In-Situ Groundwater Monitoring: State of the Art

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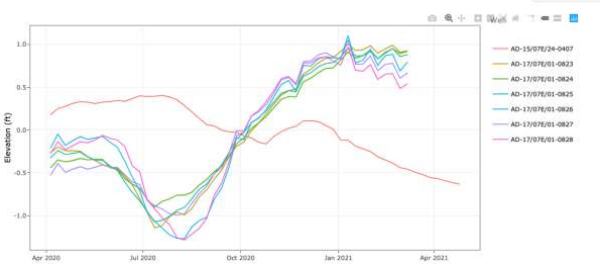
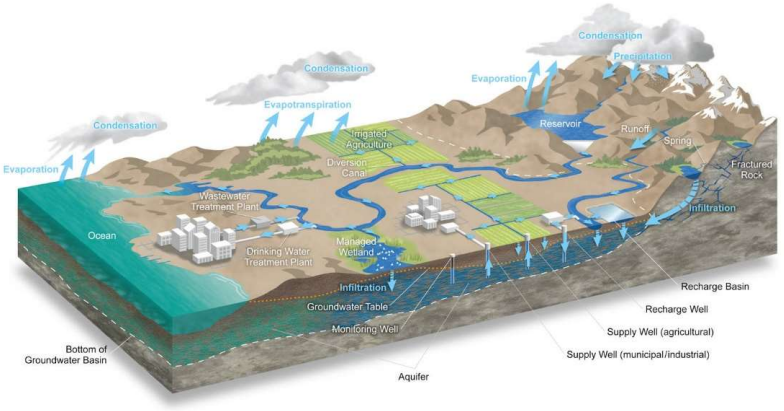


Topics of Discussion

- Traditional groundwater level measurement
- Automatic groundwater level measurement
  - Vented submersible transducers
  - Non-vented submersible transducers
  - Sonic technology
- Automatic groundwater quality measurement
- Analysis and Visualization

Groundwater and the Hydrological Cycle

- Groundwater is a key piece of the hydrological cycle
- Groundwater serves as a large subsurface water reservoir
  - 75% freshwater stored in polar ice and glaciers
  - 25% freshwater stored in groundwater
  - <1% freshwater stored in rivers, lakes and as soil moisture
- Groundwater provides half of all drinking water worldwide
- 70% of the groundwater extracted worldwide is used for agriculture



Importance of In-Situ Groundwater Measurement

- In-situ groundwater measurement allows us to directly measure the water beneath the ground and help us make smarter decisions on how best to use it
- By integrating the in-situ groundwater data into models, researchers provide a deeper understanding of how much groundwater we have now, and how much we will have in the future as climate change takes its toll
- Groundwater quality measurement is becoming more critical as groundwater sources become increasingly impacted by human interaction

Legacy Methods of Groundwater Measurements

- Steel and electronic tape are legacy solutions for ground water measurement
- Measurement is manual requiring technician to visit the site
- Measuring tapes can be shared among numerous wells
- Observations are not continuous, unless the operator stays on-site

Water Pressure and Level

- Most common automatic groundwater solution. Water pressure sensor is non-vented and uses an external atmospheric pressure sensor to compensate for changes in atmospheric pressure. No desiccant required
- Water level sensors use a vent tube and the internal pressure sensor to adjust for atmospheric pressure. Desiccant required.
- Internal batteries provide power for years (No solar panel)
- On-board data logging

Water quality

- Multi-parameter or single parameter
  - Pressure and Level
  - Temperature
  - Dissolved Oxygen (DO)
  - Conductivity (Salinity)
  - Total Dissolved Solids (TDS)
  - Turbidity
  - pH
  - Oxidation Reducing Potential (ORP)
  - Bromide

