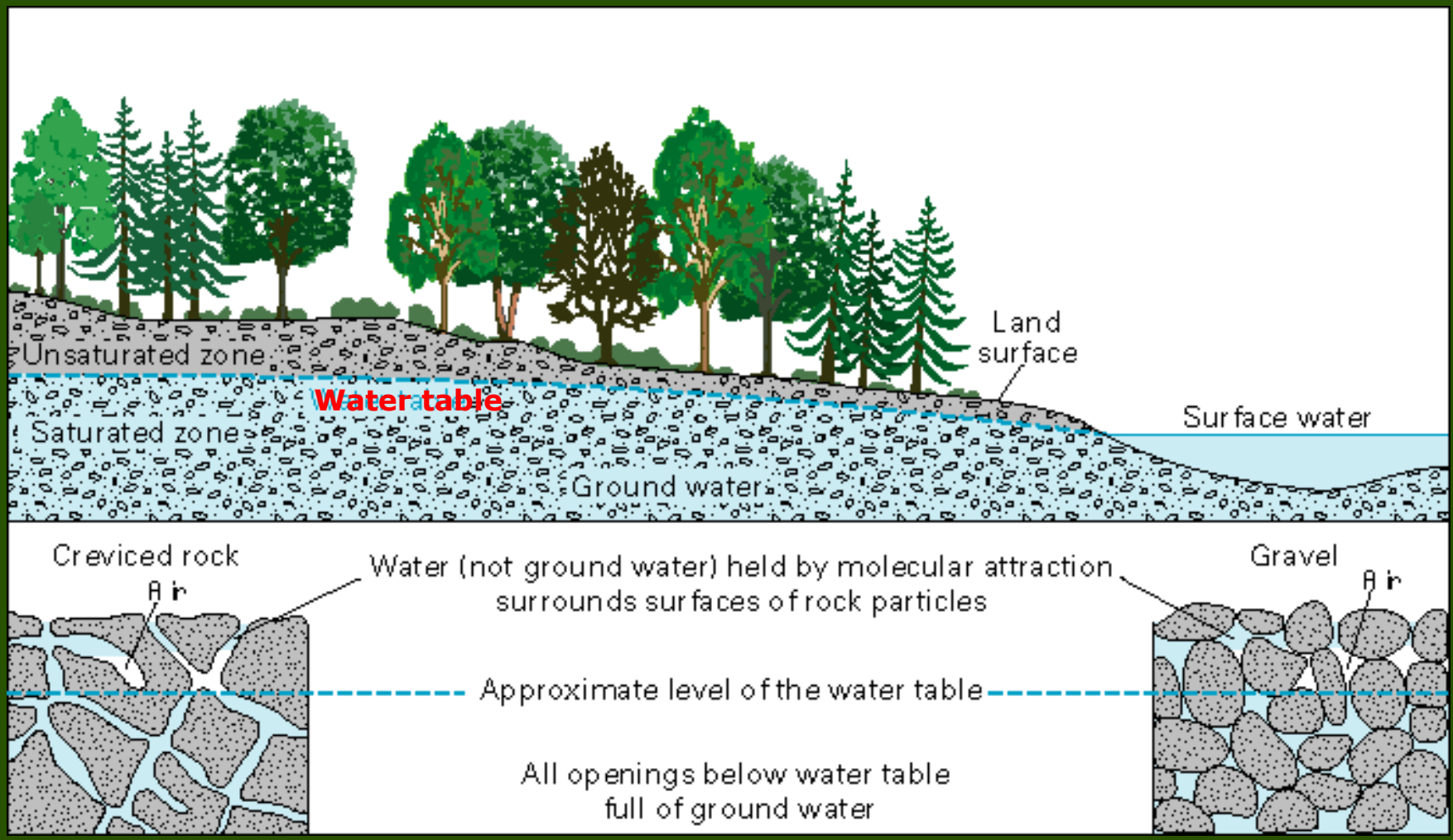
"We forget that the water cycle and the life cycle are one"

- Jacques Cousteau

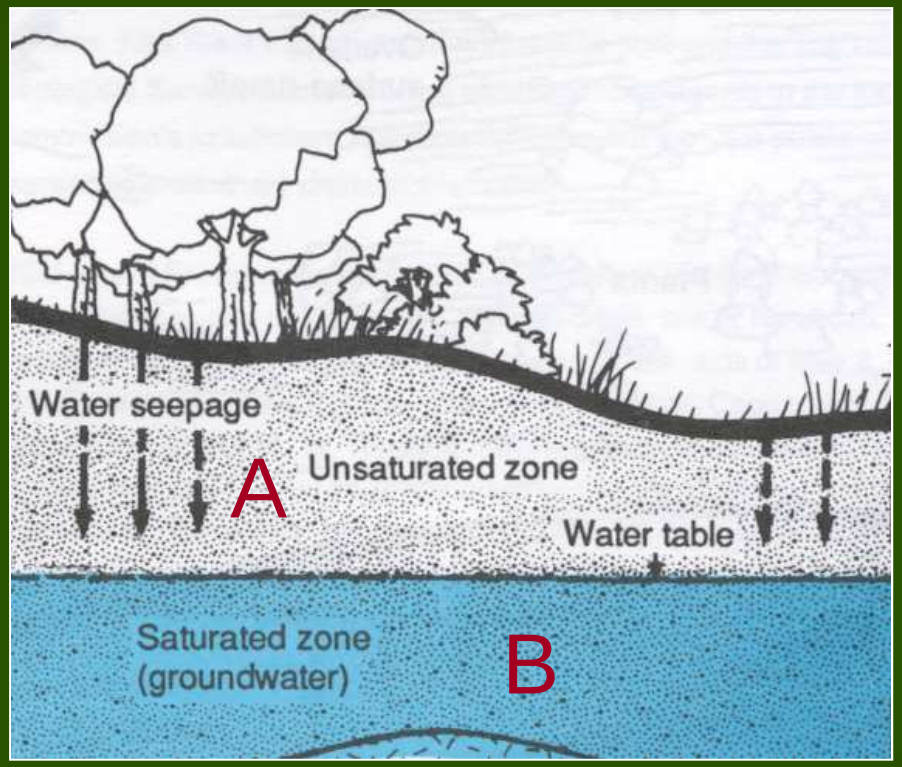
The Nature of Underground Water



The Nature of Underground Water



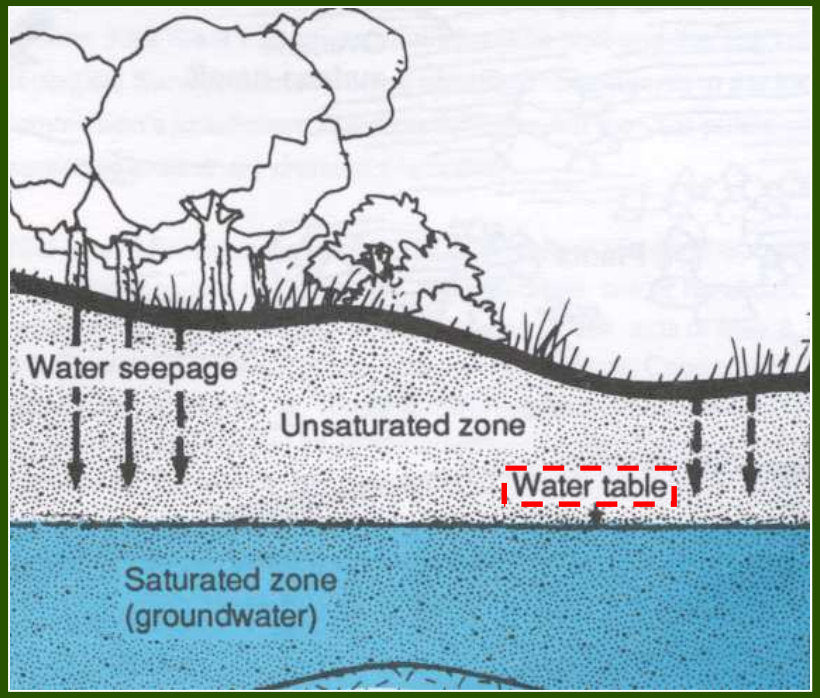
The Subsurface Can Be Divided Into Two Zones



A = The Unsaturated Zone

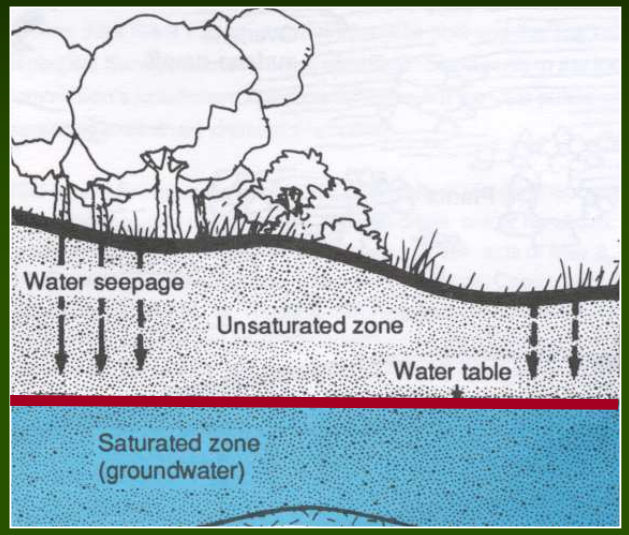
B = The Saturated Zone

The Water Table



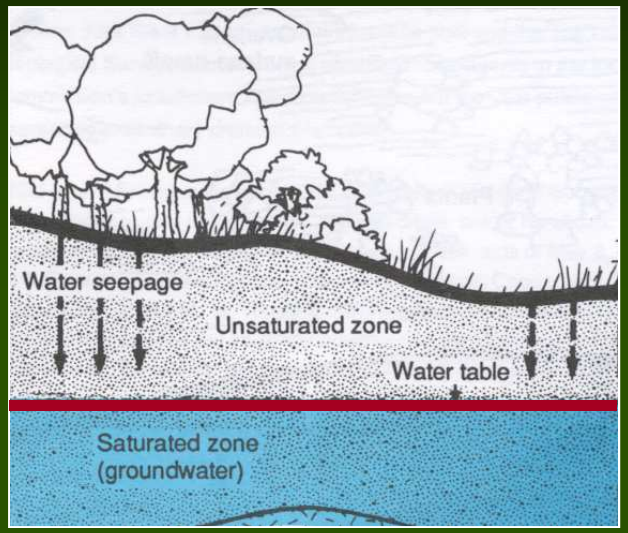
…the boundary between the unsaturated (aerated) and saturated zone

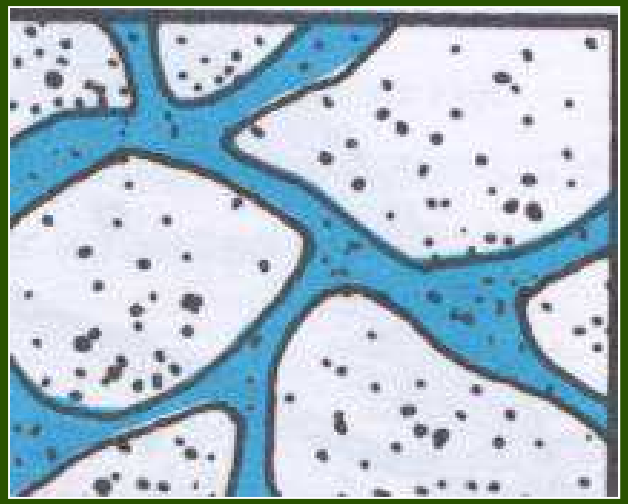
The Unsaturated Zone



- Zone between the land surface and the water table.
- Subsurface material has pore spaces between grains.
- In the unsaturated zone these pore spaces are occupied by both air and water.

Saturated Zone



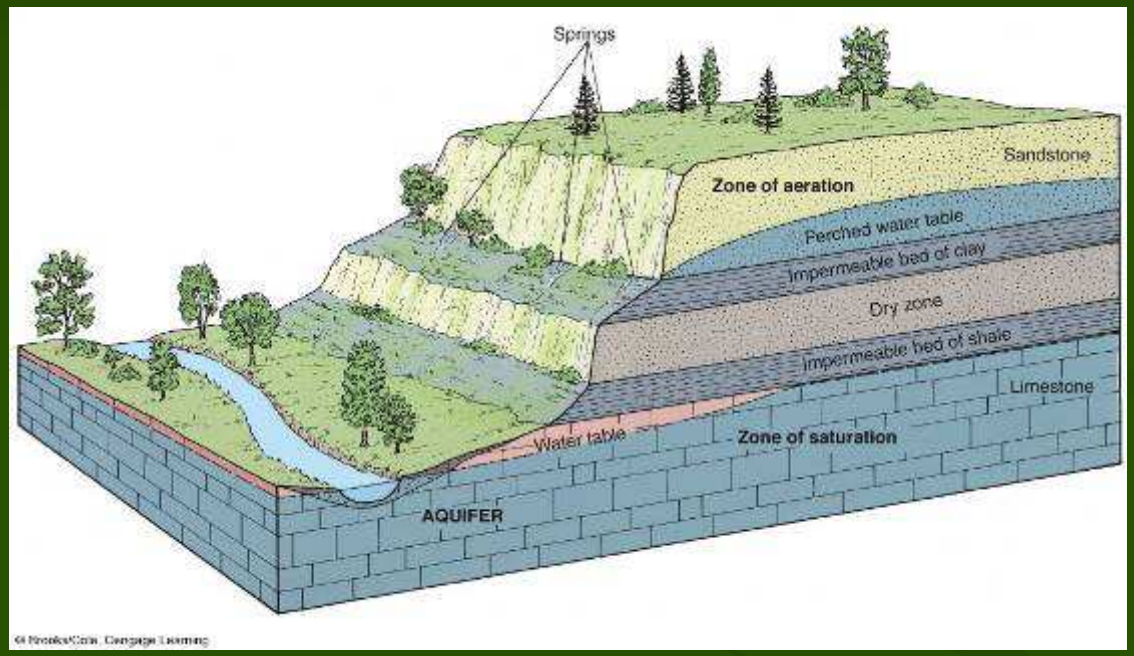


- Zone underneath the water table
- All pore spaces are filled completely with water
- The water flows both horizontally and vertically
- This is **groundwater**

Groundwater

16.1 The Nature of Underground Water

- Aquifer
- Aquiclude
- Perched water table
- Springs

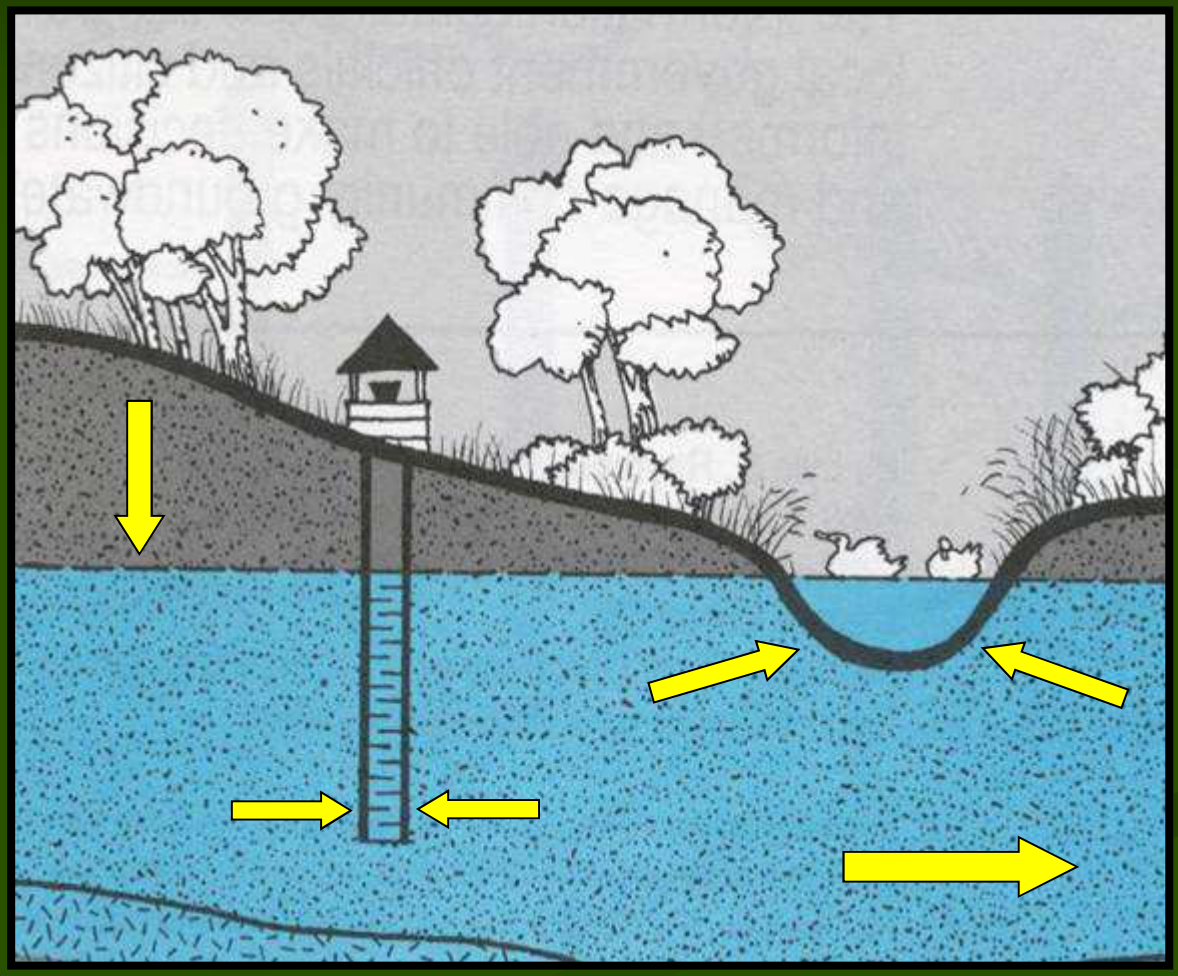


Groundwater

Groundwater is present in the pores and fractures in geologic formations ("Aquifers") below the land surface – NOT RIVERS.

Precipitation is the source of groundwater recharge.

Groundwater moves through the pores and fractures in geologic formations toward surface water, other watersheds, or pumping wells.



