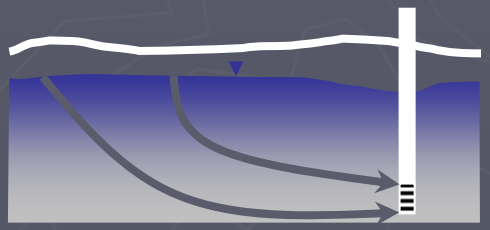
Borehole Geophysical Data Interpretations Associated with Public Supply Well and Monitoring Well Flow Dynamics



Greg Stanton and Lynne Fahlquist

Data collected by Mike Nyman, Geneva Duhon, Mike Greenslate and Jonathan Thomas

U.S. Geological Survey – Texas Water Science Center

Overview of Discussion

- Borehole Geophysical Parameters – Why Geophysical logging?
- Borehole geophysical interpretations of flow and wellfield dynamics
  - South Central Texas Example
    - Monitoring Wells near public supply wellfield
    - Flowmeter data associated with depth-dependent sampling of Edwards aquifer public supply wellfield
  - Albuquerque New Mexico Example
    - Flowmeter data associated with depth-dependent sampling of Yale 2 PSW
  - Superfund Site Example
  - Pantex Example

USGS

Geophysical Logging

An integral part of monitoring well construction and depth dependent sampling of a public supply well

- **Caliper,**
- **Natural Gamma,**
- **SP,**
- **Resistivity,**
- **Conductivity,**
- **Temperature,**
- **Borehole imaging tools,**
- **EM Flowmeter**

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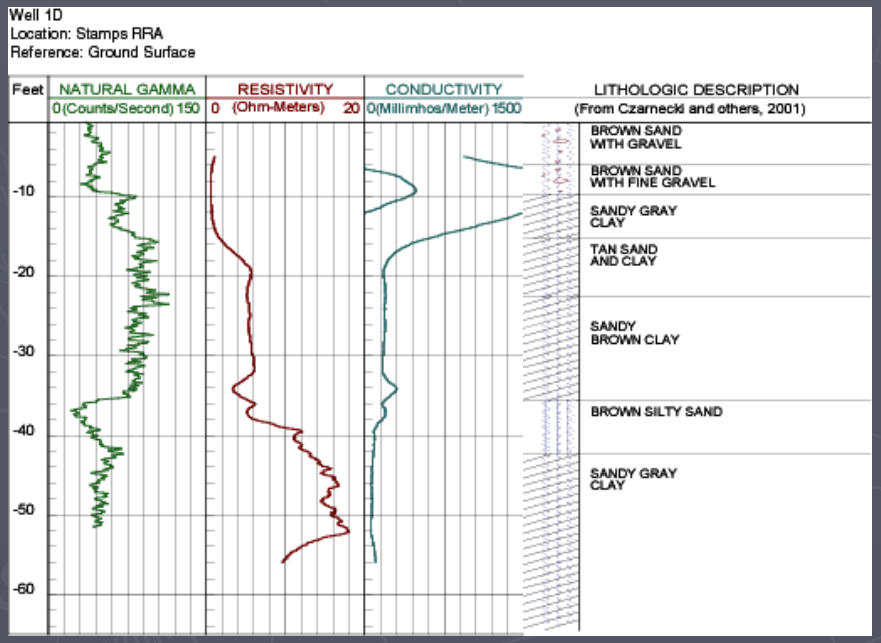
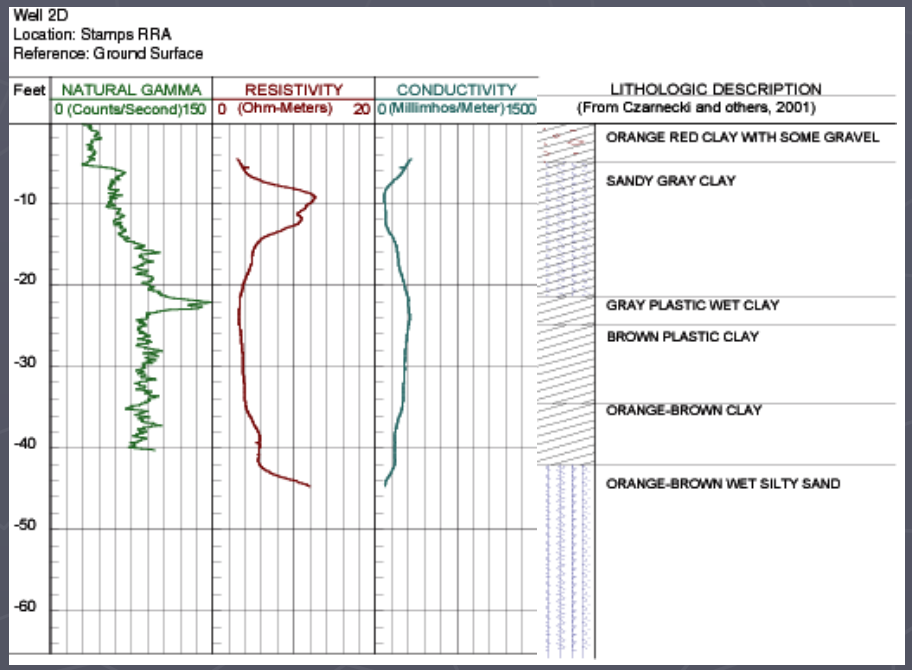
- Applications of logging – Why geophysical logging?
  - Information from drilling - Cuttings logs / Coring
    - Dependent on cuttings returns / core recovery
    - Descriptions subject to interpretation of on-site geologist
  - Borehole Geophysical Logs
    - Better depth control
    - Lithologies confirmed with multiple logs
    - Water-quality indicators





Source: Stanton and others, 2004

USGS

South-Central Texas TANC Example

- The Transport of Anthropogenic and Natural Contaminants (TANC) is a Topical Study of the National Water Quality Assessment (NAWQA) Program

- TANC study question: What are the primary

(1) contaminant sources,

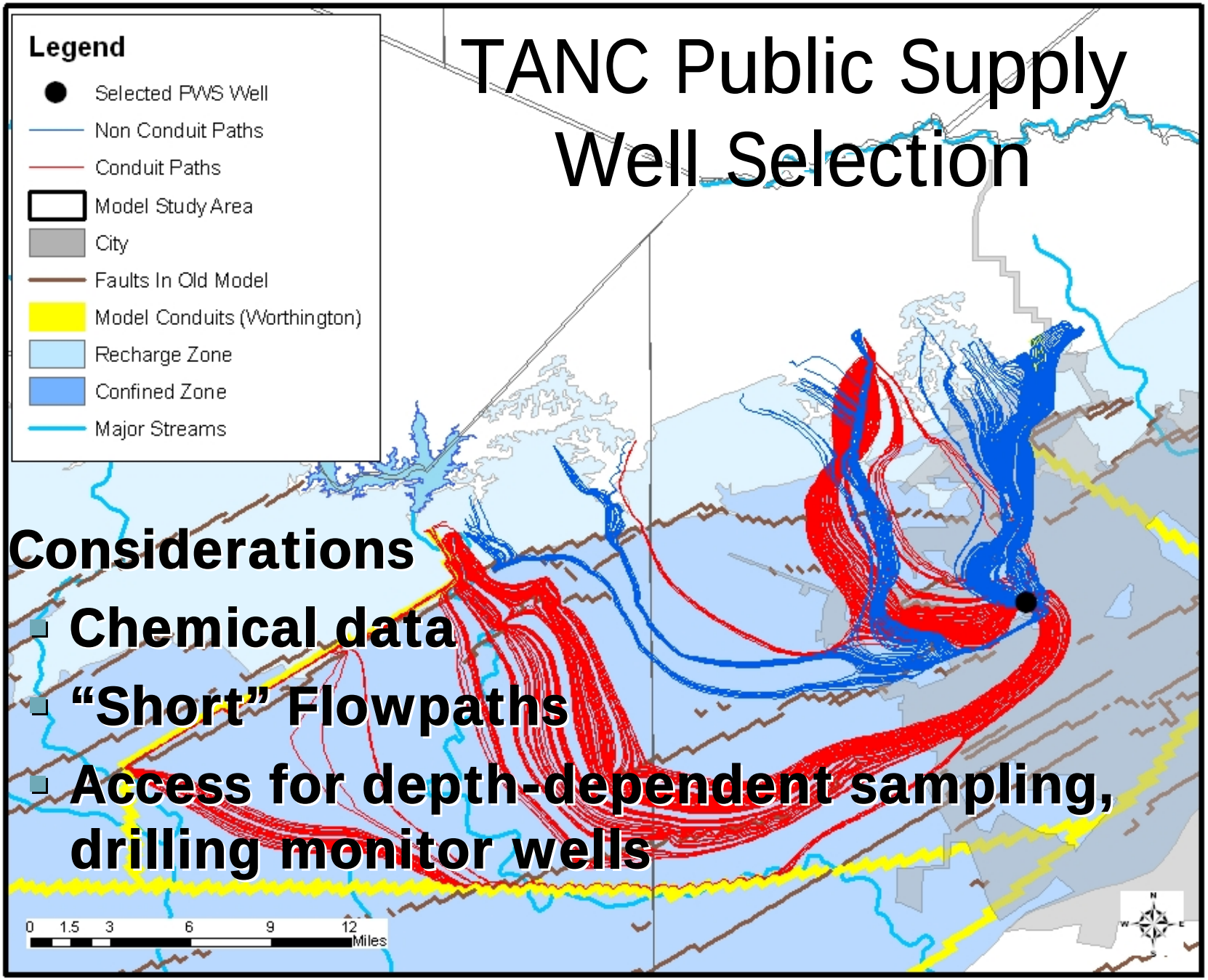
(2) aquifer processes, and

(3) well characteristics

that control the transport and transformation of contaminants from recharge areas to supply wells in representative drinking water aquifers?

