SAND2010-7899P

Culebra Long-Term Monitoring Program

KAERI Hydrology Short Course

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Kris Kuhlman
Sandia National Laboratories

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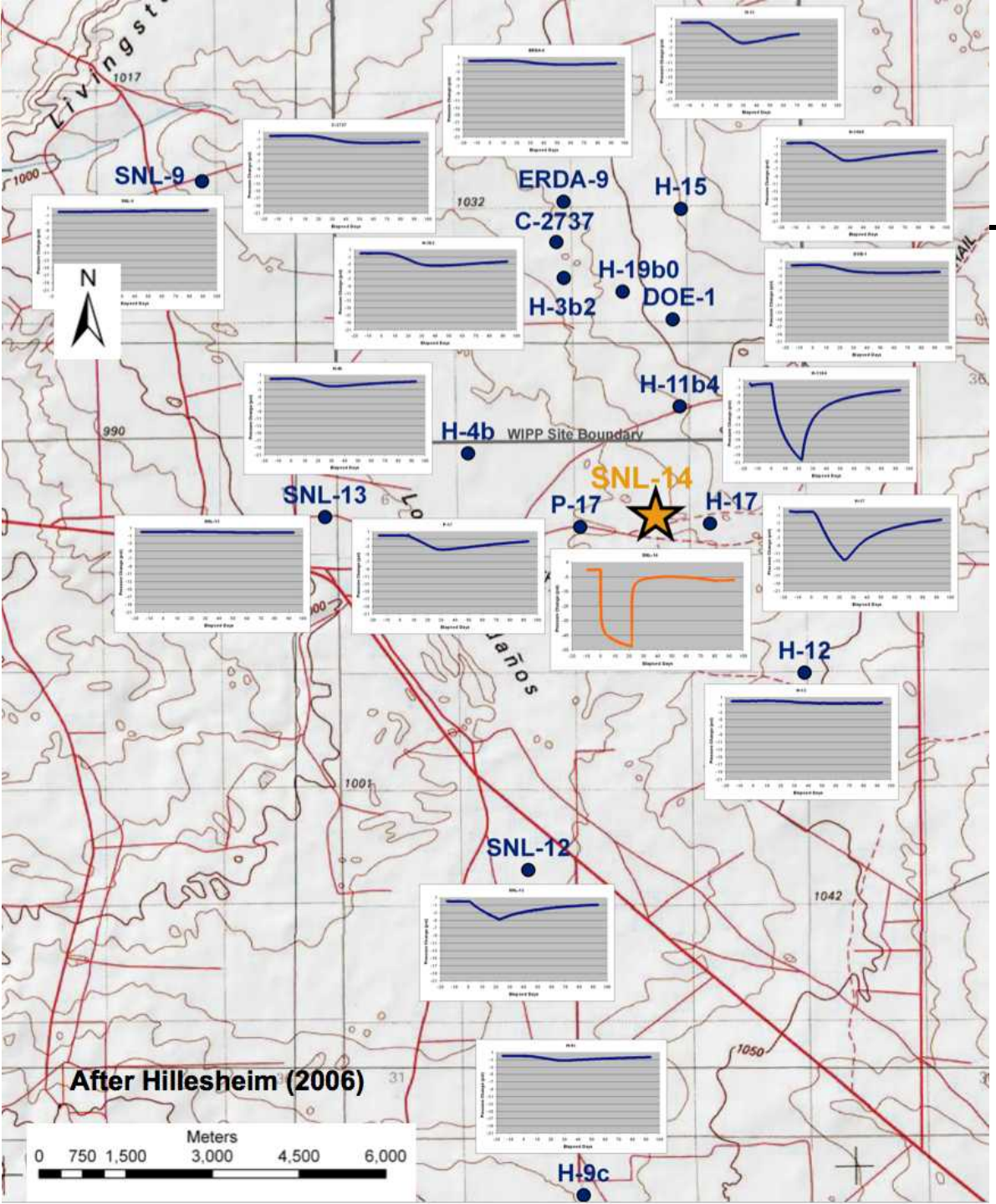
Outline

- SNL Long-Term Monitoring (LTM) Program
  - PA Driver
  - Background
  - How LTM Developed
- Pressure Data
  - Documentation
  - Data Collection
  - Network
  - SNL Hydrology Database
- Pressure Density
  - How it is Calculated
  - Freshwater Head (FWH)

Culebra Well-Testing Program

- **Performance Assessment (PA) modeling of Culebra flow + transport requires data**
  - **Local-scale Transmissivity (T) at pumping wells**
  - **Large-scale T and estimates of heterogeneity**
  - **Large-scale transient drawdown data for calibrating model**
- **~90 single-well Culebra pumping tests**
- **6 large-scale multi-pad Culebra tests**
  - **Pressure transducers (Trolls) in many wells**



Background – Well Testing

2005 SNL-14 Multipad Pumping Test

Pumped at a constant rate of 30 gpm for 22 days

Response observed in wells up to 10 km away

15 wells instrumented with pressure transducers for observing SNL-14 pumping + recovery

