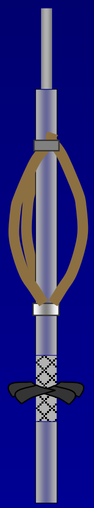
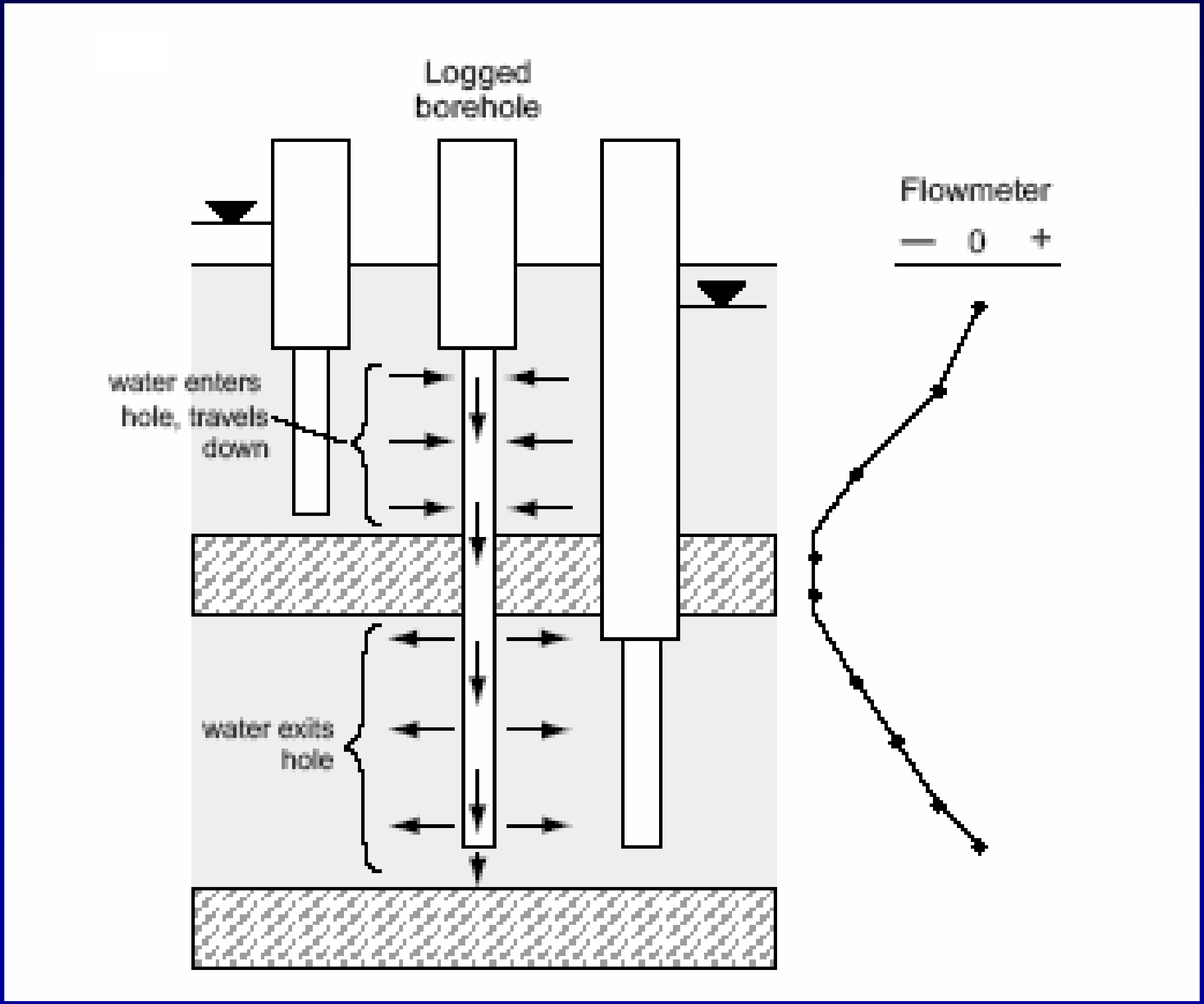
Hydraulic and Water-Quality Characterization of Fractured-Rock Aquifers Using Borehole Geophysics



John H. Williams
Office of Ground Water
Troy, New York

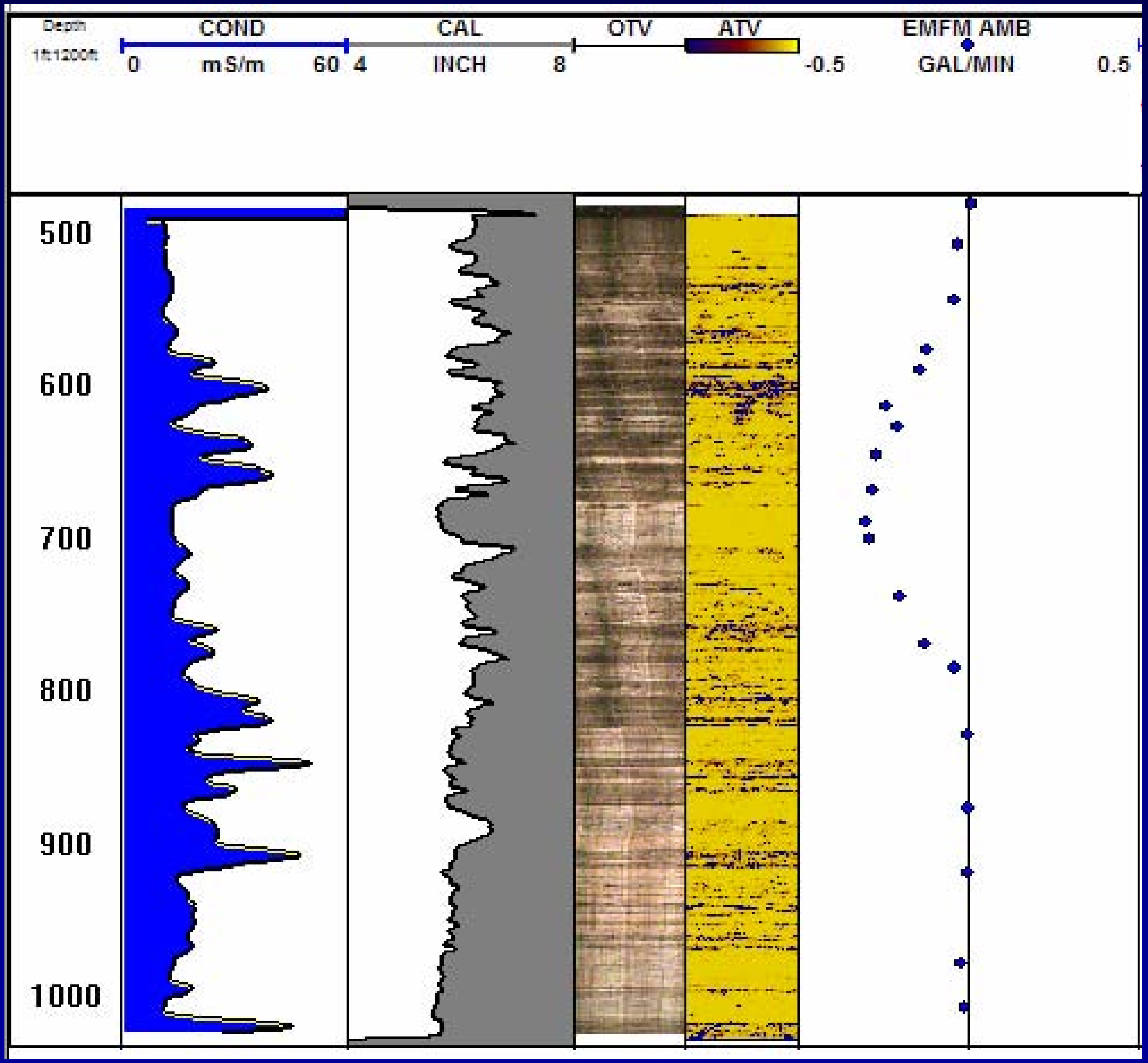
USGS

Flow in Open Borehole



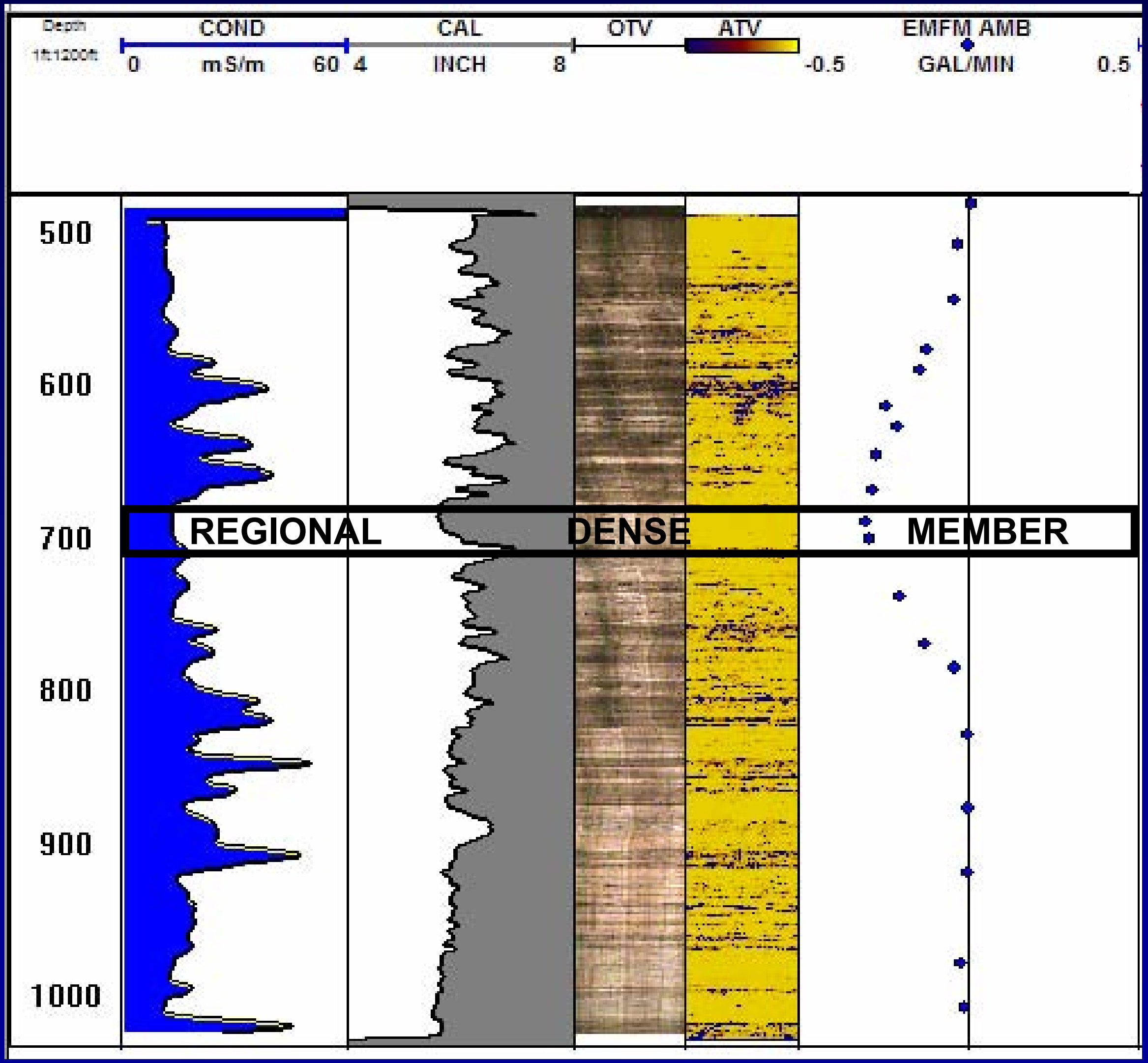
Runkel and others (2003)

