Wireless Technologies and Non-Contact Flow Measurement Open a New Door for Flow Data Delivery and Hands-Off Flow Monitoring

James Darby
jdarby@hach.com
Hach Company, 4539 Metropolitan Court, Frederick, MD 21704

Abstract

In 1999, the first practical non-contact and non-restrictive (NCNR) Area/Velocity flow meter that was suitable to measure flow in sewers was introduced. This meter utilizes an ultrasonic transducer to measure depth and digital Doppler radar to measure velocity. The sensor is mounted above and out of the flowing liquid eliminating the need for site visits for unplanned maintenance due to sensor fouling.

Advantages of these meters include a drastic reduction in confined space entry as well as a wireless communication feature that eliminates costly site visits to collect flow data. The accuracy, reliability, and non-contact nature of these meters makes it possible to offer a totally hands-off approach to flow monitoring allowing municipalities to pay only for the flow data they need without the capital expense of flow meter purchase through a rapidly growing trend in the market called Data Delivery Service (DDS).

The accuracy of these meters in low flow depths up to surcharge conditions has been independently verified many times over the years including both laboratory and field evaluations. This paper will discuss the results of these independent verifications, as well as practical applications and the stability of the data collection model.

Key Words

Flow Monitoring, Wastewater, Verification, Stability, Technology, Maintenance, Non-Contact

Introduction

Flow Measurement Methods - Level

Weirs were used to regulate flow through Roman aqueducts. More recently, flumes have become popular for measuring flow in sewers. Both flumes and weirs introduce some restriction to flow causing the level at points in the flow path to rise as a function of flow rate. Documenting this level to flow relationship in a weir or flume establishes what is called a primary flow element. Flow rate can now be derived from a simple level measurement at a particular point in the flow element. Flumes have smooth and gradual restrictions that don't collect debris making them ideal choices for measuring dirty flows such as mining slurries and sewage. Originally, level measurements were made with a simple ruler and then evolved into a float and ruler. In the second half of the 20th Century, submerged pressure devices became the standard for measuring level (depth). Many modern flumes and weirs now incorporate ultrasonic non-contact level sensors. Non-contact flow monitoring is the preferred technology because of its reliability and relatively low maintenance.

Robert Manning introduced what is now called the Manning Equation in December 1889. This empirical formula has found widespread use calculating open channel gravity flow in both natural and engineered channels. Simply put, the formula uses depth, channel slope, and roughness to infer flow rate. Even though the Manning Equation does not directly measure flow rate, an instrument implementing the formula and a means for measuring level became popular in the 1960's. A major improvement occurred when non-contact level sensors became available. These sensors combined with the Manning Equation established the first non-contact and non-restrictive means for deducing flow rate and significantly increased the popularity of this method. The method maintained popularity until the advent of Area/Velocity (AV) flow meters introduced in the late 1970's.

Limitations of Flow Calculations based on Level

Flumes and weirs introduce restrictions to flow and only measure accurately over a relatively narrow range of flow rates. This means that they must be sized correctly for the application and are prone to errors if normal flows increase over time or if flow increases significantly during storm events due to Inflow and Infiltration (I&I). Construction and installation cost for larger line sizes is not insignificant. An instrument using the Manning Equation does not restrict flow but relies on correct inputs for slope and roughness. As errors in estimating these variables are easy to make and can cause large fluctuations in the inferred flow rate, Manning's equation is not typically used as the primary means for determining flow rate but instead has found a place as a rough quality check on other flow data.

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Flow Measurement Methods – Area/Velocity (A/V)

A significant breakthrough occurred with the introduction of A/V flow meters. For the first time there was a flow meter that measured both level and velocity. The addition of velocity allowed these flow meters to implement the Continuity Equation, Q = (Vm) (A) to calculate flow rate (see Figure 1). A/V flow meters using the Continuity Equation have important advantages over level only devices. The Continuity Equation fundamentally differs from the Manning Equation in that velocity is measured directly rather than inferring a velocity from slope and roughness. Difficult estimates of pipe slope and roughness are eliminated. A/V flow meters measure accurately over a wide range of flow rates and are not limited to the narrow range of level only meters. Downstream restrictions can cause huge errors when level only devices are used. If the flow became blocked, the pipe level could be at a maximum (full pipe) with the velocity and flow rate at zero. A level only meter would register the maximum flow rate it was scaled for. In this same example, a flow meter using the Continuity Equation correctly outputs a zero flow rate by multiplying the area of the full pipe (A=100%) by a velocity of zero.

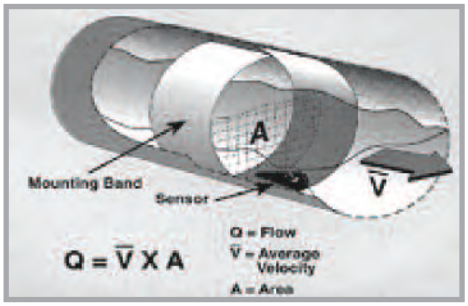

Figure 1. Continuity Equation

Non-Contact Velocity Sensing

Similar to the major improvement that occurred when ultrasonic sensors became available for monitoring level, cost reductions brought about by the commercialization of radar for applications such as police speed guns made radar velocity sensing affordable and non-contact A/V flow meters possible.