USGS

TANC Public Supply Well Selection

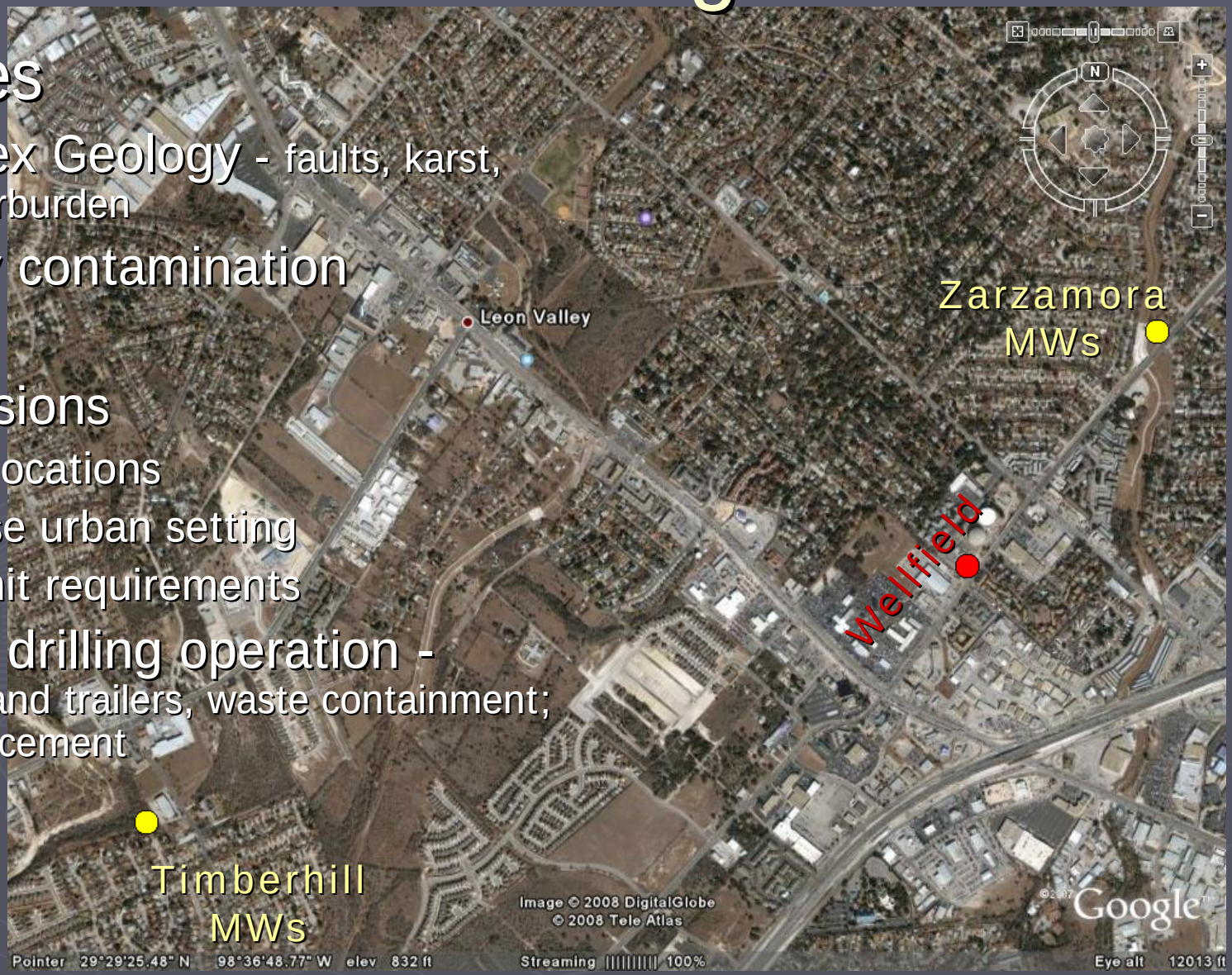


- **Considerations**
  - **Chemical data**
  - **"Short" Flowpaths**
  - **Access for depth-dependent sampling, drilling monitor wells**

South-Central Texas TANC PSW and Monitoring Wells

Challenges

- Complex Geology - faults, karst, thick overburden
- Nearby contamination
- Cost
- Permissions
  - Key locations
  - Dense urban setting
  - Permit requirements
- Size of drilling operation - vehicles and trailers, waste containment; pressure cement



USGS

South-Central Texas TANC Monitoring Wells

Producing water in shallow Edwards monitor well

Blowing well

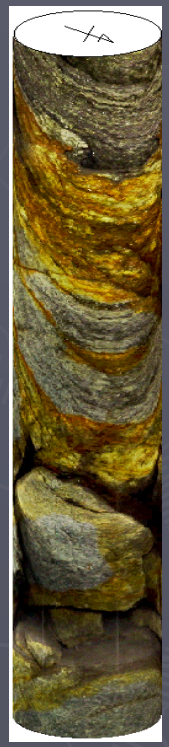
Voids, voids, and more voids

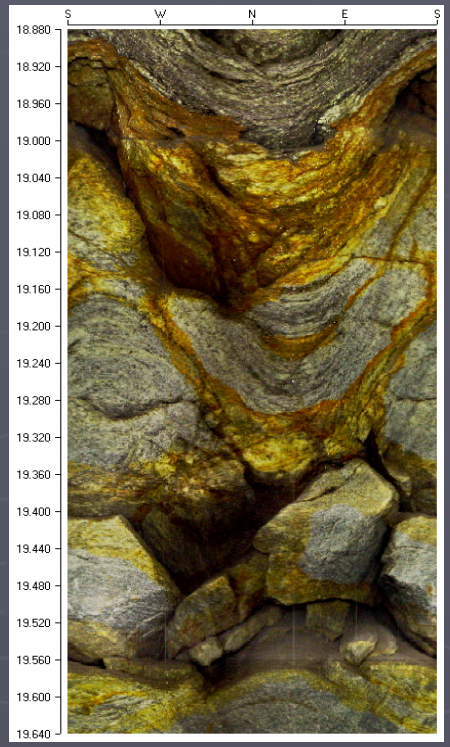
Surging water – 2 days after 10+-inch rain

USGS

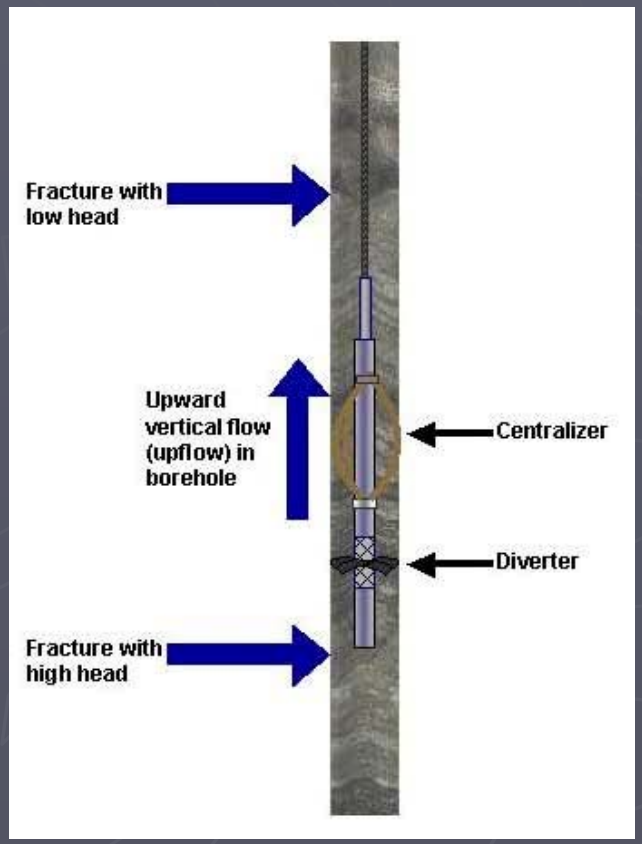
Karst, Fracture and Flow Characterization

