Using Pressure Transducers for Stream Restoration Design and Monitoring

1 Introduction

Pressure transducers monitor changes in pressure and can be used to measure water depth, making them a valuable tool for collecting stream data. While the data sets produced by pressure transducer gauges are straight-forward, there are a variety of applications for the data. Instead of identifying bankfull events with crest gauges or wrack lines, pressure transducers provide the exact time and date, duration, and maximum stage of every event. They can also be installed in unstable streams during pre-restoration stream assessment to correlate rain events to stream stage. In this way, they can be used as a design tool to verify bankfull or designed storm discharges. The data can be gathered over short time periods to evaluate stream response to storm events, or the gauges can be maintained over longer periods of time for long-term analysis. The initial purchase of these gauges can be expensive, but they can be used for years and require minimal maintenance.

The self-contained gauges have internal batteries and download to a portable data transfer device or a computer through an optical sensor. These gauges are placed in a water column where they automatically record the water pressure at preset times. A second gauge is installed at the site (not in the water column) to record changes in the ambient air pressure. Using the software that comes with the gauges, the data are then downloaded from the logger and barometrically compensated with the data from the second gauge to provide the water depth above the gauge sensor. The software produces a set of records with the time and date of each measurement and the depth of water above the sensor at that time.

2 Gauge Installation

Before heading out into the field to install the gauge, it must first be programmed with the manufacturer's software. This step is necessary to select the start date and time and to set the measurement interval. For stream monitoring, five or ten minute intervals is generally frequent enough. Each gauge must also be programmed with a name. It is convenient to name the gauge according to how it may be labeled on a site map. Once the gauge is programmed, it is ready to be installed in the stream.

The location for gauge installation depends on the goals for data collection. If the intent is to only record bankfull events, then the gauge can be placed anywhere along the stream where the bankfull elevation is known in relation to the gauge elevation. If the purpose of the gauge is to collect data that can be used to create a discharge hydrograph, the gauge needs to be installed in a surveyed stable riffle cross-section. The riffle should be in a free-flowing portion of the stream without any large debris up or downstream of the gauge that could create backwater conditions. Also avoid placing gauges where they could be influenced by the backwater from downstream tributaries or other water bodies. To get a more accurate discharge measurement from a stream, it is beneficial to install gauges in more than one cross-section along a stream reach where there is the same hydrologic regime. Installing gauges upstream and downstream of contributing hydrologic sources such as tributaries or stormwater outfalls can also produce useful information.

Photo 1

Pressure transducers can be installed in a variety of ways depending on the stream conditions. Three different installation methods are depicted in Figure 1. Method 1 can be used in a variety of settings. This method requires digging a trench in the side of the stream bank and then installing the gauge housing, made of 2” slotted and solid PVC assembled in an L shape, into the trench and then stabilizing it with backfill. Method 2 is best suited for streams where there is the potential for high flows that could wash away the other gauge installation methods. The advantage to this method is that is close to the bottom of the stream channel and only needs to stick up from the bottom of the stream 9”- 10”. The gauge maintains a low profile during large storm events and there is less risk that large debris will knock over or damage the gauge. Whenever installing a gauge according to this method, it is important that the rebar is driven into the streambed deep enough so that it will not be washed away if the bed material becomes mobile. The third method depicted in Figure 1 is best used on low-gradient, slower-moving streams. Because the PVC structure sticks up higher than Method 2, there is the potential for large woody debris to get caught on the gauge during large storm events. All three of these methods could be used on small streams that do not have the potential for large damaging flows. These methods of gauge installation are only a few examples. Every stream site is different and each method can be adapted to unique site conditions. Above all else, the gauge must be installed securely so that it will not wash away. Not only is this important to preserve the gauge itself, but also to avoid losing valuable data.

While the exact method of installation can vary, the elevation of the sensor (as seen in Photo 1) must be known. This could be the real elevation of the sensor, or the elevation relative to a known feature adjacent to the stream, such as a permanent cross-section pin. To determine the sensor elevation, measure the distance from the top of the locking cap to the sensor on the transducer. After recording this length, install the transducer in the PVC pipe and secure the locking cap. Then take a survey measurement on top of the locking cap, either with a total station or a laser level. Subtract the length from the top of the cap to the sensor from the elevation of the cap to get the sensor elevation. After the data are downloaded and processed, add the water depth values to the sensor elevation to get the water surface elevation. It may be easier to just use the water depth value and not the water surface elevation. However, with a known elevation, it is easy to compare the water surface elevation with other elevations at the stream, so the data are not limited to just the stage above the sensor in one location.

