Sampling Method/Media: **Transducers/Groundwater**	Title: **Standard Operating Procedure for Pressure Transducer Deployment and Data Correction**
Revision No: Original **Revision Date: 24 November, 2020**	**Reference No: SOP-E2-04** **Parent Document: BC Field Sampling Manual – Part E2**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instruction for the deployment of pressure transducers in groundwater monitoring wells within the provincial jurisdiction of British Columbia (BC). Pressure transducers for these applications typically include an incorporated datalogger (PTDLs) that are routinely used for measuring and recording water levels during long-term groundwater monitoring, and during single well response testing and aquifer testing. Once the monitoring or testing program is complete, the collected data may be downloaded from the PTDL to a computer as a raw data file (unedited and uncorrected). This data should then be corrected, which includes barometric correction (if required), removal of erroneous data points such as those logged when the transducer was not in the well, and converted to depth-to-water measurements if required.

Figure 1. Pressure transducer dataloggers and optical reader.

This SOP forms part of the British Columbia Field Sampling Manual (BCFSM). Additional information on transducer deployment is provided in Part E2 – Groundwater, which must be used in conjunction with the information provided in this SOP. Further guidance regarding groundwater is provided in the Water Sustainability Act (WSA) and the Groundwater Protection Regulation (GPR) which are available at:

https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules/groundwater-protection-regulation.

The Environmental Management Act (EMA), the Contaminated Sites Regulation (CSR) and associated guidance documents provide information specific to groundwater monitoring wells installed to investigate and remediate contaminated sites; these documents are available at:

https://www2.gov.bc.ca/gov/content/environment/air-land-water/site-remediation/contaminated-sites.

Groundwater well installations, sampling, monitoring and decommissioning conducted for regulatory purposes within the provincial jurisdiction of BC must be carried out with consideration to the WSA, the GPR, the EMA, and the CSR, all as applicable, Part E2 of the BC Field Sampling Manual, and this document.

2. Document Control

This Standard Operating Procedure (SOP) is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

3. Principle of the Measurement/Correction Method

PTDLs measure absolute pressure; which means when submerged, they measure a combination of the overlying water pressure and the atmospheric barometric pressure. To obtain the pressure of just the overlying water, the barometric pressure must first be subtracted. The suggested method to compensate the data is to measure and record barometric pressure using a dedicated barometer data logger (barologger) installed within the well and above the water level as illustrated in Figure 2. If a barologger is not available, data from a local weather station may be available.

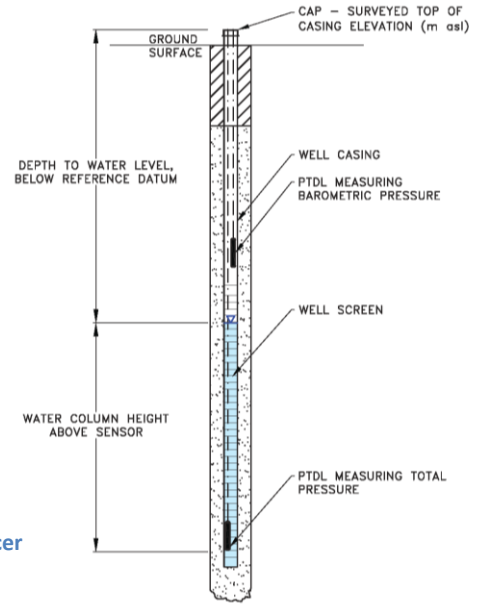

Figure 2. Schematic of pressure transducer and barologger installation.

4. Quality Control

- Ensure that all instruments are functioning before starting and that all required information is recorded in the field.
- All material entering the well (water level probes and transducers) must be fully decontaminated prior to deployment if working on a site where soil and or groundwater contamination may be present (a three-bucket rinse using a purpose-made detergent solution, tap water and deionized water is recommended).
- The appropriate software must be installed on the laptop to interface with the PTDL.
- Prior to field deployment, PTDLs should be upgraded with the most recent firmware, and, along with the optical reader, confirmed to be functioning, and compatible with the laptop.
- Ensure that field notes during deployment and download are legible (recorded in ink where possible) and complete. Retain all field notes in the project file to ensure that all pertinent information is available to field crews and project manager is reported, accurate and defensible.

5. Recommended Equipment and Materials

Field equipment should include the following:

- Field book/forms to record PTDL installation details,
- Borehole logs if available,
- PTDL,
- Decontamination equipment (i.e. bucket, laboratory grade detergent, deionised water) if working on a site where contaminated soil or groundwater is known or suspected,
- Electric water level meter to measure static water levels,
- Direct read cable or non-stretch cable to suspend the PTDL within the monitoring well,
- Laptop and required software,
- Optical reader; and,
- Barologger if a non-vented (absolute) transducer is used.