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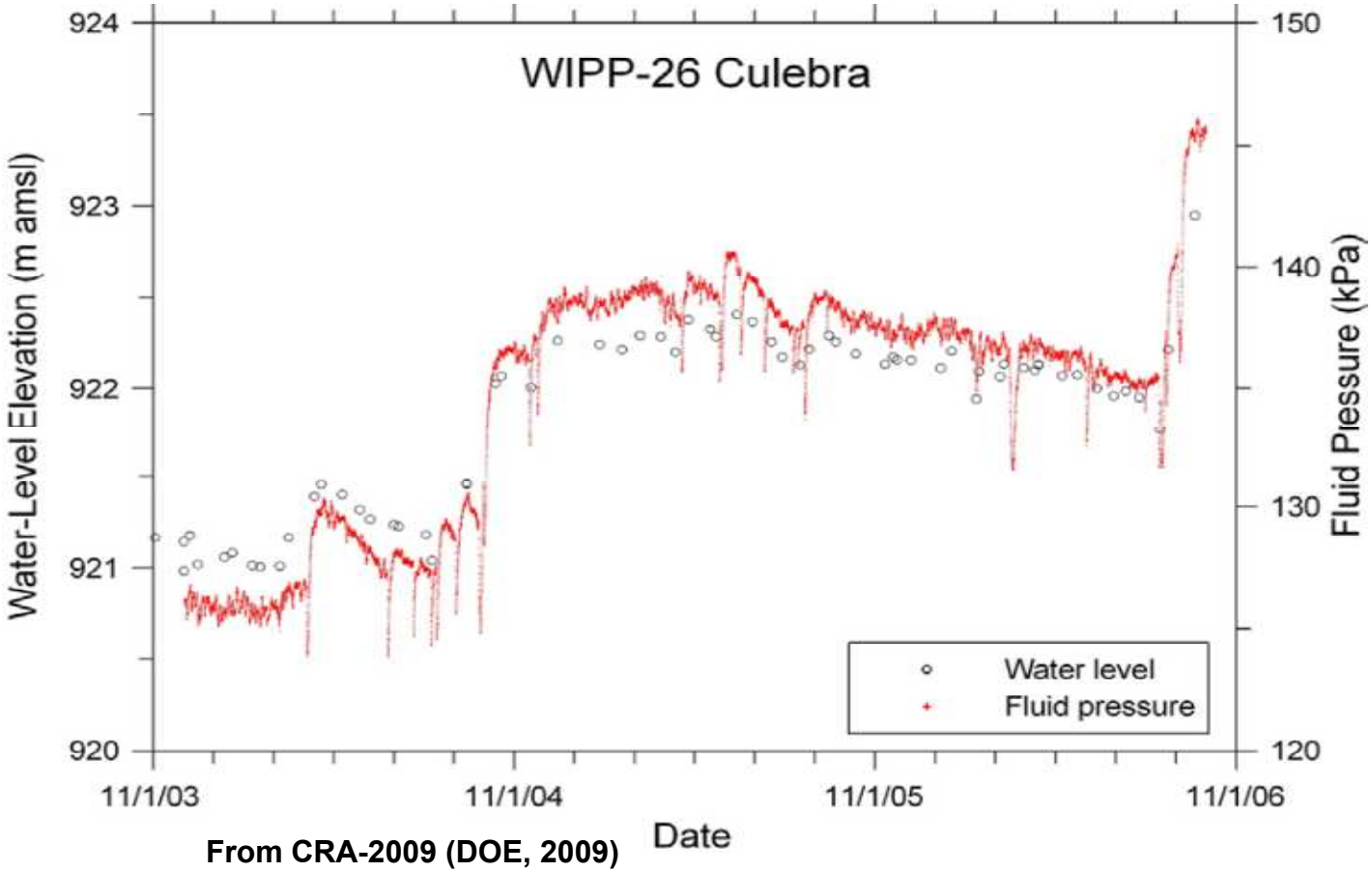
Background - Pressure Head Data

- Hourly pressure-head vs. monthly water-level data



From CRA-2009 (DOE, 2009)