Underground Rivers

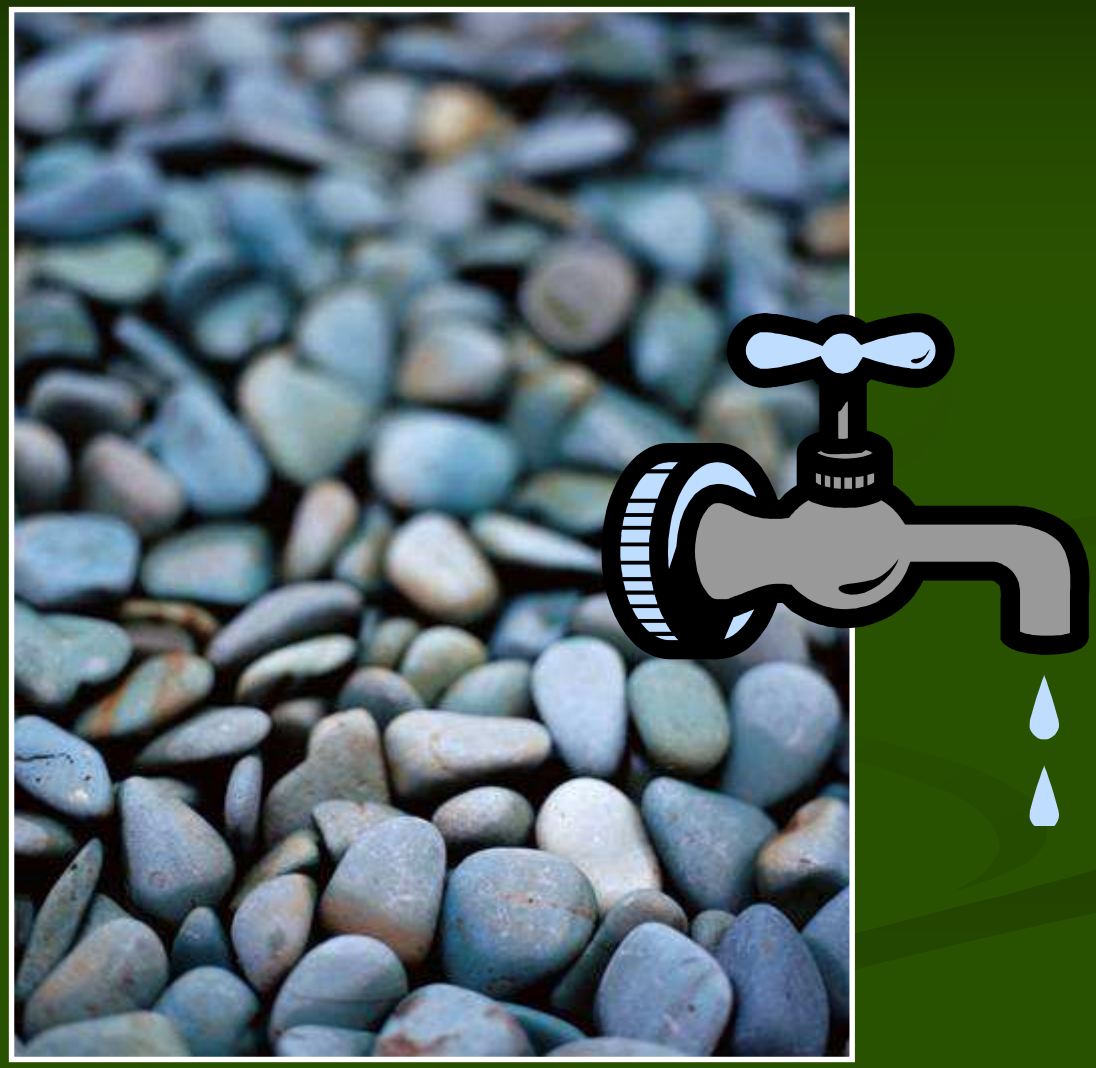
They Do Exist, But……

Important Concepts

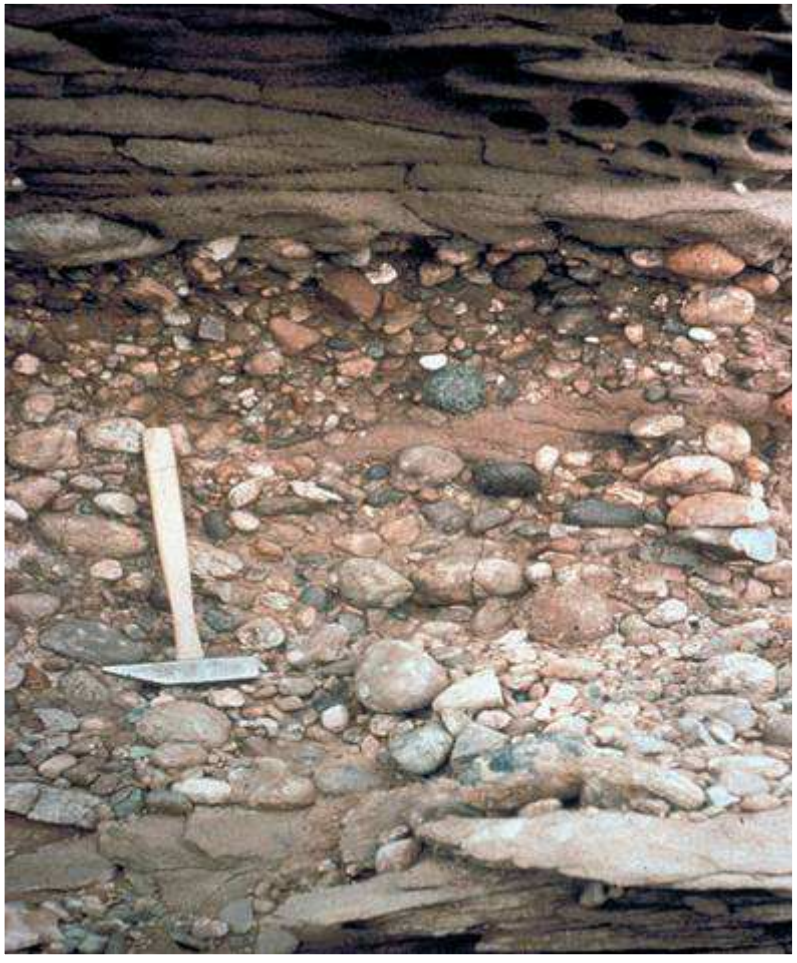
Hydrologic Cycle
Aquifers
Hydraulic Conductivity
Hydraulic Head
Hydraulic Gradient
Drawdown
Capture

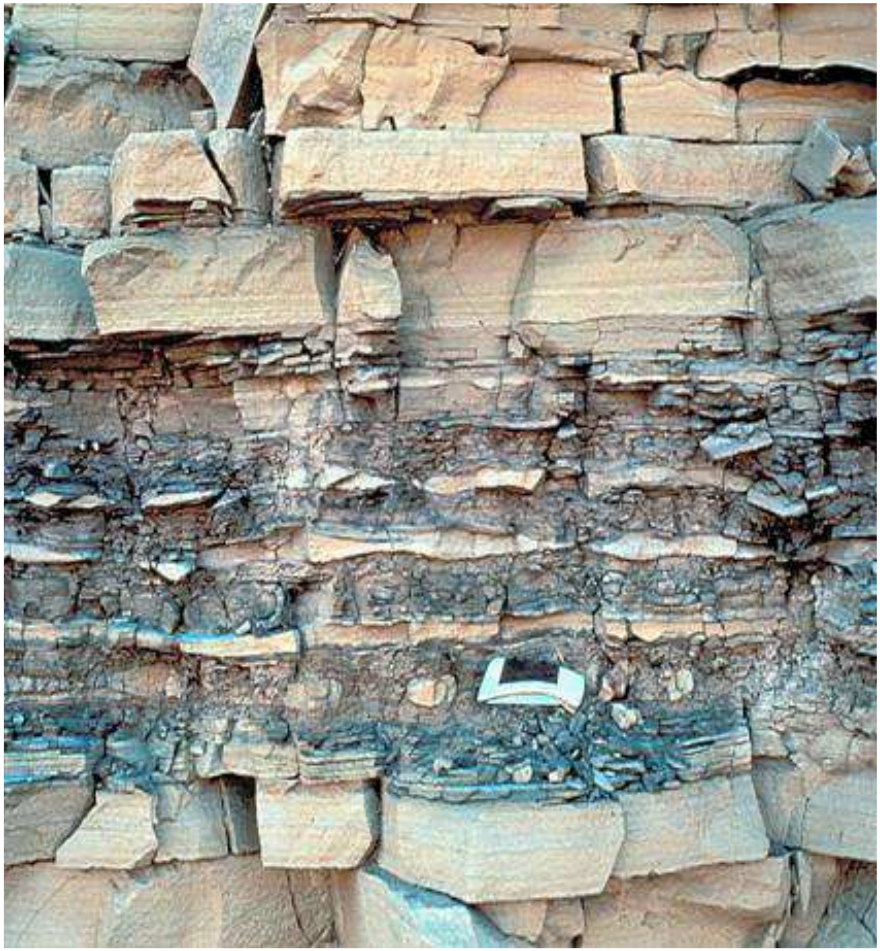
Aquifers

- **Definition:** A geological unit which can store and supply significant quantities of water.
- Depends on local geology.



GW Flow Through Pores



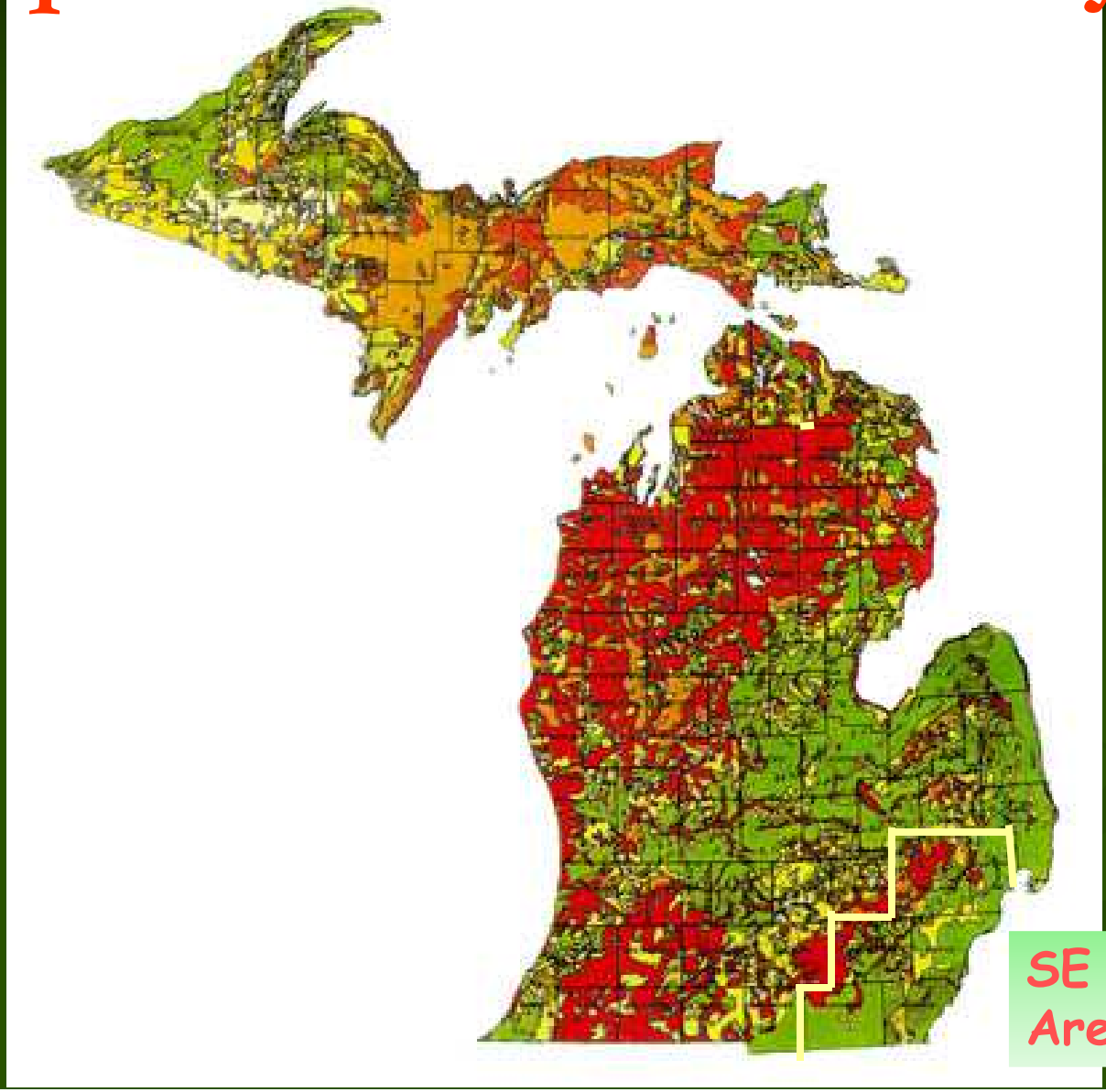


Michigan Aquifers

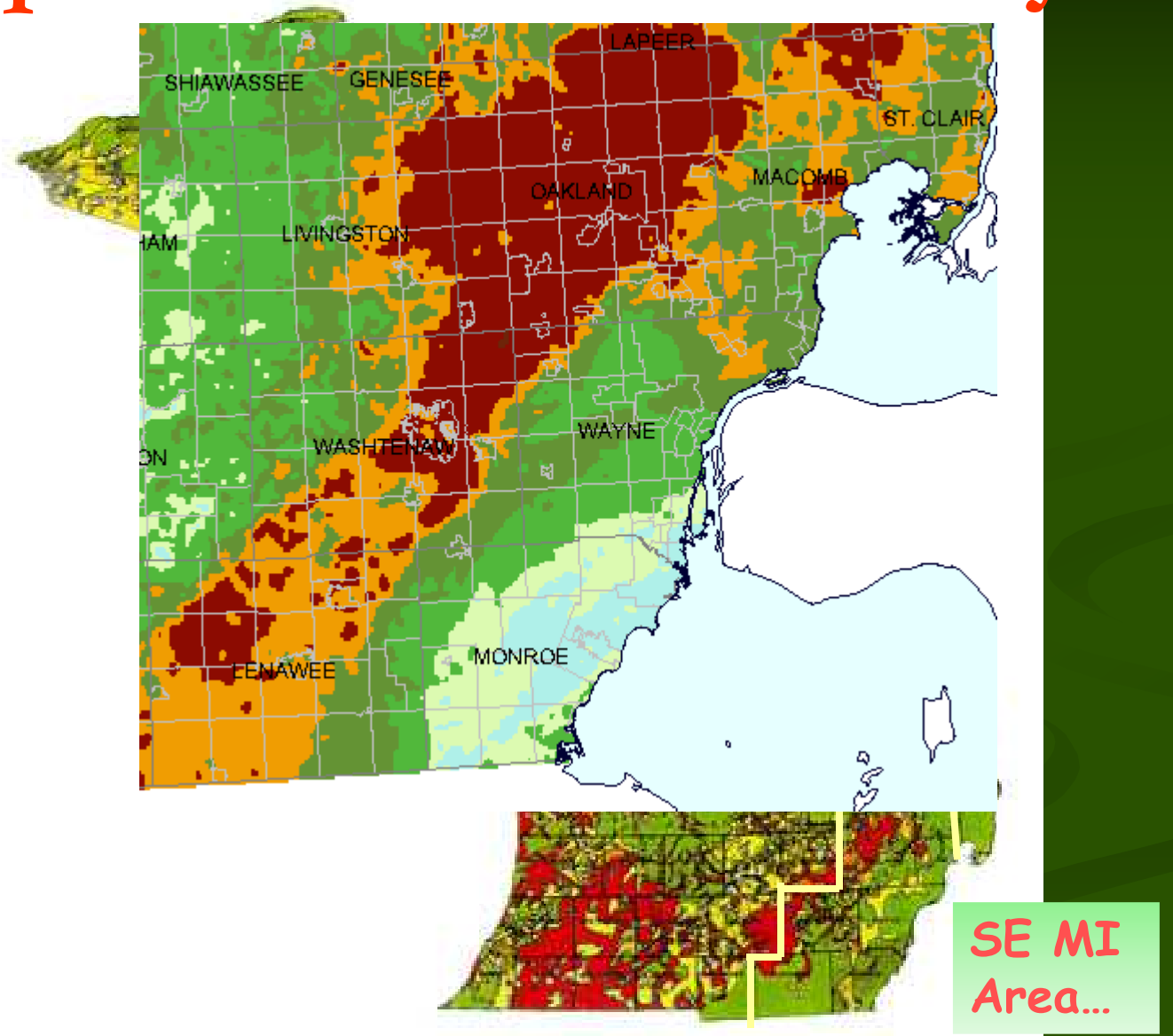
Principal aquifers in Michigan by sediment/rock type:

- Glacial (a.k.a. 'glacial drift')
  - Sand and Gravel
- Bedrock (a.k.a. 'rock')
  - Sandstone
  - Limestone and/or Dolomite
  - Igneous & Metamorphic (Western U.P.)

