Wastewater Flow Monitoring Services

For

Keck Graduate Institute Sewer Study

Claremont, CA 91711

April 20, 2016 through April 28, 2016

Leaders in Sewer Flow Monitoring Services

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www.uscubed.com
www.sewerflow.com
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Tab 1: Overview & Site Specific Information

1.1 Overview

The Claremont Waterworks Company dates back to the late 1800's. In 1954, the Claremont Waterworks Company integrated to municipal ownership. The Department of Public Works' Water, Sanitary and Stormwater Sewer Department is responsible for operation, maintenance, and construction of the City's sanitary sewer collection system and treatment. Claremont currently services over 3,500 customers with 70 miles of sewer collection mains. In addition to the sewer mains, the department maintains and services 1,150 sewer manholes, 7 sewer pump stations, and a Wastewater Treatment Facility. The treatment facility was built in 1986, and treats on average 1,300,000 gallons per day.

Since the City is responsible for properly managing, operating, and maintaining all portions of their wastewater collection system, as well as providing adequate capacity to carry peak capacity flows, sewer flow monitoring is required as a condition of development. This requirement not only helps to ensure adequate capacitance, but continually updates their database with the most current sewer capacitance information.

1.2 Project Description

Utility Systems Science & Software, Inc. (US3) was contracted by KPFF to install flow monitoring equipment at a specified sewer manhole. This sewer system assessment was developed for the current conditions to determine potential capacity limitations within the monitored sewer line. The selected monitoring site was located on Bucknell Av at its intersection with Watson Dr. The manhole location is shown on the map in Section 1.3.

US3 performed an initial site inspection to assess traffic control requirements and evaluate the site hydraulics at the selected monitoring site. Note: Each wastewater collection system is different, and some of the differences that affect flow monitoring include: slope of sewer line; age, condition and material of sewer line; number and type of connections; and sewer design, specifically the proximity of baffles, drop structures, pumps, siphons, and weirs. Even though none of these structures were found within the selected manhole, if they exist nearby, upstream or downstream, they can affect the hydraulics within the monitoring site.

Even though the levels within the sewer line were extremely low, it was determined that the hydraulics within the selected manhole were acceptable for flow monitoring and could provide an accurate representation of the flow patterns within the sewer line. Therefore, installation at the site occurred on 4/20/2016.
The manhole was equipped with a Hach Marsh-McBirney Flo-Dar® AV Sensor and Logger. With the installation and removal of the equipment, the manhole was opened and confined space entry was limited to crossing the plane with hands and arms, but not actually entering the manhole. Even though US³ personnel did not enter the manhole during equipment installation or removal, they were fully trained and certified in Confined Space Entry and CPR, and in accordance with safety standards, gas readings were taken and recorded throughout the duration of the installation and removal process.

In summary, US³ performed the following services as part of this project:

- Sewer Flow Monitoring
  - Detailed preliminary investigation
    - Assessment of traffic control requirements
    - Inspection and evaluation of the site
  - Installation of a Marsh-McBirney Flo-Dar® AV Sensor and Logger
    - Validation of hydraulic suitability
    - Calibration of flow monitoring equipment
    - Documentation of installation
  - Removal of flow monitoring equipment
  - Validation of flow monitoring data
- Evaluation of the sanitary sewer line at the selected site
- Development of a report to discuss the flow monitoring data, including system statistics and graphs
1.3 Site Maps

Figure above: The temporary wastewater flow monitoring site is located east of the Keck Graduate Institute. The manhole is at latitude 34.091613 and longitude -117.721331, which is at ~272 Bucknell Av.

1.4 Summary of Site

Figures below: The photos show the manhole in the northbound lane of Bucknell Av. Since this was at the intersection with Watson Dr, which is an access point for the Keck Graduate Institute, the field team performed the installation and removal of the monitoring equipment outside of school hours, using cones and signs for traffic control. No issues were encountered.
Figure above: The manhole provided access to an 8-inch sewer line, which entered from the north and discharged to the south. Gas levels were good. The flow monitoring equipment was set to monitor the upstream pipe as it provided the best hydraulics. Even though the level was extremely low, follow up on this installation confirmed equipment calibration.

