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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Resolution</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level/Pressure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute PSIA</td>
<td>100 PSI</td>
<td>16 bit</td>
<td>± 0.05% FSO typical</td>
</tr>
<tr>
<td>Absolute mH₂O</td>
<td>70 mH₂O</td>
<td></td>
<td>± 0.1% FSO maximum</td>
</tr>
<tr>
<td>Absolute FTH₂O</td>
<td>231 FTH₂O</td>
<td></td>
<td>(B.F.S.L. 20° C)</td>
</tr>
<tr>
<td><strong>Conductivity</strong></td>
<td>0-100 mS/cm</td>
<td>0.001 mS/cm</td>
<td>± 0.5% of measured value</td>
</tr>
<tr>
<td><strong>Salinity</strong></td>
<td>2-42 PSU</td>
<td>0.001 PSU</td>
<td>± 1% of reading or 0.1 PSU whichever is greater</td>
</tr>
<tr>
<td><strong>TDS</strong></td>
<td>4.9 - 147,000 mg/L</td>
<td>0.1 mg/L</td>
<td>± 0.5% of measured value</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>1-14 pH units</td>
<td>0.01 pH units</td>
<td>± 0.2 pH units</td>
</tr>
<tr>
<td><strong>ORP</strong></td>
<td>± 1200 mV</td>
<td>0.01 mV</td>
<td>0.1 mV</td>
</tr>
<tr>
<td><strong>Dissolved Oxygen</strong></td>
<td>0-25 ppm</td>
<td>0.01 ppm when &lt;4.00 ppm</td>
<td>1% of reading or 0.02 ppm whichever is greater</td>
</tr>
<tr>
<td><strong>Turbidity</strong></td>
<td>0-400 or 0-3000 NTU</td>
<td>± 3 NTU</td>
<td>± 2% @ 25° C or ± 2 NTU whichever is greater</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>-5° to 40°C (23° to 104°F)</td>
<td>0.1°C</td>
<td>± 0.5°C</td>
</tr>
</tbody>
</table>
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