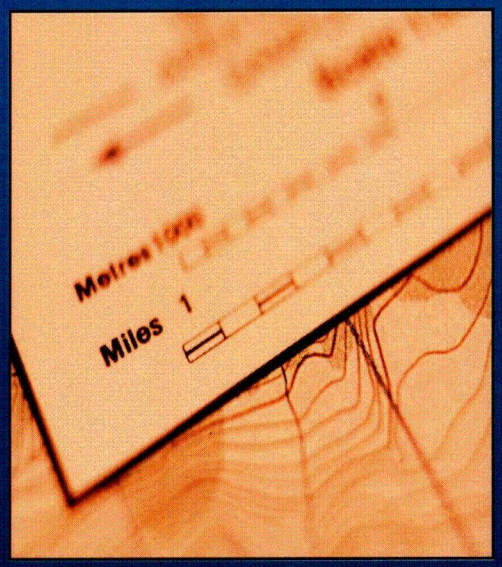
Ground Water Hydrology

Hydrogeologic Suitability of Site

- Field hydrologic tests
  - Air-entry permeameter tests
  - Packer tests
  - Bail tests
- Ground water occurrence
  - Mancos Shale aquitard
  - Discrete fractures or conduits
  - Chemistry

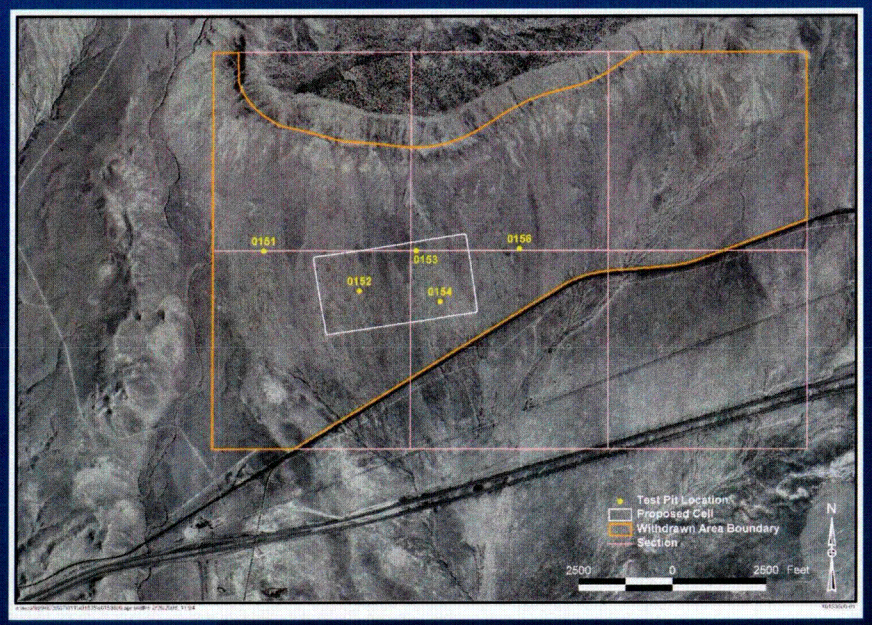


Field Hydrologic Tests

- Air-entry permeameter
  - Weathered Mancos Shale
  - Vertical hydraulic conductivity
- Packer tests
  - Weathered and unweathered
  - Horizontal hydraulic conductivity
  - Discrete estimate
- Bail tests
  - Horizontal hydraulic conductivity
  - Vertically averaged estimate

Air-Entry Permeameter (AEP) Tests

- Vertical K measurement
- ASTM D-5126; Bouwer (1966)



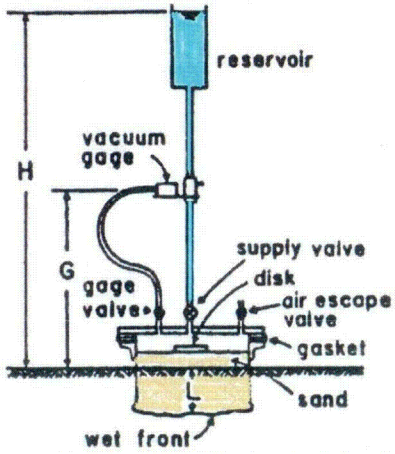


FIG. 1 Diagram of the Equipment for the Air-Entry Permeameter Technique (from Klute, 1986)

