Geology, groundwater, soils and septic design

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for

Eureka Township

Citizens Advisory Committee

June 27, 2007

Source:
Dakota County Ambient Groundwater Study

1999-2003, published in 2006

http://www.co.dakota.mn.us/NR/rdonlyres/00000697/voufacfgaabyefpolhbqfulqbvwyyace/AmbientGroundwaterQualityStudy.pdf

Goal-establish a baseline of water quality for future comparison

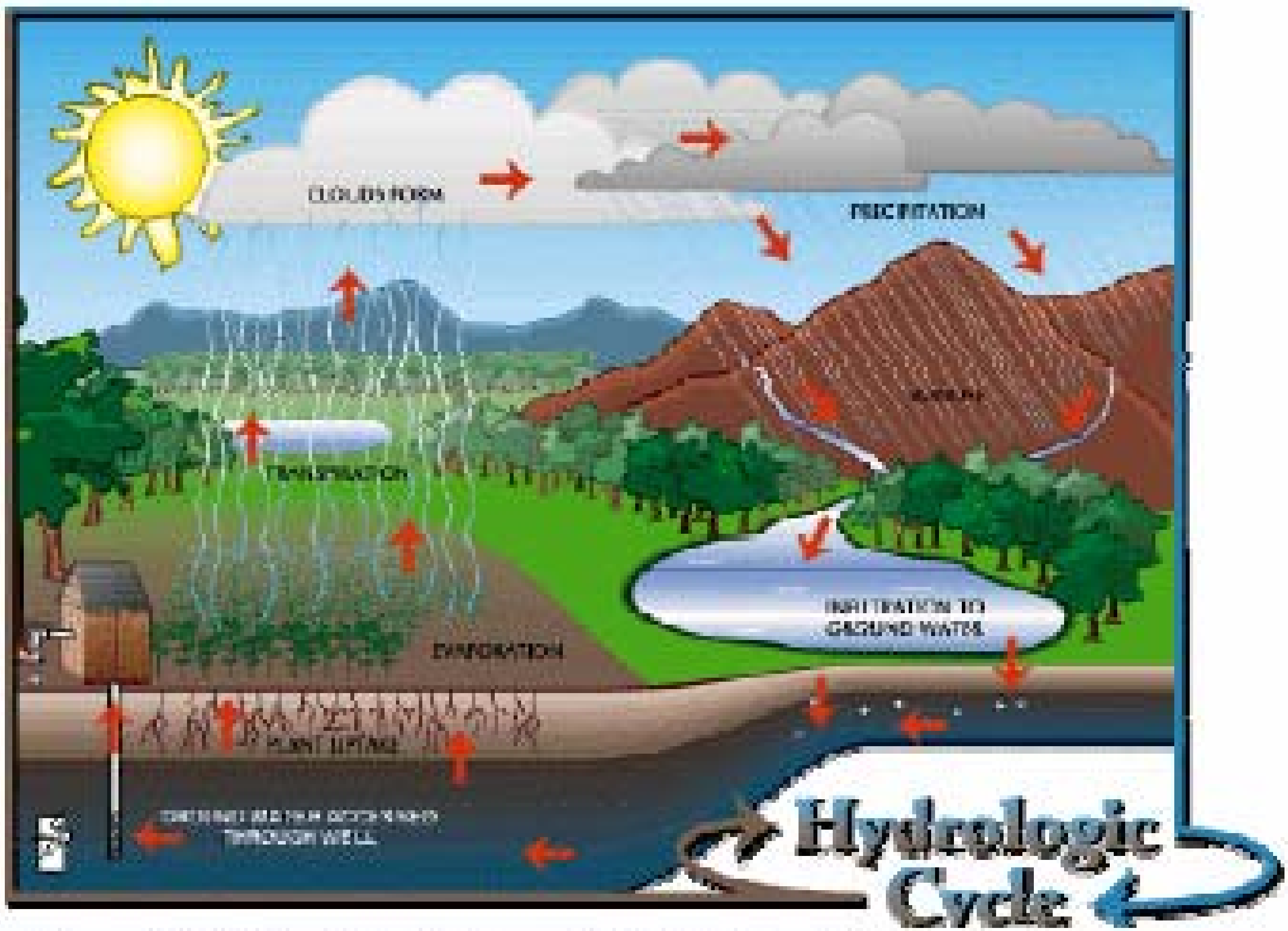
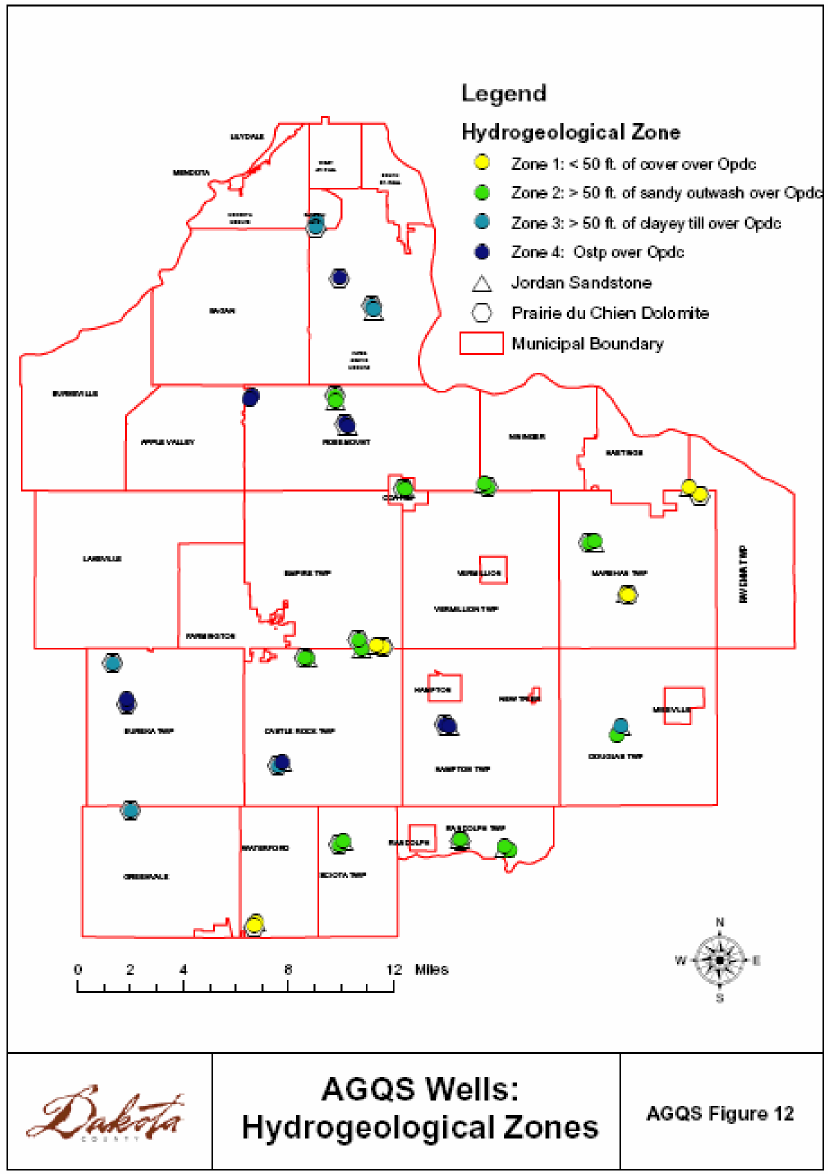


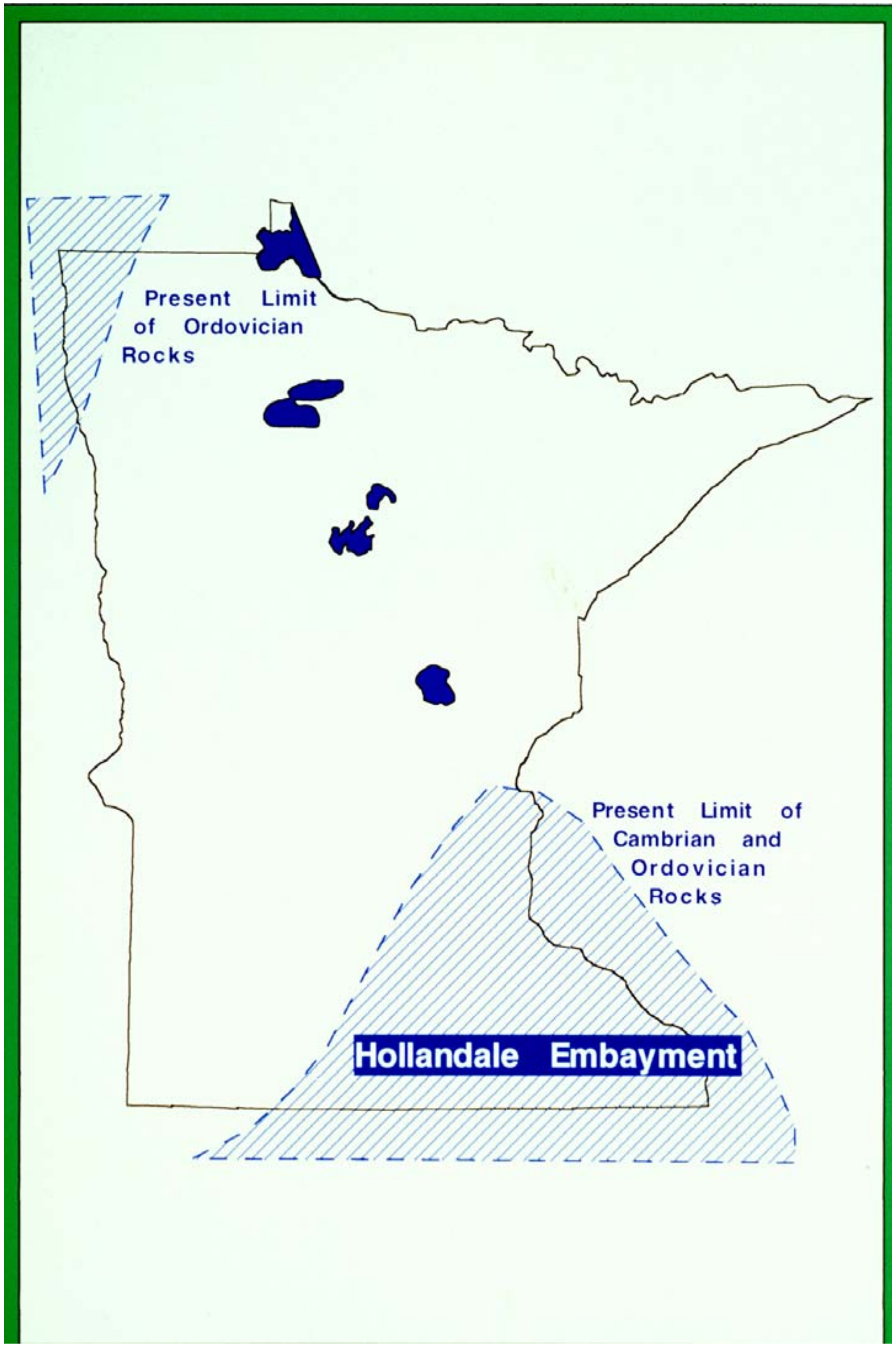
Figure 1: Hydrologic Cycle (Ground Water Primer EPA Region 5 & Purdue University)

Wells used for study

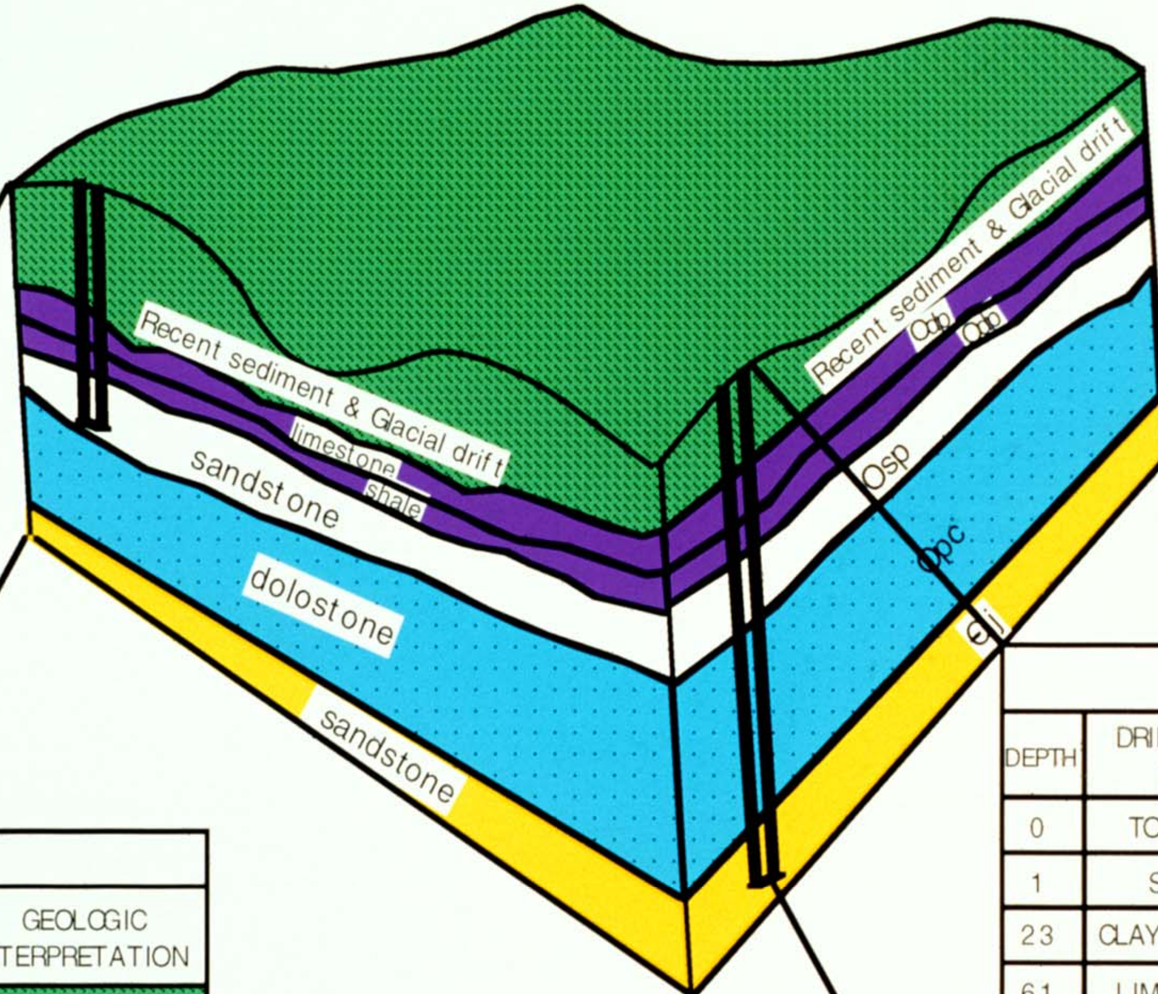


Aquifers

- Saturated rock or sediment that serve as subsurface reservoirs that store and transmit water.
- There are <u>*not*</u> free-flowing underground rivers or lakes. Water is held in pore spaces and cracks at various depths in sediment and bedrock.
- Wells are drilled to these water-bearing layers and water is pumped through a screened length of pipe.



Deposits of oceans that left behind sand from beaches and offshore carbonate platforms (like reefs) serve as aquifers in SE Minnesota



WELL B

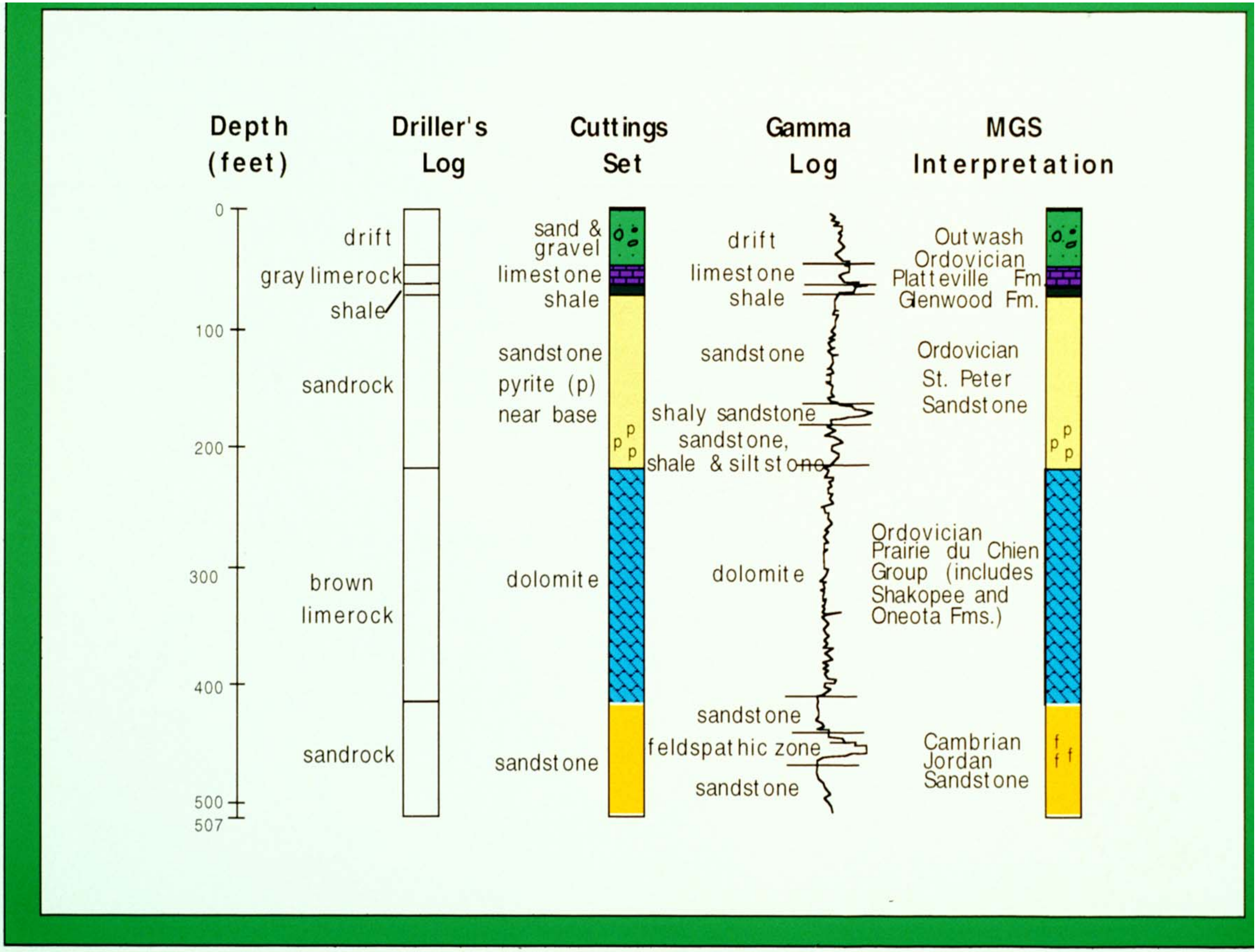
DEPTH	DRILLER'S LOG	GEOLOGIC INTERPRETATION
0	SOIL	RECENT
2	SAND, GRAVEL	GLACIAL
82	SHALE	Odp
118	SANDROCK	Osp

Log is not to scale.

WELL A

DEPTH	DRILLER'S LOG	GEOLOGIC INTERPRETATION
0	TOPSOIL	RECENT
1	SAND	GLACIAL
23	CLAY, STONES	GLACIAL
61	LIMEROCK	Odp
80	SHALE	Odp
96	WHITE SAND	Osp
230	SANDSTONE	Osp
254	LIMEROCK	Opc
565	SANDSTONE	€j

Log is not to scale.