### 1.5 Existing Capacity Analysis

The capacity evaluation method involves the following process:

1. Collect 15-minute interval depth and velocity data points at each site over the entire monitoring period and determine the depth vs. velocity relationship or pipe curve based on Manning's equation.

2. Determine statistically the minimum, maximum and average depths and flow rates at each site during the monitoring period.

3. Calculate the maximum theoretical unobstructed flow rate at each site.
4. Determine remaining capacity under peak flow conditions at each site, using the ratios of actual daily flow depths to pipe diameter.

**Figures below:** Bucknell & Watson MH graphs of level, flow & velocity, and scatter plot of level in relation to velocity from US³ Flow Monitoring Website (http://us3.uscubed.com/)

The scatter plot above shows the depth vs. velocity data points for the monitored pipe. The pattern of velocity and depth data points for a sewer operating in free-flow conditions over an extended period of time should conform to the depth-velocity relationship of the Manning Equation, which is the basis for evaluating flow monitoring data. This equation
(shown below) defines a commonly used theoretical relationship between depth and velocity in pipes operating under free flow conditions:

\[ v = \frac{1.486}{n} \times R^{2/3} \times S^{1/2} \]

Where,

- \( v \) = velocity (fps)
- \( n \) = pipe roughness, defined as the Manning’s Roughness Coefficient
- \( R \) = hydraulic radius,
  - defined as wetted area (ft^2) divided by wetted perimeter (ft)
- \( S \) = hydraulic slope

The scatter plot from Bucknell & Watson MH shows the depth vs. velocity data points for the 8-inch upstream pipe, which should resemble a theoretical hydraulic operating curve based on the site specific characteristics of the pipe. Actual flow monitoring data was used to estimate the slope of the pipe. Velocity and level readings were compared to theoretical hydraulic operating curves at different slopes, correlating with an operating curve with a slope of \(~1.01\%\) (S=0.0101).

**Figure above:** This theoretical pipe curve was generated for an 8-inch (0.67-ft) pipe with a slope of 1.01% flowing at less than half pipe.
Theoretical Curve

Figure above: Since flows at the Bucknell & Watson MH utilized ~3% to ~6% of the pipe depth during the study, that portion of its theoretical curve has been overlaid onto its scatter plot. Note that the scaling of the axes are not the same so the theoretical curve appears skewed.

As shown in the scatter plot above, the expected relationship between level and velocity is not prevalent, probably due to the extremely low levels.

To summarize the site statistics from the data analysis at the Bucknell & Watson MH:

- During peak flows, ~4% of the pipe's capacity was utilized at ~14 gpm.
- Average flow utilized ~0.5% of the pipe's capacity at ~2 gpm.
- According to common sewer design, velocity shall not be less than 2 fps a minimum of once per day to provide sufficient scouring action for self-cleaning. The maximum velocity at the Bucknell & Watson MH was 3.66 fps with an average velocity of 0.62 fps. Velocities of greater than 2 fps only occurred on three days during this study (4/21, 4/25 & 4/26). The average maximum velocity at the site was 1.83 fps. Therefore, over time, this site is likely to have issues due to settlement of normal system solids.
- According to common sewer design, the depth versus diameter (d/D) ratio for gravity drains of 12 inches in diameter or less should be no greater than 0.50 for the ultimate peak flow condition. The average d/D ratio for the site during this study was ~0.05 and the maximum was ~0.06. Therefore, this site has capacity available at peak flow.
The following is a graphical representation of the site statistics from the data analysis:

The pipe capacity was estimated using a Manning's Circular Pipe Flow Capacity chart, where n=0.013 (minimum value for vitrified sewer with manholes, inlets, etc., Chow 1959). From the theoretical hydraulic operating curve for an 8-inch pipe with a slope of 1.01% (S=0.0101), with the pipe completely full, the velocity is expected to be ~2.3413 fps. When this velocity is input into the Flo-Ware program from the Bucknell & Watson MH, a maximum capacity of 0.5273 mgd is produced. This is a reasonable assumption based on the levels and velocities observed during this study.