Flo-Dar™ was first introduced in 1999, and provided yet another breakthrough in that the flow meter brought together ultrasonic level, radar surface velocity and combined those two measurements with a novel mathematical model to translate surface velocity to mean velocity – finally making an accurate non-contact A/V flow meter. Flo-Dar is the first practical flow meter in use today that has all the advantages of the preceding technologies with none of their disadvantages. It was not the first non-contact and non-restrictive (NCNR) flow meter as there are other techniques such as laser velocimetry; however, Flo-Dar is the first practical NCNR device suited to measure flow in sewers.

Flo-Dar uses an ultrasonic transducer to measure depth and digital Doppler radar to measure velocity from a sensor that is mounted above and out of the flowing liquid. The level transducer produces acoustic pulses and measures the time required for each pulse to reach, reflect off of the water surface and return to the transducer. The sensor's microprocessor uses the speed of sound in air, adjusted for the local temperature, to calculate the distance that the water surface is from the Flo-Dar sensor. During installation the elevation of the sensor is recorded in the site setup information and is used to convert this distance into depth. The standard level transducer operates at 83 kHz and measures distance up to 60" (1.5m). The long range transducer operates at 47 kHz and measures distance up to 20' (7.9m). Acoustic time of travel is a widely accepted method for accurate, stable and non-contact level measurement.

Digital Doppler Radar

Digital Doppler radar technology is similar to what is used to create radar images in weather reports and for law enforcement to monitor the speed of traffic. Flo-Dar uses radar to measure the surface velocity of the flow being measured. Ripples, bubbles or other features on the surface reflect the transmitted radar energy back to the radar horn where the returned frequency is compared to the original transmitted frequency. The difference between these frequencies is called the Doppler frequency and is directly proportional to the velocity of the reflectors or the surface velocity of the flow. Over a period of time the various Doppler frequencies or velocity returns are sorted through a process called a fast Fourier transform (FFT). After the sorting, a large build-up in amplitude occurs corresponding to the surface velocity of the flow. This can be seen in a graph of the FFT (see Figure 2). Extensive mathematical computations are required to accomplish the FFTs in a timely fashion. This processing power is provided by an embedded digital signal processor (DSP).

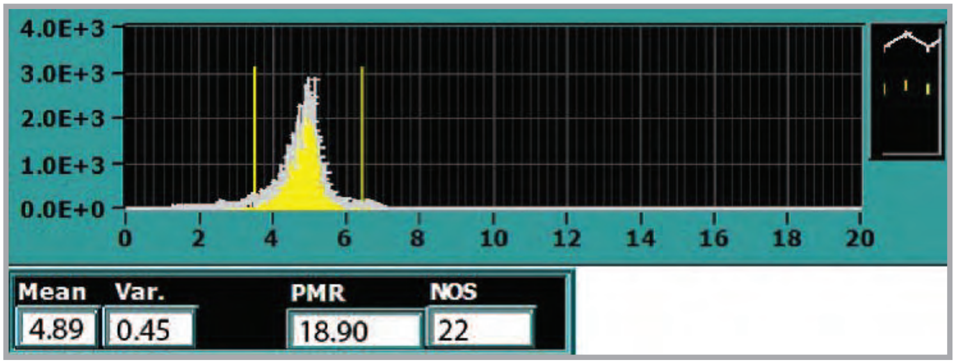

Figure 2. FFT

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Doppler shift is a physical phenomenon directly related to the radiated frequency (24GHz for Flo-Dar) and the velocity of the object the energy is reflecting back from, in this case the water surface. This makes the velocity calibration of Flo-Dar directly equivalent to the accuracy and stability of the radar frequency. Flo-Dar's radar system meets Federal Communications Commission (FCC) and other worldwide agencies stringent licensing requirements that include maintaining operation within ultra-tight frequency and stability limits. This means calibration of surface velocity is within ±0.5% and periodic calibration is not required. Flo-Dar uses the Continuity Equation to calculate flow rate.

Surface Velocity to Mean Velocity Conversion

Following the Continuity Equation, Q = (Vm)(A), mean velocity is required to accurately calculate flow rate. It is important to distinguish the difference between surface velocity and mean velocity, as surface velocity will differ from mean velocity by up to 15% in ideal conditions, and diverge even further when conditions are less than ideal. Fortunately, mean velocity can be accurately calculated once surface velocity and level are known. For gravity flow in a pipe, a natural relationship will develop between any particle in the flow with every other particle. This is called *developed flow*. Finite element modeling was used to determine the relationship of the velocity at the surface to the mean velocity. This relationship varies with level. Additional work was done to fine tune the model for variations in pipe size. Data from this mathematical model was used to create a *surface to mean velocity algorithm* that was incorporated into Flo-Dar's flow equations (see Figure 3). Flo-Dar was then tested at laboratories and calibrated field sites. The laboratory and field test results confirmed the validity of the algorithm.