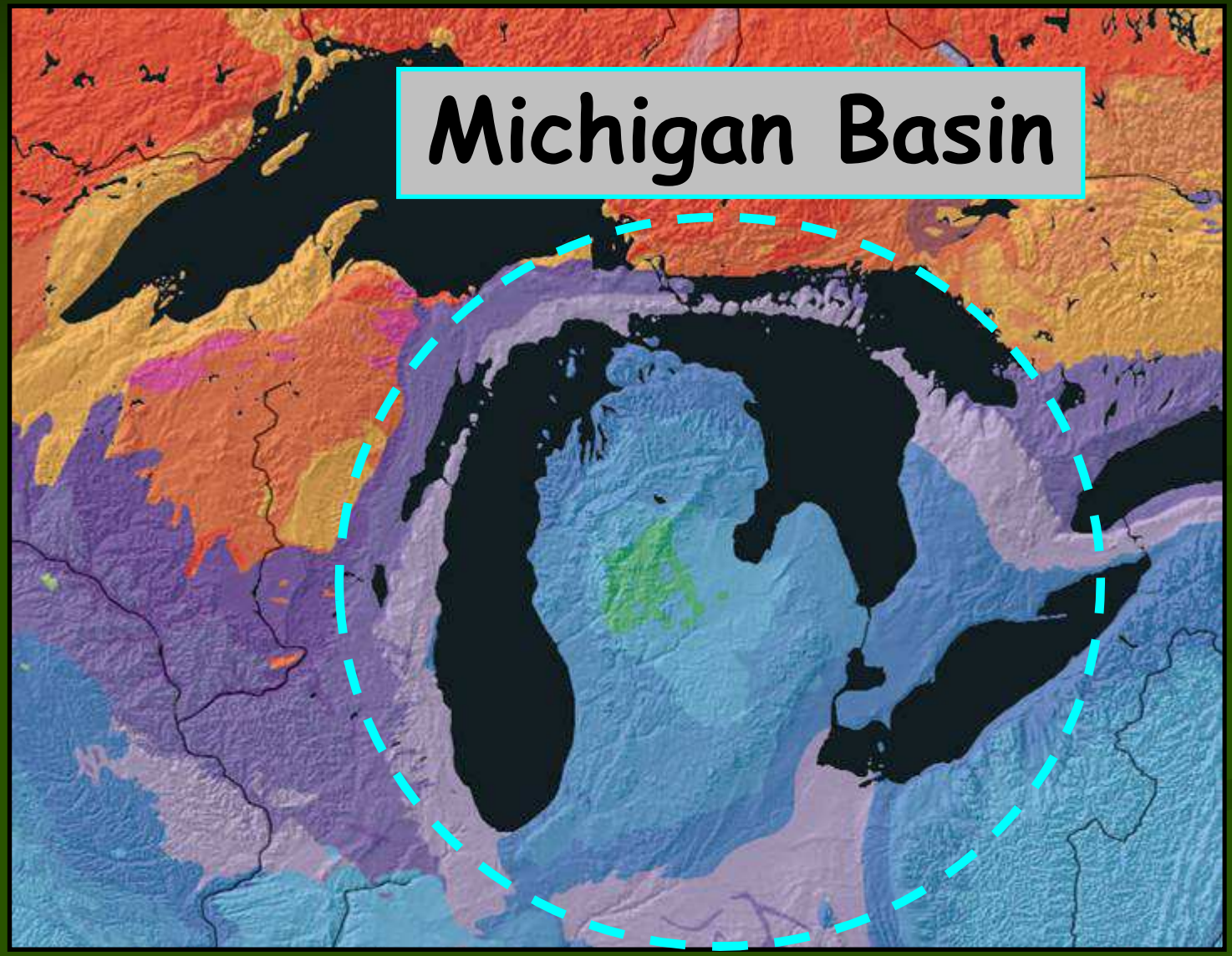
Aquifer Vulnerability



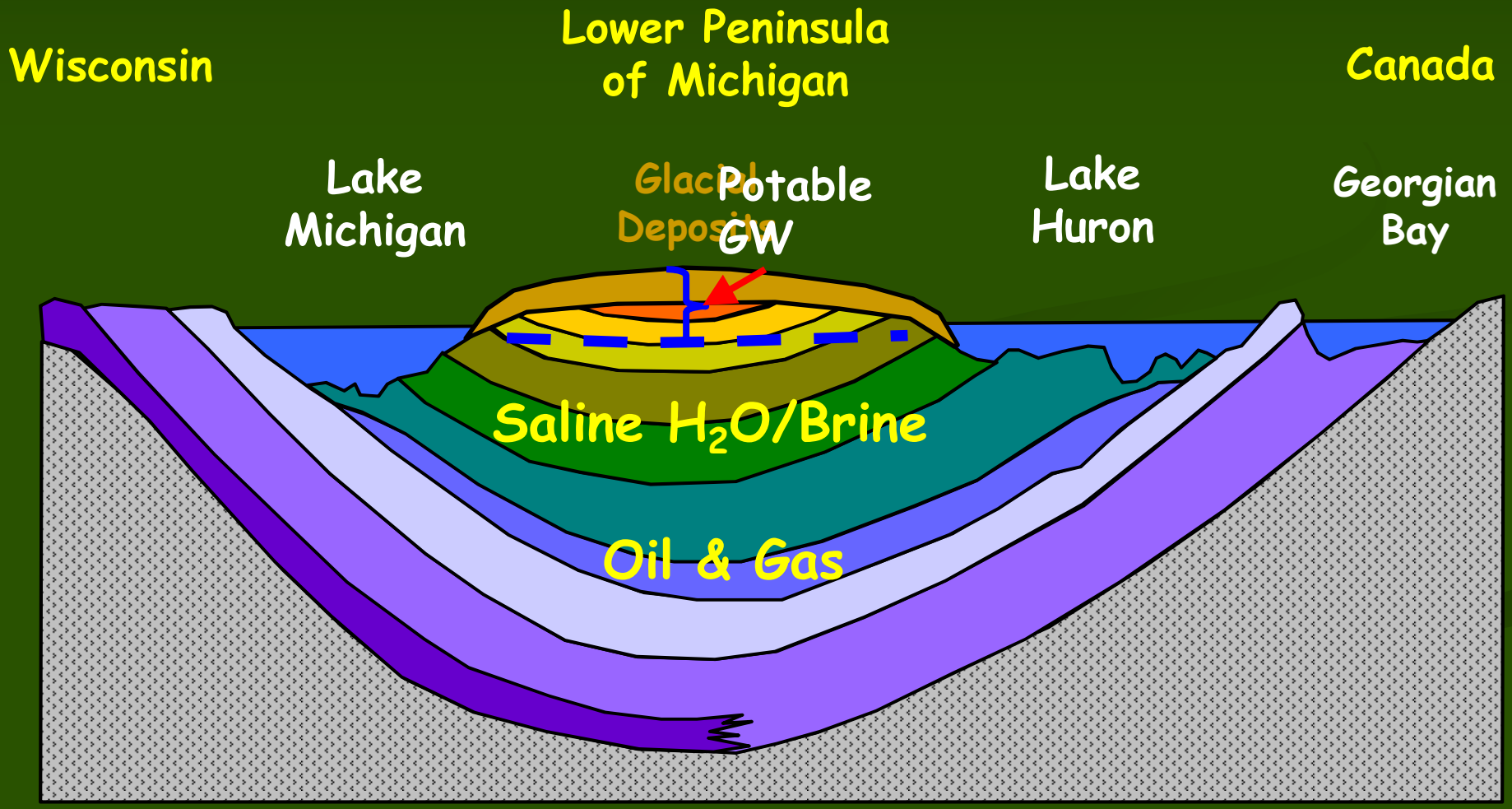
Aquifer Vulnerability



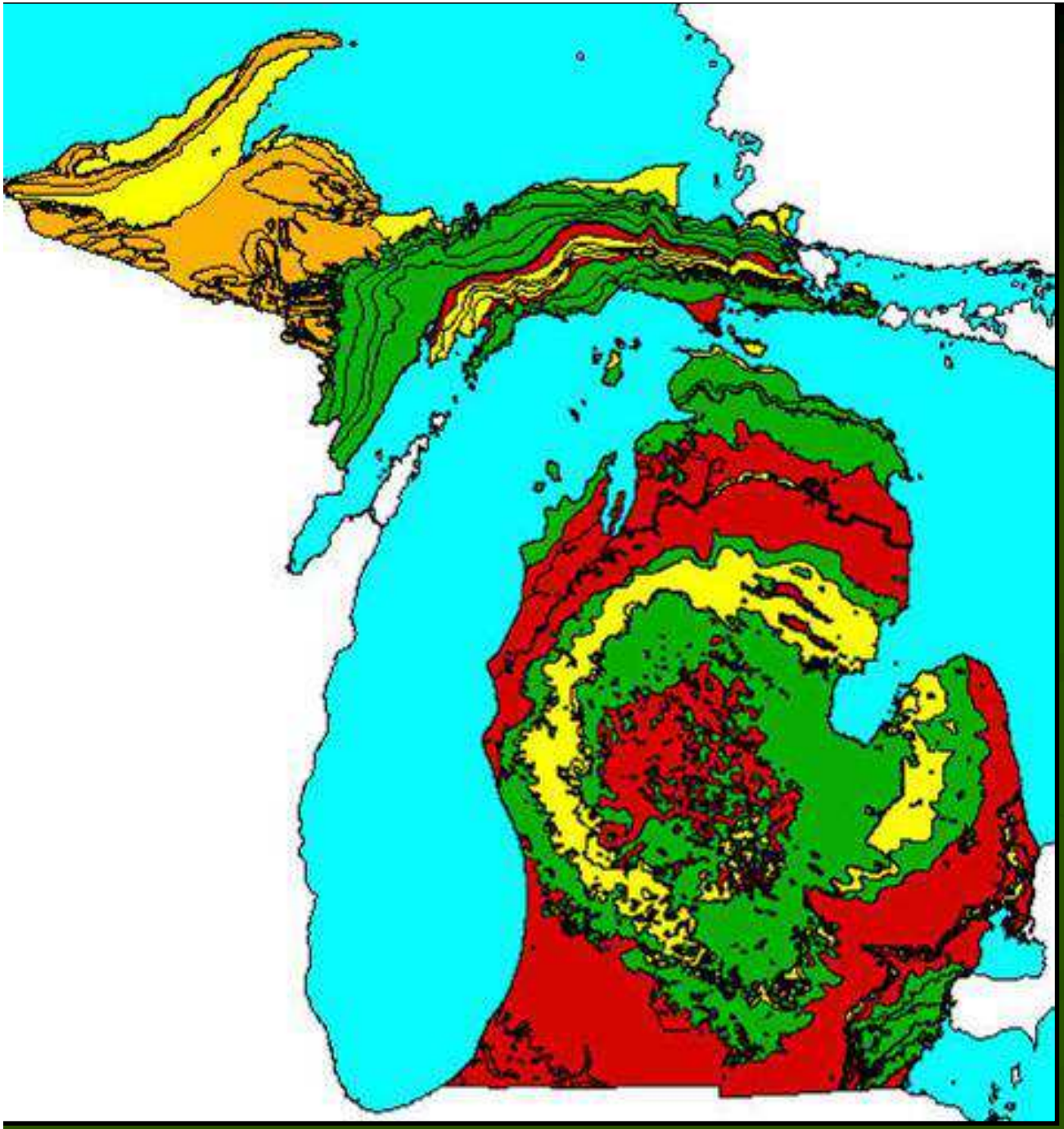
Michigan Bedrock Geology



Hydrogeologic Cross Section



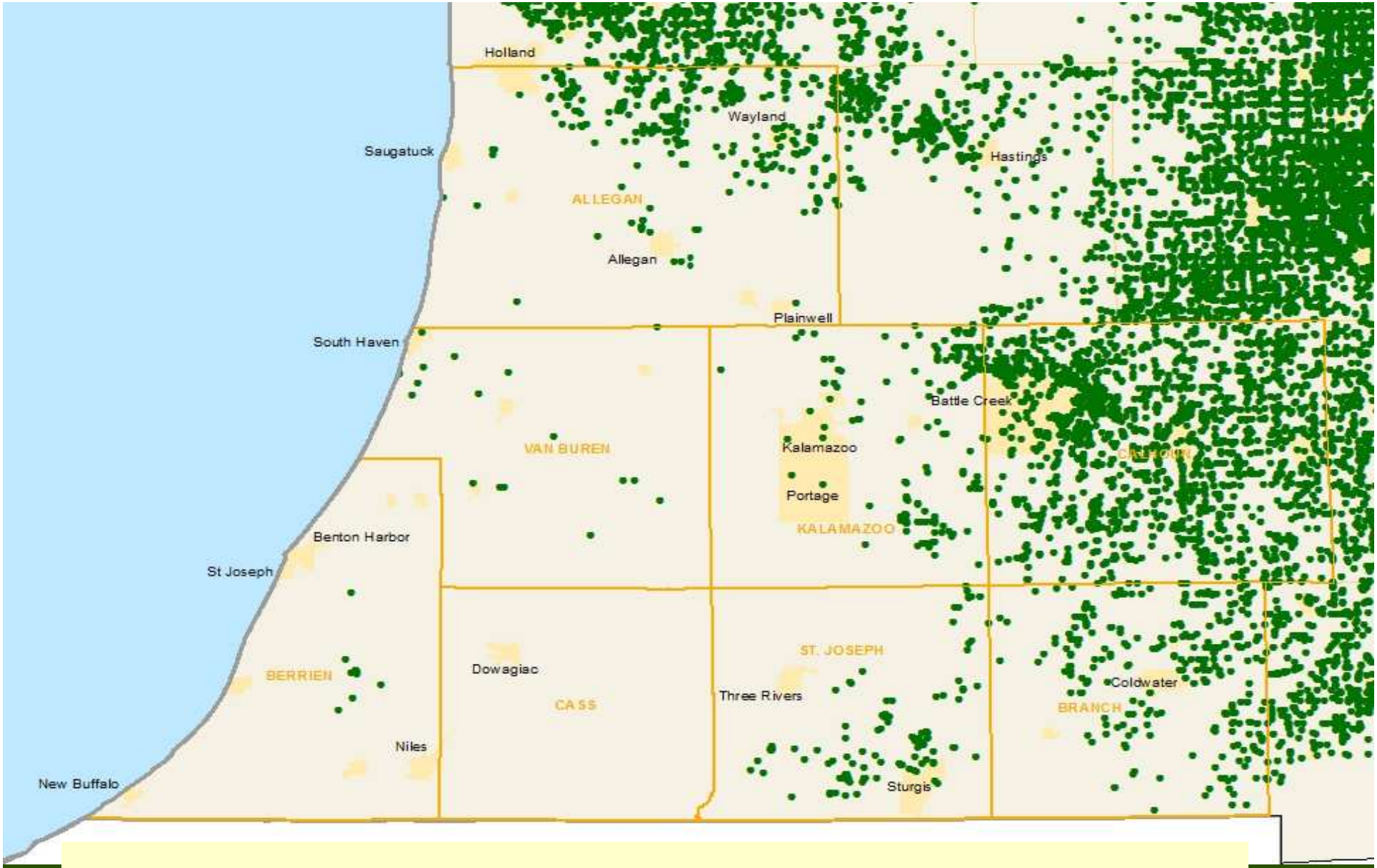
Bedrock Aquifers



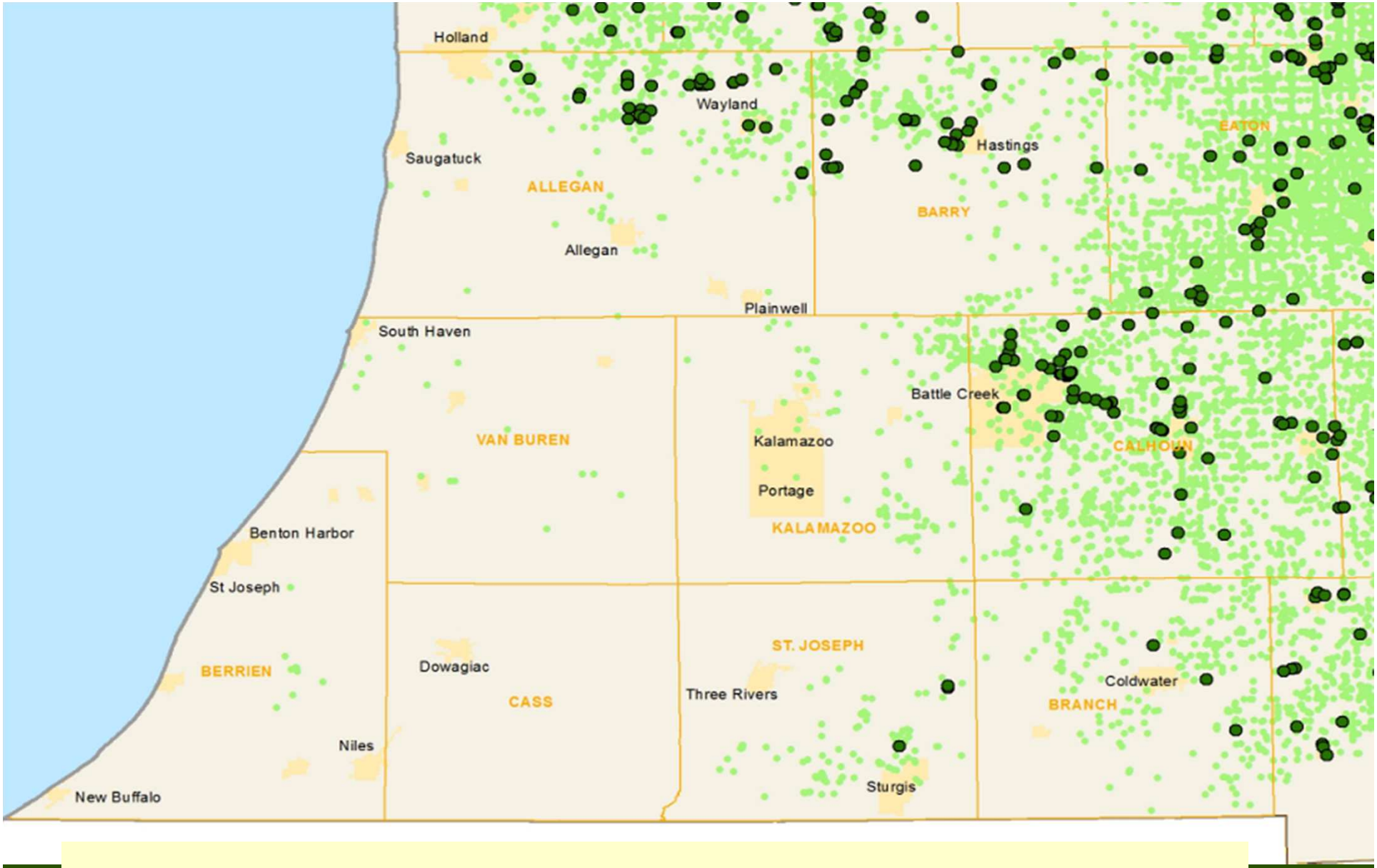
Michigan Bedrock Aquifers

- "Good"
- "Marginal Sedimentary"
- "Marginal Crystalline"
- "Not an Aquifer"