Optical Televiewer





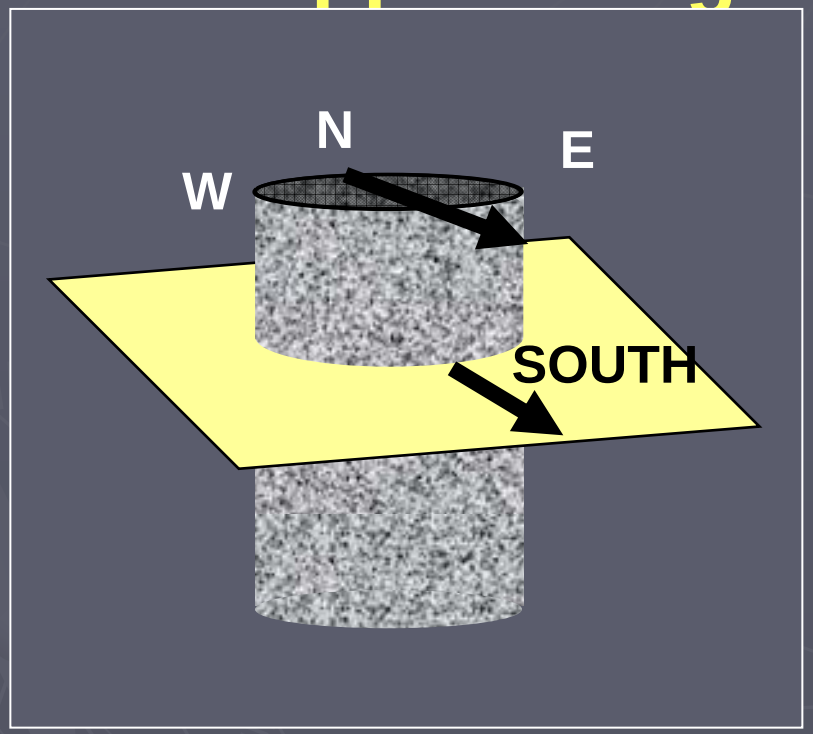
Heat-pulse & EM Flowmeters



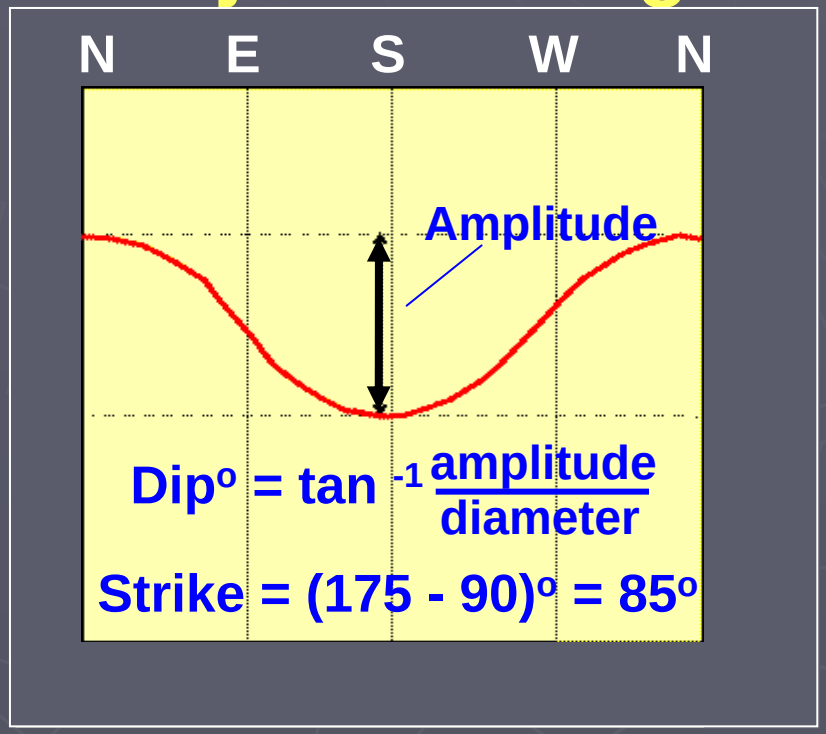
USGS

Borehole-Wall Image Fracture Analysis

3-D wrapped image

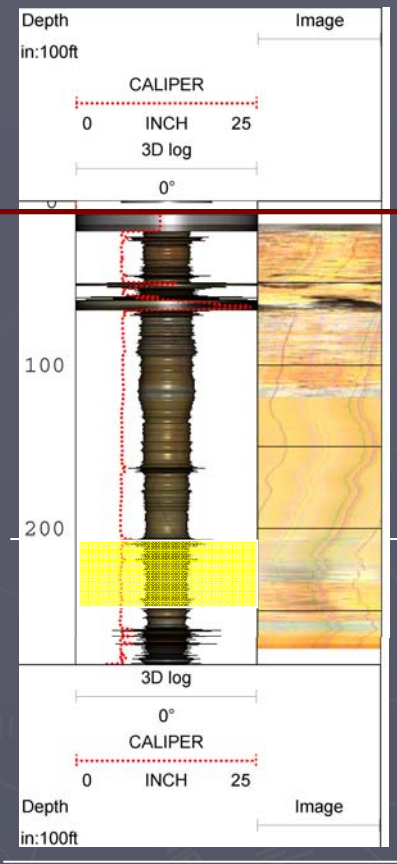


Projected image

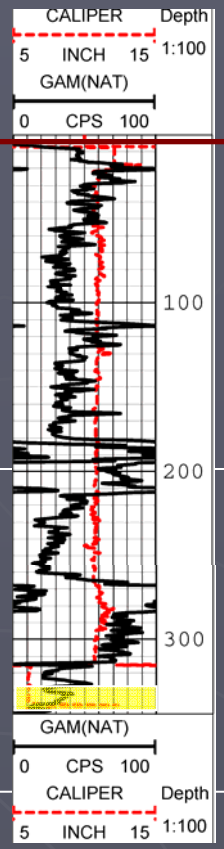


USGS

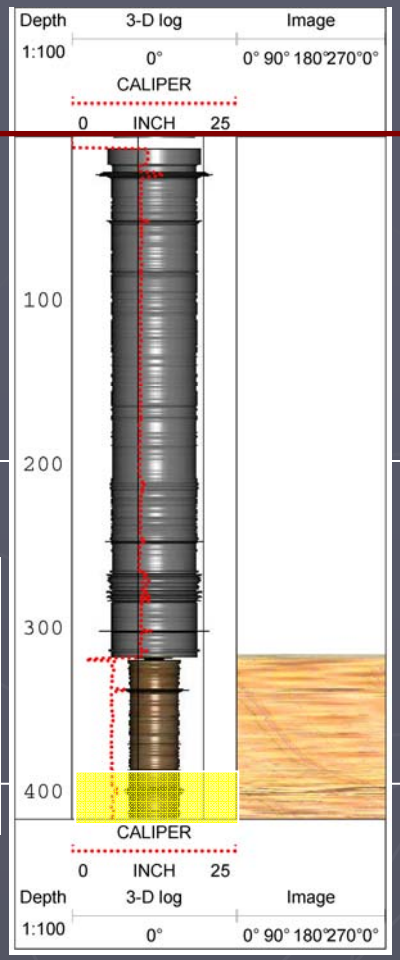
Zarzamora Monitoring Wells



Z-OVB



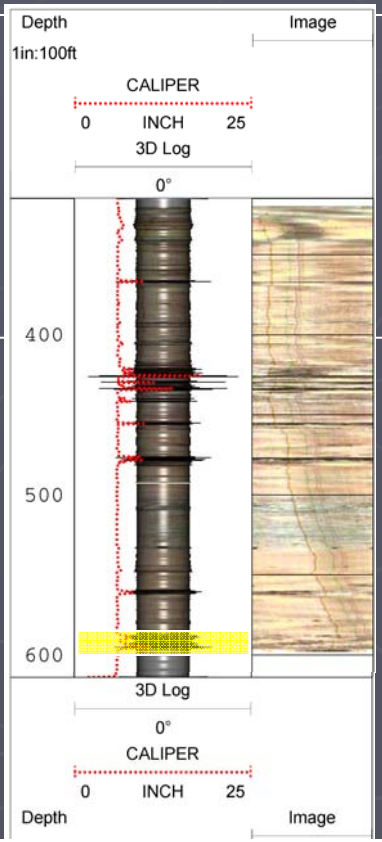
Z-SED

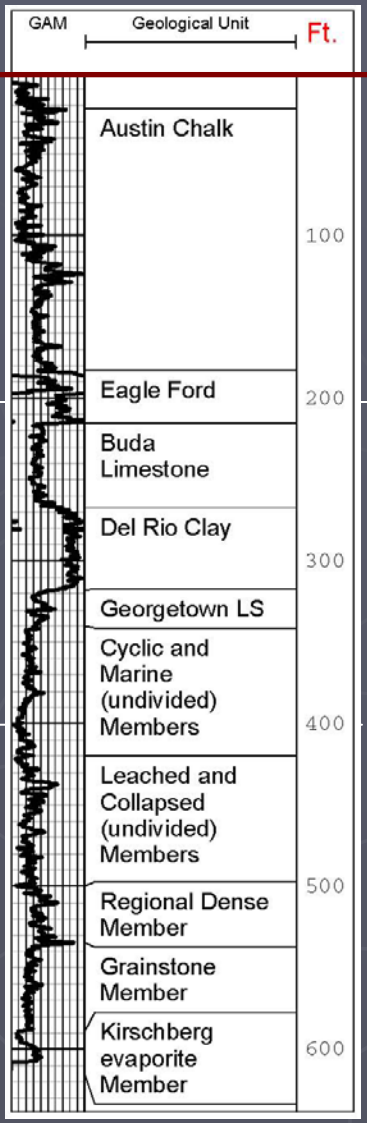


Z-IED

Land Surface

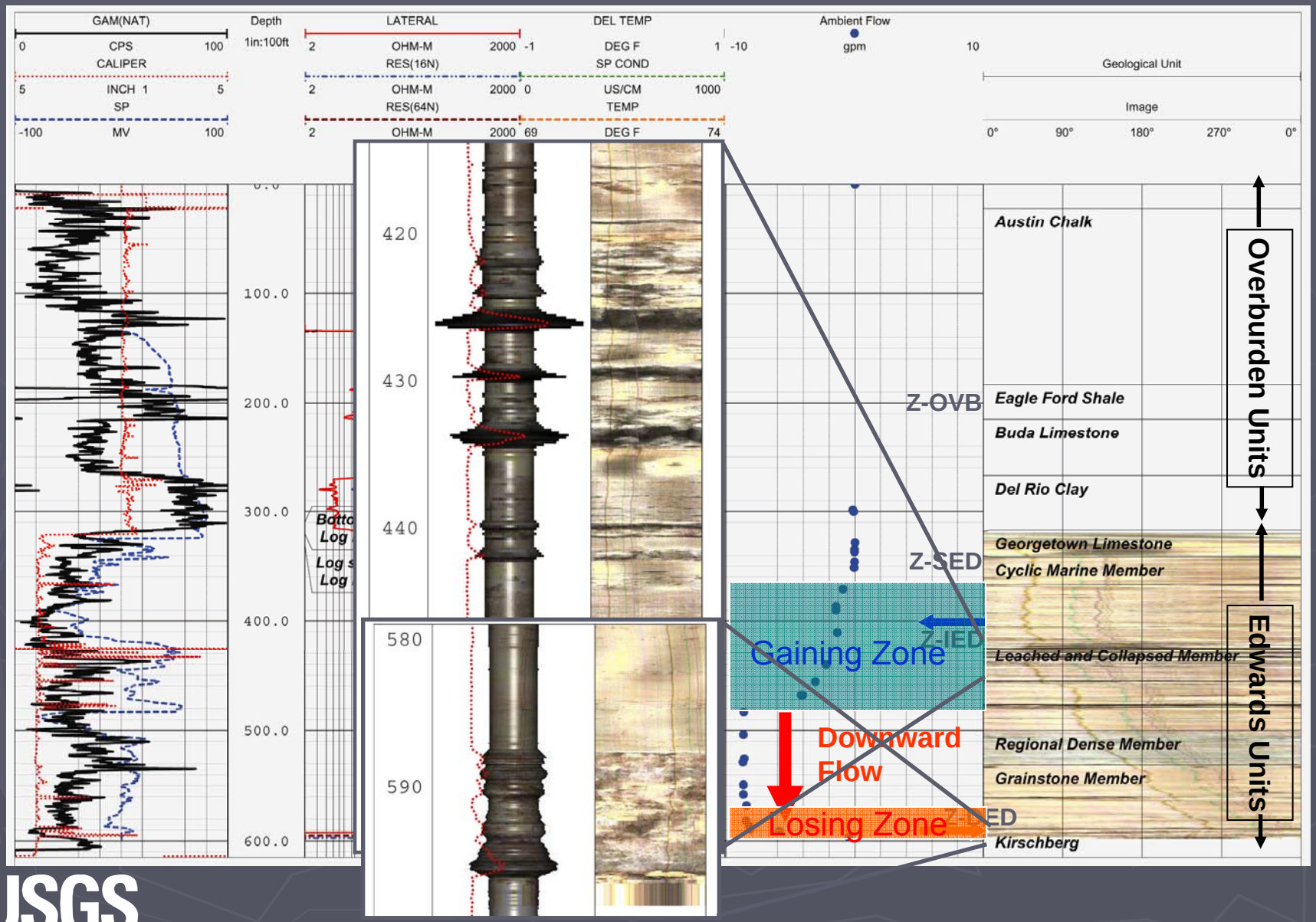
Z-DED





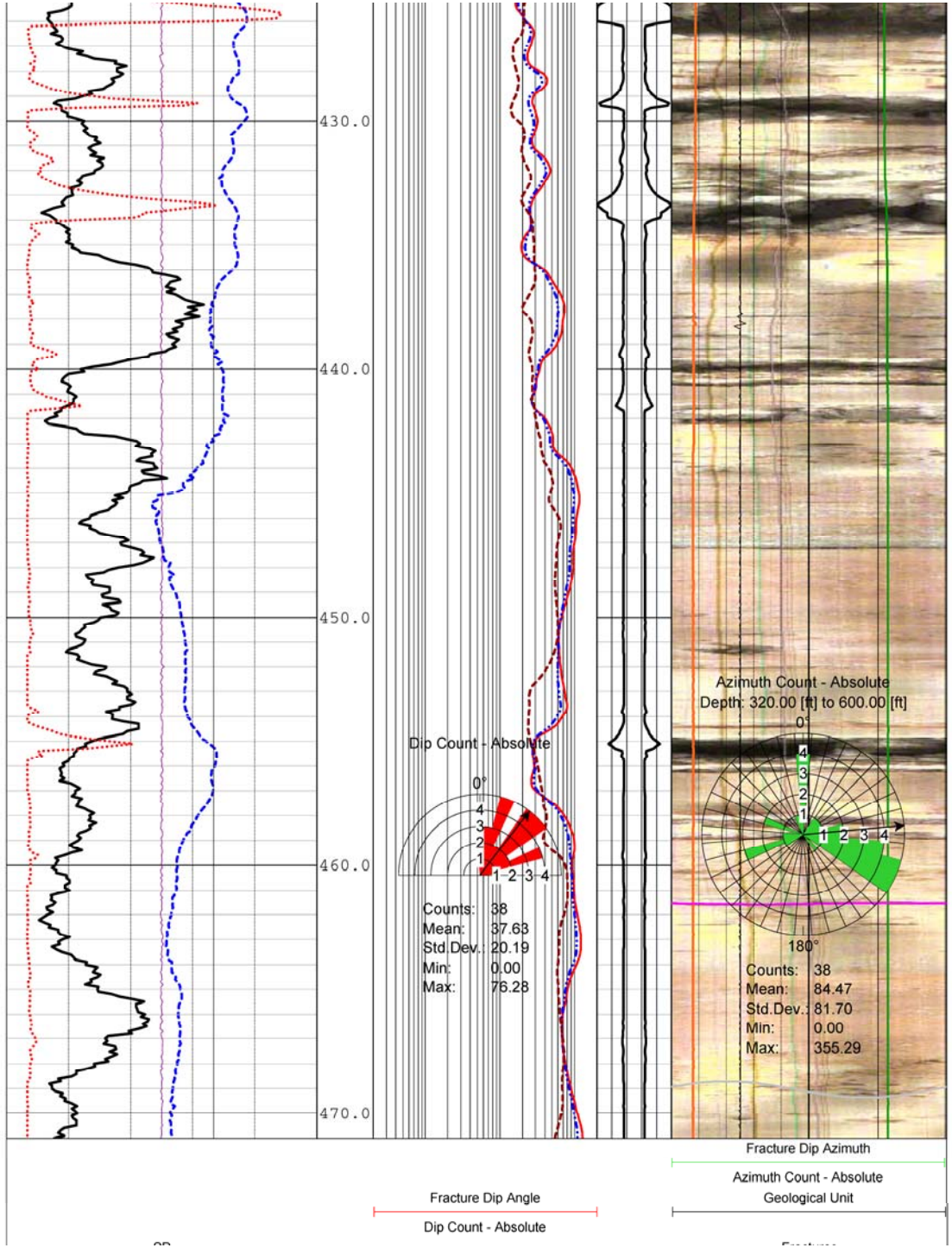
USGS

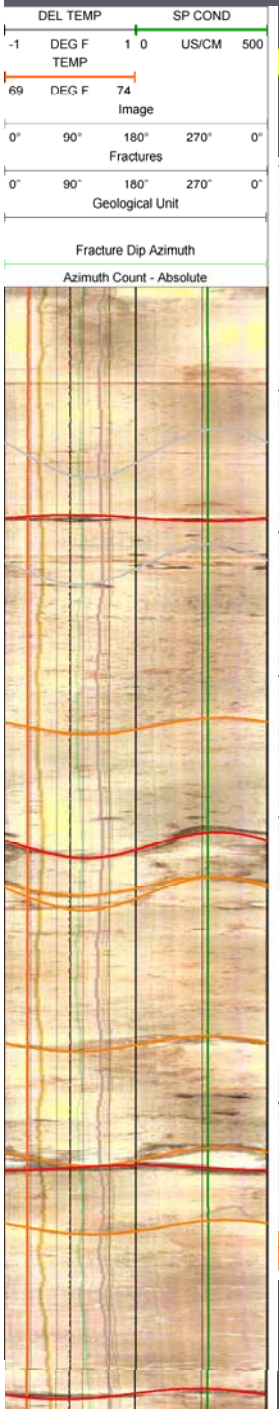
Zarzamora Deep Monitoring Well

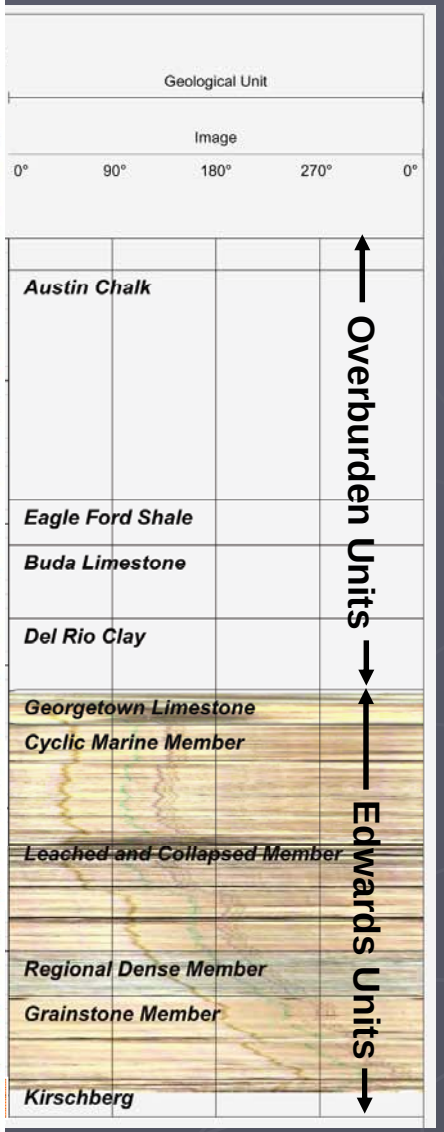


USGS

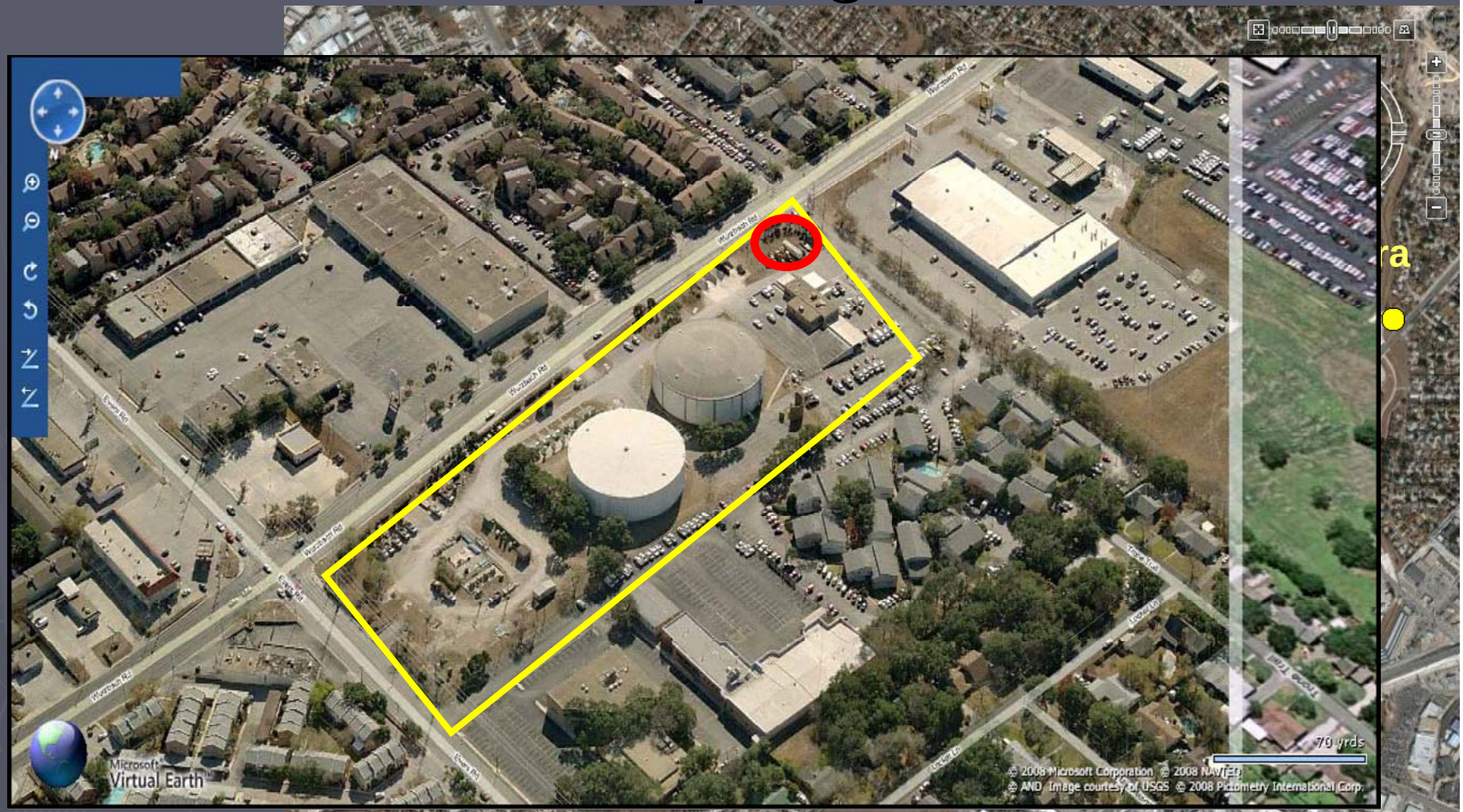
Vell


430.0
440.0
450.0
460.0
470.0
Dip Count - Absolute
0°
Counts: 38
Mean: 37.63
Std.Dev.: 20.19
Min: 0.00
Max: 76.28
Azimuth Count - Absolute
Depth: 320.00 [ft] to 600.00 [ft]
0°
180°
Counts: 38
Mean: 84.47
Std.Dev.: 81.70
Min: 0.00
Max: 355.29
Fracture Dip Azimuth
Azimuth Count - Absolute
Geological Unit