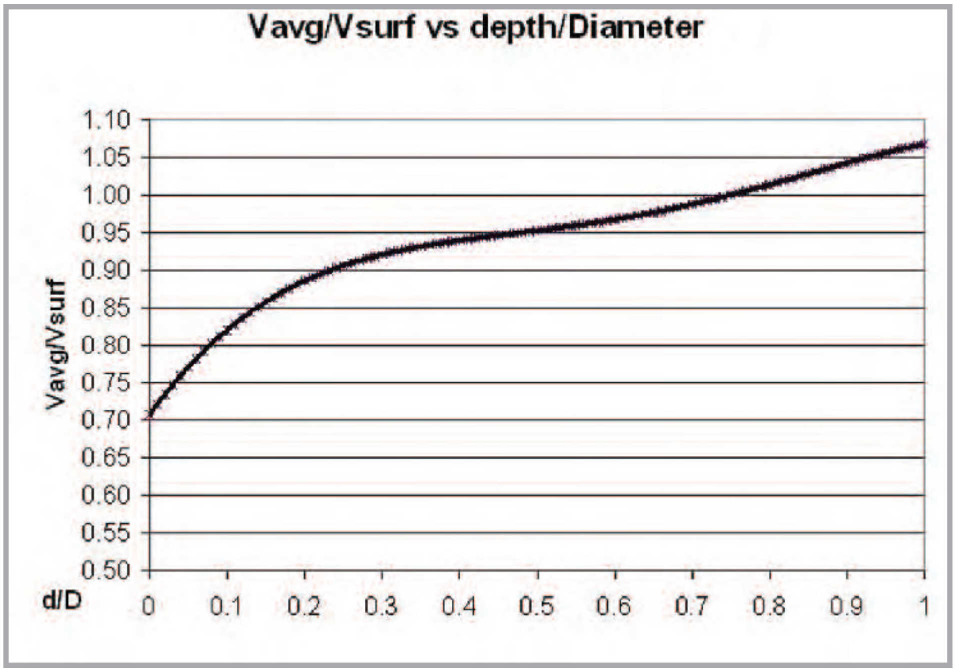


Figure 3. Surface to Average Velocity Conversion vs Depth

Surcharge

One limitation of these non-contact sensors is that they may be negatively affected when submerged. During surcharge conditions the Flo-Dar sensor is often submerged to a point where the radar and ultrasonic transducers are inoperable. An alternate flow monitoring method is required to maintain accurate measurement during surcharge. Every Flo-Dar sensor has a built in pressure transducer that measures surcharge level during these conditions. This information may be important for operators and planners to evaluate future changes in their distribution system. A surcharge velocity option is available for applications requiring seamless flow data both in normal and surcharge conditions. The surcharge velocity sensor (SVS) attaches to the bottom of the Flo-Dar sensor and begins to measure velocity when the depth is within 2 to 3 inches below the crown of the pipe and continues to measure velocity until the surcharge recedes. During surcharge, the flow area calculation assumes a full pipe and the SVS velocity is used in lieu of radar velocity to calculate flow rate. The surcharge velocity sensor is a streamlined electromagnetic type sensor that can measure very low velocities as well as reverse surcharge velocities (see Figure 4).

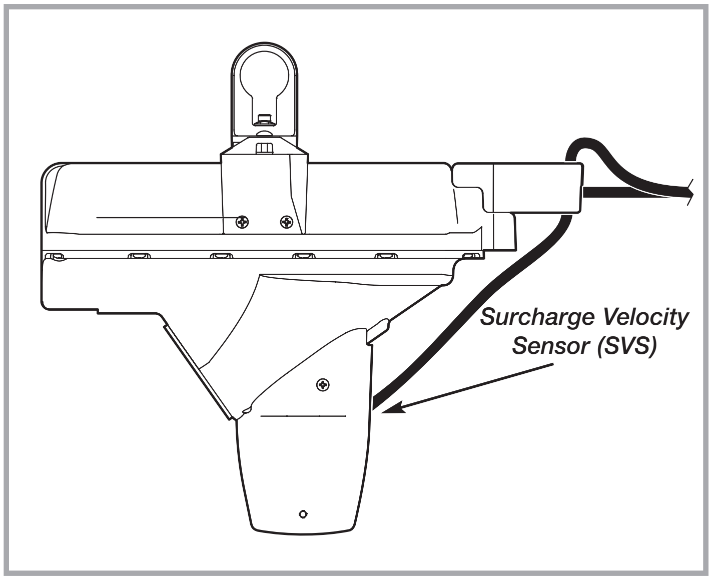
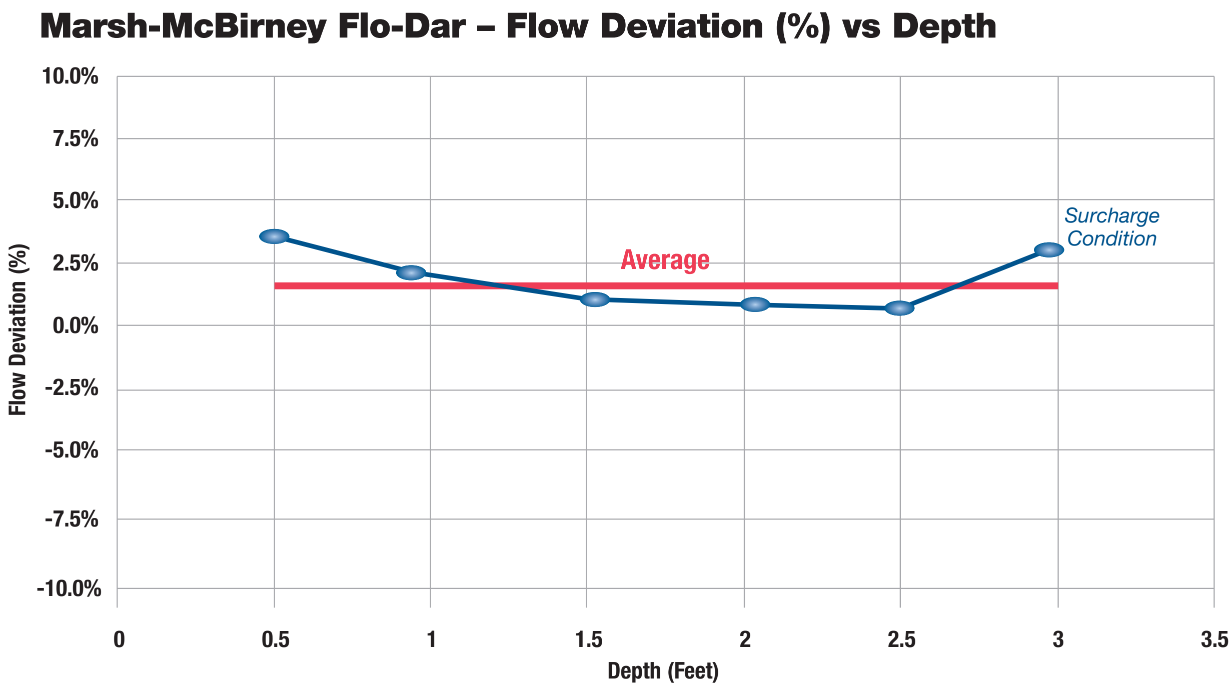


