Groundwater Mapping

Today's agenda

- Dam failure case study
- Review heterogeneity and anisotropy
- Hydrogeologic Mapping

Dam failure

Vale S.A. Dam Failure

Heterogeneity and Anisotropy

General thoughts:

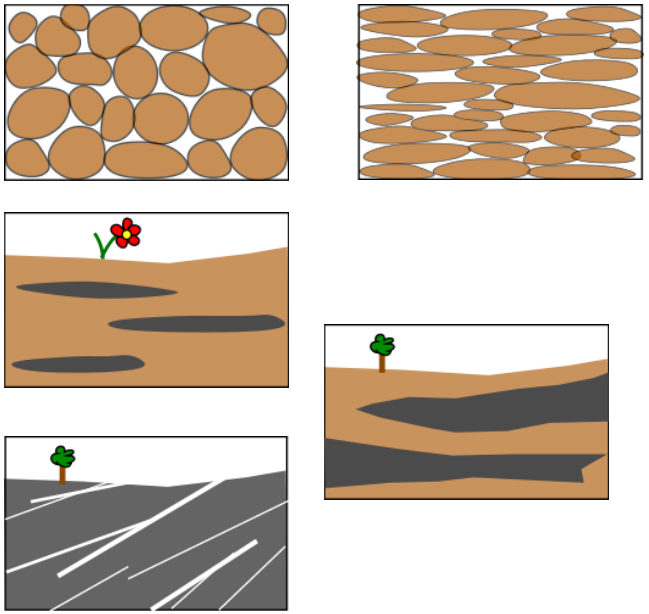
- At some spatial scale, aquifer properties always vary
- We often assume that aquifer property values are the same everywhere or can be represented by a single value that does not vary spatially. Why do we do this? Is this a good idea?

Causes of Heterogeneity (change in K over space):

- Changes in lithologic properties
  - During sedimentation (layering)
  - After sedimentation (faulting, diagenesis, tectonics)
  - Carbonate (dissolution, fracturing, precipitation)
  - Volcanics (lava tubes, fracturing)
- Changes in aquifer thickness – causes T to vary

Causes of Anisotropy:

- Grain shape: interconnection of pores is not uniform in all directions. Grain orientation can cause property differences of 5:1
- Small-scale heterogeneities: small, flat zones of clay can have the same effect as grain scale orientation
- Layering: effective properties are commonly higher in the horizontal direction than the vertical due to layering (10:1 to 100,000:1)
- Preferred pathways: fractures and conduits that have a preferential direction



Large-scale heterogeneity

Example: Uplifted formations

Rocky Mountains
(exposed outcrops in uplifted area)

Colorado Plateau

Atlantic coastal plain
(sediments derived from uplifted mountains – Appalachians – not uplifted with them)