* Saline GW/Brine at depth

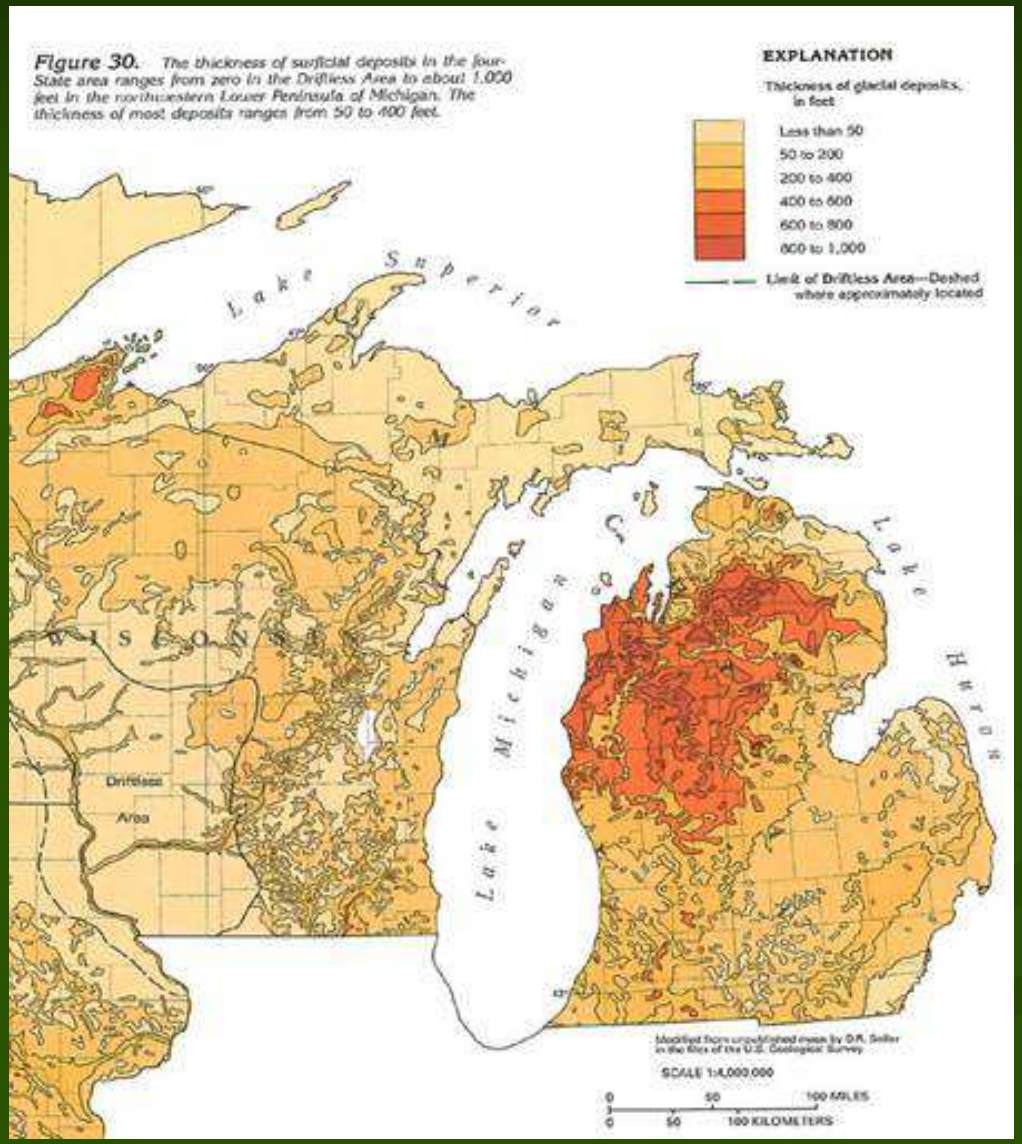


SW Michigan Bedrock Wells

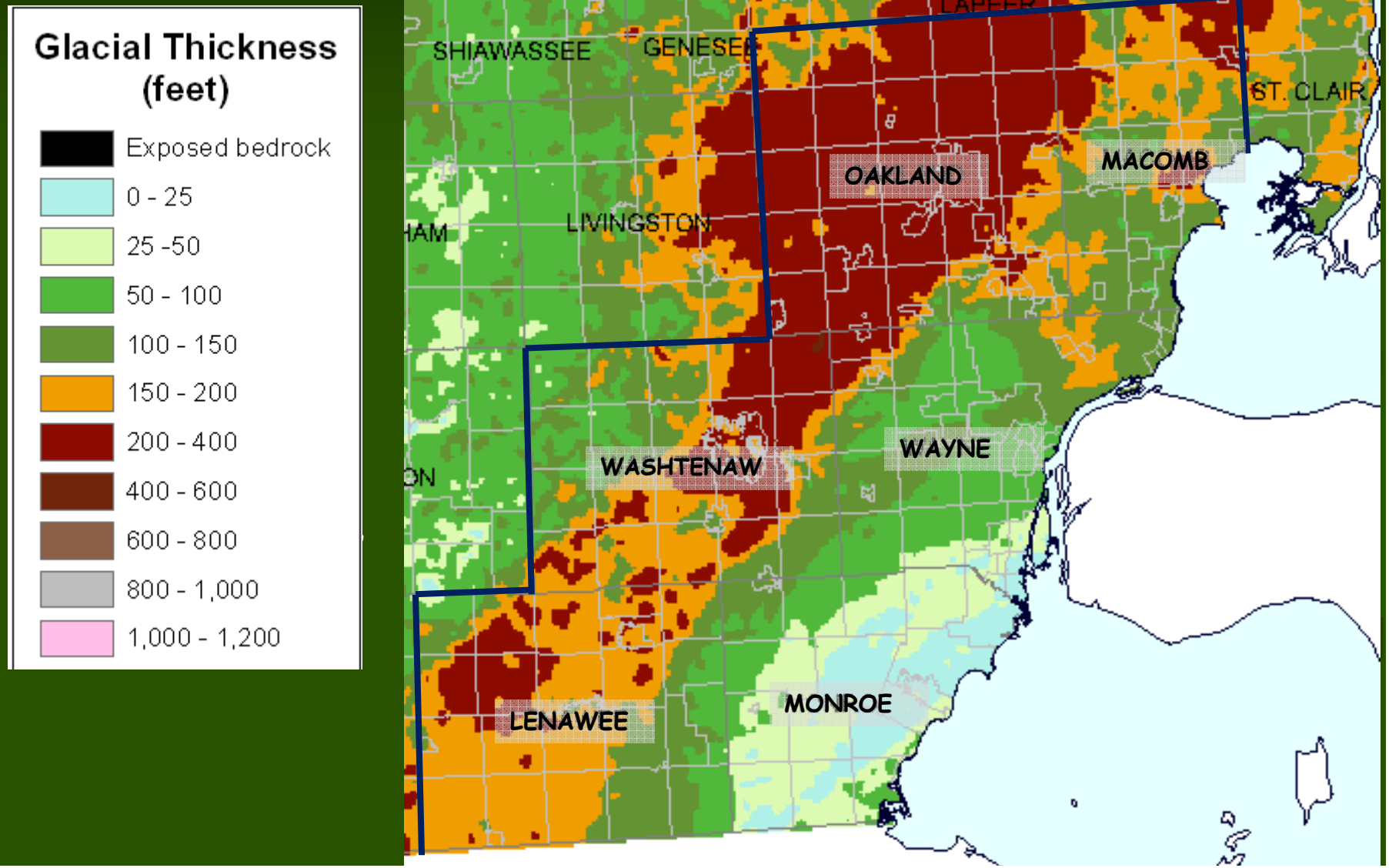


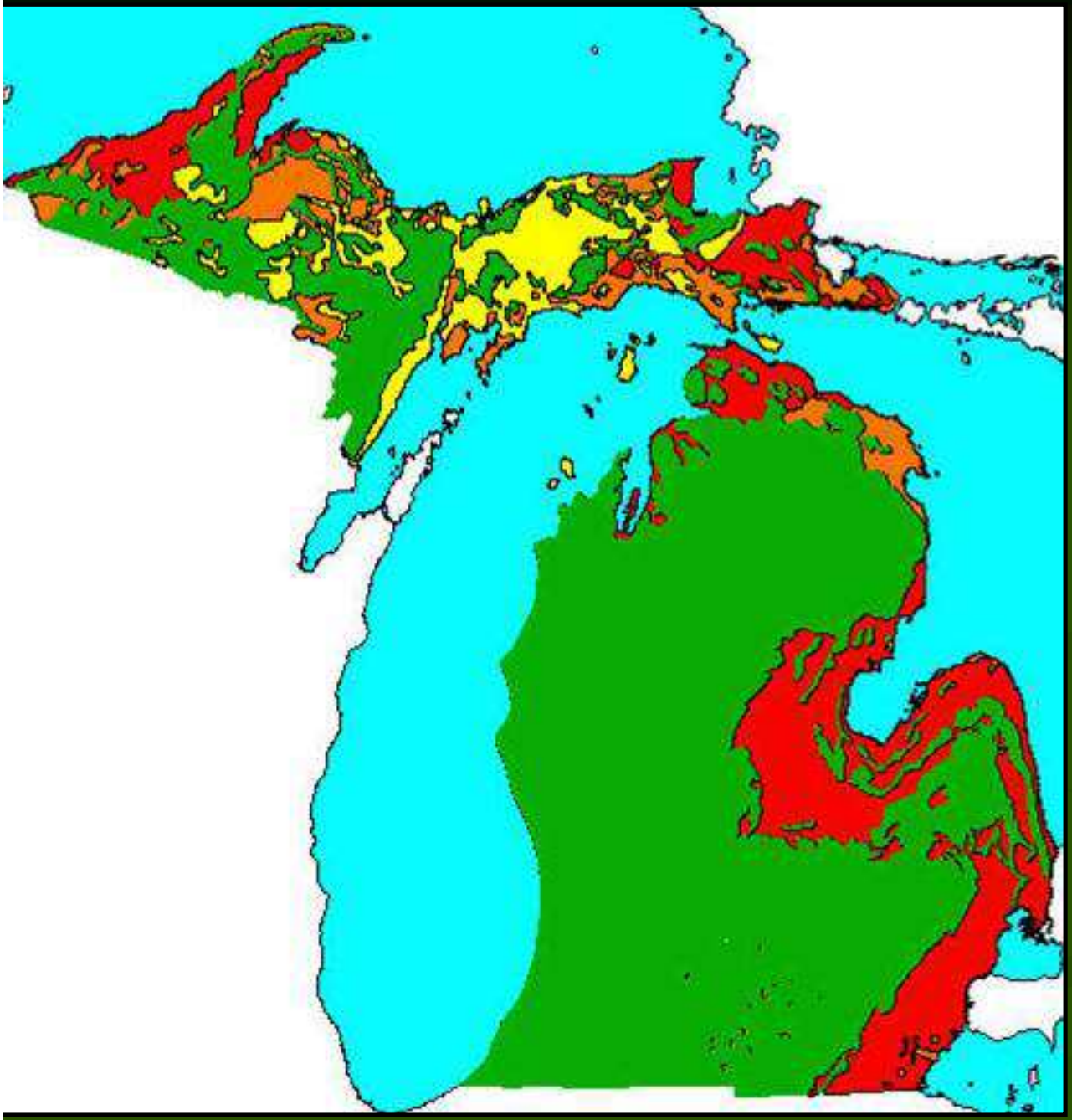
Public Supply Bedrock Wells

GLACIAL DRIFT THICKNESS



GLACIAL DRIFT THICKNESS SE Michigan

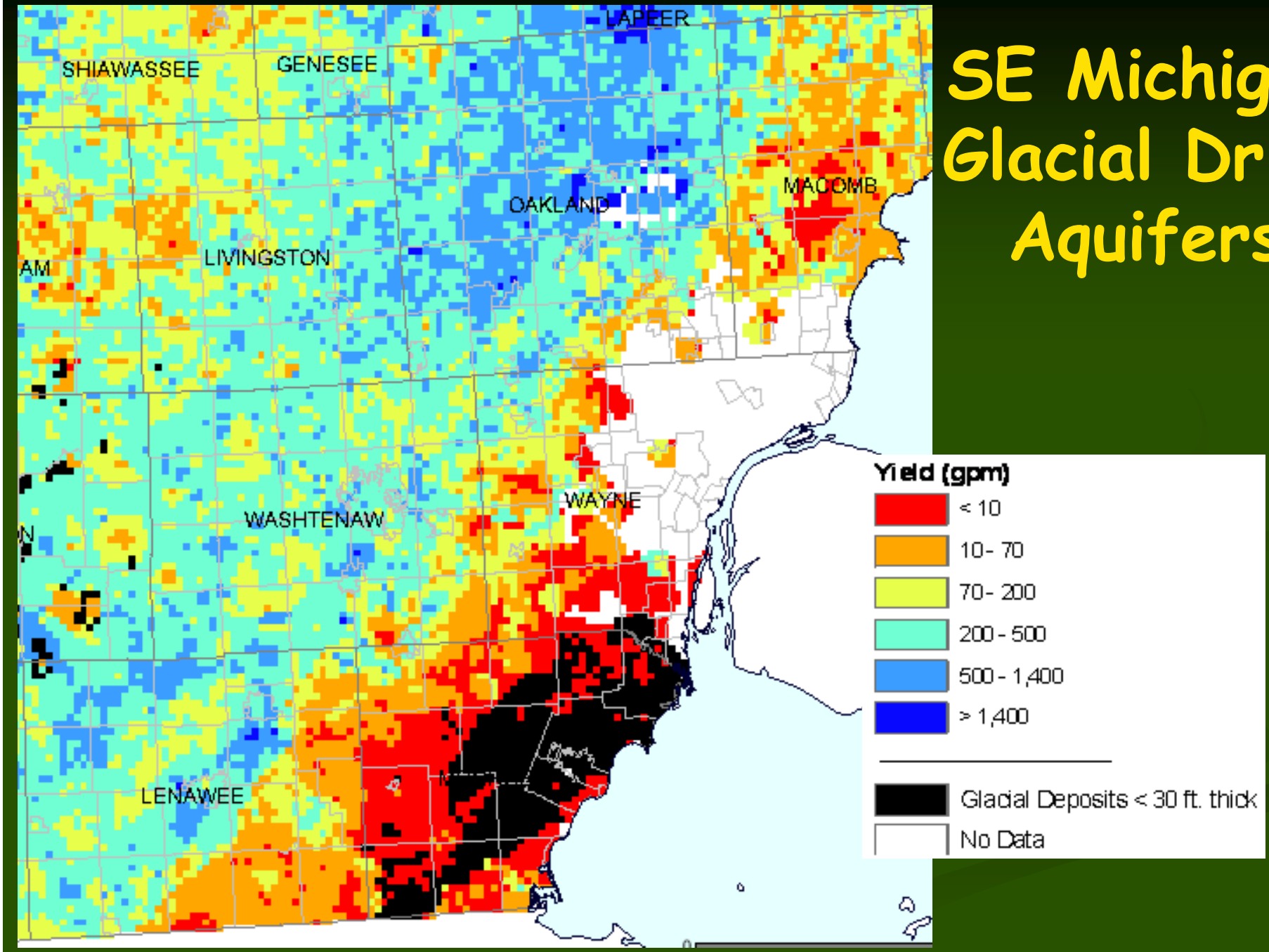




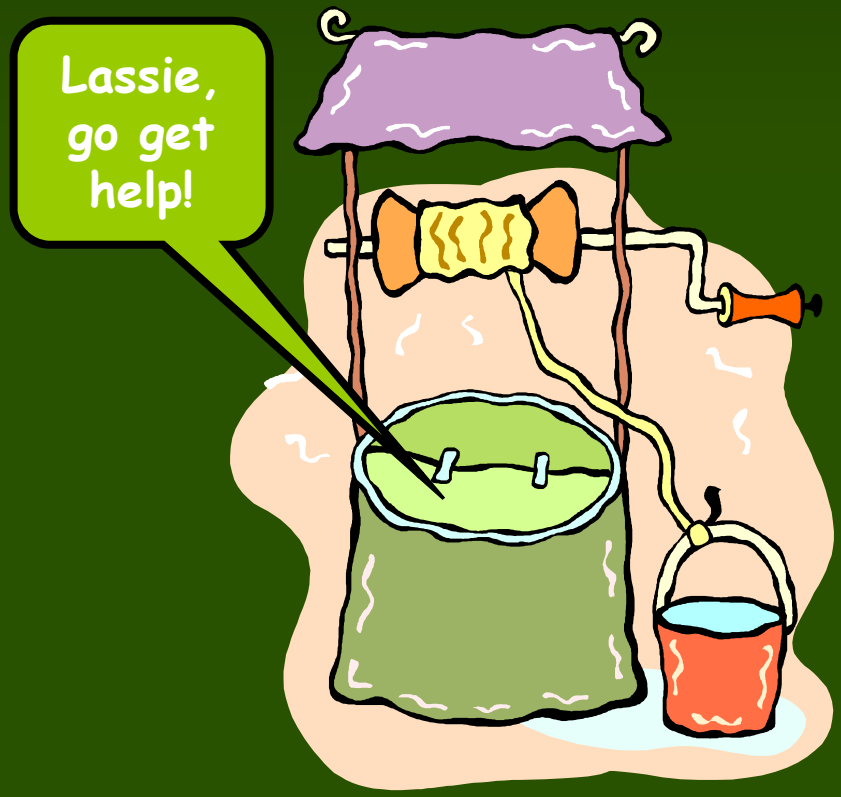
Michigan Glacial Drift Aquifers

- "Good"
- "Unconfined aquifer overlying bedrock – limited data"
- "Thin overlying bedrock"
- "Not an Aquifer"