Figure 4. SVS Sensor

System Accuracy

Flo-Dar accuracy from low flow depths up to surcharge conditions has been independently verified many times over the years including a formal evaluation (Tests of Open Channel Flow Meters in 36" Pipe by Alden Research Laboratory, Inc.) and field evaluations such as the one completed for the East Bay Municipal Utility District by V&A Engineering (EBMUD Flow Monitoring Technologies Evaluation Study). The average error in the Alden evaluation was 1.9% with a maximum error of 3.4% (see Figure 5). The EBMUD technology evaluation found Flo-Dar velocity to be within 1.4% of the velocity profile data used as a standard (see Figure 6). Flo-Dar was deemed usable in 87% of their study locations, a higher percentage than any other technology. Recently CH2M HILL was commissioned to verify the calibration of 15 Hach Data Delivery Services (DDS) Flo-Dar installations located in Lawrence, Kansas. These meters have been installed for over three years continuously sending flow data via cellular modem and the internet to city managers and engineers. The average error reported by CH2M HILL was under ±5%. The majority of the Flo-Dar velocity errors were ±3.5% or less after three years of deployment (see Figure 7).



Depth (in.)	Flow (gpm)	Flo-Dar (gpm)	Deviation (%)
6	304.2	314.5	3.4
11	1524.4	1556.2	2.1
18	4668.2	4716.1	1.0
19	4874.0	4988.9	2.4
25	8422.8	8494.6	0.9
30	12463.5	12558.5	0.8
36*	16949.7	17424.4	2.8

*Flo-Dar with Surcharge Option in 36" pipe.

Figure 5. Results from Alden Research Laboratory, Inc. Evaluation

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Profiled Velocity 2.91 fps

	Velocity (fps)	Error (%)
Flo-Dar	2.95	+1.4
Continuous Wave Doppler A	2.87	-1.4
Continuous Wave Doppler B	2.61	-10.3
Pulse Doppler A	3.05	+4.8
Pulse Doppler B	2.61	-10.3
Transit-Time	2.63	-9.6

Figure 6. Results from V&A, EBMUD Flow Monitoring Technologies Evaluation Study

Flow Comparison Summary

Manhole Number	Calculated Depth (inches)	Monitored Depth (inches)	Field Measured Average Velocity (fps)	Monitored Velocity (fps)	Field Calculated Flow (mgd)	Monitored Flow (mgd)	Percent Error
WR2-059	4.25	4.59	2.648	2.57	0.643	0.697	8.5%
WR2-151	3.25	3.00	3.550	3.64	0.617	0.564	-8.6%
WR-6-099	9.50	9.70	2.925	2.80	3.332	3.290	-1.3%
WR6-092	4.50	4.70	1.420	1.40	0.374	0.089	5.0%
WR4-18A	7.75	8.70	1.428	1.41	0.810	0.937	15.7%
WR5-187	6.00	6.06	1.928	1.86	0.957	0.923	-3.6%
YTC2-127	1.50	1.60	3.400	2.84	0.218	0.220	1.1%
WR6-137	9.25	9.50	2.980	2.80	2.778	2.700	-2.8%
KR5-092	4.50	N/A[1]	5.590	N/A[1]	1.653	N/A[1]	N/A[1]
KR4-171	4.25	4.50	2.180	1.95	0.449	0.425	-5.3%
KR2-150	4.50	N/A[2]	0.938	N/A[2]	0.180	N/A[2]	N/A[2]
KR2-214	3.75	3.70	3.000	3.10	0.608	0.616	1.3%
KR6-015	4.00	4.03	1.450	1.50	0.299	0.312	4.3%
KR5-083	3.00	3.00	3.000	2.84	0.426	0.448	5.3%
KR6-154	8.00	7.70	4.605	4.62	3.481	3.357	-3.6%
Average							**4.2%**[3]

(1) Dislodged monitor – no valid monitoring data for comparison
(2) Monitor inoperable – no valid monitoring data for comparison
(3) Average does not include monitoring site WR4-18A

Figure 7. Accuracy Data from CH2M HILL Report

System Stability

Flo-Dar has advantages that make it particularly well suited for measuring flow in sewers. The inherent stability and accuracy of the technology used to measure velocity and level reduces the need for and the cost of frequent site verifications. Trend data, scatter plots and alarms are available in near real-time for web enabled or DDS flow meters. These tools allow irregularities in the level to velocity relationship to be quickly identified and resolved.