**Bucknell & Watson MH Level (depth) vs Pipe Diameter**

<table>
<thead>
<tr>
<th>0.5 in.</th>
<th>0.45 in.</th>
<th>0.4 in.</th>
<th>0.35 in.</th>
<th>0.3 in.</th>
<th>0.25 in.</th>
<th>0.2 in.</th>
<th>0.15 in.</th>
<th>0.1 in.</th>
<th>0.05 in.</th>
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<td>0.5 mgd</td>
<td>0.45 mgd</td>
<td>0.4 mgd</td>
<td>0.35 mgd</td>
<td>0.3 mgd</td>
<td>0.25 mgd</td>
<td>0.2 mgd</td>
<td>0.15 mgd</td>
<td>0.1 mgd</td>
<td>0.05 mgd</td>
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<tr>
<th>Max Level</th>
<th>Max Flow</th>
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<td>3.66</td>
<td>0.62</td>
<td>0.25</td>
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<table>
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<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
</tr>
</tbody>
</table>
1.6 Conclusions

The graphs for the site do not show a regular daily flow pattern. The occasional high velocities allow for some measure of settlement prevention. On 4/21/2016, the velocity was at 2.93 fps for ~45 minutes (1153-1223). On 4/25/2016, the velocity was greater than 3 fps for ~75 minutes (1923-2023), and on 4/26/2016, the velocity was just over 2 fps for ~2.75 hours (0123-0353). Without the three aforementioned periods of flow, the site only averaged 0.57 fps. Even with these low velocities, the site had capacity available at peak flow. Whether or not the available capacity is sufficient is dependent upon future proposed land use in the area.

From the theoretical hydraulic operating curve for an 8-inch pipe with a slope of 1.01%, with the level at half pipe (4 inches), the velocity is expected to be 2.33125 fps, which when input into the Flo-Ware program from the site produced an expected capacity of 0.2630 mgd. Since peak flow was 0.0196 mgd, there should be capacity available for an additional 0.2434 mgd before the pipe exceeds its d/D limit of 0.50 at peak flow. This is a reasonable assumption since the average maximum velocity during the study was 1.83 fps while the level never got above 0.47 inches. In fact, the levels stayed between 0.4 inches and 0.47 inches for a majority of the time while the velocities varied dramatically (not at all in keeping with the theoretical curve): 4/20 at 1953 until 4/21 at 1653 with velocities of 0.25 fps to 2.93 fps; 4/21 at 1753 until 4/22 at 1508 with velocities of 0.25 fps to 1.36 fps; 4/22 at 1808 until 4/25 at 1423 with velocities of 0.25 fps to 1.54 fps; and 4/25 at 1808 until 4/28 the end of the study at 1108 with velocities of 0.25 fps to 3.66 fps. Note: Studies have shown that Flo-Dar sensors provide accurate velocity readings down to 0.25 fps, but below 0.25 fps, extremely laminar flow makes radar readings much less reliable. Therefore, a limit of 0.25 fps was set in the program, which means that the flow could have been moving slower or even ponding at these times.

<table>
<thead>
<tr>
<th>Existing Flow Information</th>
<th>$Q_{AF}$ (mgd)</th>
<th>$Q_{PF}$ (mgd)</th>
<th>Estimated Half Pipe Capacity (mgd)</th>
<th>Available Capacity (mgd)</th>
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</thead>
<tbody>
<tr>
<td>Bucknell &amp; Watson MH</td>
<td>0.0028</td>
<td>0.0196</td>
<td>0.2630</td>
<td>0.2434</td>
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</tbody>
</table>