SE Michigan Glacial Drift Aquifers

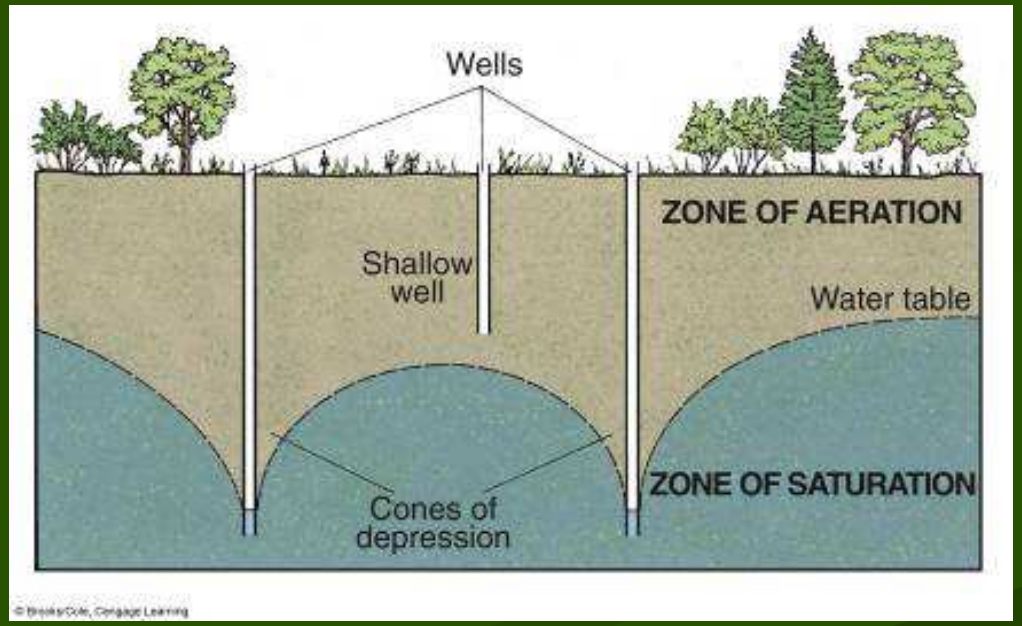


Wells

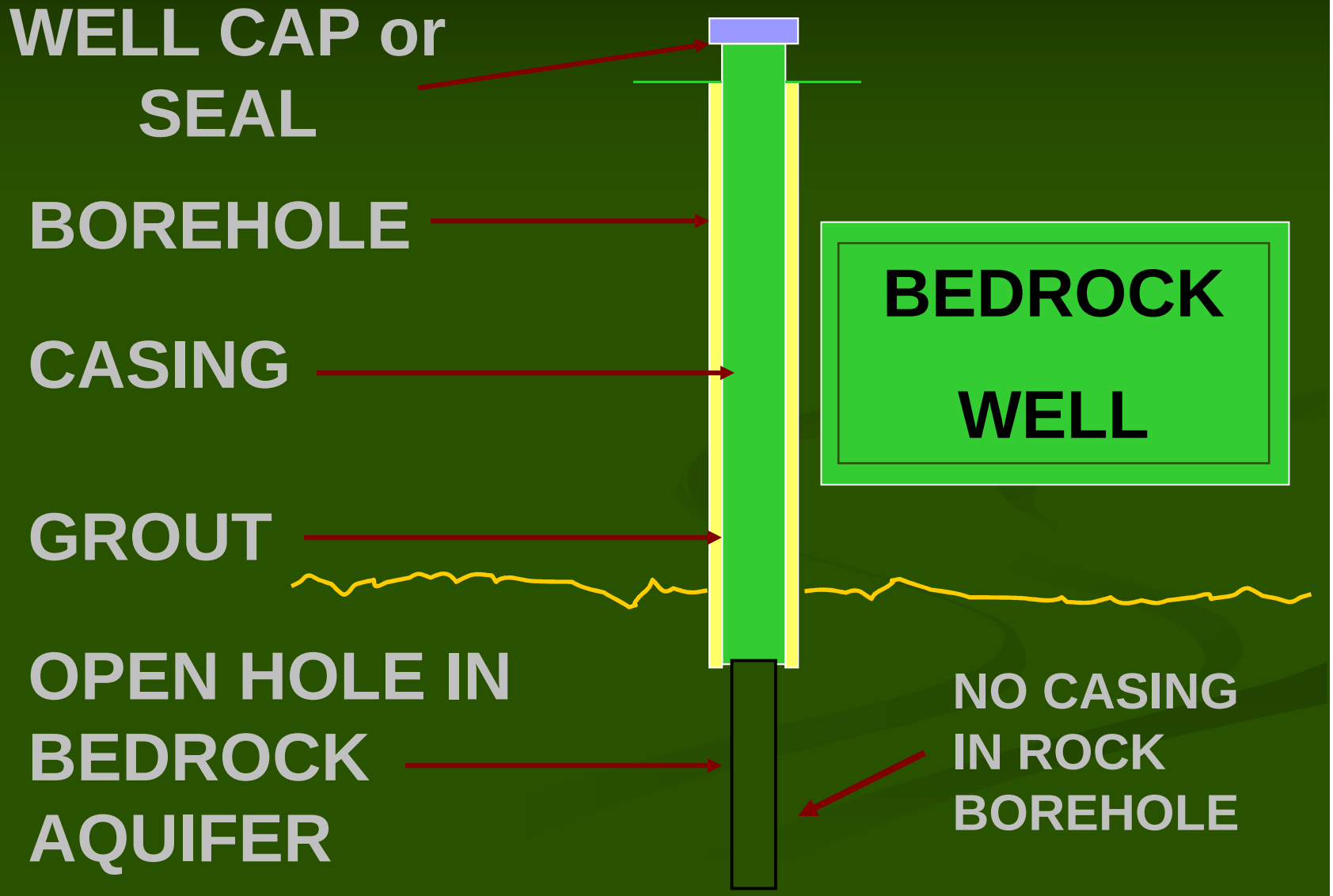


Groundwater Utilization

- **Wells**
  - Artificial openings dug or drilled below the water table to extract water
  - drawdown of water table
  - cone of depression



DRILLED WELL COMPONENTS



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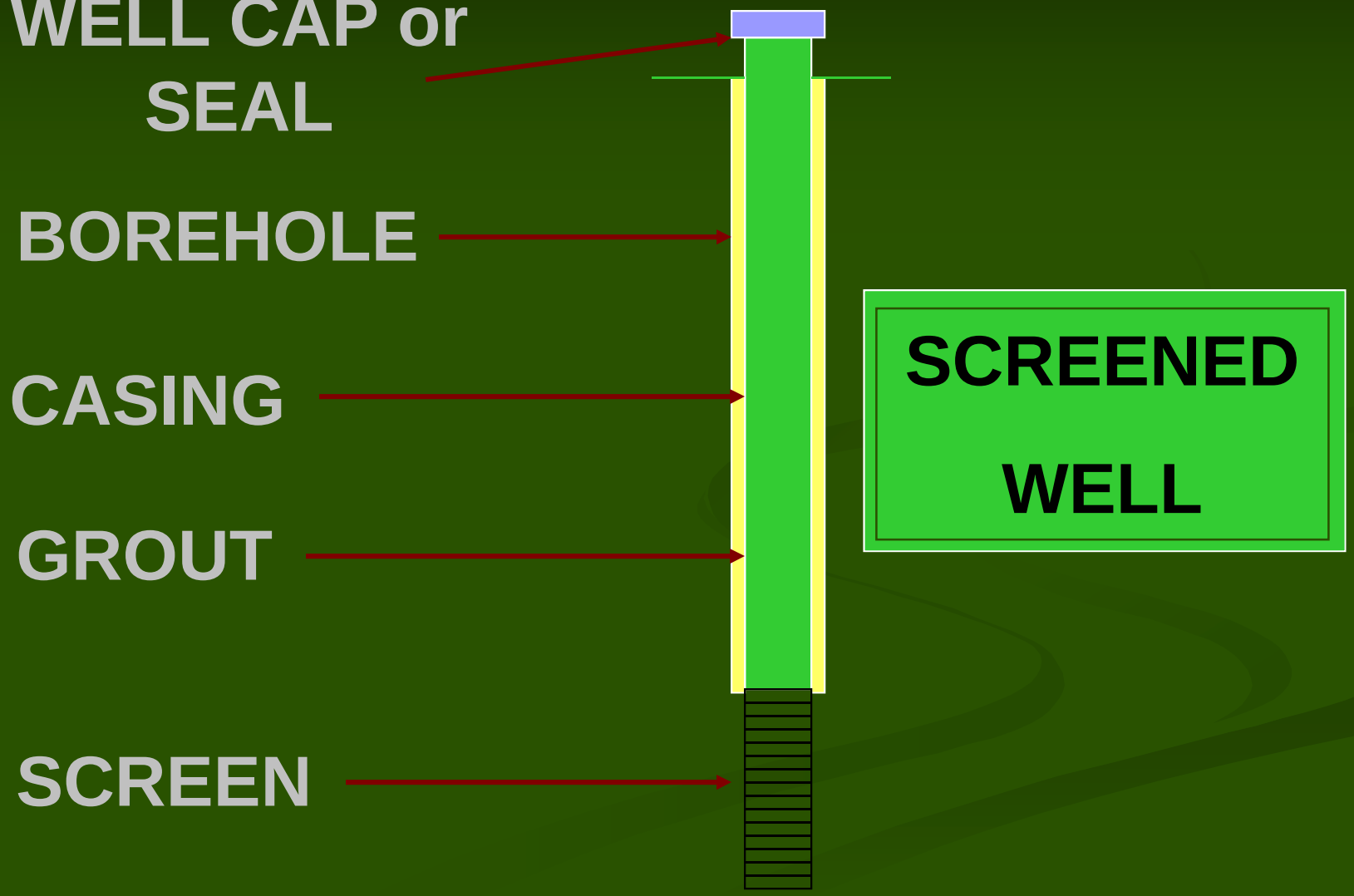
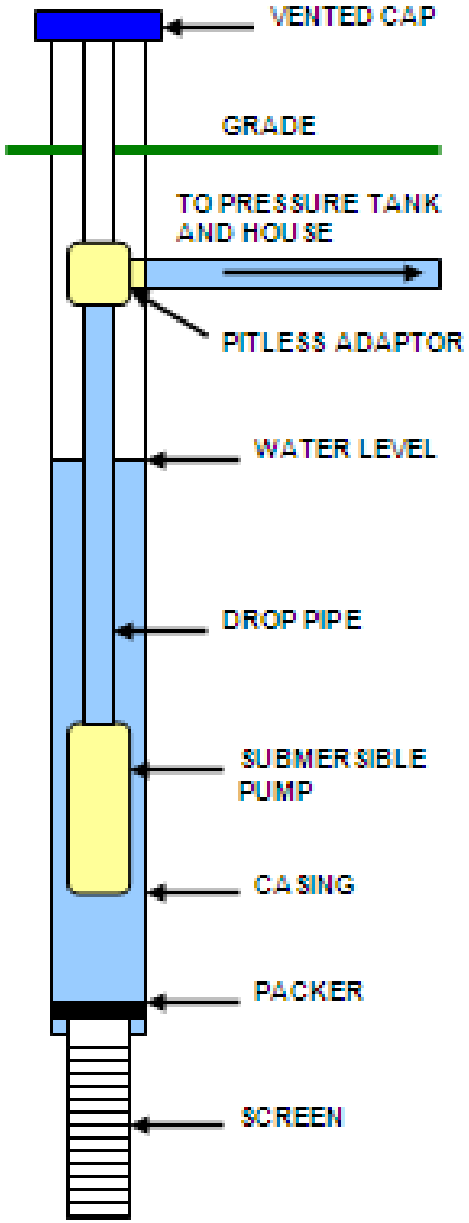


TYPICAL SCREENED WATER WELL CROSS SECTION

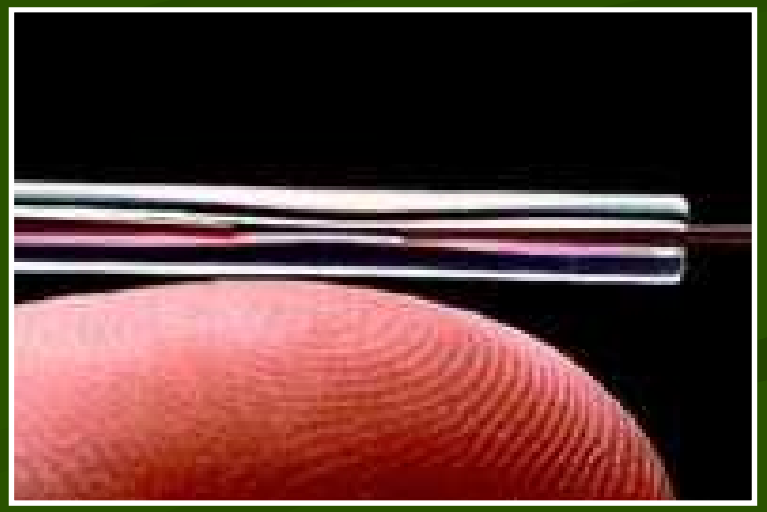


Important Concepts

- Hydrologic Cycle
- Aquifers
- Hydraulic Conductivity
- Head
- Gradient
- Drawdown
- Capture

Hydraulic Conductivity

- a.k.a. "Permeability"
- Measure of rate at which water can move through **aquifer material**
- Wide range in values due to number and size of pores and fractures *and* how well they are connected



HYDRAULIC CONDUCTIVITY RANGE

Unfractured Rock

Fractured Rock

Silty Sand-Sandy Clay

Fine Sand

Coarse Sand

Clay-Shale

Gravel

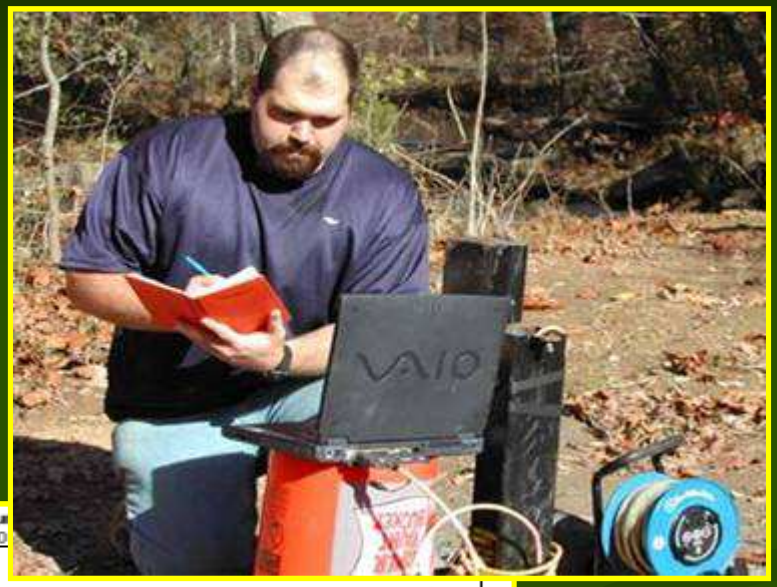
Low

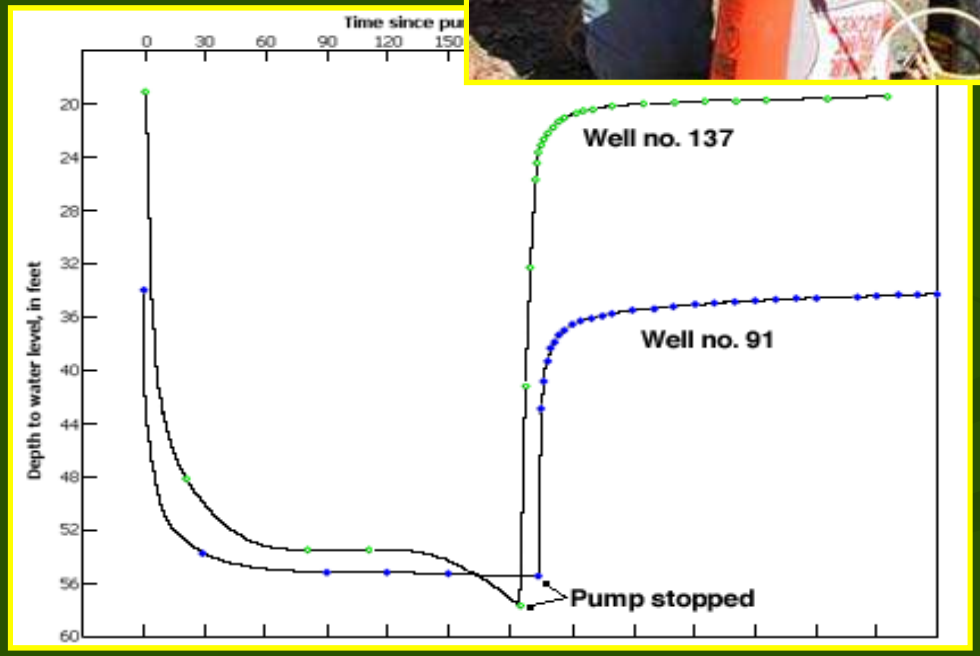
High

Sources of Hydraulic Conductivity (K) Data

- Site specific aquifer tests
- Estimated from well capacity data in WELLOGIC
- Use estimates based on sediment descriptions from well log records

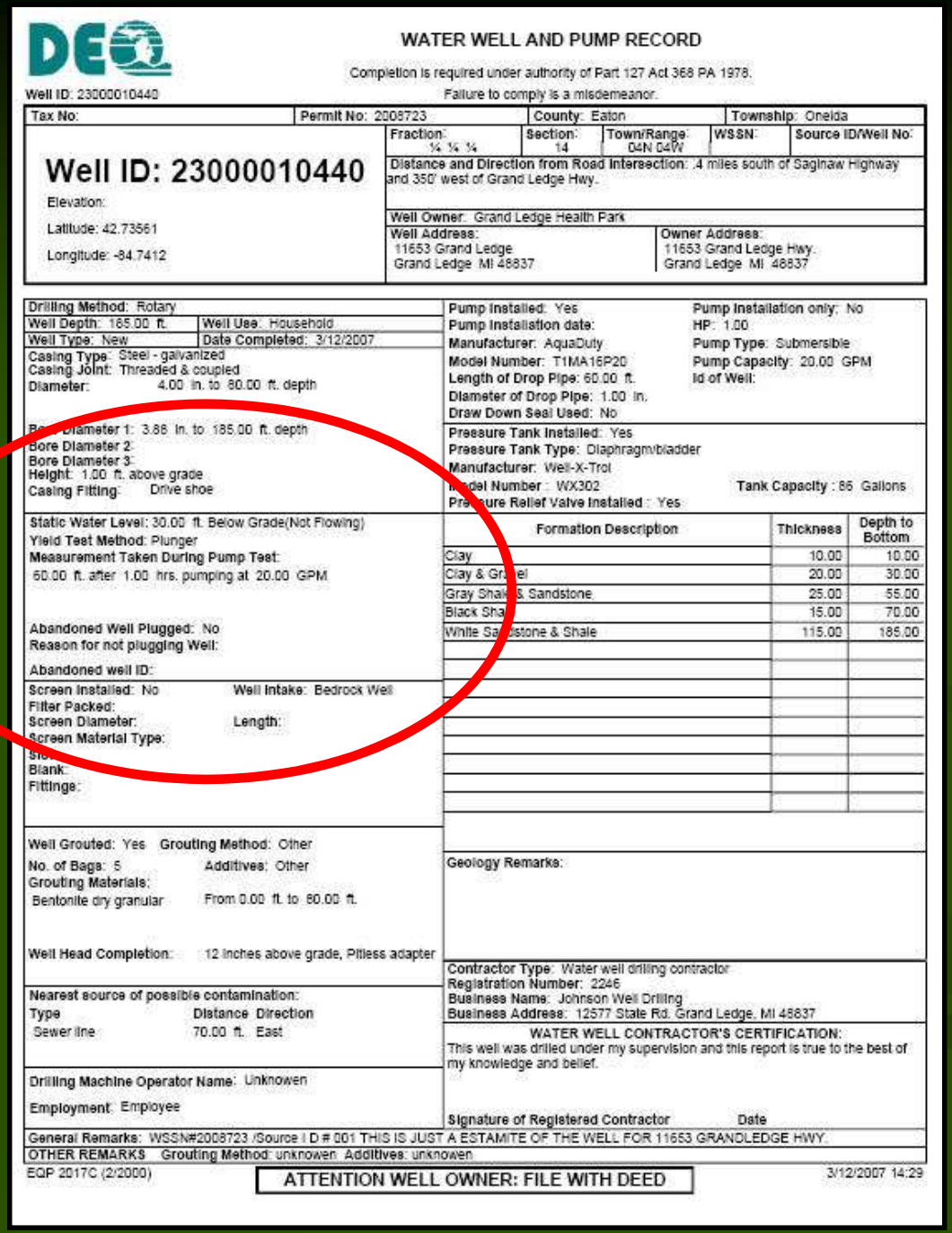
K from Site Information/Tests





K from Capacity Tests

- Static water level
- Pumping water level
- Length of test
- Estimated pumping rate
- Estimated K may be good if data good



DEQ

WATER WELL AND PUMP RECORD

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Well ID: 23000010440

Tax No:	Permit No: 2008723	County: Eaton	Township: Oneida

Fraction: ¼ ¼ ¼	Section: 14	Town/Range: 04N 04W	WSSN:	Source ID/Well No:

Well ID: 23000010440

Elevation:

Latitude: 42.73561

Longitude: -84.7412

Distance and Direction from Road Intersection: .4 miles south of Saginaw Highway and 350' west of Grand Ledge Hwy.