Depth (feet)
Driller's Log
Cuttings Set
Gamma Log
MGS Interpretation
0
100
200
300
400
500
507
drift
gray limerock
shale
sandrock
brown limerock
sandrock
sand & gravel
limestone
shale
sandstone
pyrite (p) near base
dolomite
sandstone
drift
limestone
shale
sandstone
shaly sandstone
sandstone, shale & siltstone
dolomite
sandstone
feldspathic zone
sandstone
Outwash
Ordovician Platteville Fm.
Glenwood Fm.
Ordovician St. Peter Sandstone
Ordovician Prairie du Chien Group (includes Shakopee and Oneota Fms.)
Cambrian Jordan Sandstone

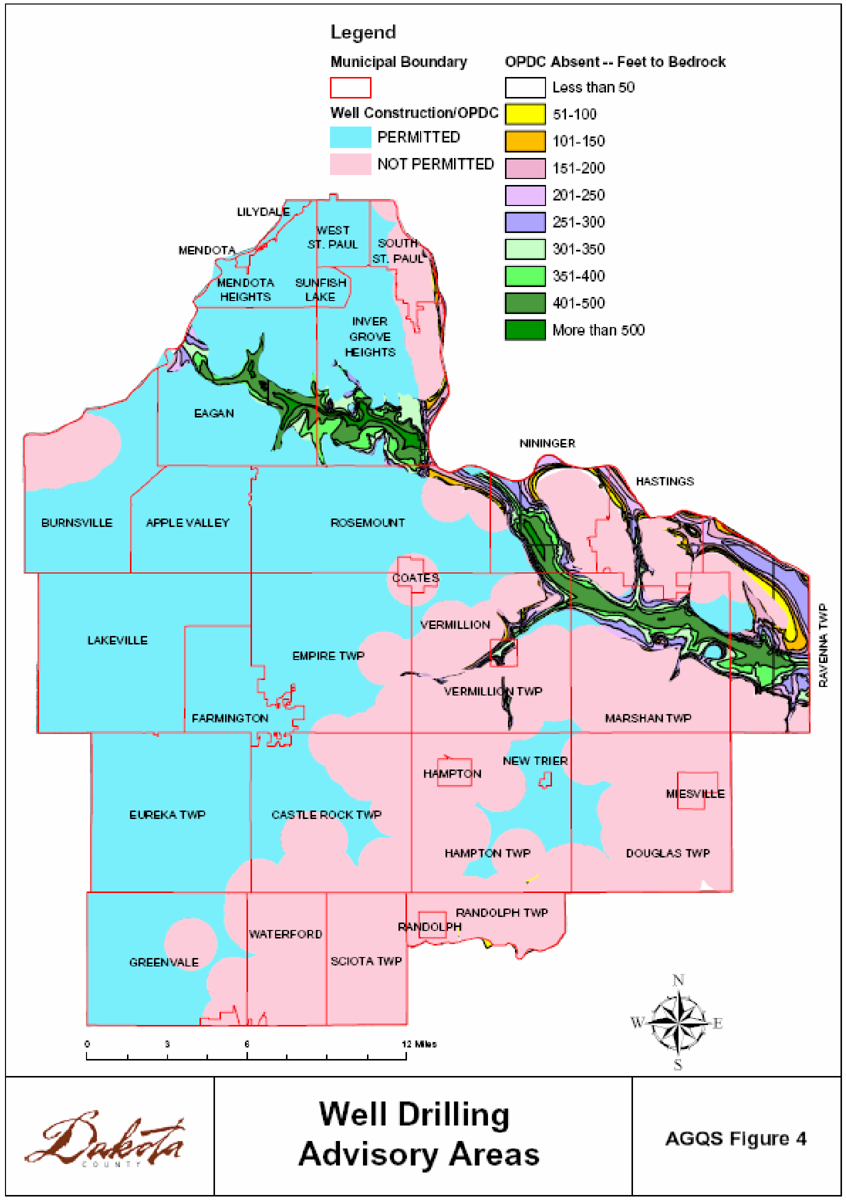

RICE
COUNTY
COURT
HOUSE
OUR
GOAL
United Way


INAUGURATED
BY THE CLASS
OF 1926 AND
ERECTED BY
THE CADETS
FACULTY AND
ALUMNI OF
SHATTUCK

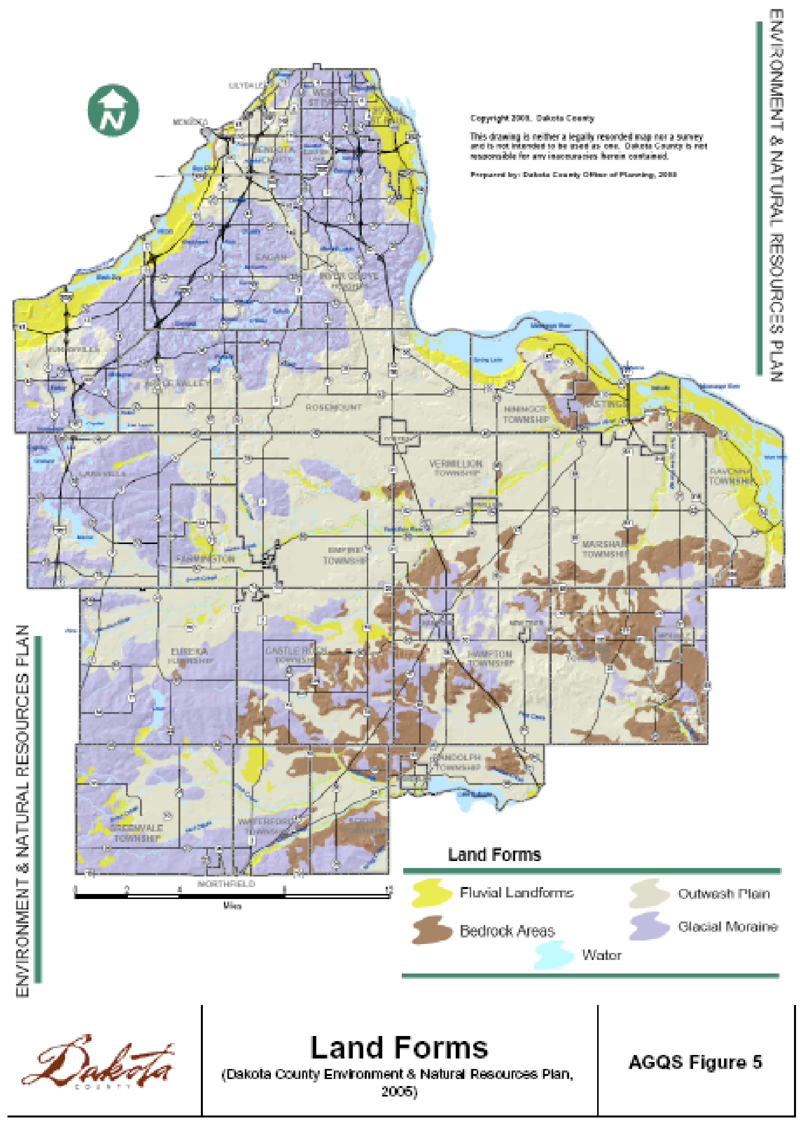
91% of Dakota County uses groundwater (as opposed to surface water—e.g. rivers)

- Prairie du Chien Dolomite
- Jordan Sandstone
  - Two most used aquifers.
- Separated by the Oneota Dolomite (in some places these bedrock units act as one combined aquifer. In Dakota County they appear to act separately.)

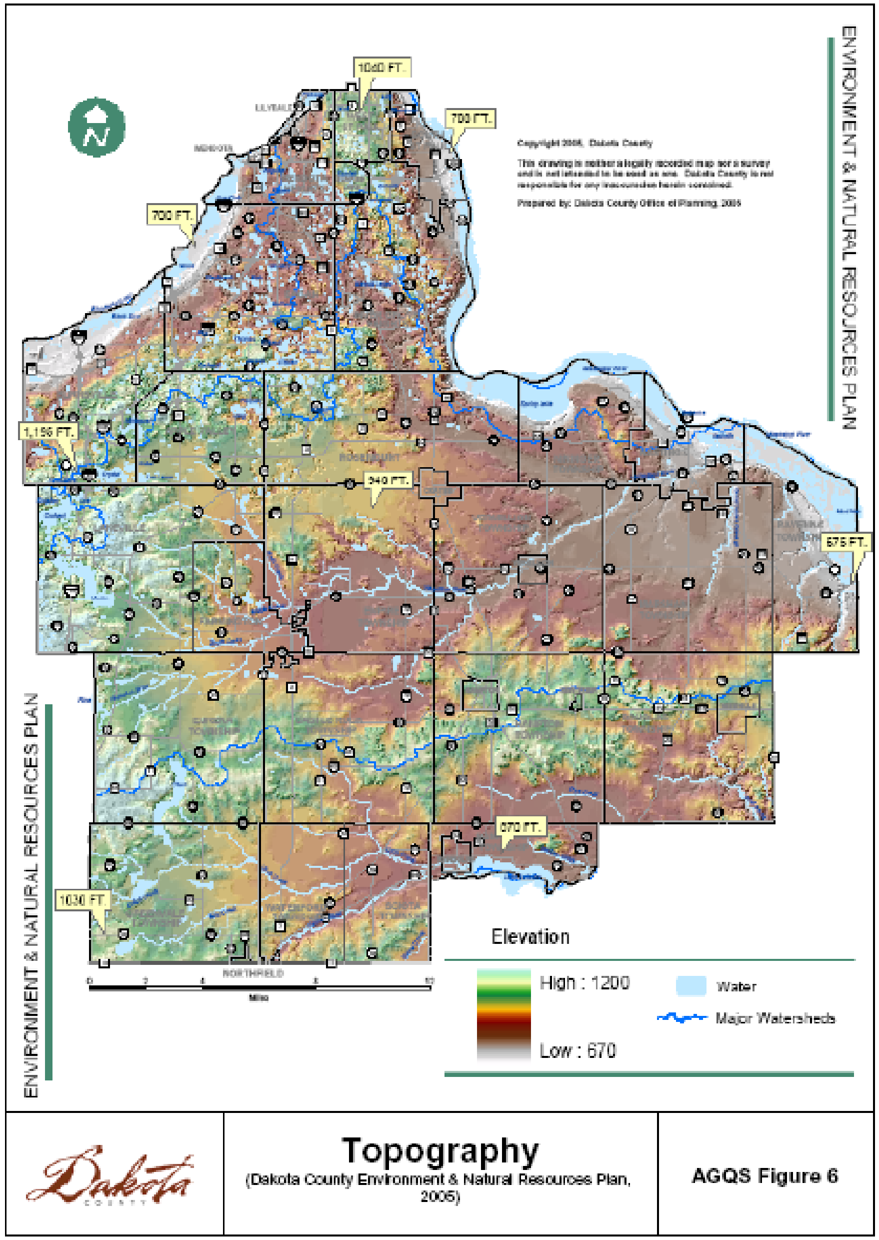
Areas where new wells cannot be drilled into Prairie du Chien because of contamination issues



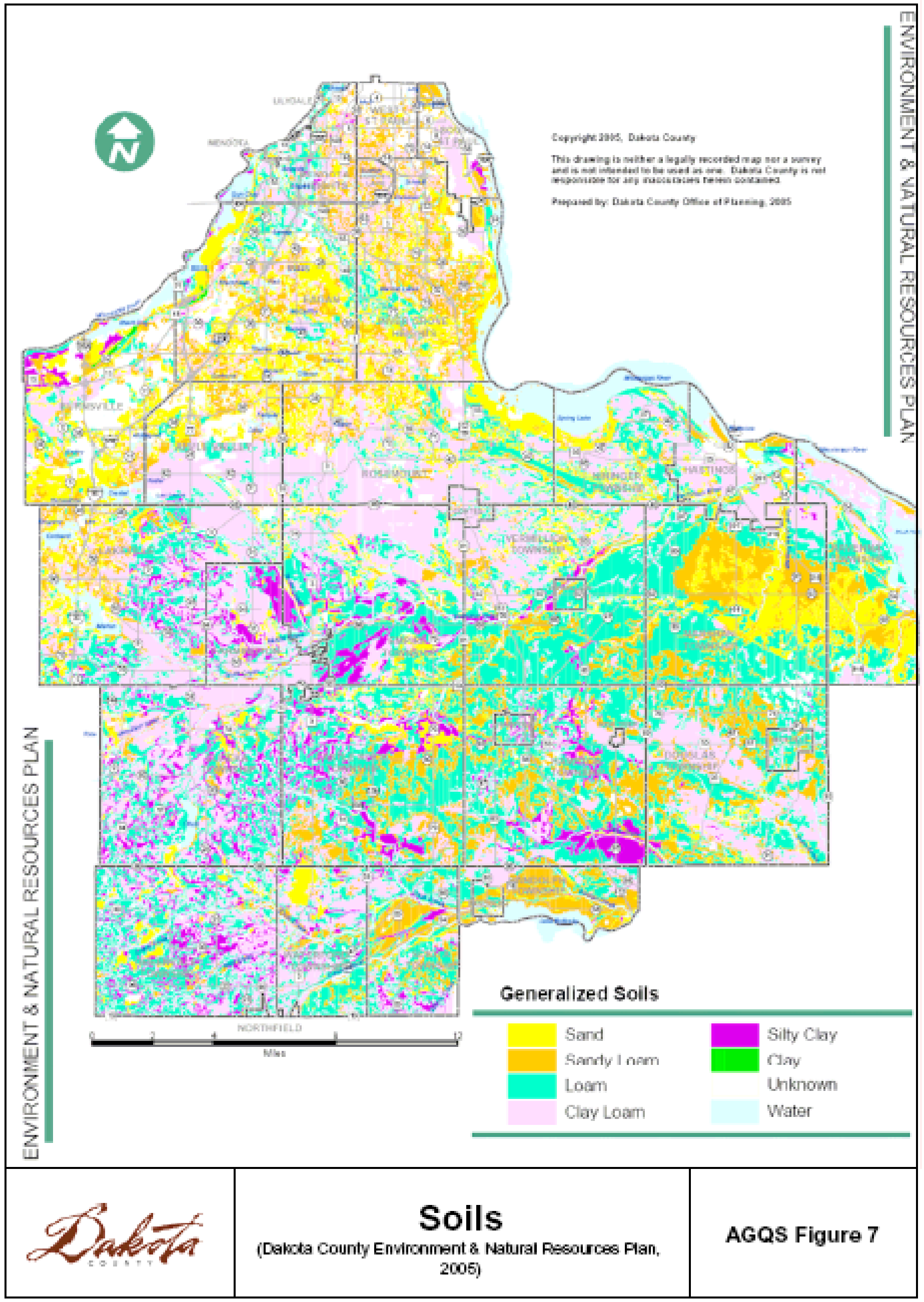
Glacial landforms and sediment are key to the susceptibility of bedrock aquifers



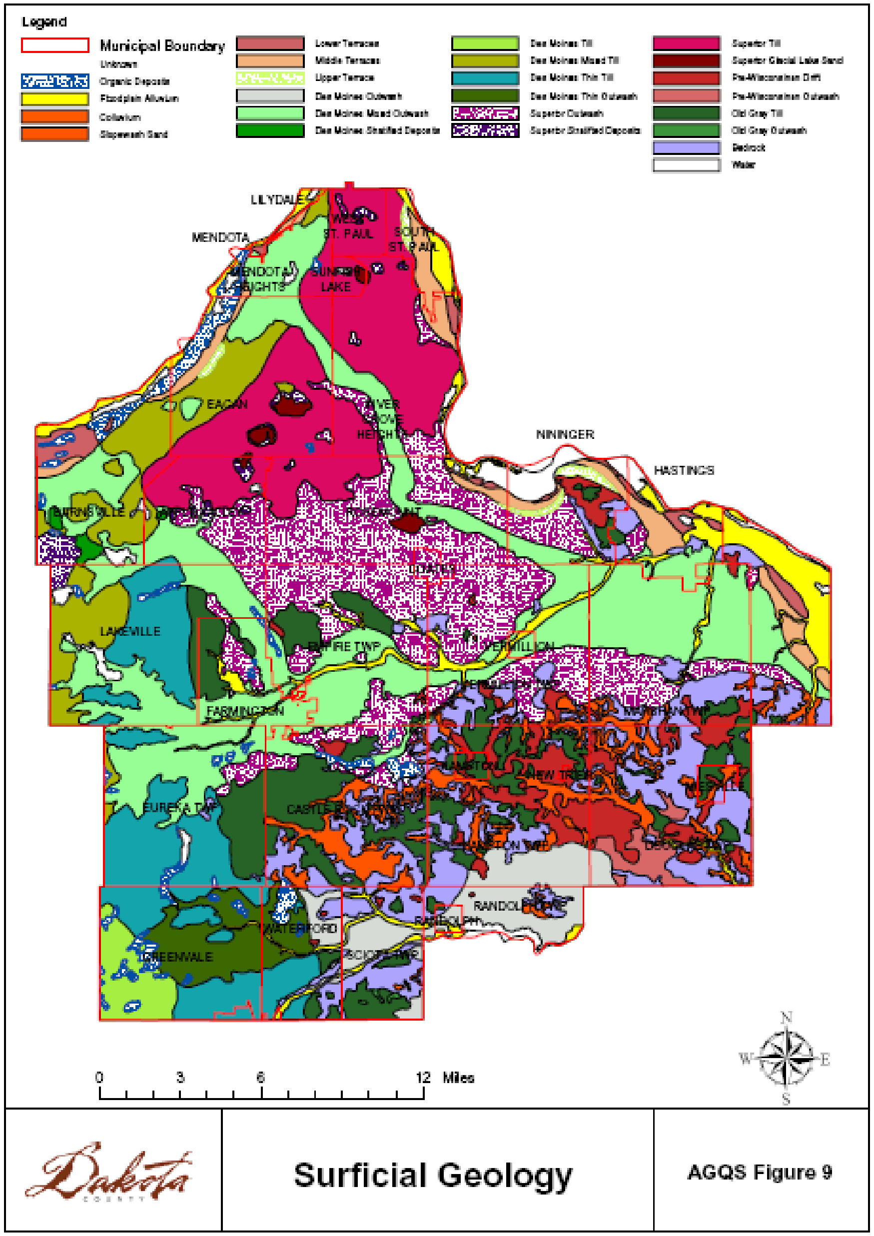
Topography also controls surface and groundwater flow directions