Even using the average maximum velocity observed during this study (1.83 fps), there would be capacity available for an additional 0.1868 mgd before the pipe exceeds its d/D limit of 0.50 at peak flow. Under the most conservative conditions, using the average velocity observed during this study (0.62 fps), this site would still have capacity available for an additional 0.0503 mgd before the pipe exceeds its d/D limit of 0.50 at peak flow.
Tab 2: Calibration Site Sheets & Flo-Ware Graphs
Manhole in northbound lane near curb

Access:

System Type:
Sanitary X Storm

Install Date: 4/20/2016

Flow Meter

Meter Depth: 75"

Very low open channel hydraulics

Avg Velocity | Avg Measured Level | Multiplier
-------------|-------------------|-------
1.0 fps | 0.25" | 1

Gas

O2 H2S CO LEL
20.9 0 0 0

Notes

Such low flows make calibration extremely difficult.

Traffic Safety

Used cones and signs.

Land Use

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<tr>
<th>Residential</th>
<th>Commercial</th>
<th>Industrial</th>
<th>Trunk</th>
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<tbody>
<tr>
<td>X</td>
<td></td>
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</table>

Manhole Depth 99"

Monitored Pipe Size 8"

Inner Pipe Size (In/Out) 8"/8"

Pipe Shape Round

Pipe Condition Good

Manhole Material Lined

Silt 0

Velocity Profile Data *

Velocity Profile Taken *

Sensor Offset 23.7"

Sensor Dist. to Crown 15.7"

Sensor Direction Upstream

Flow Heading South
Meter Site Document

KPFF

2016.04 Bucknell & Watson MH

~272 Bucknell Av

Site

Manhole Before Install

Installation Process

Installed

Upstream

Downstream
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<tr>
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<th>Velocity (fps)</th>
<th>Level (in)</th>
<th>Flow (gpm)</th>
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<td>0.404</td>
<td>1.939</td>
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<td>Maximum</td>
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<td>0.440</td>
<td>9.514</td>
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<tr>
<td>Minimum</td>
<td>0.250</td>
<td>0.210</td>
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RainFall

Inches

4/28/2016 1:00:15 PM
### 2016.04 Bucknell & Watson MH

<table>
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<th>Date</th>
<th>Time</th>
<th>Velocity (fps)</th>
<th>Level (in)</th>
<th>Flow (gpm)</th>
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<td>0.599</td>
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**RainFall**

<table>
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<th>Rain (Inches)</th>
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<tr>
<td>Maximum</td>
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<tr>
<td>Minimum</td>
<td>0.250</td>
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4/28/2016 1:00:15 PM
## Statistics from 2016.04 Bucknell & Watson MH:
### 4/20/2016 thru 4/28/2016

<table>
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<th>Date</th>
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<th>Flow (MGD)</th>
<th>Velocity (FPS)</th>
<th>Level (inches)</th>
<th>Total Gal</th>
<th>Rain</th>
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<td>Max</td>
<td>Min</td>
<td>Avg</td>
<td>Max</td>
<td>Min</td>
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<td>4/20/16</td>
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<td>3.40</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.81</td>
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<td>4/21/16</td>
<td>1.86</td>
<td>9.51</td>
<td>0.69</td>
<td>0.00</td>
<td>0.01</td>
<td>0.59</td>
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<tr>
<td>4/22/16</td>
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<td>0.01</td>
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<td>0.01</td>
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<td>Week:</td>
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<td>Totals:</td>
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<td>13.61</td>
<td>0.69</td>
<td>0.00</td>
<td>0.02</td>
<td>0.62</td>
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</table>
Utility Systems Science & Software provided KPFF with an off the shelf, non-proprietary solution that included one state of the art Hach Flo-Dar® AV Sensor system. The US³ team implemented the following procedure.

- Reviewed the identified site.
- Validated the site for suitability for flow monitoring and traffic control.
- Calibrated and installed flow monitoring equipment per manufacturer recommendations.
- Validated preliminary data.
- Modified the system to further support the monitoring requirements.