Ambient Flow



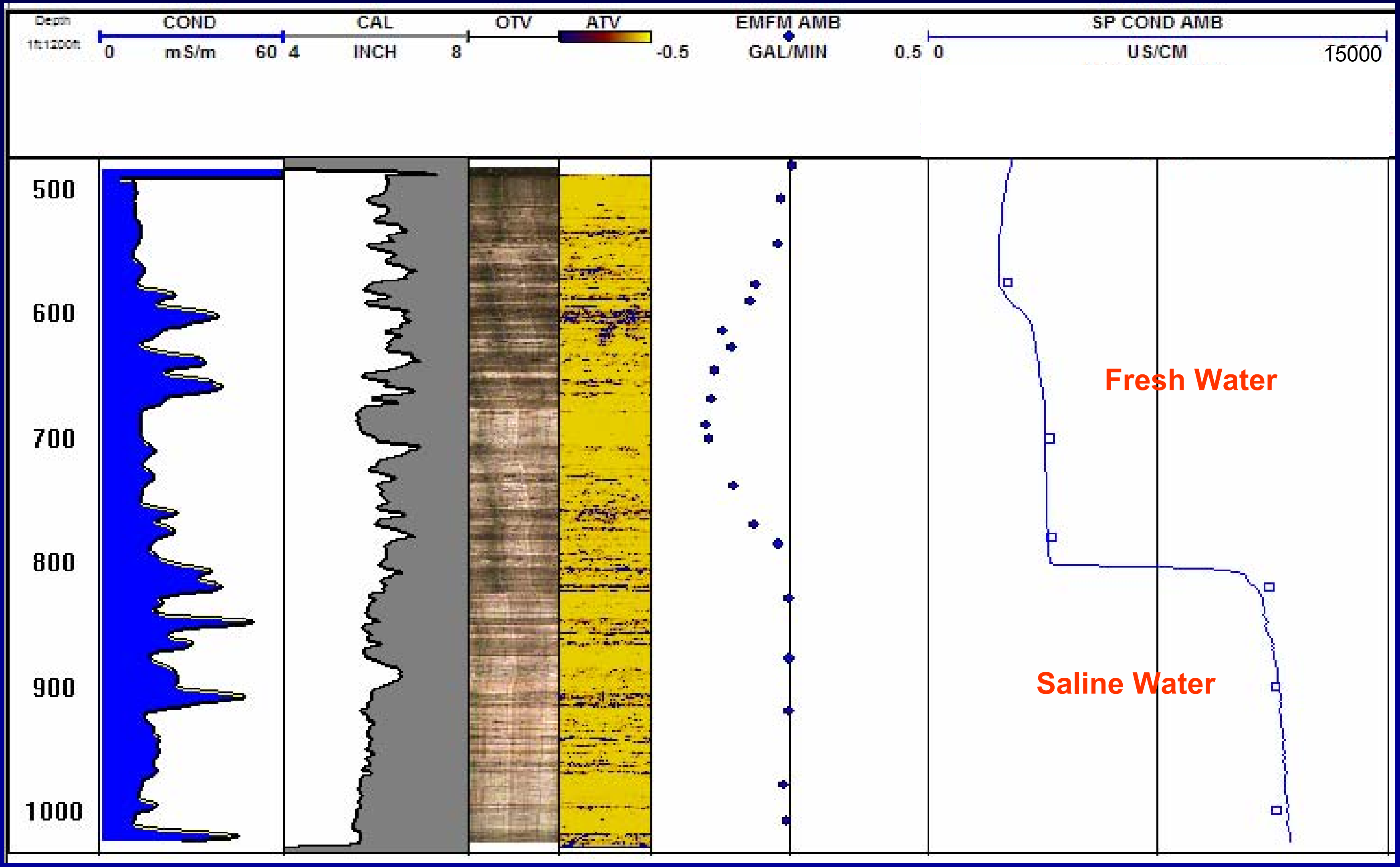
Edwards carbonate-rock aquifer, Texas

Ambient Flow



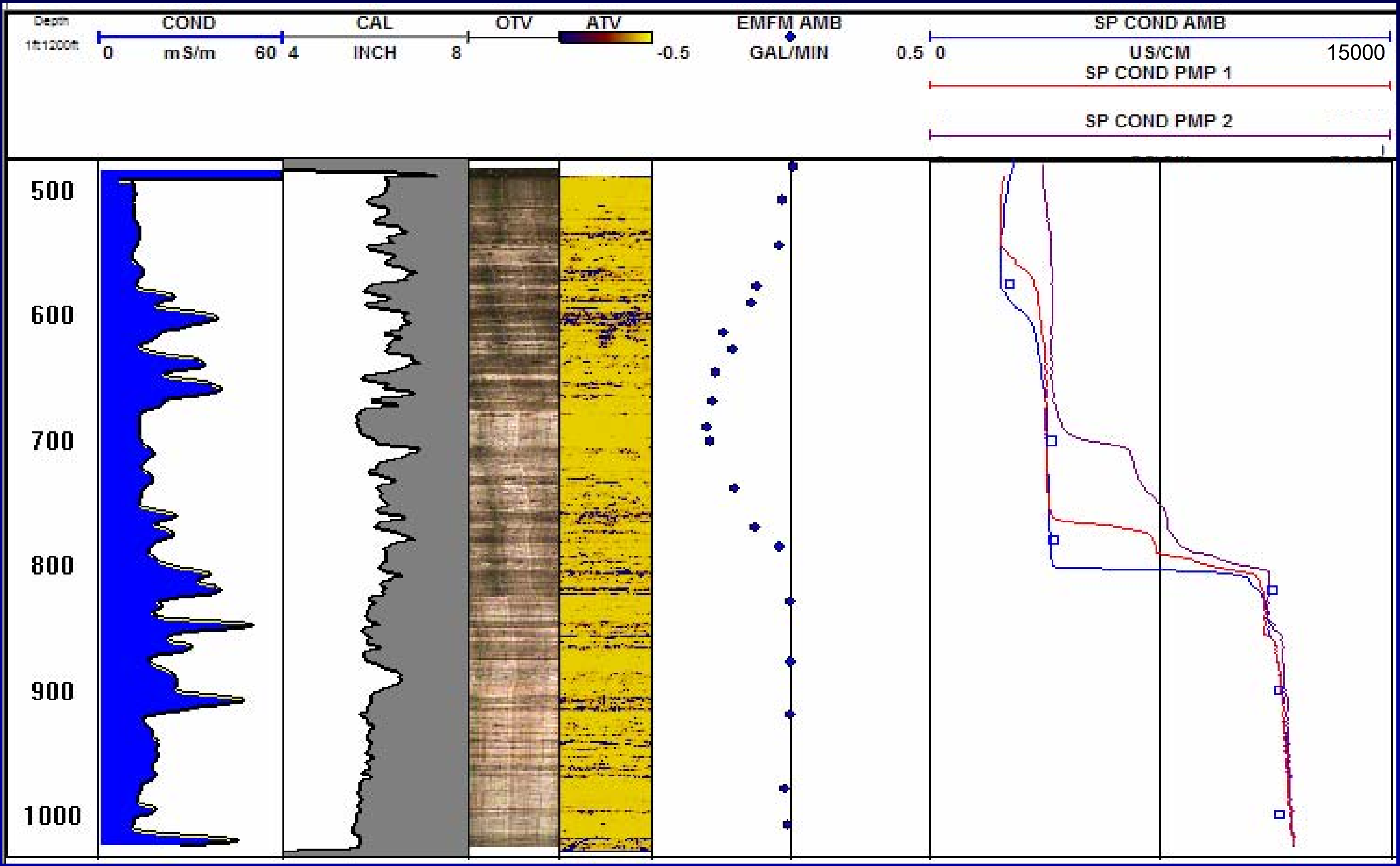
Edwards carbonate-rock aquifer, Texas

Ambient Fluid Log and FW/SW Interface



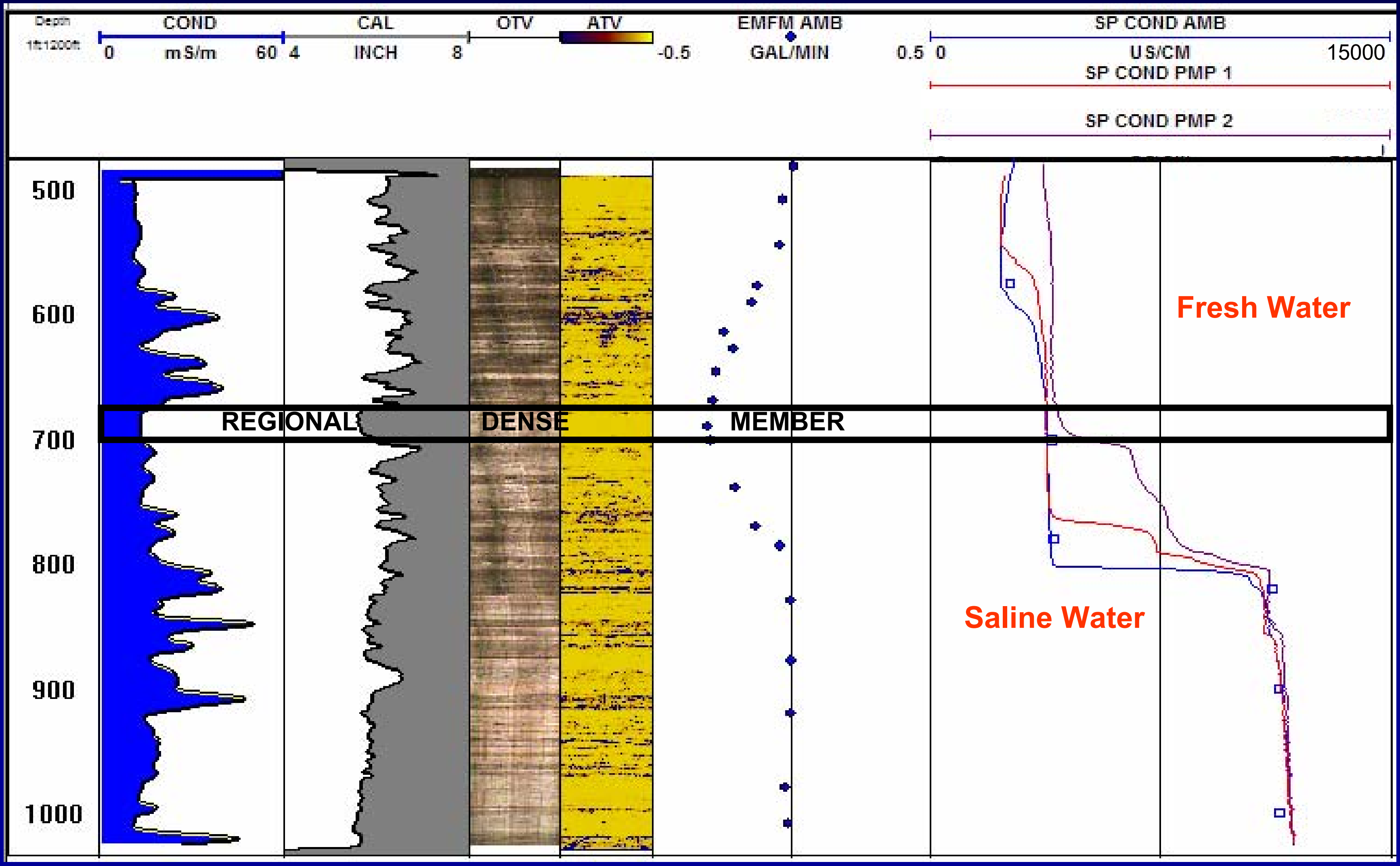
Edwards carbonate-rock aquifer, Texas

Pumped Fluid Logs



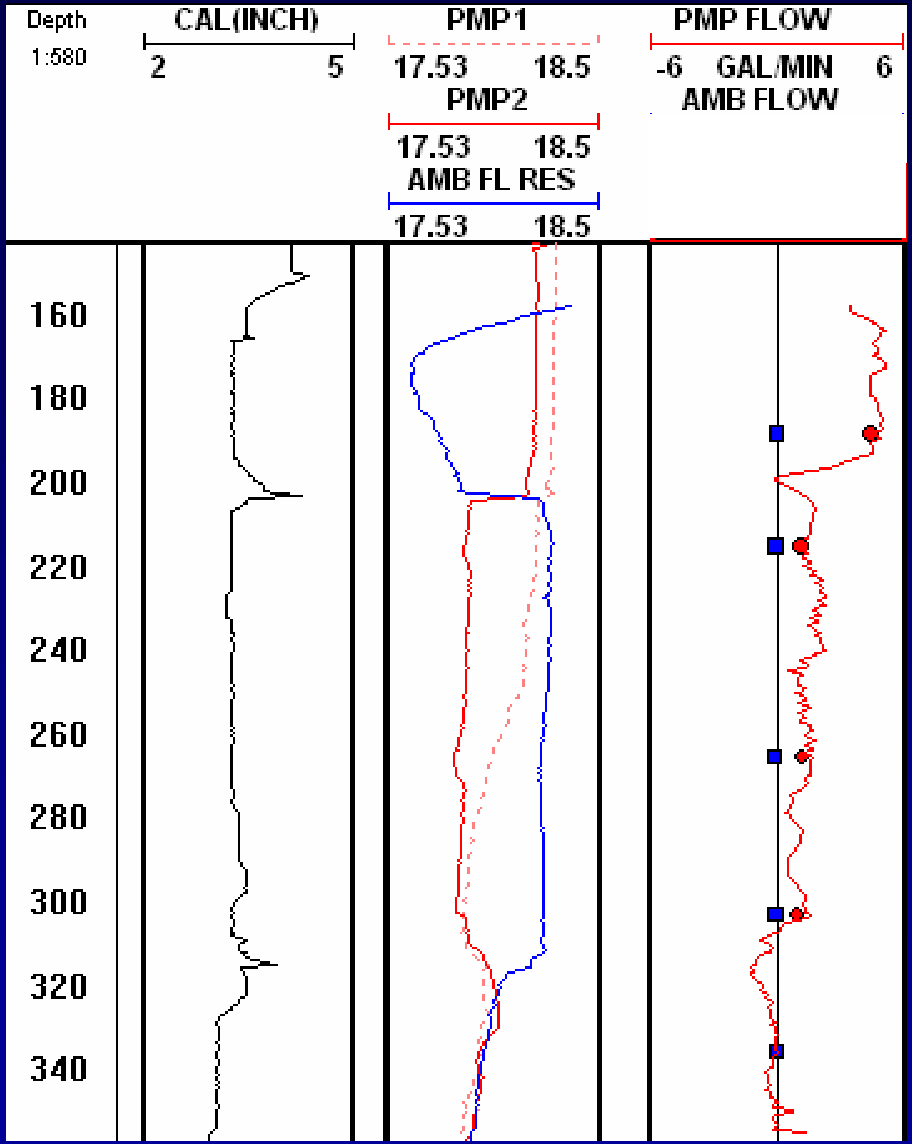
Edwards carbonate-rock aquifer, Texas

Pumped Fluid Logs and FW/SW Interface



Edwards carbonate-rock aquifer, Texas

Flow and Fluid Logging under Ambient and Pumped Conditions



Deep borehole in TCE source area, cased to 155 ft

Flow zones at 201 and 312 feet

Downward ambient flow

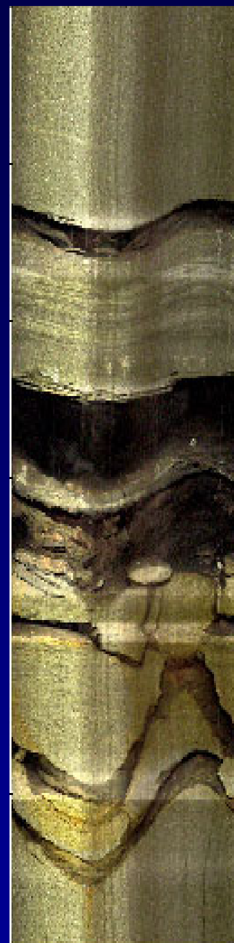
Pumped flow
80 % 201 feet
20 % 312 feet

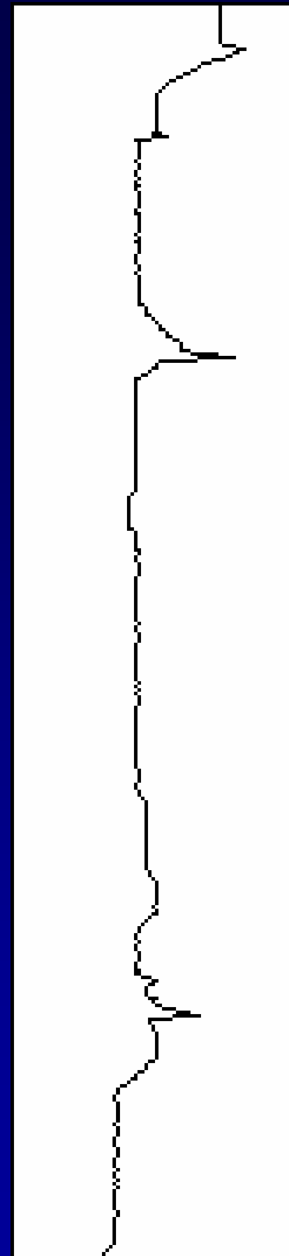
Cretaceous sandstone aquifer, southern California