Wherever one or more pressure transducer gauges are installed at a site, there must also be an extra pressure transducer installed to measure barometric pressure. This barometric control gauge should be programmed to take measurements at the same interval as the other gauges. Because this gauge takes pressure readings of the air, it should be installed somewhere that will never be inundated with water. This is easiest to do by hanging the gauge from the branch of an adjacent tree. Only one barometric control gauge is needed for any one site, even if there are multiple pressure transducer gauges installed.

3 Downloading, Compensating, and Calibrating Gauge Data

Most of the manufacturers of pressure transducers use an optical reader with a portable download device to download the gauges. This makes downloads in the field more convenient and does not require a laptop. The frequency of site visits needed to download the gauges depends on the intervals at which the gauge is programmed to take measurements. Depending on the storage of the gauge, this could require downloading on a weekly, monthly, or bimonthly basis. When programming the gauge, it can be set to overwrite data once the internal memory fills up or stop recording data once full. When downloading the gauges, there will also be an indication of the battery level. Depending on how frequently the gauge is taking measurements, the internal battery can last for over five years. The gauges can then be sent back to the manufacturer to have the battery replaced.

It is important to also download the barometric control gauge whenever downloading the stream gauges at a site. After downloading the gauges, transfer the data to a computer with the manufacturer's software installed. Use the software to compensate the gauge data. This is a straight-forward process of bringing up the file with the data, identifying the barometric compensation control file, and then letting the software compensate the data. The software program then produces a file that can be saved as or exported to Microsoft Excel format. This file will have labeled columns with the date, sampling time, and a depth of the water column. This depth column represents the depth of water over the sensor. If the gauge is being used to document bankfull events, the water surface elevations can be compared to the bankfull elevation adjacent to where the gauge was installed. This can also easily be graphed as a visual aid. Adding rain gauge data to this graph is an effective way of showing how the stream responds to rain events.

Over the course of the monitoring period, it is a good idea to check the calibration of the gauges by measuring the water surface elevation at the gauge relative to the top of the gauge's locking cap. Then compare this elevation to the elevation recorded at the same date and time by the gauge. If these elevations do not match, the setup and installation should be checked to make sure that the measurements are correct or the gauge may need to be calibrated. This can be done by sending the gauge back to the manufacturer, who will calibrate the gauge for a fee.

4 Developing a Discharge Hydrograph

The data collected by these gauges can be used to develop a discharge hydrograph for a given stream cross-section. To create this hydrograph, one will need the surveyed cross-sectional data where the gauge is installed, the water surface slope for the reach, and Manning's n values for the cross-section. From these data, create a rating table based on water surface elevation (generally in 0.1' intervals) for the bankfull channel using the Manning's n method, with a software package such as FlowMaster by Haestad Methods or RiverMorph. Then graph the data, creating a rating curve with the discharge on the y-axis and water surface elevation on the x-axis. Applying a trend line to the data (typically using a polynomial function) will create an equation describing the stage-discharge relationship. Create a discharge hydrograph of the gauged cross-section using this equation and inserting the measured stage elevation from the gauge data. These discharge data can be compared to known rain events recorded by rain gauges to assess stream response to storm events.

The pressure transducer data also can be used along with supplemental methods to improve the accuracy of the discharge relationship. The method described above uses Manning's n to calculate discharge and there could be uncertainty attached to a chosen n value. To reduce this error, a flow meter can be used to measure discharge at a given water elevation. The Manning's n value can then be adjusted for the cross-section so that the discharge for the time and date of the flow meter measurement is the same as the gauge discharge hydrograph. The most accurate results are achieved when using multiple gauged cross-sections and flow meter measurements from different stream stages.