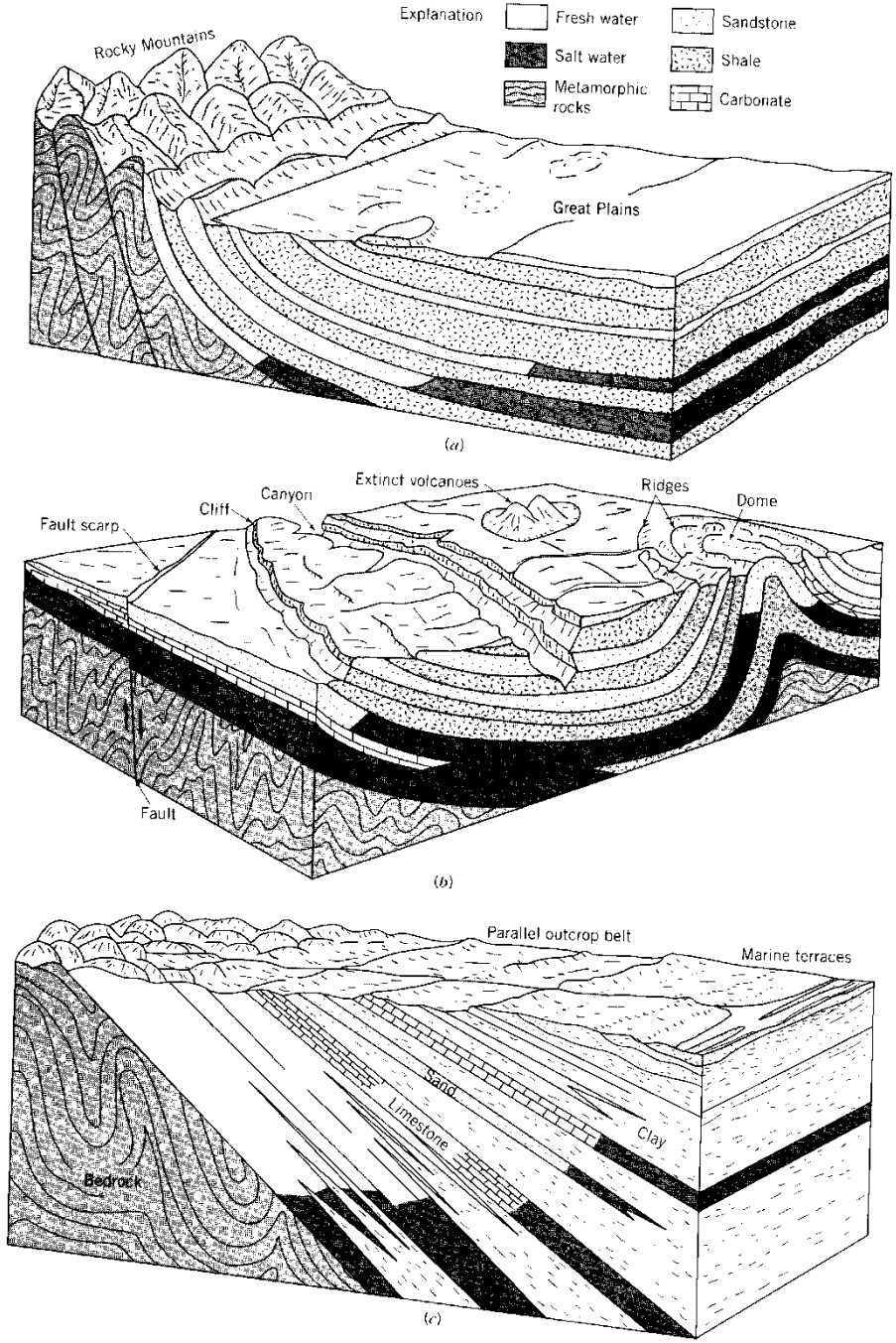
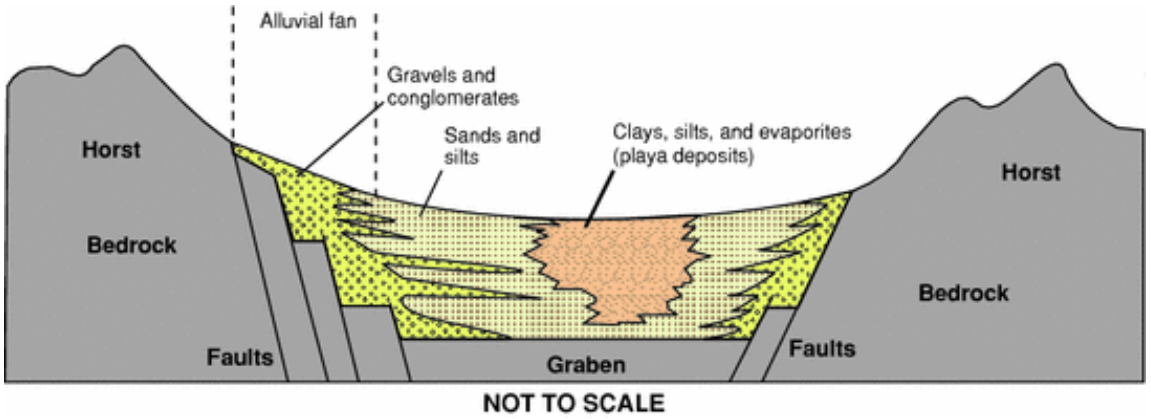