Fracture Dip Angle
Dip Count - Absolute


DEL TEMP
SP COND
-1 DEG F 1
0 US/CM 500
TEMP
69 DEG F 74
Image
0° 90° 180° 270° 0°
Fractures
0° 90° 180° 270° 0°
Geological Unit
Fracture Dip Azimuth
Azimuth Count - Absolute


Geological Unit
Image
0° 90° 180° 270° 0°
Austin Chalk
Eagle Ford Shale
Buda Limestone
Del Rio Clay
Georgetown Limestone
Cyclic Marine Member
Leached and Collapsed Member
Regional Dense Member
Grainstone Member
Kirschberg
Overburden Units
Edwards Units

Public Supply Well Depth Dependent Sampling



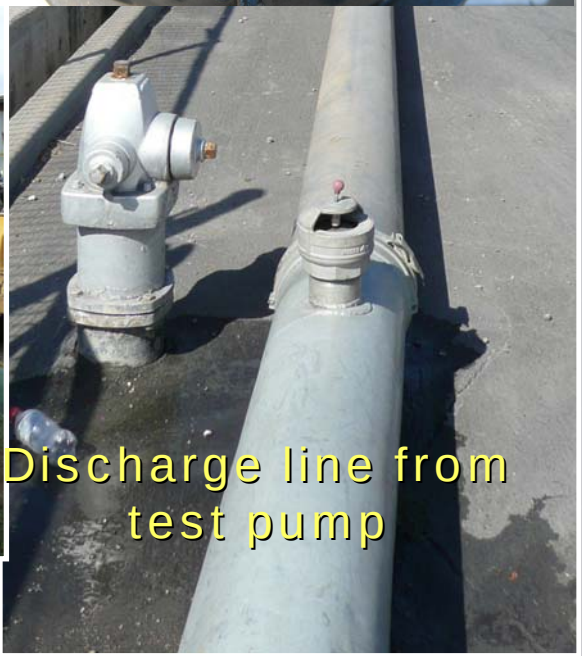
USGS

Depth-Dependent Sampling

- Borehole Geophysical Flow Data Used in Zone Selection

- Sampled 3 Zones in 3 Flow Conditions:
  - Cyclic and Marine
  - Leached and Collapsed
  - Kirschberg

Installing test pump in public supply well



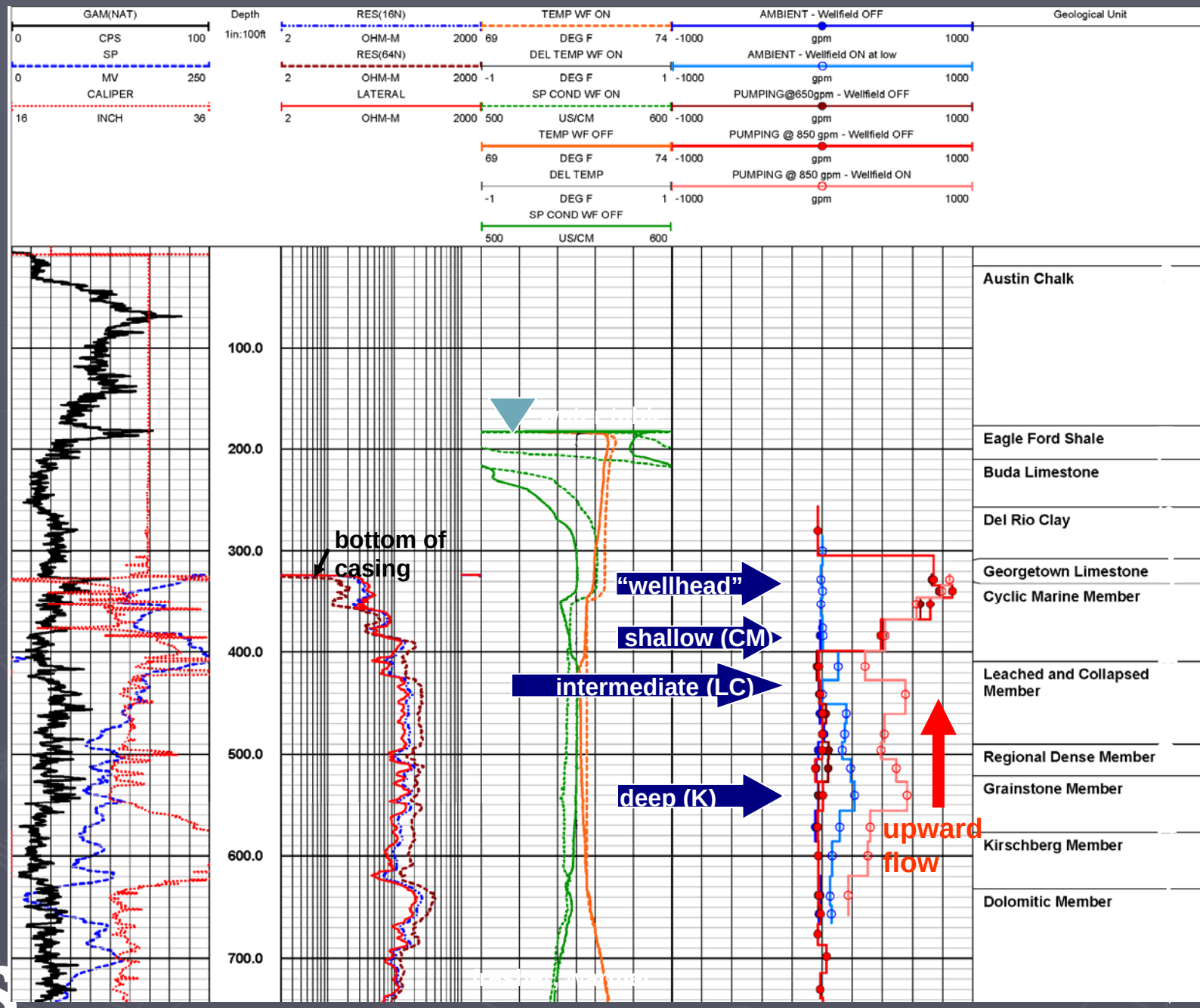
Discharge line from test pump

USGS

Borehole Geophysics and Depth Dependent Sampling

Depth Dependent Sampling

Public Supply Well Logs



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Public Supply Well Flowmeter Data