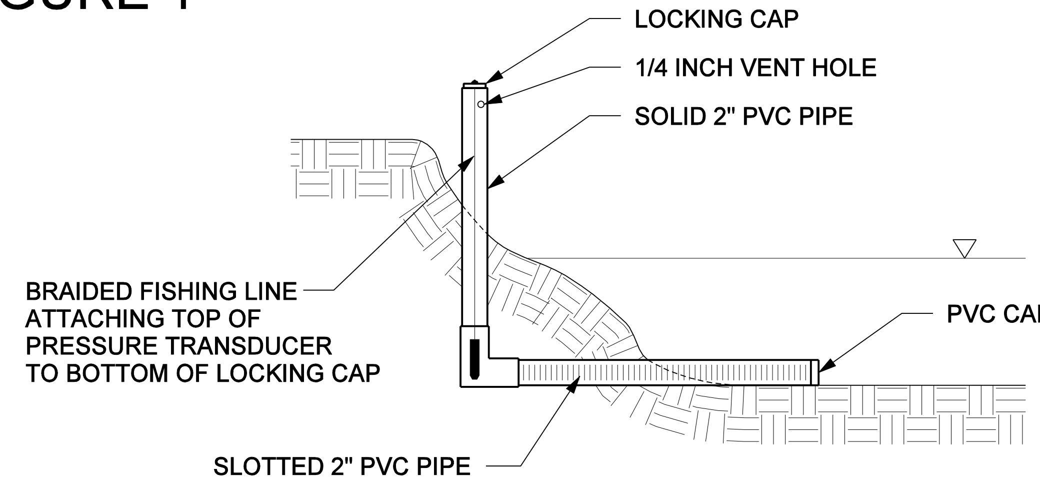
5 Commercially Available Pressure Transducer Products

Onset Computer Corporation
http://www.onsetcomp.com/water-level-logger

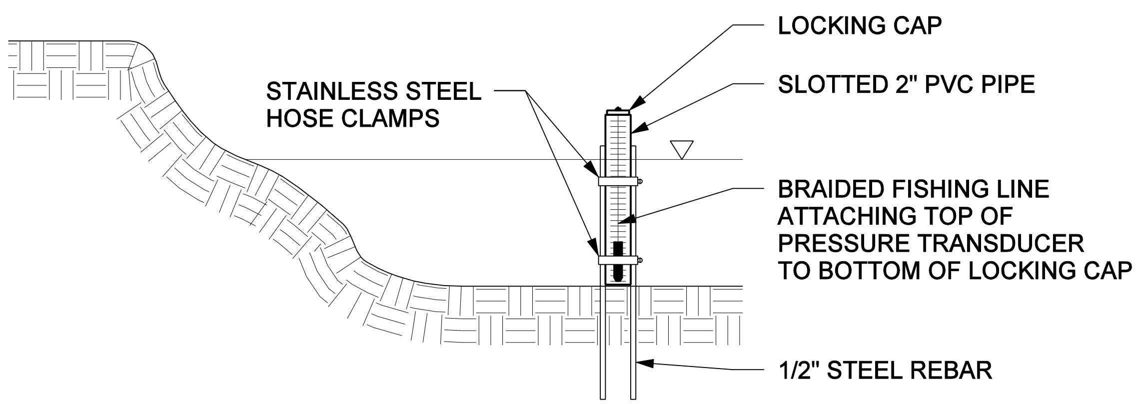
Solinst

http://www.solinst.com/Prod/Lines/Data_Loggers.html

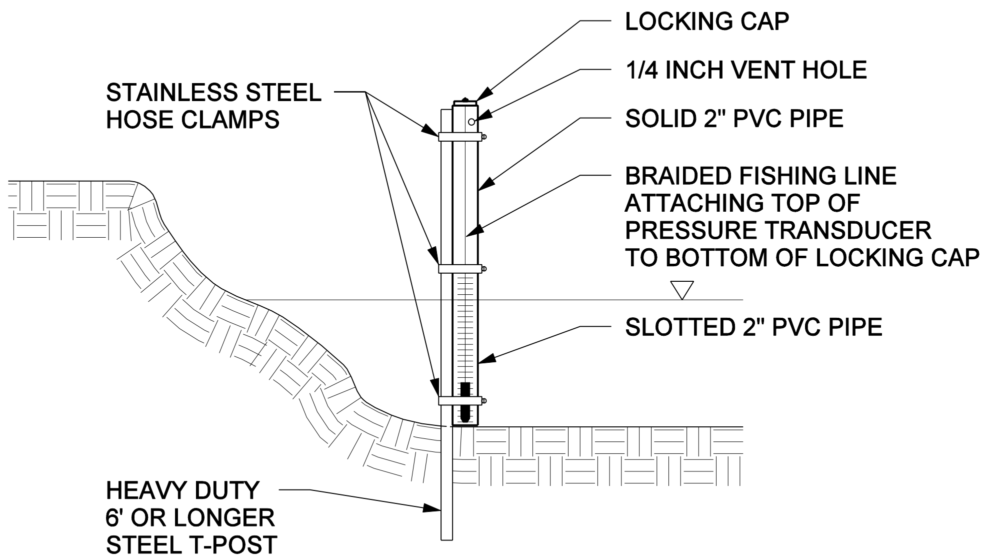
FIGURE 1



METHOD 1



METHOD 2



METHOD 3