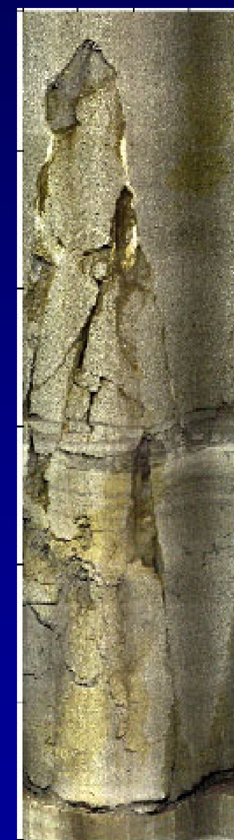
201 FOOT ZONE

Bedding fractures

Intermediate angle fractures





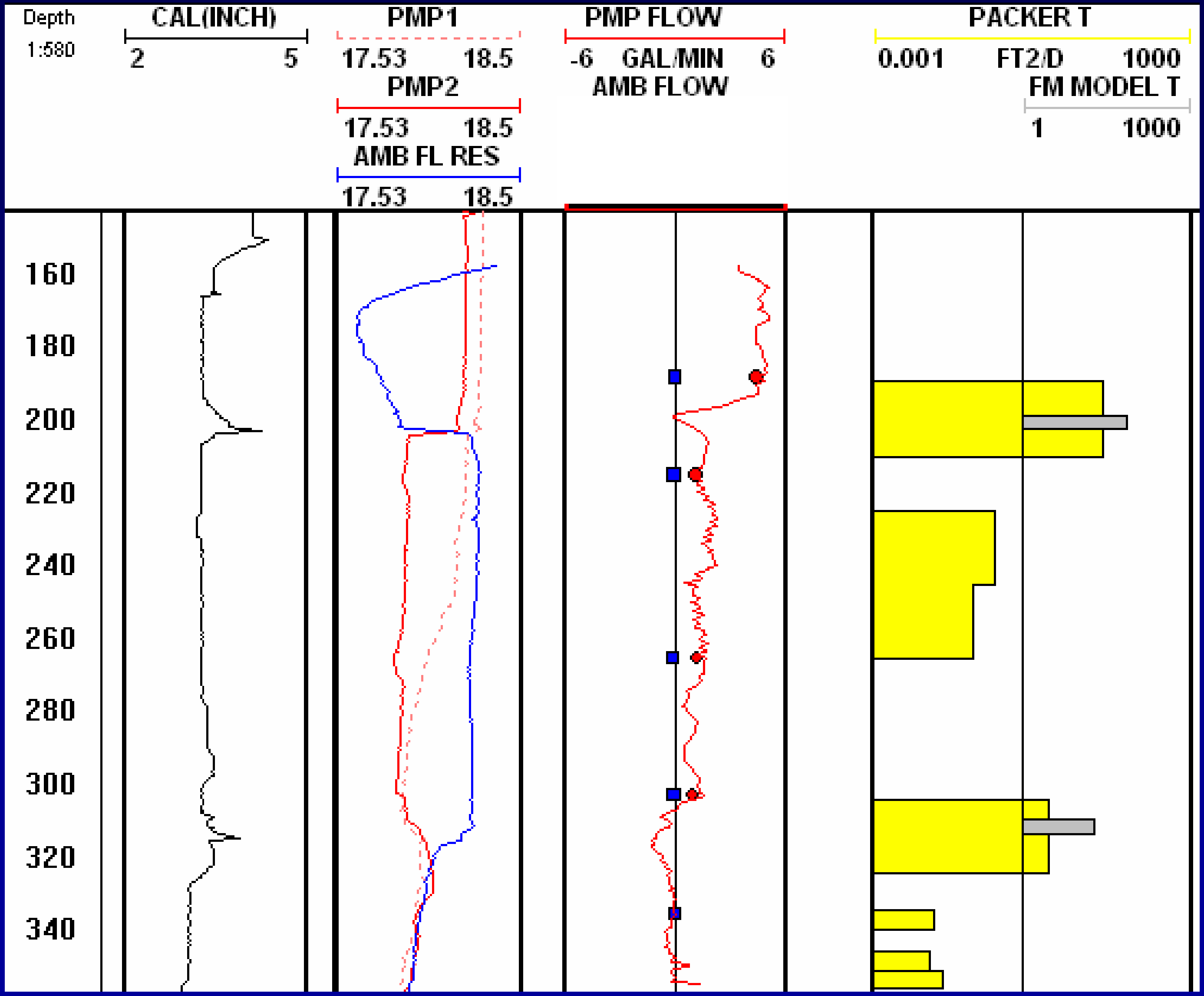


High angle fractures

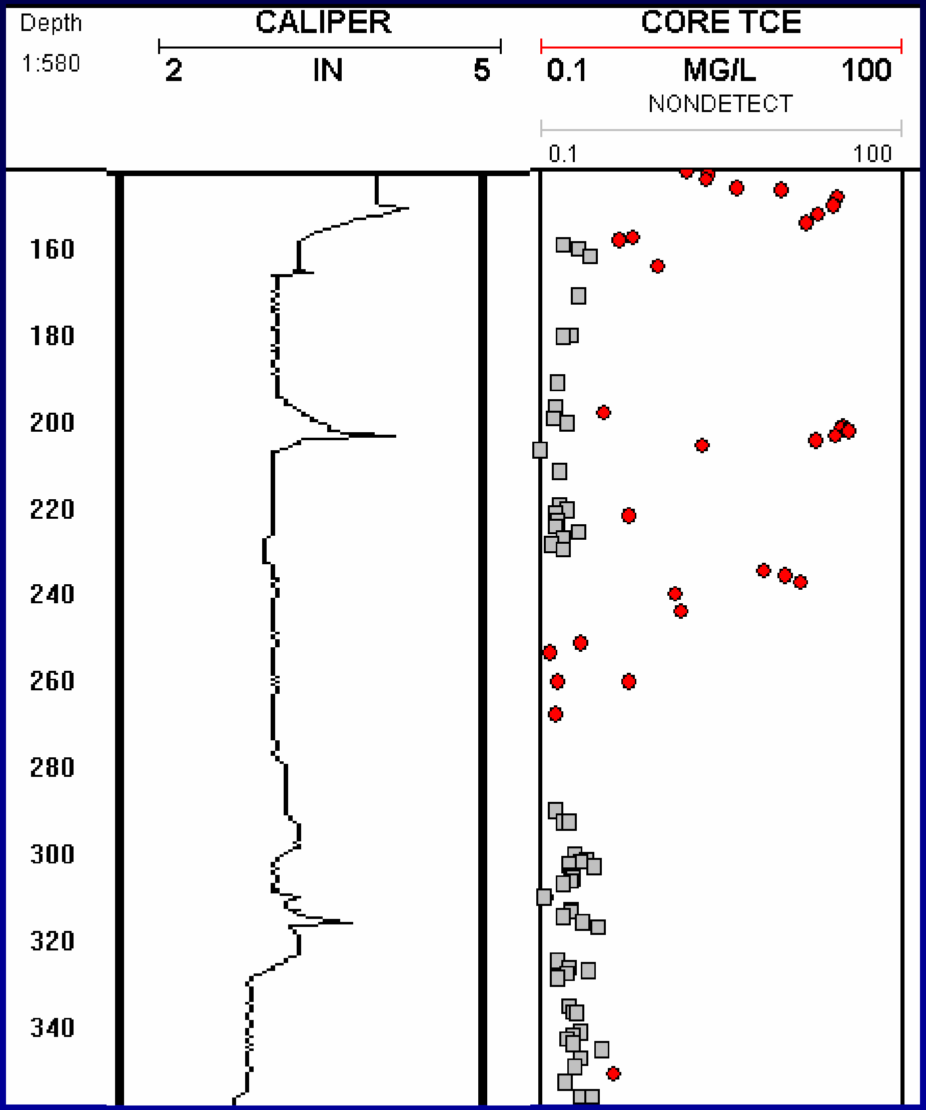
Bedding fracture

312 FOOT ZONE

Flowmeter Detects Most Transmissive Flow Zones



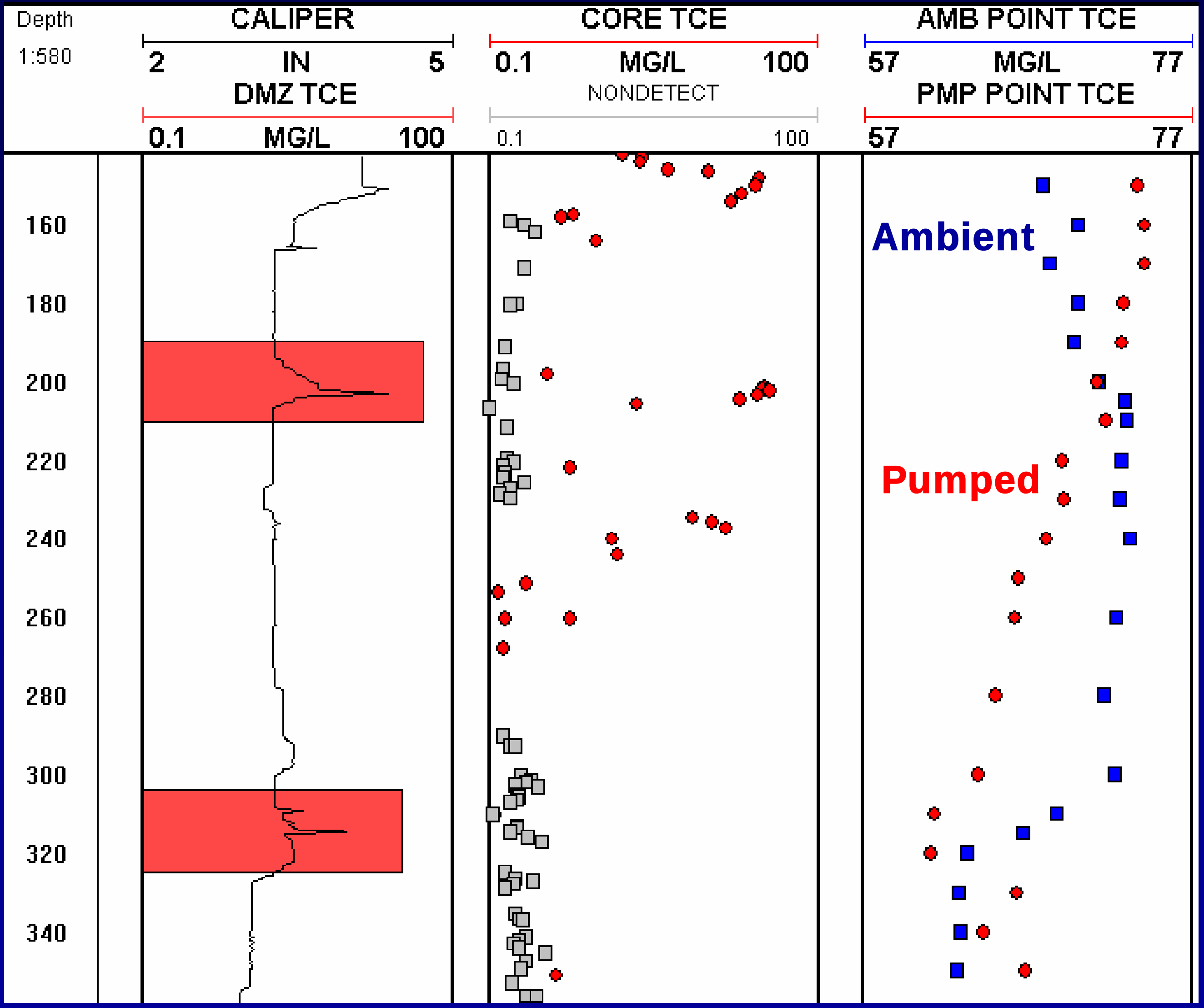
CORE ANALYSIS MATRIX DIFFUSION



High TCE in the matrix near the 201-foot zone

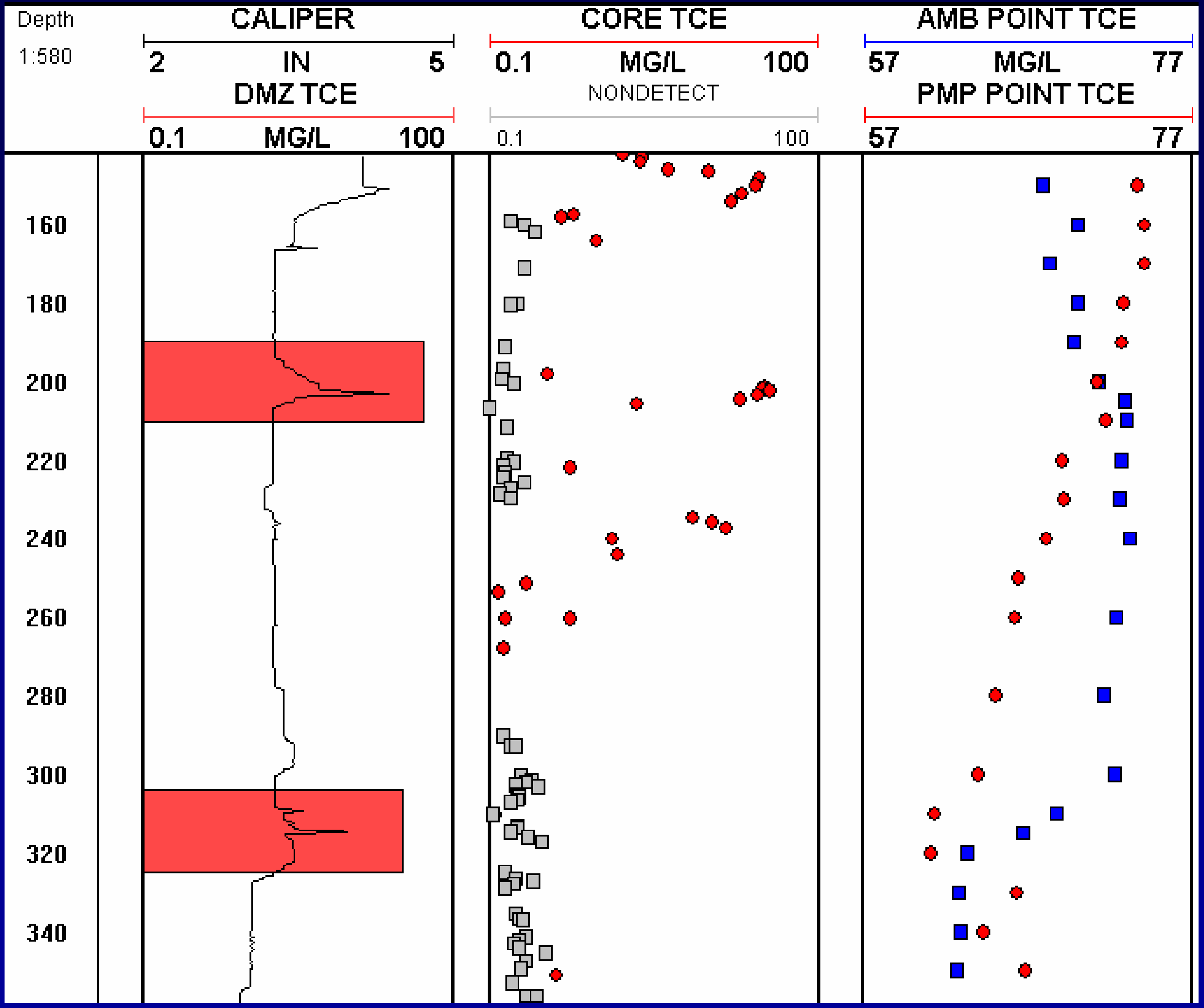
No TCE in the matrix near the 312-foot zone

CROSS CONTAMINATION

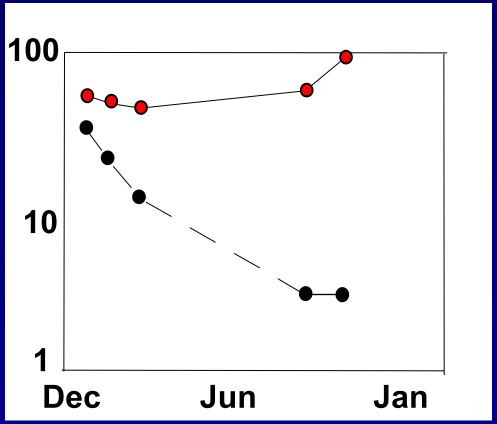


TCE point samples

CROSS CONTAMINATION



TCE Monitoring



Sterling(1999)