Well Field OFF

SAMPLED
Test pump ON
650 gpm & 850 gpm

850 gpm Up

400 gpm Up

No Flow

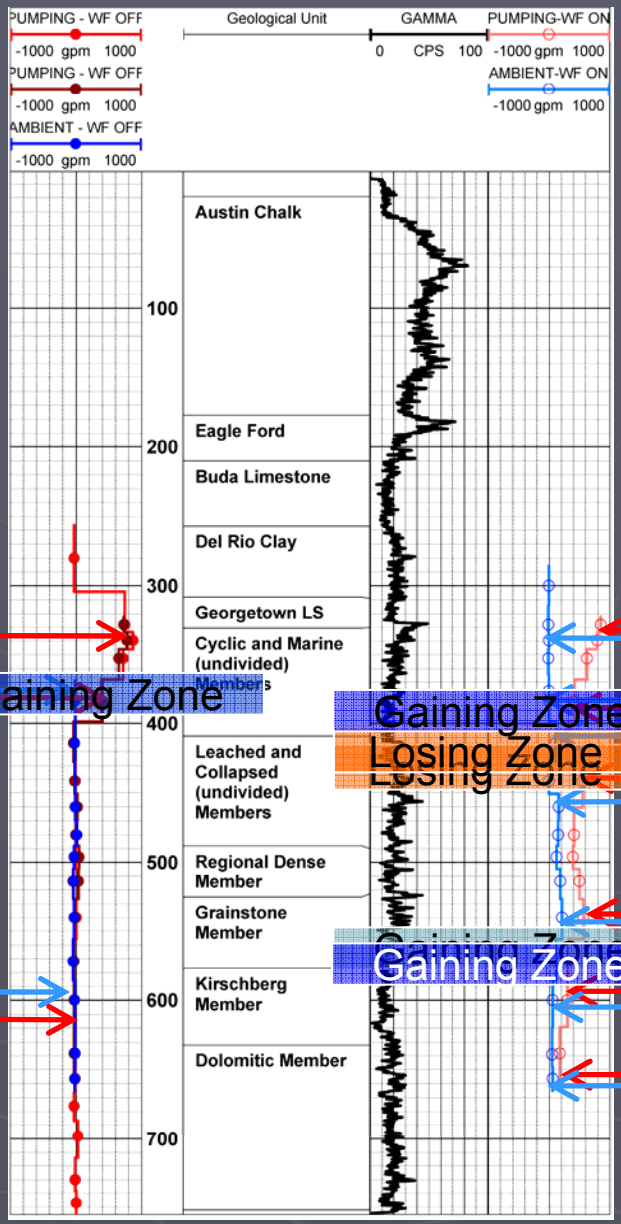
No Flow

SAMPLED
Ambient

No Flow

No Flow

No Flow



Well Field ON

SAMPLED
Test Pump ON

850 gpm Up

400 gpm Up

600 gpm Up

600 gpm Up

200 gpm Up

"Apparent Ambient"

No Flow

No Flow

100 gpm Up

200 gpm Up

200 gpm Up

50 gpm Up

<50 gpm Up

USGS

Flowmeter Logging Results (4 conditions)

Wellfield OFF
(no pumping PWS wells)

Ambient (sampled)
- No borehole flow

Test Pump On (sampled)
- No flow in lower zone
- All flow in upper zone, gained flow in Cyclic and Marine

Wellfield ON
(nearby pumping PWS wells)

Apparent Ambient
- No flow in upper Cyclic and Marine, lose flow in Cyclic and Marine (affected by nearby pumping wells)
- Gain flow in Kirschberg and Leached and Collapsed

Test Pump On (sampled)
- Upward flow throughout borehole
- Gain flow in Kirschberg and Leached and Collapsed
- Lose flow in bottom of Cyclic and Marine (affected by nearby pumping wells)
- Gain flow at top of Cyclic and Marine

Insignificant flow below Kirschberg under all conditions

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Transmissivity Estimates

Wellfield Off Test pump ON

FLOW-B INPUT AND PLOTS

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Wellname: W4 Edwards

REQUIRED INPUT:

Elevation of Measuring Point [FT]	
Number of fractures [-]	2
Well Diameter [IN]	26
Drawdown [FT]	2.06
Step Factor [-]	70
Total Transmissivity [FT^2/day]	85000
Depth to Ambient Water Level [FT]	183.81
Depth at bottom of Plot [FT]	750
Depth at top of Plot [FT]	250

PLOT LOGS

RUN FWRAP

LOAD/PLOT RESULTS

FRACTURES:	Depth [FT]	Flow above fracture Ambient [GPM]	Pumped [GPM]	Zone Tfactor [-]	Zone H [FT]
2	385.000	0.000	750.000	0.950	0.000
1	614.000	-35.000	4.330	0.050	-1.000

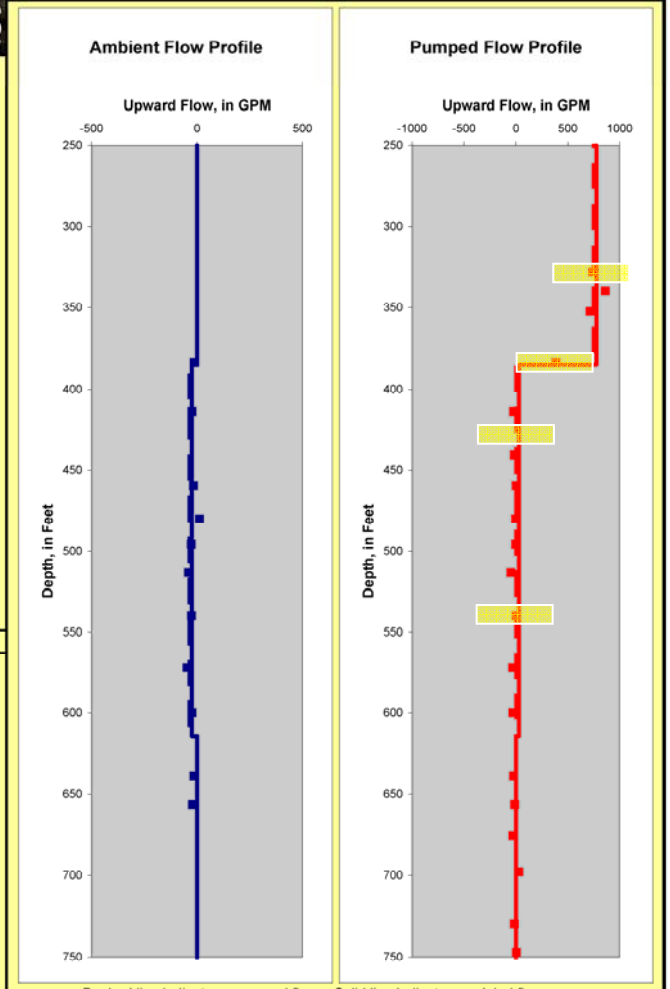
Elev, Ambient WL [FT] = -183.81 Elev, Pumped WL [FT] = -185.87

SIMULATION OUTPUT FROM FWRAP (DO NOT CHANGE)

SSE [GPM^2]	1401.20500
Ambient WL [FT]	-2.11000
Pumped WL [FT]	-0.06900

RMS Error [GPM] = 26.4688968

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	385.000	0.039	776.071	80750.000	183.760	-183.760
1	614.000	-24.369	28.998	4250.000	184.760	-184.760

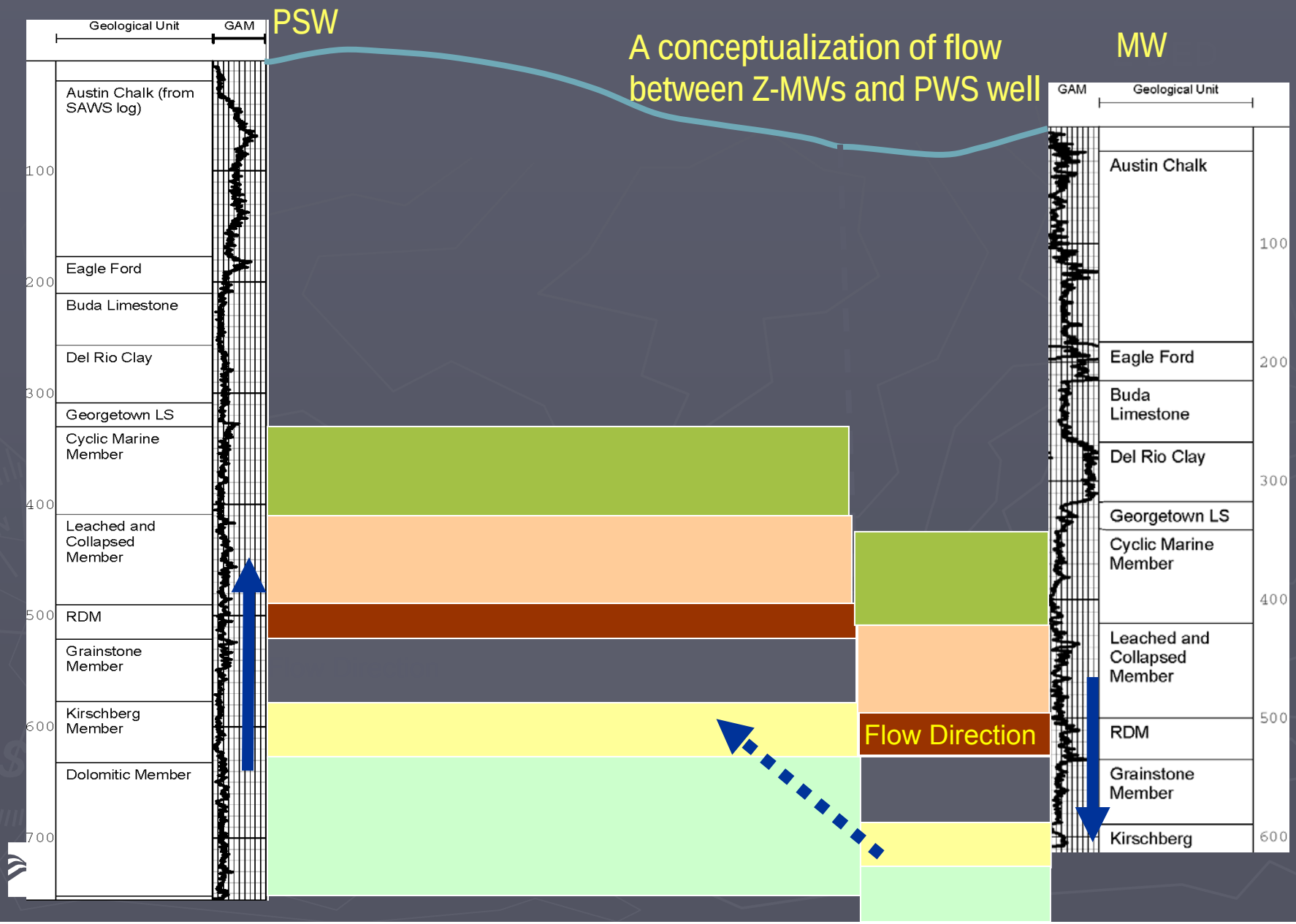


WARNINGS:

