



***Barometric Effects on Transducer Data
and
Groundwater Levels in Monitoring Wells***

D.A. Wardwell, October 2007



Barometric Effects on Transducer Data

- Barometric Fluctuations can Severely Alter Water Level Data
- 1 PSI = 2.31 ft head change
- Atmospheric Pressure = 14.5 PSI
- Uncompensated Data Can Be Off By Inches or Feet
- What To Look For
- How To Properly Compensate



Effects on Transducer Water Level Data

- ☐ • PSI Range/Accuracy/Precision
- ☐ • Vented or Non-Vented Technology
- ☐ • Barometric Data Collection Compensation
- ☐ • Well and Borehole Construction/Completion
- ☐ • Hydrogeology Confined/Unconfined Aquifer Units
- ☐ • Barometric Efficiencies
- ☐ • Delayed Barometric Responses
- ☐ • Earth Tides
- ☐ • Gravitational Strength/Elevation, Latitude, Longitude
- ☐ • Water Fluid Density



Transducer PSI Range/Accuracy/Precision

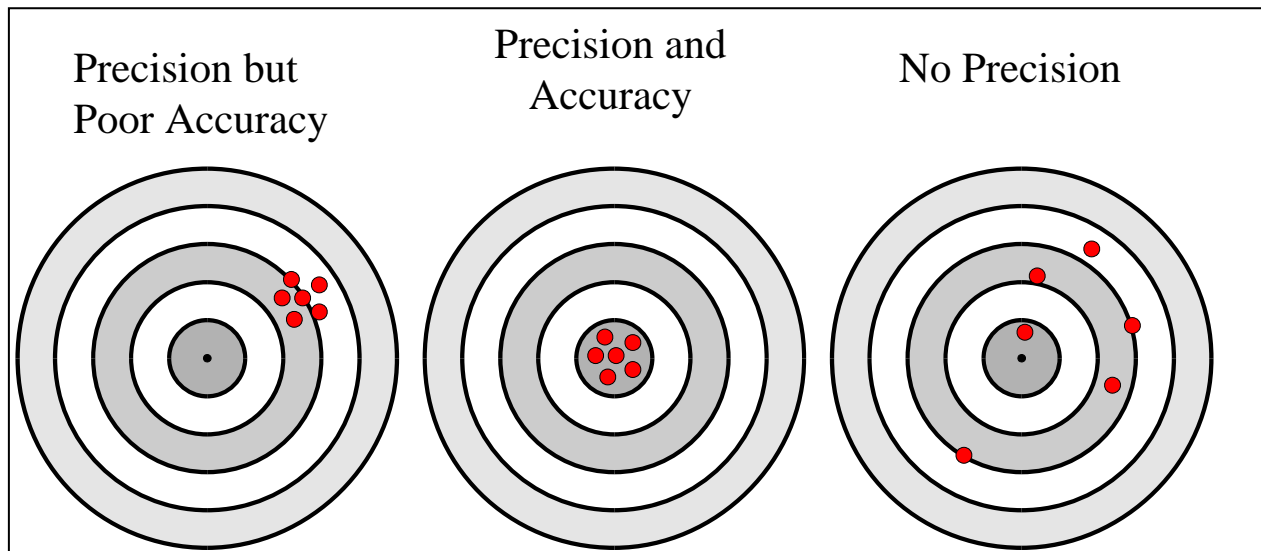
- PSI range represents the pressure range the pressure transducer diaphragm is designed, built and calibrated for .
- Head range is calculated by multiplying the PSI rating on a transducer by 2.31 ft. Therefore, a 100 psi transducer could handle a head of 231 ft.
- Do not exceed 2X Range, Sensor can be damaged.
- 3X Range is predicted burst pressure
- Exceed Calibrated Range, and you will get a response, but not accurate head range is calculated by multiplying the PSI rating on a transducer by 2.31 ft. Therefore, a 100 psi transducer could handle a head of 231 ft.