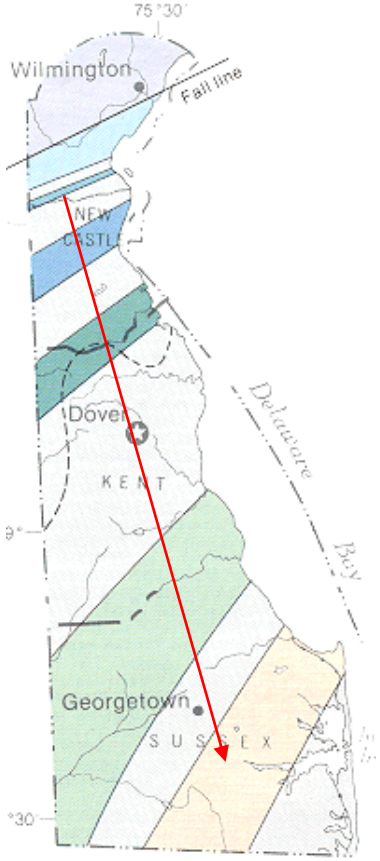
Figure 2.21 Style of uplift (from Heath, 1984).

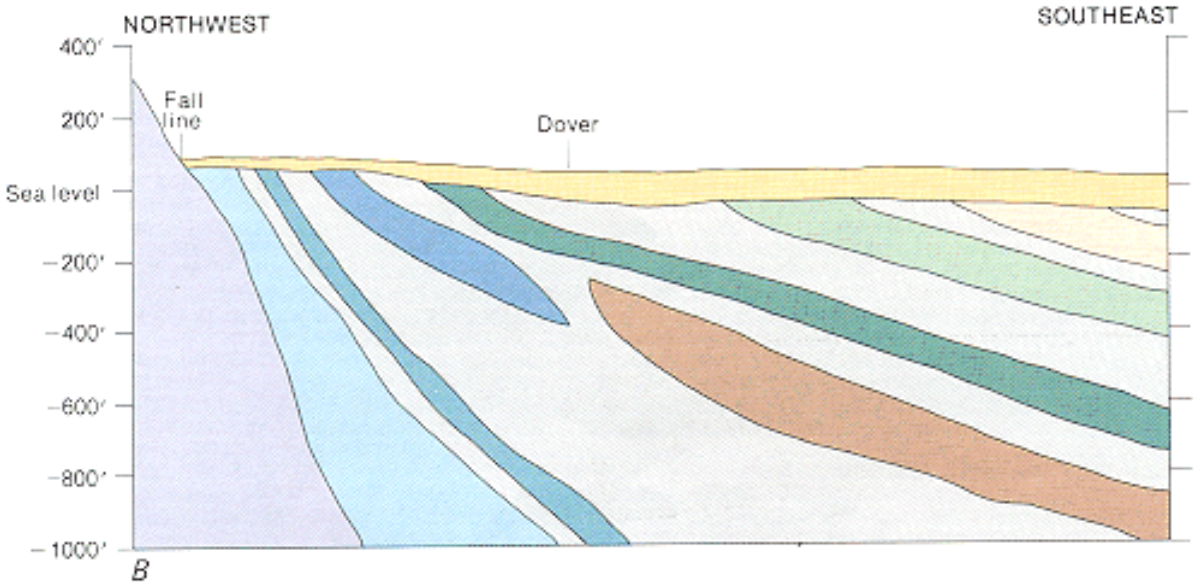
Large-scale heterogeneity