Central New York

7-mile VOC plume in Silurian-Devonian carbonate-rock aquifer

Surface-water drainage divide

Union Springs wells

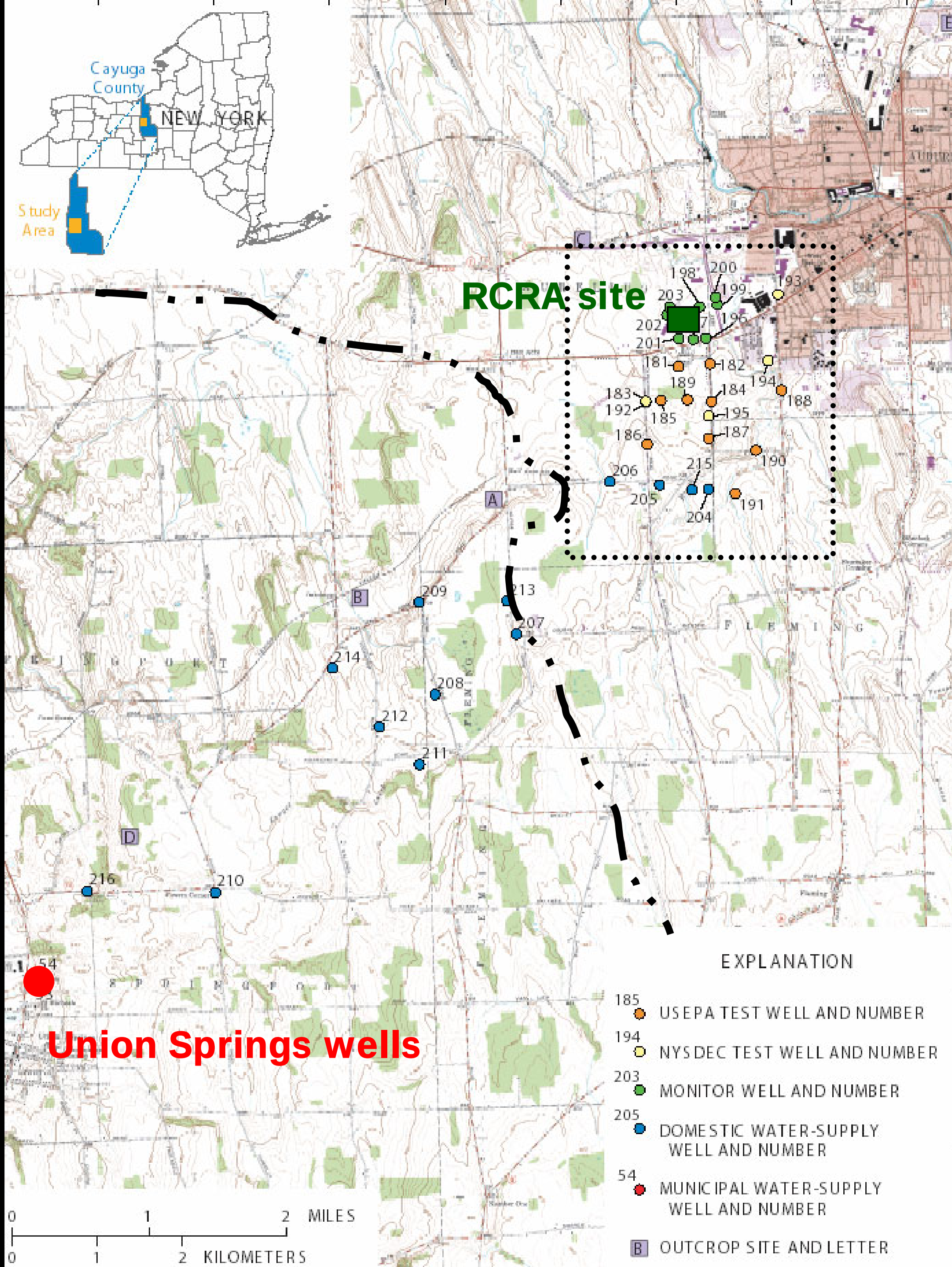
1988 – Detected DCE

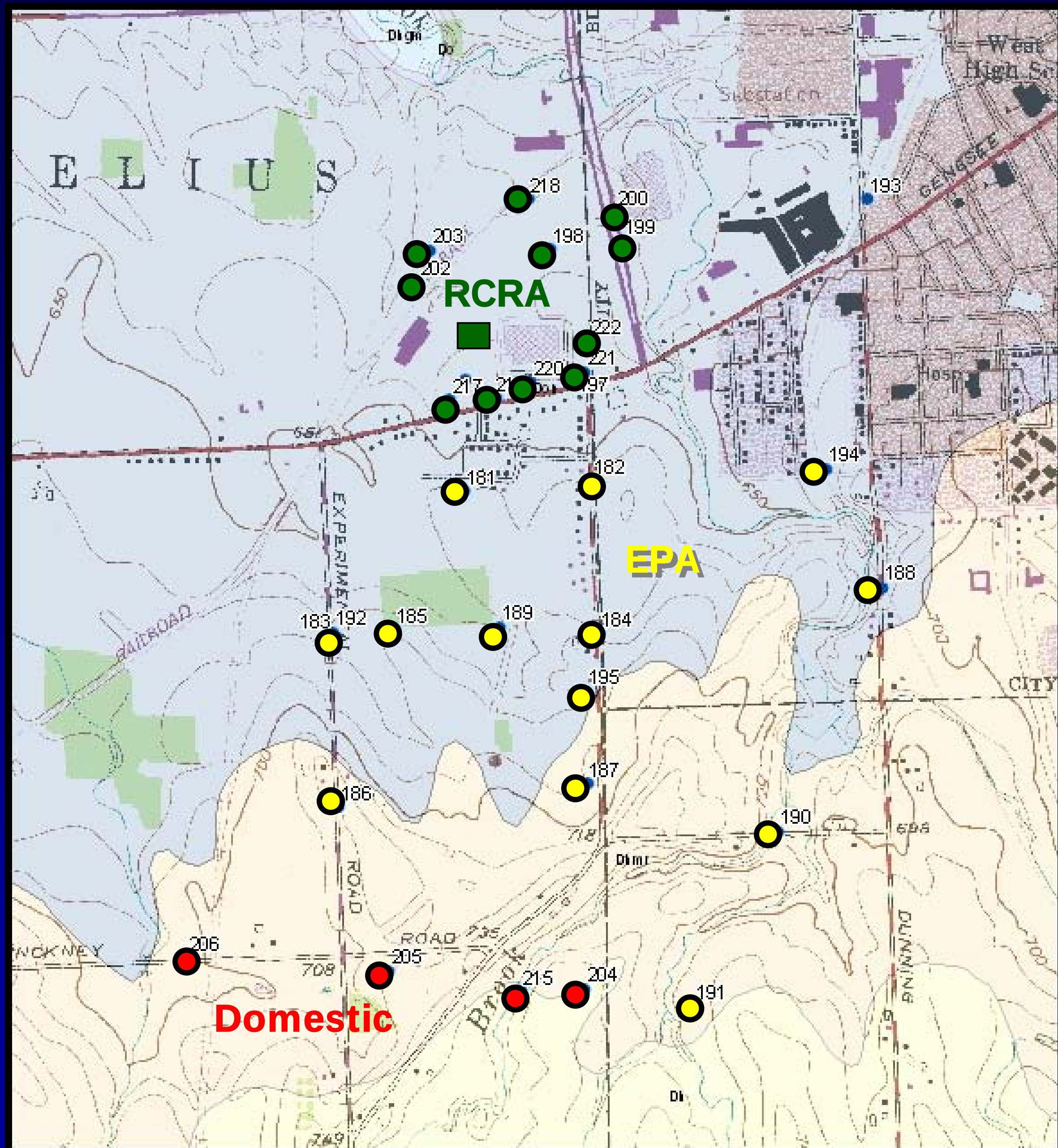
1999 – 6.2 ug/L DCE

RCRA site

1990s – TCE in shallow bedrock

2000 – Vacuum extraction




RCRA
EPA
Domestic
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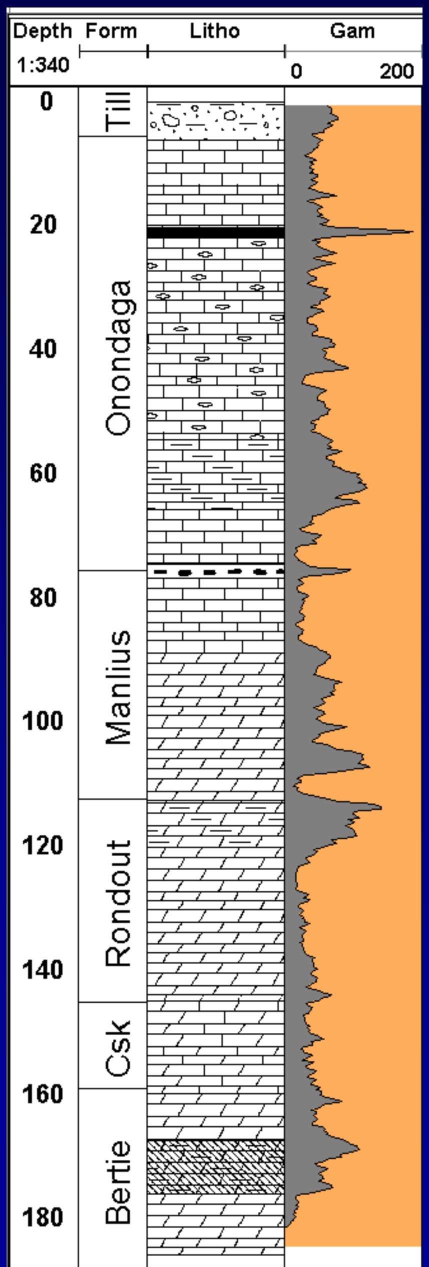
Corehole 181