Monthly water levels (dots) not revealing entire picture

Apparent measurement noise revealed to be coherent short-term fluctuations

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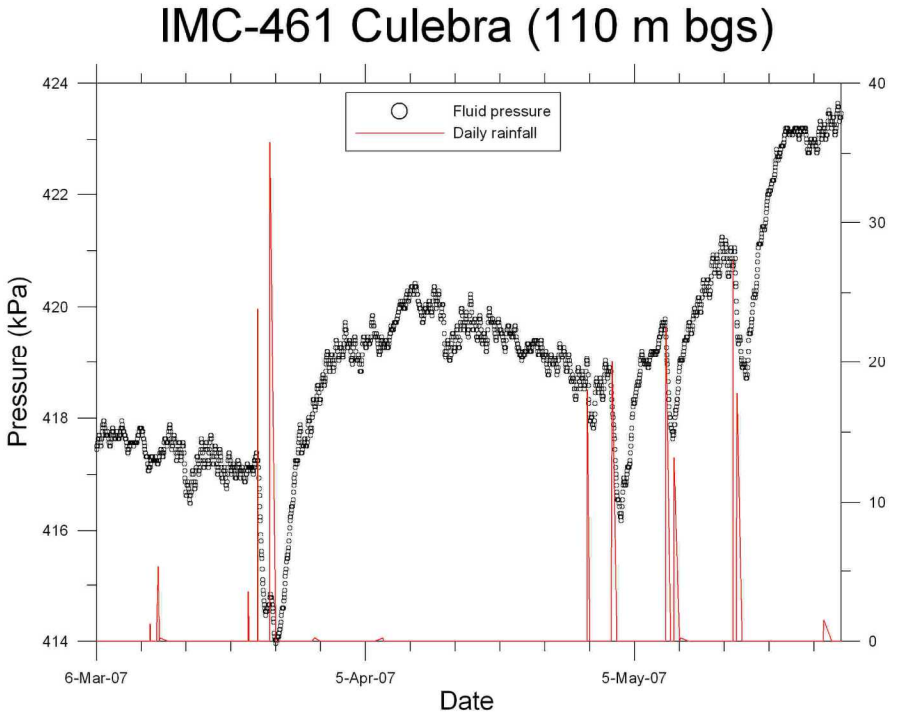
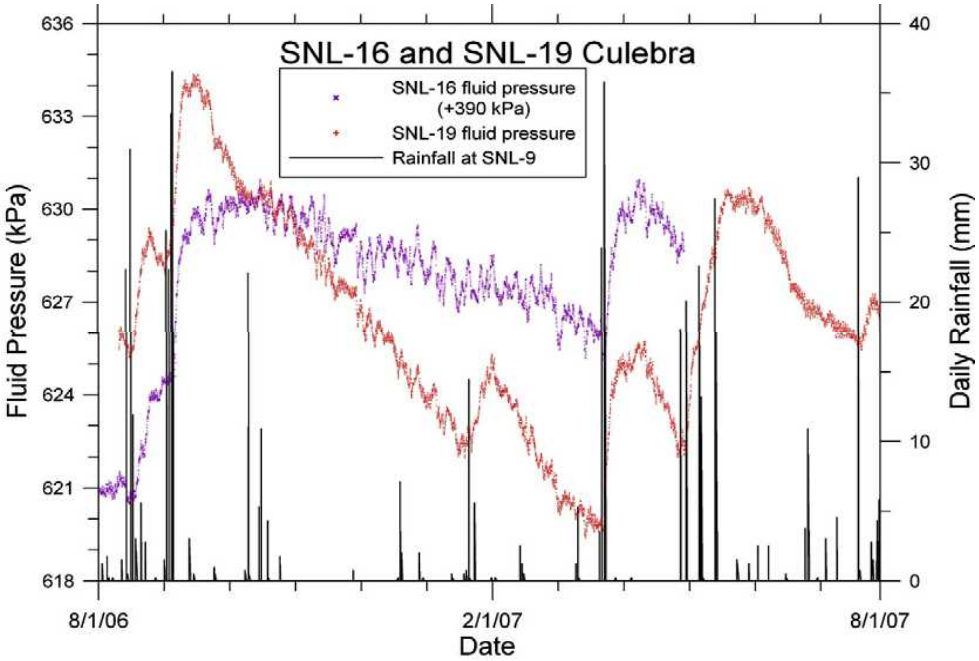
Background – Response to rainfall Events

Large/intense rainfall events appear to affect pressure-head in wells, especially those located in or near to Nash Draw.





From CRA-2009 (DOE, 2009)

Higher-frequency data reveals clear response to rainfall events.

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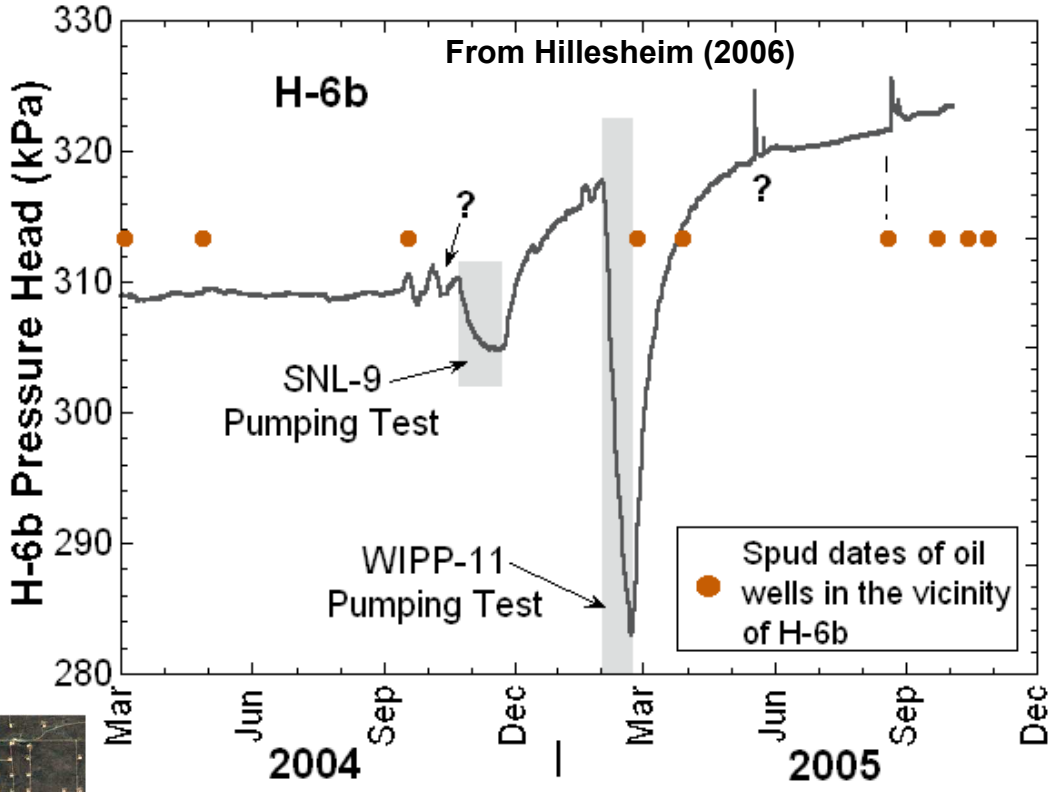
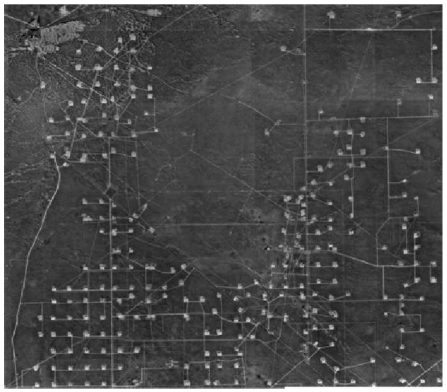
Background – Oilfield / Potash Activities