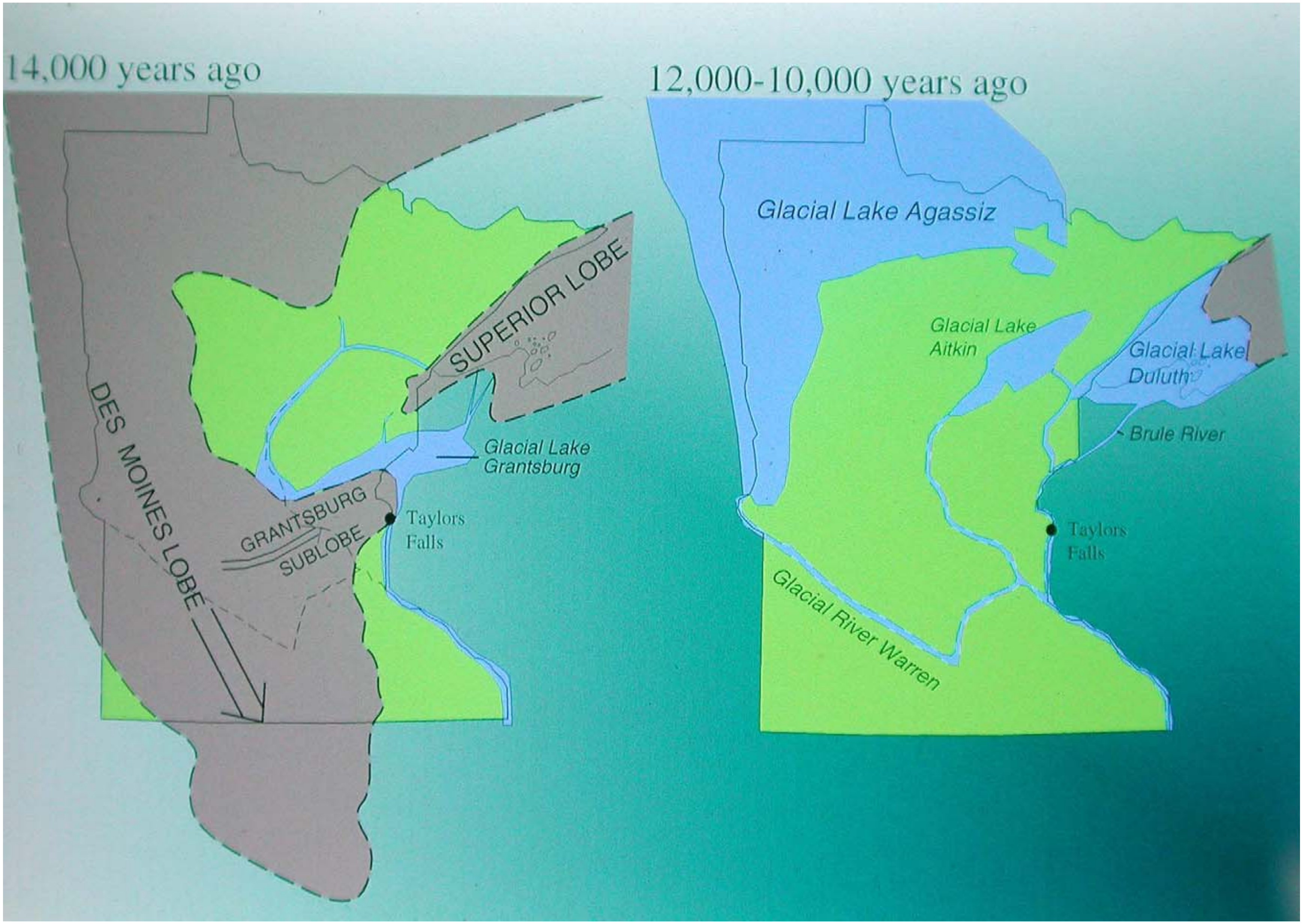


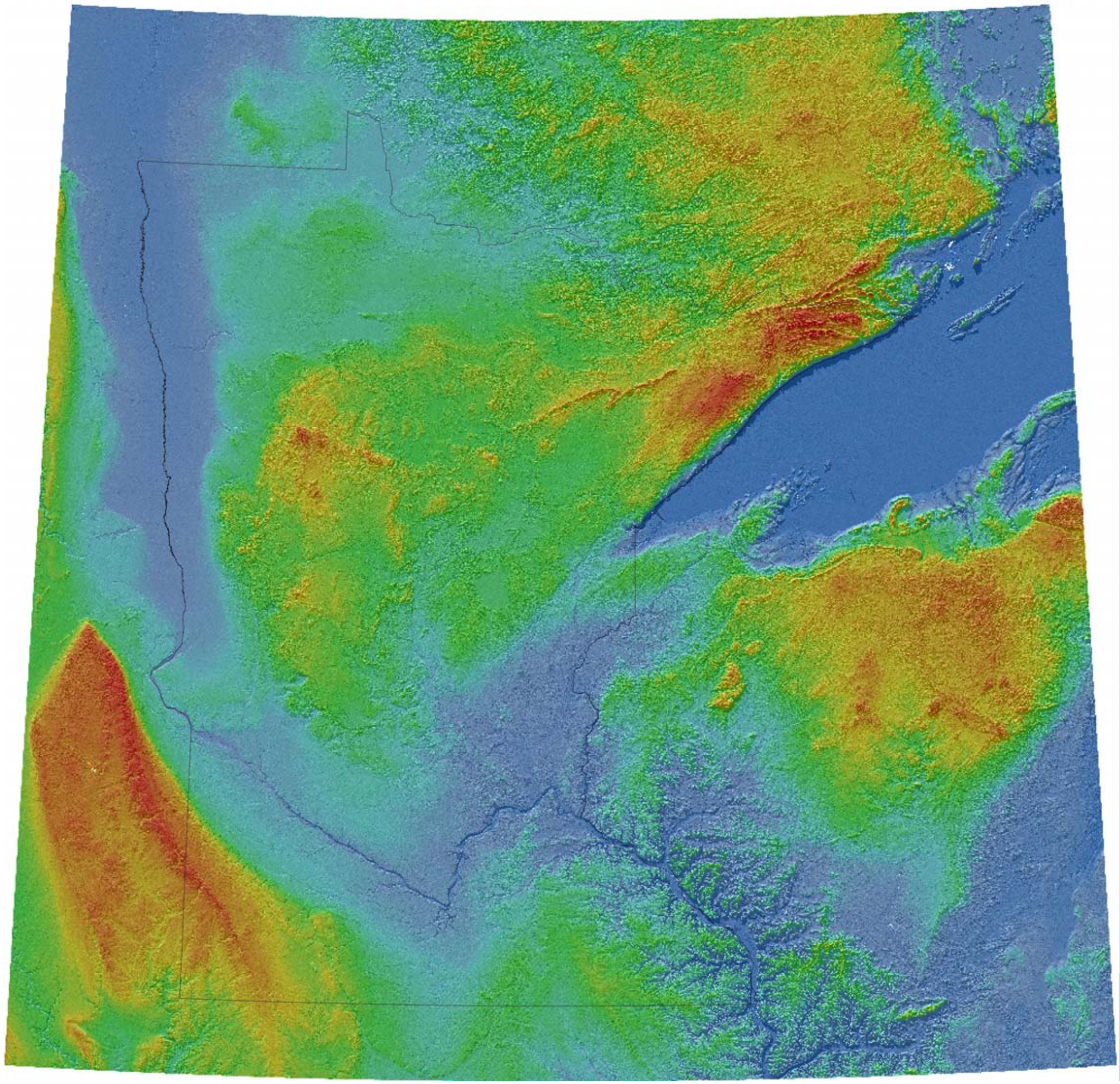
Soils have some control –they form over long periods of time in surface unit



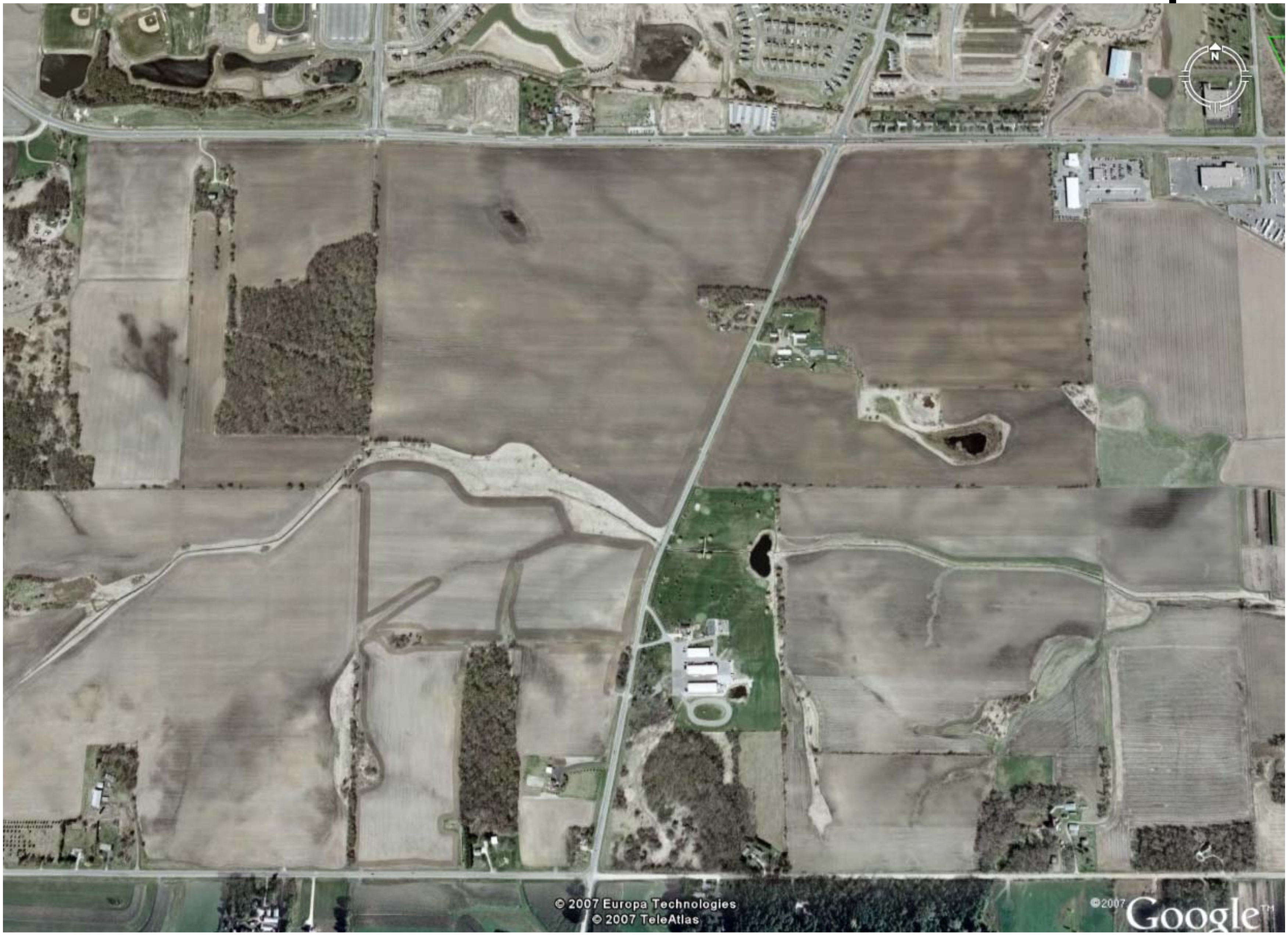
Surficial Geology -- the parent material of soils and cover for the bedrock




14,000 years ago
12,000-10,000 years ago
DES MOINES LOBE
SUPERIOR LOBE
GRANTSBURG SUBLOBE
Glacial Lake Grantsburg
Taylors Falls
Glacial Lake Agassiz
Glacial Lake Aitkin
Glacial Lake Duluth
Brule River
Taylors Falls
Glacial River Warren



Outwash stream in Eureka twp



Source of outwash to west

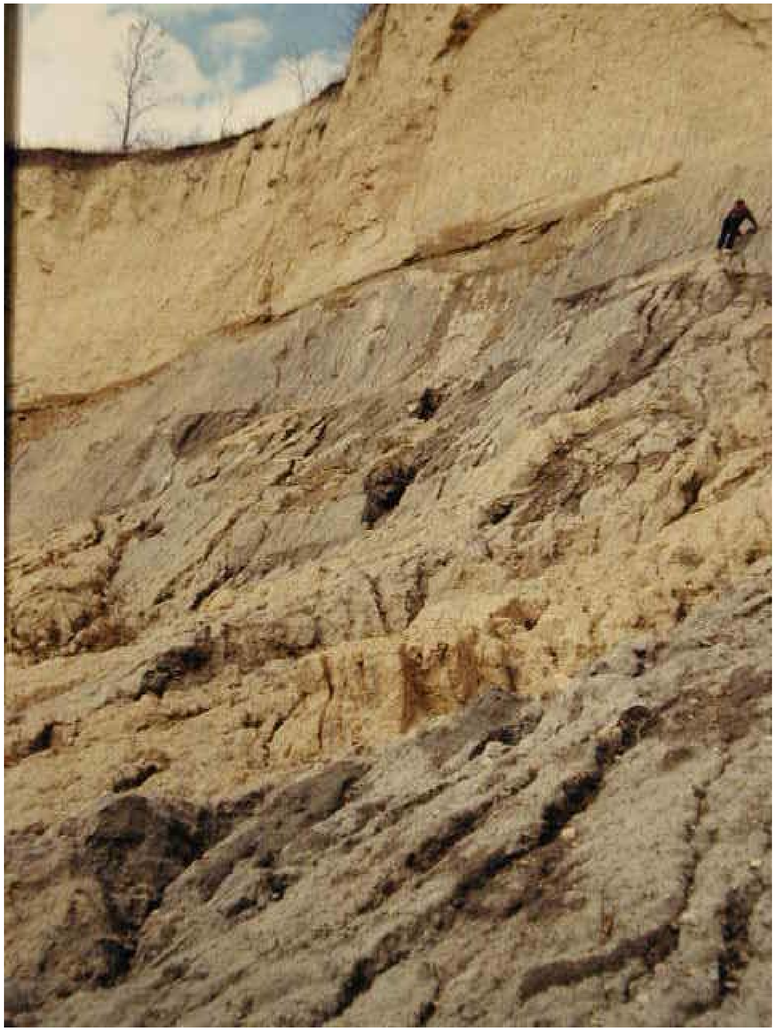
Gravel pits in outwash

Windblown sediment in glacial setting

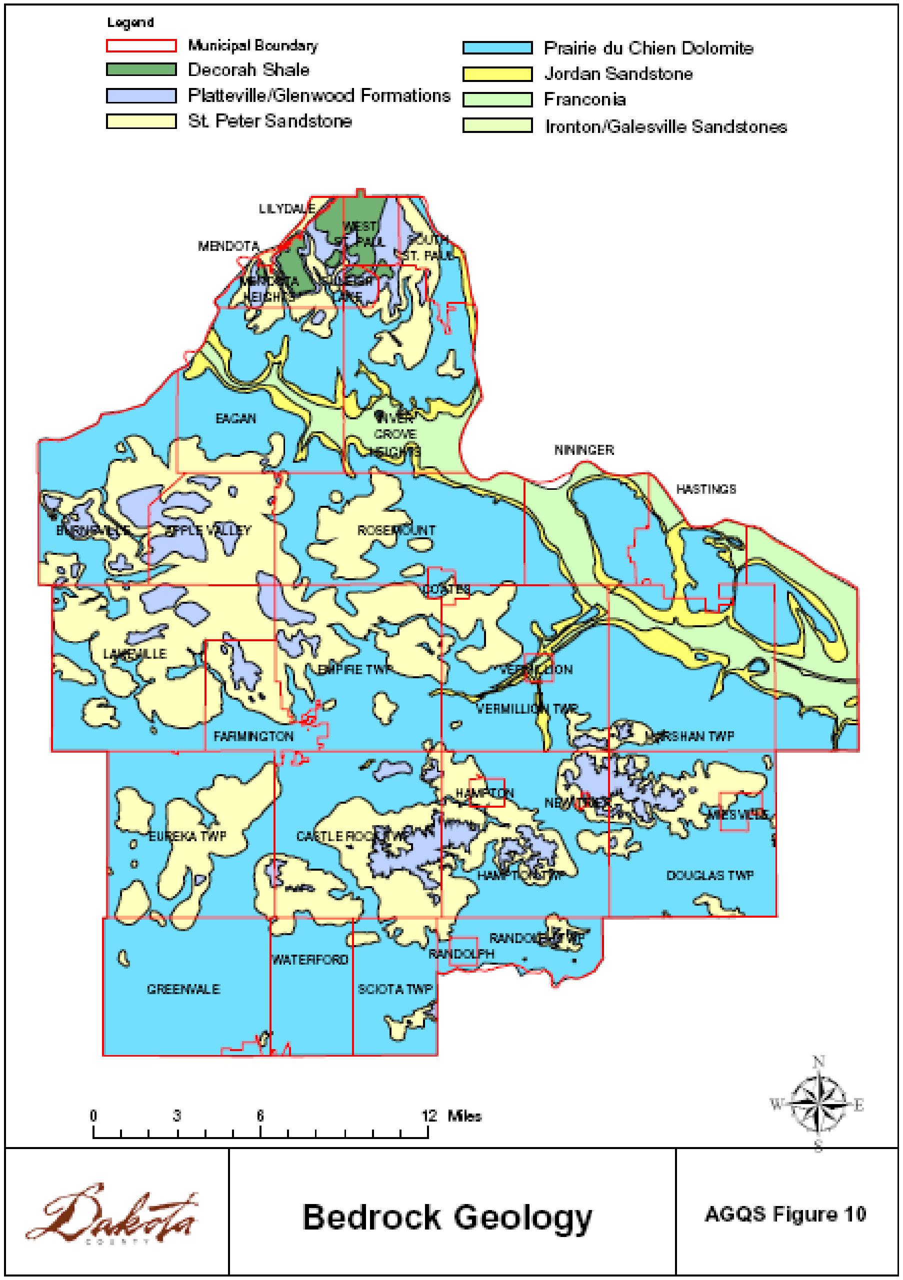
Loess drape on landscape

Quaternary Aquifers

- Wells finished in sand layers within the glacial deposits
- Older than 1974 (first well code)
- Can’t be used for municipal wells
- Used in older domestic and irrigation wells



First bedrock—St. Peter and Prairie du Chien



Bedrock Aquifers

- Platteville—older wells, water level 985’
- St. Peter—older wells, water level 650-705’
- Prairie du Chien
- Jordan
- Franconia
- Ironton-Galesville
- Mt. Simon-Hinckley--too expensive for domestic wells (depth of drilling)

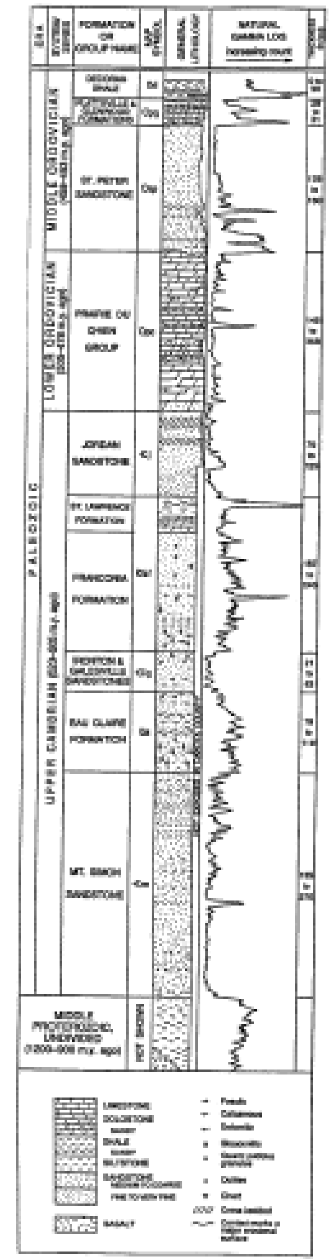
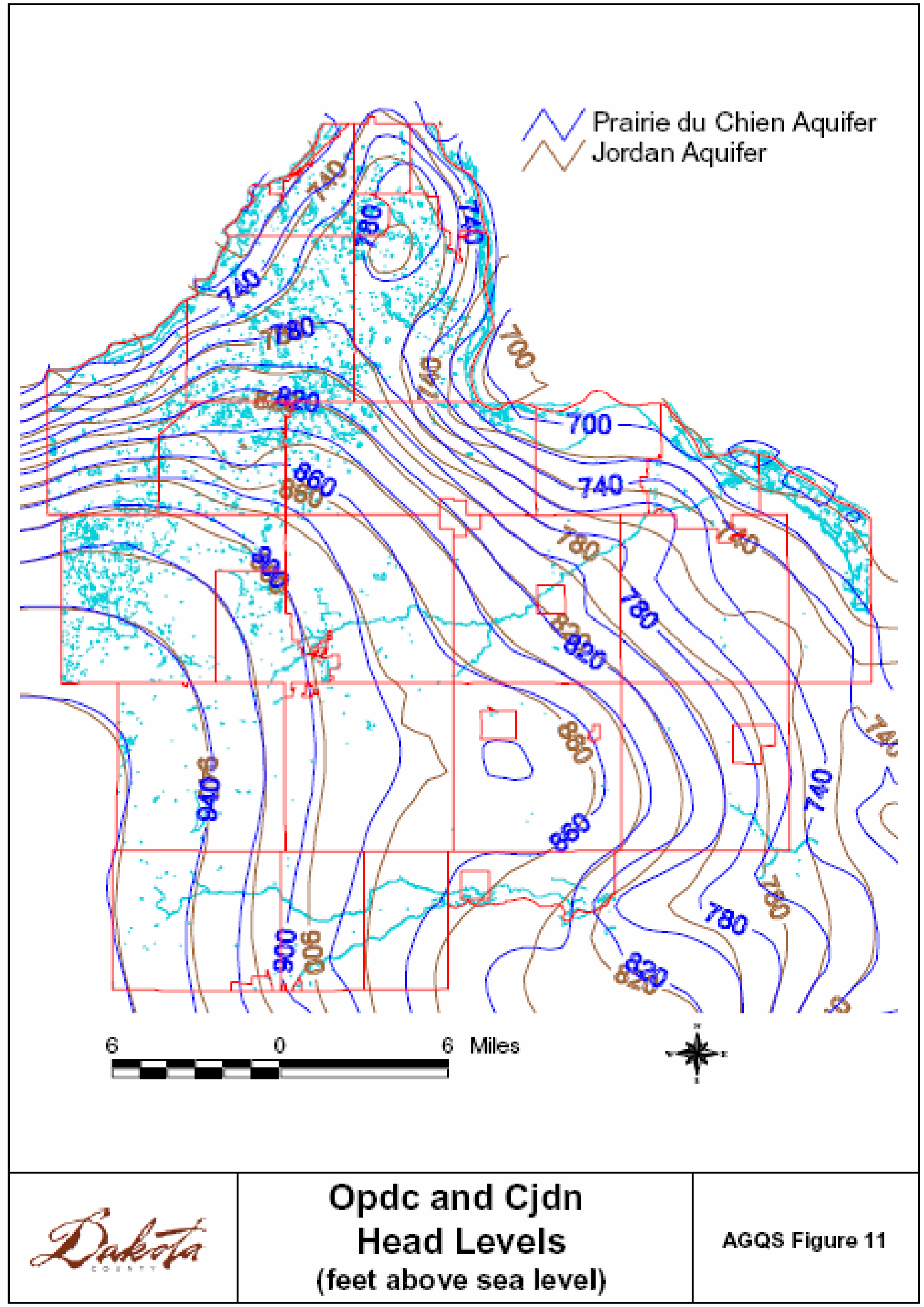


Figure 8: Geologic Column of Dak County (1991, Dakota County Geologic Atlas).