Bentonite

Phosphate clasts

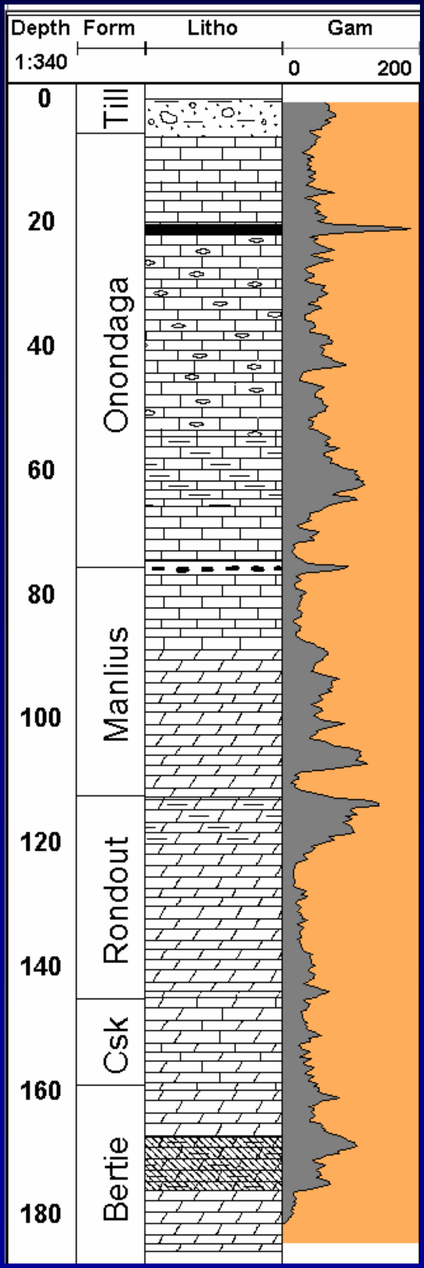
Shaley dolomite

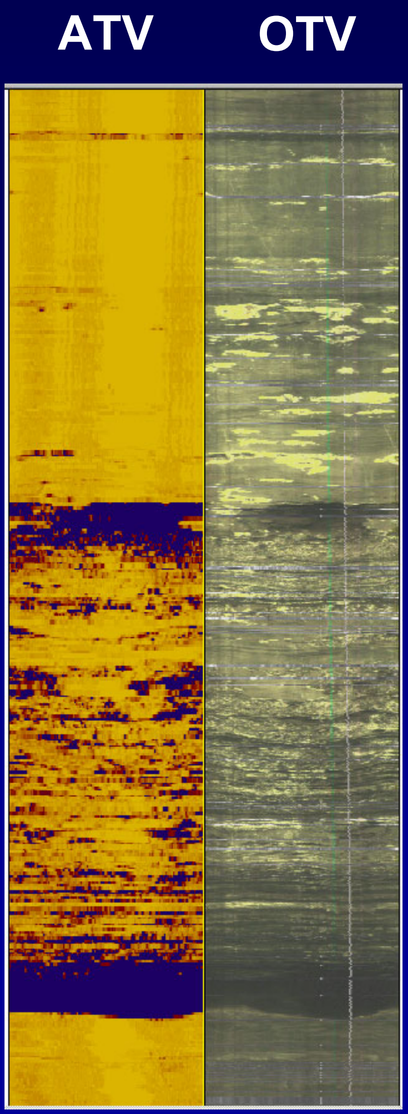
Gypsiferous

Stratigraphy

Characteristic gamma signature in Silurian-Devonian carbonate rocks

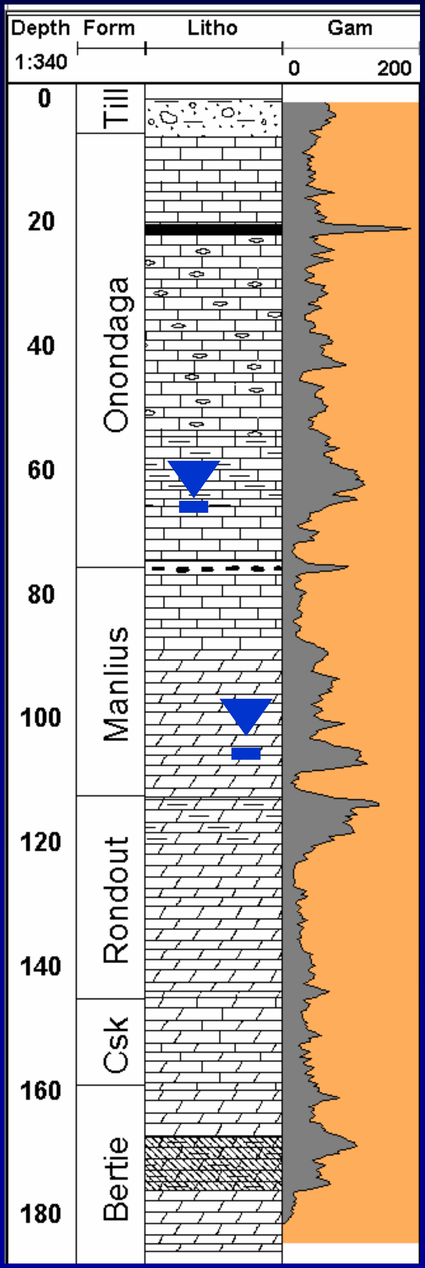
Borehole-Wall Images

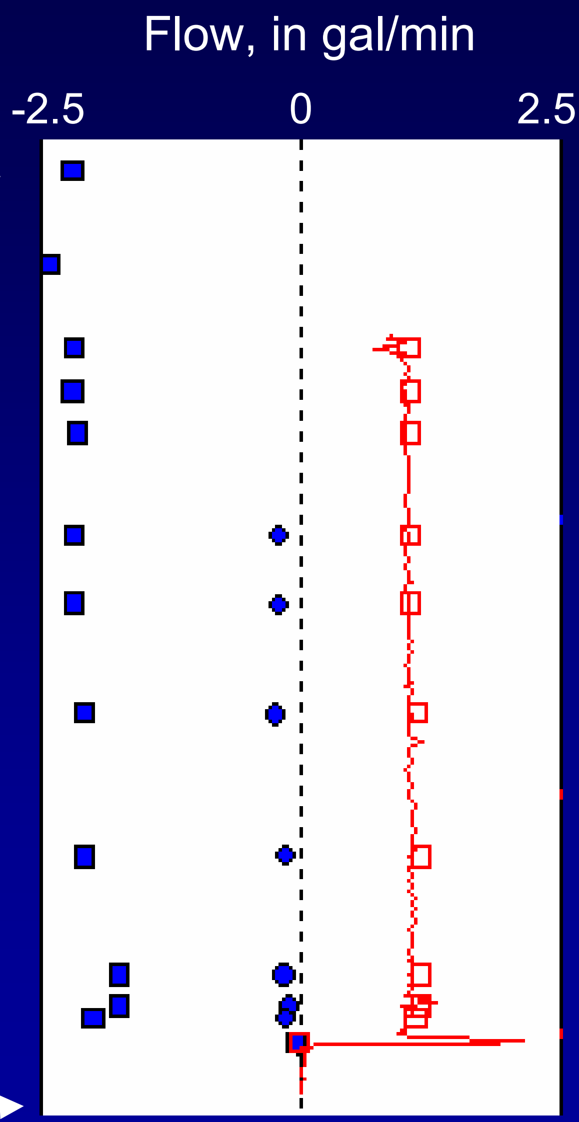




BERTIE FLOW ZONE

Flowmeter Log Analysis

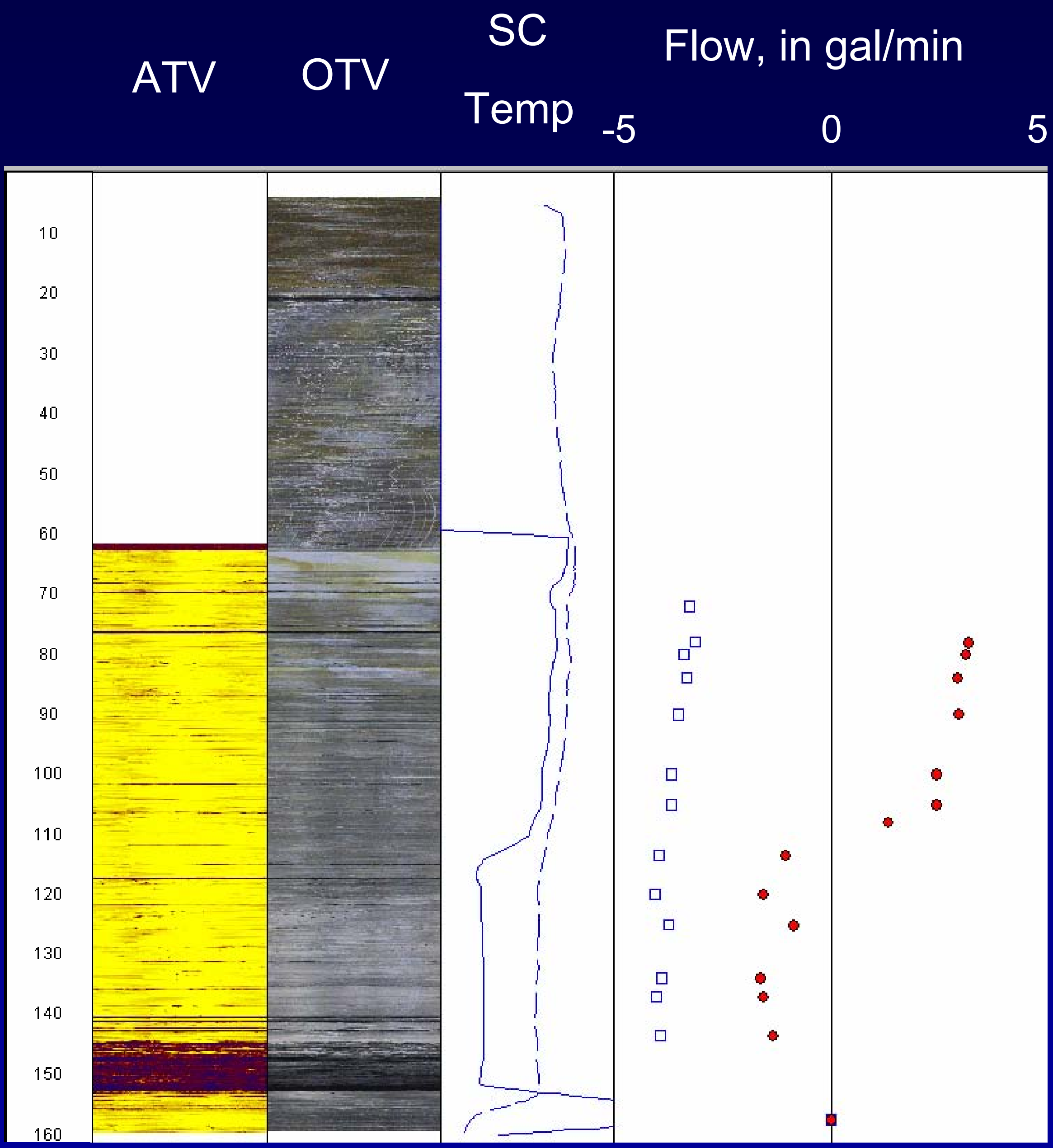




ONONDAGA FLOW ZONES

BERTIE FLOW ZONE

Corehole 219

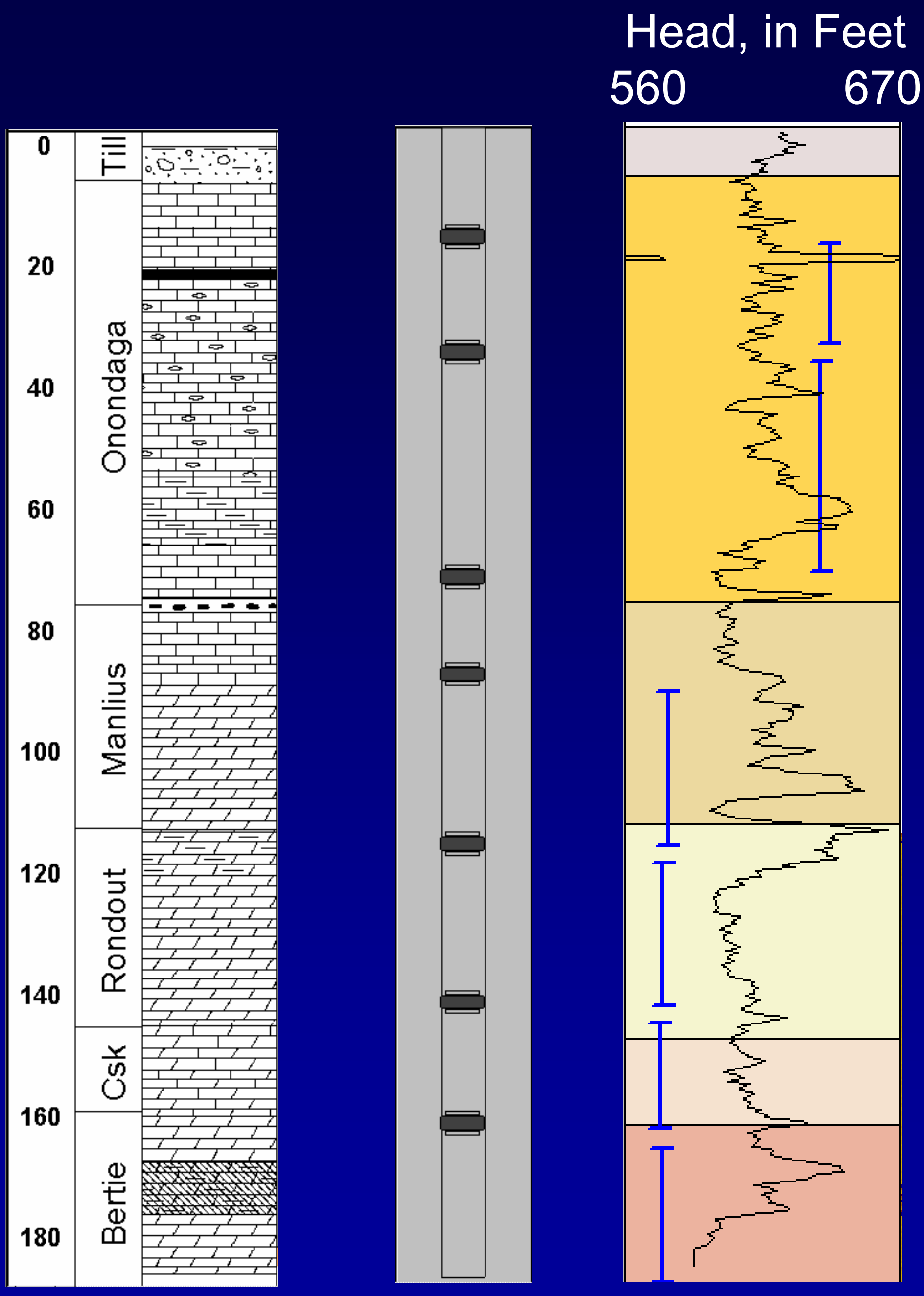


ONONDAGA FLOW ZONES

RONDOUT FLOW ZONE

BERTIE FLOW ZONE

Discrete Zone Heads in Well 181

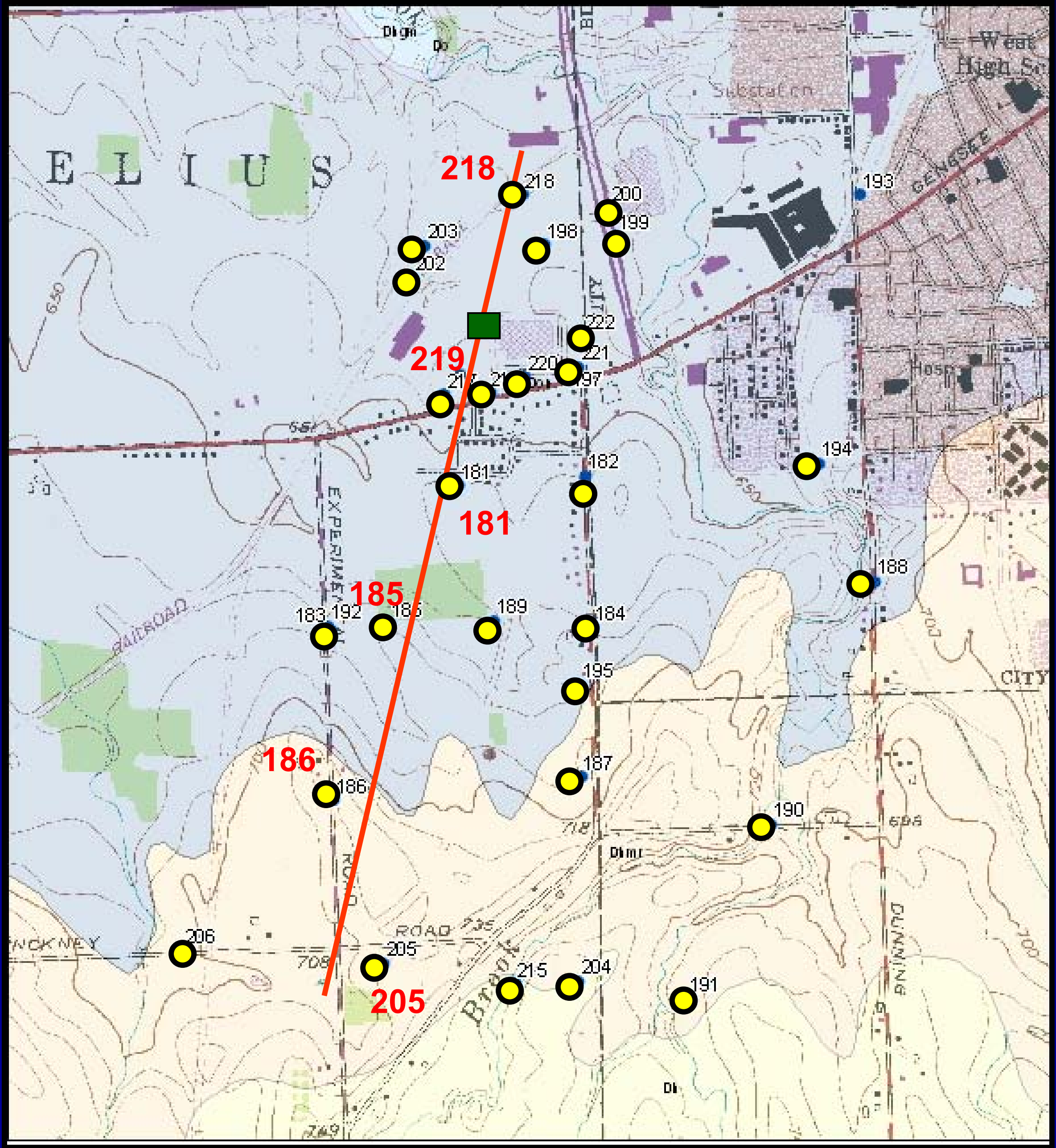


ONONDAGA FLOW ZONES

UPPER MANLIUS CONFINING UNIT

RONDOUT FLOW ZONE

BERTIE FLOW ZONE



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ROAD
Substation
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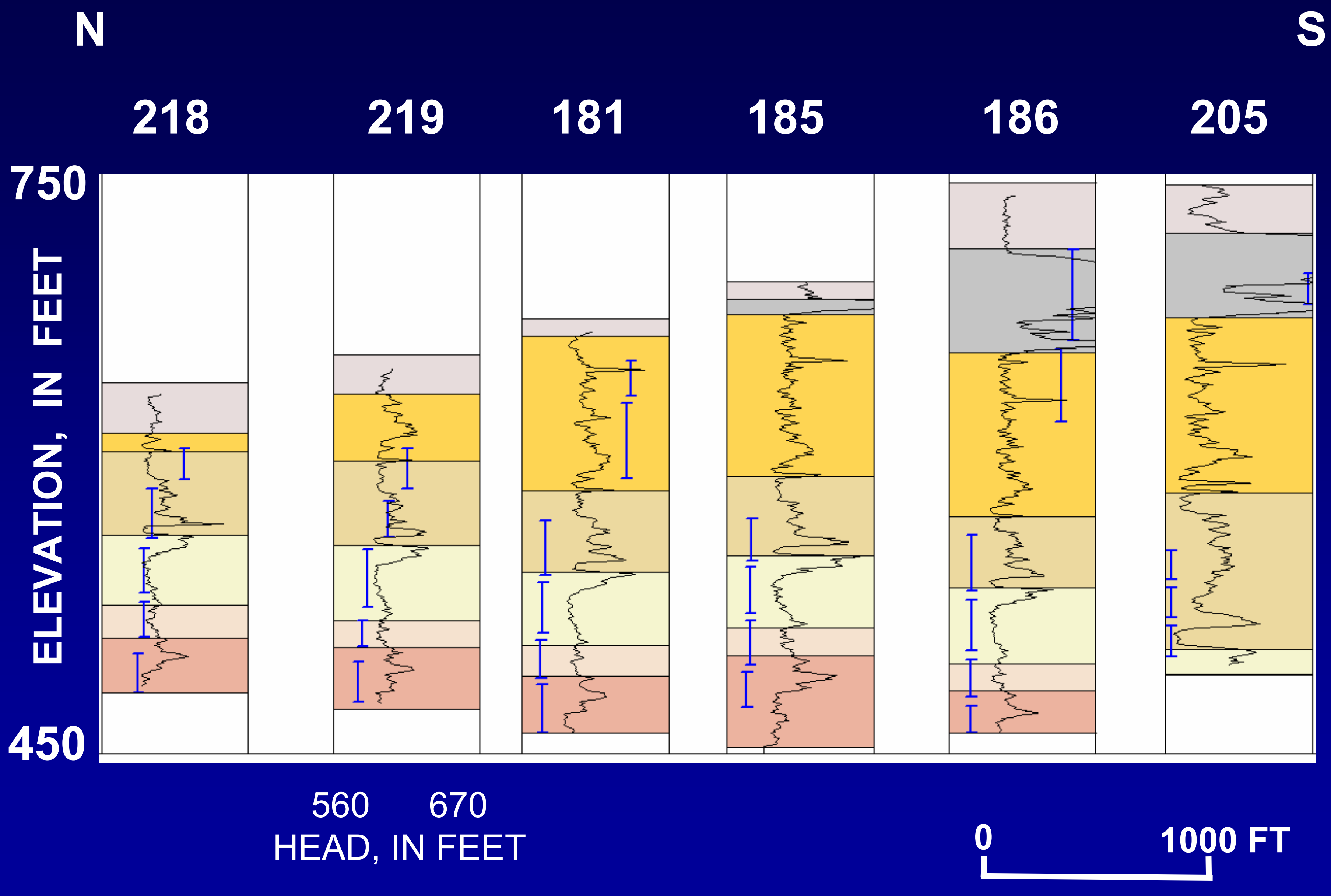
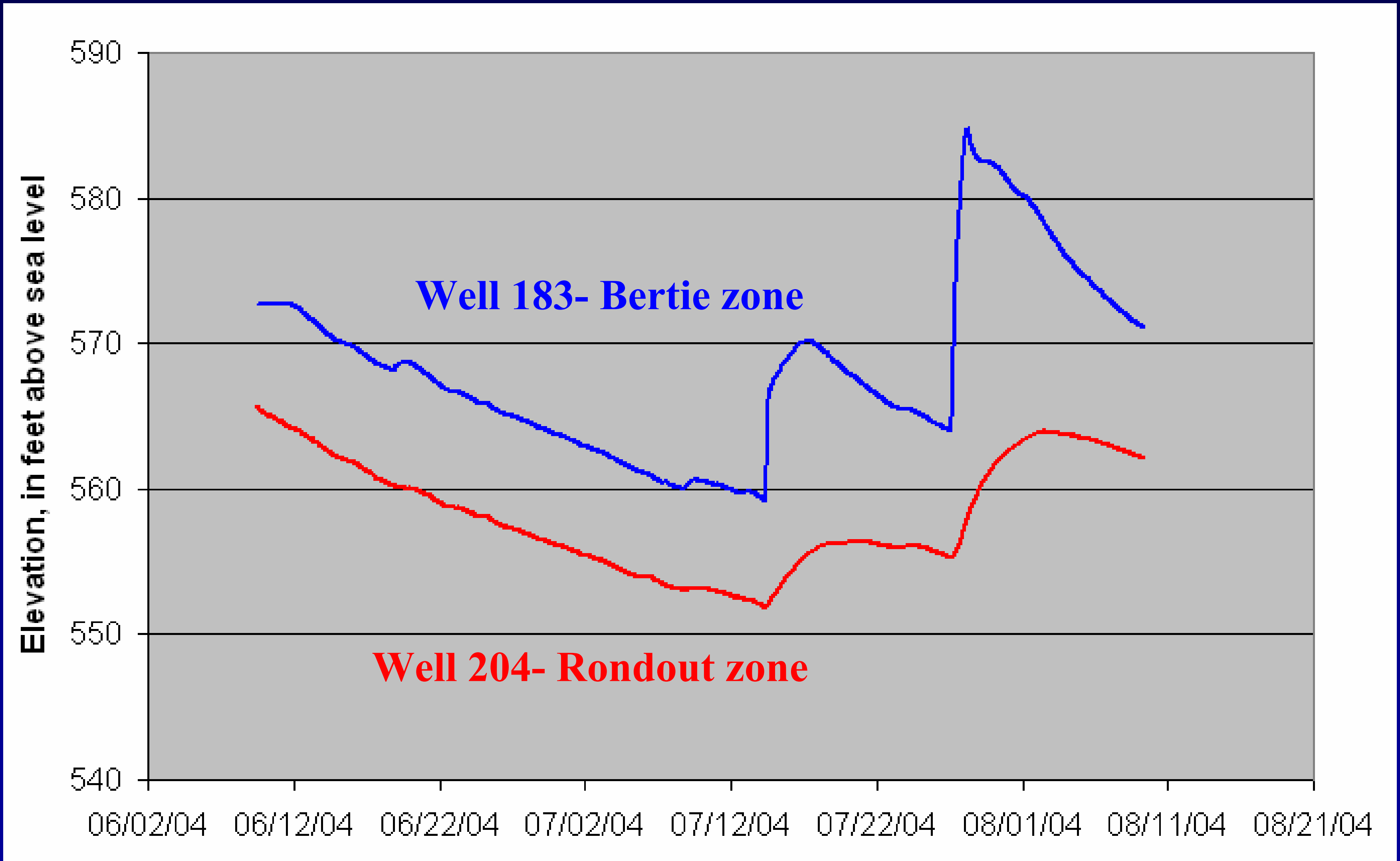
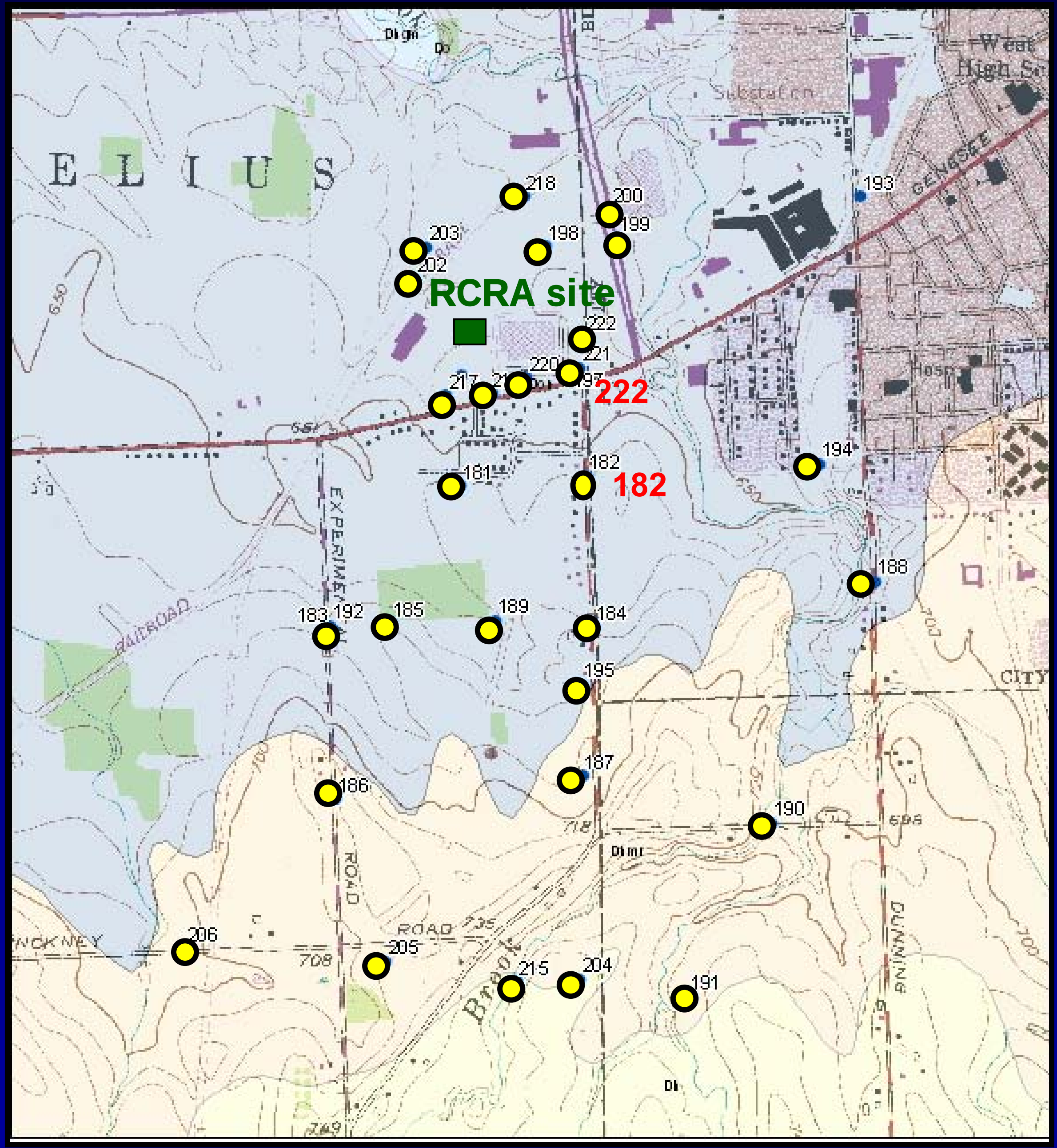
GENESEE
Hosp
CITY
DUNNING
Brook