Site verification is a valuable process and strongly recommended for any important flow study. Often site calibration at the beginning and end of the deployment is sufficient for Flo-Dar instrumented sites. The results of the CH2M HILL report on the DDS sites in Lawrence, Kansas that have been in service for 3 years, confirm the long-term stability of the Flo-Dar flow metering system.

Reduced Maintenance

Non-contact sensing eliminates costly service trips requiring confined space entry to scrub sensors as well as the cost of lost data due to sensor fouling (see Figure 6). Periodic maintenance is typically confined to battery replacement. Batteries can be configured to provide power for a one-year period. Web-enabled Flo-Dar's and DDS sites also eliminate local data retrieval thereby eliminating most site visits altogether. Because maintenance and battery replacement are included in the service, collection systems or applications utilizing DDS will never need to plan or budget for these expenses.

Flo-Dar has all the benefits of a non-contact flow meter up until surcharge conditions exist. Fouling can occur during these events if debris remains on the sensor as the surcharge recedes. Although fouling is extremely rare, it is readily identified after a surcharge event. If clearing of sensor debris is ever required, it usually can be accomplished at street level without the requirement for confined space entry. There are metering sites where Flo-Dar sensors have been in continuous service for eight years without requiring any maintenance.

Figure 6. Fouled Submerged Type Sensor

Reduced Confined Space Entry

Flo-Dar users realize a drastic reduction in confined space entry due to the elimination of sensor maintenance. Field crews are not required to be sent out to enter manholes to scrub fouled sensors. There are also other confined space entry reductions realized in temporary metering applications where meters are frequently rotated within the collection system. When previously installed Flo-Dar mounting frames are left in place, sensor re-installation can quickly be accomplished with a sensor retrieval tool. Often this can be done from street level without the need for confined space entry (see Figure 7). This is particularly useful when a site is monitored both before and after remediation. There have been custom mounts fabricated by users faced with particularly dangerous manhole atmospheres. These mounts suspend Flo-Dar from the top of the manhole and require no confined space entry. For DDS customers, installation and maintenance are included as part of the service.

Figure 7. Flo-Dar Sensor Retrieval Tool

Installation

Field crews appreciate the ease in which Flo-Dar is installed in a sewer. Even though a crewmember is required to enter a confined space, the Flo-Dar mounting frame is installed above the crown of the pipe. This mounting arrangement typically eliminates the need for a crewmember to wade in the flowing sewage while forcing a band into the pipe. Flo-Dar also reduces safety issues related to the suspension of a crewmember in the flow conduit below the crown of the pipe.

Permanent and temporary devices are available for mounting the Flo-Dar sensor. Permanent mounts are made of stainless steel and designed for long-term use in the rugged sewer manhole environment. The sensor mount attaches to the manhole wall with two 3/8" expansion bolts (see Figure 8). Temporary mounts consist of a tension jack bar designed to be easily installed, removed and reinstalled for portable flow monitoring applications without the need for drilling (see Figure 9).

