Date: February 1, 2018

To: Delta Measurement Consortium Meeting

From: Patrick Stiehr, Watermark Engineering Inc.

Re: Status Update of Measuring Siphon Flow with Pressure Sensors

Pressure sensors do indeed show changes in flow velocity per the Bernoulli principle.
The pressure lessens as velocity increases. That was clearly demonstrated when the downstream control valve was adjusted and pressure readings were recorded. However, converting the pressure readings to flow is more complex than other methods.

The typical surrogate for flow is velocity, measured by several different instruments. Velocity goes from zero to some value as the flow increases. A calibration is used to convert the measured velocity to flow and subsequently, a data logger provides a flow record.

Depending of the location of a pressure sensor, there is a given pressure when the pipe is charged and the valve is closed. During this time, the pressure fluctuates with the tidal cycle. When the valve is opened, there is a distinct pressure drop. When the valve is partially open, it remains the control, and the pressure readings fluctuate with the tidal cycle.

At The Nature Conservancy (TNC) siphon, the siphon outfall is open to the atmosphere- the downstream water level is below the end of the outfall pipe. When the valve is fully open, the reduced pressure readings do not show the tidal influence. Most likely, the reason is that the flow near the downstream end of the pipe is at or near “free-fall” and the “control” is farther upstream.

Control is defined as the hydraulic characteristics of the siphon. When the valve is closed, the valve is clearly the control. As the valve is opened, the control transitions to some combination of the valve and the hydraulic characteristics of the pipe (roughness, bends, length, type of inlet, etc). Eventually the upstream portion of the pipe becomes the control at the site. Note that if the downstream end was submerged, it would continue to be part of the control.

More testing is needed to evaluate if the pressure sensor will show the tidal effect if the outfall is submerged. This may be tested at the TNC site as well as other sites.

The second issue is mostly mathematics. The software that I am using is designed mainly for open channel flow. As the water level rises, the flow increases. Both water level and flow increase in value. For the pressure sensor application, the pressure decreases as the flow increases. This relatively small problem is being resolved. There are additional mathematical issues using pressure sensors as the surrogate for flow. These will be worked on as more data becomes available.

Finally, questions remain as to the optimum location to install a sensor and if there is a need for two sensors to accurately define flow. The limited data to date indicate a sensor on the downstream side of the levee is the most sensitive and responsive. There is not enough information to locate a second sensor.

In summary, the critical path for the pressure sensor evaluation is to test a siphon with a submerged outfall.

The reasons to continue the pressure sensor evaluation are two-fold. The installation costs are very competitive compared to other instruments currently available. Secondly, long term accuracy seems more likely compared to the other instruments. Pressure sensors are less prone to be adversely affected by debris, corrosion, algae buildup, air entrainment, and calibration drift. More testing is needed to determine if pressure sensors are truly more reliable and cost-effective.