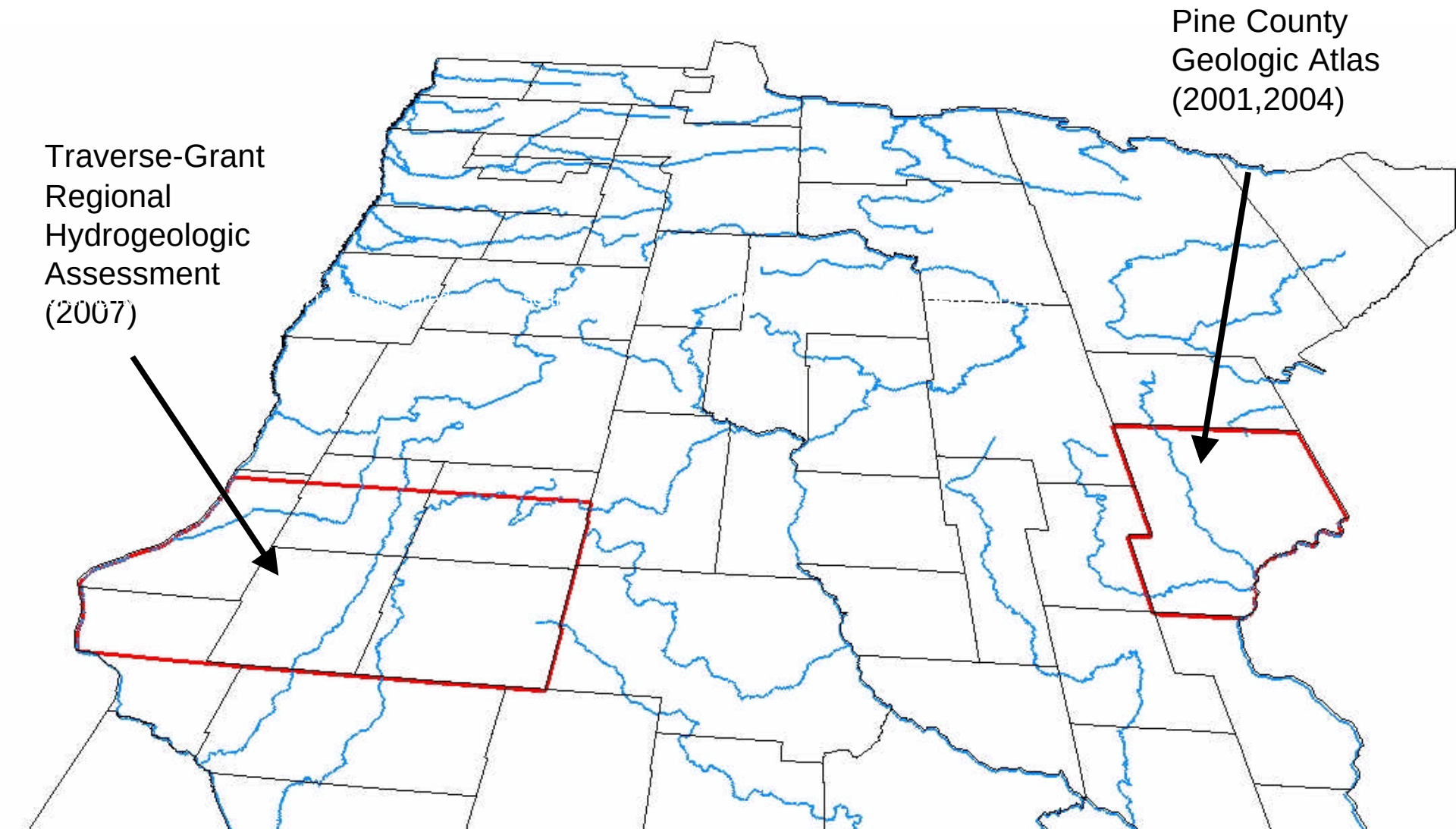
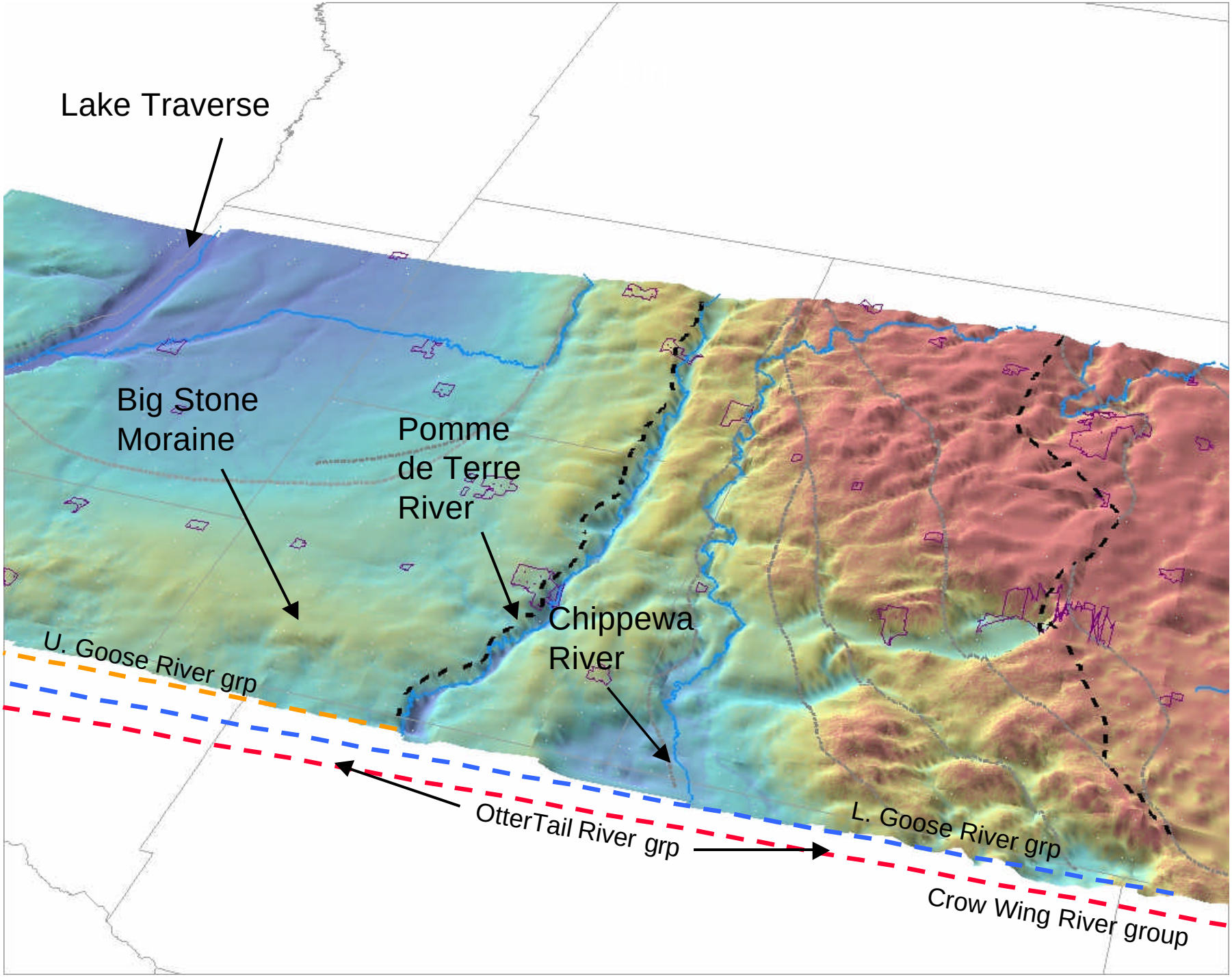
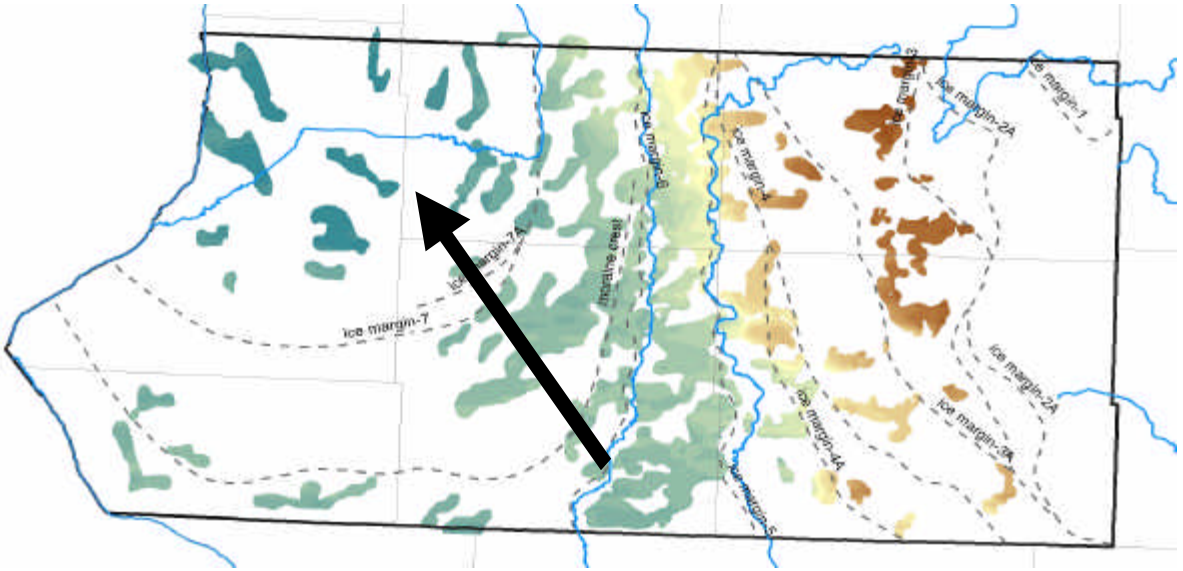
Integrating hydrogeologic tools in unconsolidated aquifer settings:

Finding the tortuous pathways

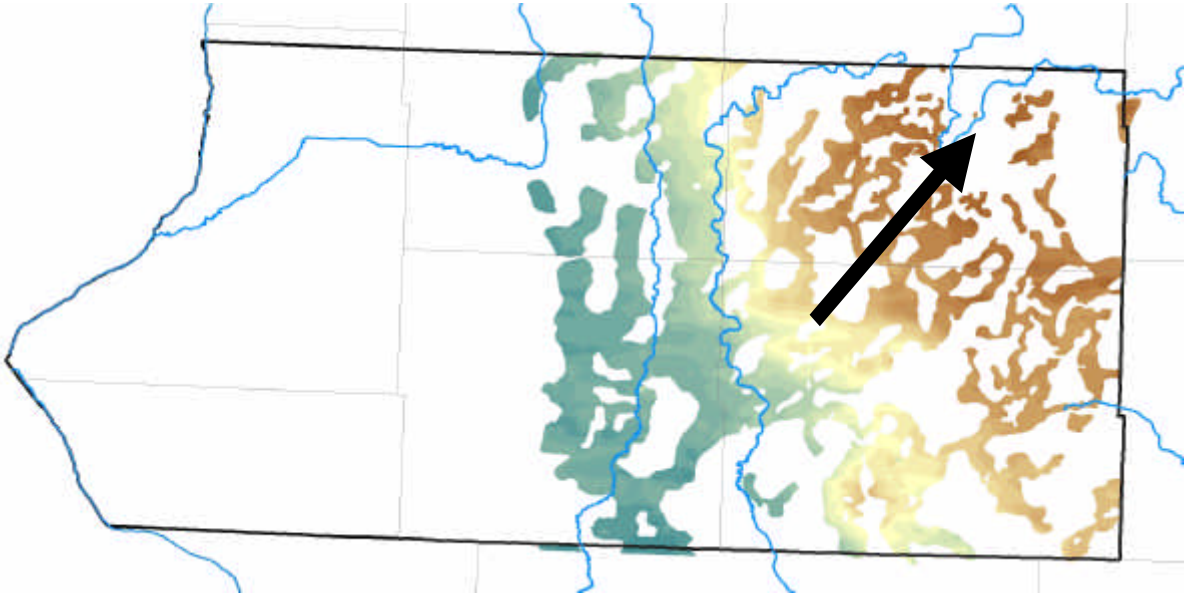
Jim Berg, Minnesota DNR, November 2007



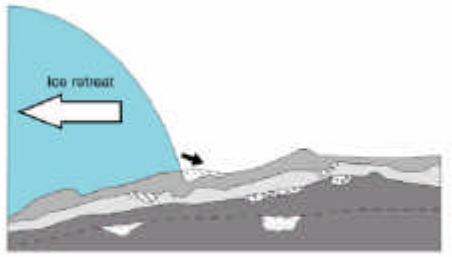

Lake Traverse
Big Stone Moraine
Pomme de Terre River
Chippewa River
U. Goose River grp
OtterTail River grp
L. Goose River grp
Crow Wing River group



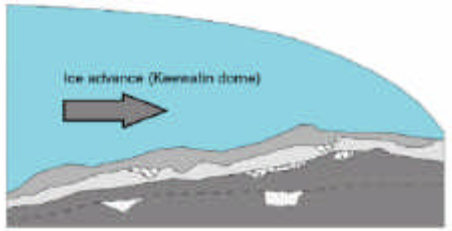
OT aquifer (top elevation)



CW aquifer (top elevation)

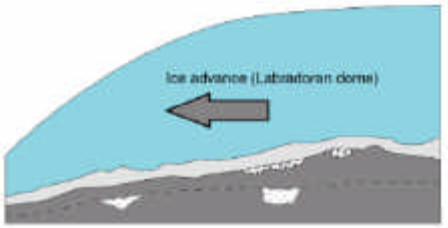


2e. Sand deposition (OT aquifer) on the Otter Tail River group.

