Interesting Field Observations During Development of an Aquifer Monitoring Network Associated with a Mine Decommissioning Project

William H. Pedler[1] and Jeffery R. Meadow[2]

[1]RealTime Aquifer Services (RAS, Inc) ***Golden, Colorado;***

www.rasinc.org

[2]Nutrien , Suite 500, 122 – 1st Avenue South, Saskatoon, SK

www.nutrien.com

REALtime Aquifer Services

Acknowledgements

- Jeff Meadows - Co-author
- Vernon Banks – Wood Consultants
- Melinda Hanson - Nutrien
  - Site Manager
- Alex Spaskyy – RAS Log Analyst
- Lacey Williams – RAS Principal
- E.R. Steeves -
- Timber Motel, Bar, Grill and Office

Unspecified Project Site in Eastern Canada

REALtime Aquifer Services

Borehole Geophysical, Hydrophysical and Straddle Packer Testing

- 5 wells were investigated
- Total Depth ranged from 200 to 300 meters
- Wellbores were advanced by air hammer methods
  - Traditional drilling measurements recorded
  - Drill chips were collected at 1 meter intervals

REALtime Aquifer Services

Borehole Methods Used

- Analog Video
- Natural gamma
- 3-arm caliper
- Resistivity (16-64 normal, single point resistance and induction)
- Gamma-gamma density
- Full Waveform Sonic

REALtime Aquifer Services

Borehole Methods Used (con't)

- Optical Televiewer
- Acoustic Televiewer
- EM - HPL Flowmeter (HPEM)
- Straddle Packer Testing (pressure monitoring, hydrogeologic evaluation and groundwater sampling)

REALtime Aquifer Services

Acoustic Televiewer

Hydrophysical Tool

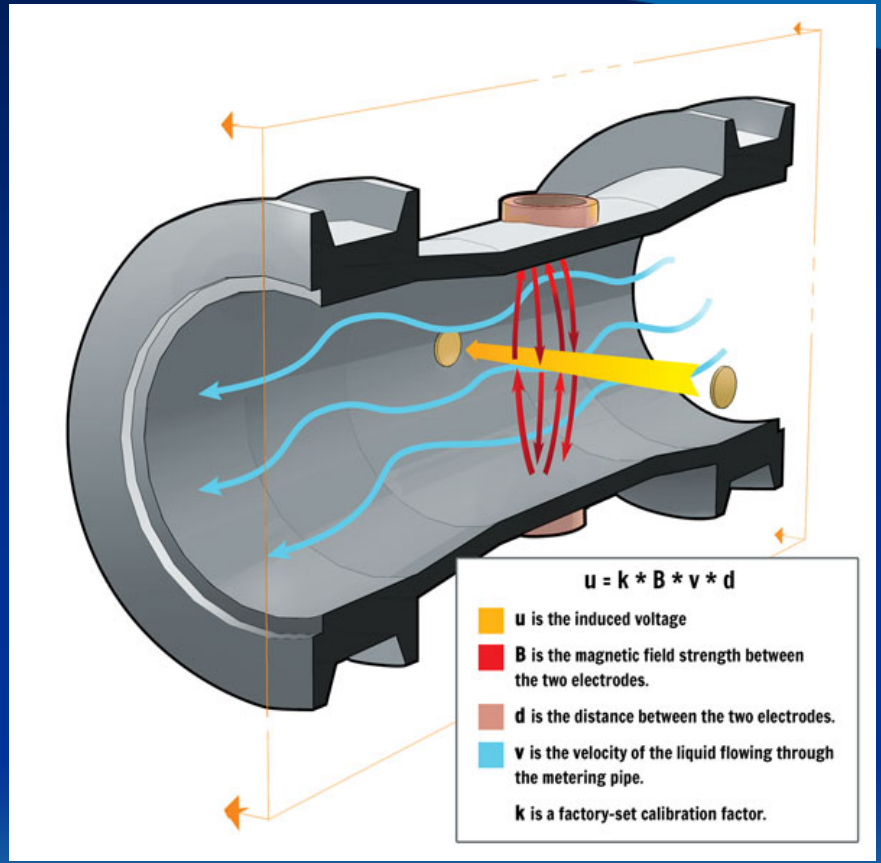
3 – Arm Caliper

EM-HPL Tool

REALtime Aquifer Services

EM FLOWMETER

Operates according to Faraday's Law of Induction. Voltage induced across a conductor moving at right angles through a magnetic field is proportional to the translational velocity of the conductor. Water is the conductor.