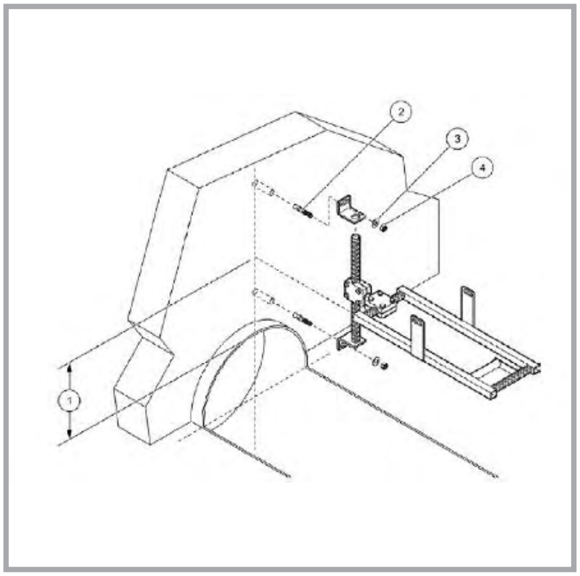

Figure 8. Permanent Sensor Mount

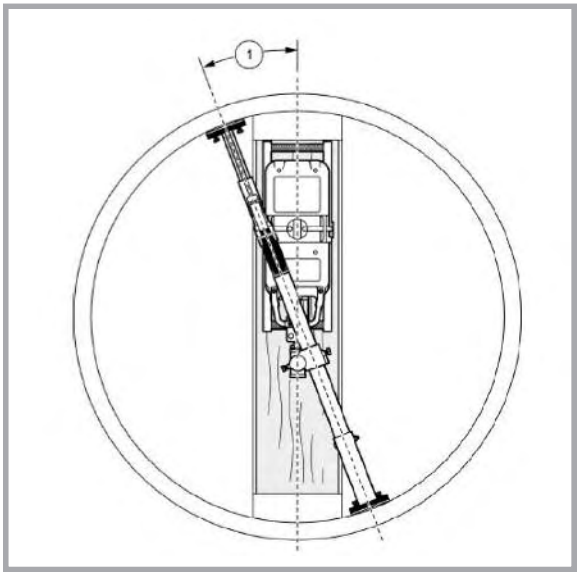

Figure 9. Temporary Sensor Mount

Flexibility

Because Flo-Dar operates above the flow stream, it will work in difficult applications where other technologies may not. Low level high velocity flow and chemically active flow are two examples. For example, flow rate in a highly sloped pipe with 0.25" (6mm) depth flowing 4 ft/s (1.22 m/s) is accurately measured by Flo-Dar. Submerged style sensors installed on a band will create a hydraulic disturbance, (rooster tail), rendering inaccurate flow measurements in these same conditions. In addition, measuring chemically active flow is possible with Flo-Dar. There is no sensor or sensor cable in the flow that can be attacked by high or low pH. The application shown has a pH of 2 (see Figure 10).

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Figure 10. (pH = 2)

Reduced Calibration Verification

Flo-Dar installations operate continually, accurately and reliably over long periods of time. This is facilitated by the inherent advantages of non-contact measurement and drift free Doppler technology. Costly site visits are drastically reduced by eliminating fouling issues and the need to perform routine site calibration verifications. The CH2M HILL *Lawrence, Kansas Long-Term Flow Monitor Profiling* study confirms Flo-Dar maintains its original calibration after three years of operation.

Data Delivery Service

An accurate, reliable, non-contact flow meter makes Hach's Data Delivery Service possible. DDS is a unique approach to sewer flow metering that provides a service that allows municipalities to pay only for the flow data they need. Secure flow data is transmitted from web-enabled Flo-Dar sensors and unedited flow data is available 24/7 via the Internet to the offices of city managers and consulting engineers. DDS allows users to take advantage of the non-contact, low maintenance features of Flo-Dar that enable quality data to be made available at low cost. The proven stability of Flo-Dar confirms that frequent periodic maintenance requirements often written into flow monitoring specifications only add cost to the data collection effort. Additionally, alerts can be automatically sent to pagers, phones and e-mail. All of the benefits of Flo-Dar are available with DDS without the capital expense of flow meter purchase (see Figure 11).

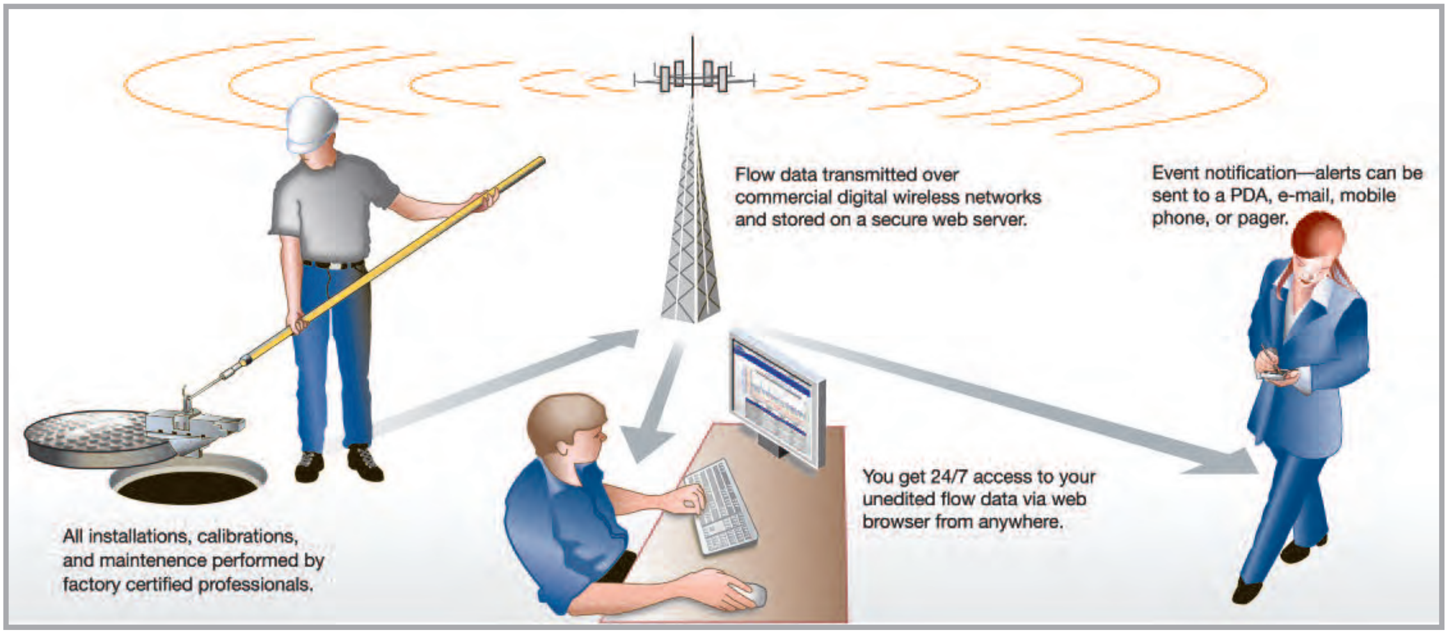

Figure 11. DDS Approach to Flow Monitoring

Conclusion

Collection systems or applications utilizing DDS obtain reliable flow data for a fixed monthly cost. Maintenance is included in this cost and there is a 95% uptime guarantee or the service is free for that period of time. It is the non-fouling nature of Flo-Dar that allows the DDS concept to be practical and very cost-efficient. The stability and drift-free technology designed into Flo-Dar and its ability to monitor real-time trends and scatter graphs, make frequent site verifications unnecessary. Flo-Dar calibration stability is confirmed by independent engineering studies. The *Lawrence, Kansas Long-Term Flow Monitor Profiling* study concludes, "Considering the extended flow monitoring duration (exceeding three years), the City of Lawrence long-term flow monitors have performed within the expected range of ±5% on average." It takes a non-contact flow meter to eliminate sensor fouling and the high cost of associated maintenance and frequent site calibration verification. Only a flow metering device with the accuracy, reliability and non-fouling qualities of Flo-Dar can supply the data guarantee and affordability DDS offers.