Typical Characteristics of Groundwater Quality Sensors

RANGE, RESOLUTION, ACCURACY

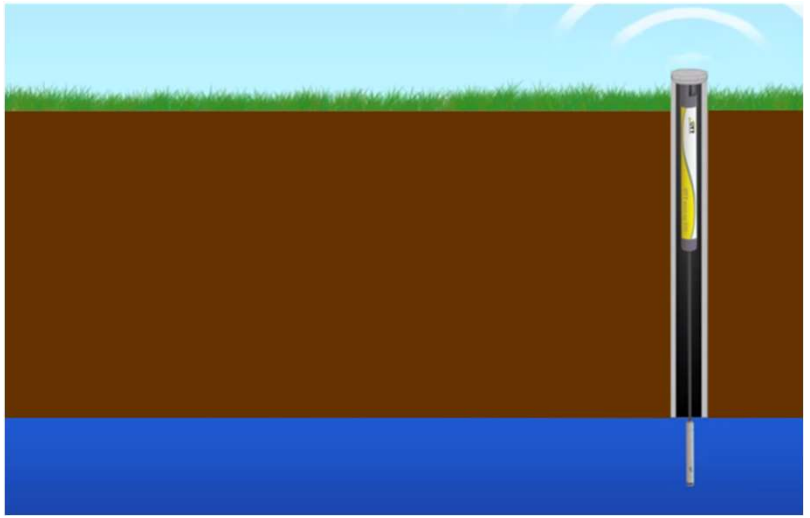
	RANGE	RESOLUTION	ACCURACY
Level/Pressure		16 bit	± 0.05% FSO typical ± 0.1% FSO maximum (B.F.S.L. 20° C)
Absolute PSIA	100 PSI		
Absolute mH_2O	70 mH_2O		
Absolute FtH_2O	231 FtH_2O		
Conductivity	0-100 mS/cm	0.001 mS/cm	± 0.5% of measured value
Salinity	2-42 PSU	0.001 PSU	± 1% of reading or 0.1 PSU whichever is greater
TDS	4.9 - 147,000 mg/L	0.1 mg/L	± 0.5% of measured value
pH	1-14 pH units	0.01 pH units	± 0.2 pH units
ORP	± 1200 mV	0.01 mVH	0.1 mVH
Dissolved Oxygen	0-25 ppm	0.01 ppm when <4.00 ppm 0.1 ppm when >4.00 ppm	1% of reading or 0.02 ppm whichever is greater
Turbidity	0-400 or 0-3000 NTU	± 3 NTU	± 2% @ 25° C or ± 2 NTU whichever is greater
Temperature	-5° to 40°C (23° to 104°F)	0.1° C	± 0.5° C

Sonic Water Level Meter

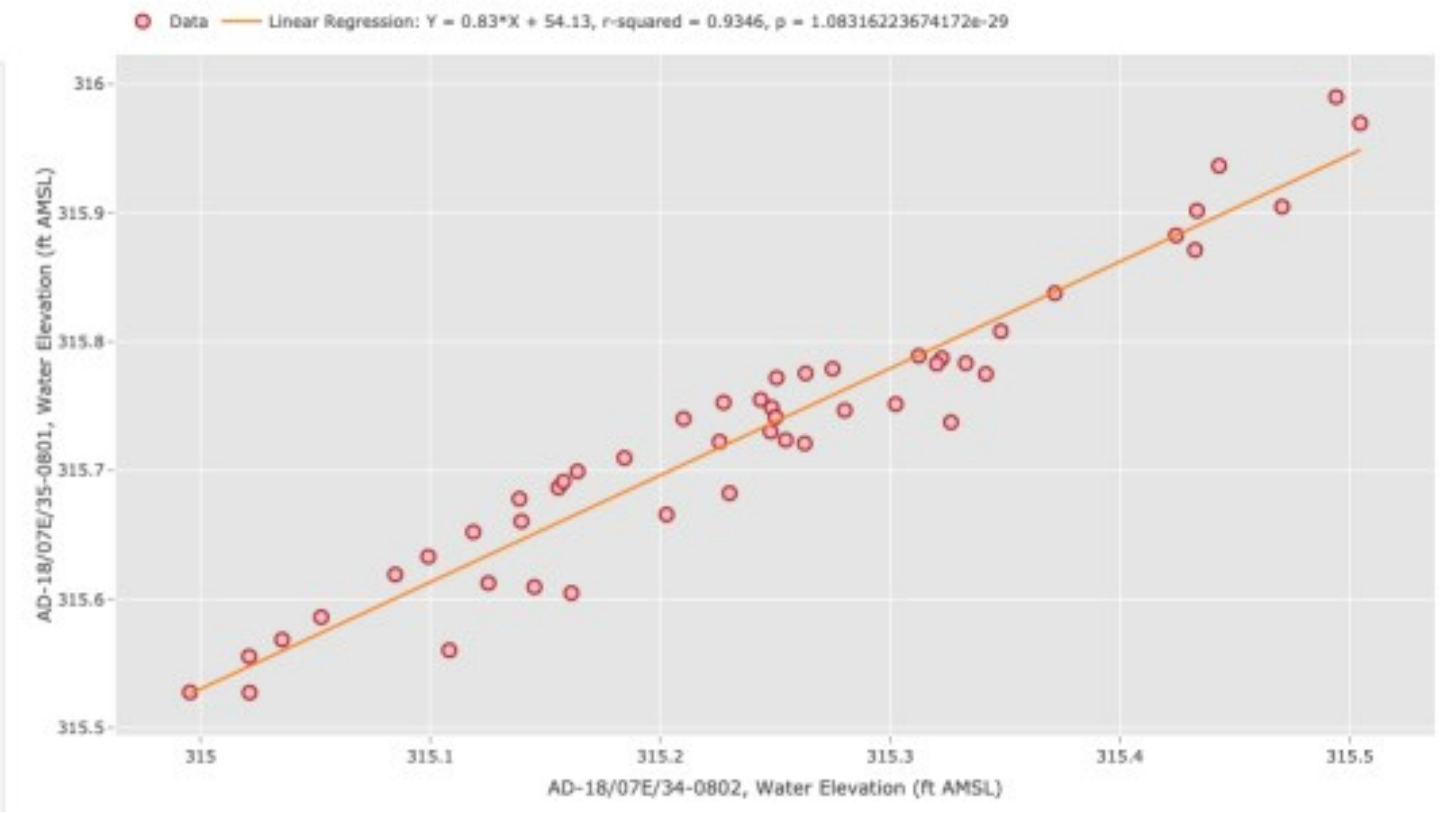
- Not as popular as submersible transducers
- Range limited (good for shallow wells)
- Item to the right (yellow), is manually operated
- Being that this is sonic, air temperature in the well casing must be either assumed or known.