Example: Horsts and Grabens

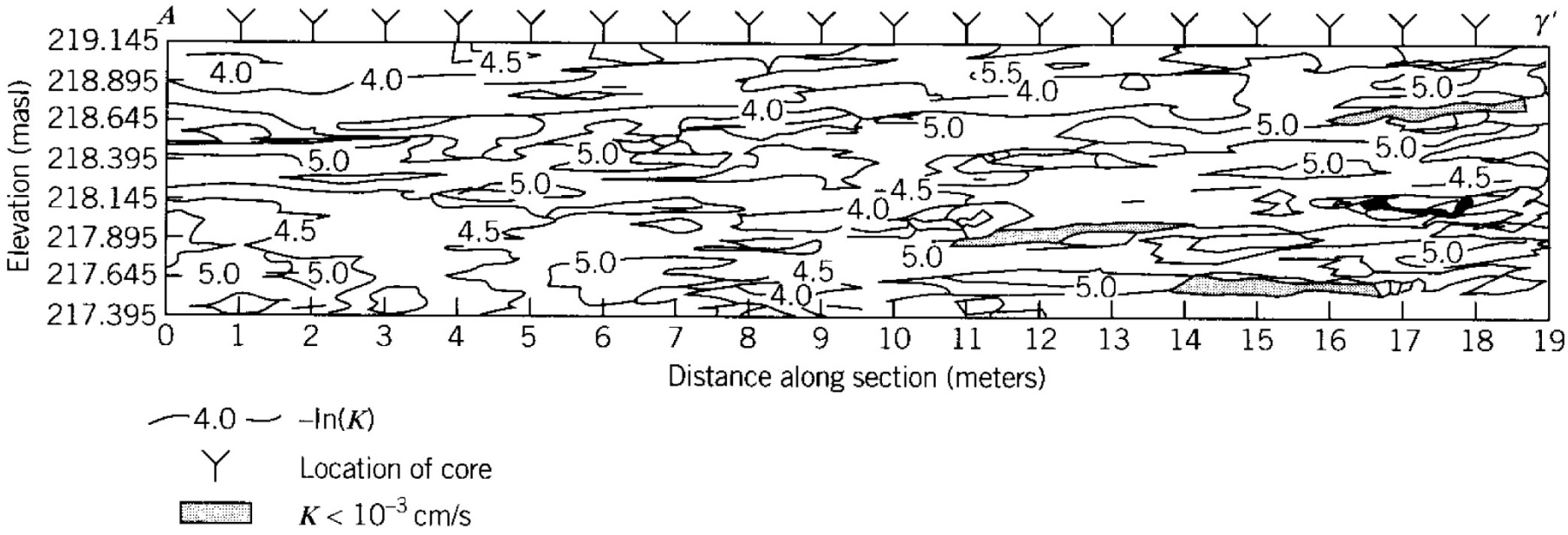


Example: Coastal Plain

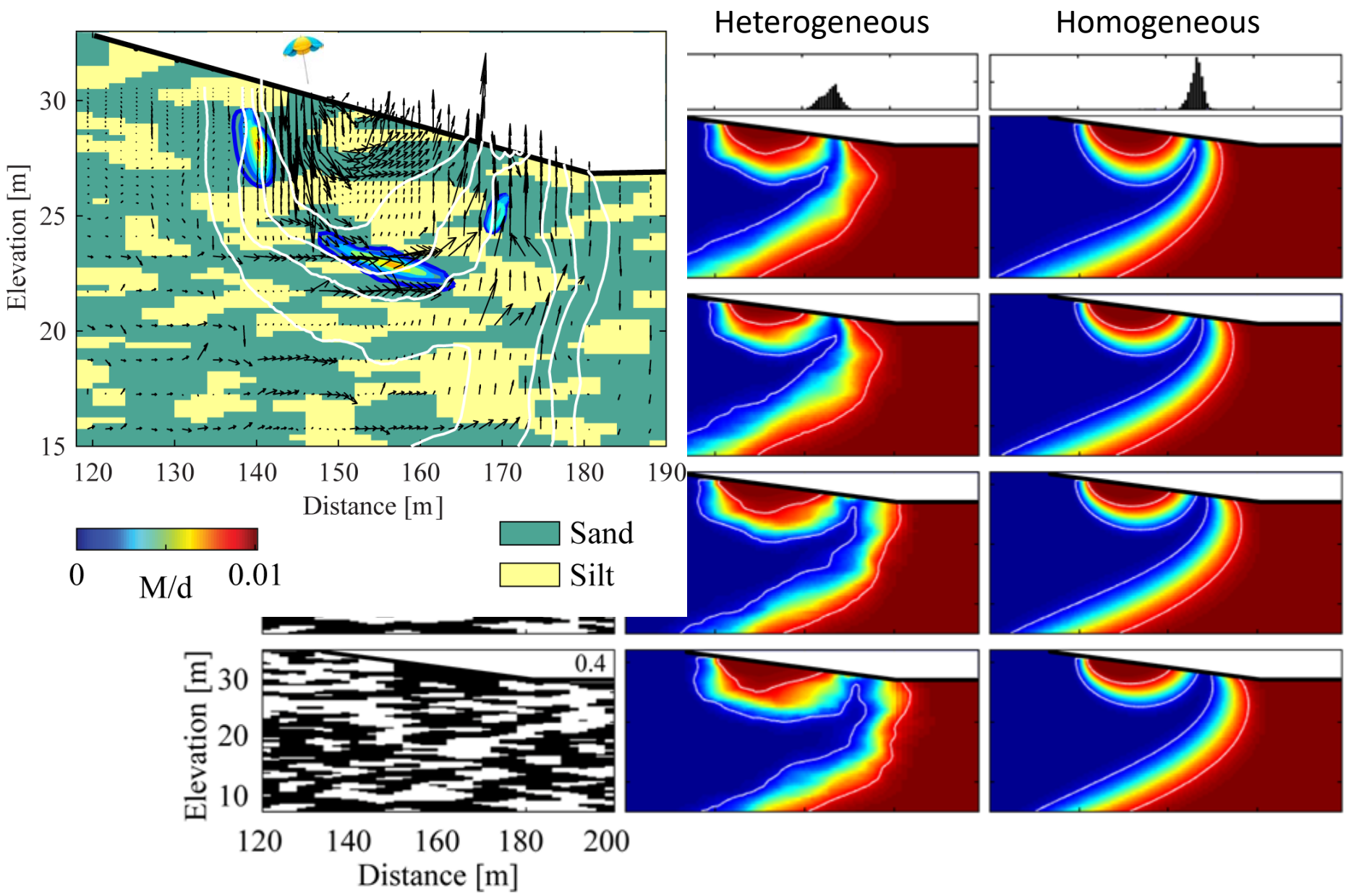




Small-scale heterogeneity