Transducer PSI Range/Accuracy/Precision

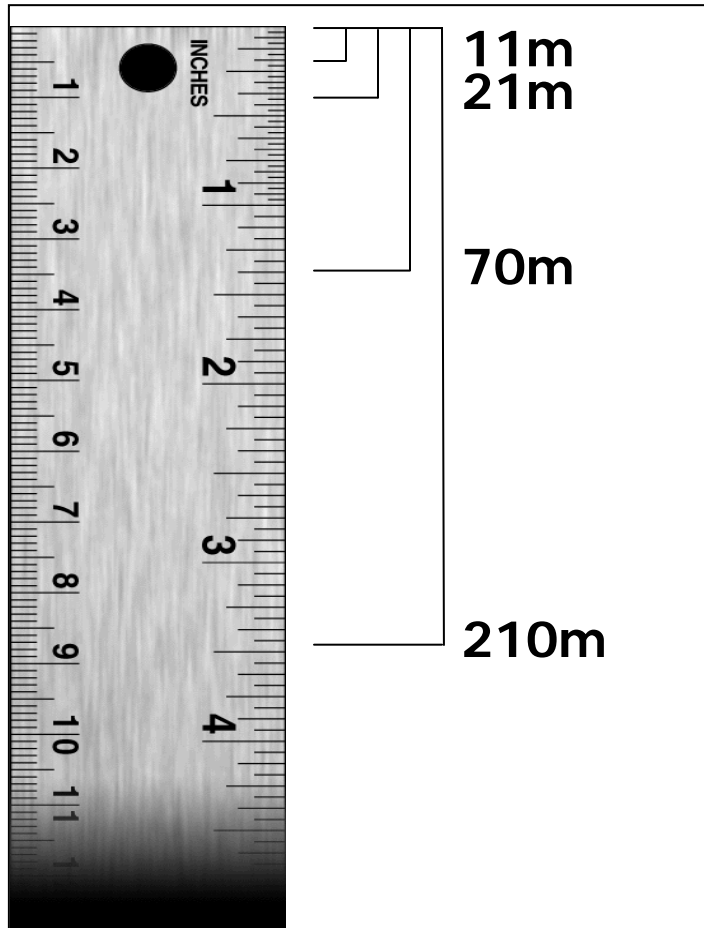
Accuracy: The error of a measurement in relation to the true value of the phenomena.

Precision: The error of a measurement in relation to other measurements made of the same phenomena.

Resolution: The smallest significant change that is measurable between any two measurements.



Transducer PSI Range/Accuracy/Precision



- Determining Actual Accuracy Range
- Multiply Calibrated Sensor Range By Transducer Accuracy Percentage
- What is the accuracy of a 11m (35ft) sensor with accuracy of 0.05%?
- Answer: $11\text{m} \times 0.05\% = 5.273$ mm of water.
- The maximum deviation is ± 5.273 mm over the entire pressure and temperature range.

PSIA – Pounds per Square Inch Absolute

- PSIA = Non-Vented Technology
- Measures all pressure, Air and Head
- Back of Sensor Measures Against Vacuum, Absolute Zero
- **$PSIA_{MEAS} = P_W + P_{ATM}$**