REALtime Aquifer Services

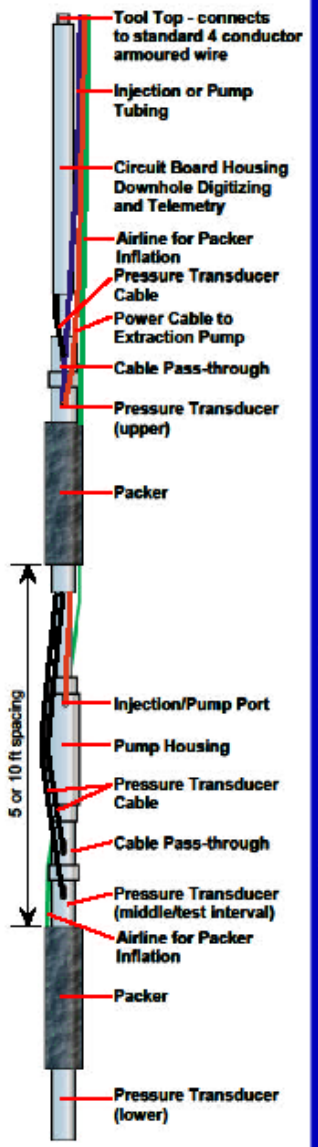
EM-HPL Flowmeter

REALtime Aquifer Services

Wireline Straddle Packer

REALtime Aquifer Services

Wireline Straddle Packer



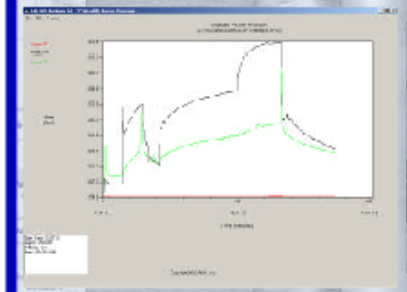
RAS has developed a new wireline straddle packer system applicable for measuring interval specific formation permeability, pressure and water quality.

Benefits -

This system is more cost effective and technically superior when compared to traditional straddle packer assemblies:

- Three zone dedicated pressure transducers for real time confirmation of hydraulic isolation.
- A single person can operate the system - no drill or pump rig is required to operate or adjust packers once they are installed;
- The depth resolution is more accurate due to incorporation of a wireline depth encoder;
- Packer depth adjustments are easier and faster for optimal packer seals against borehole wall;
- The system can be used as an efficient platform for injection of fluids into the formation as associated with:
  - remediation efforts
  - crosshole hydraulic testing (medium to large scale permeability evaluation)

Additional advantages can be realized when this system is coupled with RAS's hydrophysical logging method, a proven technology for identifying flow zones and estimating flow capacity. When these techniques are used together, the amount of time and cost required for overall permeability and contaminant evaluation can be significantly reduced.



Example of real time pressure display

Photo of WSP installation

SPECIFICATIONS	
TOTAL HYDRAULIC HEAD	600 ft
MAXIMUM PACKER INFLATION	500 psi
MINIMUM HOLE DIAMETER	3 in
MAXIMUM HOLE DIAMETER	10 in
MAXIMUM TEMPERATURE	66°C (150°F)
Can be custom configured for other borehole diameters and depths	

Wellhead setup, fluid control panel, flow data recorder, and portable winch with packer data collection computer.