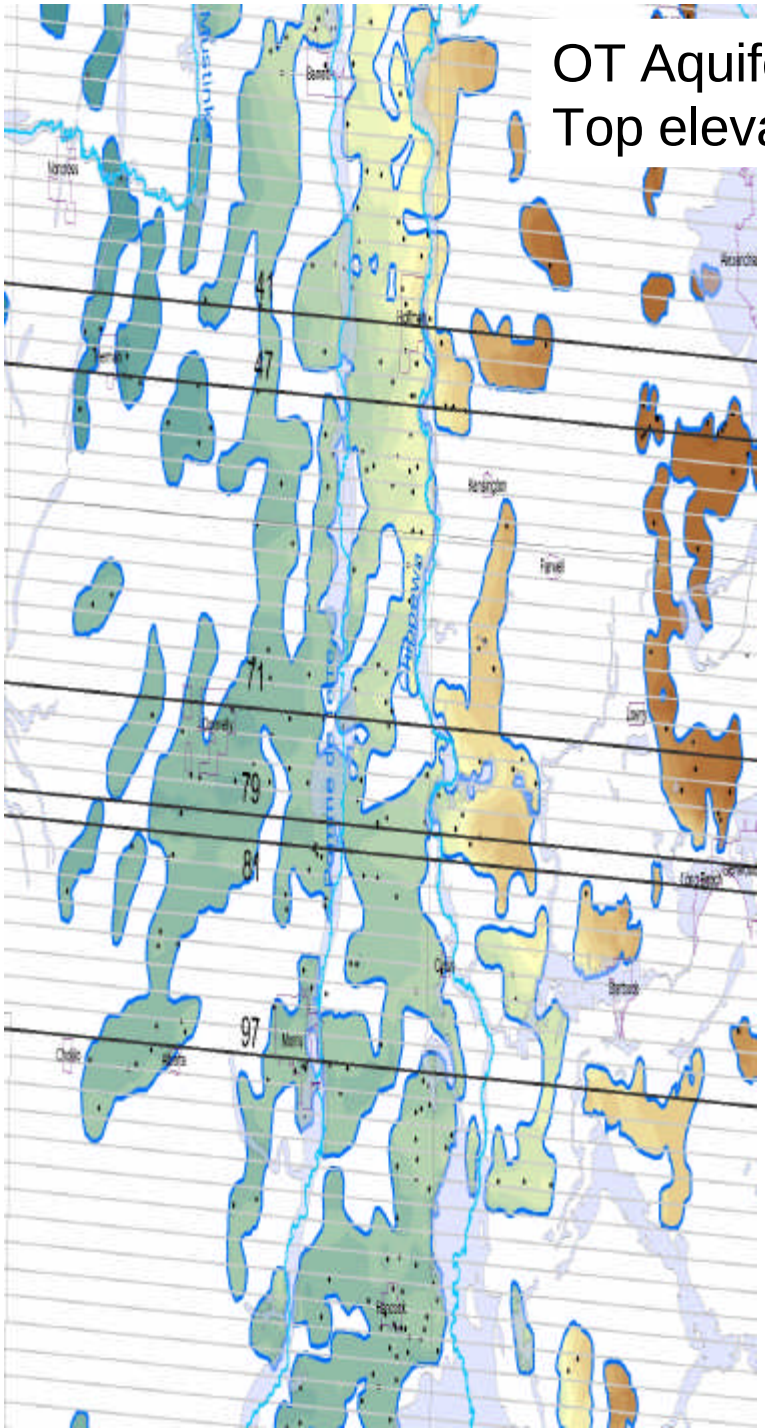


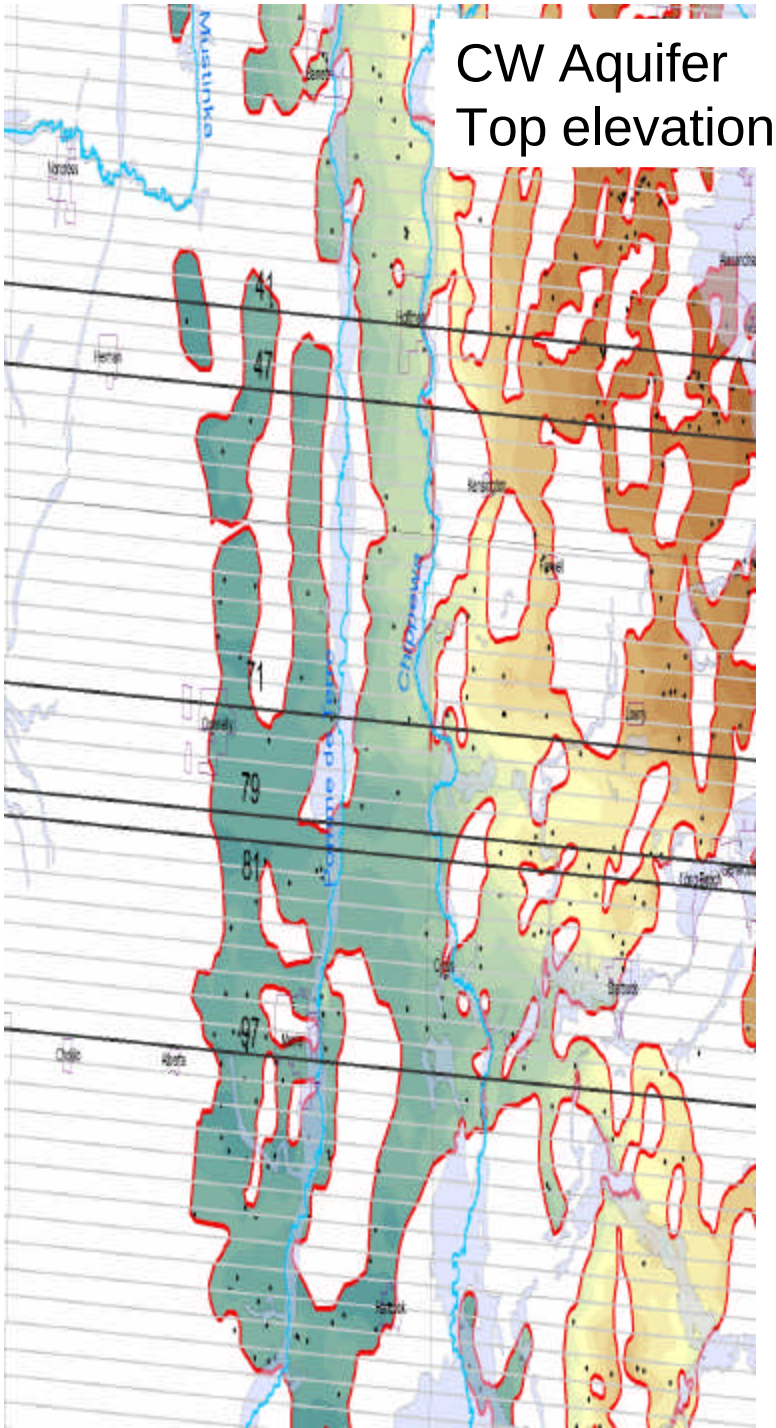
2d. Till deposition—Otter Tail River group.

2c. Sand deposition (CW aquifer) on the Crow Wing River group till.

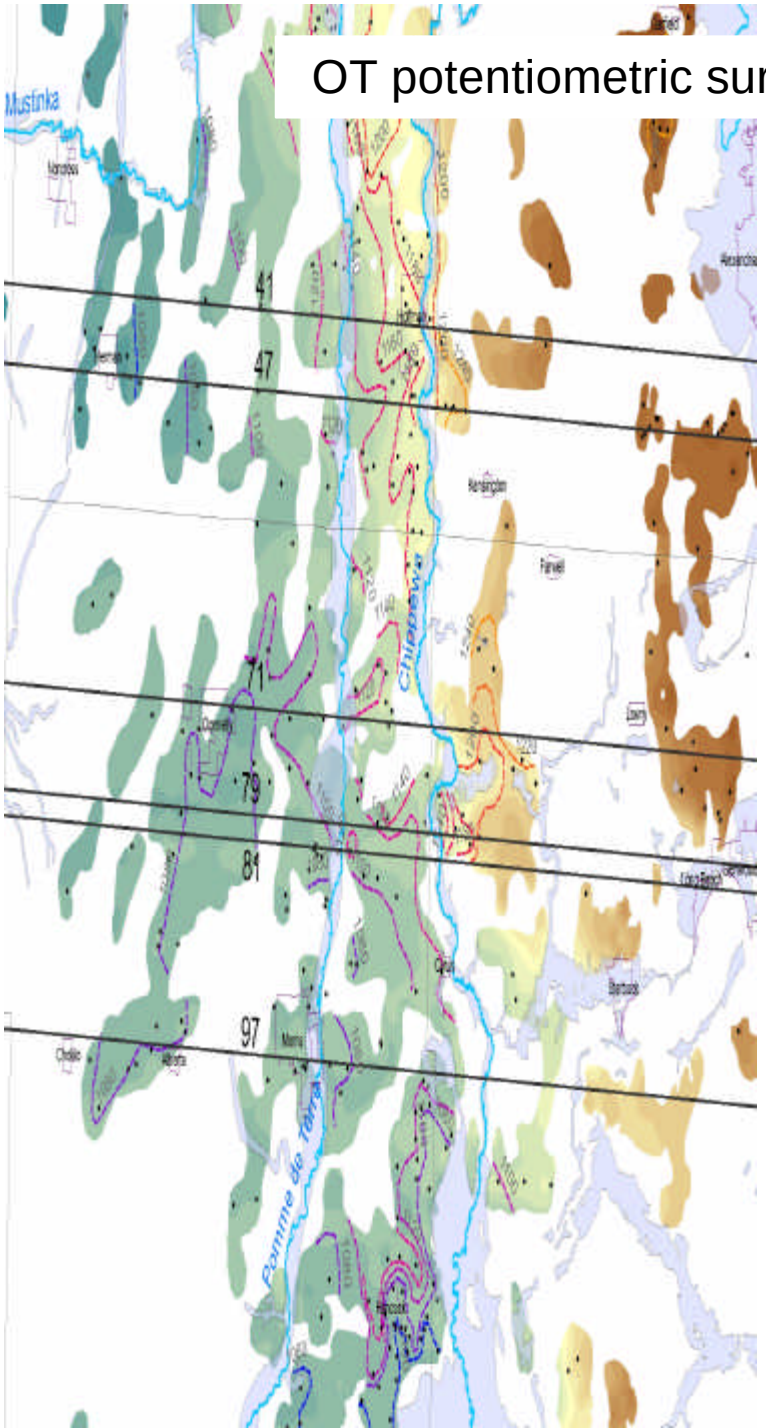


2b. Till deposition—Crow Wing River group.

