FLOWAssessment SERVICES L.L.C.

Flow Assessment Services

General Approach to Open-Channel Flow Monitoring

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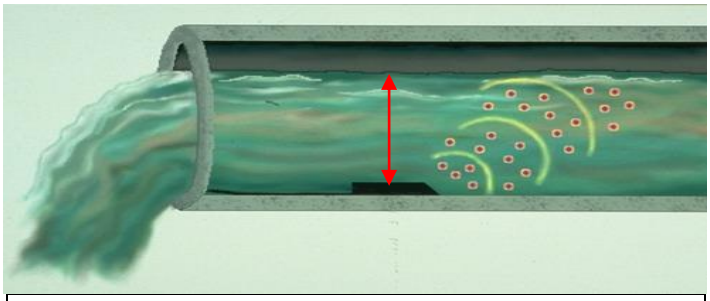
Based on our numerous years of field experience, and work with the top engineering firms in the Northeast and Mid-Atlantic States, we have found that the following are important to an accurate flow monitoring project:

- Proper site selection
- Matching flow metering equipment to flow conditions
- Rigorous measurement and calibration on installation
- Weekly maintenance visits with:
    - Thorough inspection of sensors and logging equipment
    - Field data analysis for previous week's trends
    - Calibration checks
- Expert data analysis using our proprietary software and trained data analysts

Proper Site Selection: all flow monitoring devices provide their best information when installed in an area with a fully-developed flow profile. In sewer flow, we try to help our client weed-out measurement locations with excessive turbulence such as: swirling flow from a nearby bend, churning flow from a nearby confluence of lines, or unwanted vertical flow from a nearby elevated flow line (dropped flow). Sometimes these poor conditions can be spotted from street level, but the final judgment of each site comes from a manhole entry and, eventually, from observations of the flow meter data.

Matching Flow Metering Equipment to Flow Conditions: each site presents a unique situation, and no single flow monitor is right for every one. Flow Assessment maintains a large inventory of equipment to provide the best match, and will often use combinations of different flow monitoring principles to span flow extremes.

For most applications we use a continuous wave area-velocity flow monitor as manufactured by Teledyne Isco or Hach Sigma. These measure flow velocity and flow area simultaneously, solving the equation $Q_{(flow)}$ = Velocity X Area. For velocity measurement these



Area-velocity flow sensor providing average velocity and level.

meters use a continuous wave Doppler ultrasonic beam that provides an average of the entire flow profile. Flow area is derived from the level, or head, of the flow. This is measured with a microprocessor-based level sensor that reduces drift. The level sensor has the added advantage of measuring surcharge levels. These meters can be supplemented with an independent ultrasonic down-looking sensor to provide either redundant level or information about adjacent sewer levels (such as overflows).

Most continuous wave area-velocity meters require >1" of level to provide an accurate measurement, but some residential areas drop below this for significant periods of time. The Palmer-Bowlus Flume is a good choice for areas with low flows because we can install these temporarily (or permanently) in manhole inverts. We measure the levels in these flumes primarily by using an ultrasonic down-looking sensor connected to a flow logger. This provides us with an electronic digital record of the flow rate at selected time intervals (typically every 15 minutes, but can be as often as every minute).

The continuous wave area-velocity meter provides very goo d accuracy and very good repeatability at reasonable prices. However, for some larger pipes, we can provide greater accuracy using an ADFM (accoustic Doppler) principle flow meter. These are considerably more expensive, but offer a more powerful pulsed Doppler signal in multiple paths. The stronger Doppler signals can reach further into the flow profile of very deep flows.

Flow Assessment will help guide our client on *flow meter versus cost* decisions for large pipes, and the flow monitoring purpose will steer our choice. For an I/I study (inflow & infiltration), the repeatability of the lower-cost continuous wave area-velocity meter is the most important consideration. For a capacity study the continuous wave meter is probably sufficient, especially after a meticulous installation and calibration by our experienced field crew. For a billing situation, the more expensive flow metering equipment may be merited.

Rigorous Measurement and Calibration on Installation: since flow area is derived from level, it is important that the pipe dimensions be exact. Flow Assessment crews measure the sewer pipe carefully to provide the best level-to-area calculation. The level reading of the flow monitoring equipment is carefully adjusted to the actual level at the point of measurement. Flow Assessment crews measure flow velocity at multiple points (the number of points is dictated by the pipe size and velocity conditions), and the average velocity is compared to the flow monitor. Flow Assessment crews will allow the equipment to run for a few hours, and will download the stored data to insure that everything is running as it should.

Weekly Maintenance Visits: we have found that aggressive maintenance of each site is the key to high-quality flow data. Flow Assessment field personnel visit each installation on a weekly basis. On each visit they enter the manhole (using proper confined space procedures and equipment) to visually inspect the sensors and logging equipment. Although sensor fouling is rare, this is the time the crews will clear

any debris that may block a velocity measurement. The crews will take an actual level measurement and compare it to the flow meter reading; any deviation is corrected and noted for our data analysts. Flow Assessment field crews will then download the previous week's data and perform a field analysis. This analysis will determine whether flow conditions have changed, possibly mandating a change of equipment or a supplement with an additional flow meter. If the flow metering equipment needs update or repair, we do that on the spot to minimize downtime. Batteries are checked and changed well before they are depleted.

Expert Data Analysis Using our Proprietary Software and Trained Data Analysts: Flow Assessment data analysts review all data for outliers. They apply field observations, experience and our proprietary software to provide accurate data that modelers find valuable. After QA/QC our data is posted to an internet website; anyone with the proper user name and password can view the data in graphical (hydrograph or scattergraph) or tabular format. Final data reports can be in almost any format desired.