Stratigraphy and Discrete Zone Heads



Recharge and Head Response




RCRA site
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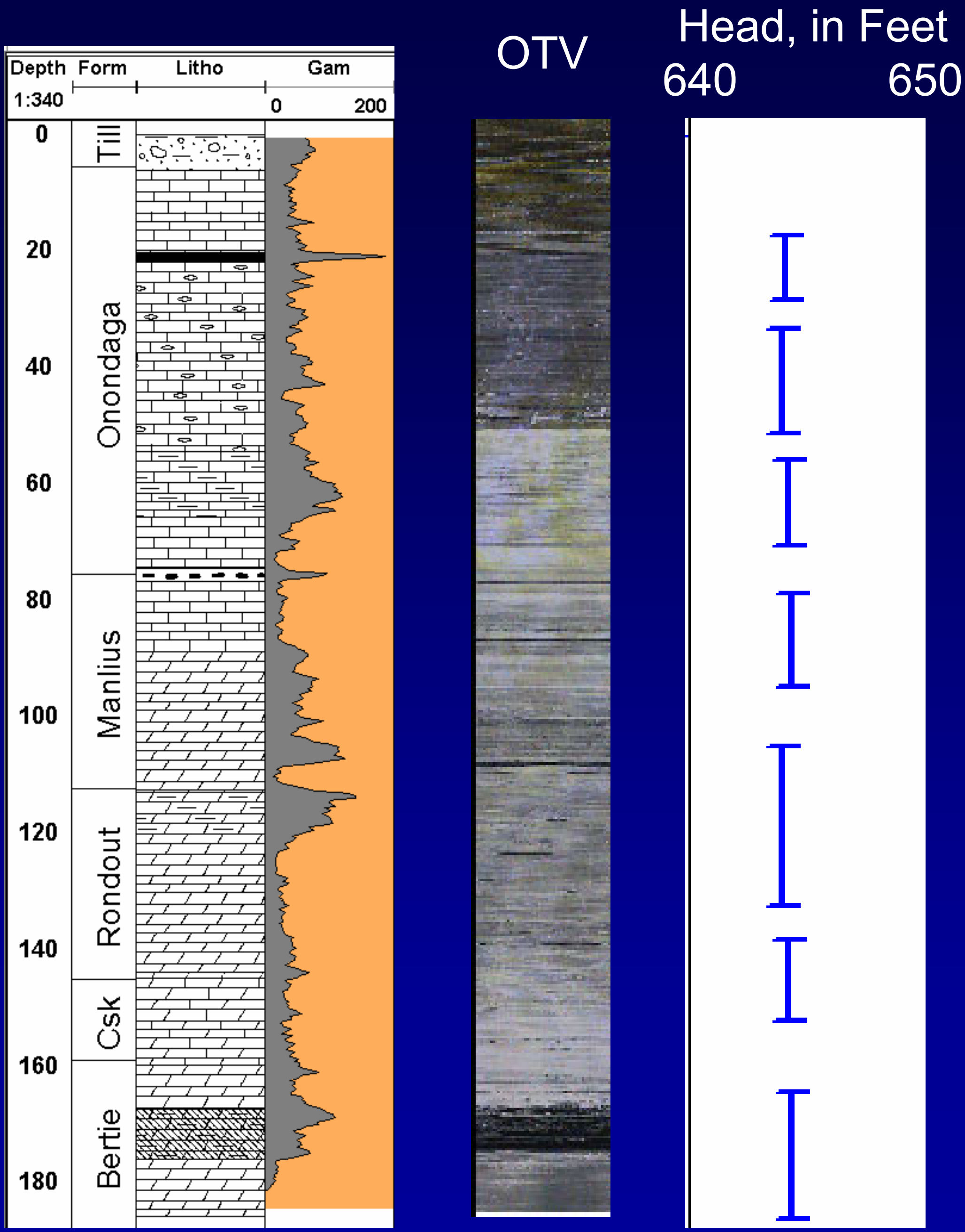
RAILROAD
DUNNING
CITY
Substation
Brook

Discrete Zone Heads in Well 222



ONONDAGA FLOW ZONES

UPPER MANLIUS CONFINING UNIT

RONDOUT FLOW ZONE

BERTIE FLOW ZONE

Advances in Flow Log Analysis

File Edit View Insert Format Tools Chart Window Help

FLOW-B INPUT AND PLOTS

USGS science for a changing world

Wellname: Temple Terrace PW Nawga Tanc

REQUIRED INPUT:

Elevation of Measuring Point [FT]	50
Number of fractures [-]	2
Well Diameter [IN]	12
Drawdown [FT]	2.3
Step Factor [-]	1
Total Transmissivity [FT^2/day]	1000
Depth to Ambient Water Level [FT]	57.16
Depth at bottom of Plot [FT]	170
Depth at top of Plot [FT]	110

PLOT LOGS

RUN FWRAP

LOAD/PLOT RESULTS

FRACTURES:	Depth [FT]	Flow above fracture Ambient [GPM]	Flow above fracture Pumped [GPM]	Zone Tfactor [-]	Zone H [FT]
2	153.500	0.000	270.000	6.600	0.280
1	161.500	-6.400	187.000	20.000	0.000

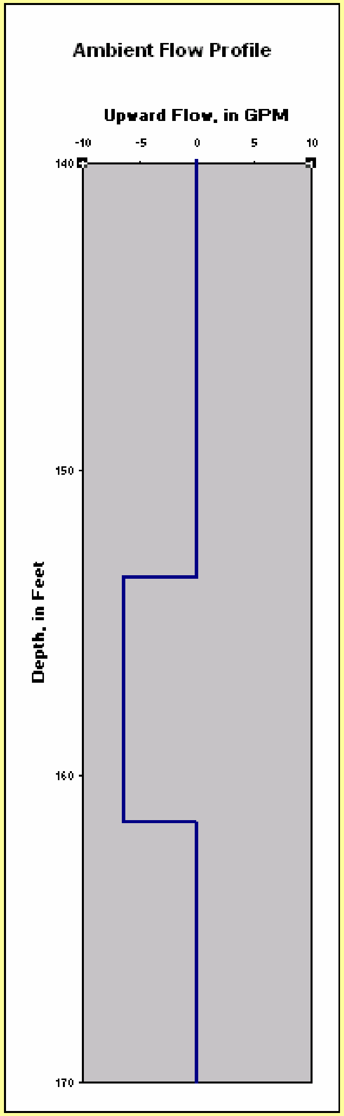
Elev. Ambient WL [FT] = -7.16 Elev. Pumped WL [FT] = -9.46

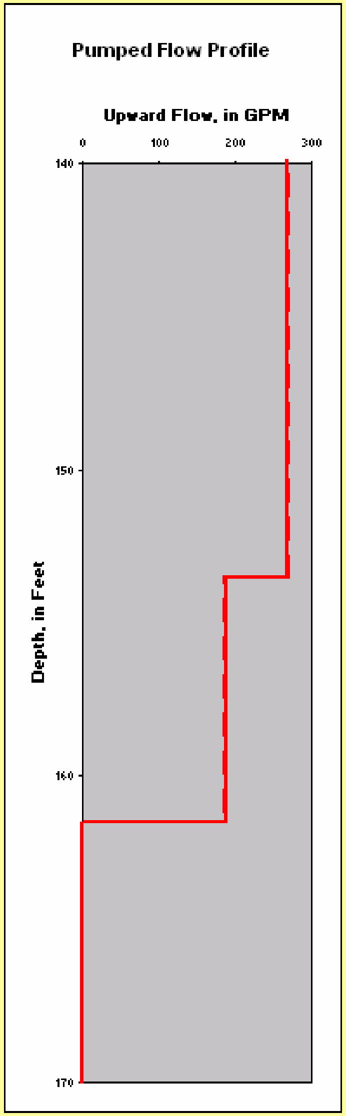
SIMULATION OUTPUT FROM FWRAP (DO NOT CHANGE)

SSE [GPM^2]	11.77613
Ambient WL [FT]	-2.23053
Pumped WL [FT]	0.07511

RMS Error [GPM] = 2.426533536

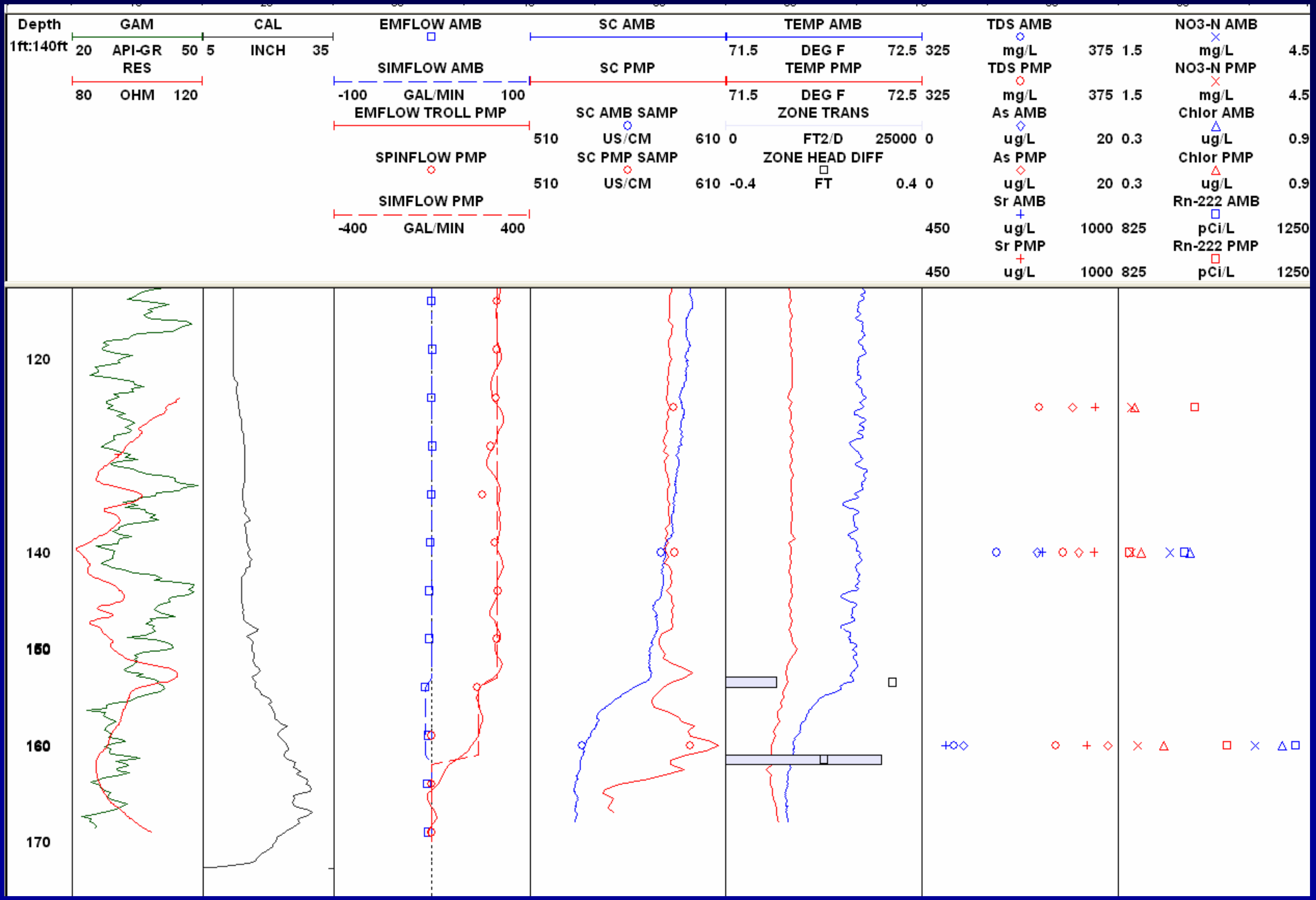
FRACTURES:	Depth [FT]	Ambient Flow above [GPM]	Pumped Flow above [GPM]	Zone T [FT^2/day]	Water Level [FT]	Elevation of Water Level [FT]
2	153.500	0.000	267.563	6600.000	56.949	-6.949
1	161.500	-6.378	189.416	20000.000	57.229	-7.229