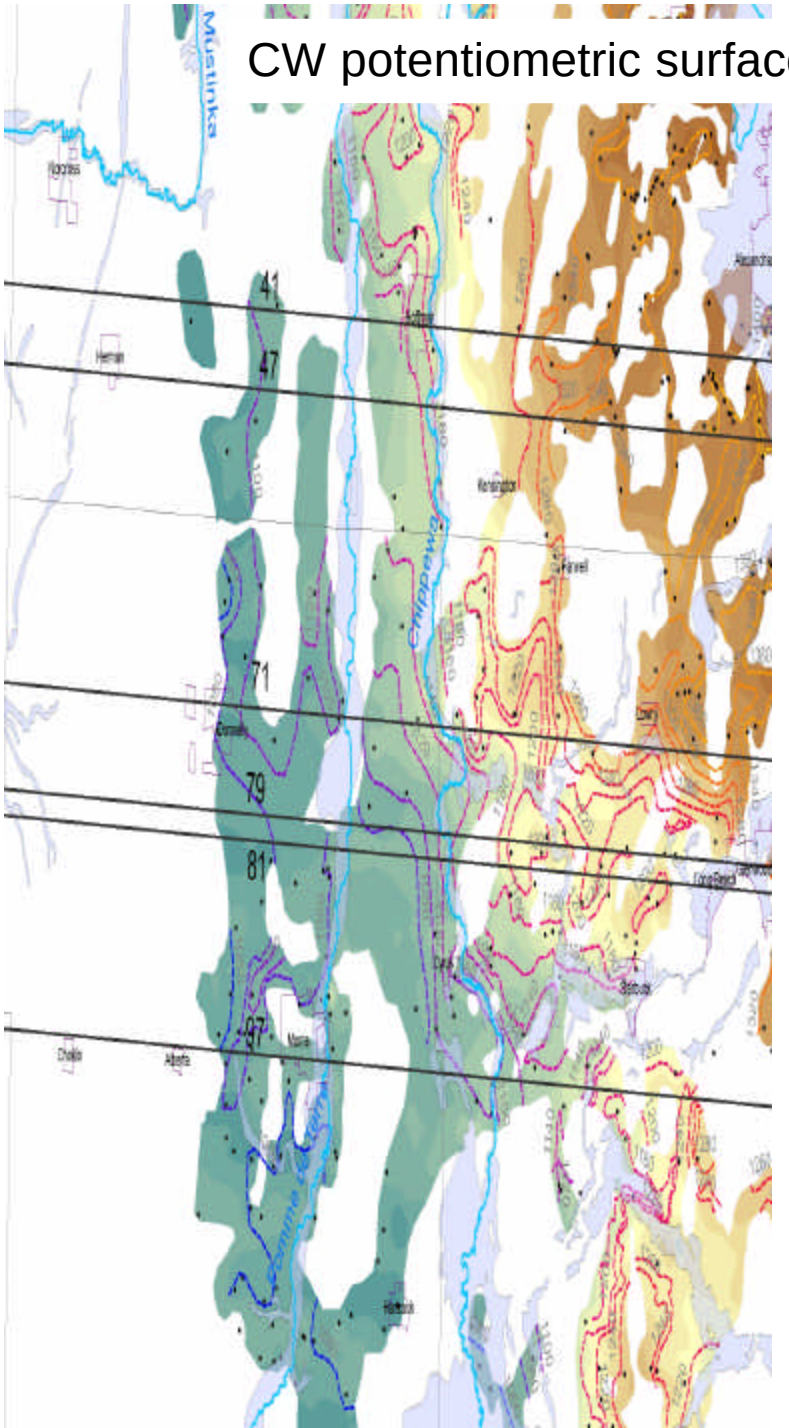

OT Aquifer
Top elevation

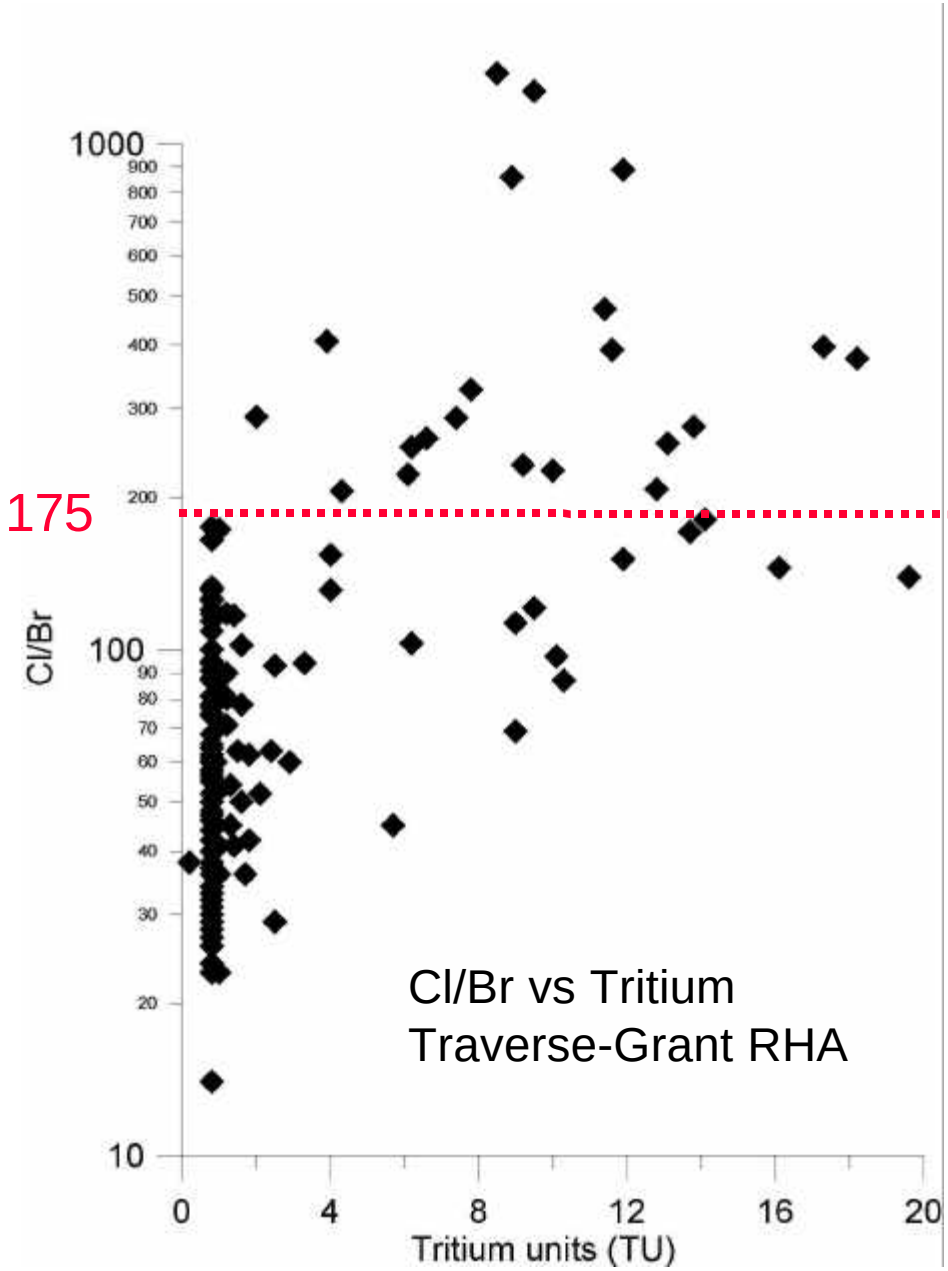

CW Aquifer
Top elevation

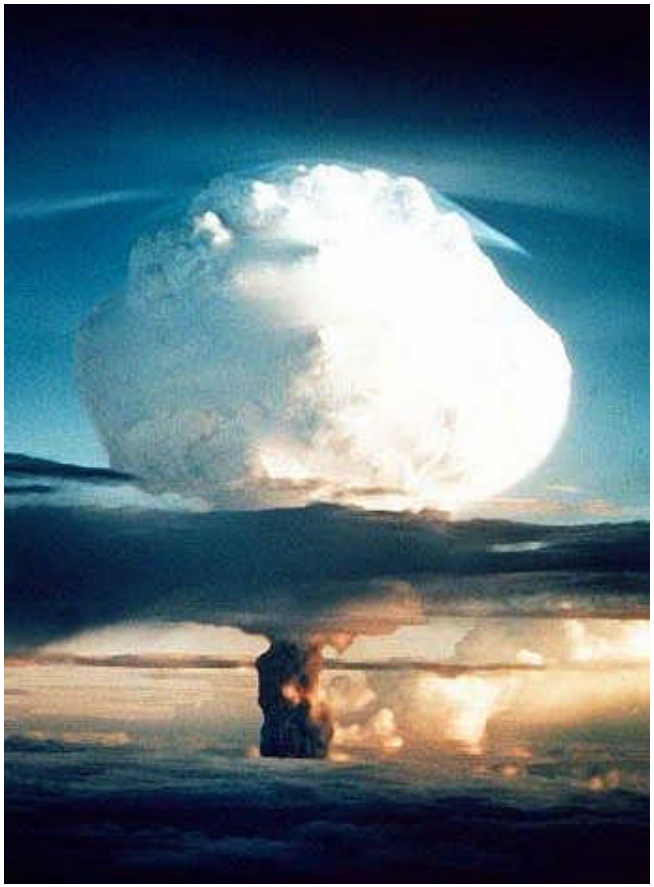
OT potentiometric surface

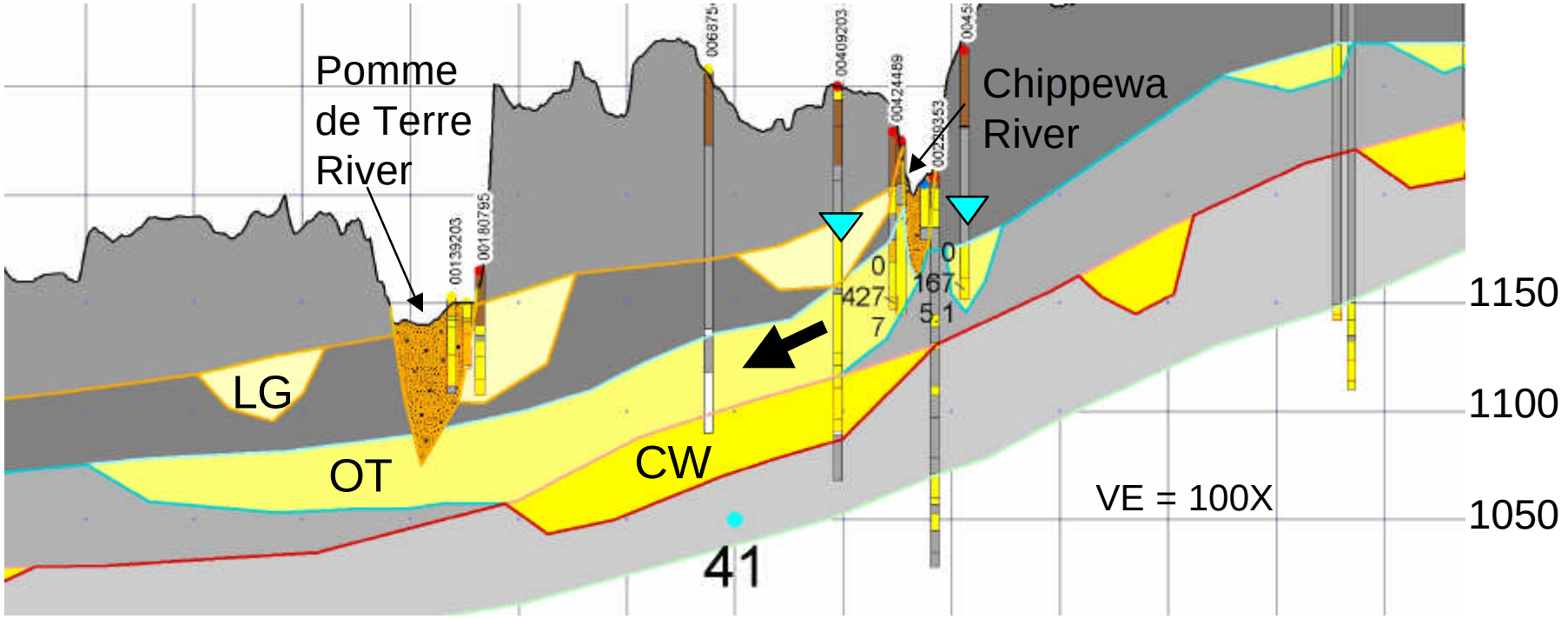


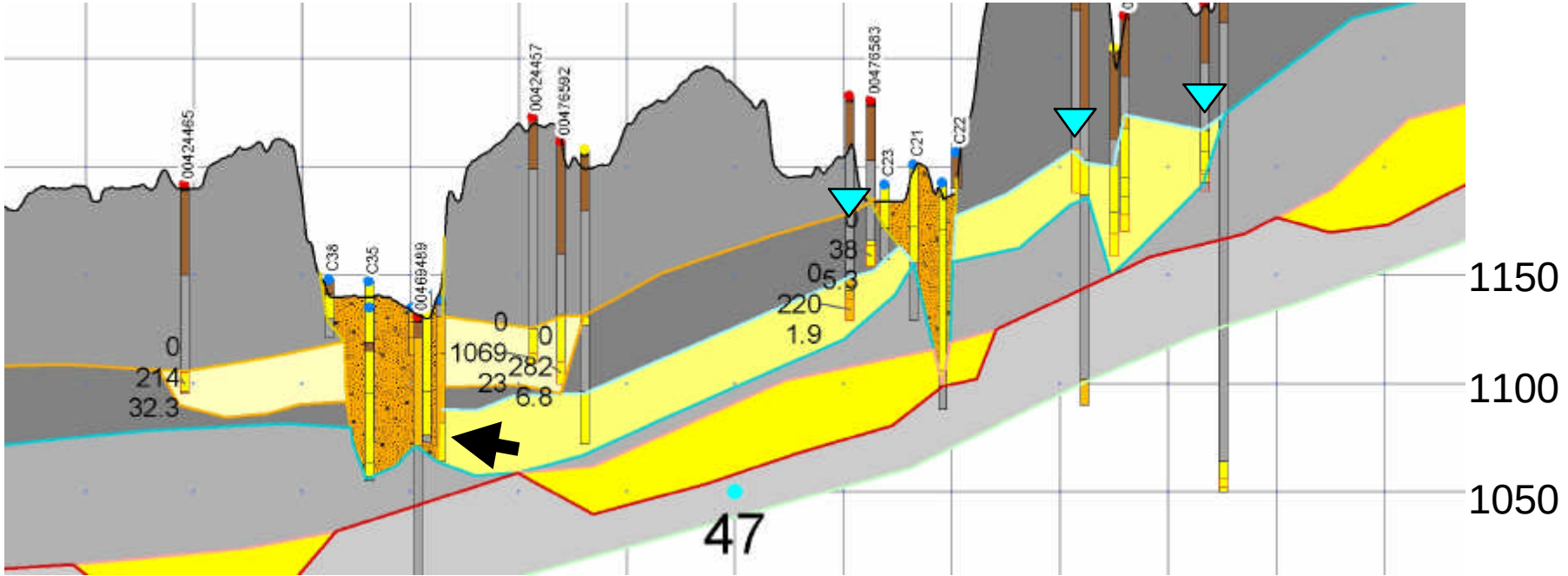
CW potentiometric surface

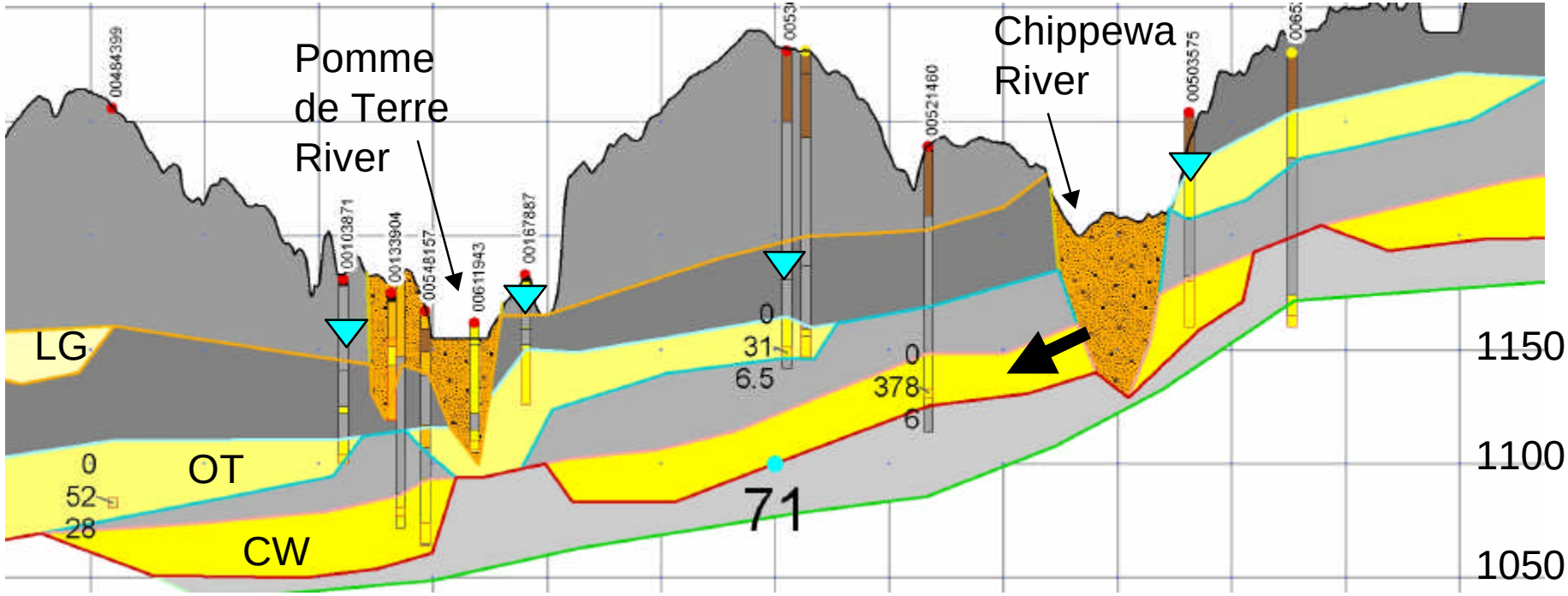


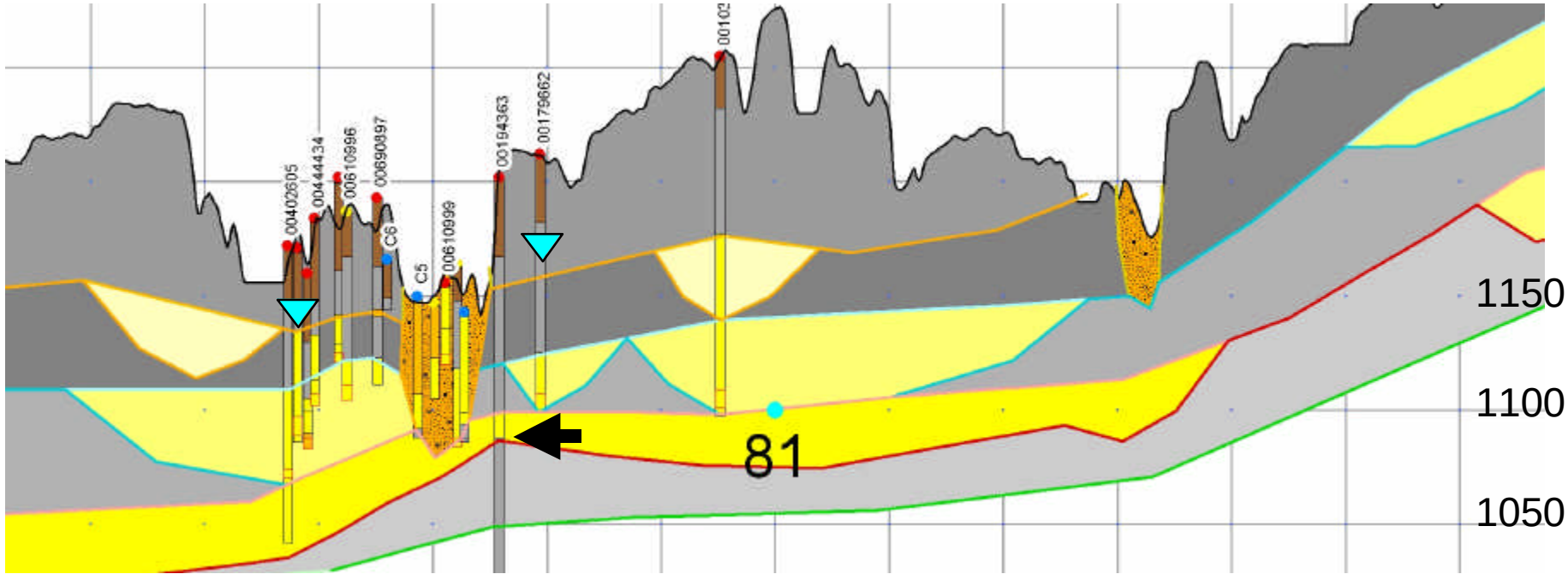

175
Cl/Br
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
0
4
8
12
16
20
Tritium units (TU)