RAS Integrated Subsurface Evaluation

311 Rock Avenue • Golden, CO 80401
http://www.rasinc.org
PH: 303.526.4432 • FAX: 303.526.4426

Pipe Mounted Straddle Packer

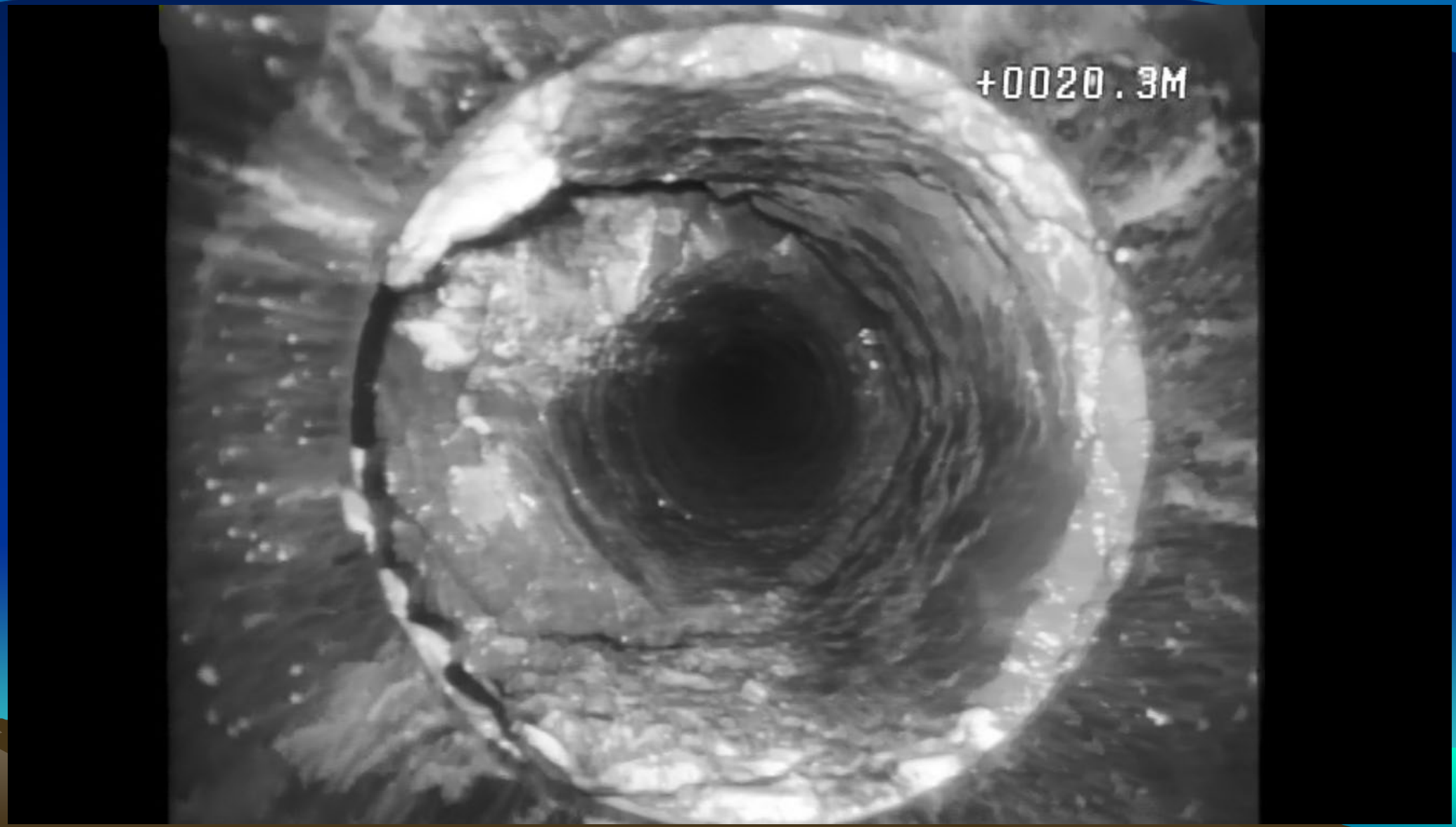
REALtime Aquifer Services

Analog Video

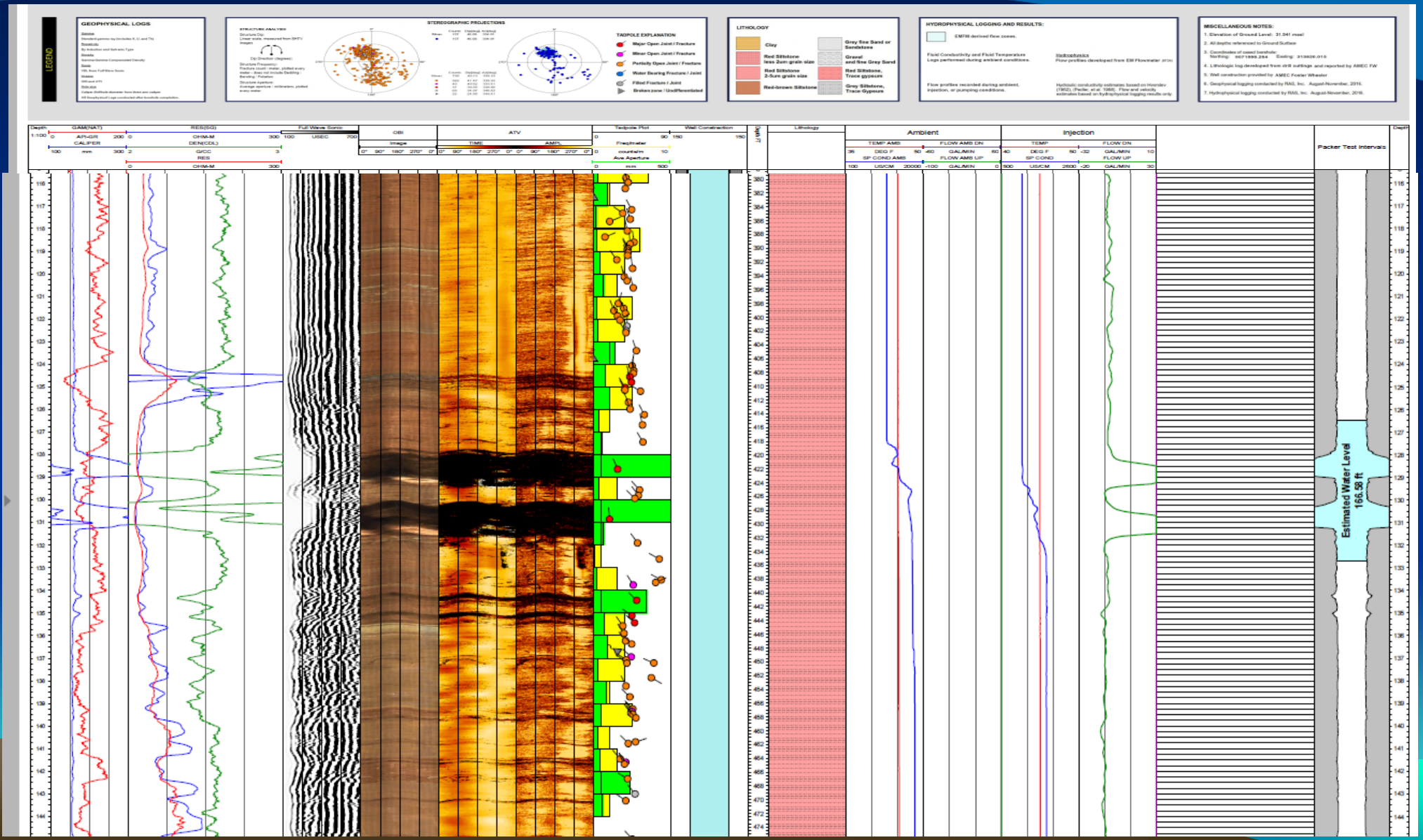
- Cascading water from “perched” zones
- Multiple perched inflowing zones
- Additional inflow zones in saturated
- Extreme downflow (<100 lpm) and exiting at bottom of wellbore
  - Erosion of borehole wall?
  - Enhanced inflow to mine pool?
  - Impact to the local system we are characterizing
  - Need to put a plug in the drain!