Oil and gas and/or potash exploration activities

Some short-term effects due to oil / gas well drilling through Culebra.

Monthly monitoring might miss this entirely.




DOQQ taken sometime in 1996-1998


DOQQ taken 2005 Irrigation Season

Very active oil/gas field area near WIPP.

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Controlling Documents

- **TP 06-01 "Monitoring Water Levels in WIPP Wells"**
  - **LTM Formalized in 2006.**
  - **The governing/strategy document for SNL LTM covers:**
    - Monitoring strategy (pressure-head, barometric pressure, rainfall etc.)
    - Data collection
    - Data retrieval and control
  - **Developed under the guidance of SNL QA:**
    - **NP 20-1 "Test Plans"**
    - **NP 20-2 "Scientific Notebooks"**
    - **NP 17-1 "Records".**
  - **Subject to annual audits by EPA and DOE.**
  - **Subject to internal QA audits and surveillances.**

Supporting and QA Documents

- Supporting Documents
  - SP 9-7 “WIPP Well Water-Level Monitoring”
  - SP 12-5 “Depth-to-Water Measurement using a Solinst Brand Electric Sounder”
  - SP 12-23 “Rainfall Measurements Using an ONSET Brand Data-Logging Rain Gauge”
- Other QA Documents
  - NP 12-1 “Control of Measuring and Test Equipment”

Monitoring Instrumentation

– **Solinst Brand Water Level Meter**
  - **Graduated tape on reel**
  - **Electric buzzer indicating water**

– **ONSET Brand Rain Gage**
  - **Tipping bucket**
  - **Internal datalogger**

Instrumentation - Troll

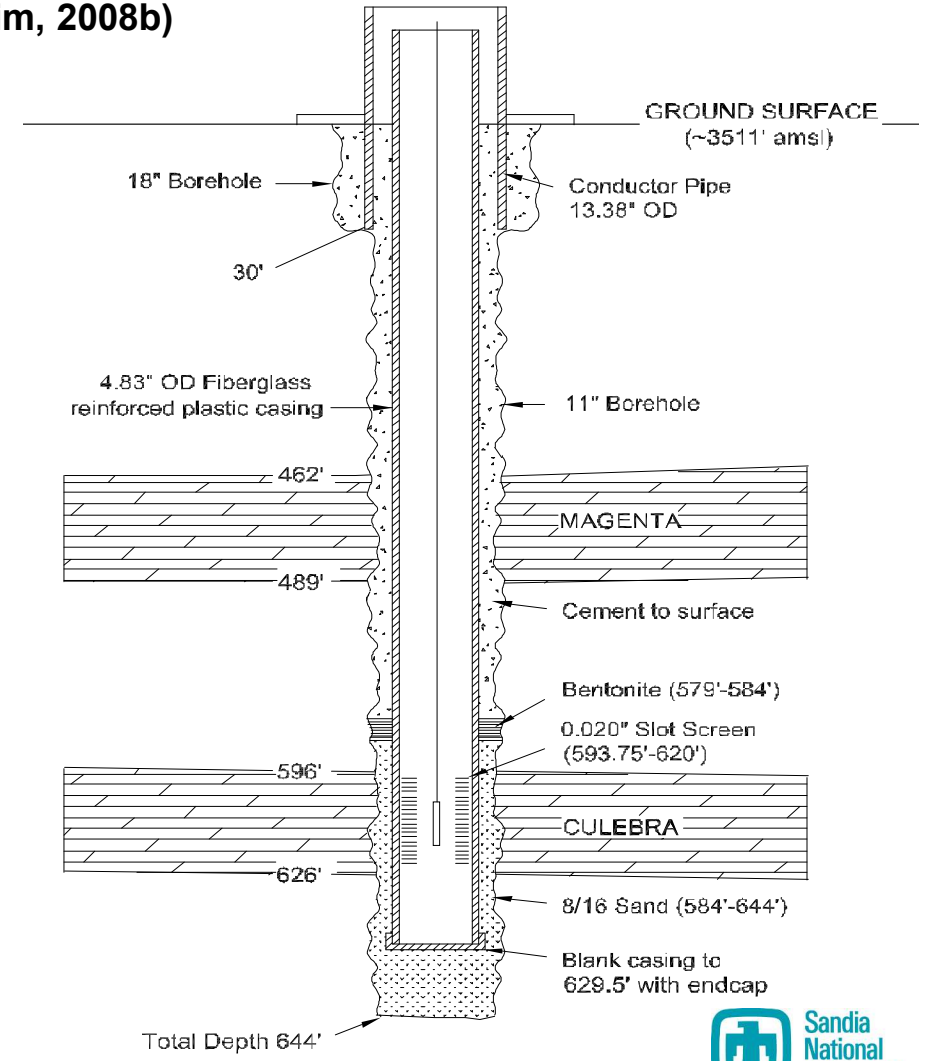
- **In-Situ Brand MiniTROLL (calibrated every 2 yrs)**
  - **(accuracy = 0.08% of full-scale range)**
- **In-Situ Brand LevelTROLL 700 (calibrated every 1 yr)**
  - **(accuracy = 0.05% of full-sale range)**
- **w/ In-Situ Brand cables**