AEP Tests (continued)

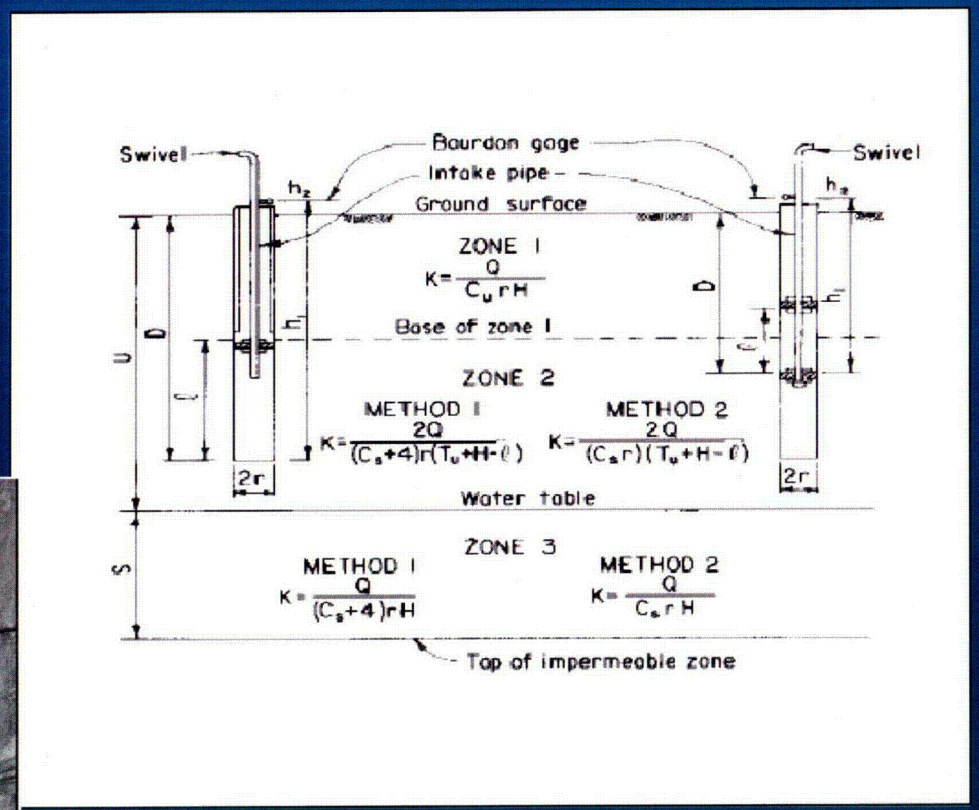
- Test pit excavation
- Cut circular channel for AEP ring
- Set ring

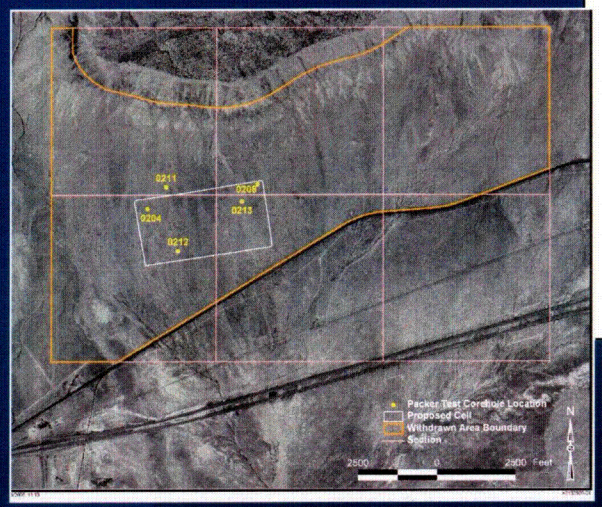
AEP Tests (continued)

- Seal ring
- Fill graduated cylinder
- Measure rate of declining fluid level
- Kz ≈ 1 E-04 cm/s