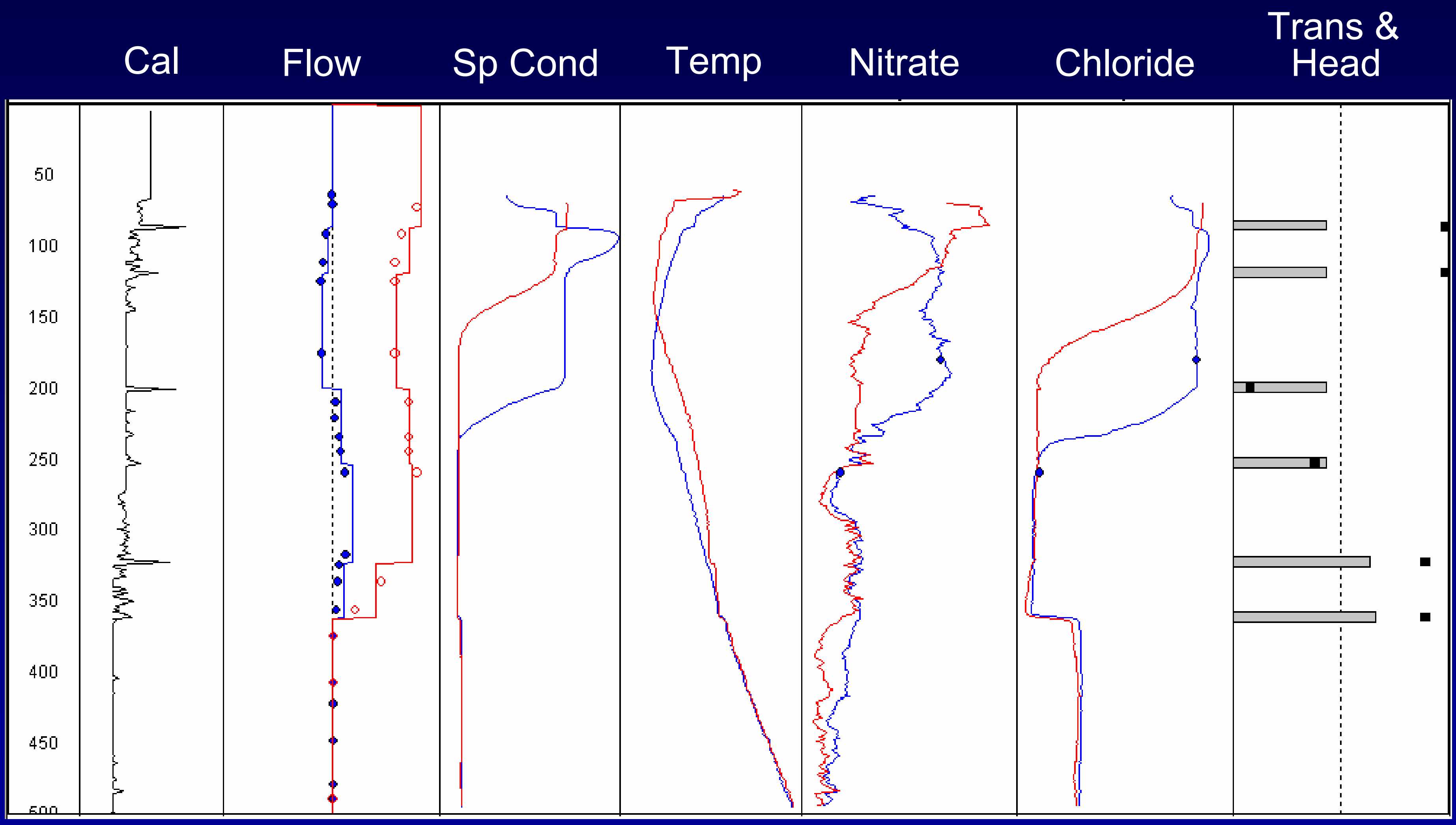
Dashed line indicates measured flow. Solid line indicates modeled flow.

Flow Logging and QW Point Sampling in Production Wells



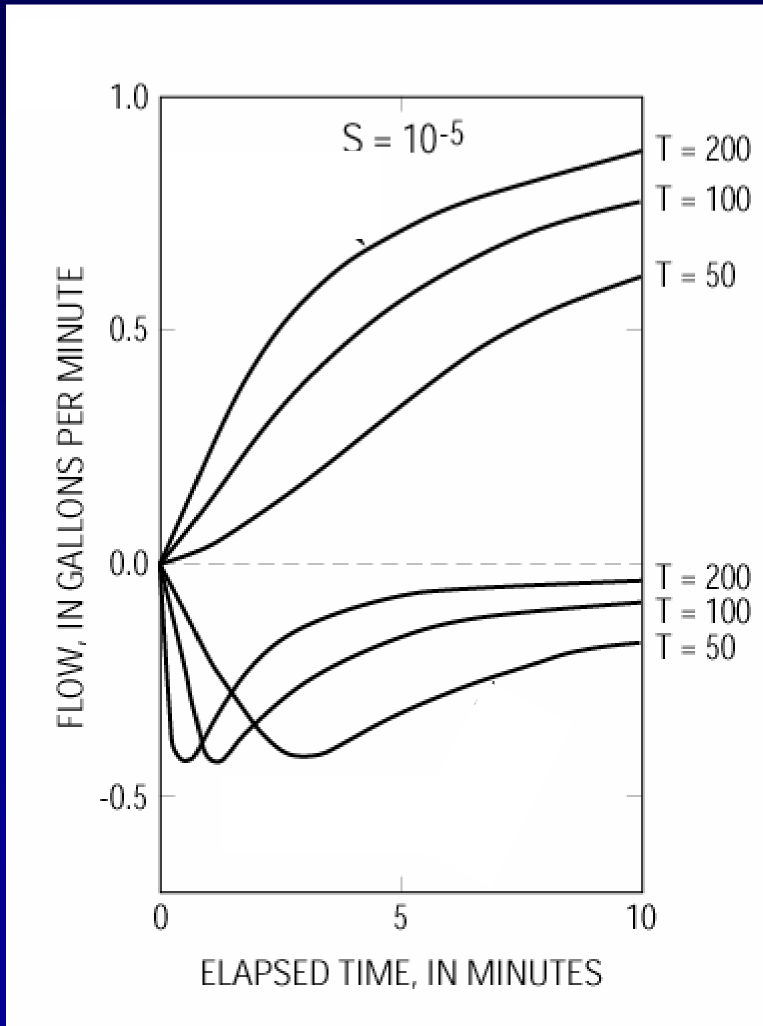
Floridan carbonate-rock aquifer

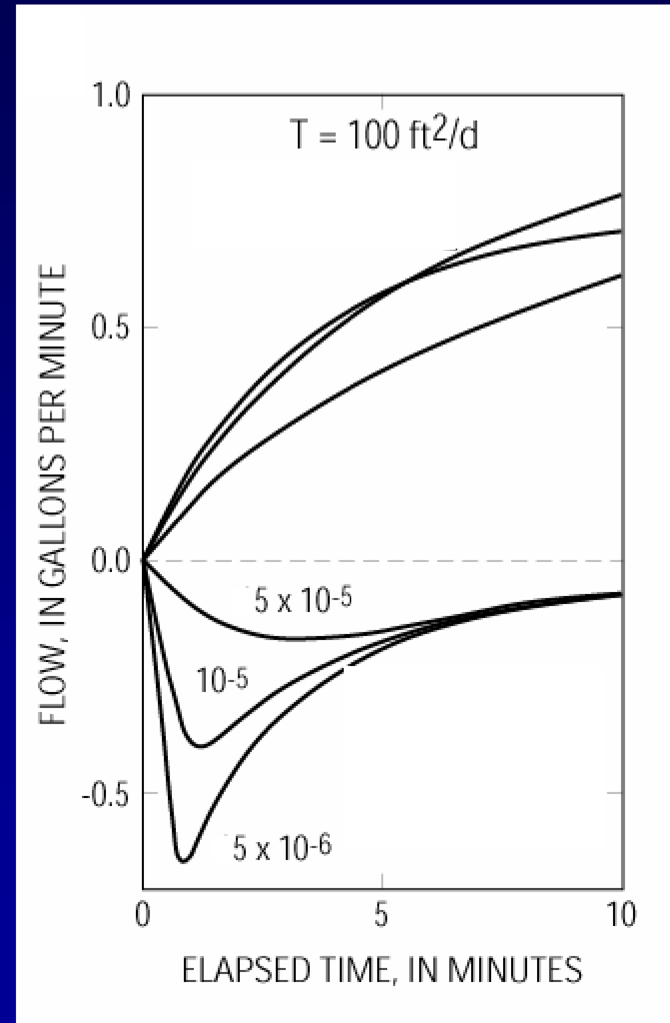
Specific Ion logging



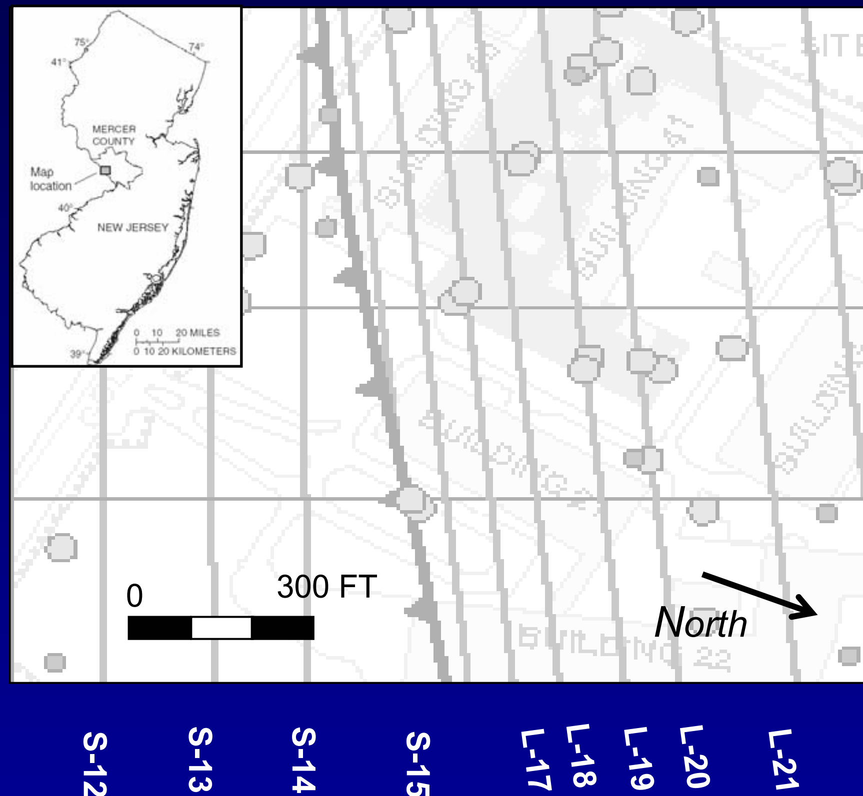
Crystalline-rock aquifer, southeastern New York