3.2 Equipment

Figures: Equipment installed as part of the Sewer Flow Monitoring Study
3.2.1 SPECIFICATIONS

- **Enclosure**
  - IP68 Waterproof rating, Polystyrene

- **Dimensions**
  - 160.5 W x 432.2 L x 297 D mm (6.32 x 16.66 x 11.7 in.),
  - With SVS, D = 387 mm (15.2 in.)

- **Weight**
  - 4.8 kg (10.5 lbs.)

- **Operating Temperature**
  - -10 to 50°C (14 to 122°F)

- **Storage Temperature**
  - -40 to 60°C (-40 to 140°F)

- **Power Requirements**
  - Supplied by FL900 Flow Logger, Flo-Logger, or Flo-Station
- **Interconnecting Cable**
  - Disconnect available at both sensor and logger or Flo-Station
  - Polyurethane, 0.400 (±0.015) in. diameter; IP68
  - Standard length 9 m (30 ft), maximum 305 m (1000 ft)

- **Cables – available in two styles:**
  - Connectors at both ends
  - Connector from sensor with open leads to desiccant hub, desiccant hub with connector to logger. A potting/sealant kit will be included. This can be used to run the cable through conduit.

- **Certification**
  - Certified to: FCC Part 15.245: FCC ID: VIC-FLODAR24
  - Industry Canada Spec. RSS210. v7: IC No.: 6149A-FLODAR24

**SURCHARGE DEPTH MEASUREMENT**
- Auto zero function maintains zero error below 0.5 cm (0.2 in.)

**Method**
- Piezo-resistive pressure transducer with stainless steel diaphragm

**Range**
- 3.5 m (138 in.), overpressure rating 2.5 x full scale

**VELOCITY MEASUREMENT**
- **Method**
  - Radar

- **Range**
  - 0.23 to 6.10 m/s (0.75 to 20 ft/s)

- **Frequency Range**
  - 24.075 to 24.175 GHz, 15.2 mW (max.)

- **Accuracy**
  - ±0.5%; ±0.03 m/s (±0.1 ft/s)

**DEPTH MEASUREMENT**
- **Method**
  - Ultrasonic

- **Standard Operating Range from Flo-Dar® Housing to Liquid**
  - 0 to 152.4 cm (0 to 60 in.)

- **Optional Extended Level Operating Range from Transducer Face to Liquid**
  - 0 to 6.1 m (0 to 20 ft.) with 43.18 cm (17 in.) dead band, temperature compensated.

- **Accuracy**
  - ±1%; ±0.25 cm (±0.1 in.)
FLOW MEASUREMENT

- **Method**
  - Based on Continuity Equation

- **Accuracy**
  - ±5% of reading typical where flow is in a channel with uniform flow conditions and is not surcharged, ±1% full scale max.

SURCHARGE CONDITIONS DEPTH/VELOCITY DEPTH (Std with Flo-Dar® Sensor)

- **Surcharge depth supplied by Flo-Dar® sensor.**

VELOCITY (Optional Surcharge Velocity Sensor)

- **Method**
  - Electromagnetic

- **Range**
  - ±4.8 m/s (±16 ft/s)

- **Accuracy**
  - ±0.15 ft/s or 4% of reading, whichever is greater.

- **Zero Stability**
  - ±0.05 ft/s

The Flo-Dar® Open Channel Flow Meters provide an innovative approach to open channel flow monitoring. Combining digital Doppler radar velocity sensing with ultrasonic pulse echo level sensing, Flo-Dar® provides accurate open channel flow monitoring without the fouling problems associated with submerged sensors.