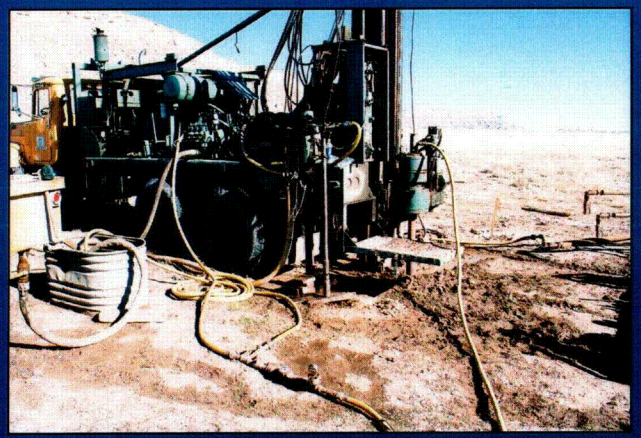
Packer Tests

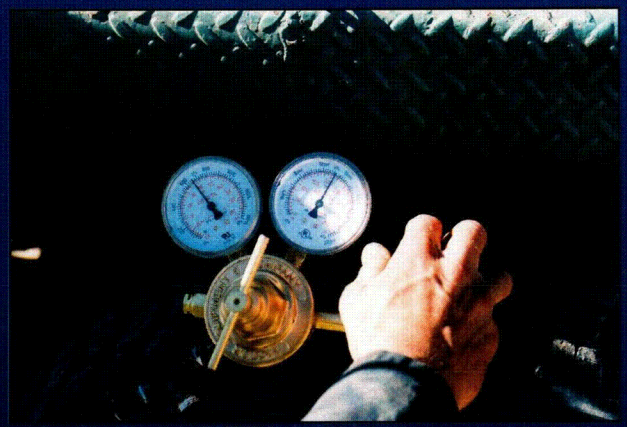
- 5 Locations
- USBR methods
- Dual packer
- Single packer





Packer Test Setup

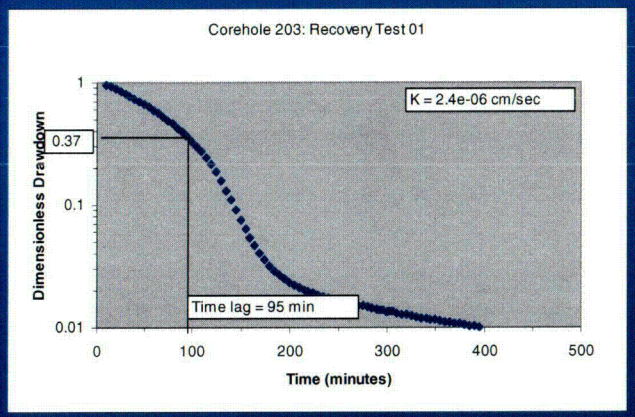


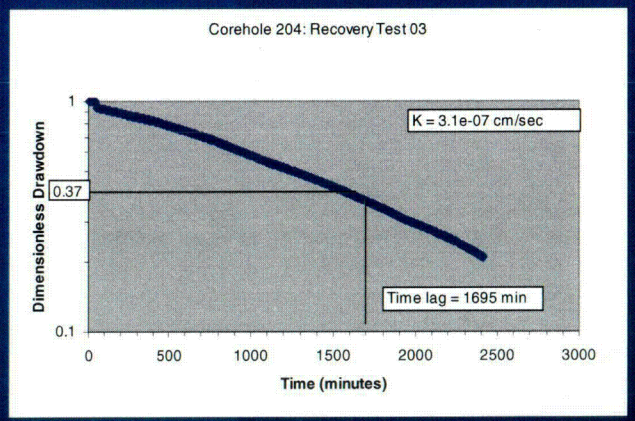


Preliminary Packer Test Results

- Weathered Mancos Shale
  - 20 to 40 ft BGS
  - K ≈ 1.3 E-03 to 2.6 E-03 cm/s
- Unweathered Mancos Shale
  - 80 to 300 ft BGS
  - K ≈ 1.2 E-06 to 2.2 E-09 cm/s
- Permeability: decrease with depth