Groundwater Level Measurement with Telemetry

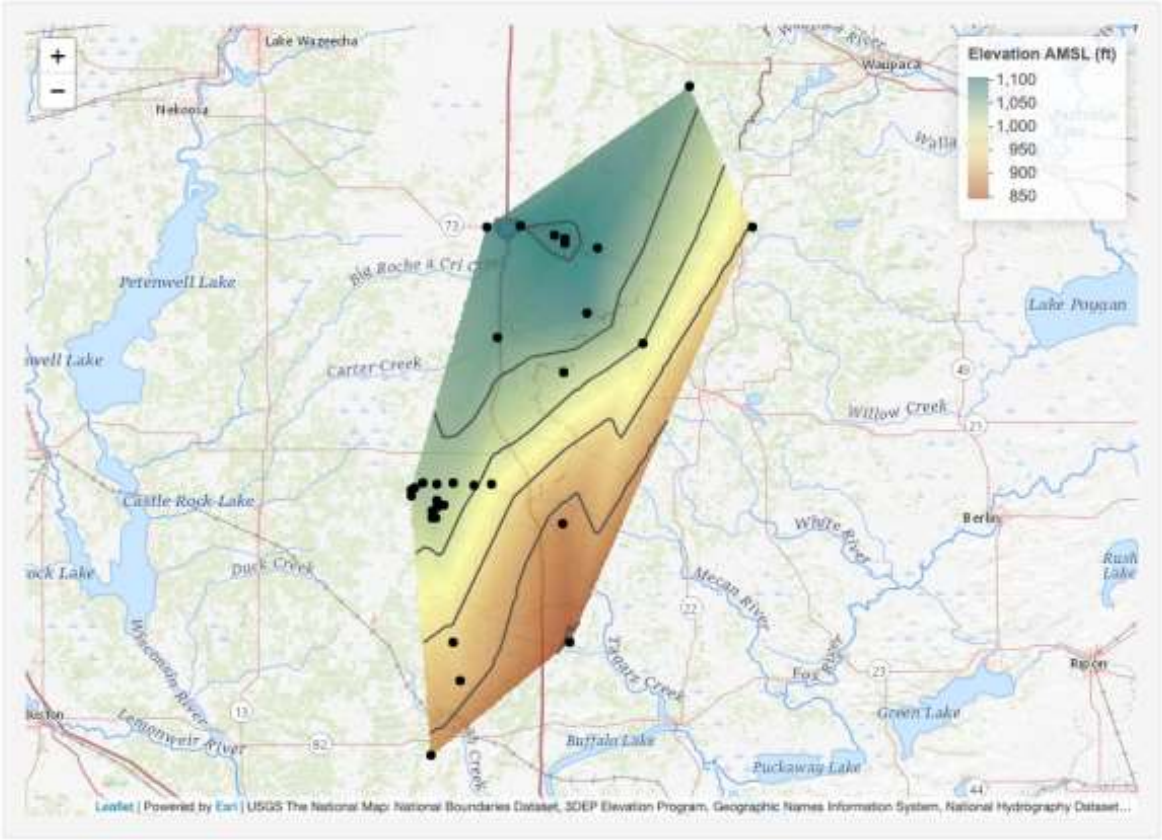
- Groundwater level measurement with mobile network connectivity
- Internal battery provides autonomous operation for over 10 years assuming:
  - One measurement per hour
  - One transmission per day