Well Owner: Grand Ledge Health Park

Well Address:	Owner Address:
11653 Grand Ledge Grand Ledge MI 48837	11653 Grand Ledge Hwy. Grand Ledge MI 48837

Drilling Method: Rotary
Well Depth: 185.00 ft. | Well Use: Household
Well Type: New | Date Completed: 3/12/2007
Casing Type: Steel - galvanized
Casing Joint: Threaded & coupled
Diameter: 4.00 in. to 80.00 ft. depth

Bore Diameter 1: 3.88 in. to 185.00 ft. depth
Bore Diameter 2:
Bore Diameter 3:
Height: 1.00 ft. above grade
Casing Fitting: Drive shoe

Static Water Level: 30.00 ft. Below Grade(Not Flowing)
Yield Test Method: Plunger
Measurement Taken During Pump Test:
60.00 ft. after 1.00 hrs. pumping at 20.00 GPM

Abandoned Well Plugged: No
Reason for not plugging Well:

Abandoned well ID:

Screen Installed: No | Well Intake: Bedrock Well
Filter Packed:
Screen Diameter: | Length:
Screen Material Type:
Slot:
Blank:
Fittings:

Well Grouted: Yes | Grouting Method: Other
No. of Bags: 5 | Additives: Other
Grouting Materials:
Bentonite dry granular | From 0.00 ft. to 80.00 ft.

Well Head Completion: 12 inches above grade, Pitless adapter

Nearest source of possible contamination:

Type	Distance	Direction
Sewer line	70.00 ft.	East

Drilling Machine Operator Name: Unknowen
Employment: Employee

Pump Installed: Yes | Pump Installation only: No
Pump Installation date: | HP: 1.00
Manufacturer: AquaDuty | Pump Type: Submersible
Model Number: T1MA16P20 | Pump Capacity: 20.00 GPM
Length of Drop Pipe: 60.00 ft. | Id of Well:
Diameter of Drop Pipe: 1.00 in.
Draw Down Seal Used: No

Pressure Tank Installed: Yes
Pressure Tank Type: Diaphragm/bladder
Manufacturer: Well-X-Trol
Model Number : WX302 | Tank Capacity : 86 Gallons
Pressure Relief Valve Installed : Yes

Formation Description	Thickness	Depth to Bottom
Clay	10.00	10.00
Clay & Gravel	20.00	30.00
Gray Shale & Sandstone	25.00	55.00
Black Shale	15.00	70.00
White Sandstone & Shale	115.00	185.00

Geology Remarks:

Contractor Type: Water well drilling contractor
Registration Number: 2246
Business Name: Johnson Well Drilling
Business Address: 12577 State Rd. Grand Ledge, MI 48837

WATER WELL CONTRACTOR'S CERTIFICATION:
This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor | Date

General Remarks: WSSN#2008723 /Source I D # 001 THIS IS JUST A ESTAMITE OF THE WELL FOR 11653 GRANDLEDGE HWY.
OTHER REMARKS Grouting Method: unknowen Additives: unknowen

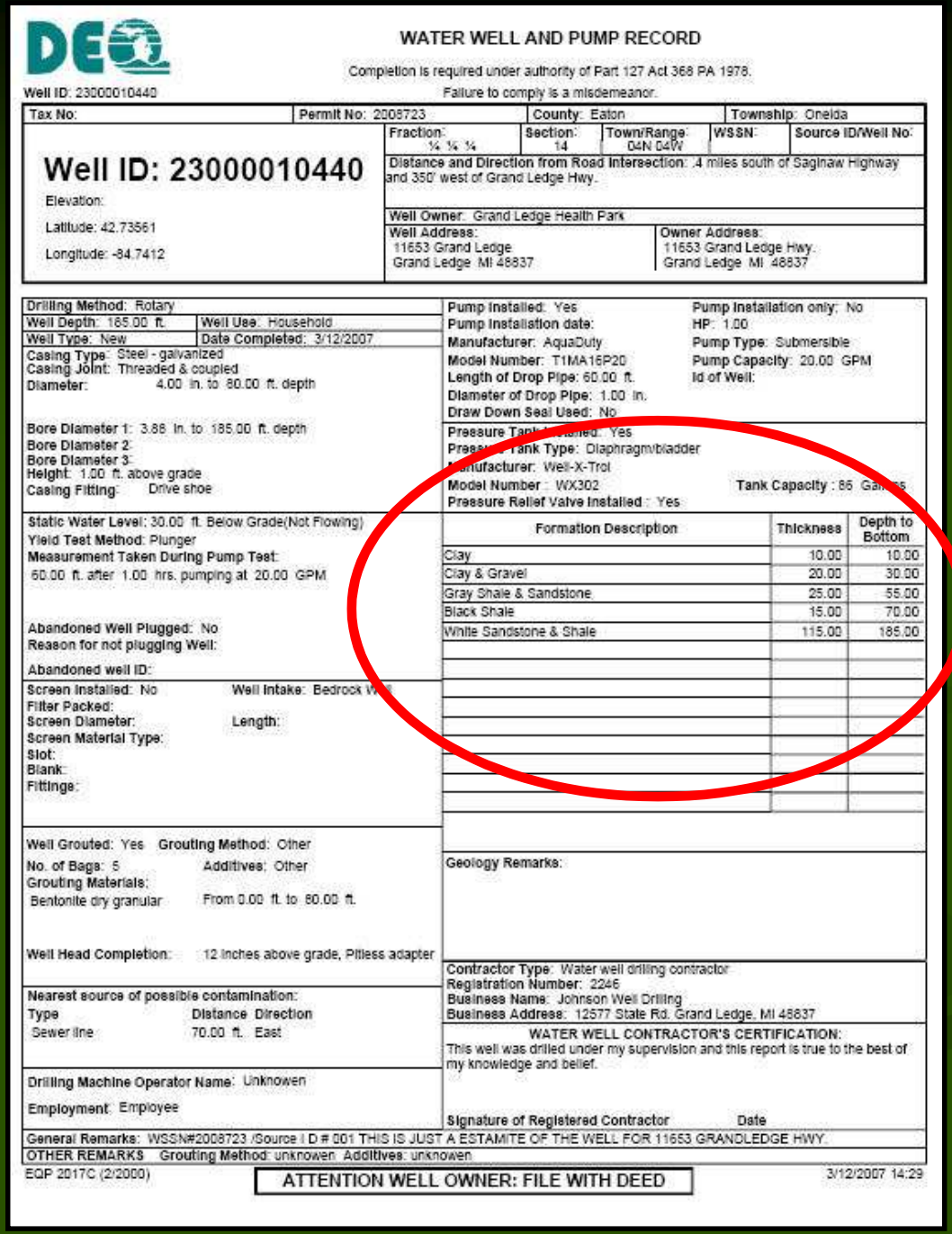
EQP 2017C (2/2000)

ATTENTION WELL OWNER: FILE WITH DEED

3/12/2007 14:29

K from Lithologic Descriptions

- Description of sediment or rock
- Thickness
- GWIM - Each material (sand, clay, etc) is assigned a unique K.
- Estimated K appears to be reasonable.



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Reason for not plugging Well:

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Filter Packed:
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Blank:
Fittings:

Well Grouted: Yes | Grouting Method: Other
No. of Bags: 5 | Additives: Other
Grouting Materials:
Bentonite dry granular | From 0.00 ft. to 80.00 ft.

Well Head Completion: 12 inches above grade, Pitless adapter

Nearest source of possible contamination:

Type	Distance	Direction
Sewer line	70.00 ft.	East

Drilling Machine Operator Name: Unknowen
Employment: Employee

Pump Installed: Yes | Pump Installation only: No
Pump Installation date: | HP: 1.00
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Model Number: T1MA16P20 | Pump Capacity: 20.00 GPM
Length of Drop Pipe: 60.00 ft. | Id of Well:
Diameter of Drop Pipe: 1.00 in.
Draw Down Seal Used: No

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Pressure Relief Valve Installed: Yes

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Gray Shale & Sandstone	25.00	55.00
Black Shale	15.00	70.00
White Sandstone & Shale	115.00	185.00

Geology Remarks:

Contractor Type: Water well drilling contractor
Registration Number: 2246
Business Name: Johnson Well Drilling
Business Address: 12577 State Rd. Grand Ledge, MI 48837

WATER WELL CONTRACTOR'S CERTIFICATION:
This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor | Date

General Remarks: WSSN#2008723 /Source I D # 001 THIS IS JUST A ESTAMITE OF THE WELL FOR 11653 GRANDLEDGE HWY.
OTHER REMARKS Grouting Method: unknowen Additives: unknowen

EQP 2017C (2/2000)

ATTENTION WELL OWNER: FILE WITH DEED

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Important Concepts

- Hydrologic Cycle
- Aquifers
- Hydraulic Conductivity
- Head
- Gradient
- Drawdown
- Capture

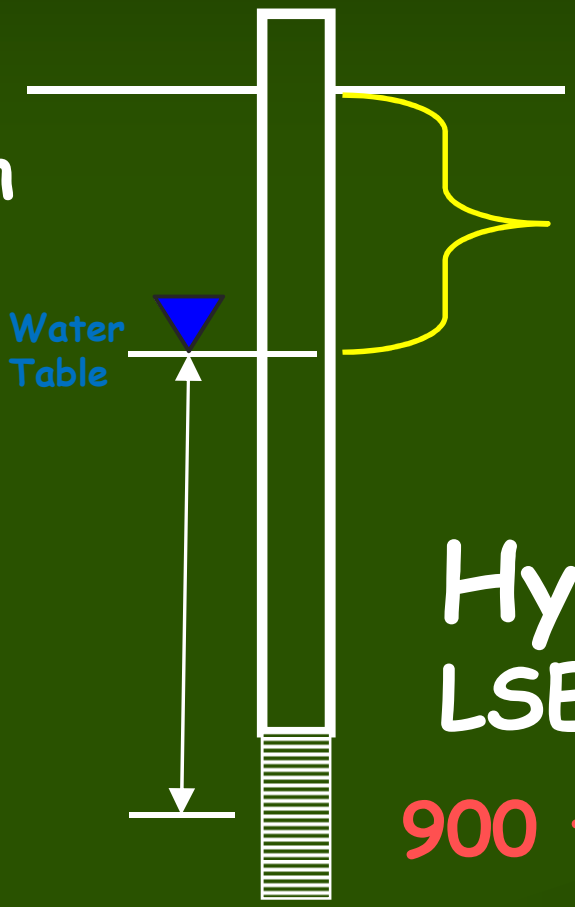
GW Flow Direction

- GW wants to move from a point of high hydraulic head (elevation) to low hydraulic head (elevation) in the direction of steepest hydraulic gradient…
  IMPORTANT CONCEPT

- Hydraulic Head ("GW Elevation")
- Hydraulic Gradient ("Slope")

Hydraulic Head

Land Surface Elevation (LSE)

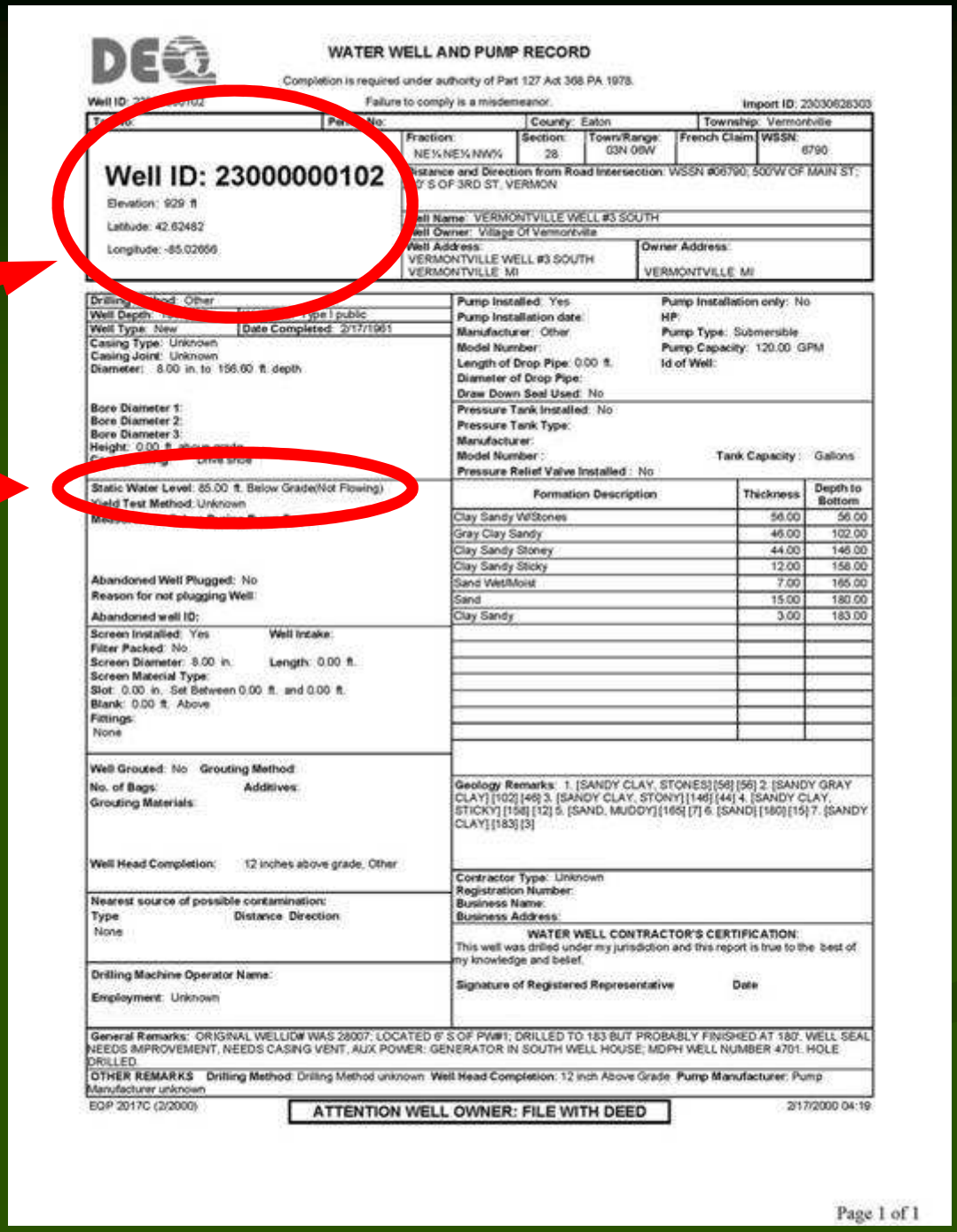


Depth to water (a.k.a. static water level or "SWL")

Hydraulic Head = LSE - SWL

900 ft – 20 ft = 880 ft

Where does the head information come from?



DEQ

WATER WELL AND PUMP RECORD

Completion is required under authority of Part 127 Act 368 PA 1978.

Failure to comply is a misdemeanor.

Well ID: 23000000102 Import ID: 20030628303

County: Eaton | Township: Vermontville

Fraction: NE¼ NE¼ NW¼ | Section: 28 | Town/Range: 03N 08W | French Claim: | WSSN: 6790

Distance and Direction from Road Intersection: WSSN #06790; 500'W OF MAIN ST; 50' S OF 3RD ST, VERMON

Well ID: 23000000102

Elevation: 929 ft

Latitude: 42.62482

Longitude: -85.02666

Well Name: VERMONTVILLE WELL #3 SOUTH

Well Owner: Village Of Vermontville

Well Address: VERMONTVILLE WELL #3 SOUTH VERMONTVILLE MI

Owner Address: VERMONTVILLE MI

Drilling Method: Other

Well Depth: Type I public

Well Type: New | Date Completed: 2/17/1961

Casing Type: Unknown
Casing Joint: Unknown
Diameter: 8.00 in. to 156.00 ft. depth

Bore Diameter 1:
Bore Diameter 2:
Bore Diameter 3:
Height: 0.00 ft. above grade

Static Water Level: 85.00 ft. Below Grade(Not Flowing)
Yield Test Method: Unknown

Abandoned Well Plugged: No
Reason for not plugging Well:
Abandoned well ID:

Screen Installed: Yes | Well Intake:
Filter Packed: No
Screen Diameter: 8.00 in. | Length: 0.00 ft.
Screen Material Type:
Slot: 0.00 in. Set Between 0.00 ft. and 0.00 ft.
Blank: 0.00 ft. Above
Fittings:
None

Well Grouted: No | Grouting Method:
No. of Bags: | Additives:
Grouting Materials:

Well Head Completion: 12 inches above grade, Other

Nearest source of possible contamination:
Type | Distance | Direction
None

Drilling Machine Operator Name:
Employment: Unknown

Pump Installed: Yes | Pump Installation only: No
Pump Installation date: | HP:
Manufacturer: Other | Pump Type: Submersible
Model Number: | Pump Capacity: 120.00 GPM
Length of Drop Pipe: 0.00 ft. | Id of Well:
Diameter of Drop Pipe:
Draw Down Seal Used: No

Pressure Tank Installed: No
Pressure Tank Type:
Manufacturer:
Model Number: | Tank Capacity: Gallons
Pressure Relief Valve Installed: No

Formation Description	Thickness	Depth to Bottom
Clay Sandy W/Stones	56.00	56.00
Gray Clay Sandy	46.00	102.00
Clay Sandy Stoney	44.00	146.00
Clay Sandy Sticky	12.00	158.00
Sand Wet/Moist	7.00	165.00
Sand	15.00	180.00
Clay Sandy	3.00	183.00

Geology Remarks: 1. [SANDY CLAY, STONES] [56] [56] 2. [SANDY GRAY CLAY] [102] [46] 3. [SANDY CLAY, STONY] [146] [44] 4. [SANDY CLAY, STICKY] [158] [12] 5. [SAND, MUDDY] [165] [7] 6. [SAND] [180] [15] 7. [SANDY CLAY] [183] [3]

Contractor Type: Unknown
Registration Number:
Business Name:
Business Address:

WATER WELL CONTRACTOR'S CERTIFICATION:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Signature of Registered Representative | Date

General Remarks: ORIGINAL WELLID# WAS 28007; LOCATED 6' S OF PW#1; DRILLED TO 183 BUT PROBABLY FINISHED AT 180'. WELL SEAL NEEDS IMPROVEMENT, NEEDS CASING VENT, AUX POWER: GENERATOR IN SOUTH WELL HOUSE; MDPH WELL NUMBER 4701. HOLE DRILLED.