Bail Tests

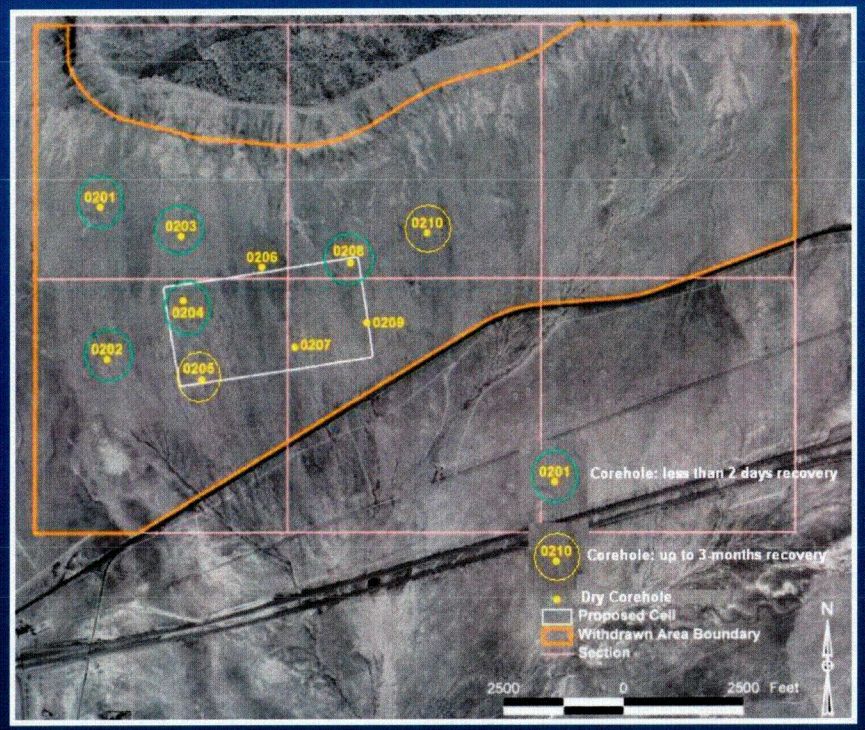




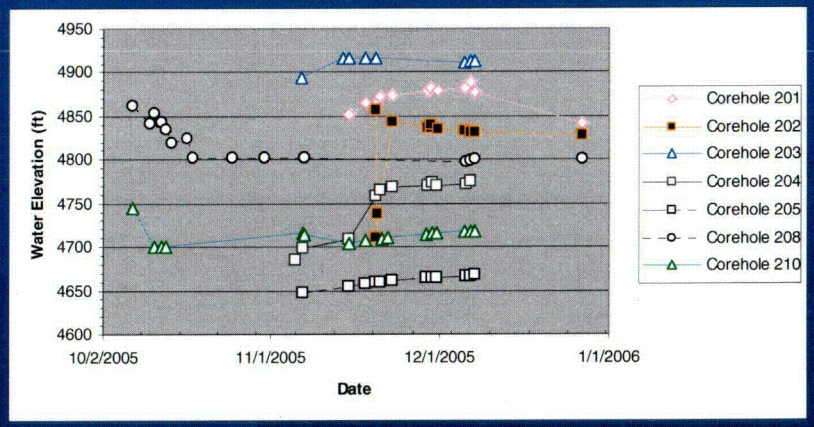
- Unweathered Mancos Shale
  - Hvorslev method
  - Vertically averaged hydraulic conductivity
  - K ≈ 1.4 E-06 cm/s to 3.1 E-07 cm/s
  - Recovery: < 2 day