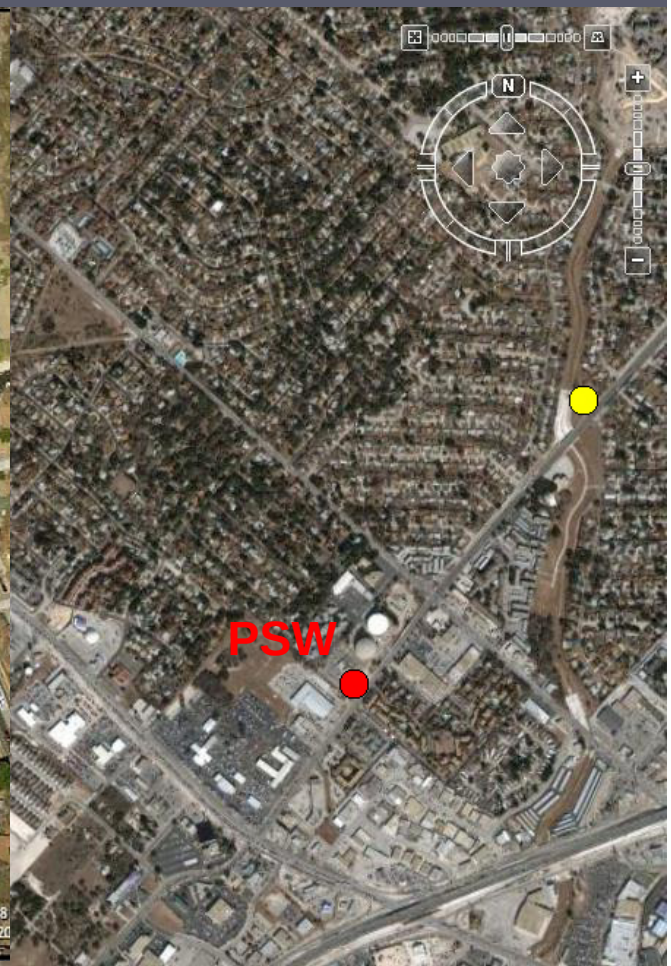
USGS

Paillet, F. L. (2000), A field technique for estimating aquifer parameters using flow log data: Ground Water, v. 38, no. 4, p. 510-521.

"Apparent Ambient" Flow Conditions

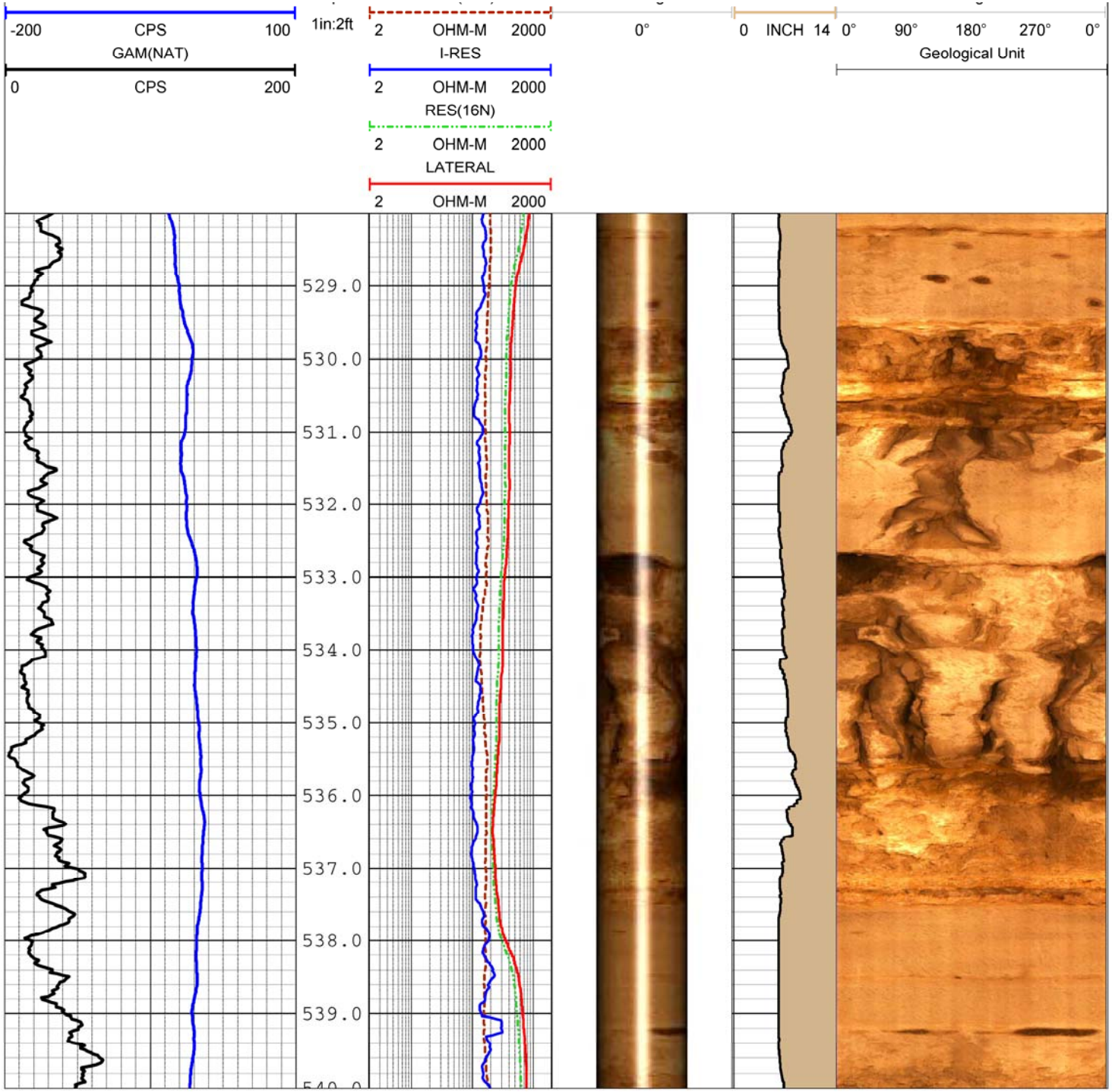


Timberhill Monitoring Wells



USGS

ls


-200 CPS 100
GAM(NAT)
0 CPS 200
1in:2ft
2 OHM-M 2000
I-RES
2 OHM-M 2000
RES(16N)
2 OHM-M 2000
LATERAL
2 OHM-M 2000
0°
0 INCH 14
0° 90° 180° 270° 0°
Geological Unit
529.0
530.0
531.0
532.0
533.0
534.0
535.0
536.0
537.0
538.0
539.0

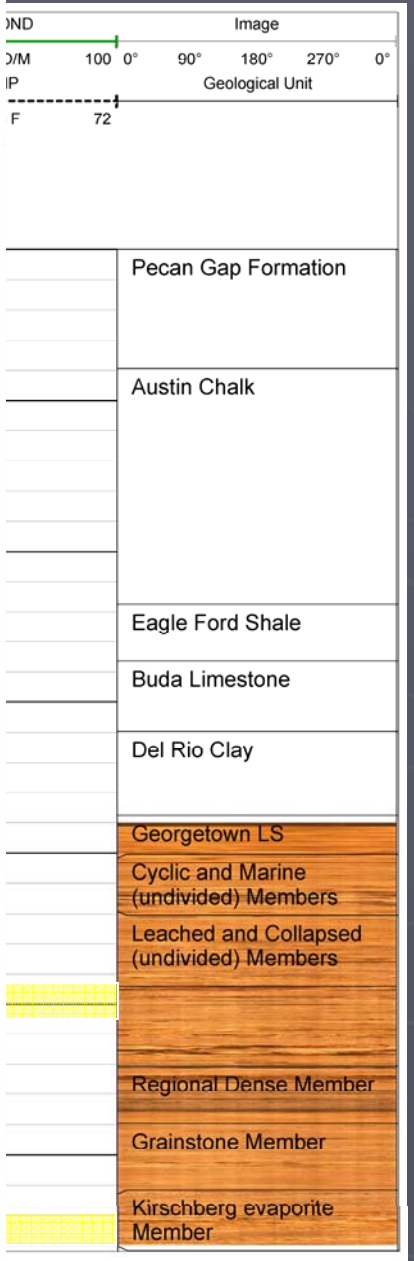
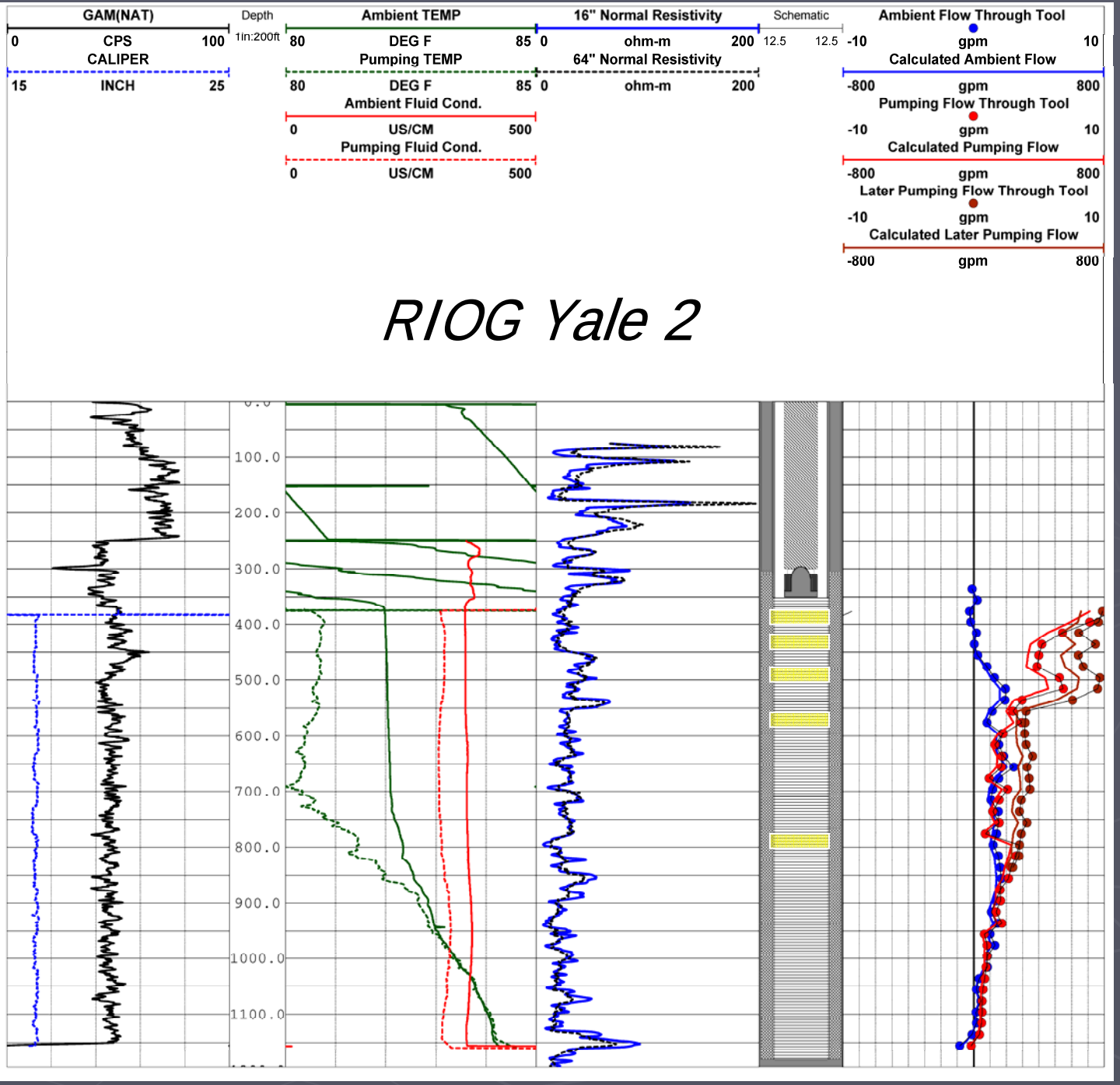