OTHER REMARKS: Drilling Method: Drilling Method unknown Well Head Completion: 12 inch Above Grade Pump Manufacturer: Pump Manufacturer unknown

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ATTENTION WELL OWNER: FILE WITH DEED

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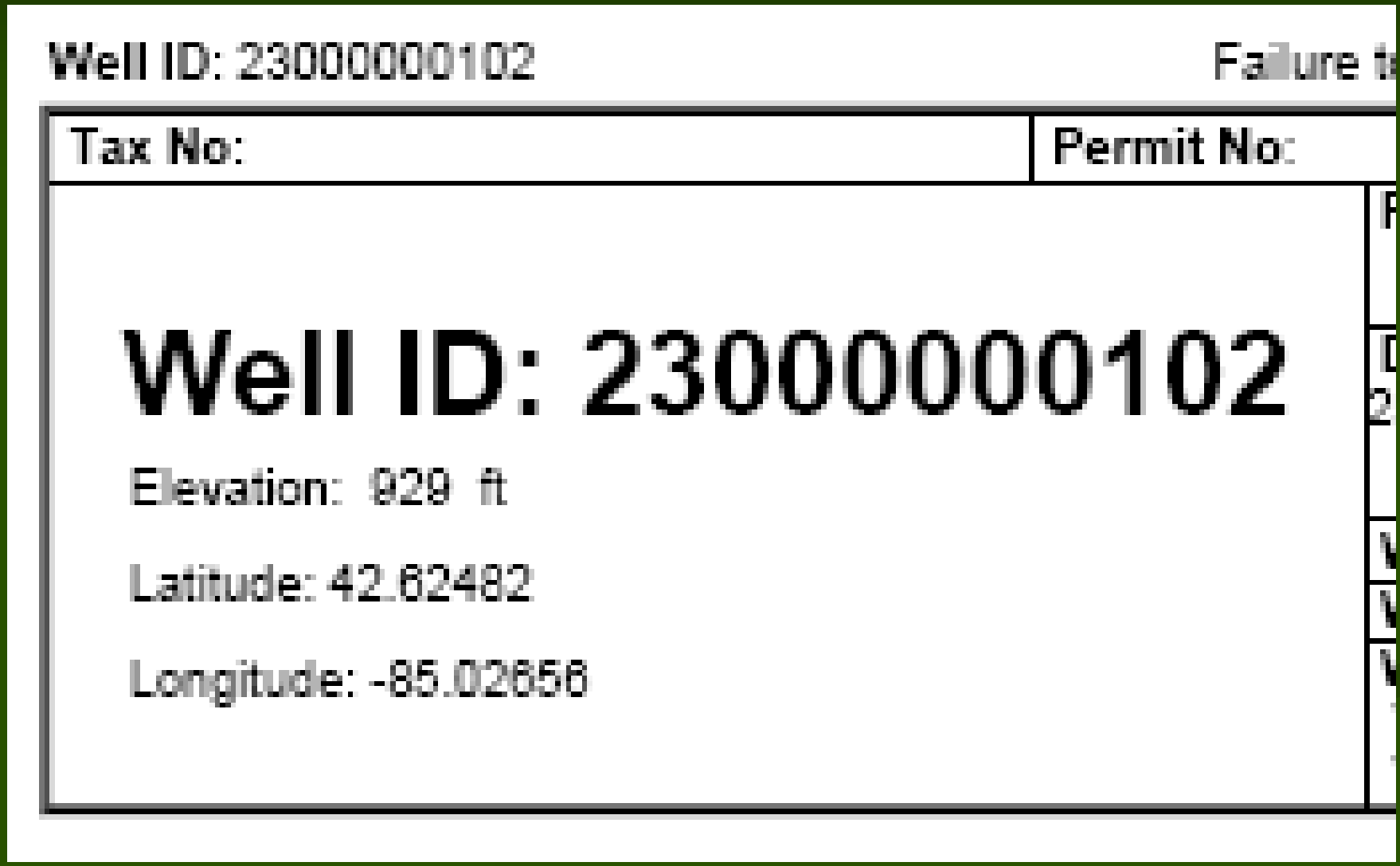
Page 1 of 1

Ground Surface Elevation and Location



Static Water Level (SWL)

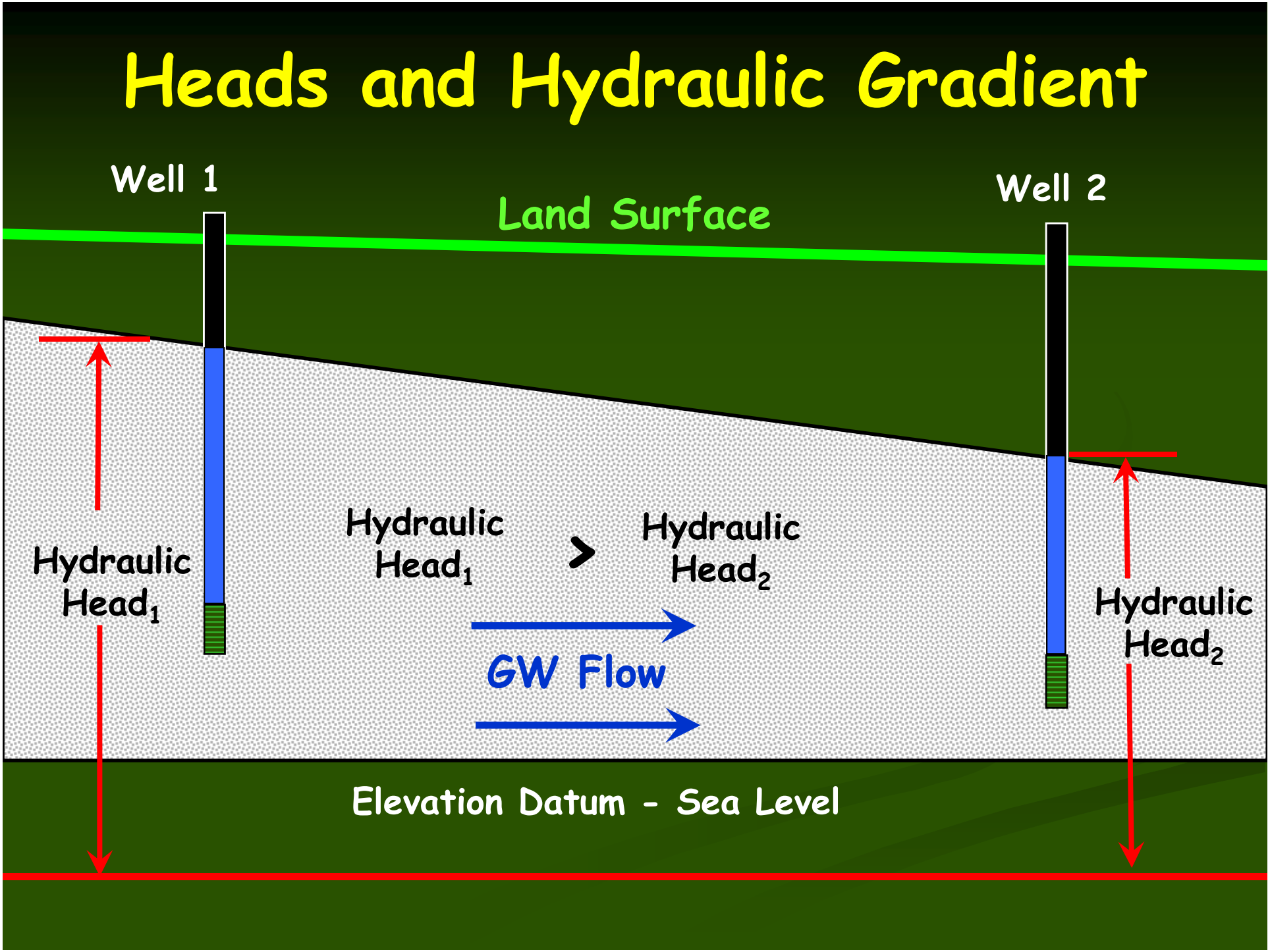
Static Water Level: 85.00 ft. Below Grade(Not Flowing)
Yield Test Method: Unknown
Measurement Taken During Pump Test:

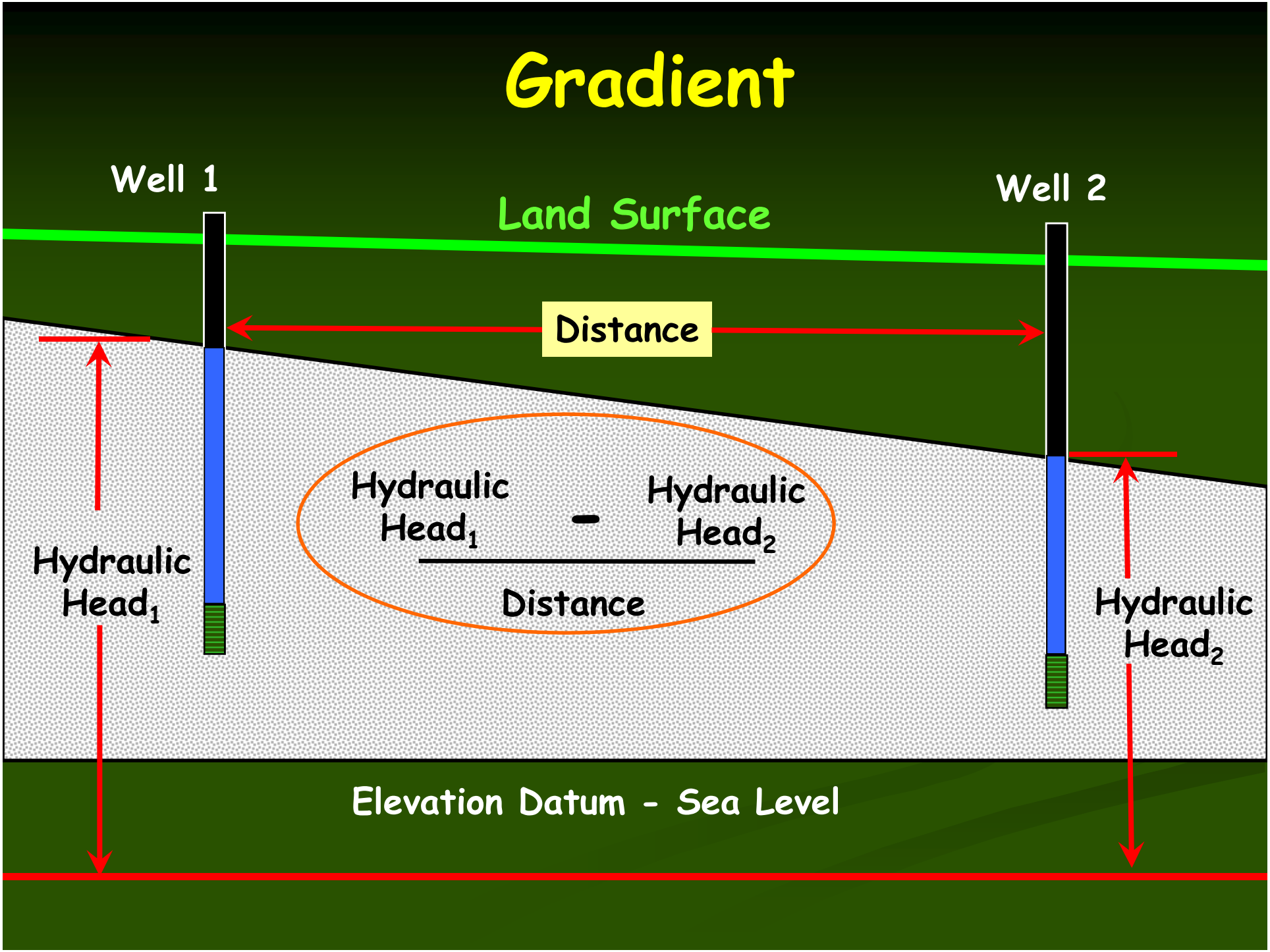
Ground Surface - SWL = Head ft AMSL

Example: 929 - 85 = 844 ft AMSL

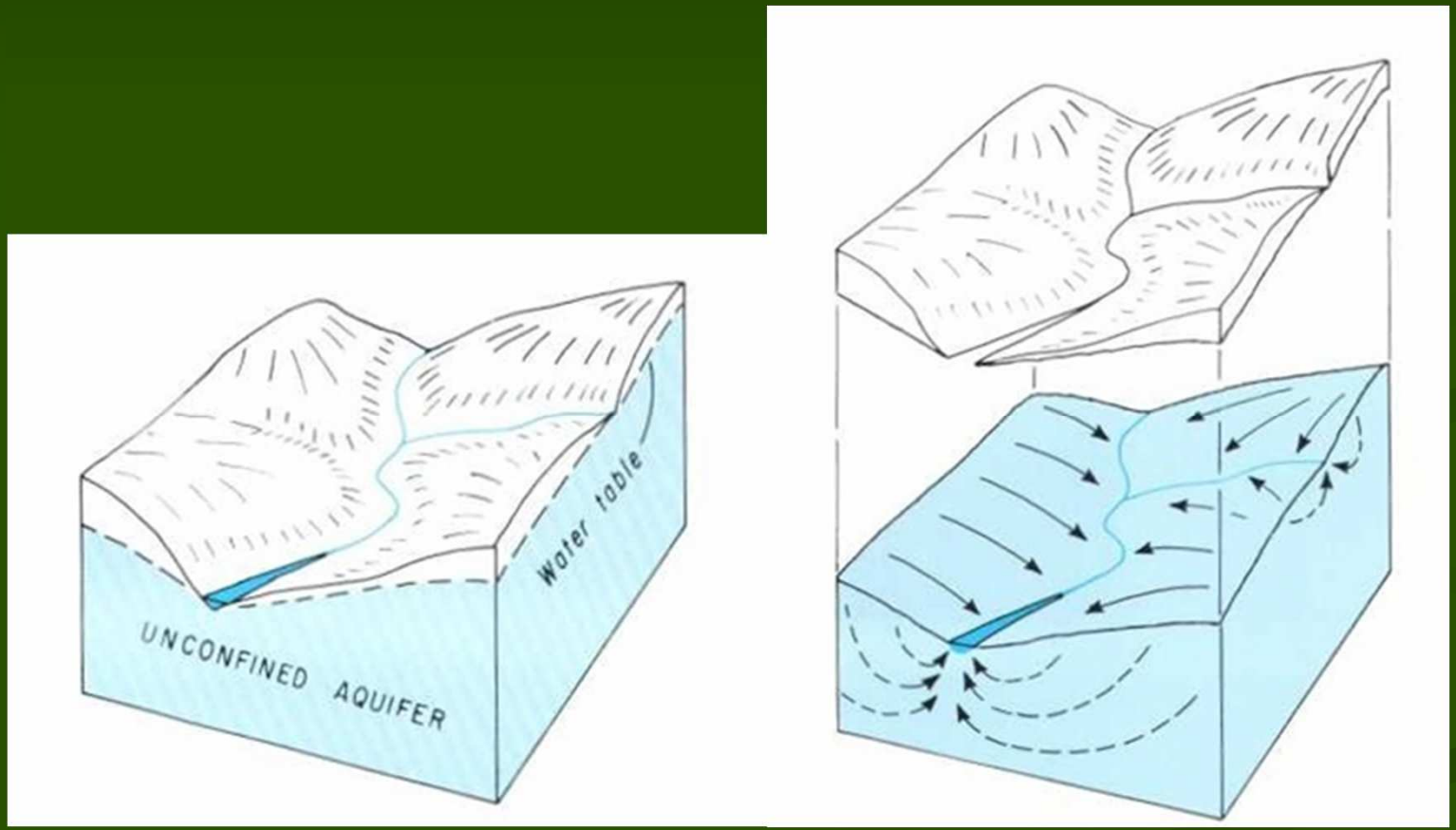
Important Concepts

- Hydrologic Cycle
- Aquifers
- Hydraulic Conductivity
- Head
- Gradient
- Drawdown
- Capture