Cl/Br vs Tritium
Traverse-Grant RHA

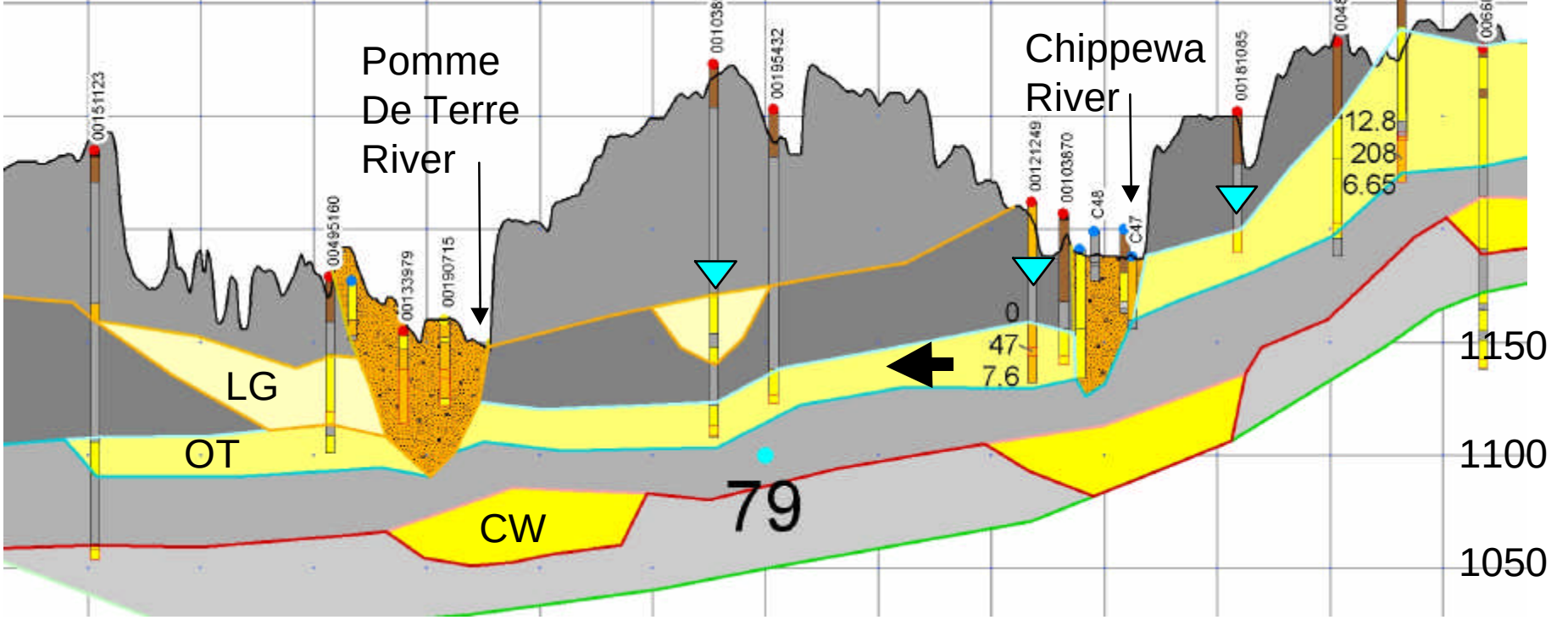


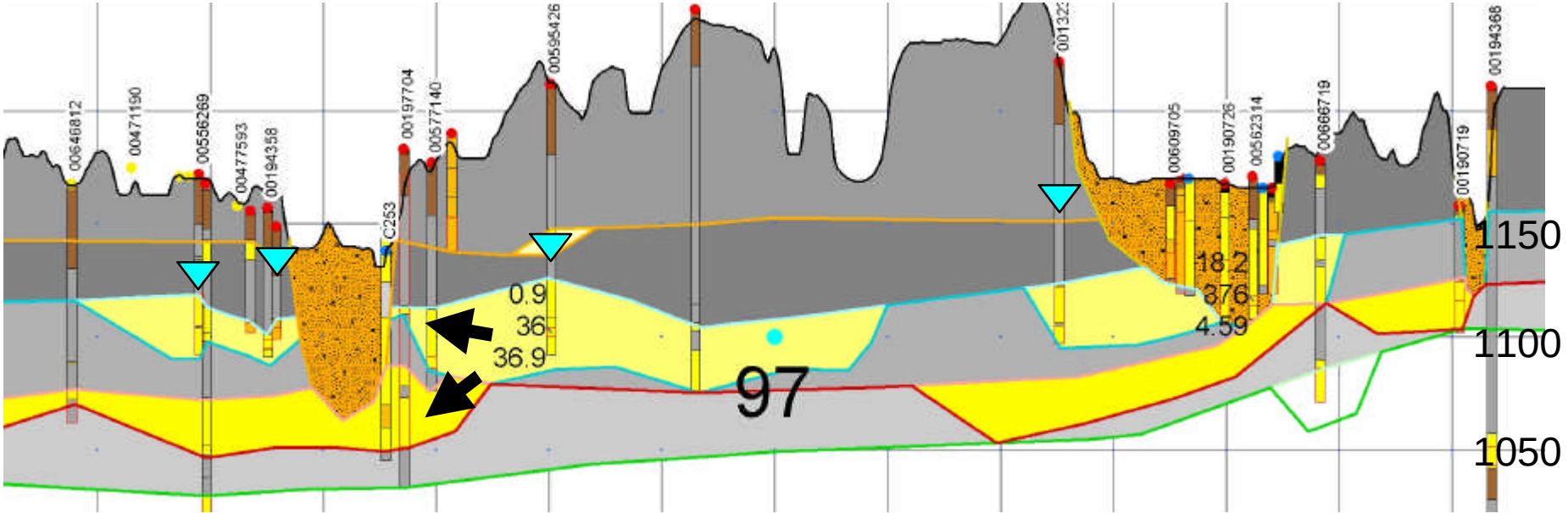

Pomme
de Terre
River
Chippewa
River
LG
OT
CW
VE = 100X
41
1150
1100
1050
0
427
7
0
167
5.1


47
1150
1100
1050
0
214
32.3
0
1069
23
0
282
6.8
0
38
0
5.3
220
1.9

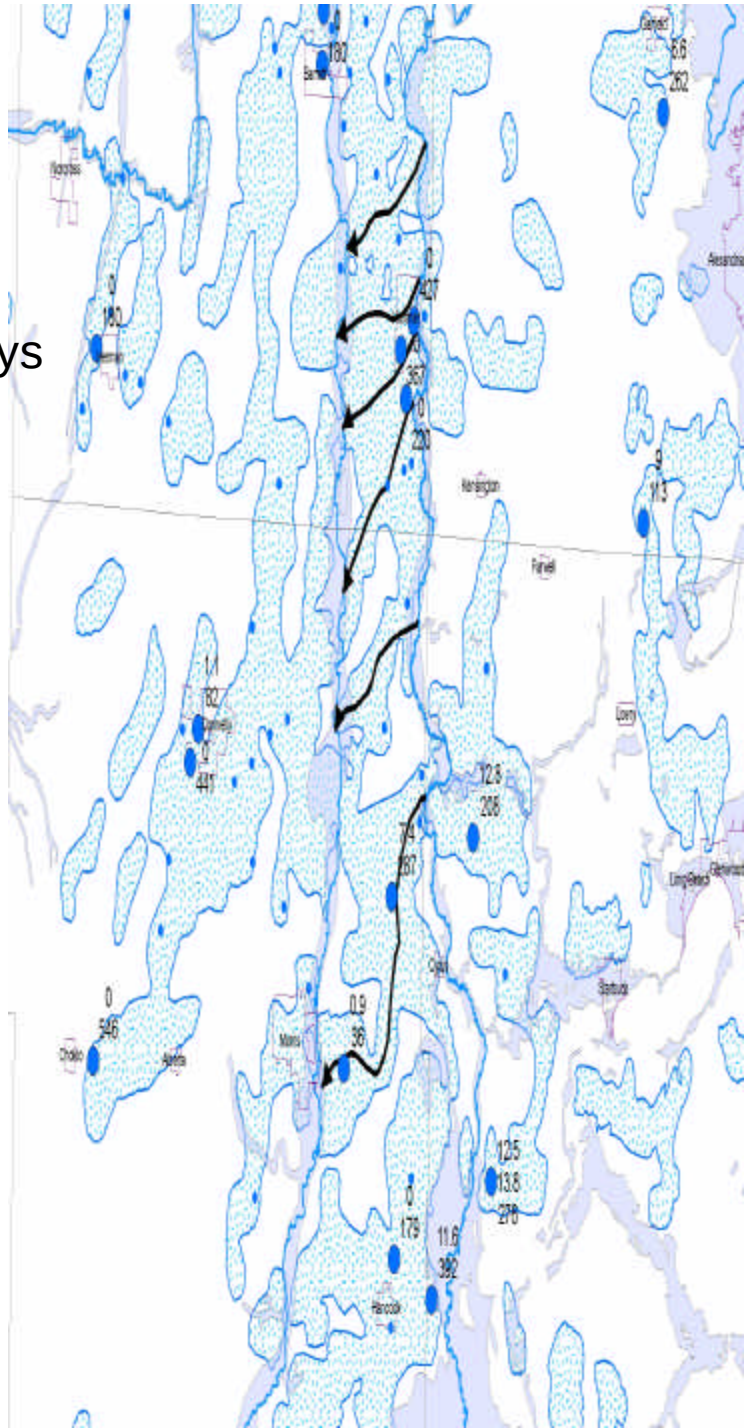

Pomme
de Terre
River
Chippewa
River
00484399
00103871
00133904
00548157
00611943
00167887
00521460
00503575
LG
OT
CW
0
52
28
0
31
6.5
0
378
6
71
1150
1100
1050