Ground Water Occurrence

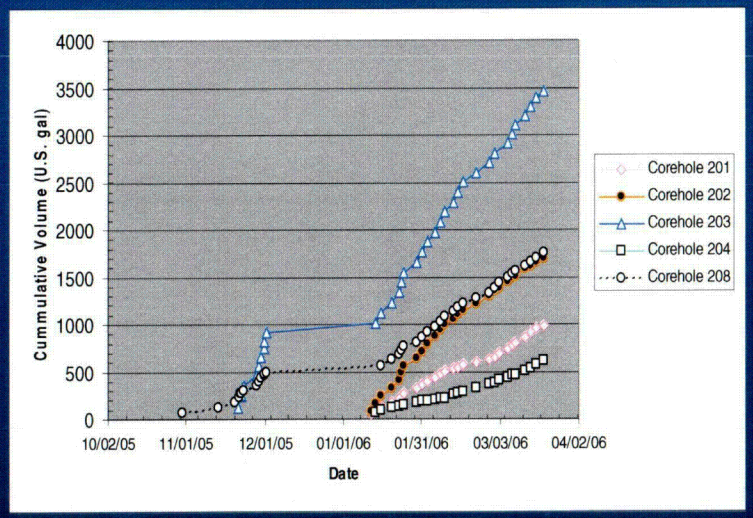
- 5 locations: up to 2-day recovery
- 2 locations: up to 3- month recovery
- 3 locations dry
- Sparse, discontinuous, water-bearing conduits
- Disparate water levels
- Brine signature
- TDS variability
- *Connate* water



Ground Water Occurrence (continued)



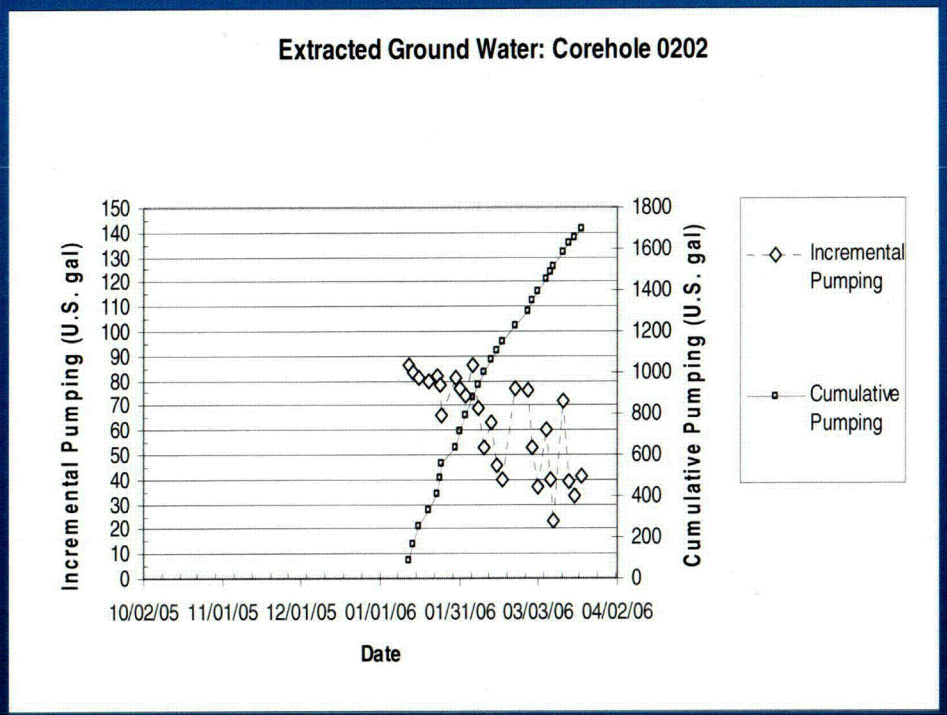
Water elevations (ft)



Water yield (U.S. gal)

Systematic Pumping

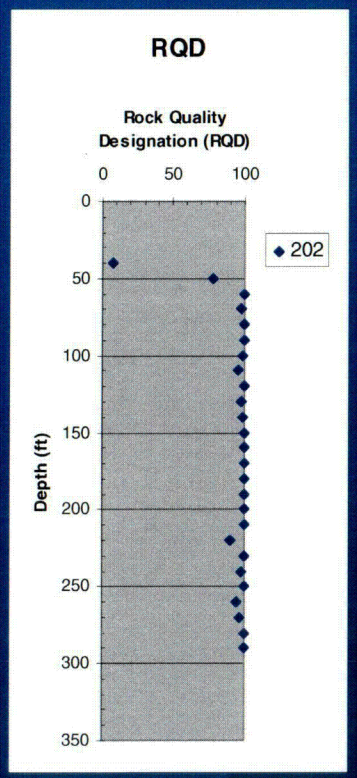
- Incremental pumping: yields are declining
- Cumulative pumping: change in slope
- Incipient source depletion