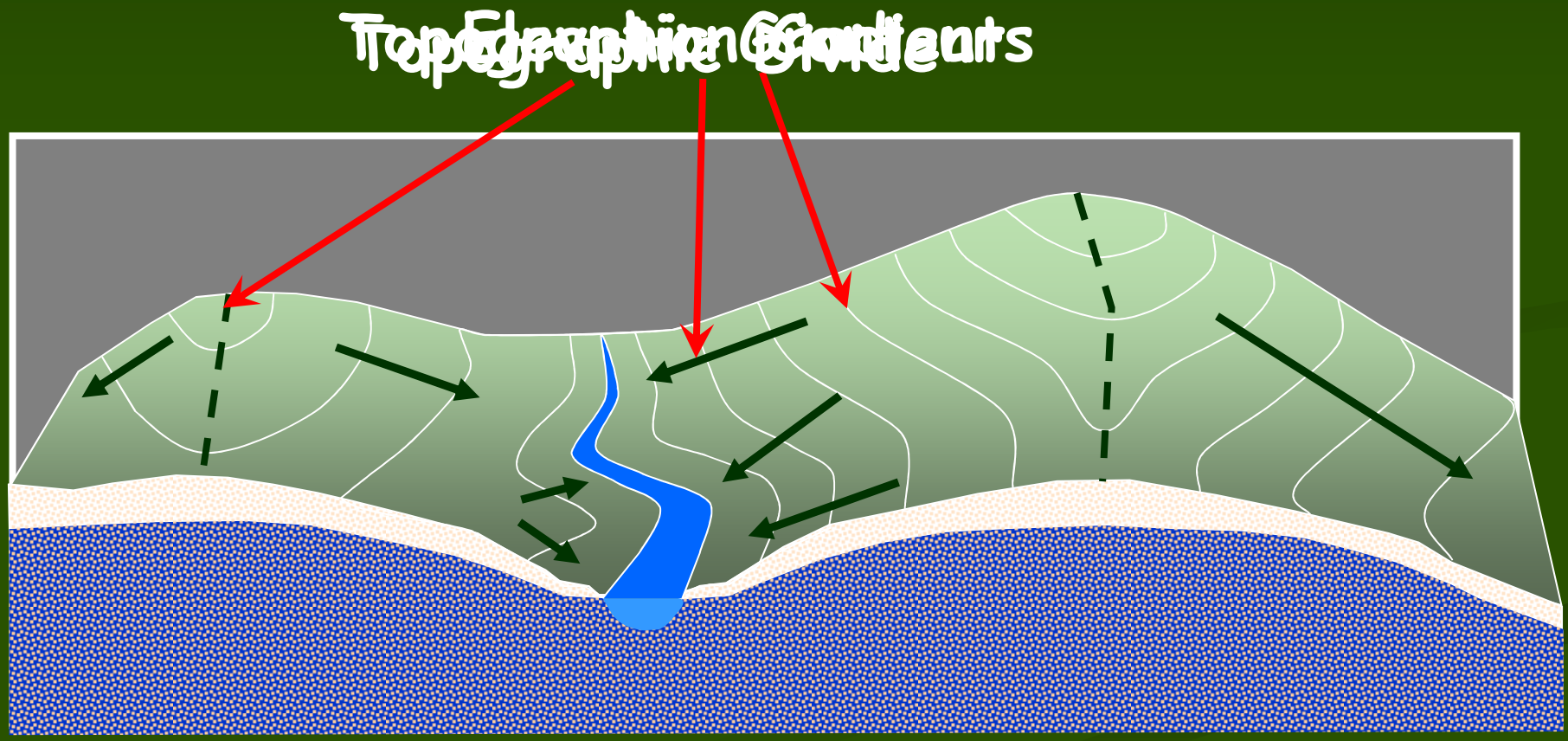

Heads and Hydraulic Gradient
Well 1
Land Surface
Well 2
Hydraulic Head1
Hydraulic Head1 > Hydraulic Head2
Hydraulic Head2
GW Flow
Elevation Datum - Sea Level


Gradient
Well 1
Land Surface
Well 2
Distance
Hydraulic Head1
Hydraulic Head1 − Hydraulic Head2
Distance
Hydraulic Head2
Elevation Datum - Sea Level

Groundwater Movement

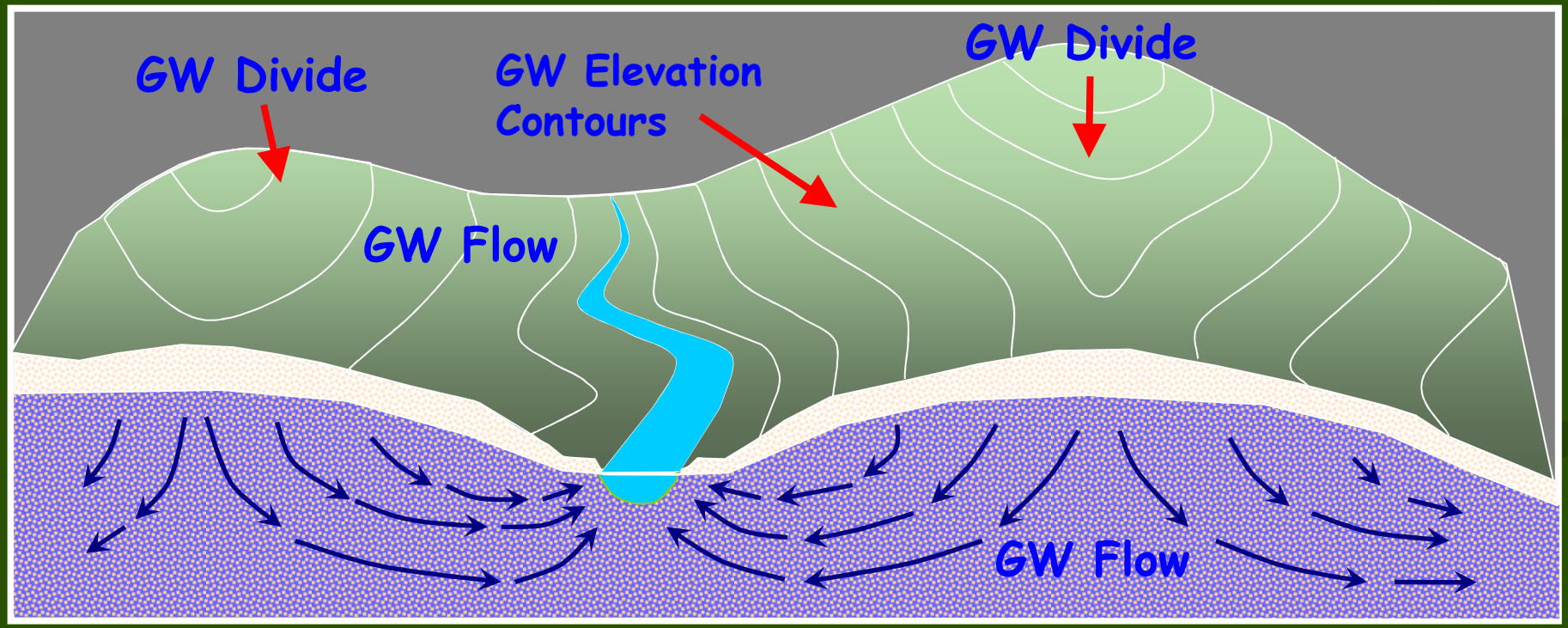


Land Surface - Gradients and Divides

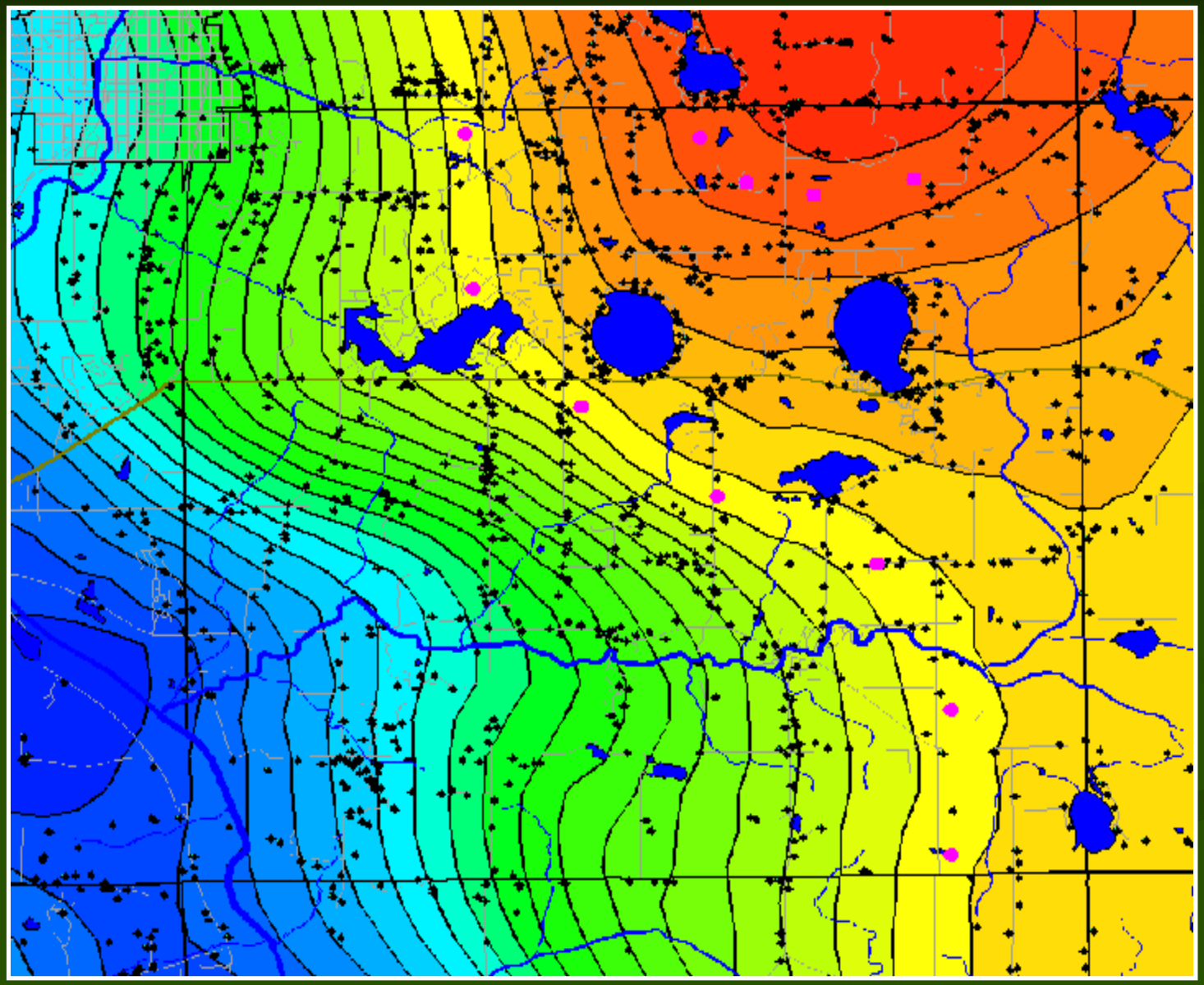


GW Elevation Surface – Gradients and Divides

Remove Land Surface to Expose Water Table



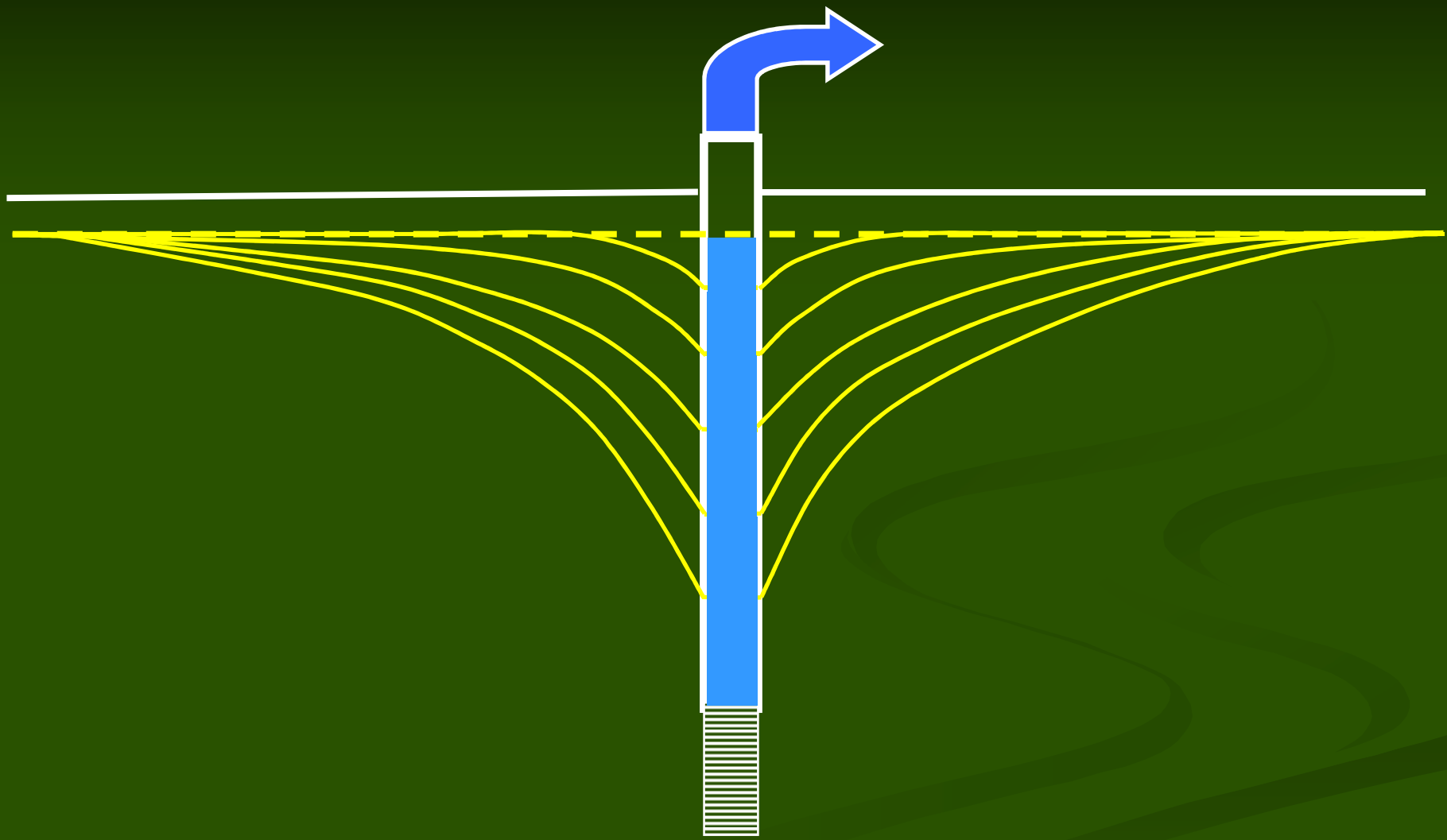
Cannon Twp - water table map with GW flow directions



Important Concepts

- ✓ Hydrologic Cycle
- ✓ Aquifers
- ✓ Hydraulic Conductivity
- ✓ Head
- ✓ Gradient
- ✓ Drawdown
- ✓ Capture

Drawdown from pumping



Important Concepts

- Hydrologic Cycle
- Aquifers
- Hydraulic Conductivity
- Head
- Gradient
- Drawdown
- Capture

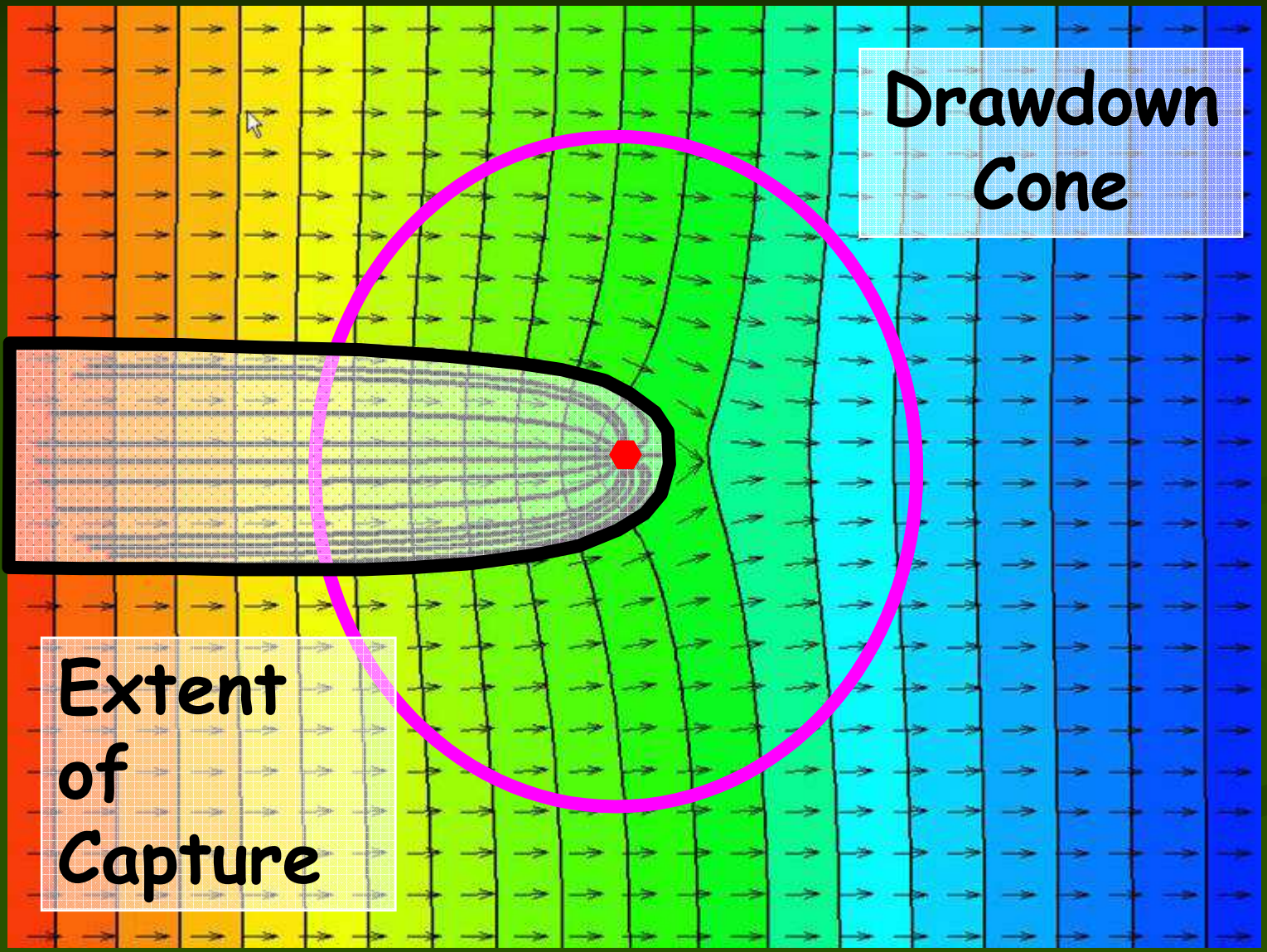
Capture

- Capture – GW within Aquifer that flows toward and is removed by pumping well.

- Extent of Capture NOT THE SAME as Extent of Drawdown.

ANOTHER IMPORTANT CONCEPT

Extent of Capture vs Drawdown Cone



Wellhead Protection Area = WHPA = Area of Captured GW

HE FOUND THAT HIS ARMS AND LEGS WERE TIGHTLY FASTENED TO THE GROUND.

Wellhead Protection

Questions ???