(Hillesheim, 2008b)

TROLL Installation Procedure

(per Hillesheim, 2008b)

- **Prior to Installation, perform surface check: determine if it is within Acceptance Criteria (AC).**
- **A TROLL is then installed at mid-formation, on a graduated TROLL cable.**
- **TROLL checked at depth to confirm operation**



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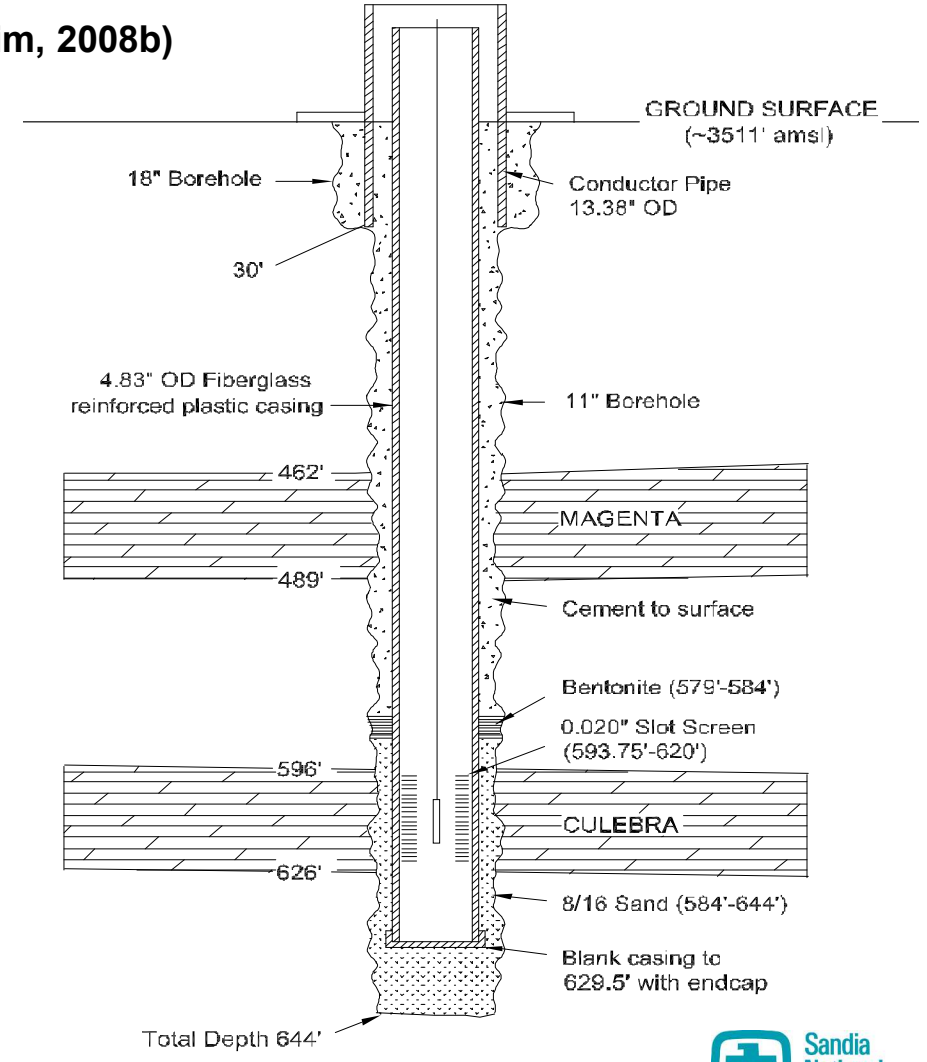
TROLL Installation Procedure (2)