Image
100 0° 90° 180° 270° 0°
Geological Unit
72
Pecan Gap Formation
Austin Chalk
Eagle Ford Shale
Buda Limestone
Del Rio Clay
Georgetown LS
Cyclic and Marine (undivided) Members
Leached and Collapsed (undivided) Members
Regional Dense Member
Grainstone Member
Kirschberg evaporite Member

Rio Grande TANC - Yale 2
Ambient and Pumping Flowmeter


GAM(NAT)
0 CPS 100
CALIPER
15 INCH 25
Depth
1In:200ft
Ambient TEMP
80 DEG F 85
Pumping TEMP
80 DEG F 85
Ambient Fluid Cond.
0 US/CM 500
Pumping Fluid Cond.
0 US/CM 500
16" Normal Resistivity
0 ohm-m 200
64" Normal Resistivity
0 ohm-m 200
Schematic
12.5 12.5
Ambient Flow Through Tool
-10 gpm 10
Calculated Ambient Flow
-800 gpm 800
Pumping Flow Through Tool
-10 gpm 10
Calculated Pumping Flow
-800 gpm 800
Later Pumping Flow Through Tool
-10 gpm 10
Calculated Later Pumping Flow
-800 gpm 800
RIOG Yale 2
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1000.0
1100.0

Flowmeter Analysis - RIOG Yale 2

FLOW-B INPUT AND PLOTS

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Wellname: Yale 2 Alb

REQUIRED INPUT:

Elevation of Measuring Point [FT]	5144
Number of fractures [-]	4
Well Diameter [IN]	16
Drawdown [FT]	13.73
Step Factor [-]	400
Total Transmissivity [FT^2/day]	17000
Depth to Ambient Water Level [FT]	249.38
Depth at bottom of Plot [FT]	1156
Depth at top of Plot [FT]	336

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]
3	516.000	21.000	645.000	0.860	0.000
2	800.000	128.000	272.000	0.080	10.000
1	950.000	122.000	146.000	0.050	20.000
1	1136.000	16.000	50.000	0.010	25.000

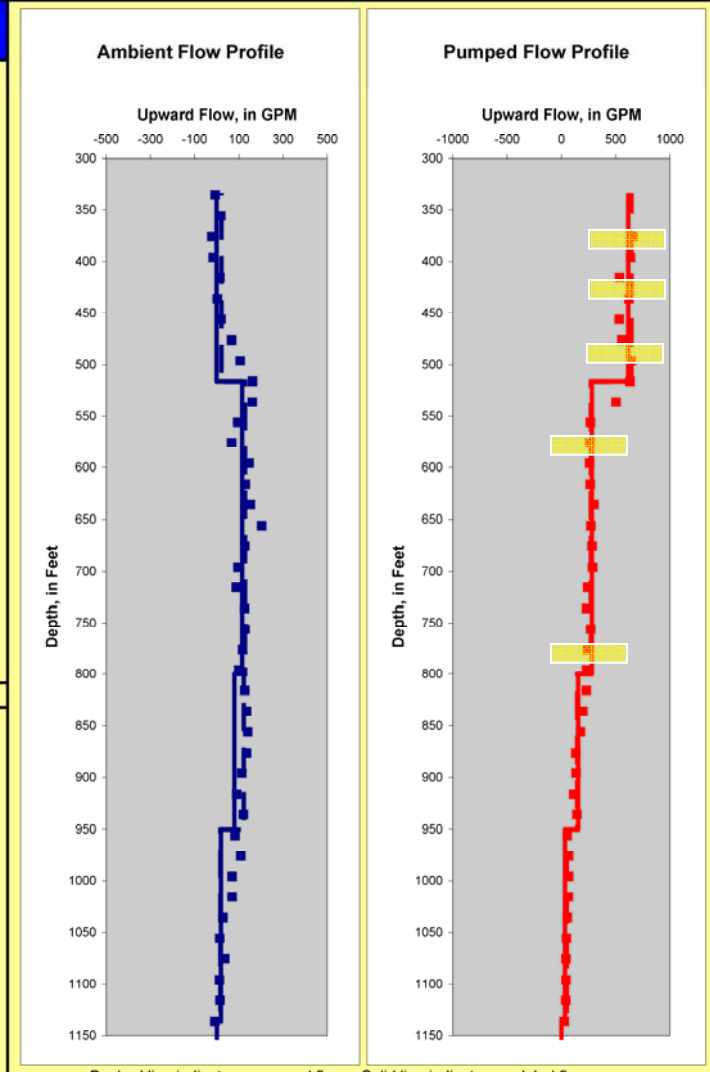
Elev, Ambient WL [FT] = 4894.62 Elev, Pumped WL [FT] = 4880.89

SIMULATION OUTPUT FROM FWRAP (DO NOT CHANGE)

SSE [GPM^2]	3682.14500
Ambient WL [FT]	-11.68000
Pumped WL [FT]	4.02502

RMS Error [GPM] = 30.3403403

FRACTURES:	Depth [FT]	Ambient Flow above [GPM]	Pumped Flow above [GPM]	Zone T [FT^2/day]	Water Level [FT]	Elevation of Water Level [FT]
4	516.000	-0.001	614.887	14620.000	251.430	4892.570
3	800.000	115.064	280.987	1360.000	241.430	4902.570
2	950.000	80.198	154.476	850.000	231.430	4912.570
1	1136.0000	19.4624	34.0320	170.0000	226.4300	4917.56982
0						



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

WARNINGS:

WARNING: INCREASE STEP FACTOR!!!!

USGS

Paillet, F. L. (2000), A field technique for estimating aquifer parameters using flow log data: Ground Water, v. 38, no. 4, p. 510-521.

Superfund Site Example

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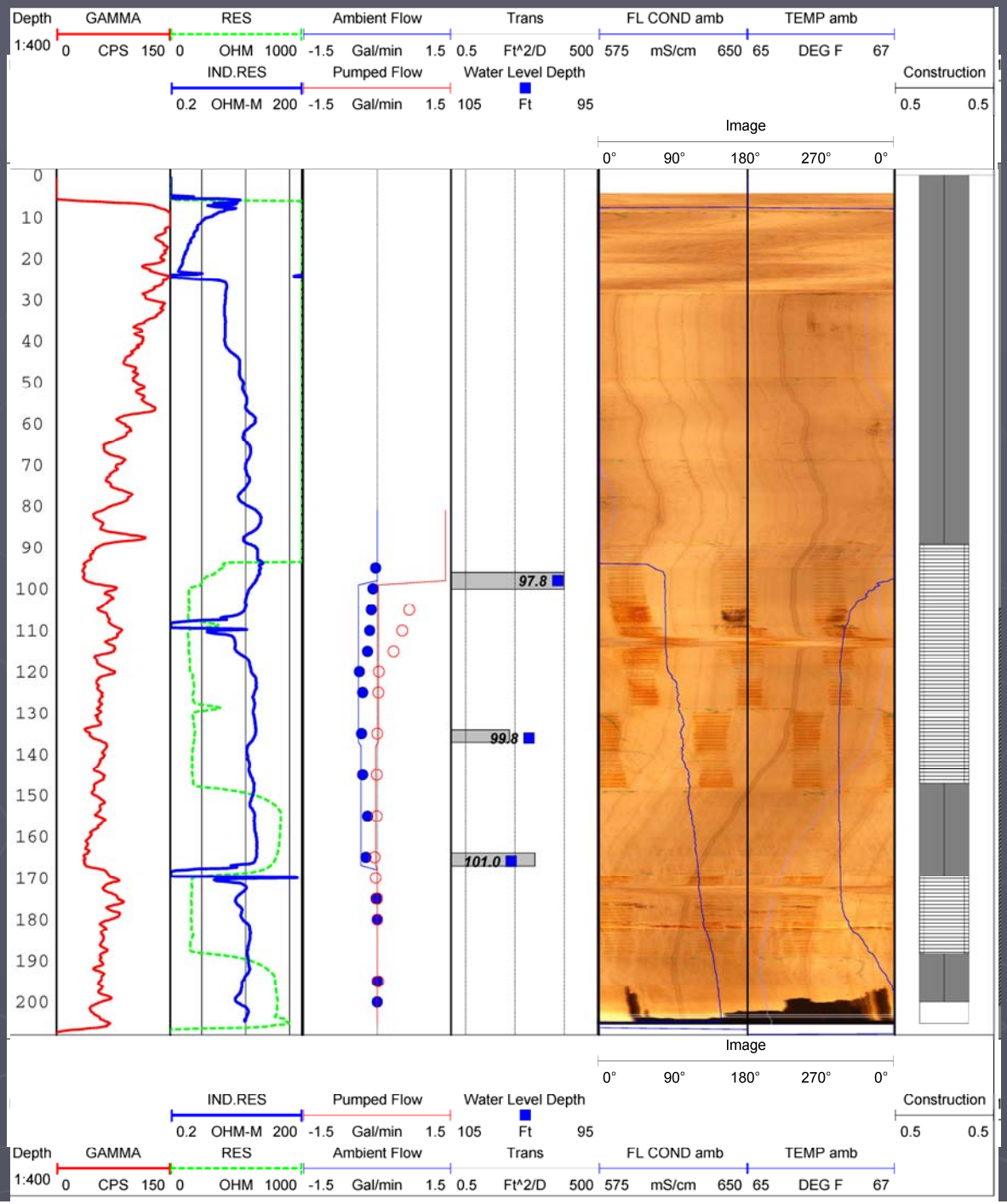
Ambient and Pumped Monitor Well Flow

- Ambient Flow causing downward movement in well
- Well Completion info incorrect
- Screen openings determined
- Correct well construction and flow info changes monitoring strategy