**3.2.2 Perfect solution for Difficult Flow Conditions:**

- Flows with High Solids Content
- High Temperature Flows
- Caustic Flows
- Large Man-Made Channel
- High Velocities
- Shallow Flows
3.3 Benefits

3.3.1 Personnel have no contact with the flow during installation.
3.3.2 Maintenance caused by sensor fouling is eliminated
3.3.3 Field Replaceable/Interchangeable Sensors and Monitors

3.4 How It Works

Flo-Dar® transmits a digital Doppler radar beam that interacts with the fluid and reflects back signals at a different frequency than that which was transmitted. These reflected signals are compared with the transmitted frequency. The resulting frequency shift provides an accurate measure of the velocity and the direction of the flow. Level is detected by ultrasonic pulse echo. Flow is then calculated based on the Continuity Equation:

\[ Q = V \times A, \text{ Where } Q = \text{Flow, } V = \text{Average Velocity and } A = \text{Area} \]

3.5 Accurate Flow Measurements

Flo-Dar® provides the user with highly accurate flow measurements under a wide range of flows and site conditions. By measuring the velocity of the fluid from above, Flo-Dar® eliminates accuracy problems inherent with submerged sensors including sensor disturbances, high solids content and distribution of reflectors.
Understanding the Flo-Dar™ Flow Measuring System

Independent tests verify non-contact flowmeter is highly accurate under both open channel and surcharge conditions

Flo-Dar is the only non-contact open channel velocity/area type flow meter available for measurement of flows in municipal wastewater and storm water sewers. Flo-Dar consists of a radar-based velocity measurement system and an ultrasonic-based pulse echo depth measurement system.

Flo-Dar combines the information from the velocity and depth systems along with site specific data (pipe size, pipe shape, velocity profile) and provides the user with highly accurate, reliable flow data under a wide range of flow velocities and depths. Since the radar velocity sensor and the ultrasonic depth sensor cease to provide useful data when submerged, Flo-Dar has an optional surcharge velocity sensor (electromagnetic type) and depth sensor (pressure transducer) that provides for the continuous measurement of accurate flow data where intermittent, surcharged flow conditions are experienced.

The data system merges the data from these two independent flow systems and provides the user with a single flow signal that accurately represents flow over a range from a dry pipe to extreme surcharge conditions. Accuracy tests performed at Alden Research Labs have shown that the Flo-Dar is highly accurate under both open channel and surcharge (submerged) conditions.

Measurement of Flow Under Free Flow, Non-submerged Conditions

Open Channel Velocity

Open channel flow is any flow in a channel that has a free surface. Flo-Dar measures open channel flow as depicted in Figure 1. The radar velocity sensor measures flow in a manner similar to how radar guns measure the velocity of a baseball or an automobile.
A radar “horn” contained inside of the watertight housing transmits a microwave beam through the housing at a defined angle to the flow surface. Disturbances on the surface reflect some of the microwaves back to the horn. The frequency of these returning microwave signals have been shifted (the Doppler effect) by an amount directly proportional to the speed of the moving surface. This frequency shift is detected and measured by the Flo-Dar flow meter and the data is stored as a measure of the surface velocity.

Since the accurate measurement of open channel flow requires the accurate determination of the average velocity of the flow stream, the measured surface velocity must be dynamically modified to obtain an accurate average velocity for use in the Continuity Equation, \( Q = V_{av} \times A \). Marsh-McBirney has developed and patented a process that yields an accurate determination of the average velocity from the measurement of the surface velocity at a known point on the flow surface.

If one analyzes each of the four factors that influence the accuracy and stability of the measured surface velocity signal, it becomes obvious that a Doppler Radar based velocity sensor is very accurate and stable:

1. Transmitted Frequency - The transmitted frequency of 24.175 GHz is controlled to an accuracy of +/- 0.065%
2. Speed of Microwaves in Air - Essentially constant at the speed of light
3. Angle of Microwave Beam - The sensor is placed in a rigid mount that is positioned parallel to the water surface (i.e. nearly level). The sensor can be removed from the mount and reinstalled while easily maintaining its original mounting location.
4. Calculation of Mean Velocity—The relationship between the sensed (surface) velocity and the average velocity varies with pipe size and water depth.

Marsh-McBirney has developed and patented a process that yields an accurate determination of the average velocity from the measurement of the surface velocity at a known point on the flow surface.