00402605
00444434
00610996
00690997
00610999
00194363
00179662
C6
C5
81
1150
1100
1050

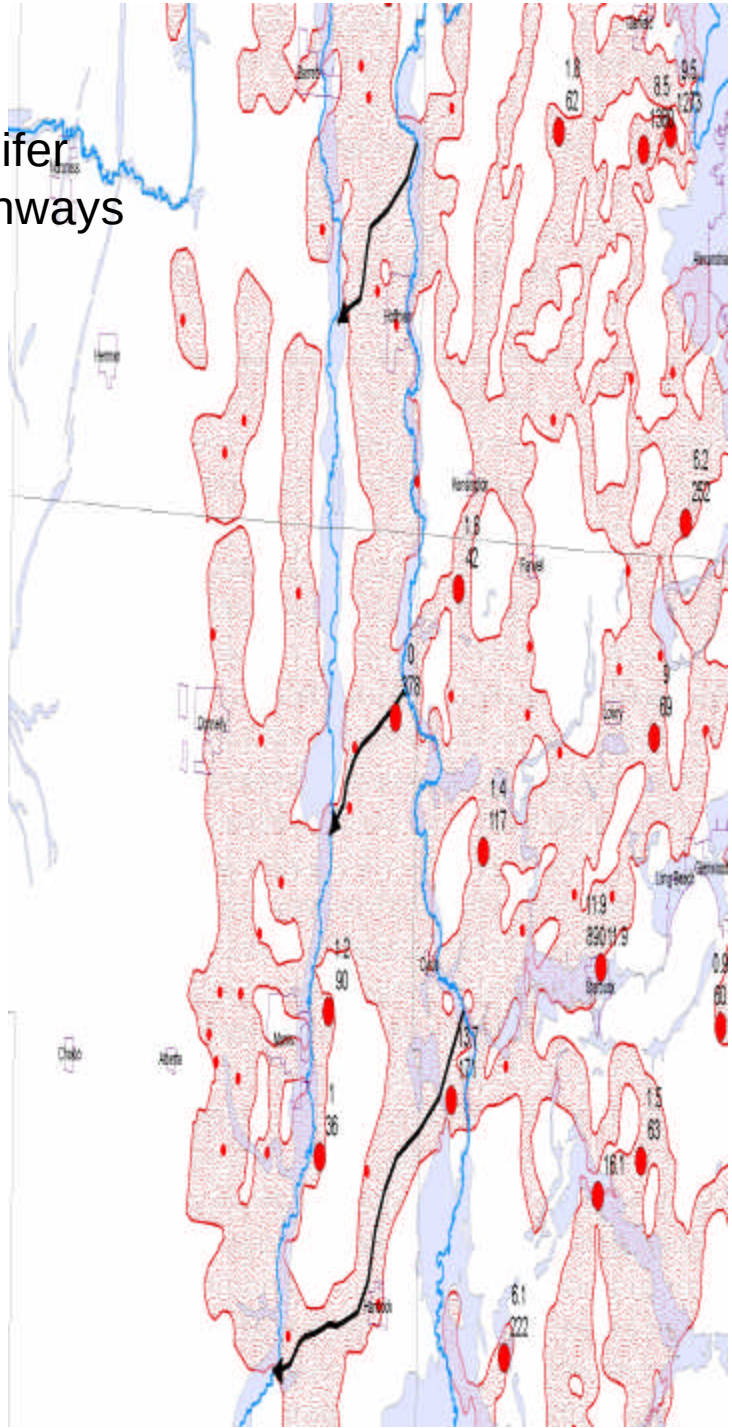

Pomme
De Terre
River
Chippewa
River
00151123
00495160
00133979
00190715
00195432
00121249
00103870
C48
C47
00181085
12.8
208
6.65
0
47
7.6
LG
OT
CW
79
1150
1100
1050

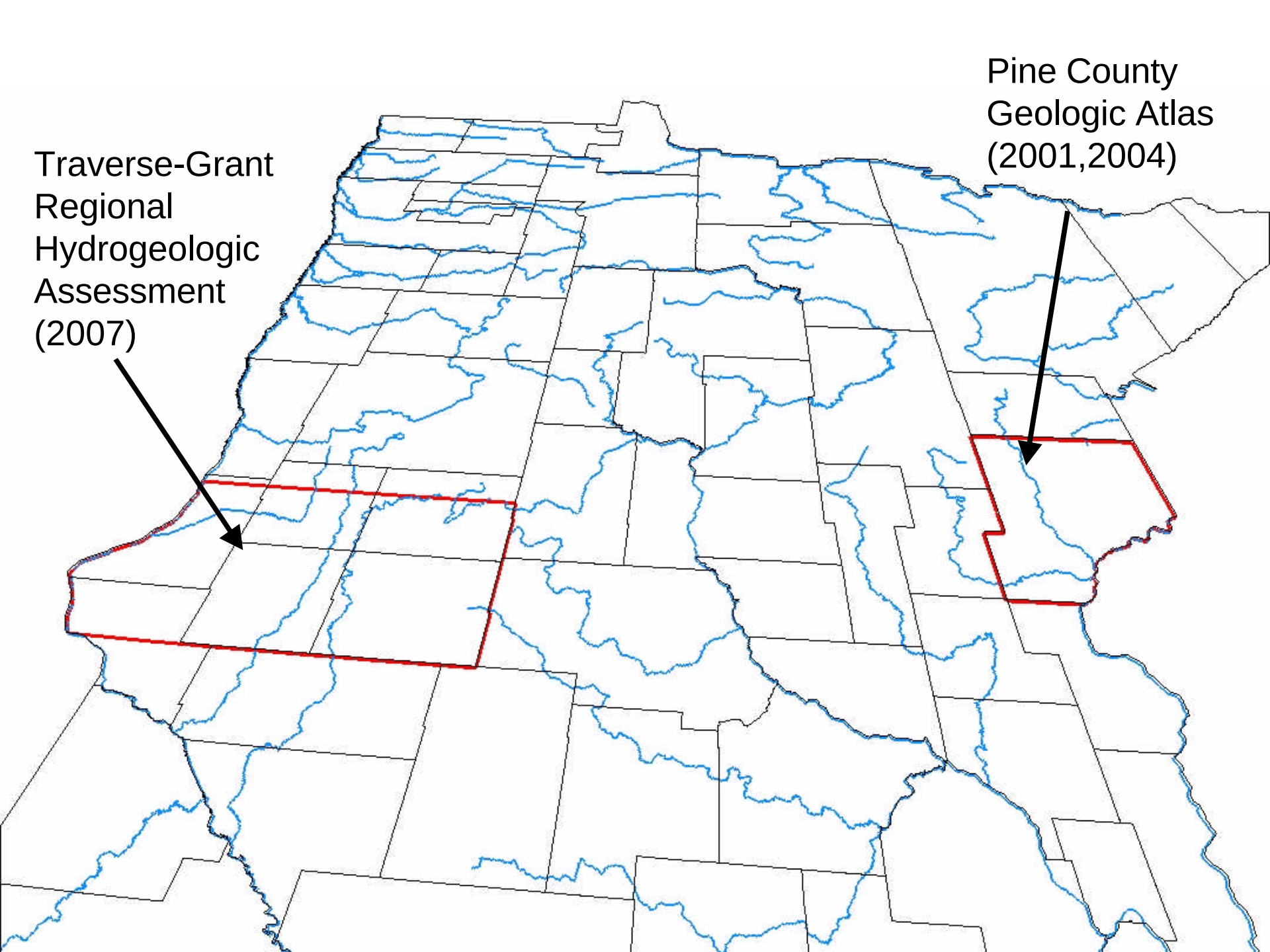

00646812
00471190
00556269
00477593
00194358
C253
00197704
00577140
00595426
00609705
00190726
00562314
00666719
00190719
00194368
0.9
36
36.9
18.2
376
4.59
97
1150
1100
1050