Groundwater surfaces have topography and groundwater slowly flows



Flows from high to low pressure or head

- Generally from high to low topography
- Surface lows that intersect this result in groundwater fed lakes or streams
- Rate of flow controlled by:
  - Recharge (rainfall)
  - Discharge (natural and pumping)
  - Porosity and permeability of rock unit

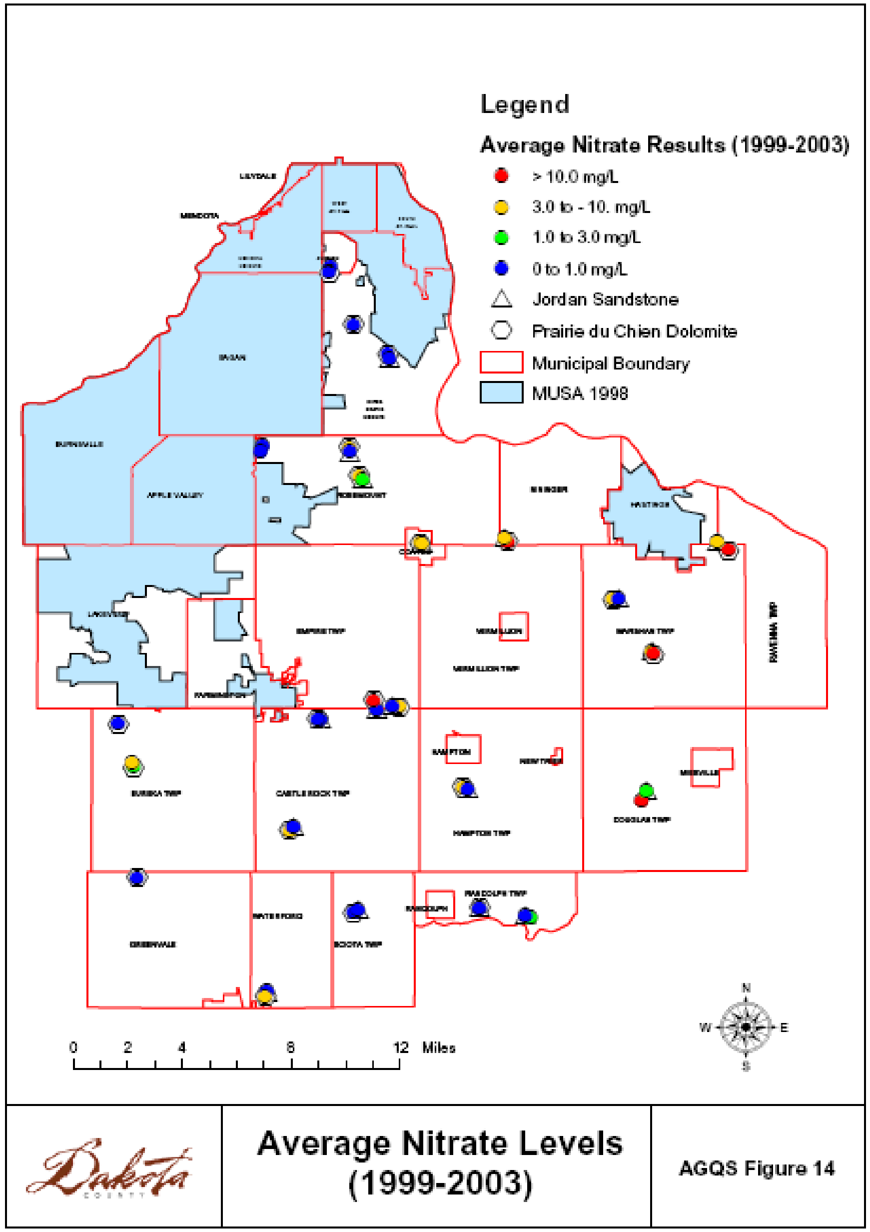
Groundwater parameters measured

- Temperature (between 35 – 40 Deg. F)
- pH (Ranges between 6-8)
- Specific conductivity (dissolved ions in water)
- Dissolved gases (oxygen, nitrogen, hydrogen sulfide, carbon dioxide)
- Eh (oxidation potential or chemical activity of the water)
- Turbidity (cloudiness)

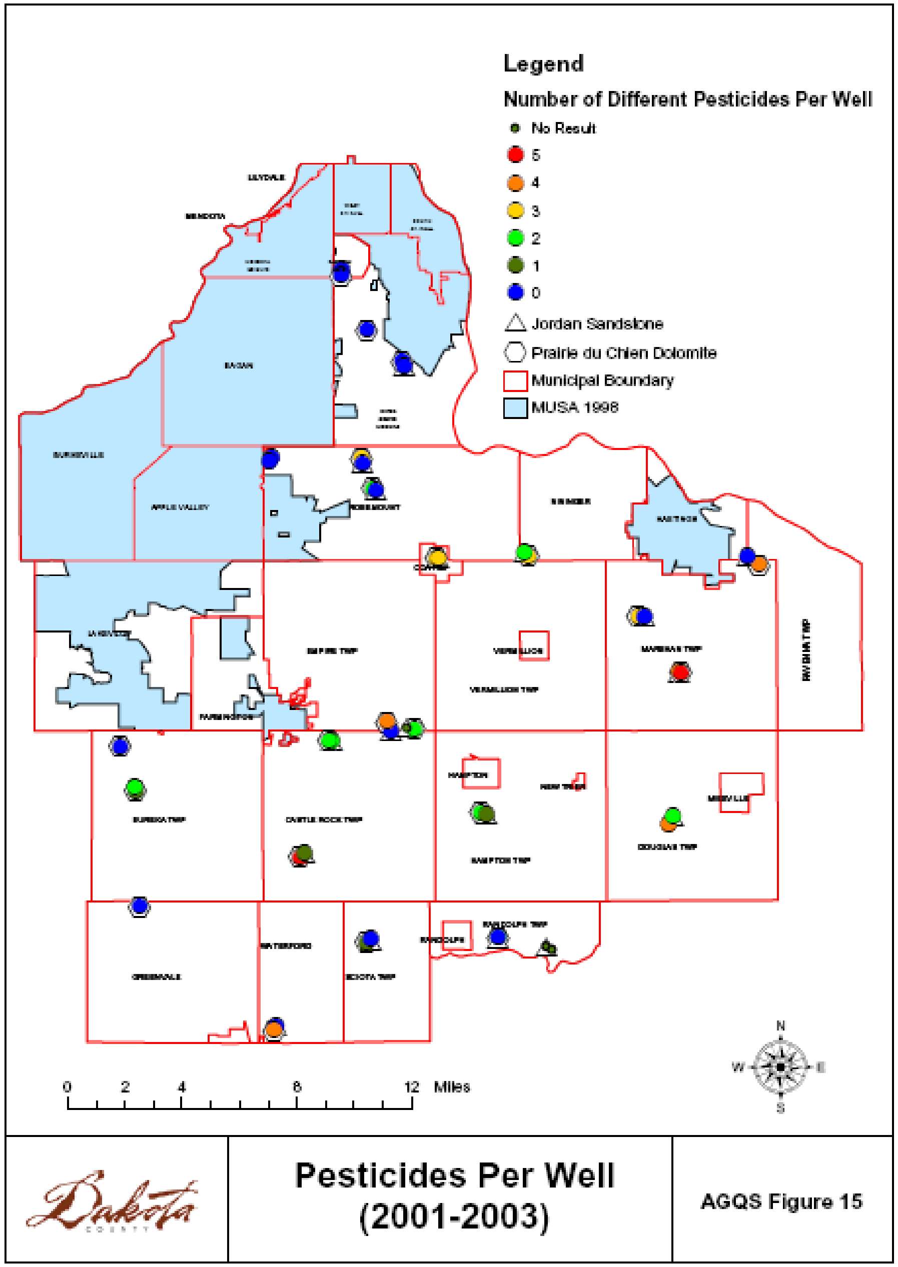
Chemical parameters measured

- Major ions (calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, and bromide)
- Nutrients (nitrogen, phosphorus and potassium)
- Total organic carbon (derived from living organisms—includes volatile organic compounds which are almost totally anthropogenic (manmade) and are the most dangerous (gasoline, alcohols, caffeine and many others)
- Pesticides (insecticides, herbicedes and fungicides)
- Fertilizers and their metabolites (things they turn into)
  - Nitrate the most dangerous as it replaces oxygen in the blood

Average Nitrate levels



Pesticides



Legend
Number of Different Pesticides Per Well
No Result
5
4
3
2
1
0
Jordan Sandstone
Prairie du Chien Dolomite
Municipal Boundary
MUSA 1998
0 2 4 8 12 Miles
N
W
E
S
Pesticides Per Well
(2001-2003)
AGQS Figure 15

Although no pesticides exceed drinking water standards…

- 61% of wells have detectable levels of pesticides (lower detection levels than nitrate)
- 48% detectable levels of nitrate
- MDH cumulative risk assessment
  - 1 in 100,000 incidences of cancer or noncancer health effects
  - Concern over multiple pesticides

Pesticides and well depth

Table 5: Hydrogeological Zone and Pesticide Results

Zone	# Of Samples	Median Pesticide Results (ug/L)	Samples with Detections	Median Number of Active Ingredients
1 (Less than 50 ft. of cover over Opdc)	14	2.33	10 (71.4%)	3.5
2 (More than 50 ft. of sandy outwash over Opdc)	34	0.83	24 (70.6%)	2
3 (More than 50 ft. of clayey glacial till over Opdc)	16	0.00	5 (31.3%)	0
4 (St. Peter Sandstone over Opdc)	20	0.12	12 (60.0%)	1

Types of pesticides detected

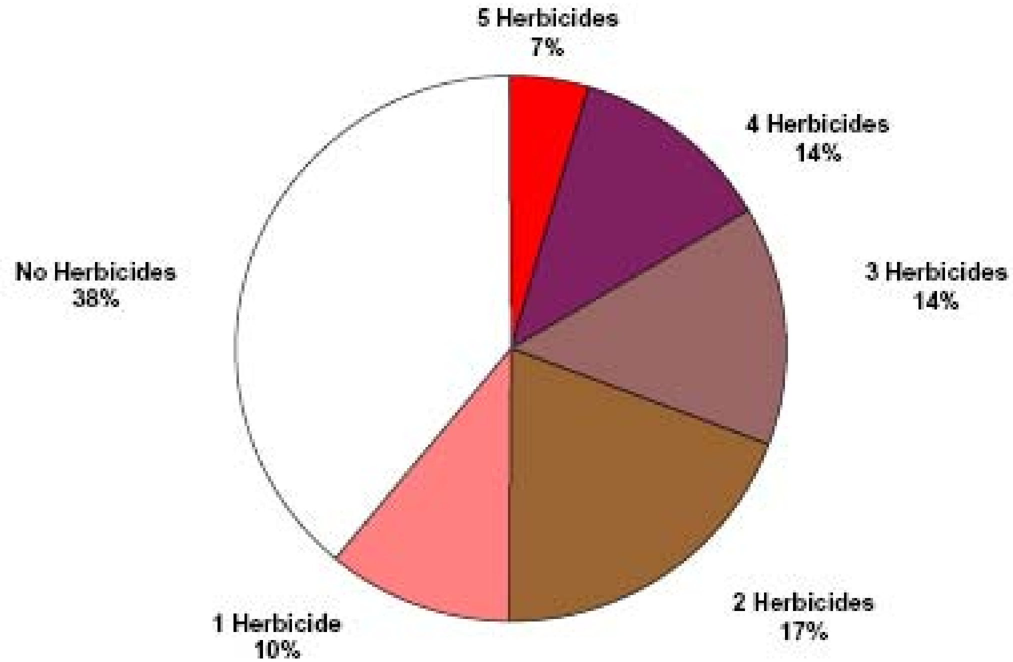


Chart 1: Pesticides per Well

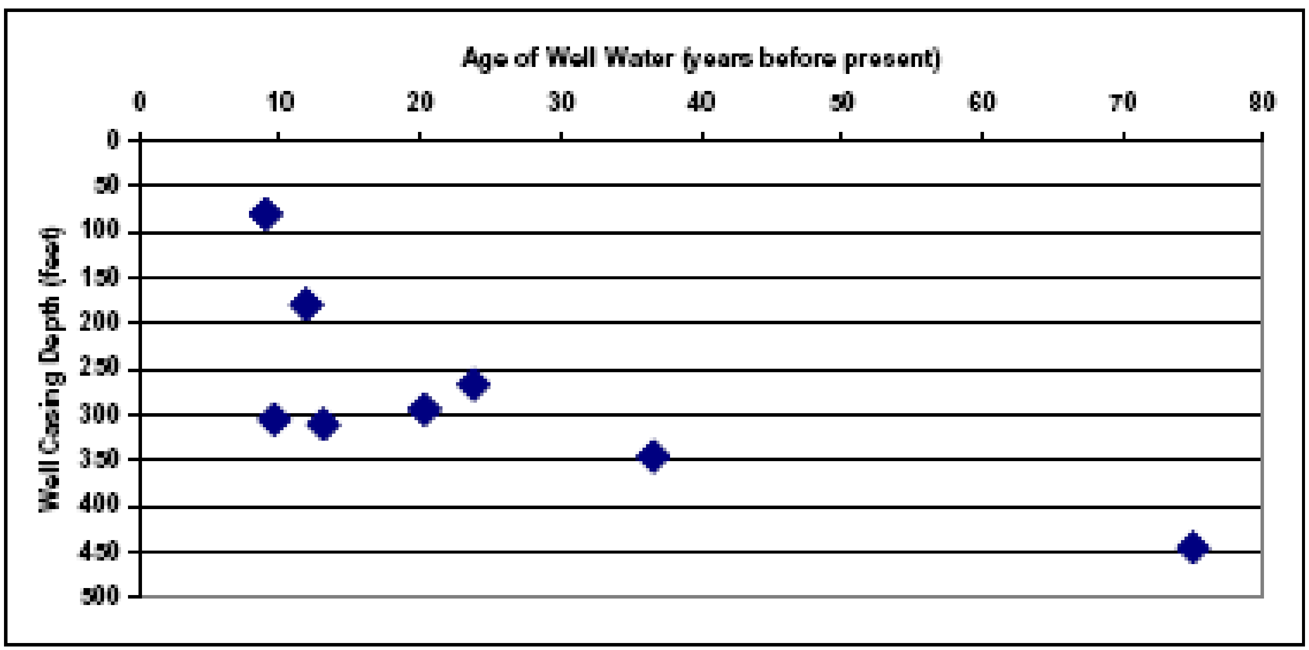
In the 2002-2003 AGQS results:

- When 1 pesticide contaminant was detected, it was Alachlor;
- When 2 were detected, they were Alachlor and Metolachlor;
- When 3 were detected, they were Alachlor, Metolachlor, and Atrazine;
- When 4 were detected, they were Alachlor, Metolachlor, Atrazine, and Acetochlor.

Age-dating groundwater: in general, deeper = older

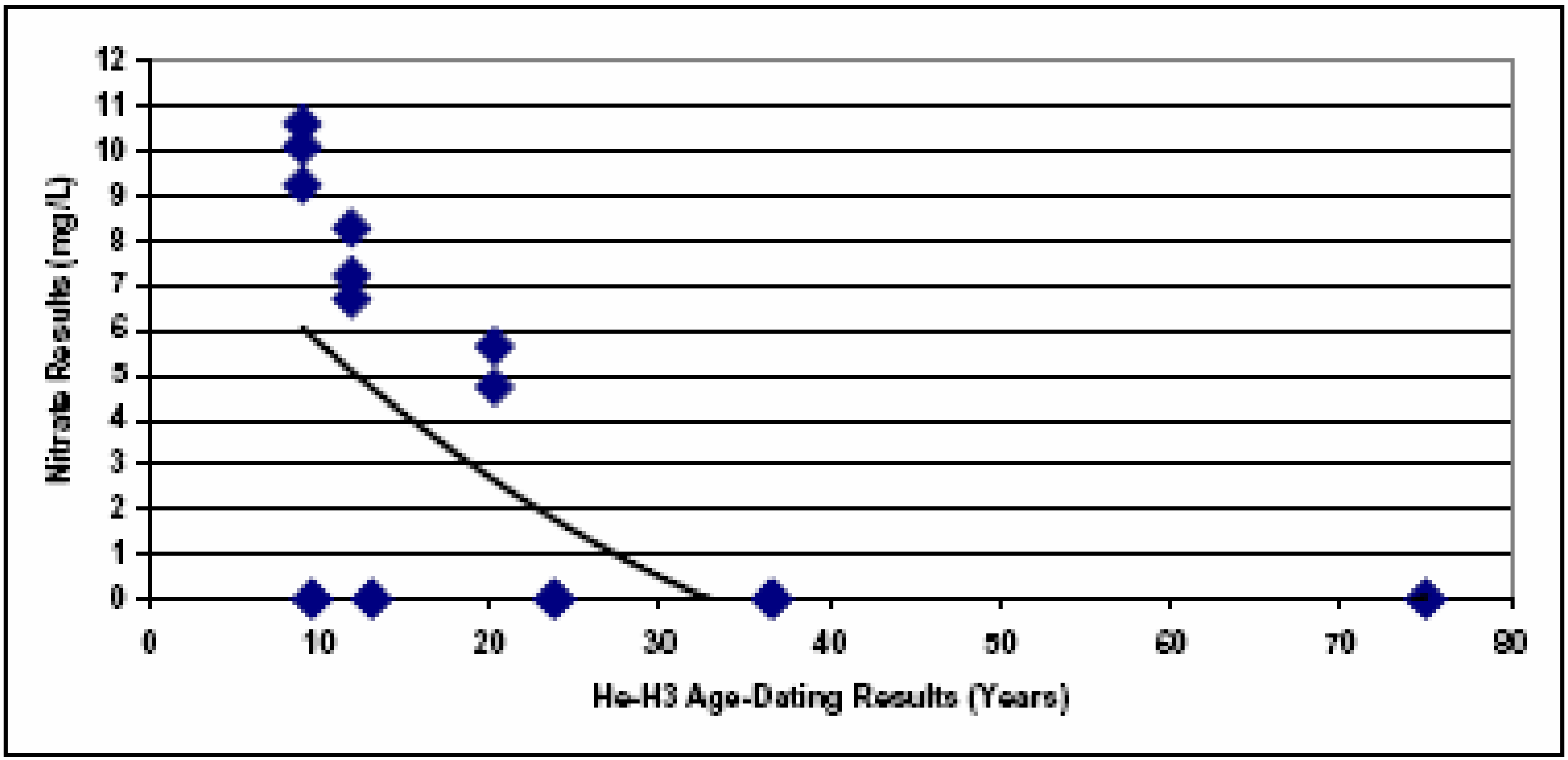
- Ranged from more than 100 years to less than one year, median, 20.3 years

Chart 3: He-H3 Age-Dating Results and Well Casing Depth



Nitrate concentrations vs. age of groundwater

Chart 4: He-H3 Age-Dating Results and Nitrate Concentrations



Nitrate concentrations vs depth of cover

Table 4: Hydrogeological Zone and Nitrate Results

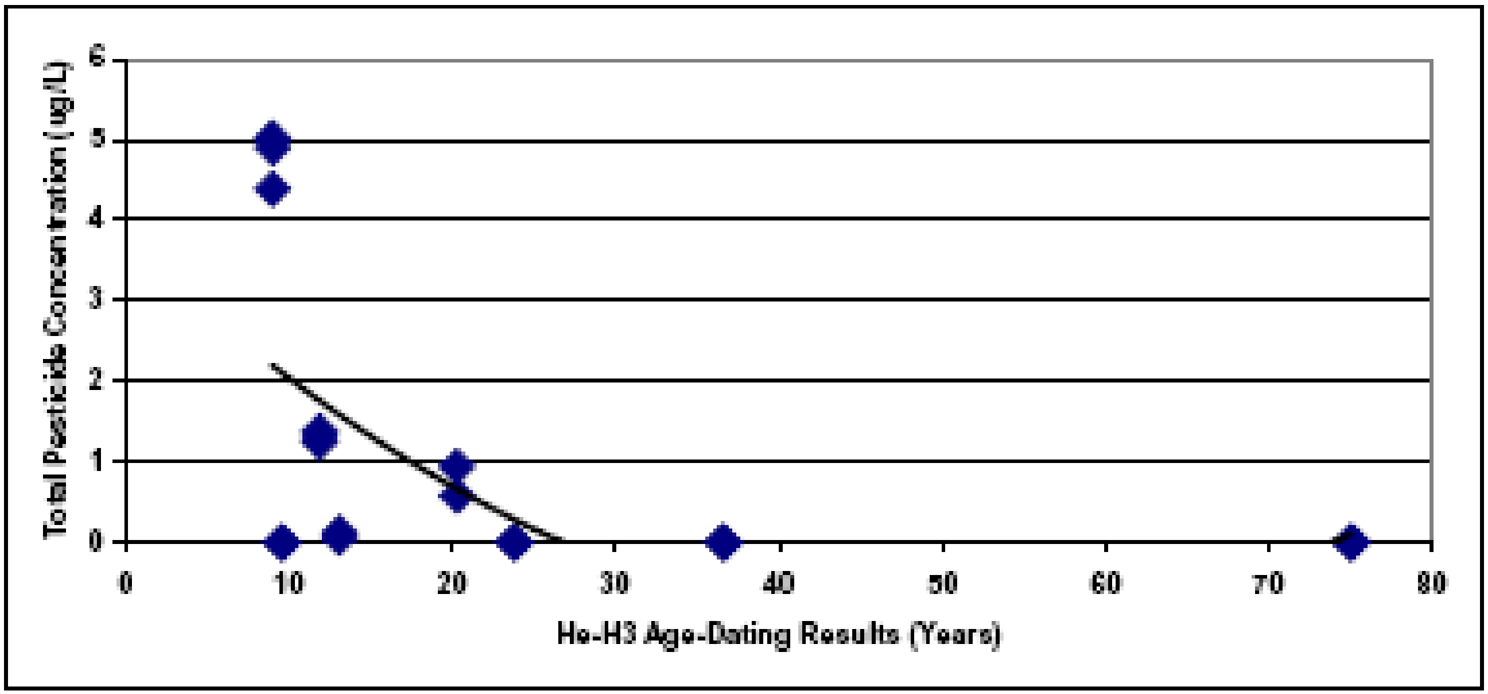
Zone	# Of Samples	Median Nitrate Results (mg/L)	Samples with Detections	Samples > 10 mg/L
1 (Less than 50 ft. of cover over Opdc)	35	5.00	28 (80%)	9 (26%)
2 (More than 50 ft. of sandy outwash over Opdc)	78	0.00	34 (44%)	9 (12%)
3 (More than 50 ft. of clayey glacial till over Opdc)	38	0.00	9 (24%)	2 (5%)
4 (St. Peter Sandstone over Opdc)	48	0.24	25 (53%)	0 (0%)

Pesticide levels were also significantly correlated to the hydrogeological zone (Kruskal-Wallis $H = 8.1384$, $p = 0.0432$).