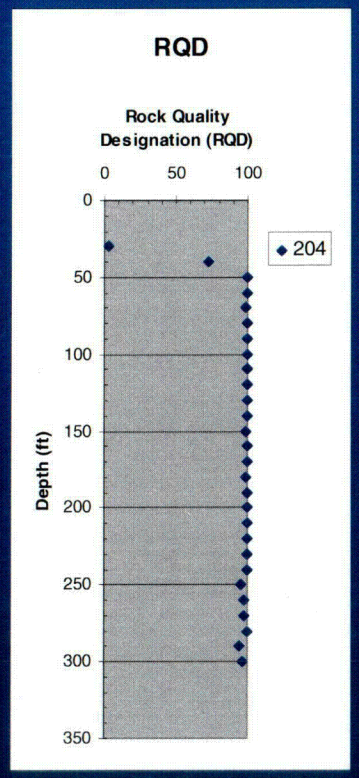


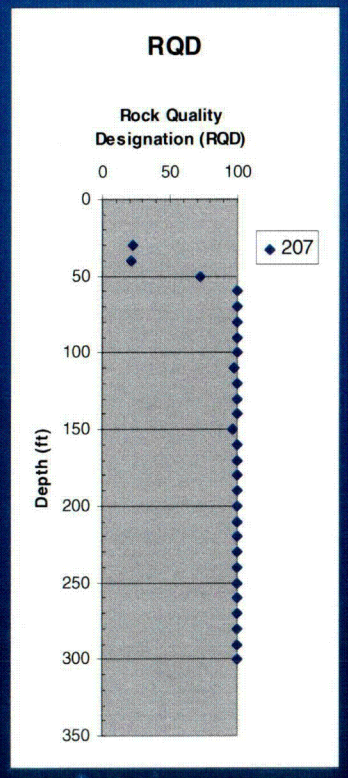
Ground Water Occurrence

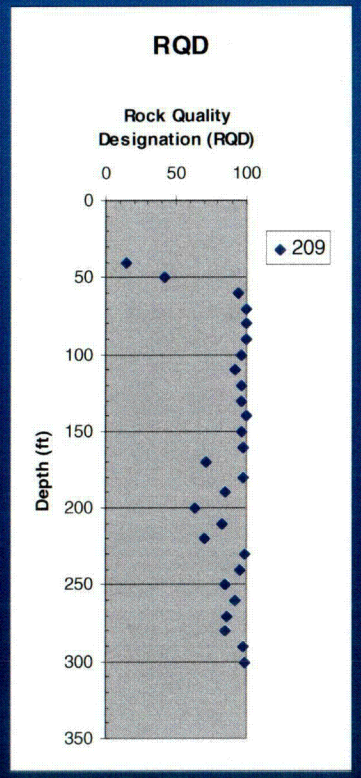
- Borehole camera
- Discrete conduits
- Slow recovery
- Isolated pockets
- Apparent differential head
- Low effective porosity