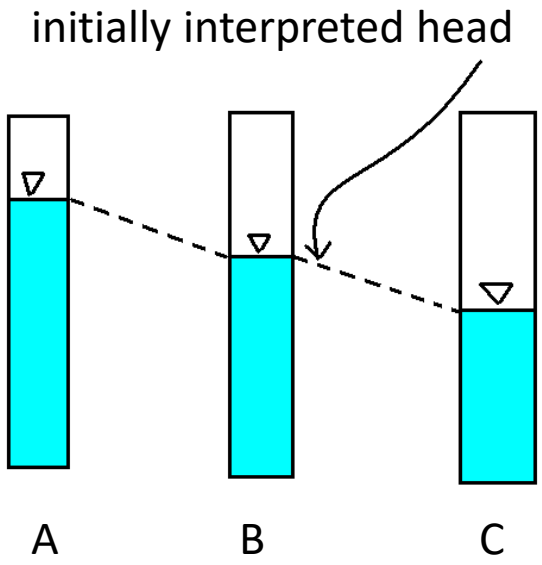


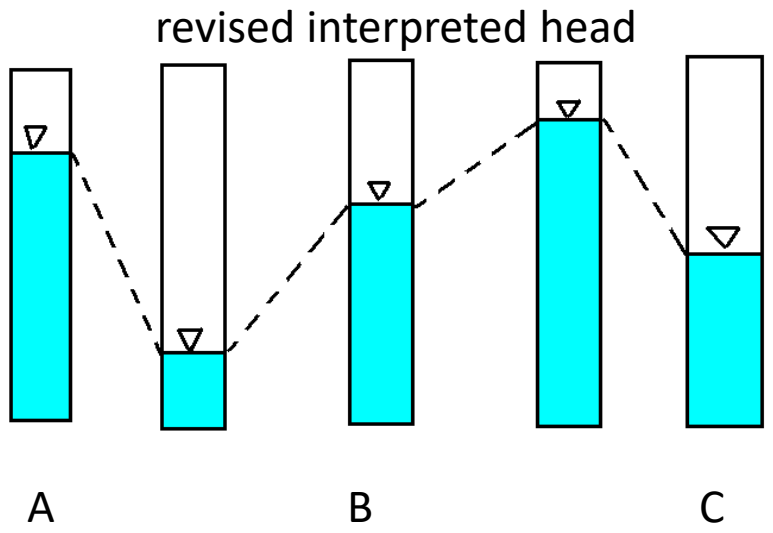
K distribution at Borden site (Canadian Forces Base), Sudicky (1986), *Water Resources Research*