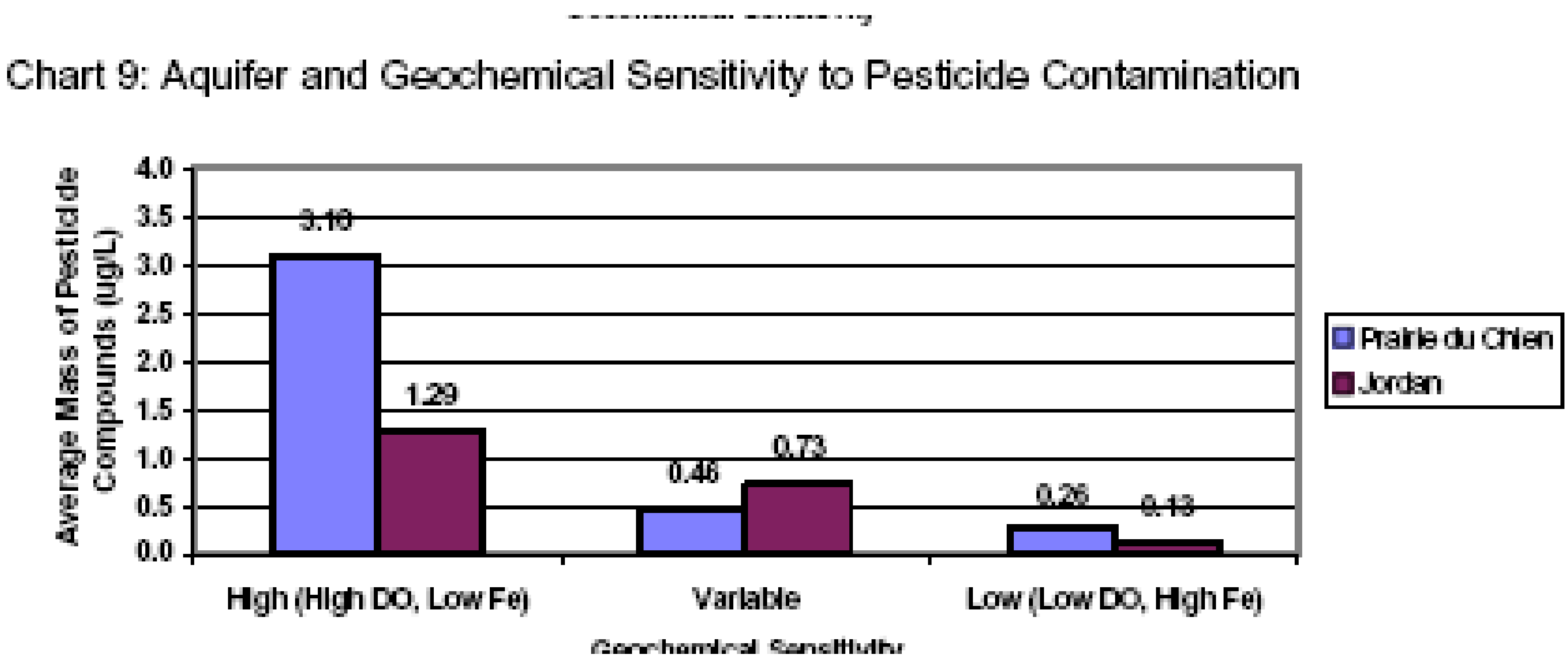
Pesticide introduction vs detection

- Acetochlor introduced in 1994, found in groundwater in 2002 estimated to be 9 years old= went directly to groundwater

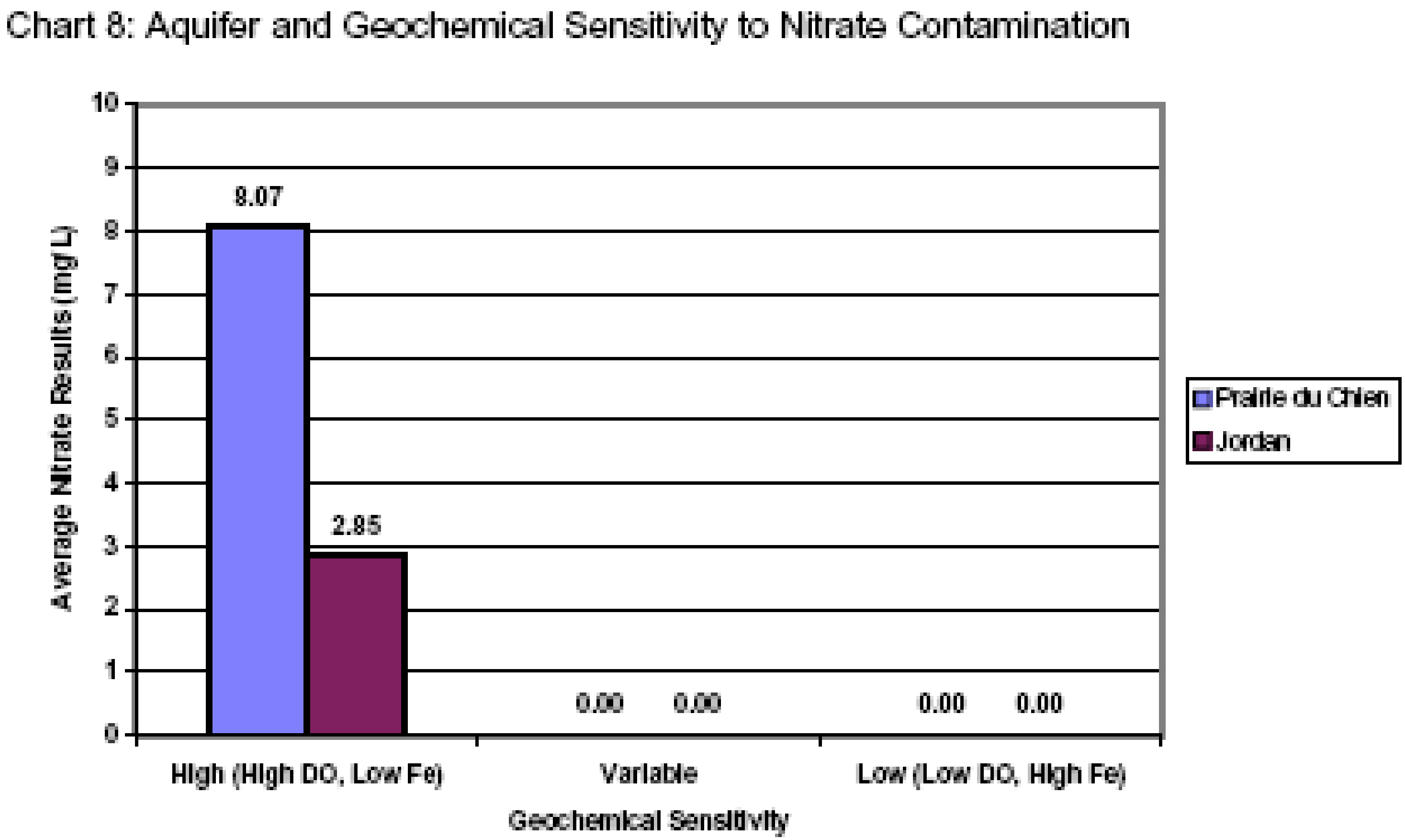
Chart 5: He-H3 Age-Dating Results and Total Pesticide Concentrations



Pesticide sensitivity by aquifer



Nitrate sensitivity by aquifer

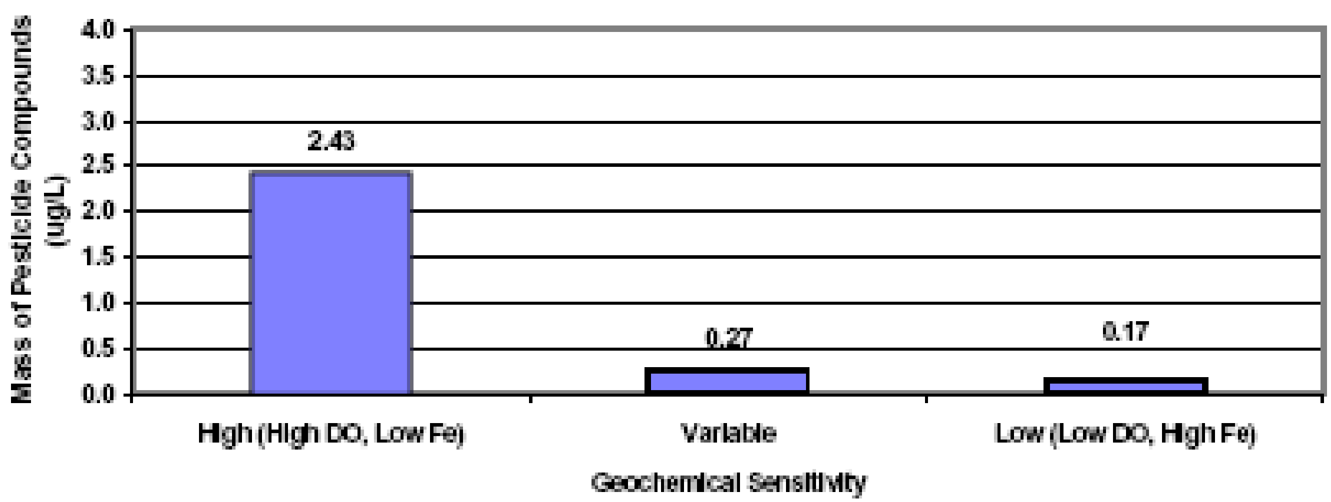


Overall geochemical sensitivity

Table 10: Geochemical Sensitivity and Pesticide Results

Geochemical Sensitivity	# Of Wells	Wells w/ no pesticide compounds detected (annual average)	Wells w/ pesticide compounds detected (annual average)	Average mass of pesticides (ug/L)
High	27	5 (18.5%)	22 (81.5%)	2.43
Variable	5	4 (80%)	1 (20%)	0.27
Low	10	7 (70%)	3 (30%)	0.17
Total	43	22 (49%)	23 (51%)	1.63

Chart 7: Geochemical Sensitivity and Pesticide Results



Hydrogeologic zones used to rank geochemical sensitivity

Zone 1: Less than 50 feet of cover over the Prairie du Chien (Opdc)

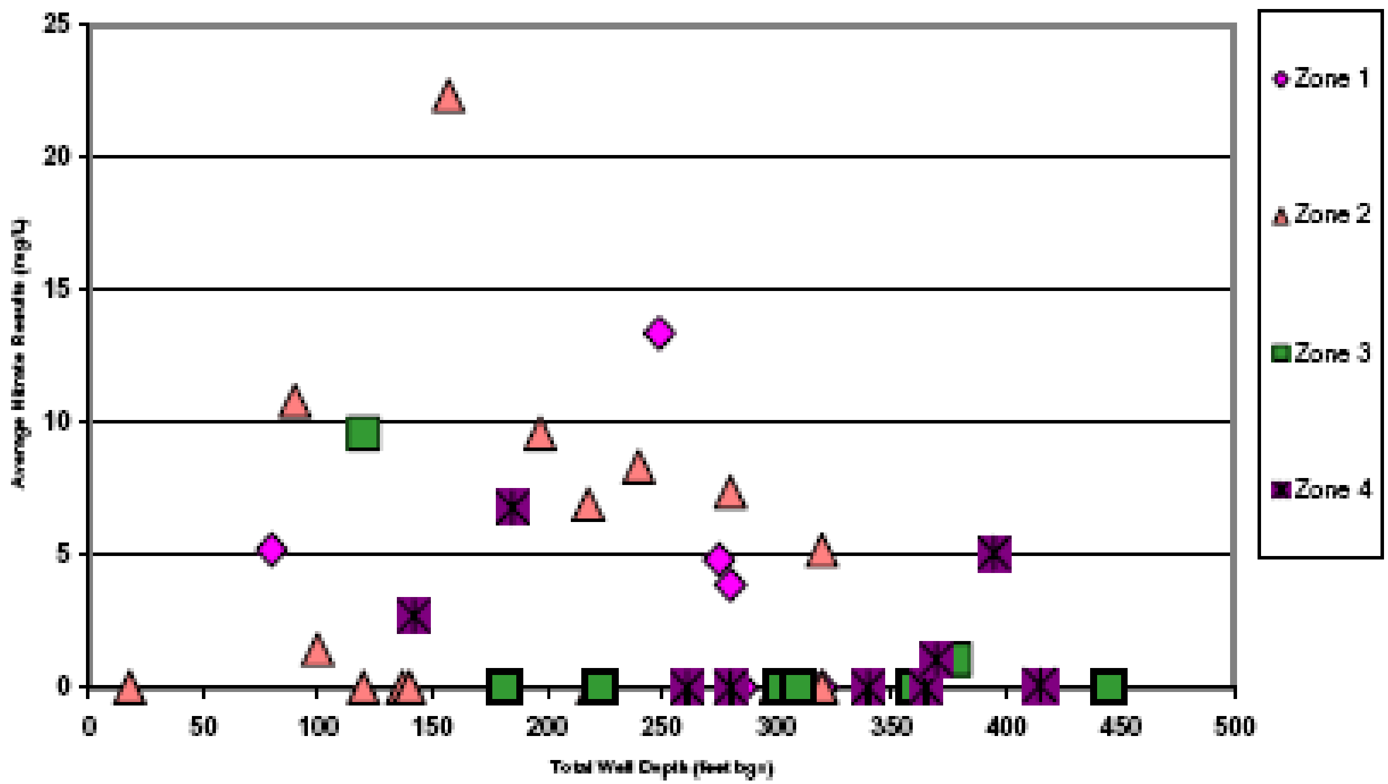
Zone 2: More than 50 feet of sandy outwash over Opdc

Zone 3: More than 50 feet of clayey till over Opdc

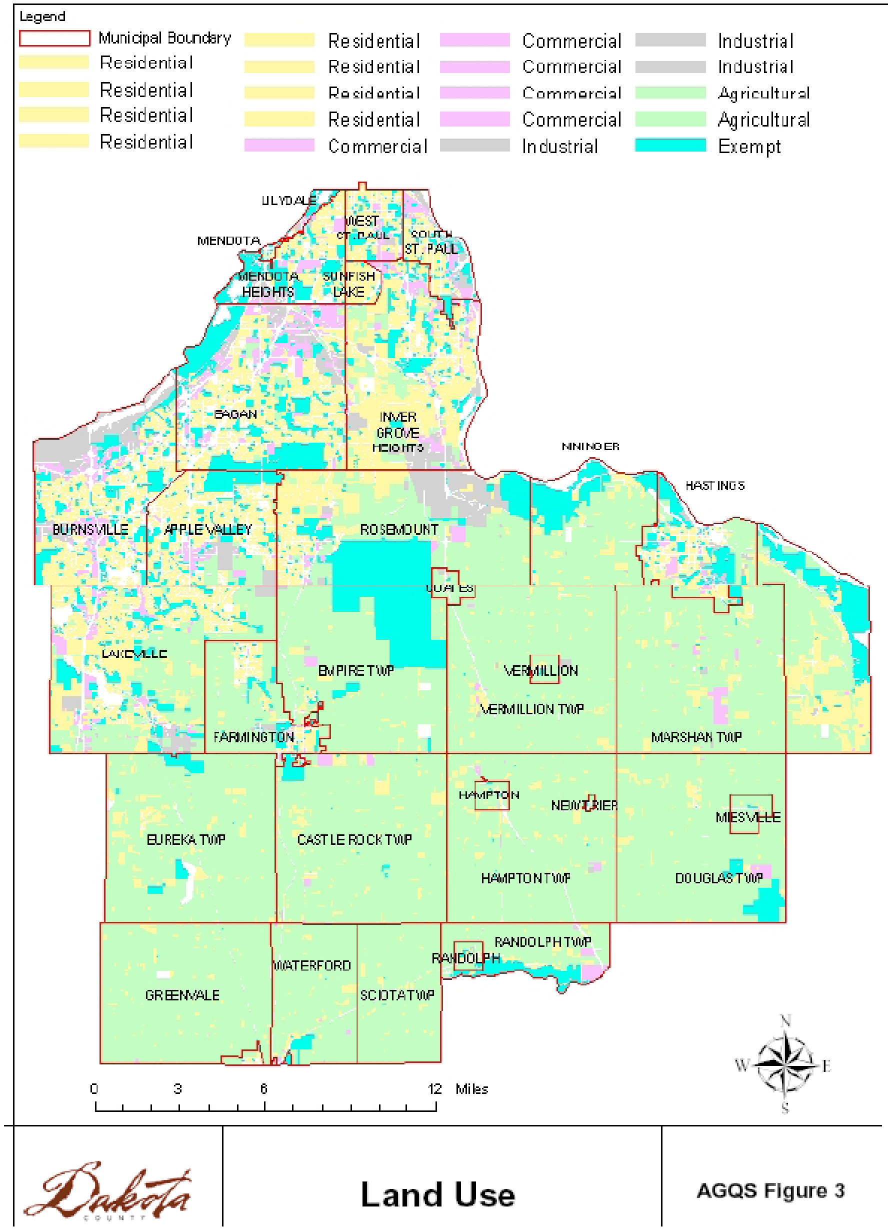
Zone 4: St. Peter Sandstone over Opdc

10, below, show average nitrate results by well depth interval and hydrogeological zone. Unfortunately, as can be seen from this table, in Dakota County bedrock wells there is no magic combination of well depth and hydrogeological zone in which nitrate will be completely undetected. Nonetheless, in Zone 3, nitrate is typically low below 120 feet; in Zone 4, nitrate is low below 200 feet; in Zone 1, nitrate is low below 320 feet; and in Zone 2, nitrate is low below 320 feet.