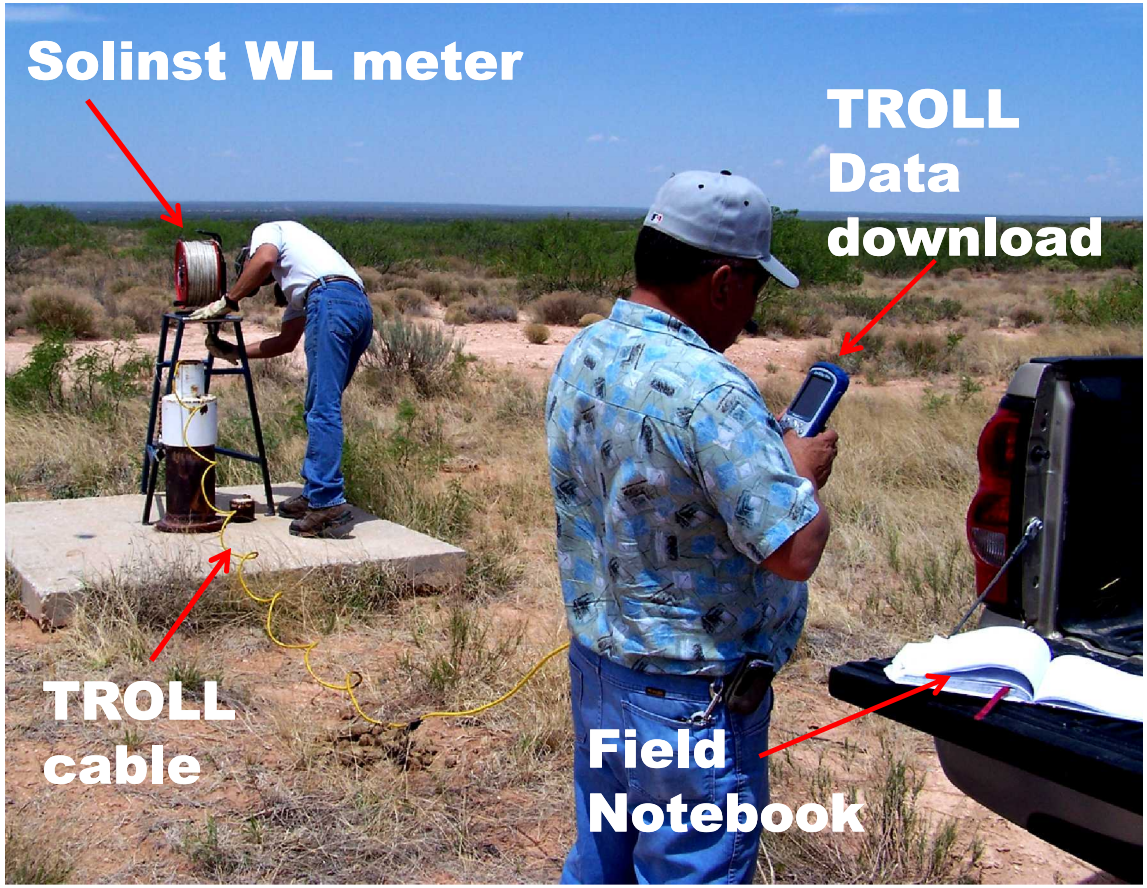
(per Hillesheim, 2008b)

- After removing TROLL (i.e., due for calibration, suspected failure, etc.) another surface check is completed.
- If a TROLL is found to be outside of AC it is replaced and data are flagged using the corrective action reporting (CAR) process.



Data Collection

- Data is downloaded from the TROLLs as part of the SNL Monthly Monitoring Run (MMR), which is logged in a Scientific Notebook along with other supporting information.



At the time of data download a depth-to-water (DTW) measurement is made to a surveyed reference point on the wellhead using a field-checked Solinst.

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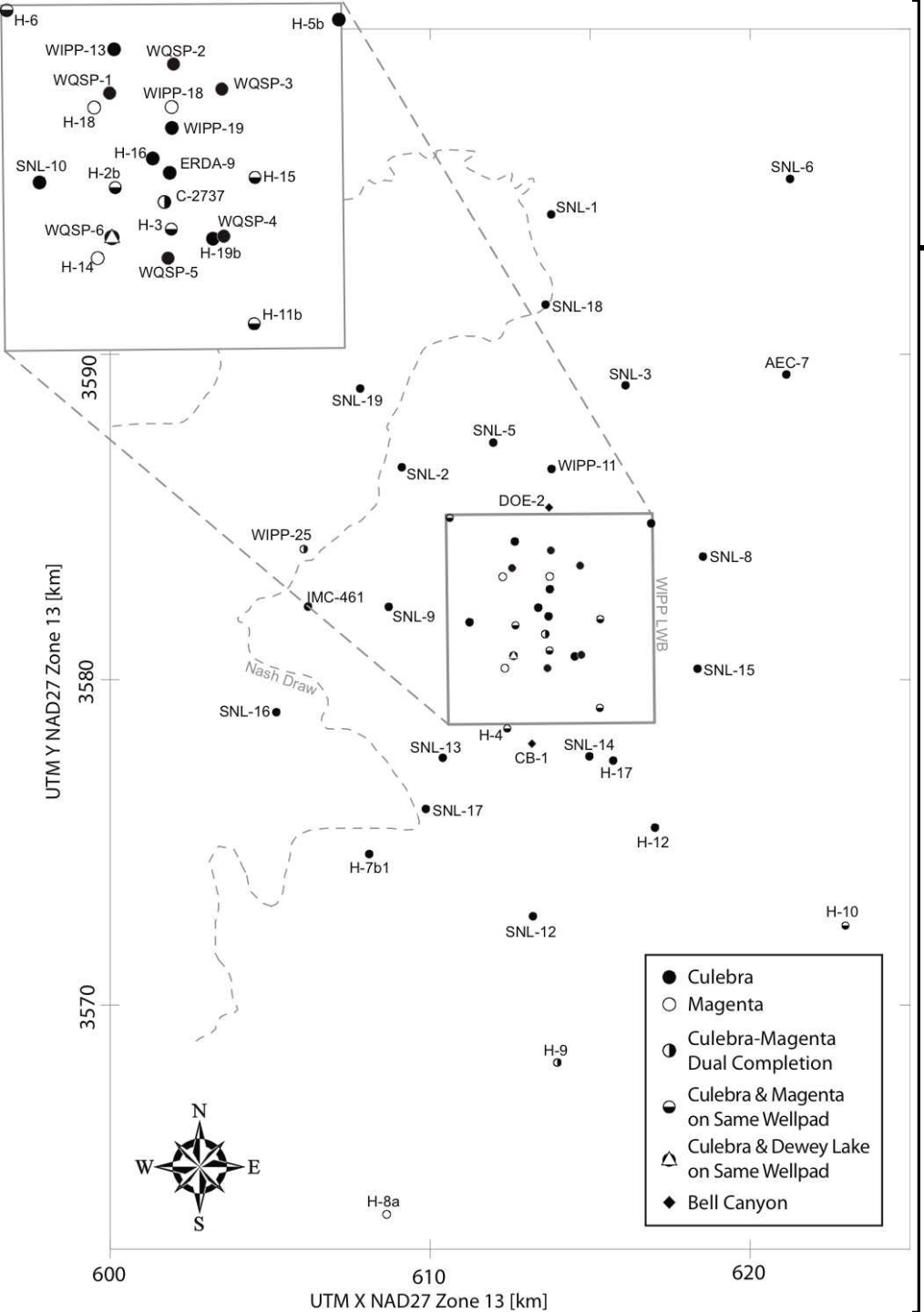
Scientific Notebook and TROLL Data Review