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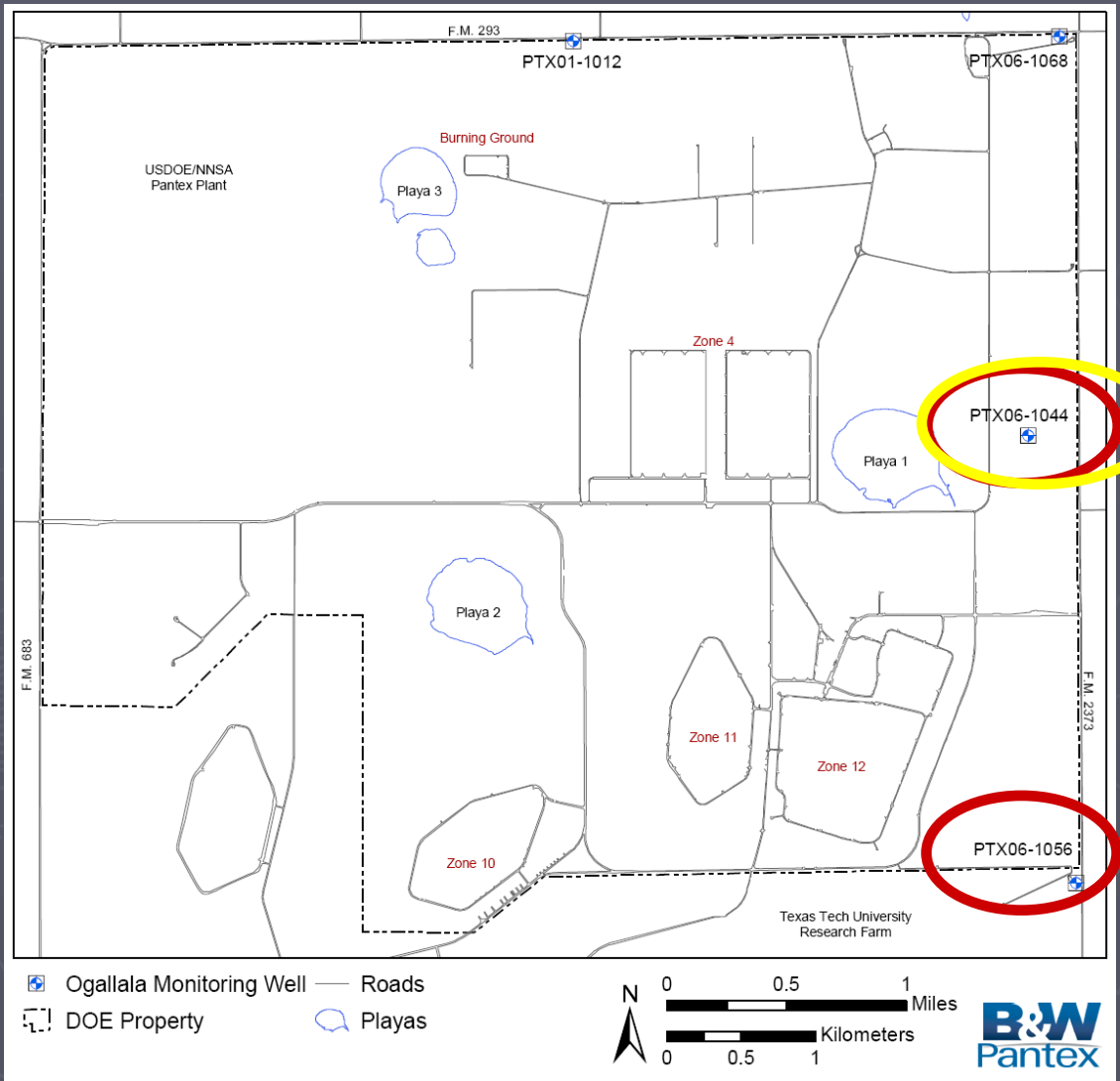
Ogallala Flowmeter Measurements at Pantex

Redeveloped Monitor Well Locations



USGS

PTX06-1044

FLOW-B INPUT AND PLOTS

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Wellname: PTX061044 Post Redevelopment Ogallala

REQUIRED INPUT:

Elevation of Measuring Point [FT]	
Number of fractures [-]	6
Well Diameter [IN]	4
Drawdown [FT]	17.2
Step Factor [-]	90
Total Transmissivity [FT^2/day]	520
Depth to Ambient Water Level [FT]	482
Depth at bottom of Plot [FT]	620
Depth at top of Plot [FT]	470

PLOT LOGS

RUN FWRA

LOAD/PLOT RESULTS

FRACTURES:	Depth [FT]	Flow above fracture Ambient [GPM]	Flow above fracture Pumped [GPM]	Zone Tfactor [-]	Zone H [FT]
6	495.000	0.019	5.000	0.002	0.000
5	530.000	-0.172	4.800	0.935	-9.000
4	555.000	0.040	2.400	0.020	-8.000
3	570.000	0.036	1.700	0.030	-8.000
2	590.000	0.022	0.600	0.013	-8.000
1	609.000	0.000	0.020	0.000	0.000

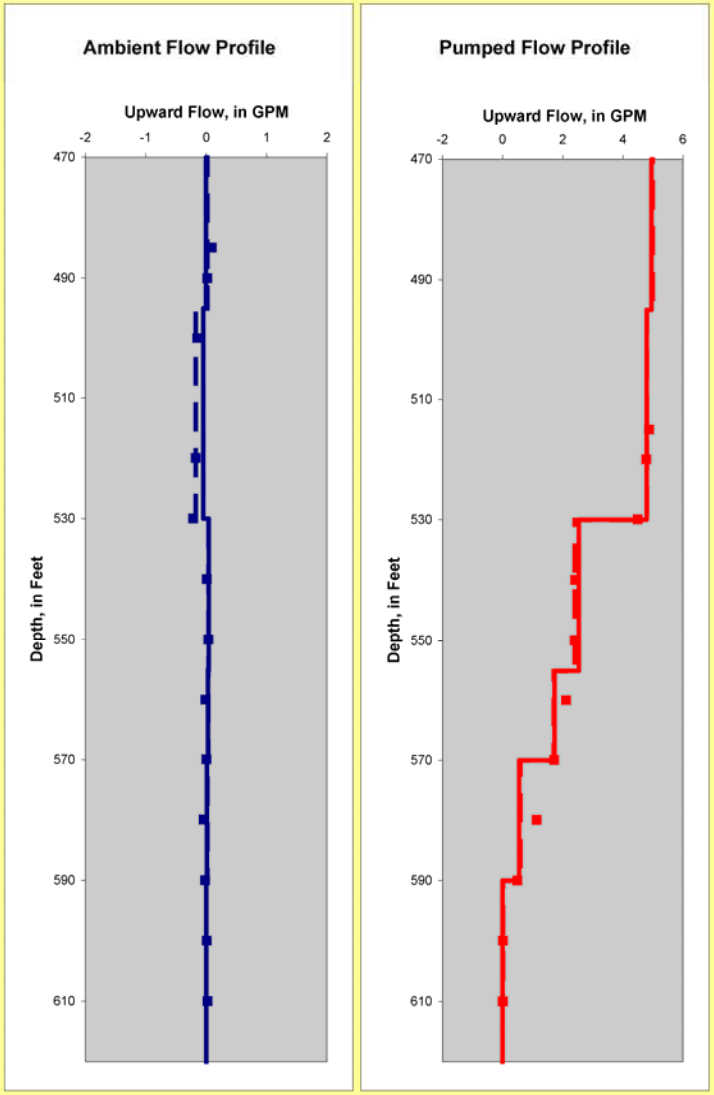
Elev, Ambient WL [FT] = -482.00 Elev, Pumped WL [FT] = -499.20

SIMULATION OUTPUT FROM FWRAP (DO NOT CHANGE)

SSE [GPM^2]	0.04151
Ambient WL [FT]	-26.11900
Pumped WL [FT]	-8.30373

RMS Error [GPM] = 0.08317363

FRACTURES:	Depth [FT]	Ambient Flow above [GPM]	Pumped Flow above [GPM]	Zone T [FT^2/day]	Water Level [FT]	Elevation of Water Level [FT]
6	495.000	0.000	4.952	1.040	473.081	-473.081
5	530.000	-0.049	4.798	486.200	482.081	-482.081
4	555.000	0.043	2.542	10.400	481.081	-481.081
3	570.0000	0.0289	1.7254	15.6000	481.0810	-481.08099
2	590.0000	0.0092	0.5511	6.7600	481.0810	-481.08099
1	609.0000	0.0000	0.0000	0.0000	473.0810	-473.08099
0						



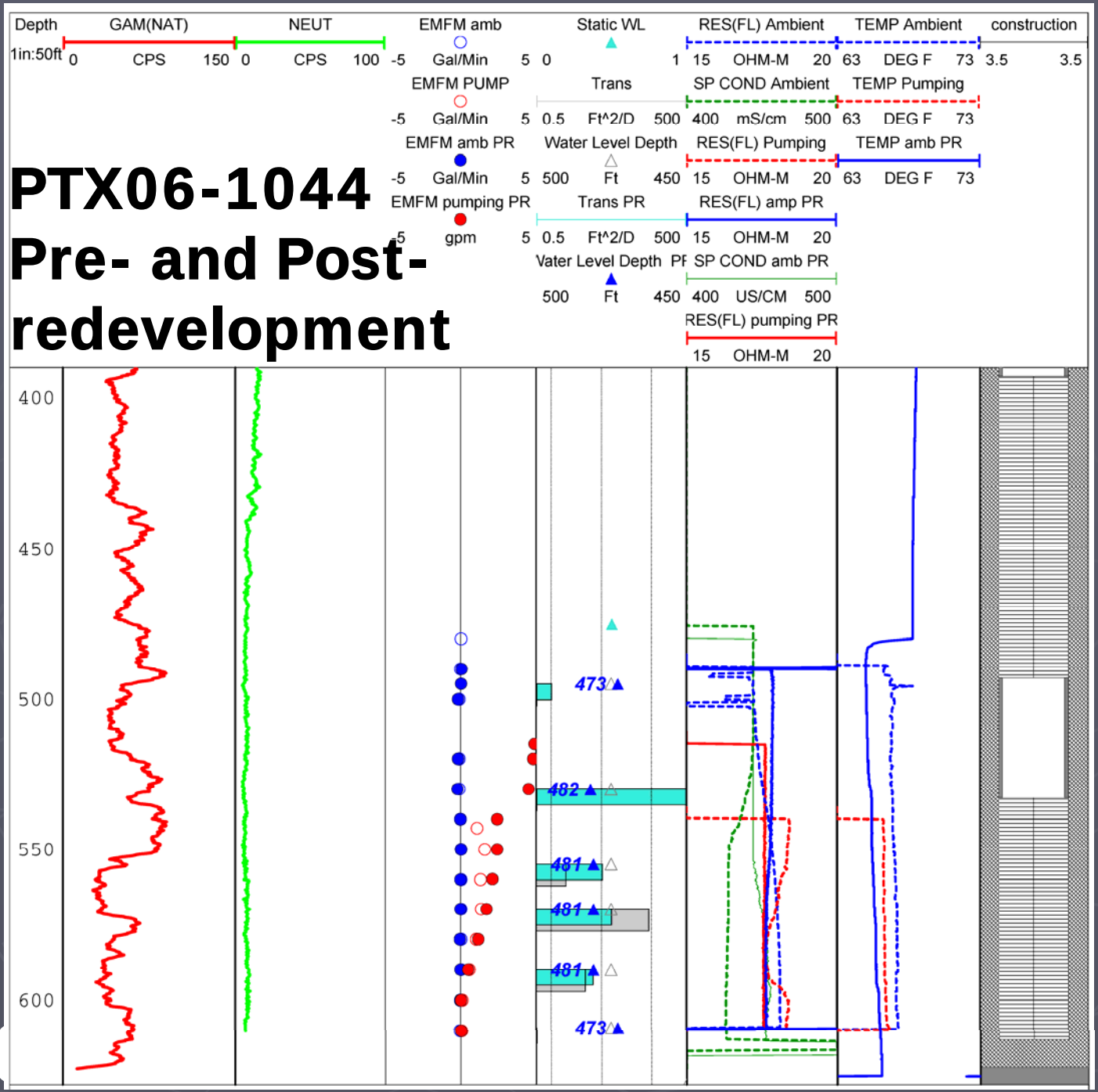
Dashed line indicates measured flow. Solid line indicates modeled flow.

WARNINGS:

WARNING: INCREASE STEP FACTOR!!!!

Flow-B5_PTX06_1044_post_redevel.xls

PTX06-1044 Pre- and Post-redevelopment



Conclusions

- Borehole geophysics goes beyond basic stratigraphy, and provides insight for sampling strategies
- Flowmeter logging in public supply wells can provide insight to wellfield dynamics that would be otherwise unknown
- Flowmeter logging coupled with imaging can confirm or correct well construction information and quantify zones of sampled inflow
- Flowmeter logging can be used to evaulate the need and results of redeveloping wells

USGS

USGS Geophysical Resources

- Office of Ground Water Branch of Geophysics
  - John Williams, Alton Anderson, (Troy, NY) or Carole Johnson (Storrs, CT)
- Borehole Geophysics in Region VI
  - Arkansas WSC – Brian Clark, Jonathan Gillip, Rheannon Scheiderer
  - Texas WSC – Greg Stanton, Mike Nyman, Jon Thomas
- Surface Geophysics
  - Texas WSC – Wade Kress
  - Nebraska WSC – Jim Cannia
  - Geologic Discipline – Crustal Imaging – Vic Labsen, Bruce Smith, Jared Abraham
- Other USGS Borehole Resources
  - National Research Program – Denver
    - Roger Morin/Barbara Corland
  - Central Region Drilling Program - Denver

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