Chart 10: Well Depth, Zone, and Average Nitrate Results



Land Use in Dakota County



Population growth increases demand on groundwater

- Lowers water levels in aquifers
- Surface water features not replenished
  - Fens and wetlands
  - Trout streams
- Reduces available drinking water

Trends--20 year out

- Estimated growth of 110,000 people
- 50,000 acres farmland and natural areas converted
- Increasing pressure on groundwater resources and quality
- 20-30% of groundwater resources ALREADY unsafe for human consumption

[illegible]	[illegible]
Empire Township	1,638
Eureka Township	1,490
Farmington	12,365
Greenvale Township	684

Minnesota Onsite Wastewater Association

- http://www.mostca.com/
- Mission: to protect public health and the environment by promoting professionalism in the Minnesota on-site wastewater treatment industry.
- Methods: promoting standards, products and services that reflect the belief that customers are best served by professionals who are well trained, have the resources needed and place a high valaue on the protection of natural resources

On-site systems

- 30% of Minnesotans use one
- 55-70% are failing or out of compliance

Tank

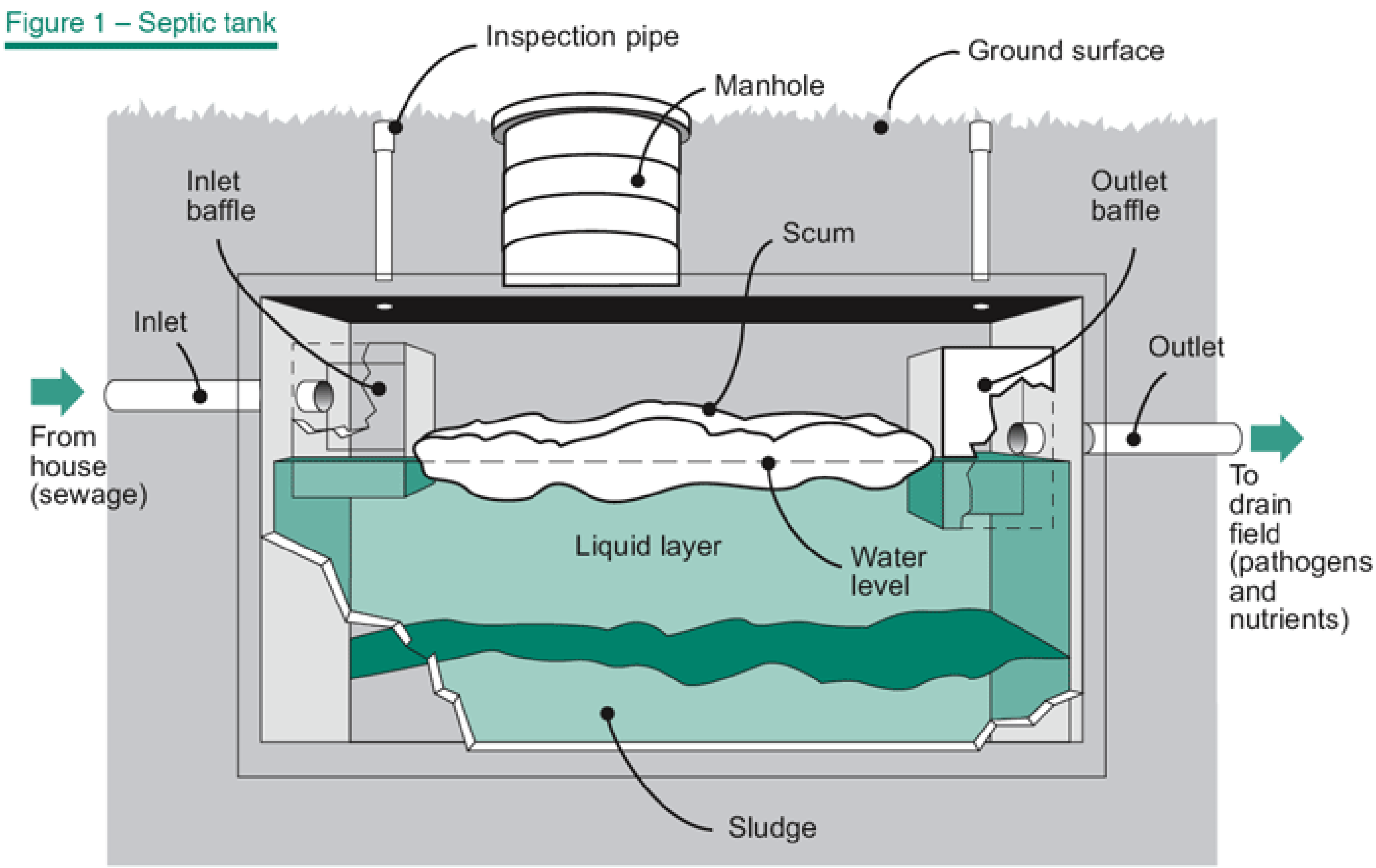
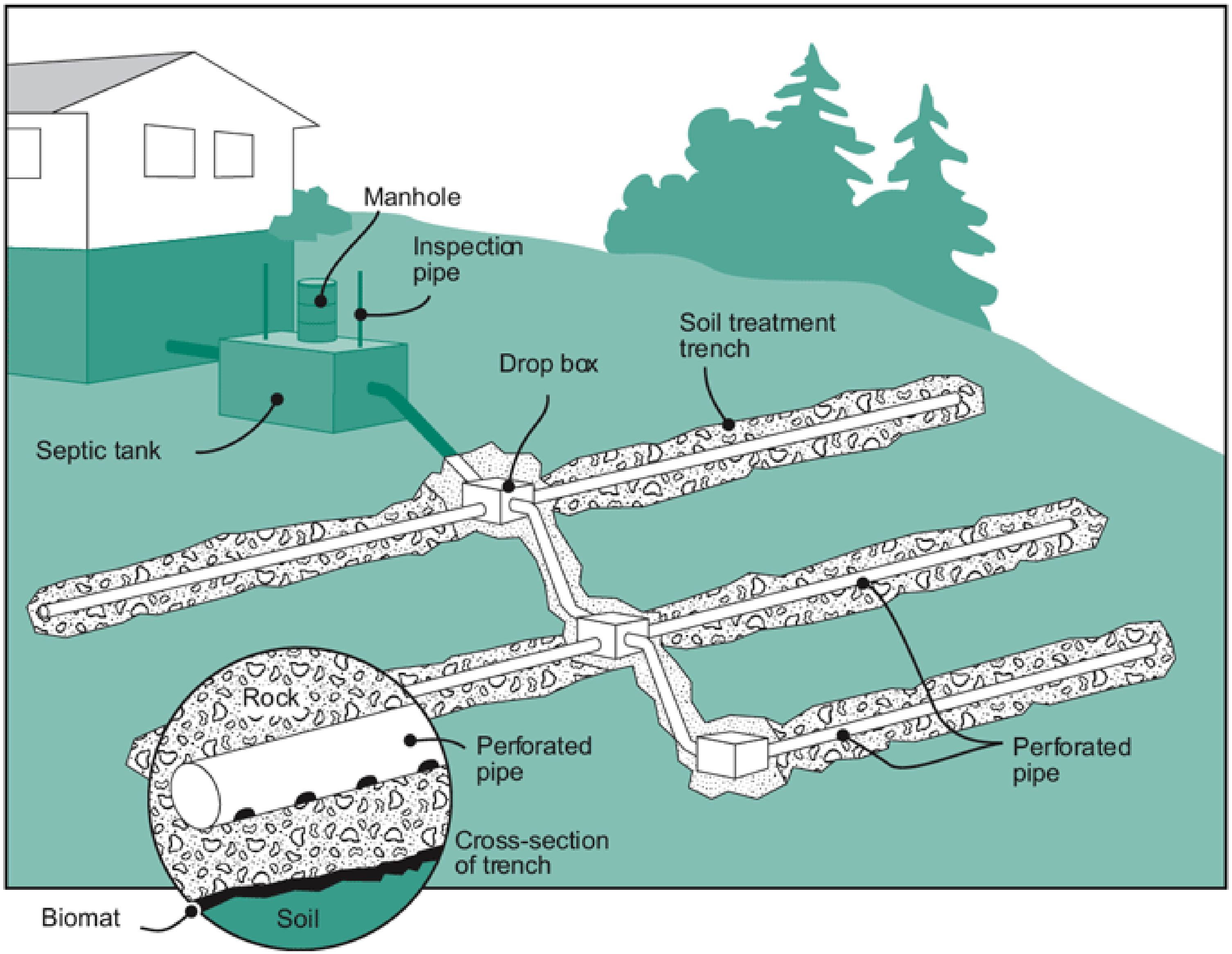


Figure 1 – Septic tank
Inspection pipe
Manhole
Ground surface
Inlet
baffle
Outlet
baffle
Scum
Inlet
Outlet
From
house
(sewage)
To
drain
field
(pathogens
and
nutrients)
Liquid layer
Water
level
Sludge

How the tank works

- Separates waste into three layers
  - Floating scum layer
  - Liquid layer
  - Sludge
- Naturally occurring bacteria begin to break down organic materials
  - “primary treatement”
  - Pathogens not destroyed
- Liquid leaving tank is effluent

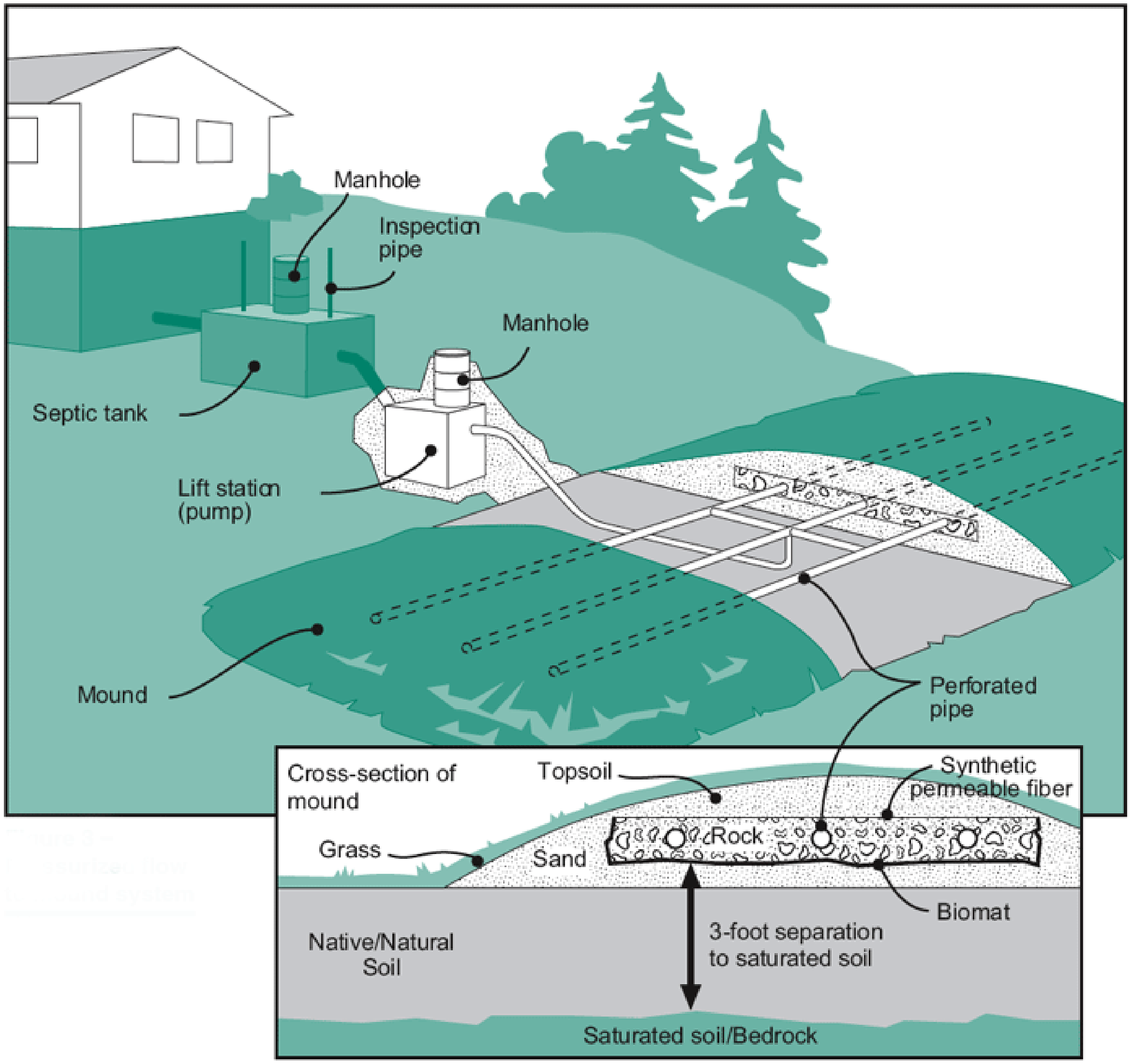
Drainfield


Manhole
Inspection pipe
Soil treatment trench
Drop box
Septic tank
Rock
Perforated pipe
Perforated pipe
Cross-section of trench
Biomat
Soil

How the soil treatment system works (drainfield)

- Pathogens will be destroyed in oxygenated environment
- Soil will filter out fine particles in effluent
- Phosphorus will be absorbed by soil particles
- Nitrate-nitrogen may be removed through the soil water

Mound System



Mound vs buried

- Current requirement is 3’ vertical separation between the soil treatment (bottom of the rock bed) and the:
  - The water table
  - A mottled area in the soil

What new technologies are available in onsite sewage treatment?

- One of the most current areas of interest is pre-treatment.
- Treatment wastewater before it is discharged minimizing the work of the treatment area, and possibly extending the life of the system.
  - Aerobic tanks
    - http://septic.umn.edu/research/past/NRRI/atufinal.pdf
  - Peat filters
    - http://septic.umn.edu/research/past/ASAE/performanceofpeatfilters.pdf
  - Sand filters
    - http://septic.umn.edu/research/past/ASAE/recirculatingsandfilters.pdf
  - Constructed wetlands
    - http://septic.umn.edu/research/past/ASAE/ssfconstructedwetlands.pdf

Aerobic treatment system

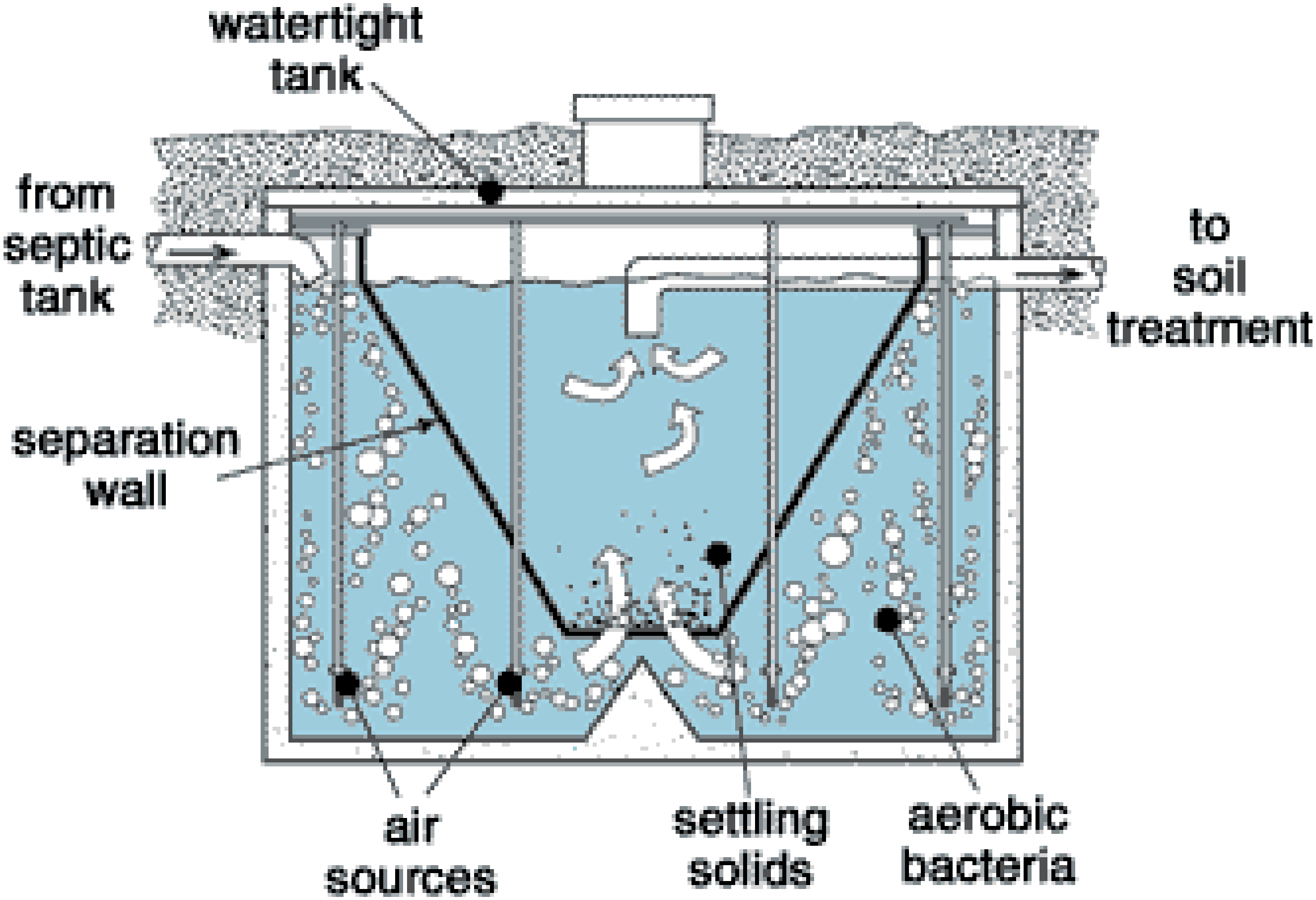
- Adds air to organic matter
- Reduces pathogens
- Transforms nutrients

igure 1. Aeration in an ATU breaks down organic matter.