Mancos Shale RQD Profiles









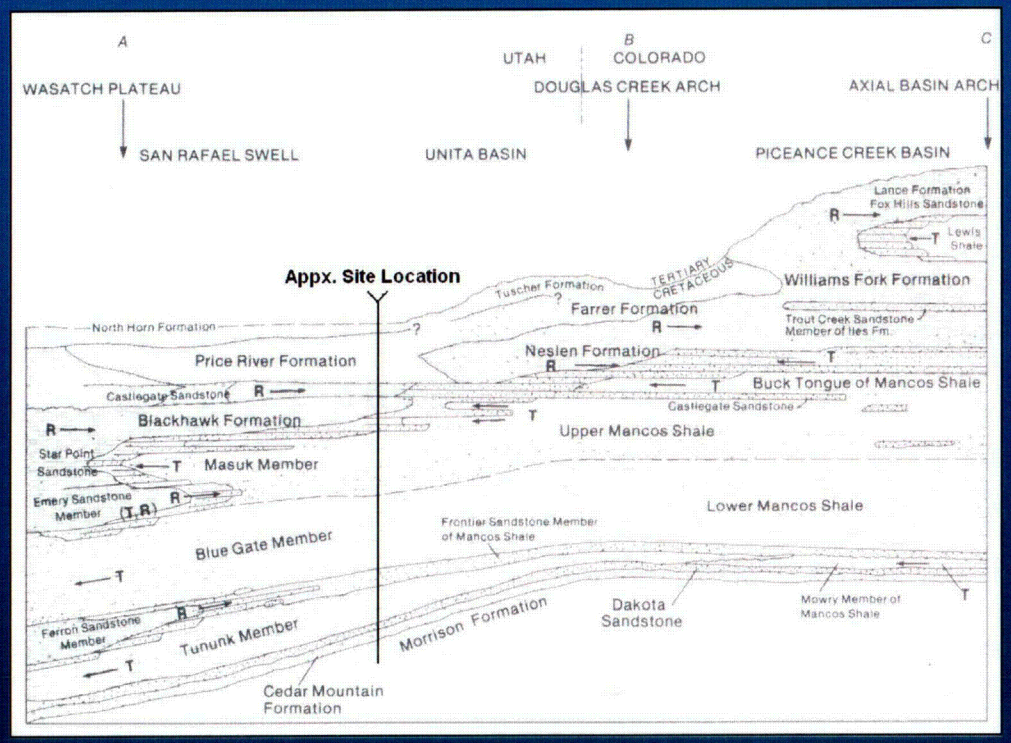
RQD = (sum of core sticks >10cm)/(total length of run)

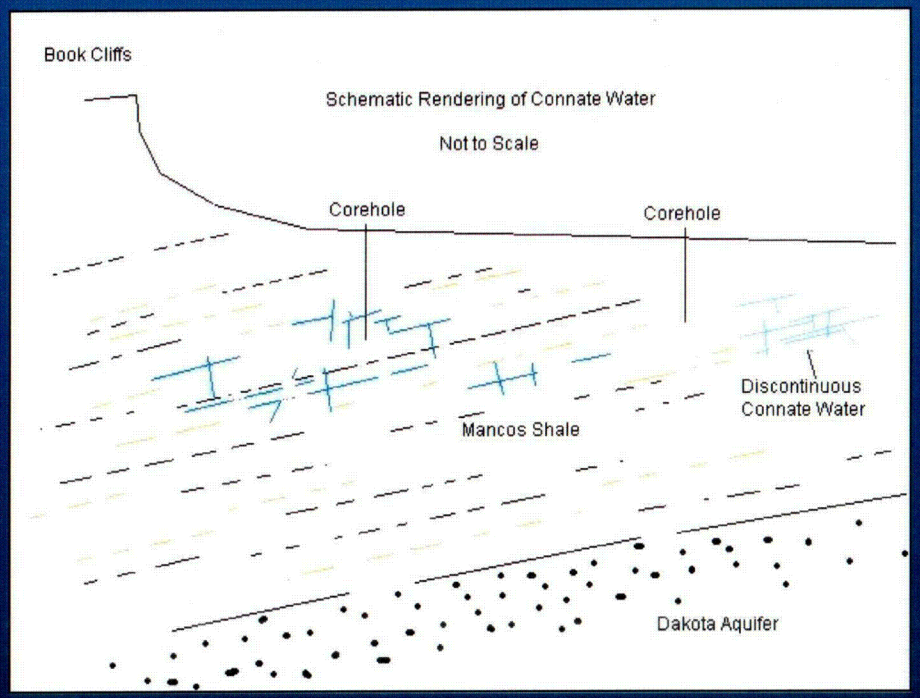
TDS Concentrations in Connate Water

Corehole	*TDS (mg/L)*
0201	42,000
0202	38,000
0203	37,000
0204	42,000
0208	23,000
0210	37,000

Mancos Shale Ground Water

- Aquitard-like behavior
  - Storage
  - Little to no transmittal
- Connate water
  - Discontinuous zones
  - Very saline to briny
  - Few water-bearing conduits
- 2,400- ft depth to Dakota aquifer



Site Suitability With Regard to Ground Water

- Geologic isolation
- Mancos Shale
  - Aquitard
  - Low hydraulic conductivity
  - Low effective porosity
  - Connate water
  - Very saline to briny
  - No beneficial use
- Dakota aquifer
  - Low yield
  - Salty water