FRACTURE GEOMETRY, TRANSMISSIVITY, AND STORAGE





LOCATION OF SITE AND HYDROGEOLOGIC FRAMEWORK



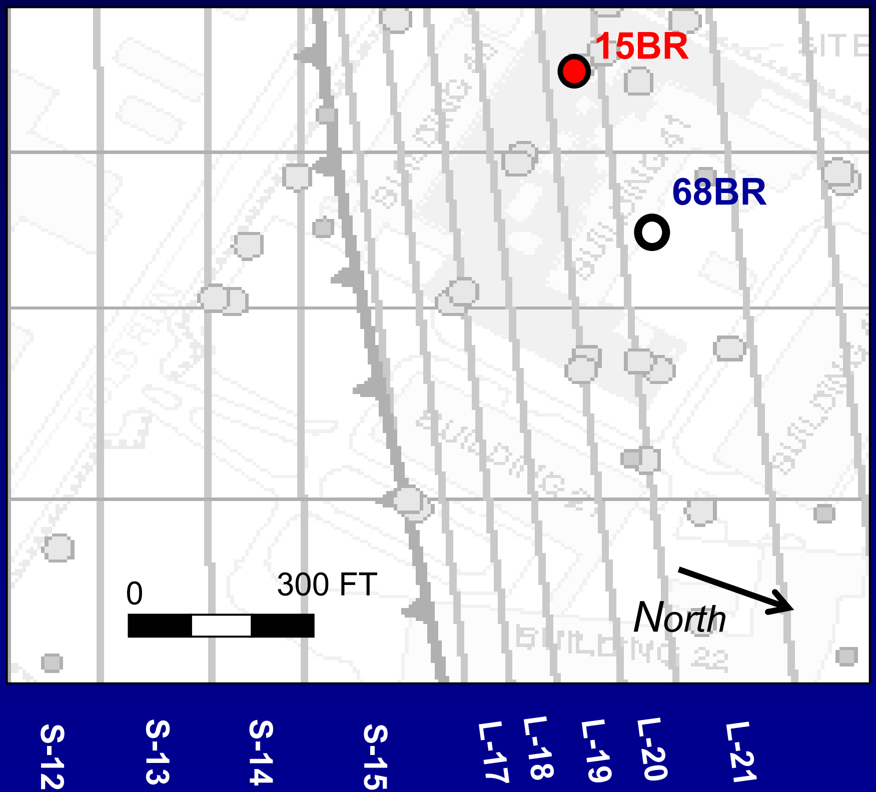
EXPLANATION

L-19 Lockatong lithostratigraphic unit

S-12 Stockton lithostratigraphic unit

Mesozoic clastic-rock aquifer, Newark Basin

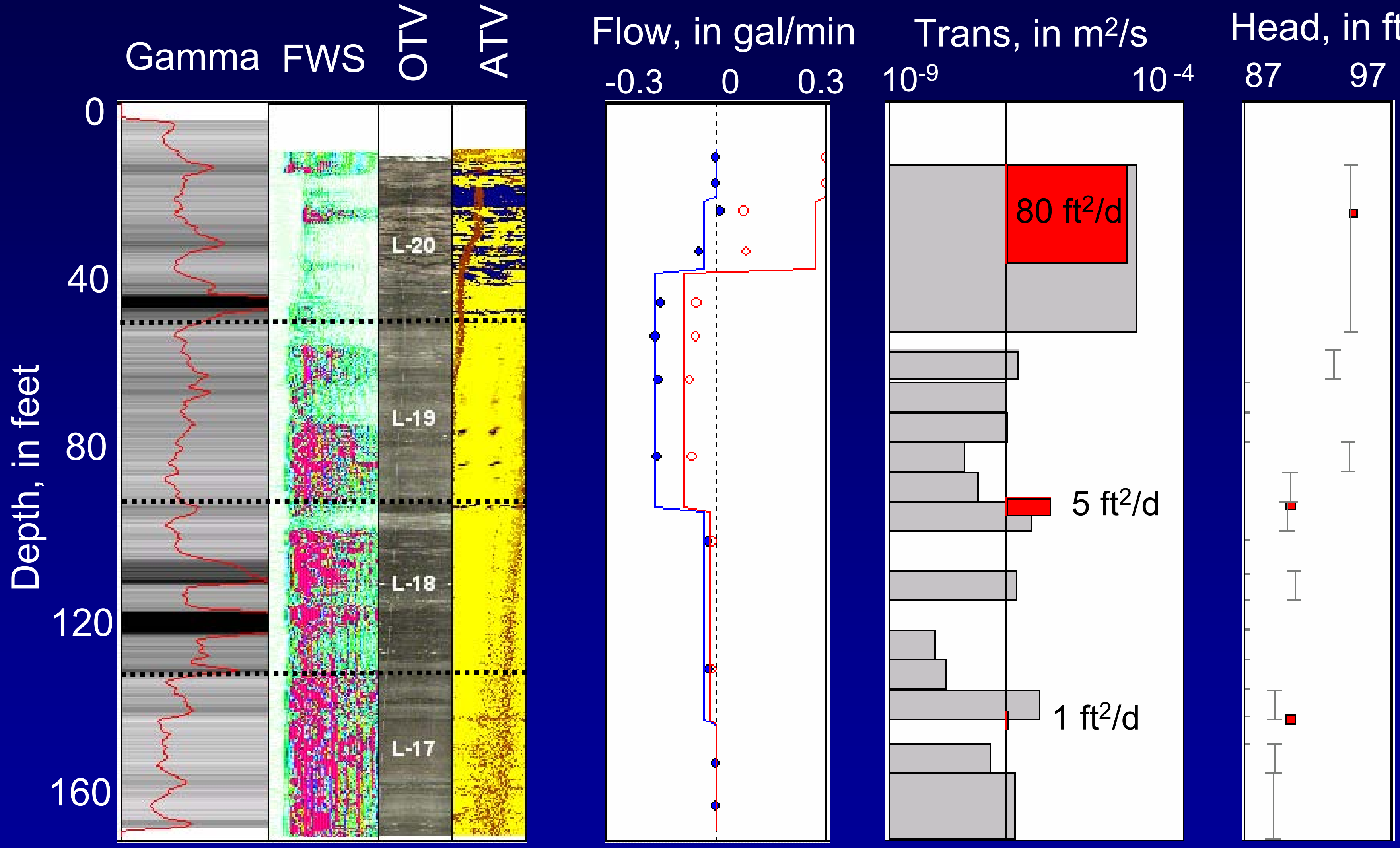
CROSS-HOLE FLOW TEST IN MUDSTONE



EXPLANATION

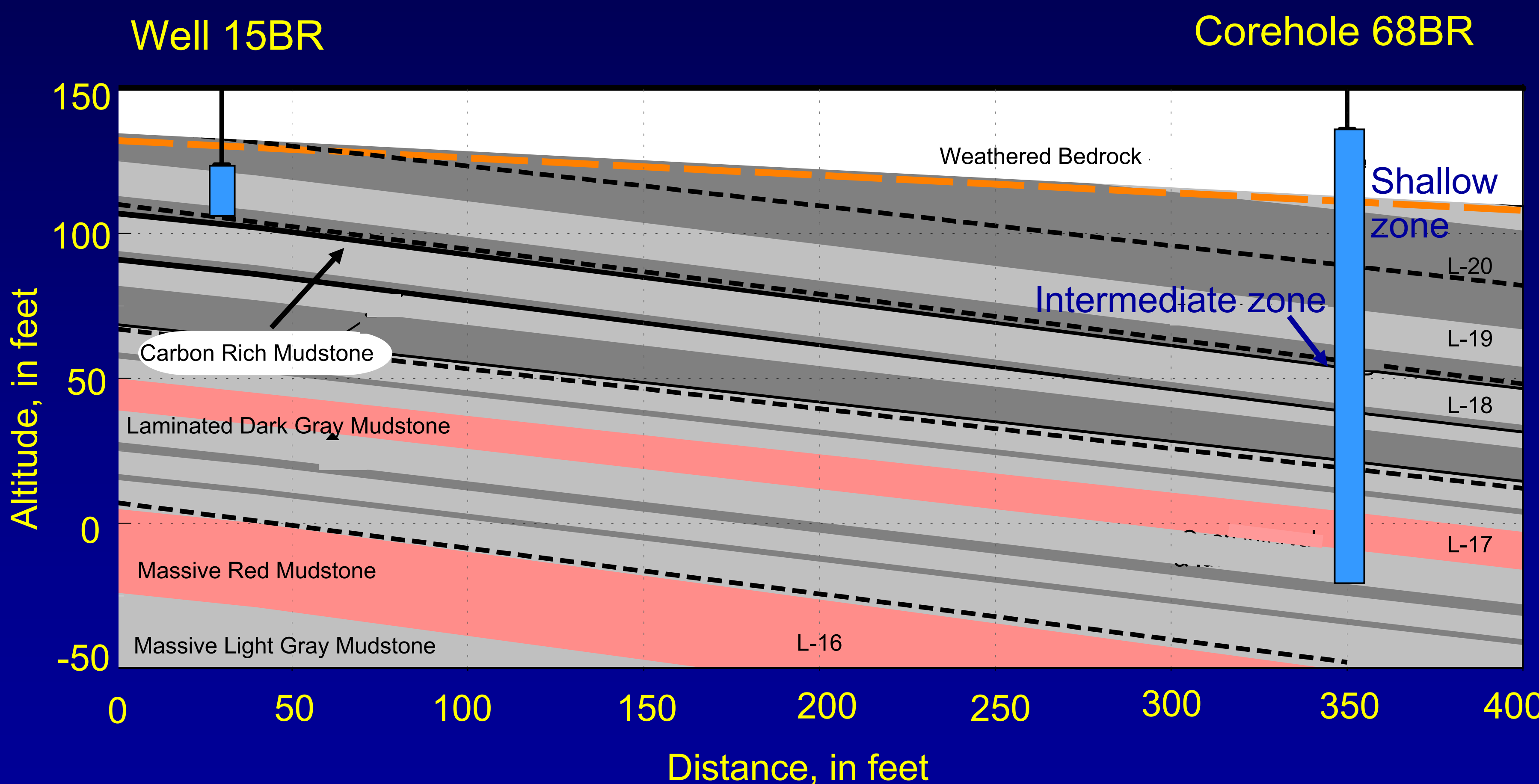
- Extraction well
- Corehole

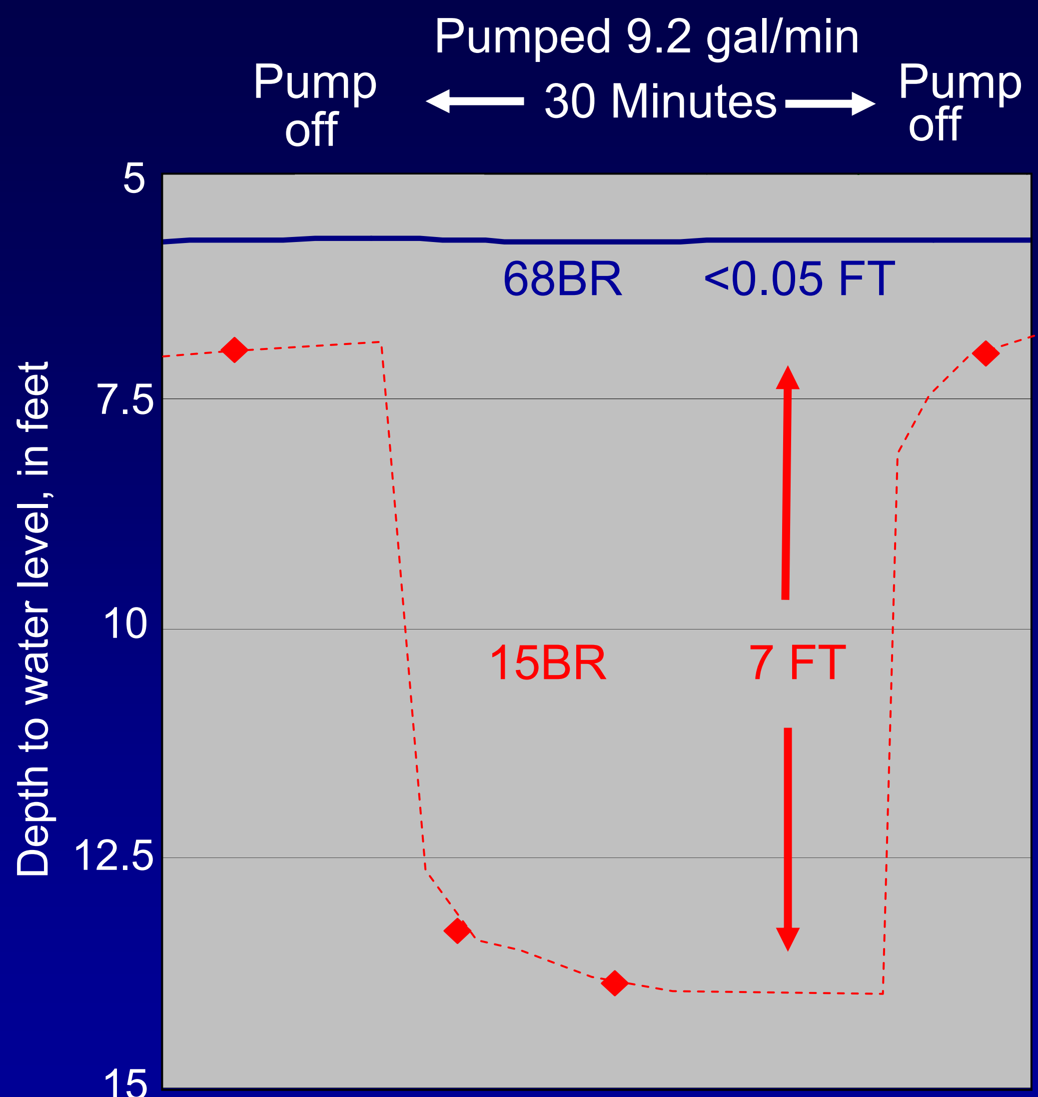
GEOPHYSICAL LOG AND HYDRAULIC ANALYSIS



Corehole in Mesozoic mudstone, Newark Basin

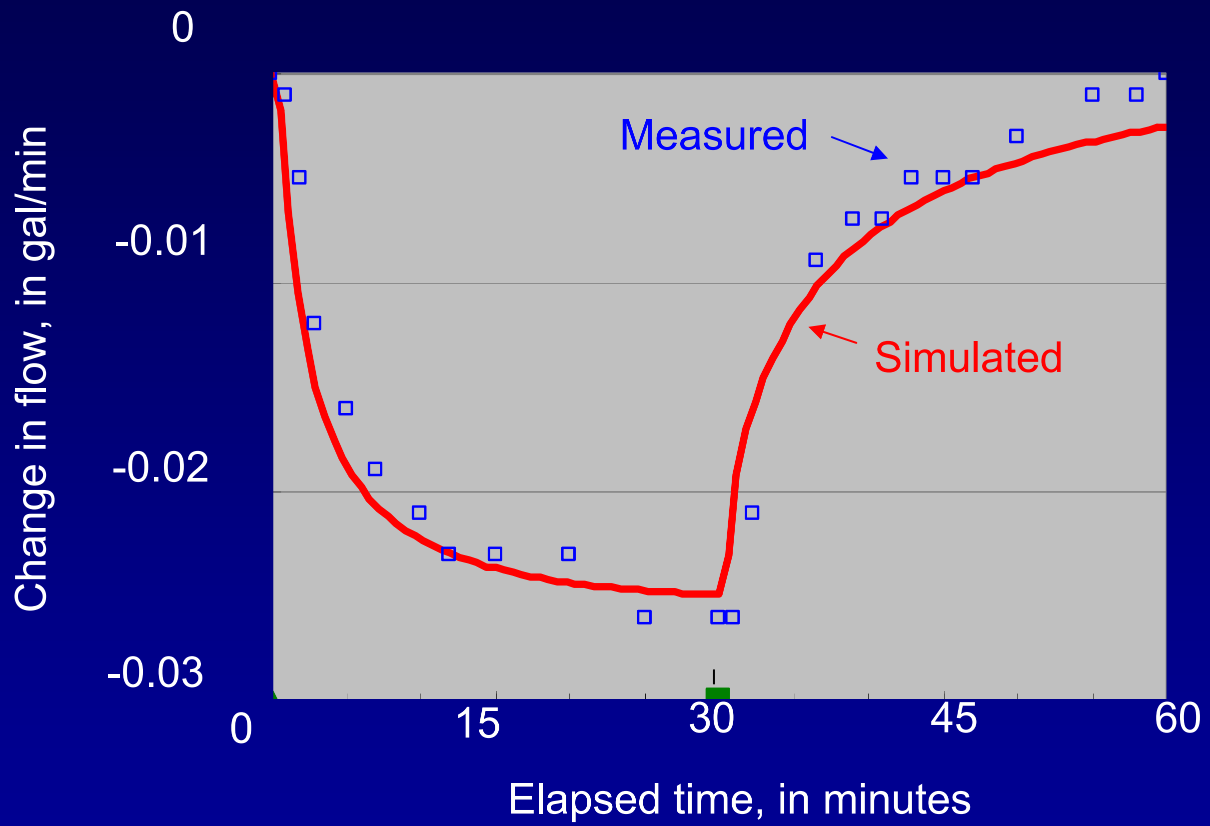
CROSS-BOREHOLE FLOW TEST DESIGN





WATER-LEVEL RESPONSE

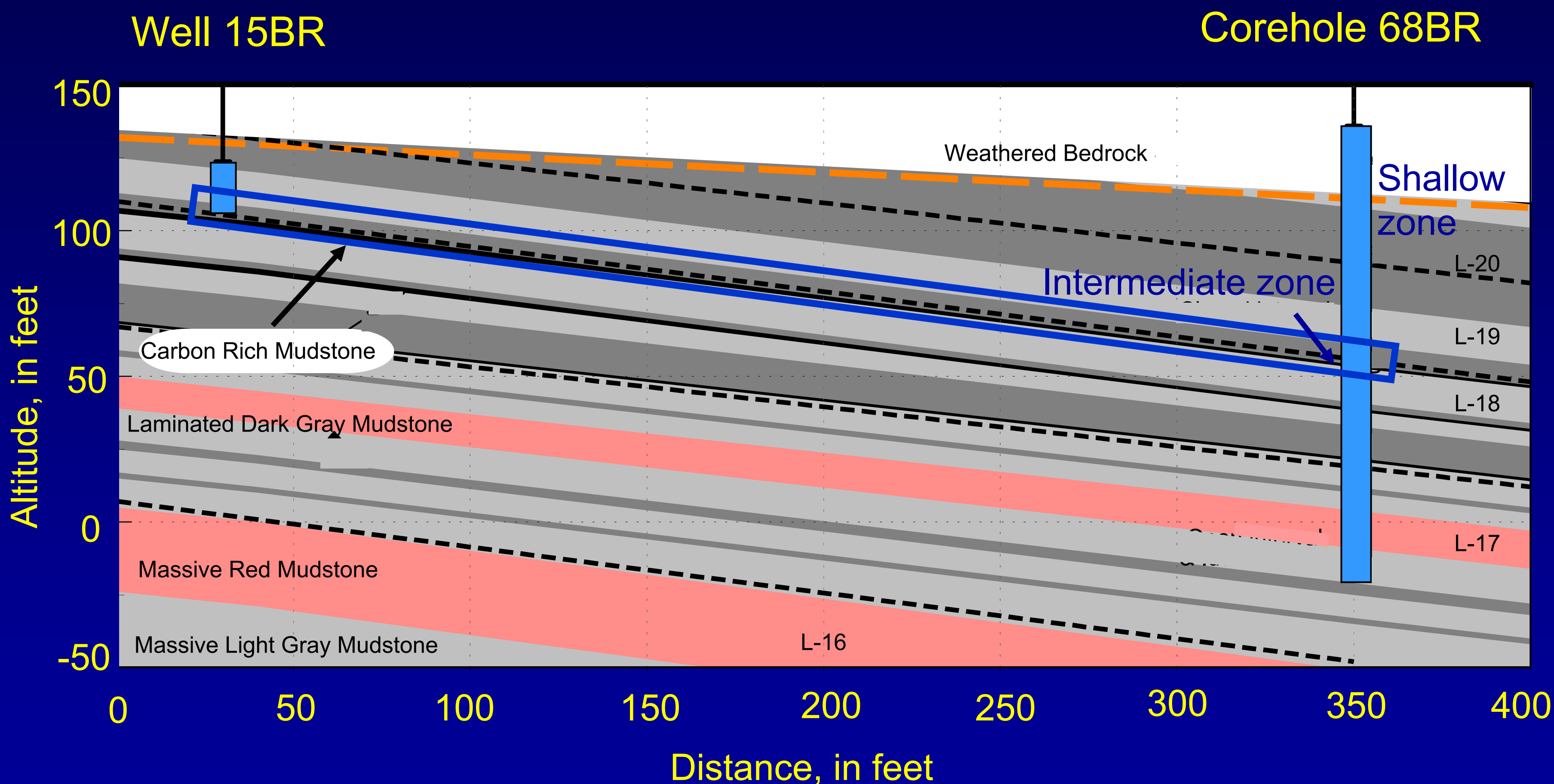
TRANSIENT FLOW RESPONSE IN COREHOLE 68BR



Simulated Shallow Zone Isolated and Intermediate Zone Connected

BETWEEN SHALLOW AND INTERMEDIATE FLOW ZONES

CROSS-BOREHOLE FLOW TEST RESULTS



SUMMARY

- Borehole geophysics provides critical hydraulic and water quality information for fractured-rock investigations
- Borehole-wall images and other logs help define the lithologic, stratigraphic, and structural framework
- Borehole-flow logs under ambient and stressed conditions are used to estimate zone transmissivity and head
- Cross-borehole, transient flow tests are used to evaluate the hydraulic connectivity of the zones
- Borehole-fluid logs and point samples provide insights into zone water quality and cross-contamination
- Newly developed specific-ion tools for logging dissolved oxygen, chloride, and nitrate