REALtime Aquifer Services

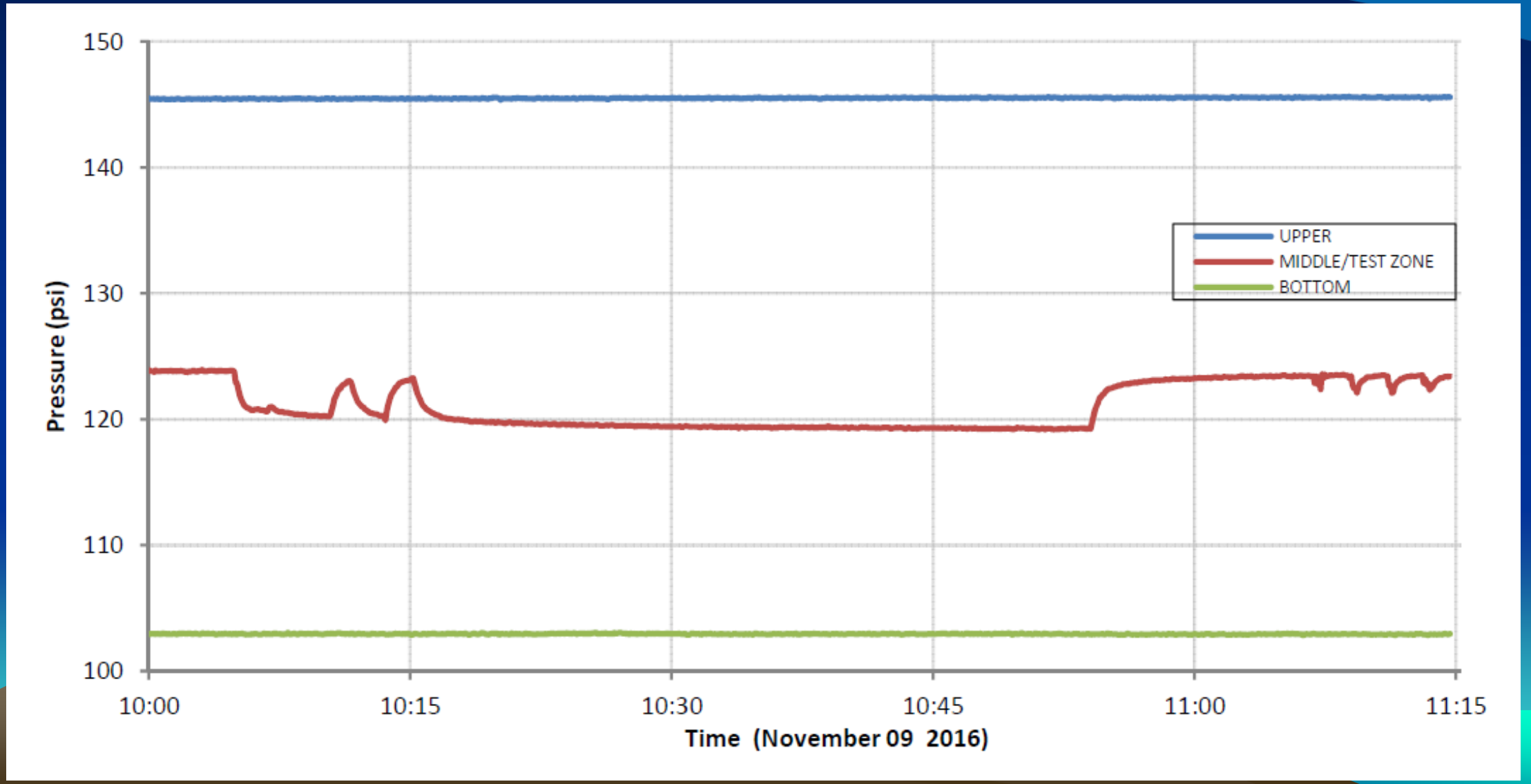
Video Log with minor inflow at BOC



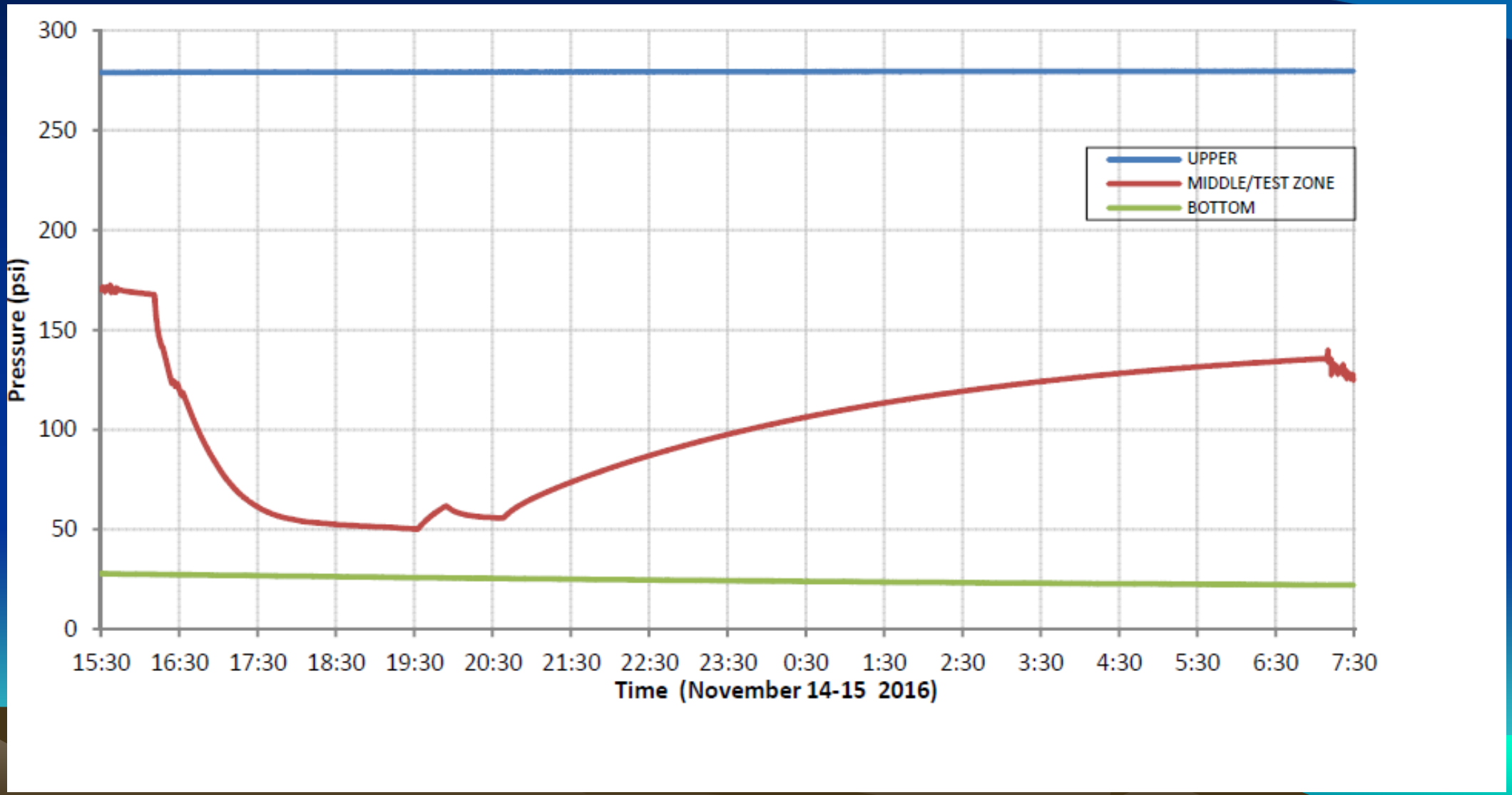
Data Montage Well 16-117
Highlight of Conductor #2