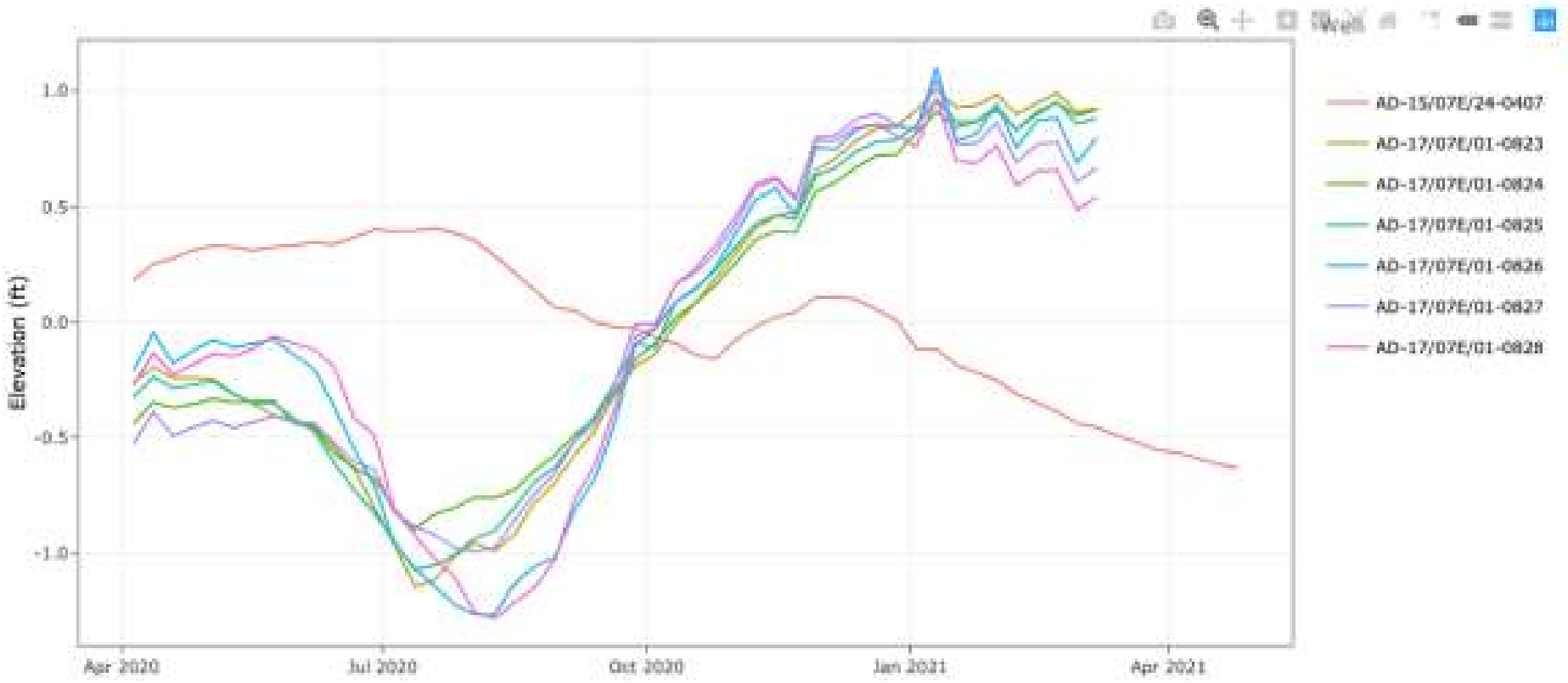
Statistical Relationships between two or more sites



Water Elevation Maps



Trends and Outliers



End of Presentation