OT
Aquifer
Pathways

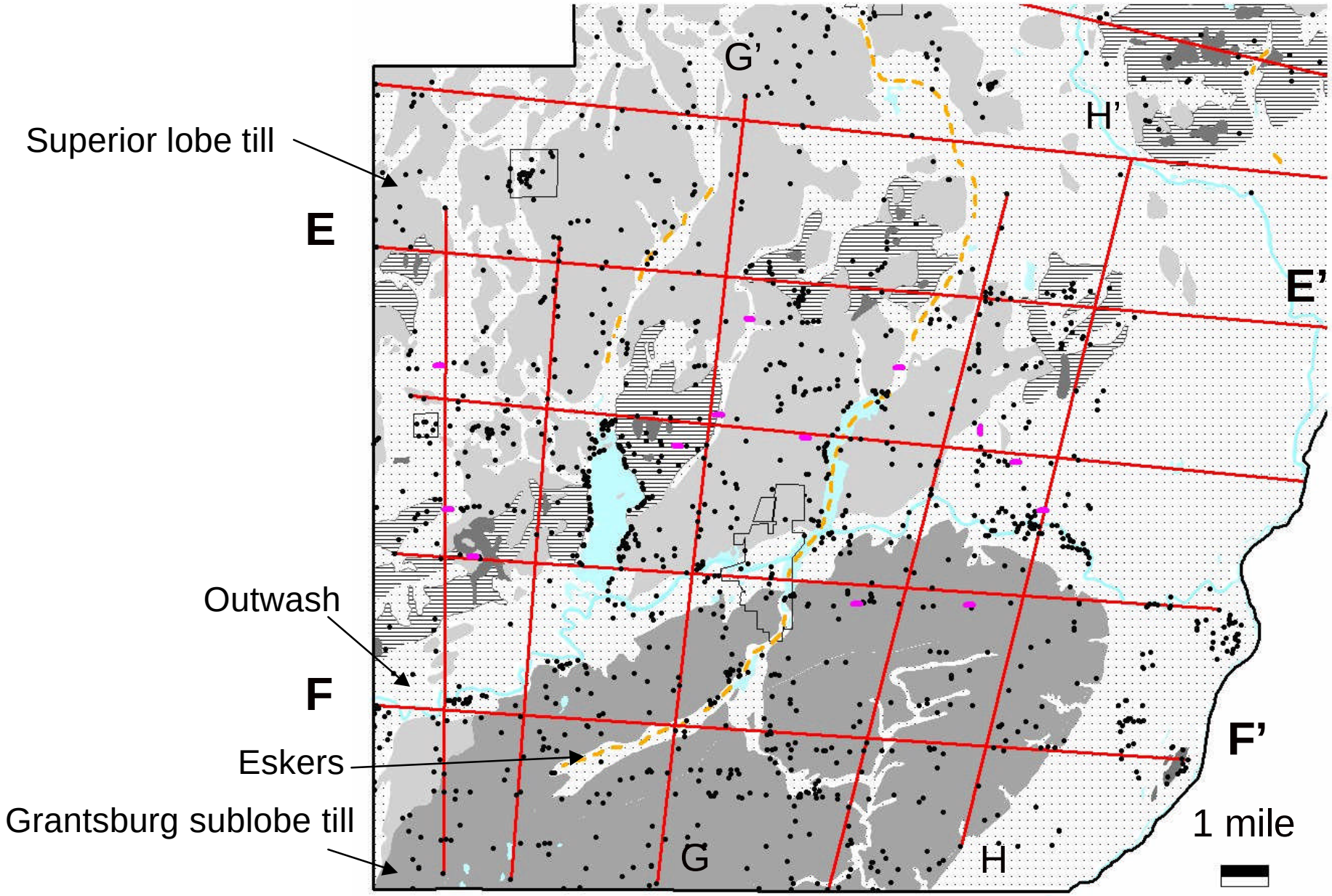


CW
Aquifer
Pathways



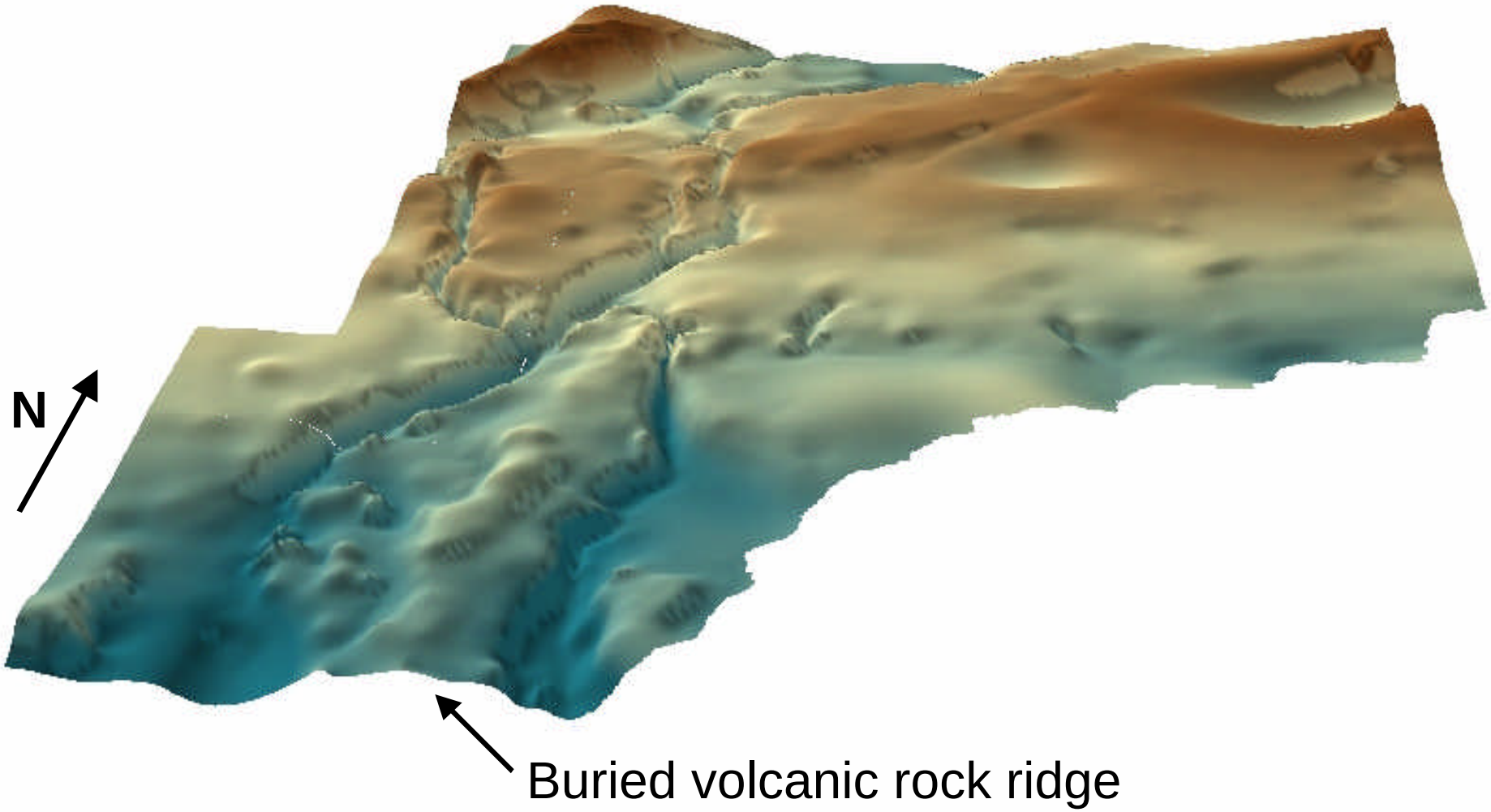

Traverse-Grant Regional Hydrogeologic Assessment (2007)
Pine County Geologic Atlas (2001,2004)

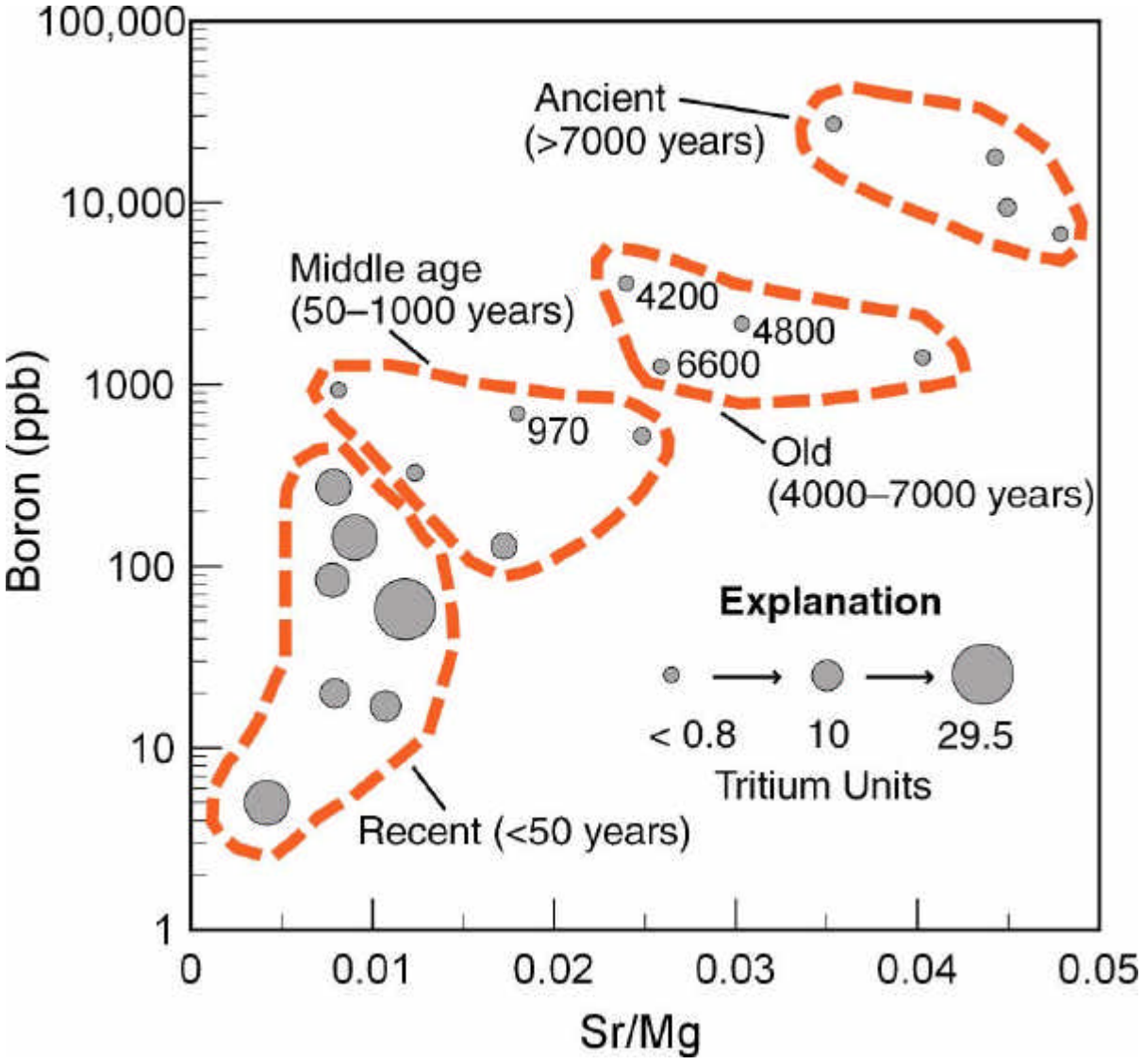
Simplified Surface Geology and Cross Sections

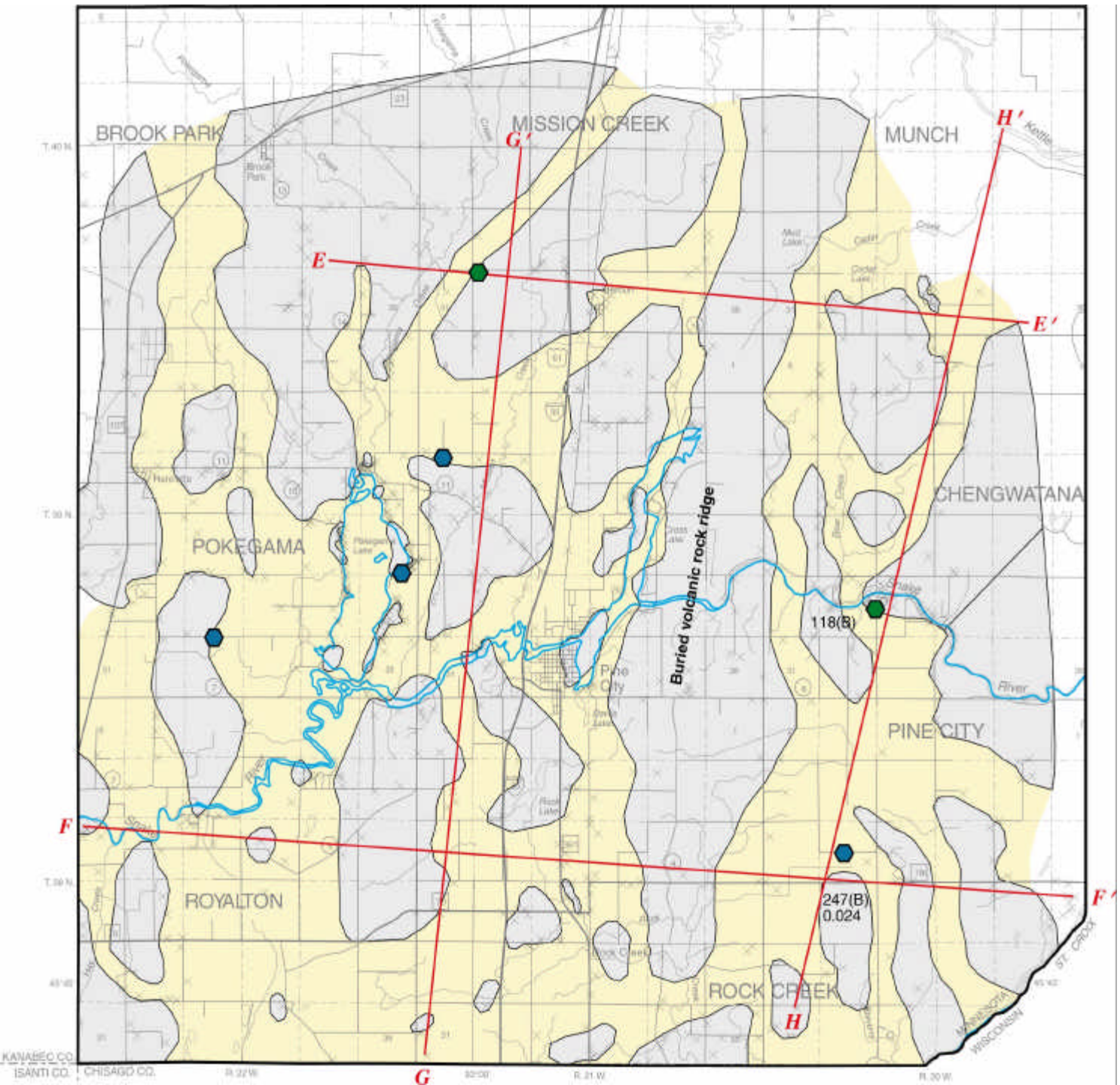


Pine County Bedrock Topography

(from Setterholm 2001)



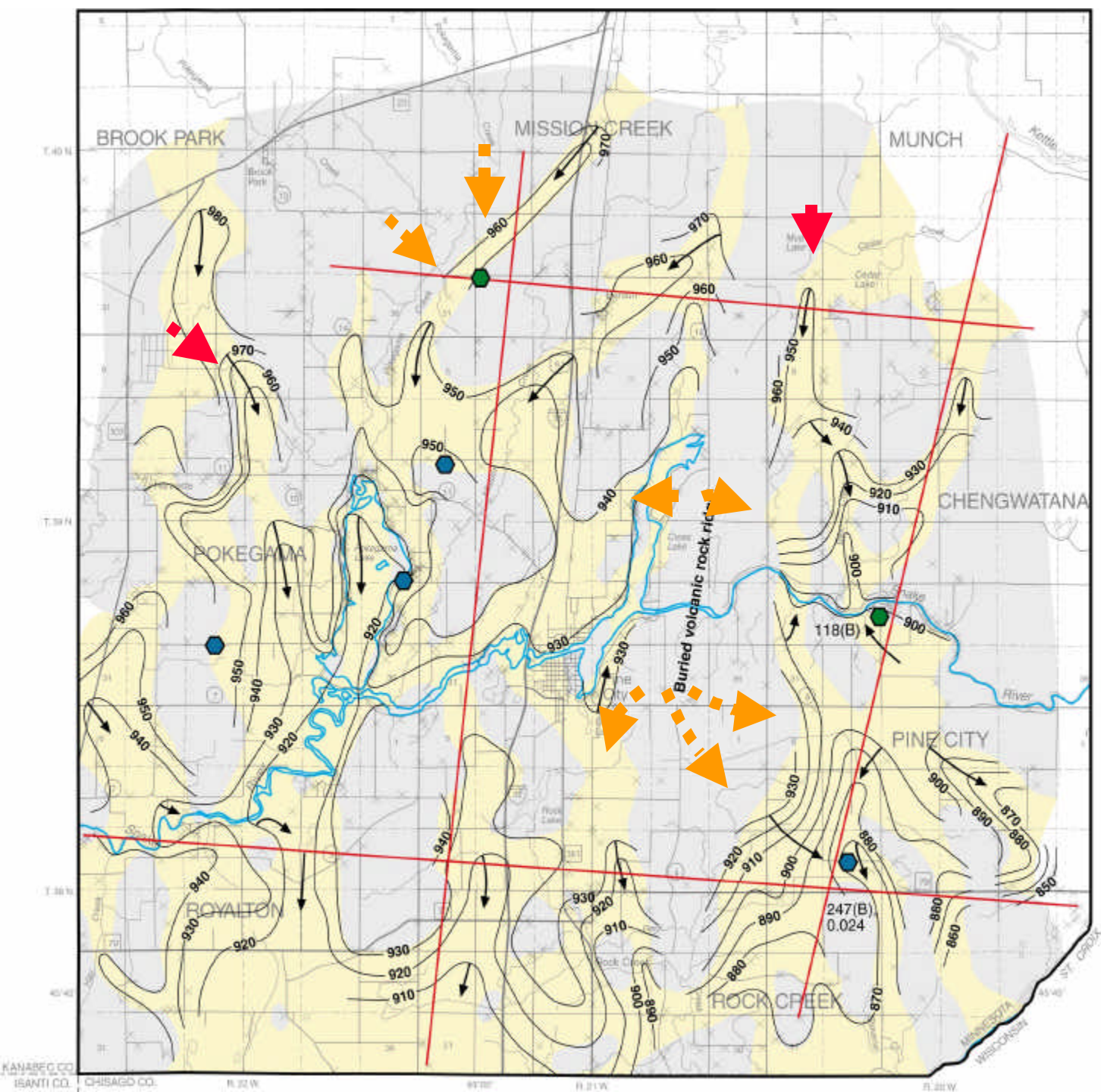

100,000
10,000
1000
100
10
1
Boron (ppb)
0
0.01
0.02
0.03
0.04
0.05
Sr/Mg
Ancient
(>7000 years)
Middle age
(50–1000 years)
4200
4800
6600
970
Old
(4000–7000 years)
Explanation
< 0.8
10
29.5
Tritium Units
Recent (<50 years)