- 2 Reviews within one week of the :
  - Monitoring Coordinator review of entries for completion and accuracy (i.e., no write-overs) and collection of the TROLL metadata.
  - Monitoring Team Lead review of entries and TROLL metadata to identify any possible problems with TROLLs and/or TROLL data.
- After major events and/or at the end of the each notebook, technical and QA reviews are completed.
  - Has monitoring followed steps in procedures?

SNL TROLL Network

- **Well Network 65 wells**
  - **50 Culebra monitoring points (38 w/ TROLLS)**
  - **14 Magenta monitoring points (10 w/ TROLLS)**



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SNL Hydrology Database

- SNL is in the process of developing a database that will integrate its hydrology data.
  - TROLL Data (w/ metadata)
  - Water Level Data
  - Well Construction Information
  - Rainfall Data
  - Water-Quality Data

- The database will make reporting and analysis more efficient and robust.

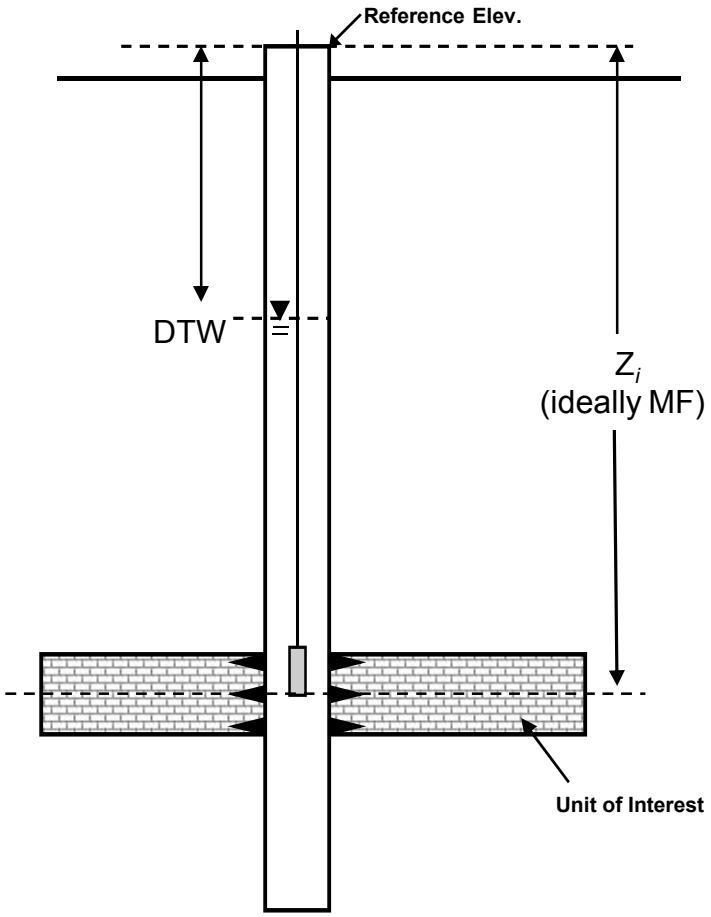
Calculation of Water Density

- Freshwater head (FWH) required to assess flow direction, accounting for density effects.
  - Convert observed WL to equivalent FWH using density
  - Convert TROLL pressure to FWH directly
- Well Water Density Data Feeds
  - Hourly Pressure-head data
  - Water-level data (based on DTW measurements)
  - Barometric-pressure data
  - Metadata:
    - TROLL installation depth information (ideally mid-formation elevation)

Calculation of Water Density

(per Johnson, 2009)

$$\rho_p = \left[\frac{\left(P_{meas*} \times \rho_f \right)}{\left(Z_i - DTW \right)} \right] / C$$



Where,

ρ_p = pressure density (g/cm^3)

ρ_f = density of freshwater (~1.0 g/cm^3)

P_{meas*} = measured pressure head corrected for barometric pressure, if necessary (psia or psig)

Z_i = installation depth of TROLL (m), ideally mid-formation (MF) depth from Johnson (2008)

DTW = depth to water (measured in ft, converted to m)

C = conversion coefficient (~1.4222 psi/m, for fresh water)