6. Procedures

1) ***Pre-Field Activities**:* Confirm the number, type (non-vented, also called absolute, or vented) and range (typically 5 m, 10 m, or 30 m for non-vented) of PTDL required. Confirm if a barologger is required for the project. Non-vented PTDLs measure absolute pressure (hydraulic head and barometric pressure) and

require a barologger to compensate for barometric pressure changes. A barologger is generally required for long-term monitoring and aquifer testing when barometric pressure change relative to water level change will be significant. A barologger is typically not necessary for single-well response testing (K-testing) unless the test is conducted in a low permeability unit and expected to last more than a few hours. Vented PTDLs measure gauge pressure eliminating the need for barometric correction. However, care must be taken to ensure water does not enter the vented cable as this could damage the transducer. Test field equipment before leaving (including compatibility of software, laptop and optical reader).

***2) Installation of PTDL**:*

a. All PTDLs used should be synchronized to the same time and should be set to collect data following the same interval. Measurement frequencies that are typically recommended are as follows:

   i. measurement every 0.5 or 1 second for single-well response testing in high hydraulic conductivity units, measurement every 30 seconds for aquifer testing,
   ii. measurement every 15 minutes to one hour for groundwater monitoring in a tidal environment; and,
   iii. measurement every hour, every six hours or every twelve hours for groundwater monitoring. Note: Your watch/computer should match the time of the PTDL.

b. Install the PTDL within the monitoring well from a fixed point, typically from a hook in the well cap. The well needs to be open to the atmosphere for vented transducers, as they need to measure barometric pressure. Wells should also be open to the atmosphere for non-vented transducers, particularly for wells with submerged screens, as positive or negative pressure may build up in the enclosed airspace above the water column. It may be necessary to drill a hole in the well cap if it is not open to the atmosphere.

c. The depth of installation of the PTDL will depend on well construction, and historical groundwater elevations. If the transducer is being used for a slug test, it should be installed below the maximum slug deployment depth. The depth of installation should not exceed the range of the PTDL, but care should be taken to ensure that the water level will not fall below the base of the transducer. This is a common problem during pump tests, in tidal environments or near rivers where significant variations in groundwater elevation occur. The transducer should be suspended at least 0.2 m above the base of the well to avoid plugging the sensor with silt.

d. If installing a barologger, a common practice is to install the barologger within a monitoring well above the water table. The barologger should be set to record at the same frequency as other PTDLs. One barologger per project is usually sufficient (one is reasonable for a 30 km radius). The barologger should be installed and retrieved at the same time as the PTDL for accurate data compensation. If the barologger is installed within a well, the well must be open to the atmosphere.

e. After installation, at approximately the same time that the transducer is set to take an automated water level measurement, measure the water level in the well using a water level meter and record this value in field notes.

f. When the PTDL is retrieved or replaced, take a water level measurement prior to removing the PTDL from the well, preferably near the time interval mark. Inspect the non-stretch cable, and any attachments such as crimps, for damage and replace as needed. Make sure that the PTDL is to exactly the same level (a mark on the casing can be used for this). Record the water level again after the PTDL is re-installed.

***3) Considerations for Groundwater Monitoring in a Tidal Environment**:*

a. In tidal conditions, it is important to install PTDLs at the appropriate height within each well. The range should be selected based on the water level variation expected in each well. PTDLs should be placed at a depth that is not too shallow nor too deep, to ensure the data is not cut off. It is good practice to conduct a round of water measurements at low tide and look at tide charts to determine the lowest water level expected. The transducers should be placed approximately 1 m below this level. It is also a good idea to let the PTDLs sit in the wells for a few days and then download the data to ensure that the data is not cut off. In general, the best practice is to use a transducer with a 10 m range and place the transducer at least two metres below the water table at low tide.

b. During groundwater monitoring in a tidal environment, water levels should be measured before the PTDL is removed and after the PTDL is replaced. The measurements are then used to calibrate the transducer readings to an accurate water level.

c. It is generally beneficial to install a transducer in the ocean from a fixed point, such as a pier. This will allow the comparison of ocean tides directly to groundwater tidal influence, which can be used to calculate lag times and estimate hydraulic conductivity.

4) Download Data. Once the monitoring or testing program is complete, download the data from the PTDL to the field computer, or retrieve the transducers for downloading at a later time. Ensure that all of the data has been downloaded before deletion in preparation for re-deployment of the PTDL. Data should be downloaded in all formats available (e.g.,.xle and .lev, if using Solinst® pressure transducers and Levelogger software) and exported in .csv format.