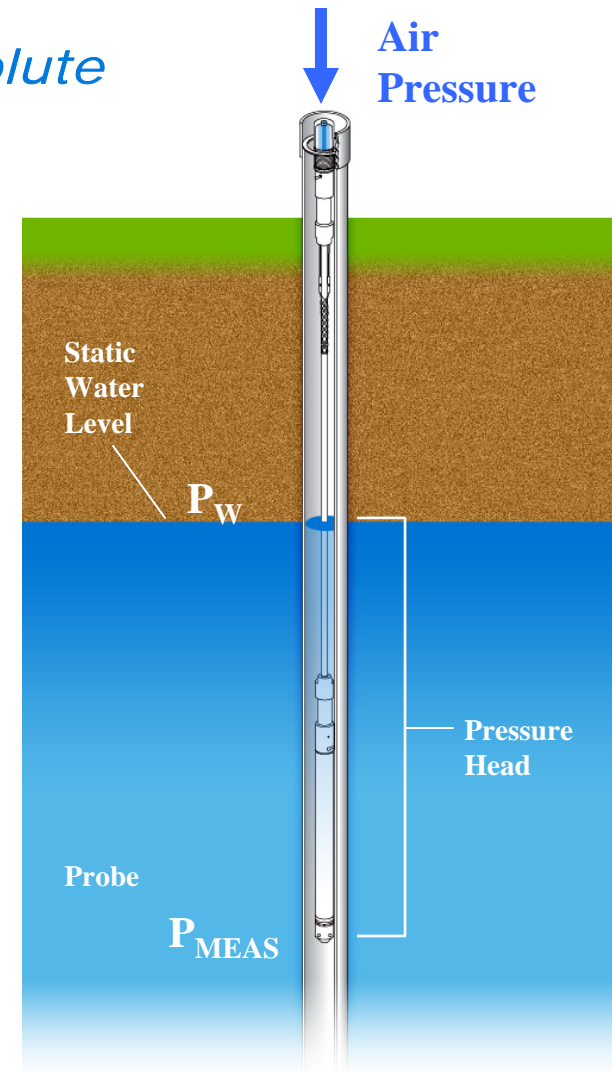


Figure 1

PSIG – Pounds per Square Inch Gauge

- PSIG = Vented Technology
- Automatically Compensates for Barometric Pressure Changes
- Measures Water Head Only
- Back of Sensor Measures Against Vented Barometric Pressure
- Corrects for Barometric Effects, Does Not Record Barometric Effects.
- **$PSIG_{MEAS} = P_{FRONT} - P_{BACK} = (P_W + P_{ATM}) - (P_{ATM}) = P_W$**

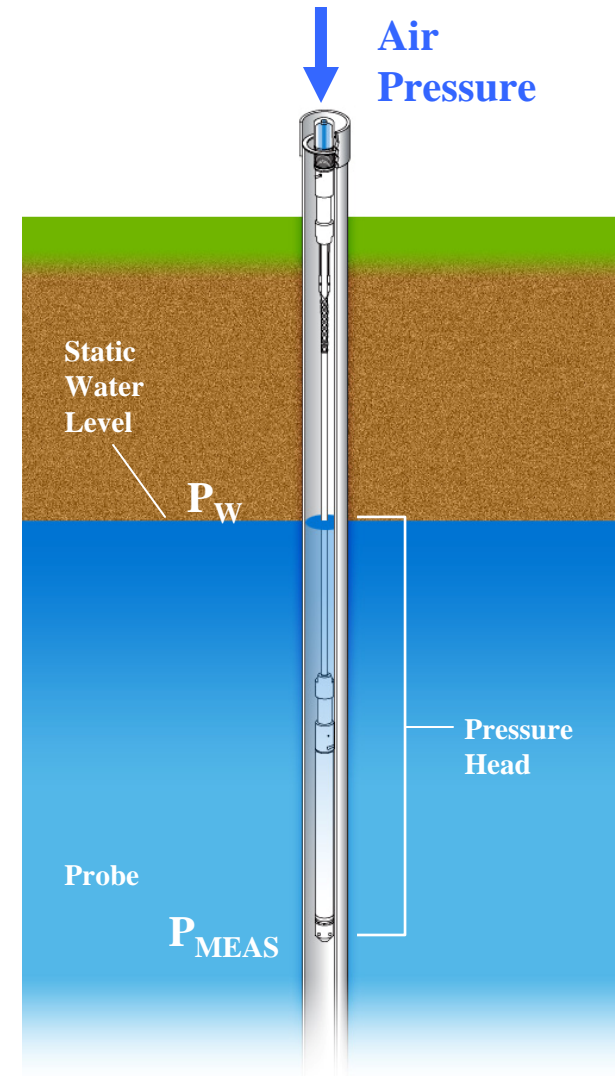


Figure 1

Total Head

- It has become widely accepted that Total Head must be determined to accurately define hydraulic gradients.
- If the gradient is very small, barometric effects can and will alter the results of a potentiometric surface.
- The total head, **H**, is the sum of the barometric pressure head, **B**, and the water surface elevation head, **W**:
- **$H = B + W$**