Calculation Water Density

(per Johnson, 2009)

- **For TROLLs with absolute pressure (psia) sensors, the closest corresponding barometric pressure values were subtracted from the pressure head value to remove the effects on atmospheric pressure.**

- **The pressure-density value for a given date and time is calculated using the closest corresponding water level data (from both SNL and WRES) to the pressure-head data points.**

- **Depending on data availability, a number of pressure densities are calculated and averaged for a final value.**

Calculation of Freshwater Head

- **FWH Calculated using pressure density**

$$FWH = \left[\left(WL - MF \right) \times \left(\frac{\rho_p}{\rho_f} \right) \right] + MF$$

Where,
WL = water level elevation (m amsl)

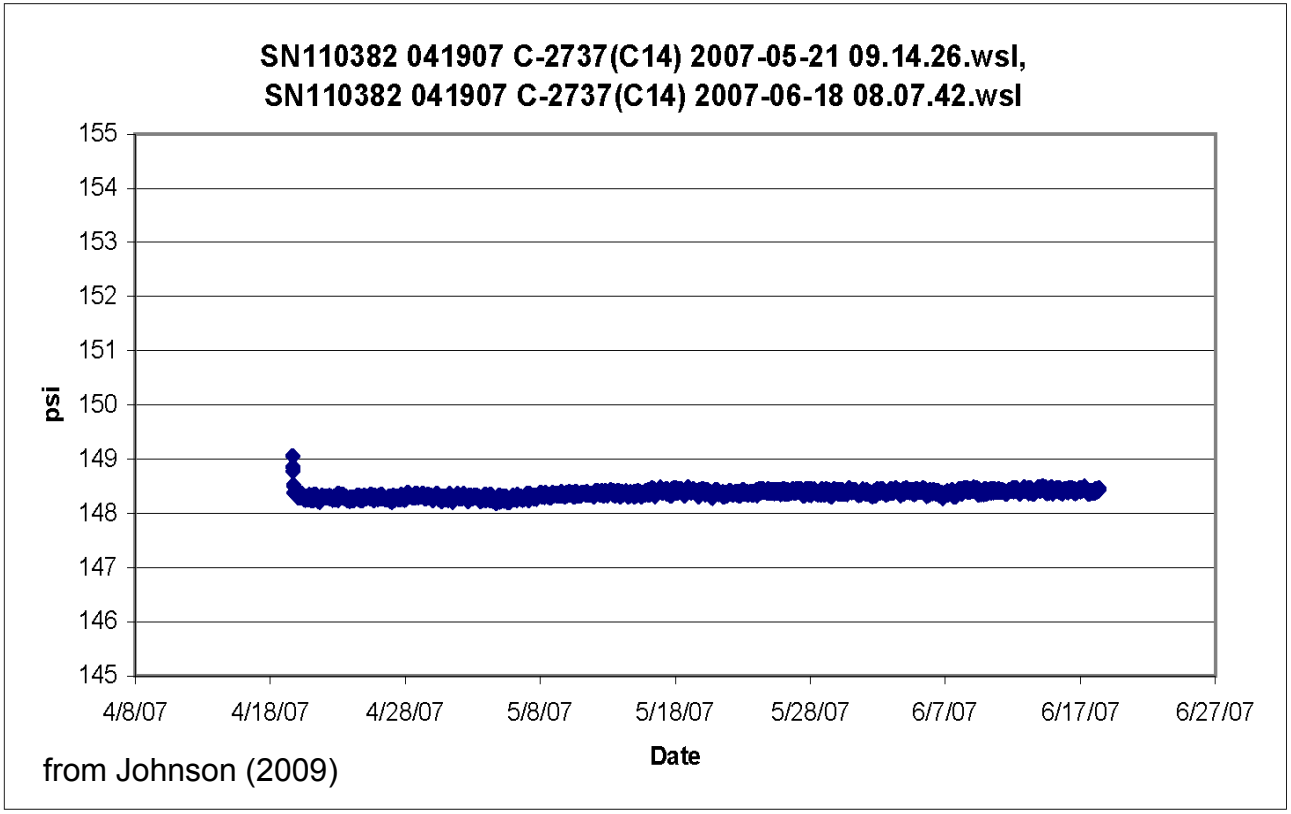
MF = mid-formation elevation of unit (m amsl), from Johnson (2008)

ρ_p = pressure density (g/cm^3)

ρ_f = density of freshwater (1.000 g/cm^3)

Example of Density Calculation

Date/Time	PSI	DTW	DTW Source	Troll Depth	Baro Pressure	Calc Dens	Average
5/9/2007 14:20	148.331	381.55	WRES	690.5	13.032	1.0102	
5/21/2007 9:13	148.374	381.23	SNL	690.5	12.955	1.0101	1.0103
6/13/2007 13:47	148.416	381.35	WRES	690.5	12.985	1.0106	
6/18/2007 8:06	148.423	381.12	SNL	690.5	12.936	1.0102	



from Johnson (2009)

Direct Calculation of Freshwater Head

- **FWH Calculated using pressure head**

$$FWH = \left(\frac{P_{meas^*}}{C} \right) + Z_i$$

Where,

P_{meas^*} = measured pressure head corrected for barometric pressure, if necessary (psia or psig)

C = conversion coefficient (~0.4335 psi/ft, for freshwater)

Z_i = installation elevation of TROLL (ft), ideally mid-formation (MF) elevation from Johnson (2008)

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