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About the Author: Currently serving as Applications Development Manager for Hach Company's Flow & Sampling Business Unit, Jim Darby has over 35 years of flow experience in the water and wastewater industry. During his tenure at Marsh-McBirney, Jim held numerous positions and is considered an expert on electromagnetic and radar flow technology. Jim's knowledge and experience was instrumental in the design and development of numerous Marsh-McBirney flow meters and he holds a patent on flow measurement techniques. Mr. Darby is a frequent contributor of technical and opinion articles in various flow industry publications. He is an active member of the American Water Works Association (AWWA) where he served on the Standards Committee on Rate Type Flow Meters for 8 years and is also a member of the Water Environment Federation (WEF).

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"I've got better things to do than maintain flow meters, don't you?"

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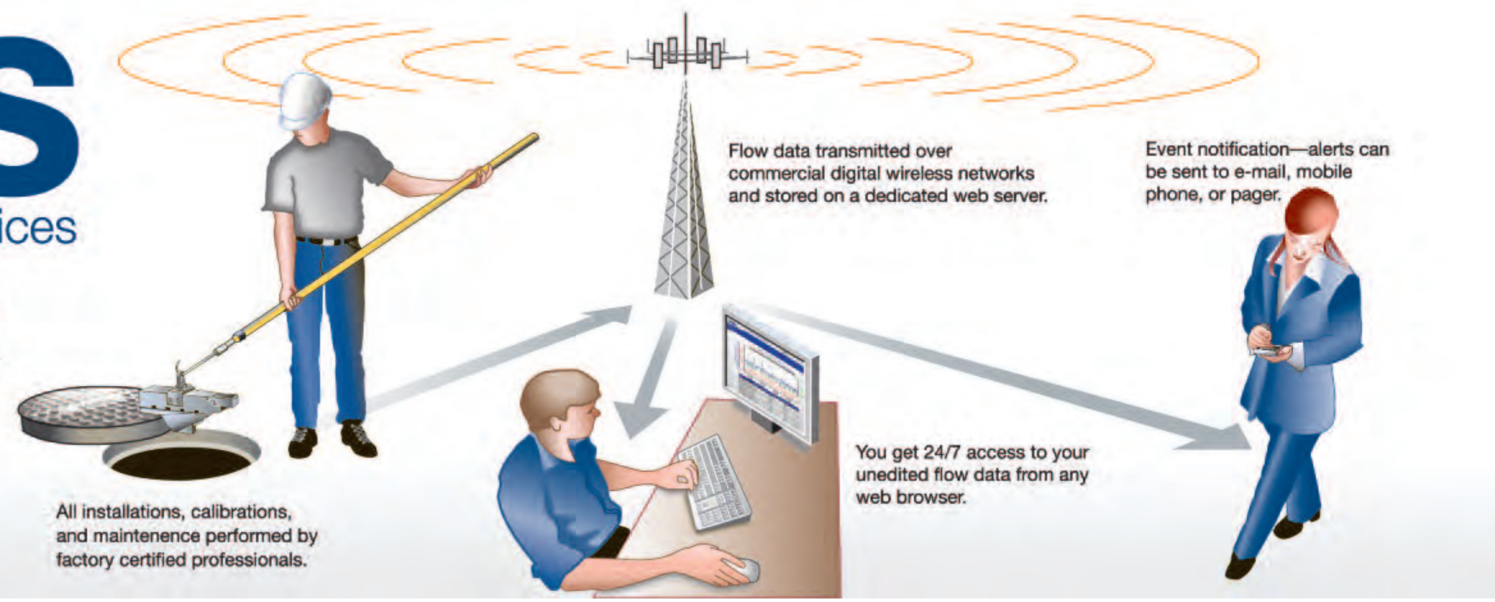
DDS

Data Delivery Services

- **No flow meter purchase required**
- **Includes web-enabled flow meter installed and maintained by our certified personnel**
- **24/7 access to your unedited sewer flow data from any web browser**



THE NEW APPROACH

Imagine...

a reliable sewer flow monitoring network that doesn't require manhole visits.

Imagine...

accessing your sewer flow data anytime, anywhere—from the comfort of the Internet.

Imagine...

receiving this unedited, accurate data at a fixed monthly price.

Imagine...

having all the benefits of superior data quality from a Hach web-enabled flow meter—without the upfront capital expense associated with a flow meter purchase.

With DDS (Data Delivery Services) you pay only for sewer flow data and you don't have to leave your office to get it. For a fixed monthly fee, Hach Company will furnish you with a web-enabled sewer flow meter and all of the following:

- *24/7 access to your unedited sewer flow data from any web browser*
- *95% data uptime guarantee or it's FREE*
- *Secure password protected access*
- *Ideal for short or long-term flow monitoring*
- *Daily data back-ups*
- *Live customer support*

Whether you need data from one monitoring site or many more, Data Delivery Services will change the way you think about sewer flow metering.