5) Data Correction/Compensation. Ensure that transducer files have two versions. The first should be saved as a RAW data file (unedited and uncorrected). The second data file should be CORRECTED, which should have been barometrically corrected (if required), edited to remove erroneous data points (e.g., measurements logged when the transducer was not in the well), converted to depth-to-water values (if required) and edited to correct erroneous measurements such as data points that may have been logged while the transducer was lowered or raised in the water column. Additional corrections may be required, which could include external influences (tidal or pumping wells), gas ex-solution, or correcting for well deviation.

a. Convert pressure into m H_2O: If required, use the applicable conversion to obtain m H_2O units.

Table 1: Pressure Conversion

Unit	Unit
cm	m (x 0.01)
ft	m (x 0.305)
psi	m (x 0.703)
mbar	m (x 0.0102)
kPa	m (x 0.102)
bar	m (x 10.2)
mm Hg	m (x 0.0136)

b. Barometric Compensation: If required, compensate the data for barometric changes. If a barologger was used for the same period of time, barometric compensation can be easily completed using the software. Otherwise, barometric compensation can be completed in an excel spreadsheet by subtracting the barometric reading from the corresponding PTDL reading(s) to give true water level measurements. Ensure that the reading times and units are consistent for both the transducer and barologger.

c. Remove surplus data: Remove data recorded when the PTDL was not installed in the monitoring well (before and after the monitoring period or during a sampling event that occurred during the monitoring period). It is a good idea to use a scatter time series graph to identify non representative data (e.g. early data) and also identify periods when the water level is below the transducer (raw readings are very low and match barometric readings when not compensated) or above the PTDL operational limit (readings may flatline).

d. Convert the corrected data to depth to water and/or groundwater elevations: The value recorded from the pressure transducer is representative of the height of water above the PTDL. During aquifer or single-well response testing, measurement of the relative change of the water level with time is needed, and therefore, converting measured height of water to depth of water or groundwater elevation is not necessary. However, when PTDLs are used for groundwater monitoring purposes, the height of water above the PTDL is usually converted to depth to water and groundwater elevation using the depth to water measured manually with a water level tape at a corresponding time. Manual data compensation can be completed using software such as *Data Wizard* in Solinst®. Otherwise, the conversion can be completed in an excel spreadsheet by converting the manual depth of water reading to a groundwater elevation using the known elevation of the top of the casing (TOC). The groundwater elevation is then set to equal the PTDL reading at the equivalent time. The pressure change for subsequent time intervals

should be applied to the initial pressure reading (i.e. if the pressure increases, this means the groundwater elevation increased, if the pressure decreases, groundwater elevation decreases).

e. Correct for drift and/or measurement jumps for long-term monitoring: Nearly all submersible PTDLs are capable of providing accurate results for short-term studies but as the study duration increases, the chance of sensor failure and the amount of drift increases. It is recommended to download data quarterly during long-term monitoring programs so that malfunctioning PTDLs can be reconditioned and recalibrated or replaced in a timely manner. Calculate the amount of drift over the monitoring period and correct the data as appropriate. During long-term monitoring programs, jumps in measurements are sometimes observed. They may be attributed to several factors but is generally related to the PTDL not being redeployed to the exact same depth (often during groundwater sampling events). This is usually identified on a time series graph and can be corrected by using the appropriate manual water level measurement taken after the PTDL was redeployed.

6) Data Correction for Groundwater Levels in a Tidal Environment*:* Tidal fluctuations in surface water bodies produce progressive pressure waves in adjacent aquifers. As these pressure waves propagate inland, groundwater levels and hydraulic gradients continuously fluctuate, creating a situation where a single set of water level measurements cannot be used to accurately characterize groundwater flow. At any point where groundwater tidally fluctuates, the magnitude and direction of the hydraulic gradients fluctuates about the mean or regional hydraulic gradient. The net effect of these fluctuations on groundwater flow can be determined using the mean hydraulic gradient, which can be calculated by comparing mean groundwater and surface water elevations. Filtering methods traditionally used to determine daily mean sea level can be similarly applied to groundwater to determine mean levels. The method, described in Serfes (1991), suggests using a moving average of either 25 or 71 consecutive hourly water level observations to accurately determine the mean level.

7. Common Pitfalls

- Not obtaining an accurate static water level at the time of installation i.e. removal of Waterra tubing or other in-well equipment, or pressure issues, or forgetting to collect this measurement,
- Installation depth exceeding the range of the PTDL,
- Water level falling below the base of the transducer i.e. during pump tests, in tidal environments or near rivers where significant variations in groundwater elevation occur,
- Cable breaks or was inappropriately secured and transducer is lost down the well,
- Barologger recording at different sample frequency and time than PTDL; and,
- Forgetting to start or set up transducer properly.

8. References

1. Serfes, M.E., 1991. Determining the mean hydraulic gradient of groundwater affected by tidal fluctuations. Groundwater, Vol. 29, No. 4, pp. 549-555.

Revision History: 0.0 (New document)

Approval