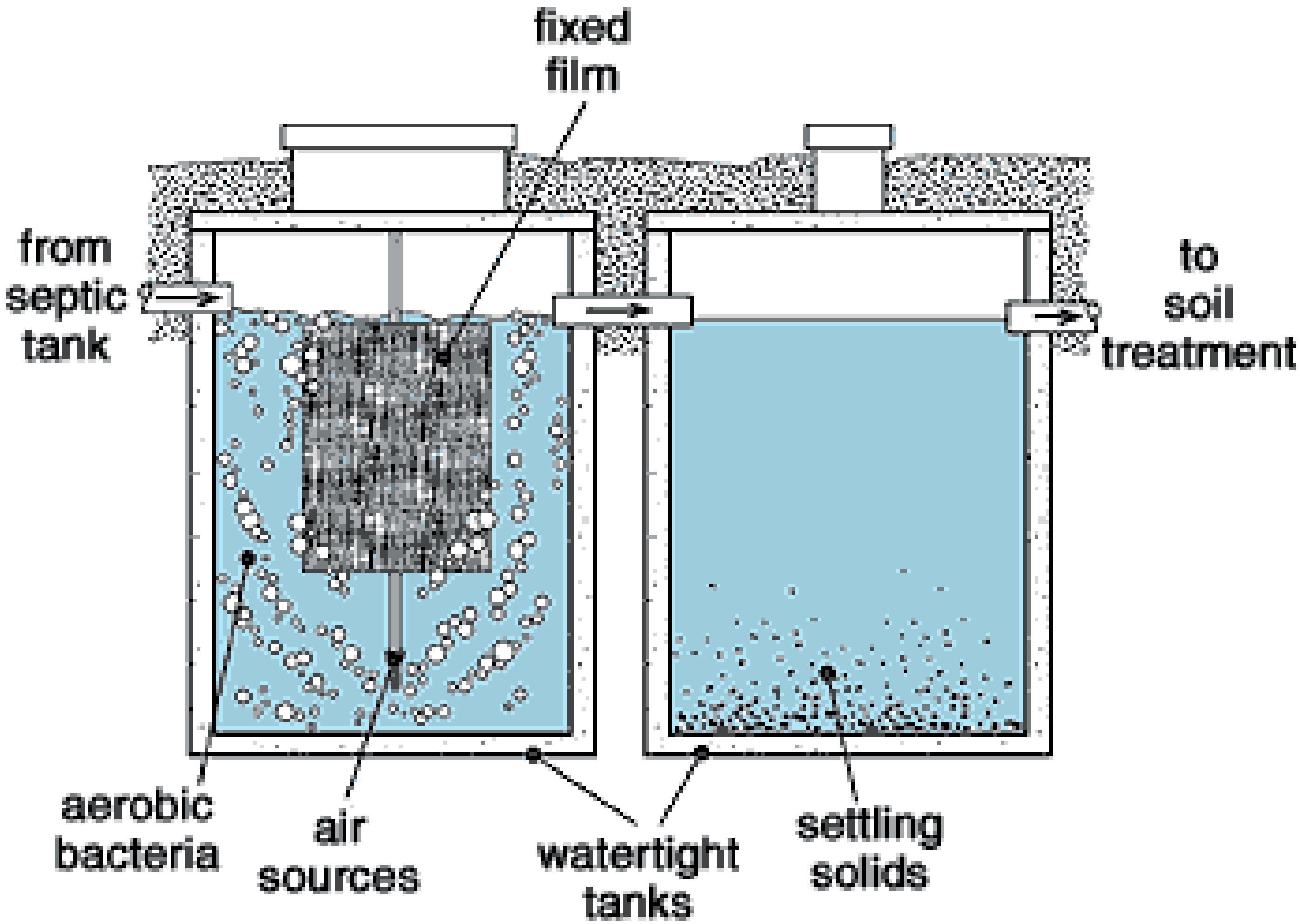
Aerobic treatment

- Bubbles air through liquid effluent in tank
- Requires less installation space (25 sq ft for 3 bedroom home)
- Effluent still goes to soil treatment system
- More complicated than septic tanks
- Solids do not settle out--stay well mixed
- Trash tank or septic tank still used prior to aerobic unit to remove large solids

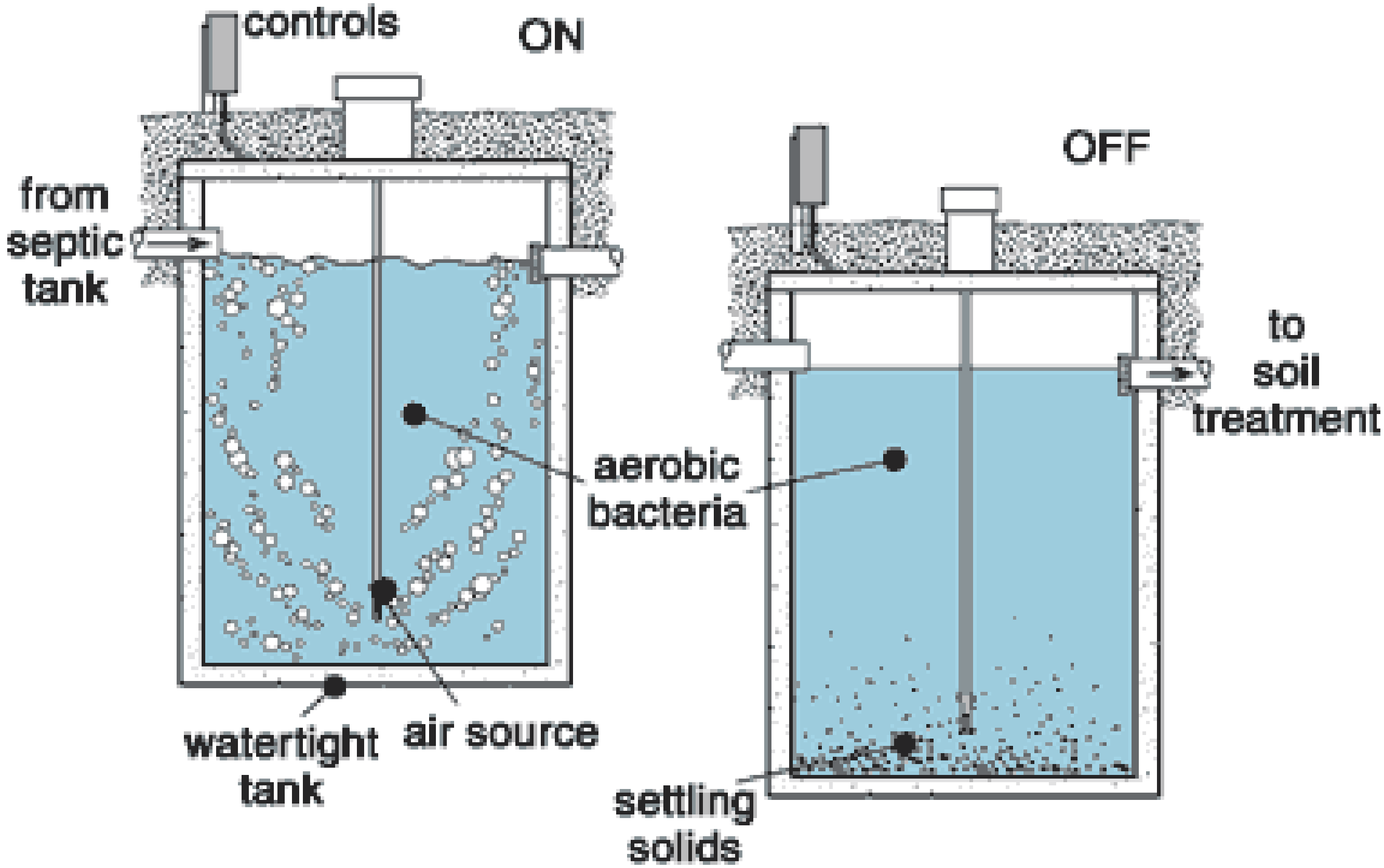
Aerobic treatment—suspended growth ATU



Aerobic—fixed film reactor

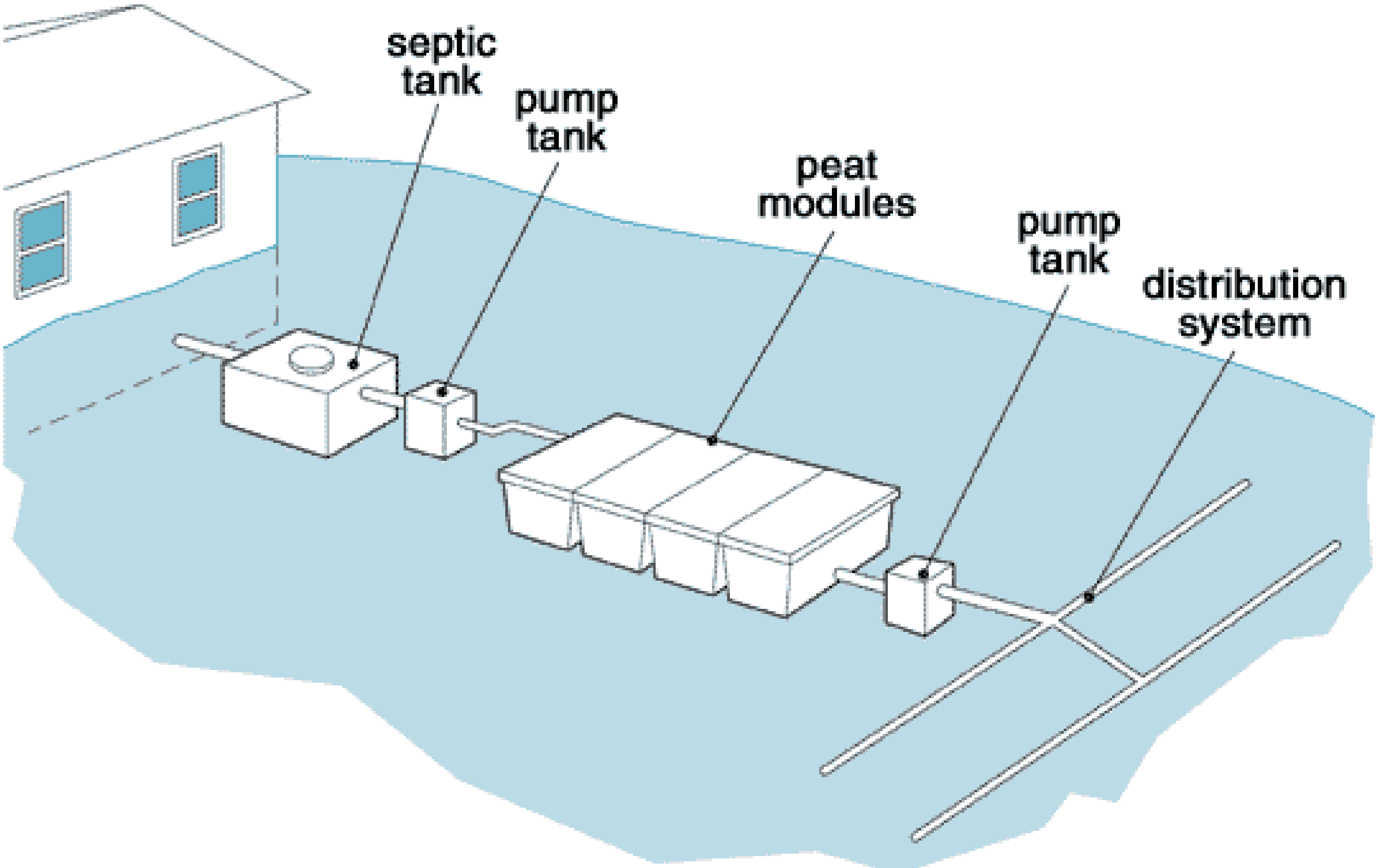


Aerobic—sequencing batch reactor

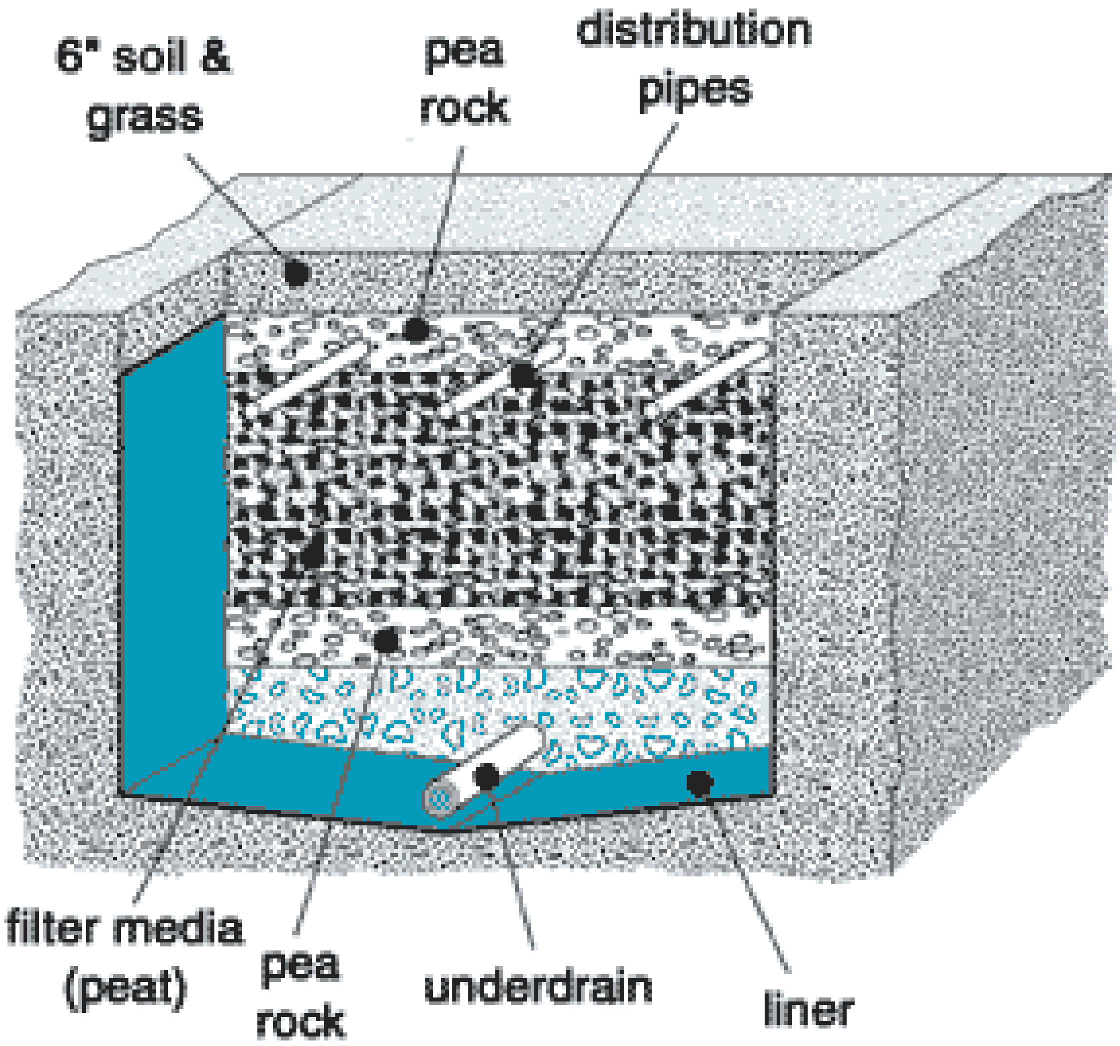


Peat filters

Peat filters



Linear Peat filter

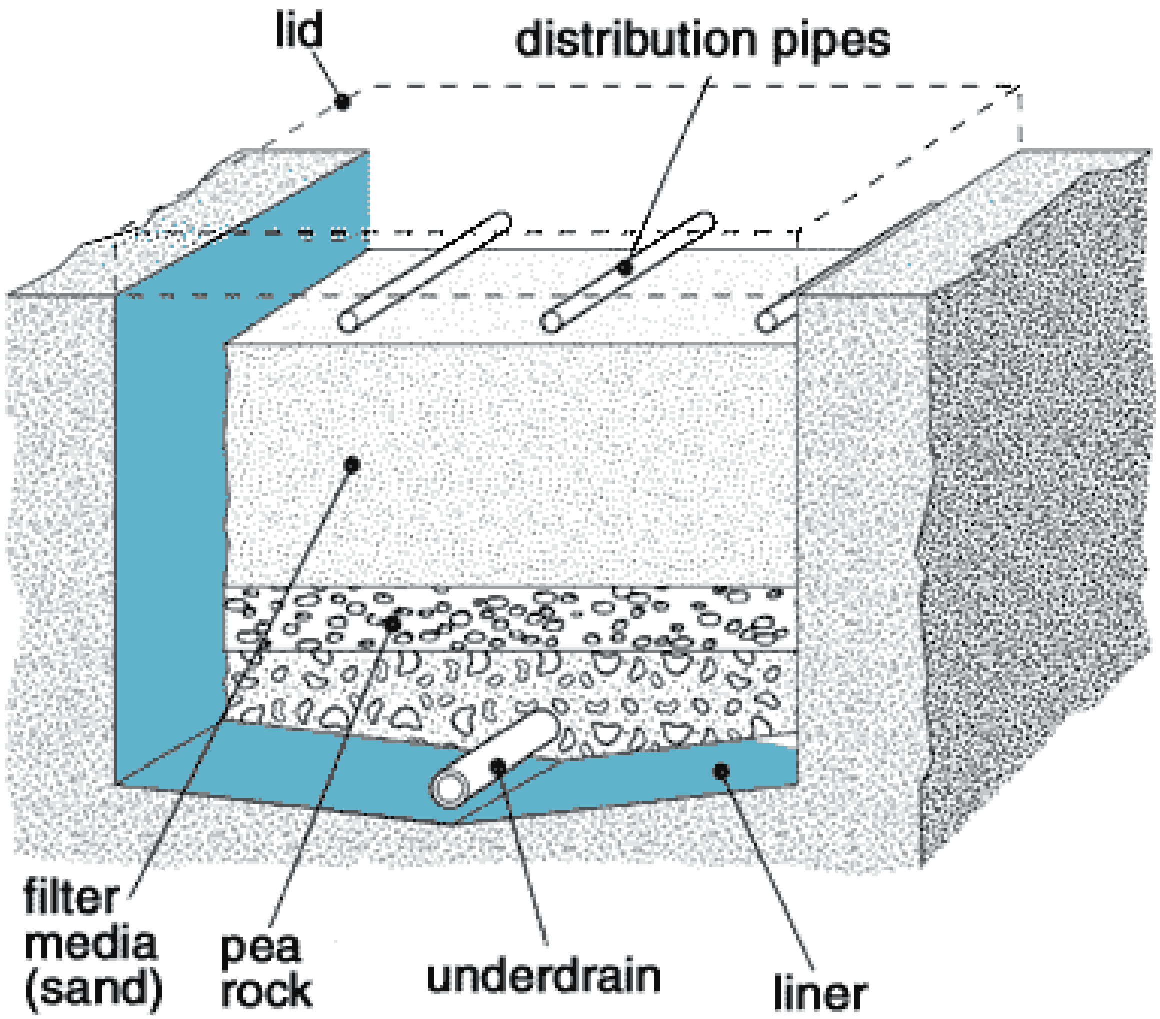


How do peat filters work?

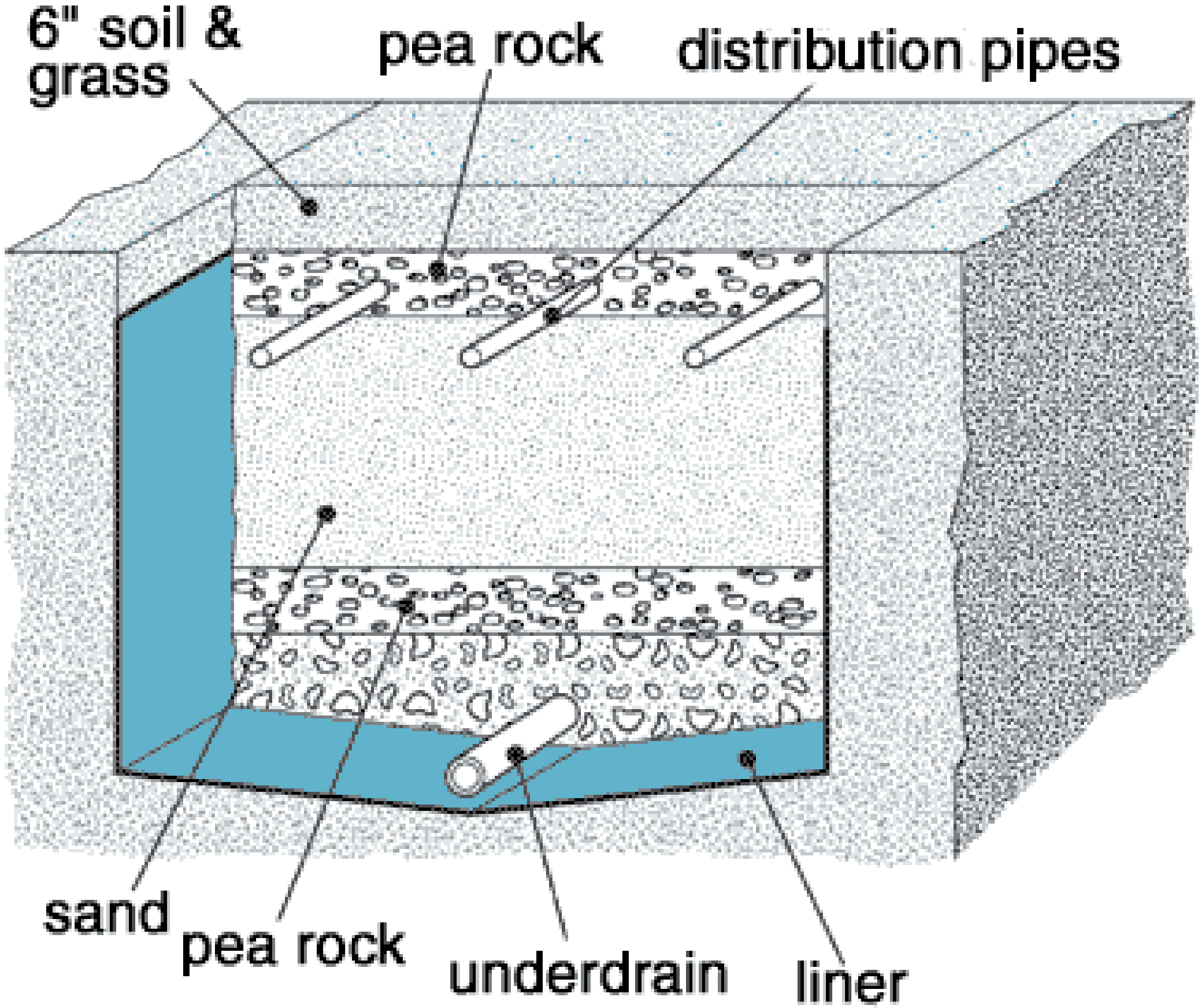
- Solids still settle out in tank
- Effluent screen or filter installed to restrict smaller solids and grease from flowing out of septic tank
- Liquid effluent pumped to peat filter
- Then delivered to drain field