S2 unit

Buried volcanic rock ridge separated area into two sub-basins

Valley or tunnel valley sand and gravel distribution

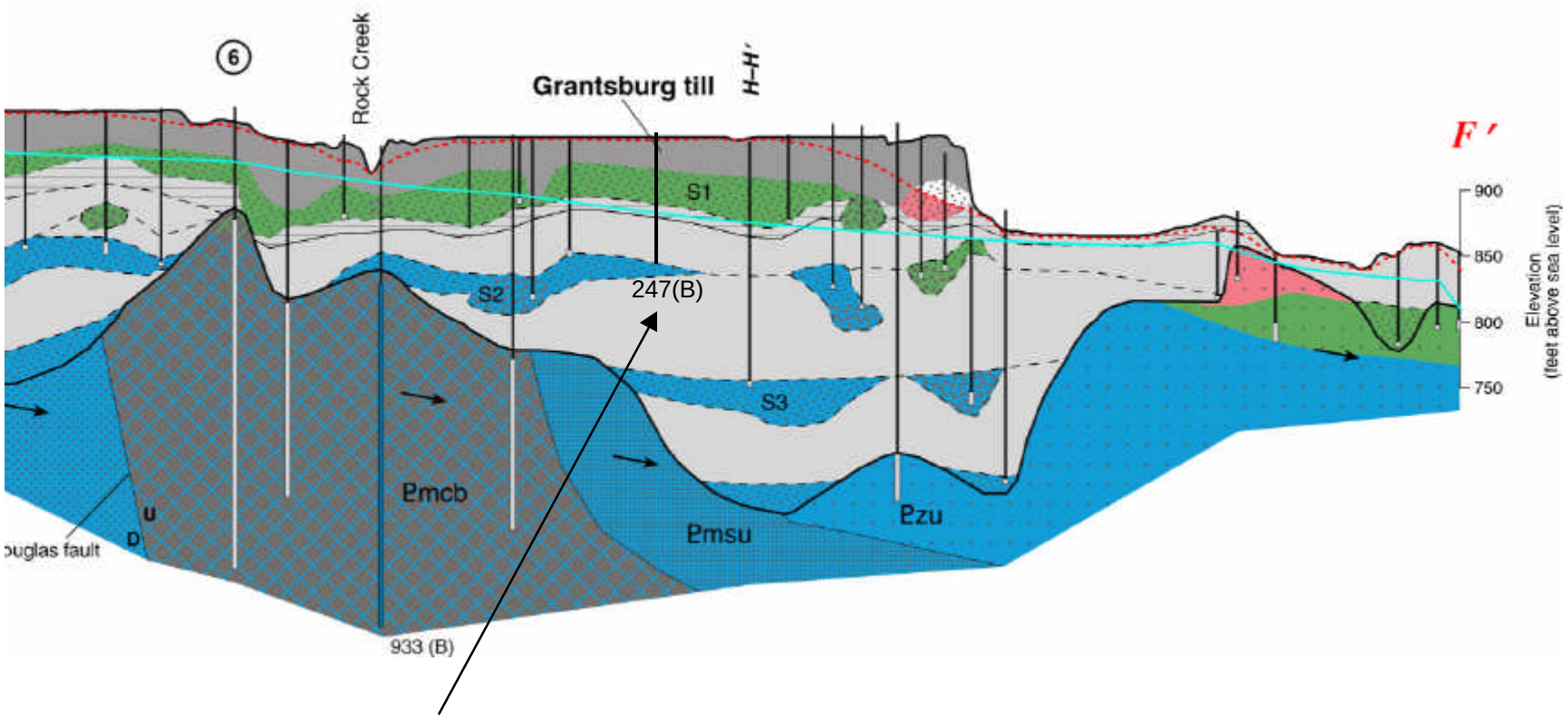


S2 aquifer

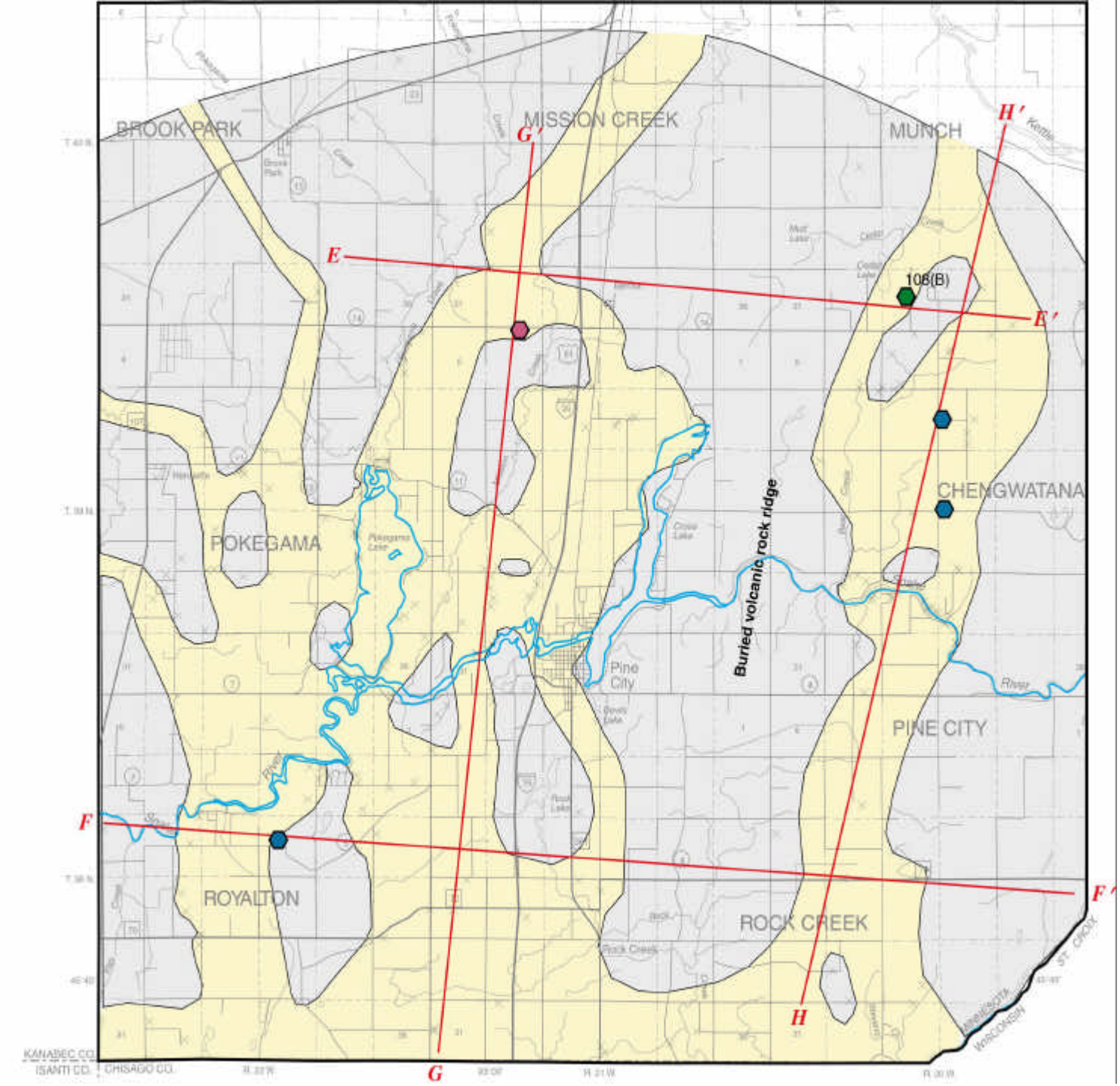
Mixed tritium only near northern edge suggesting important northern recharge area.

Leached basalt rock constituents east of ridge indicating flow through buried volcanic ridge.