Straddle Packer Data Example
Conductor #2



Straddle Packer Data Example 240.18 – 246.28 metres



Well 16-117
Straddle Packer Evaluation Results

Straddle Packer Interval No.	Depth of Straddle Packer Interval (m)	Estimated Hydraulic Conductivity (m/day)	Average Flow Rate During Sampling (Lpm)	Maximum Drawdown During Sampling (m)	Interval Salinity (µS/cm)	Estimated Depth to Ambient Water Level (mbgs)
1	70.71-76.81	*	13.2	*	900	*
2	126.5-132.6	1.67	20.4	3.2	6,000	50.77
3	158.5-164.6	1.52	24.2	4.2	1,200	59.79
4	183.5-189.6	6.01E-02	16.3	71.8	1,300	56.97
5	197.2-203.3	1.23	20.8	4.5	1,600	62.10
6	204.2-210.3	3.36E-01	18.9	14.9	2,200	66.55
7	215.2-221.3	8.78E-01	20.4	6.1	14,000	64.73
8	240.2-246.3	4.85E-02	15.1	82.7	86,000	133.50

REALtime Aquifer Services

Summary of Straddle Packer Testing

- Eight (8) conductive intervals were identified;
- All the conductive intervals could be tested with the same sample length;
- Packer testing in the subject well took three, 10- hour shifts to complete.
- Hydraulic conductivity estimates were calculated and ranged over three orders of magnitude (6.0E-02 to 1.7 m/day).
- salinity ranged from 900 to 86,000 µS/cm.
- hydrostatic pressure dramatically decreased with depth.

REALtime Aquifer Services

Conclusions

Geology and structure/fractures

Fractures were distributed among all the geologic units, no single geologic unit had a greater propensity for fractures

Structure and groundwater relationships

22.8 % of all fractures were water-bearing

increase in hydraulic conductivity apparent aperture

decrease in hydraulic conductivity not observed

Mine pool and structure/fractures

Boreholes with greater conductive fracture density were, in general, closer to the mine footprint.

REALtime Aquifer Services

Conclusions (con't)

- **Groundwater and Mine Pool –**

  this well displayed collapsed structure features and associated fracture dilation.

  Wells further away from the mine pool were highly fractured but typically did not contain fractures with large apertures and displayed much fewer flow features.

REALtime Aquifer Services

Summary

- Results of this work provided initial ground water quality, characterized conductive features and identified hazards
- Information used for selection/design of monitoring system
  - Select a robust system that would survive installation
  - Design input
    - location of conductive features, borehole diameters for good seals, pressure gradient, water chemistry
  - Consideration of strong down flow and cascading water

REALtime Aquifer Services