Pre-treatment-sand filters

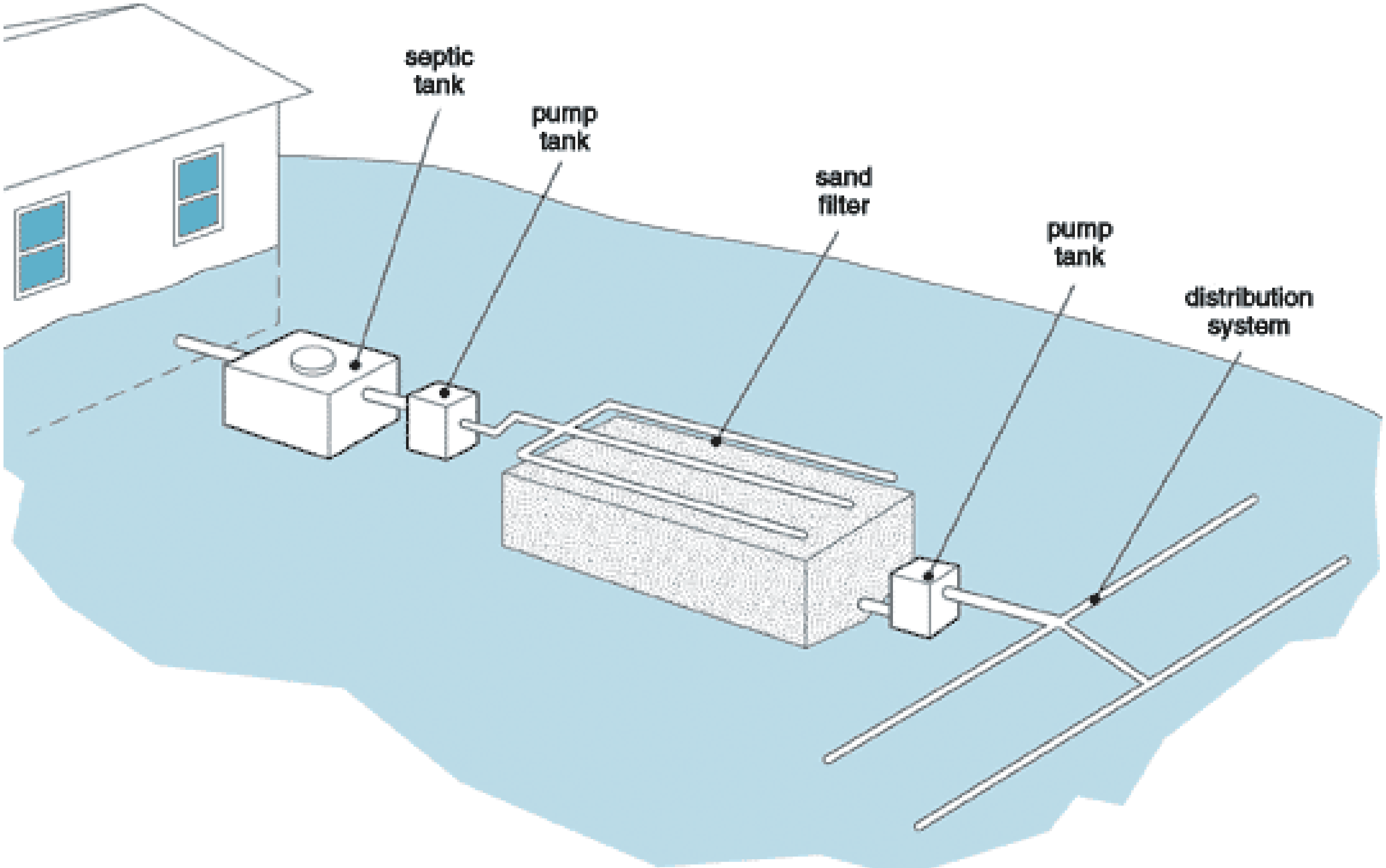
High rate sand filter



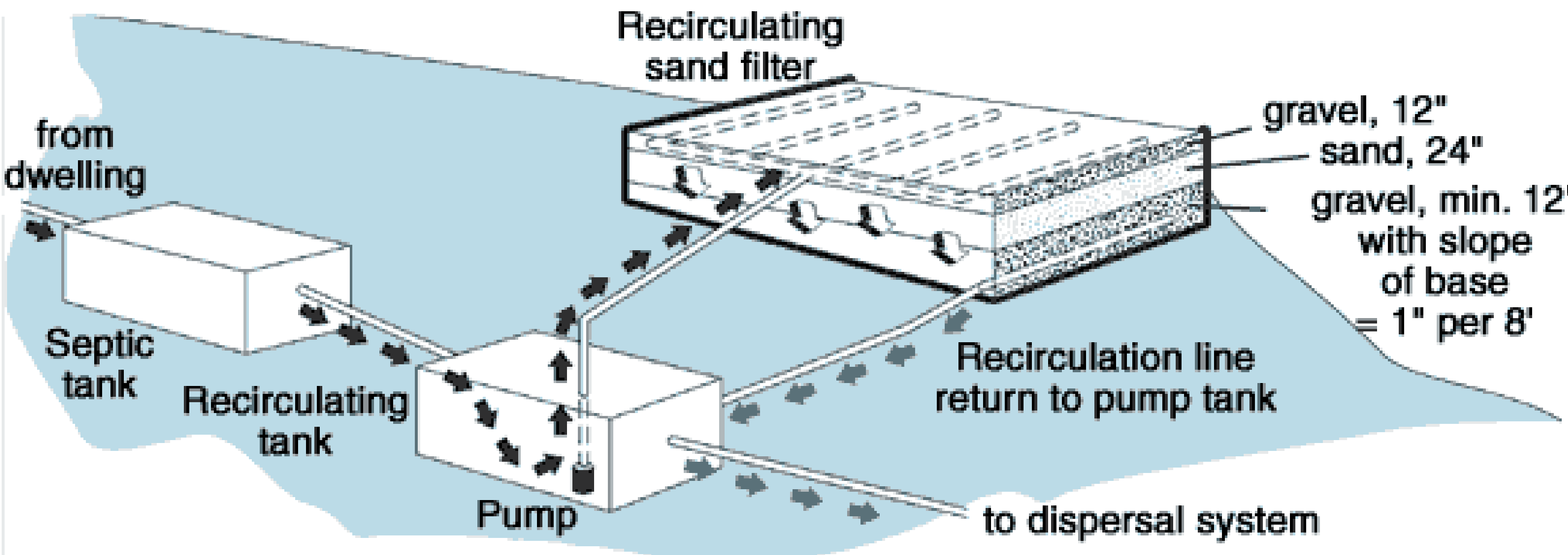
Low rate sand filter



Still requires a drainfield even though effluent very clean



Recirculating media filter



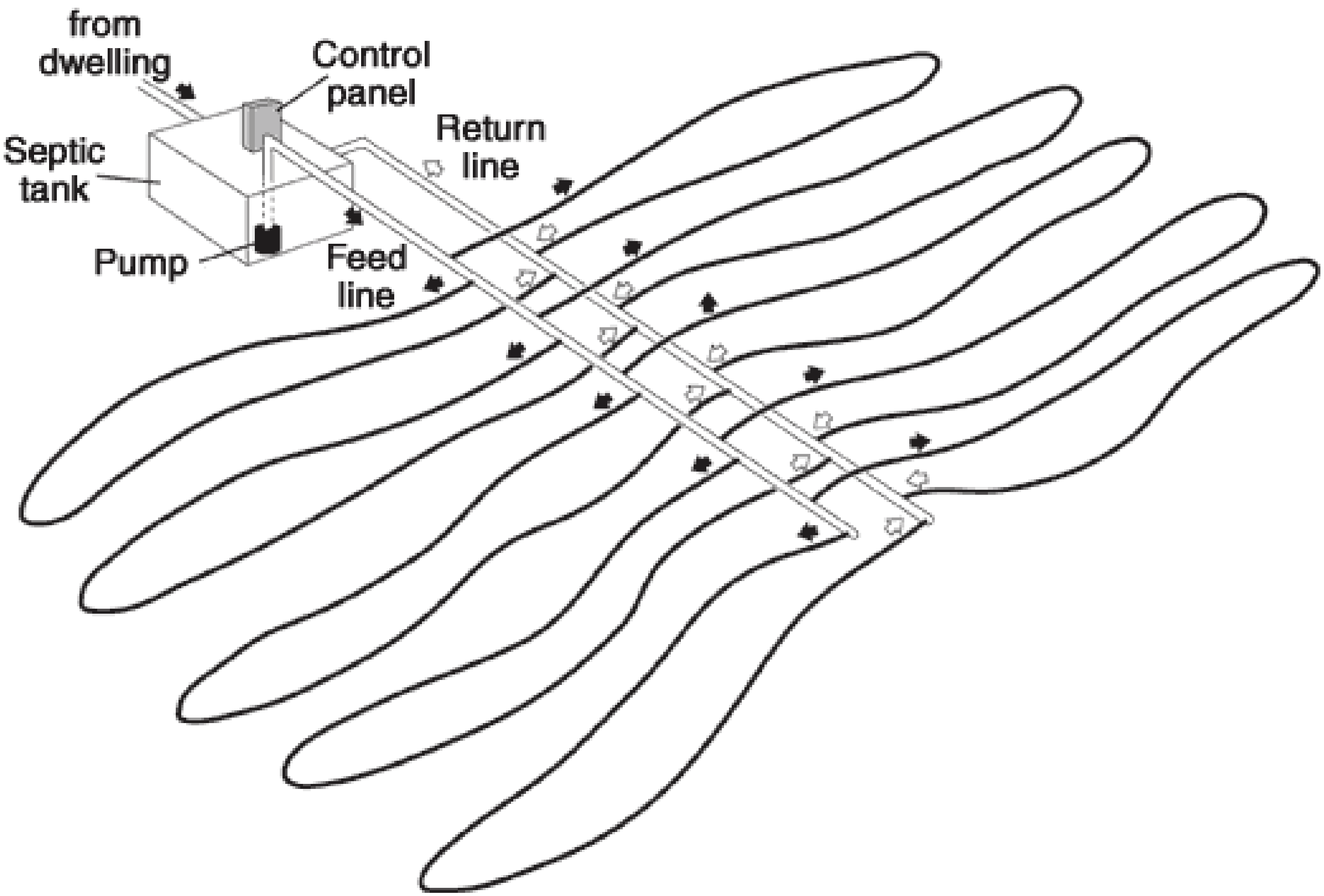
Effectiveness of recirculating media filter

	BOD (mg/l)	TSS (mg/l)	Fecal Coliform (MPN/100mL)	Nitrogen % removal	Phosphorus % removal
Septic tank effluent	175	65	1 million–1 billion	0	0
RMF effluent	20	20	5,000–100,000	30-70	10-30

Recirculating media filter

- Require more maintenance
- Small land requirement
- Increased ability to remove nitrogen
- Do not remove fecal coliform as effectively as single pass sand or peat filters (large media size)

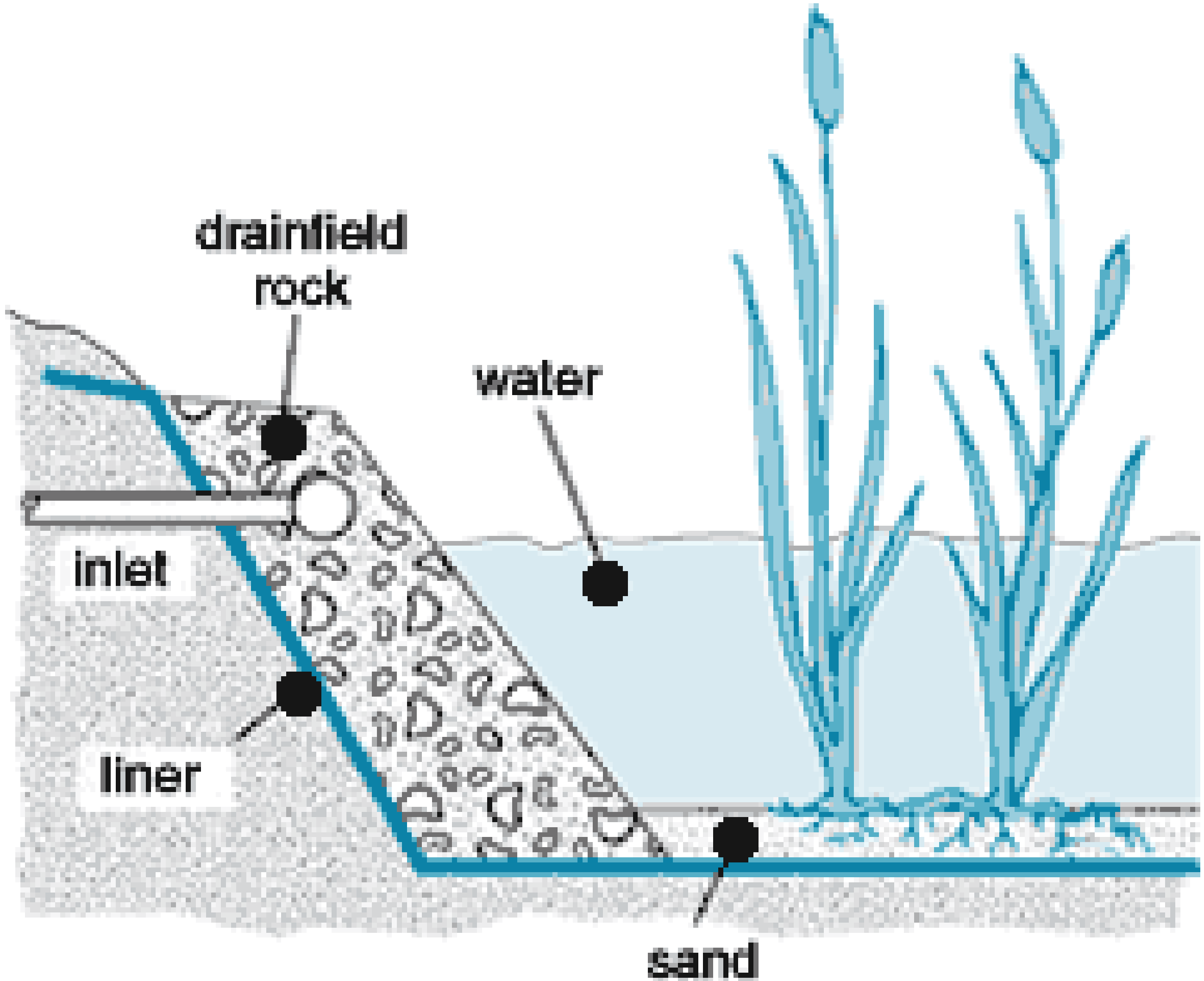
Drip distribution—used after a pretreatment system



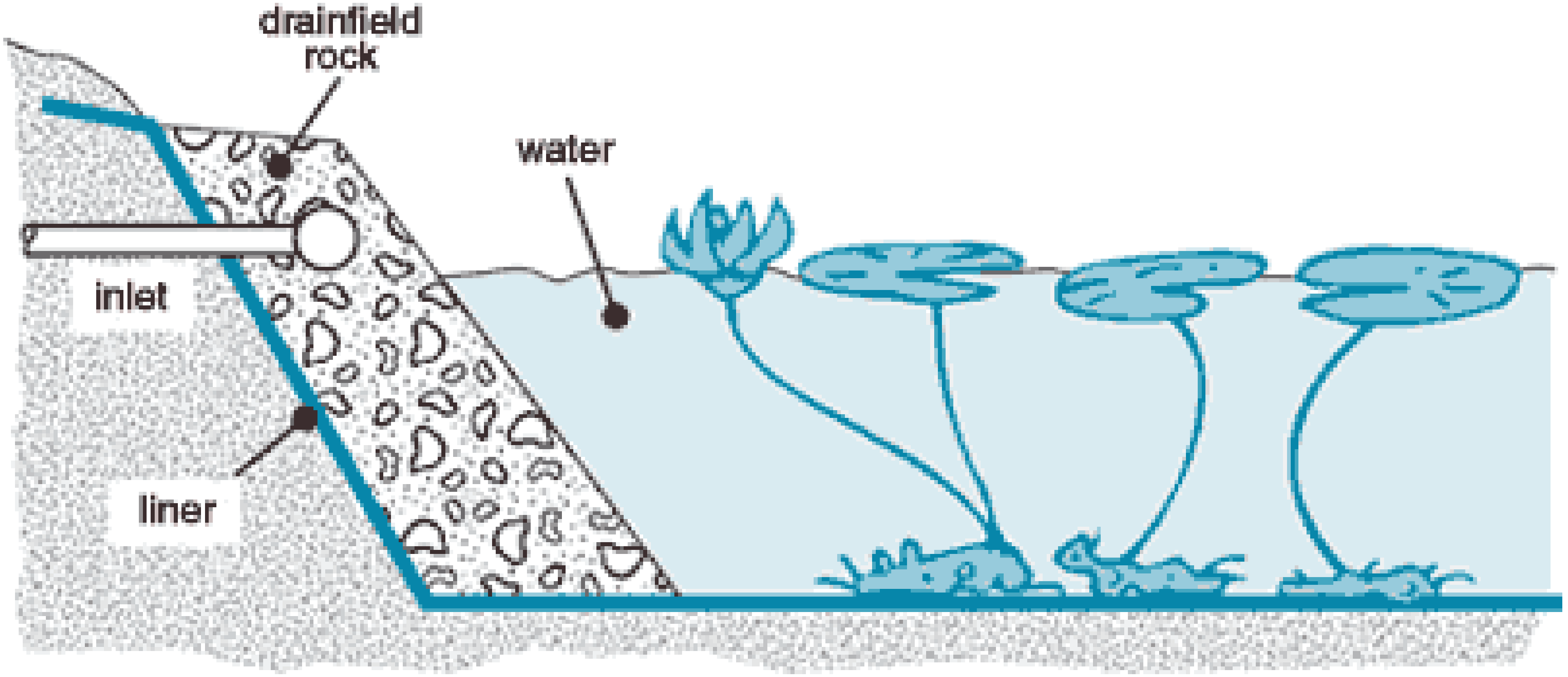
Constructed Wetland

Open water wetland

- Better suited for large community systems
- Better in milder climates



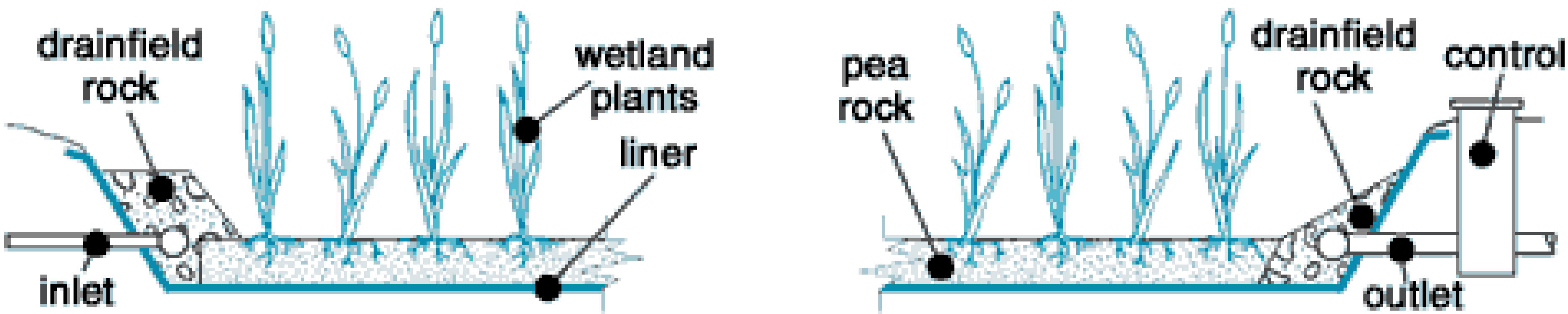
Hydroponic wetland



Subsurface Flow wetland

- Minimizes exposure to people
- Reduces mosquito breeding
- Most common used for small flows (individual homes, small clusters, resorts)

igure 4: Subsurface flow constructed wetland



How do wetlands work?

- Solids removed by physical filtration and settling within gravel/root hair matrix
- Organic matter also removed by these processes
- Organic matter ultimately biodegrades
- May be anaerobic or aerobic (without or with oxygen)
  - Aerobic is faster

Four parts of the wetland

- Liner—keeps wastewater in and groundwater out
- Distribution media—coarse rock (pea gravel) that spreads wastewater across the width of the wetland
- Plants—often cattails but includes bullrushes, reeds and sedges. Flora must flourish to operate at maximum efficiency
- Underdrain system—slotted 4” pipe covered with drainfield rock—moves treated effluent out of wetland

Links
http://www.mostca.com/Links.html

- Minnesota rules and regulations:
  - http://www.revisor.leg.state.mn.us/arule/7080/
- University of Minnesota Water Resources Center (extension, but for water)
  - http://wrc.umn.edu/outreach/
  - http://septic.umn.edu/