Heterogeneous
Homogeneous
Elevation [m]
30
25
20
15
120
130
140
150
160
170
180
190
Distance [m]
0
M/d
0.01
Sand
Silt
0.4
Elevation [m]
30
20
10
120
140
160
180
200
Distance [m]

Spatial interpretation/interpolation of measured data

Groundwater data is ALWAYS too sparse and must be interpreted to obtain full spatial/temporal distributions





new data changes interpretations…

Important Points for Potentiometric Surfaces (elevation that water level rises in wells throughout the aquifer):

1) In the absence of flow, a potentiometric surface will be flat
2) A sloping potentiometric surface indicates that water is flowing
3) The potentiometric surface map must relate to ONE aquifer
4) For maps (2D), typically assume flow is horizontal (no vertical flow, equipotential lines are projected vertically)
5) Head loss between adjacent pairs of equipotential lines are equal – constant contour interval

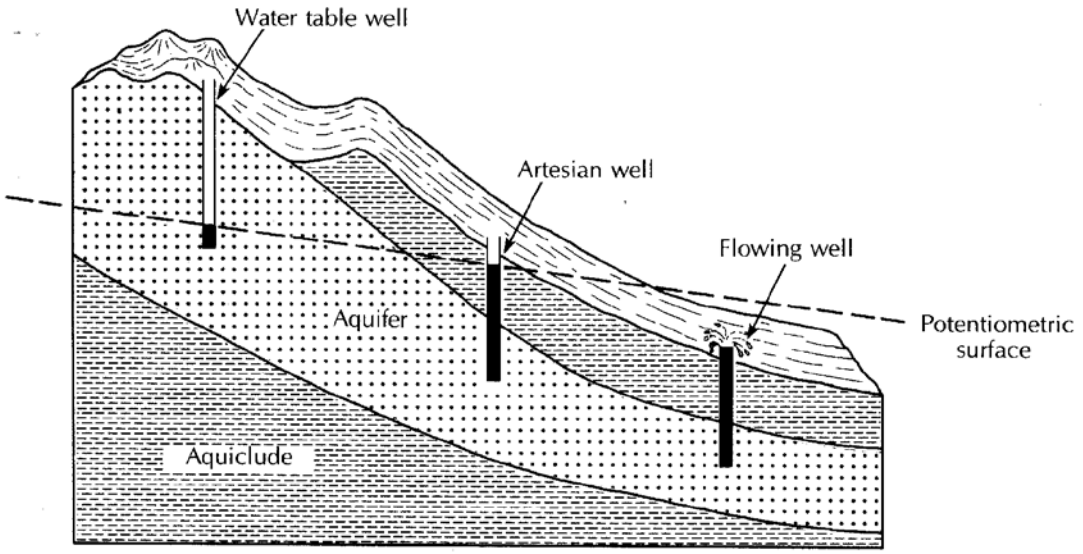
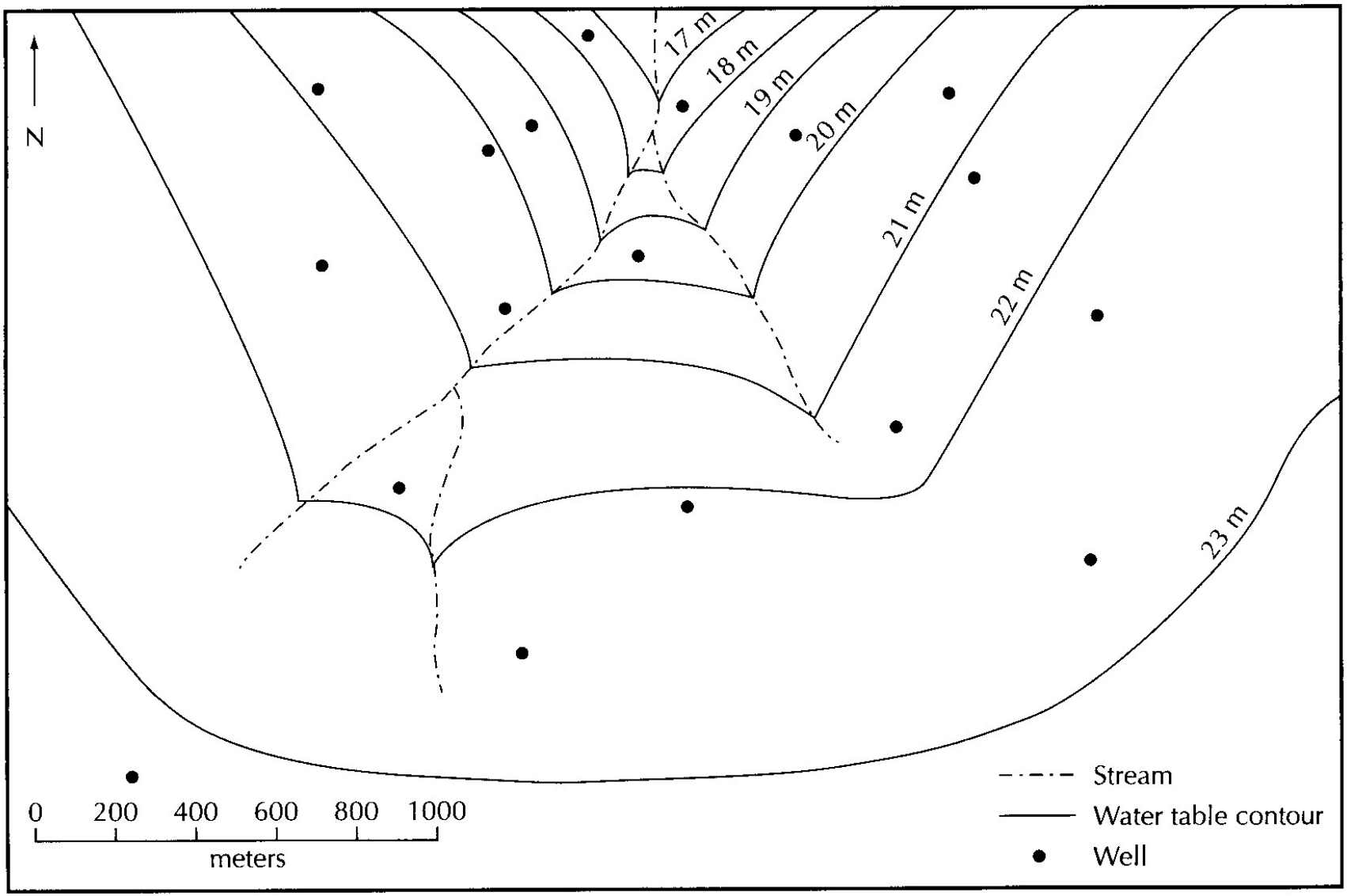