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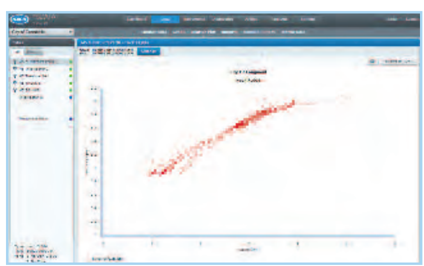
WHAT YOU GET

Web-Enabled Flow Meters

DDS includes a web-enabled flow meter with a long-life battery and a special antenna that continuously sends data from the meter in the sewer to a dedicated server.

Professional Flow Reporting

Professional flow data reporting is easily accomplished via the graphical web-based user interface. Hydrographs, scatter-plots, and tabular data indicating min, max, and average values for any user-selectable measurement including level, velocity, flow, battery voltage, call log, temperature, and sensor specific diagnostics are provided.



Collection system flow data can be used for:

- *Inflow and Infiltration Analysis*
- *Operations and Maintenance*
- *Capacity Analysis*
- *Rehabilitation, Repair, or Replacement*
- *Regulatory Compliance*
- *Billing and Custody Transfer*
- *Alarming*
- *Modeling*
- *Master Planning*

Flow data can be used to determine the following:

- *Average daily flow—dry weather*
- *Peak flow—dry weather*
- *Average daily flow—wet weather*
- *Peak flow—wet weather*
- *Peak inflow rates*
- *Total I/I volume*
- *In-situ pipe capacity (dry and wet weather)*
- *Custody transfer and billing application information*

Flow Data—Anytime, Anywhere

View your flow data from any internet connected web browser through a secure log-in. Multiple users can be granted different data access levels based on job function.

Event Notification

Alarms can be set for any sensor parameter and are sent by SMS messaging or email to specified recipients.

Data Uptime Guarantee

Hach Company monitors the health and status of all networked flow meters 24/7. Hach guarantees a 95% uptime or the data is free.

Certified Installation & Calibration

Hach Company provides factory-certified installation and initial calibrations of DDS flow meters.

Password Protected Server

All data is routed through our dedicated, protected server located in Loveland, Colorado and backed by Hach's IT systems.

Maintenance & Repair Included

You never have to worry about unforeseen costs. If there is ever a problem with any of the meters, they are repaired or replaced within the data uptime guarantee.

Rain Gauge Option

Rain gauges can be included in the DDS network for I&I and capacity studies. Rain data is provided along with flow data on the DDS website for further data analysis and reporting.

What **DDS** customers are saying…

City of Lawrence, Kansas

Inflow and infiltration work in several collection system basins in Lawrence,Kansas, required long-term flow monitoring. Attracted by the DDS approach to flow monitoring, they are seeing 'BIG' savings as well as freeing up their personnel for other tasks. "It's great for us because we don't have to buy all of the meters, we don't have to pay for the maintenance on them, and we don't have to provide labor for anything."

Bob Brower, Manager, Lawrence, Kansas
Wastewater Field Operations

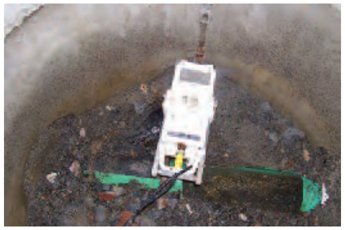
US Steel

In mid-2006, the US Steel Great Lakes Works facility determined a need for three flow meters to accurately monitor discharge water in their 'hot roll' process. Due to the less than ideal conditions at the sites, it was strongly preferred that a monitoring solution that eliminated sensor maintenance, as well as personnel site visits for data collection, could be found. "Now, with DDS we don't have to have anybody come in and get a flow reading on their day off. Now we just go to the website and look at the flow for the 24 hour period from Sunday to Monday. It's quite a timesaver. Everything is taken care of for us with DDS."

Don Thayer, Manager - U.S. Steel
Water Compliance/Environmental Department

Cutting Edge Group, LLC

When the Cutting Edge Group, LLC, (CEG) a design-build firm located in Lake George, New York, was contracted to provide flow services for the Village of Whitehall, New York, their first task in the pilot study was to monitor the flow of the Village's service laterals."The conclusion that we came to was to select DDS based on the pricing structure.It's definitely a cost savings! When you really look at the big picture, we found that DDS was the most cost effective way to go."



Tom Davey,
Cutting Edge Group LLC

"Data Delivery Services is extremely helpful and has significantly increased our efficiency."
AH Environmental

"It did not make sense to invest a large sum of money into capital expenditures that were only needed for two years. With a fixed price per meter, per month, DDS was perfect for us."
City of Carmel, Indiana

"These radar meters are right on the money …they work very good!"
Stephl Engineering

"It just was more cost efficient to do DDS."
City of Hilliard, Ohio

"The system has helped us provide quality data while saving us time in the field."
O'Brien & Gere

"It really fulfills our needs. The price was right, too."
City of Scottsdale, Arizona

"It's maintenance free and the installation was very quick and convenient."
HMT Engineering & Surveying

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301.874.5599 • 800.368.2723 • Fax 301.874.8459
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