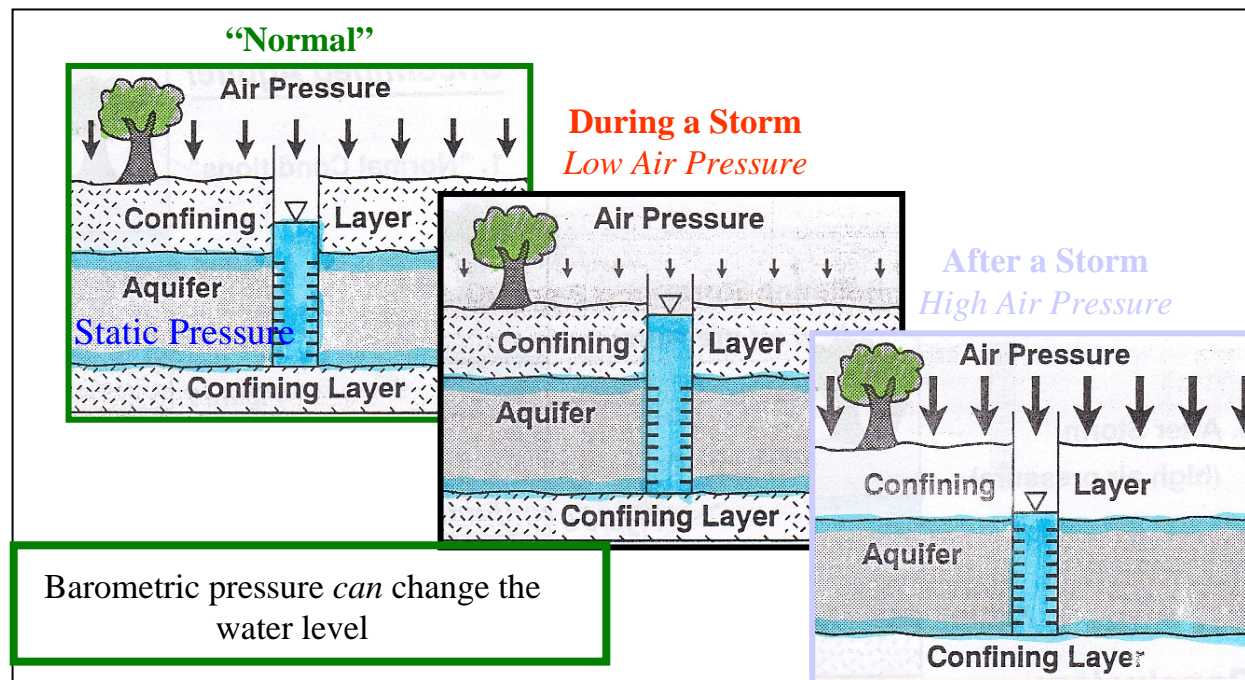
Barometric Efficiency

- The relationship between water level and barometric pressure is an inverse one; increases in barometric pressure declines in observed water levels and vice versa.
- Barometric pressure measurements are used to establish barometric efficiency, which is the ratio of change in hydraulic head to the change in barometric pressure:
- $\partial = - (\Delta W / \Delta B)$
- Where ∂ is the barometric efficiency, ΔW is the change in the water surface elevation in the well during an arbitrary unit of time, and ΔB is the change in the barometric pressure head at the water surface during the same time interval.

Hydrogeology – Confined Aquifer Response

- In general, barometric effects, and water level change is greater and more pronounced in confined aquifers.
- the transmission of atmospheric pressure effects is instantaneous, both to the well and the aquifer.
- The magnitude of water level change and formation pressure change is a function of the degree of aquifer confinement, the aquifer skeletal matrix, and specific weight of groundwater.