Sensitivity – moderate to very low

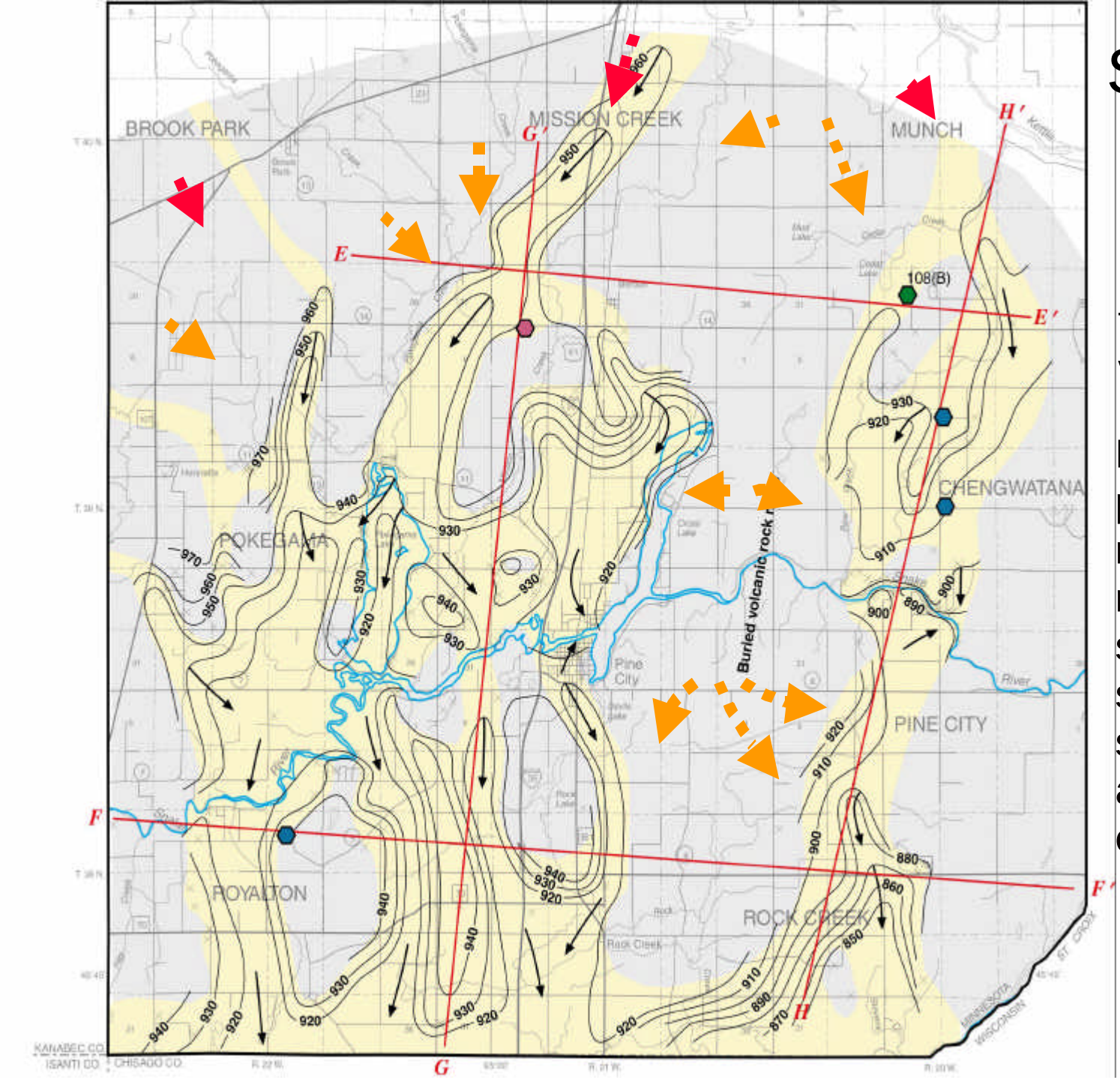


Elevated boron value in buried
Sand and gravel aquifer



S3 unit

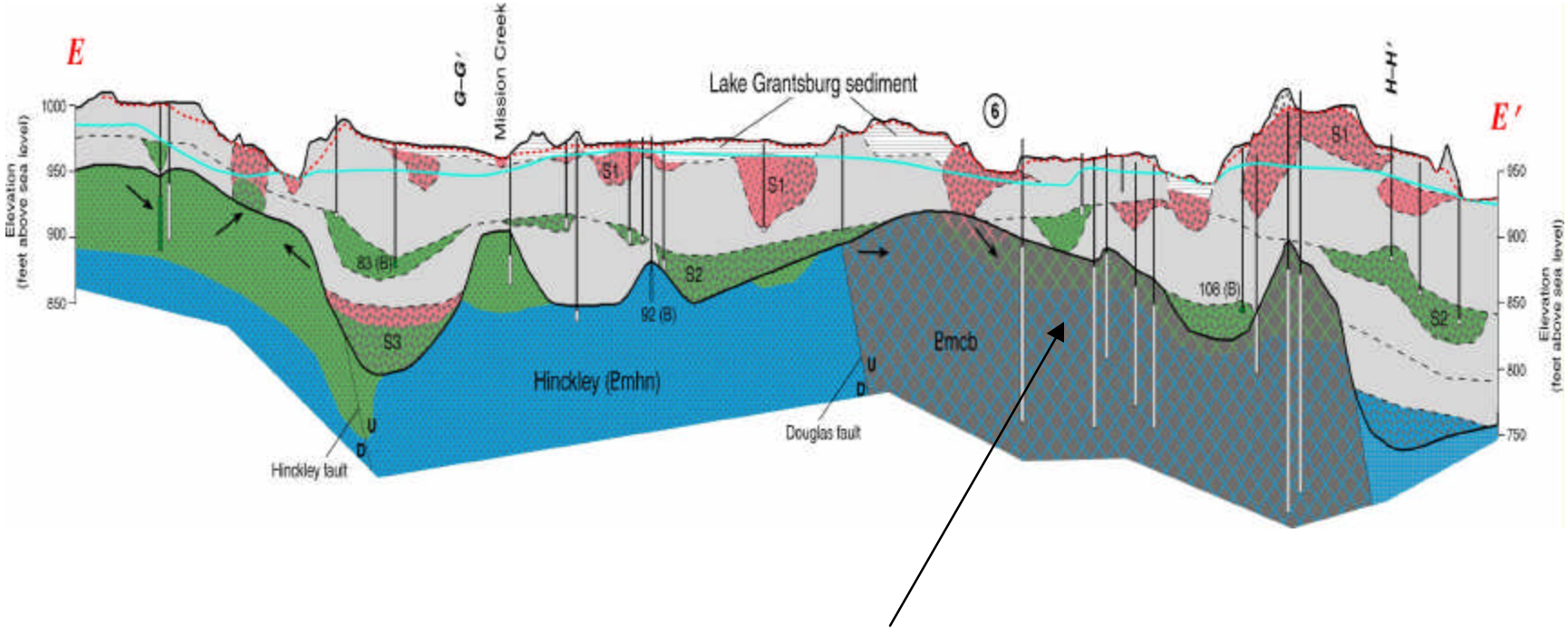
Similar to S2 with valley-type distribution
- less control



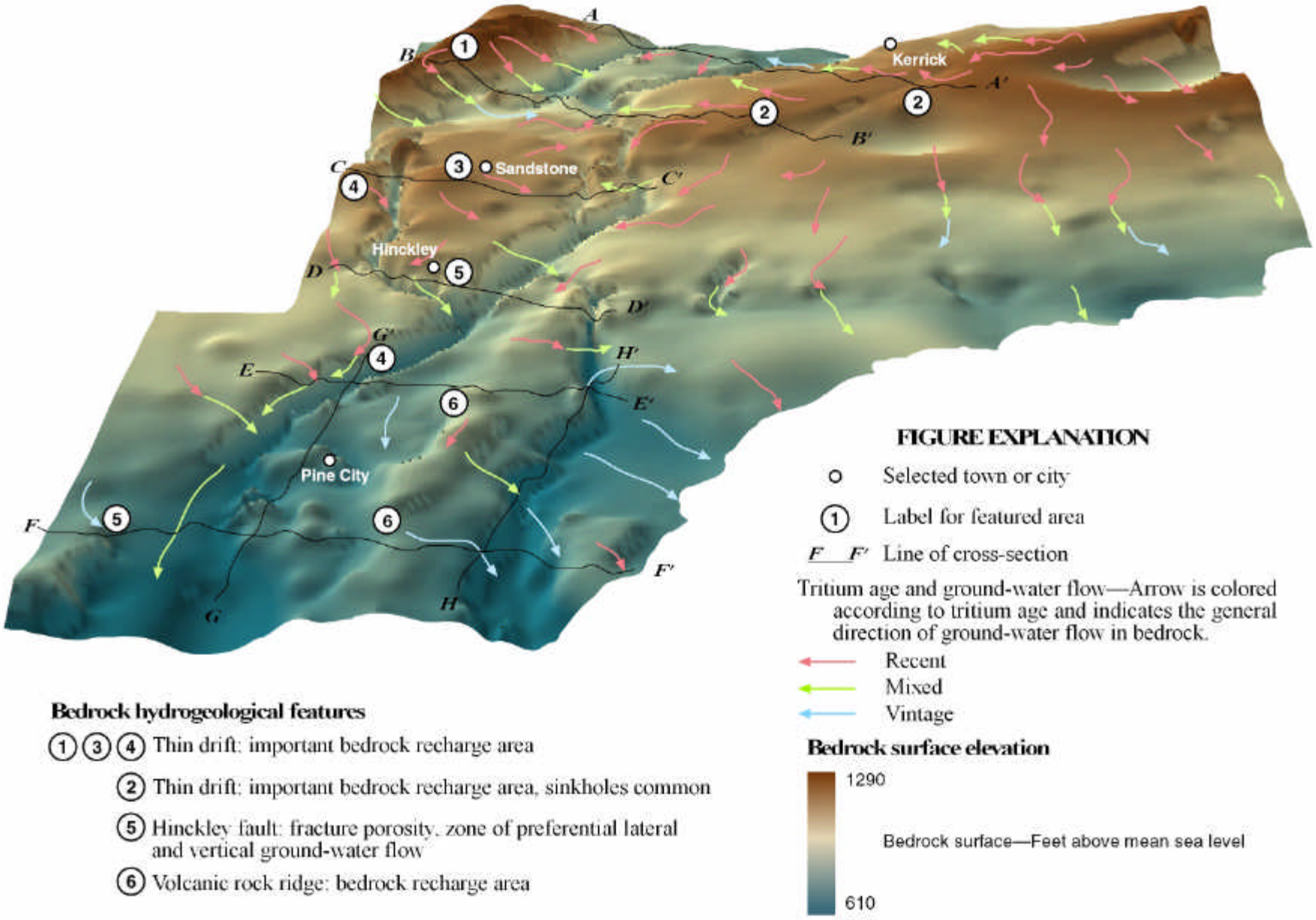
S3 aquifer

Leached basalt rock constituent indicating flow through buried volcanic ridge.

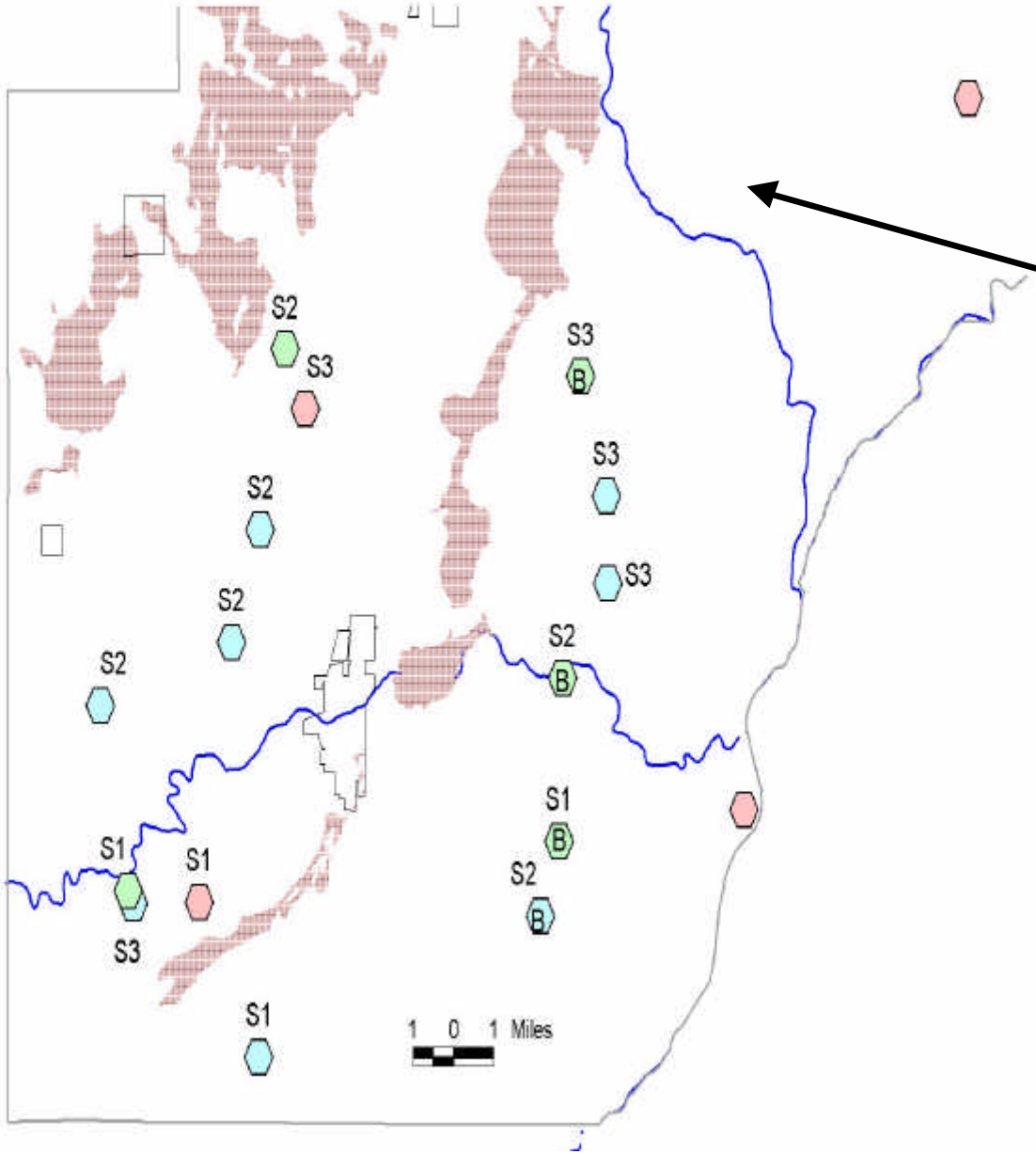
Recent recharge probably 2-3 miles north of recent tritium sample location suggesting strong recharge around northern edge



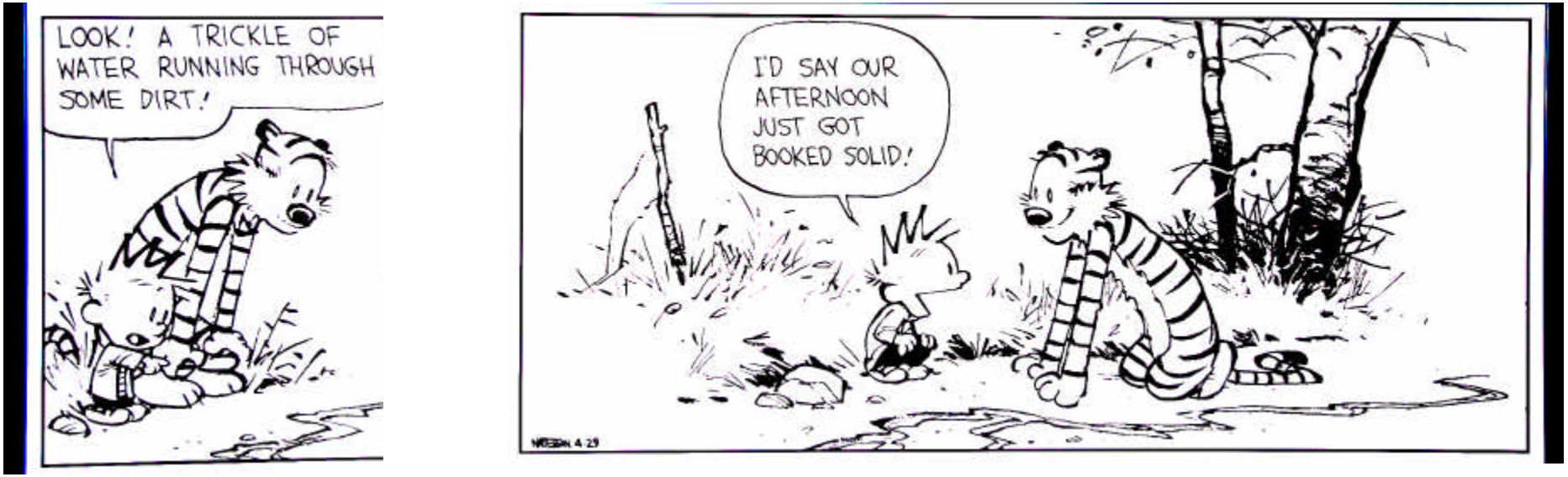
Elevated boron value in
Buried sand and gravel aquifer


A
B
1
Kerrick
A'
2
2
B'
C
3
Sandstone
C'
4
Hinckley
D
5
D'
G'
4
H'
E
E'
6
Pine City
F
5
6
F'
G
H
FIGURE EXPLANATION
Selected town or city
1 Label for featured area
F F' Line of cross-section
Tritium age and ground-water flow—Arrow is colored according to tritium age and indicates the general direction of ground-water flow in bedrock.
Recent
Mixed
Vintage
Bedrock surface elevation
1290
Bedrock surface—Feet above mean sea level
610
Bedrock hydrogeological features
1 3 4 Thin drift: important bedrock recharge area
2 Thin drift: important bedrock recharge area, sinkholes common
5 Hinckley fault: fracture porosity, zone of preferential lateral and vertical ground-water flow
6 Volcanic rock ridge: bedrock recharge area

Buried Quaternary sand and gravel aquifer sensitivity summary



Buried Q Aquifer high – Very high sensitivity



Tracing the tortuous pathways (trickle of water running through some dirt) using wide ranging disciplines (tools):

Surface water studies

Potentiometric surfaces/hydraulic properties/digital simulations/geochemistry

Sand and gravel aquifer distribution

Glacial history/stratigraphy