FIGURE 4.21 Artesian and flowing well in confined aquifer.

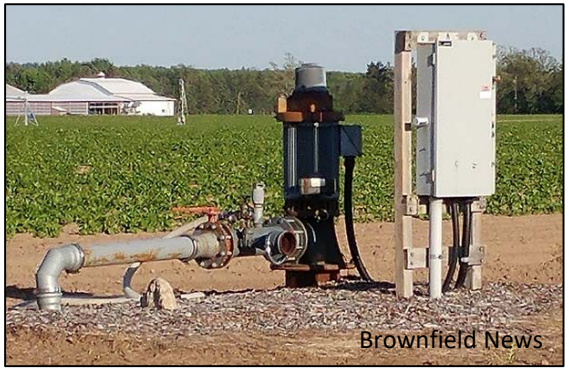


What are the head values at each of the points?
Which way is water flowing?
What are the highest and lowest hydraulic gradients on the map?

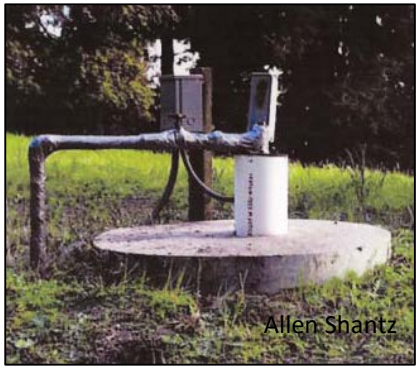
Piezometers and Wells

Piezometers and Wells

Irrigation



Domestic



Municipal

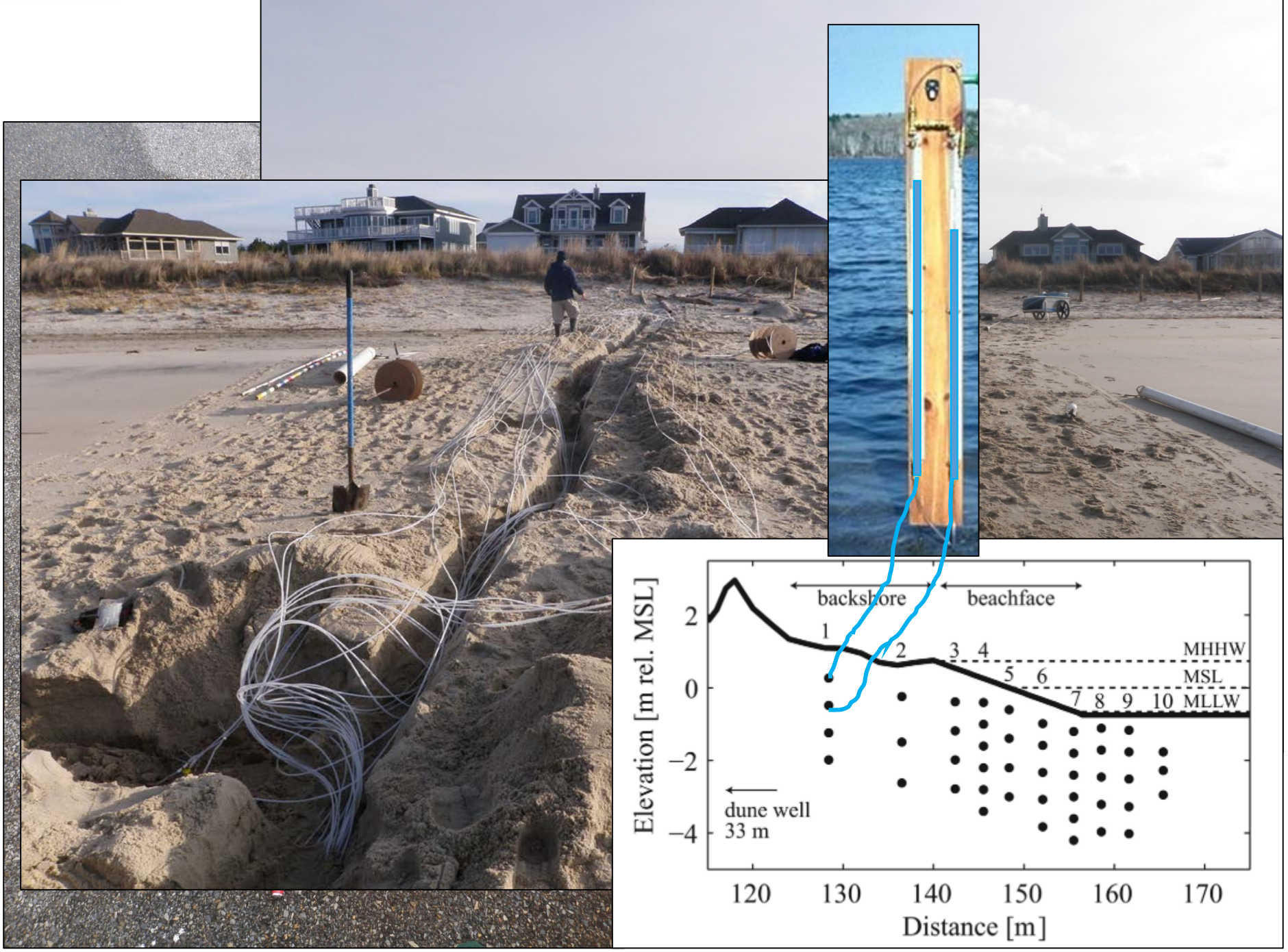
Measuring hydraulic head

- Chalk tape

- Electric tape
  - Water completes the circuit

- Pressure transducer
  - Generally >$1000
  - Used for continuous monitoring
  - Internal computer with battery
    - Can lead to more problems

- Potentiomanometer
  - Used for head *gradients*


backshore
beachface
1
2
3
4
5
6
7
8
9
10
MHHW
MSL
MLLW
dune well
33 m
Elevation [m rel. MSL]
2
0
−2
−4
120
130
140
150
160
170
Distance [m]