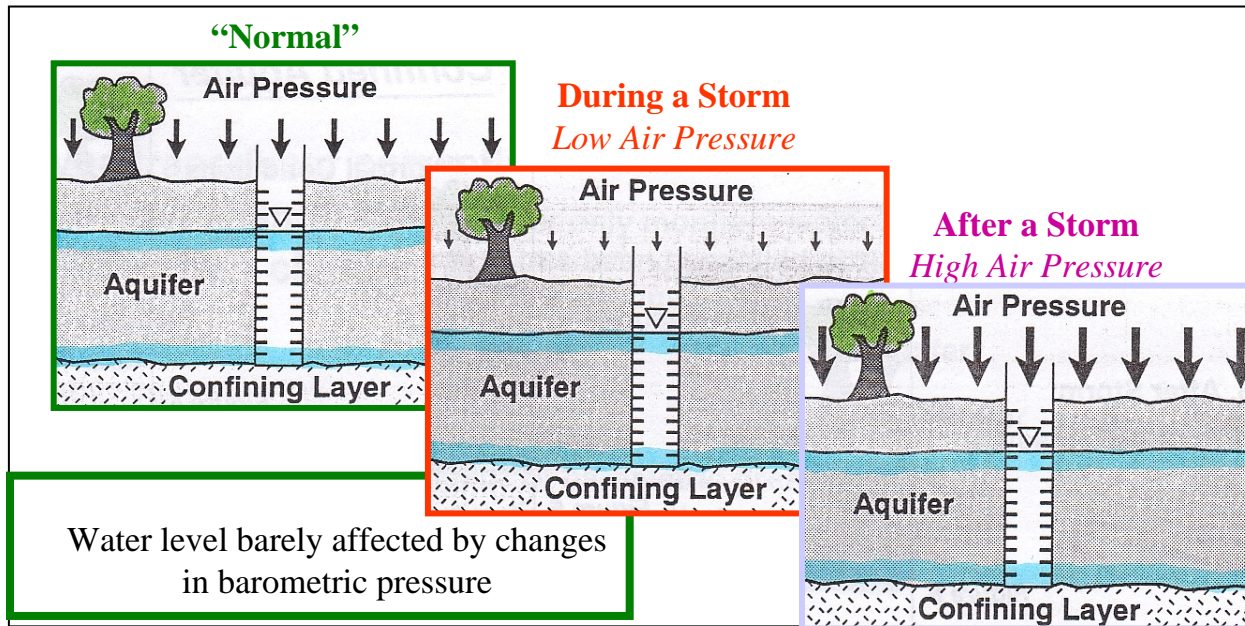
Hydrogeology – Confined Aquifer Response



Hydrogeology – Unconfined Aquifer Response

- Barometric pressure response is instantaneous in the monitoring well for unconfined aquifer systems, but have a time-lagged response at the rest of the water table because air must move into or out of the overlying vadose zone to transmit the change in pressure.
- This is a result of varying ability for soil gas to flow imposed by the materials composing the unsaturated vadose zone and the compressibility of the soil gas within the air-filled pores.
- The rate of air movement within the vadose zone is a direct function of its vertical pneumatic diffusivity, which is a function of the vadose zone vertical permeability and moisture content.

Hydrogeology – Unconfined Aquifer Response



Wellbore Effects (Borehole Storage & Skin Effects)

- The transmission of the barometric pressure change between the well/aquifer system is delayed because of the time required for movement of a finite volume of water between the well and the surrounding aquifer.
- The time delay associated with the movement of wellbore fluid is dependent on the aquifer properties (i.e., transmissivity, storativity) and existing well/borehole conditions (i.e., wellbore-storage and well-skin effects).
- Other factors include differing hydraulic conductivity and permeability of screen or sand packs surrounding screened well sections, between the well and the natural aquifer formation.



Water Fluid Density

A significant error is introduced into water level measurements when density is approximated as 1,000 kg/m³. Ground water at 20 °C has a density of 998 kg/m³ resulting in an error of 0.20%. Density (ρ) in kg/m³ is calculated using the following equation:

$$\rho = \frac{(P2 - P1) \times 6894.757}{g \times (L2 - L1)}$$

where

g is the gravitational acceleration for the location of the well in m/s²

P is pressure in PSI units

L depth of the probe in meters as measured via the cable

Gravitational Strength

- The acceleration due to gravity actually varies depending on where you are on the surface of the earth. The earth's gravitational value depends on the distance from the equator, latitude, and elevation with respect to the mean sea level. Incorrect assumptions of the gravitational value can introduce errors as large as 0.27% in a water level measurement.

The following formula can be used to determine g in m/s^2 for a specific location:

$$g = 9.780356 (1 + 0.0052885 \sin^2 \phi - 0.0000059 \sin^2 2\phi) - 0.003086 H$$

City	Latitude	Error introduced using average g (15 PSI)
Edmonton, Canada	54°N	7.6 mm
Amsterdam	52°N	6.4 mm
London	51°N	5.7 mm
Paris	48°N	3.3 mm
New York	41°N	4.6 mm
Tokyo	36°N	9.6 mm
Los Angeles	34°N	11.0 mm
Hyderabad, India	17°N	23.6 mm
Caracas, Venezuela	10°N	26.7 mm