Factors that influence the accuracy and stability of the measured surface velocity signal:

1. Transmitted Frequency
2. Speed of Microwaves in Air
3. Angle of Microwave Beam
4. Calculation of Mean Velocity
By applying algorithms developed through basic hydraulic principles and from actual flow data taken at Alden Labs and at various customer sites, the surface velocity is transformed into an accurate representation of the mean velocity.

Since the location of the sensing region on the flow surface is known, the repeatability of the surface velocity measurement is excellent and its relationship to the mean velocity is predictable.

Figures 2a, 2b, 2c and 2d depict the relationship that exists between various velocity contours and the mean velocity at different depth/Diameter ratios. Note that the velocity gradients that exist throughout the flow cross section are generally represented at the flow’s surface - essentially creating a “fingerprint” of the velocity contours that exist beneath the surface.

As one might expect, the velocities near the wall are less than the mean velocity and those near the surface are greater than the mean velocity. Since a) the radar sensor measures surface velocity at a know location on the flow surface, and b) these various surface velocities have known relationships to the mean velocity, then the mean velocity can be reliably and accurately calculated.

Note that the velocities present on the surface are typically within 10% of the average velocity. The accuracy of the calculated mean velocity, after correction, is typically between 2% to 5%. (See Note 1.)

**Ultrasonic Pulse Echo Depth Measurement**

Ultrasonic pulse echo depth sensors operate by energizing a piezoelectric transducer with an electronic pulse. This pulse creates an ultrasonic pulse of energy that travels to the flow surface where a portion of the energy returns to the transducer.

The transit time to the flow surface and back is recorded and the distance calculated by knowing the speed of sound at the site which has been corrected by an embedded temperature sensor. The accuracy of the depth measurement is 1%, +/- 0.1 inch.

**Measurement of Flow Under Submerged Conditions**

**Electromagnetic (EM) Surcharge Velocity Sensor**

As stated previously, the radar based velocity sensor measures the surface velocity of the flowing stream by detecting the average speed of the surface irregularities. When the radar sensor becomes totally submerged, it becomes “blind” and is no longer capable of measuring the fluid velocity.
Figures 2a, 2b, 2c and 2d depict the relationship that exists between various velocity contours and the mean velocity at different depth/Diameter ratios. Note that the velocity gradients that exist throughout the flow cross section are generally represented at the flow’s surface—essentially creating a “finger-print” of the velocity contours that exist beneath the surface.
To allow for the uninterrupted measurement of flow under conditions that change from open channel flow to submerged flow as experienced in sewers that surcharge, Marsh-McBirney has added an additional surcharge velocity sensor. Placed on the underside of the standard Flo-Dar sensor, this electromagnetic sensor becomes active when the flow level rises to within four inches of the Radar horn and remains activated until the flow once again falls beneath that depth.

The optional surcharge velocity sensor is based on the Faraday Principle of Electromagnetic Induction. This is the same well-proven principle that “full bore” or “spool-piece” magmeters utilize, the most widely used method of measuring wastewater flow in full pipes.

In the Marsh-McBirney design, an electromagnet embedded within the streamlined sensor generates a magnetic field in the flowing stream. The flow of the water passing through this magnetic field generates voltages in the water that are directly proportional to the speed of the water passing the sensor. Marsh-McBirney uses an in-house 120 foot long towing basin for calibration of electromagnetic sensors. Tow carriage accuracy is better than +/- 0.5%.

**Surcharge Depth Sensor**

Once submerged conditions exist, the ultrasonic depth sensor ceases to provide useful depth information. To measure depth of the flow during surcharge conditions, a pressure transducer embedded in the Flo-Dar sensor is used in the system.

The location of the surcharge velocity sensor relative to the crown of the pipe is shown in Figure 3. This location provides sensing of the velocity stream just below the crown of the pipe where the flow exits the upstream piping. Empirical data, verified by independent tests at Alden Labs in Holden, Massachusetts indicate that the velocity measured at this location, when multiplied by 0.9, is typically equal to the average velocity.
Laboratory Tests

In September 2002 Marsh-McBirney contracted Alden Research Labs of Holden, Massachusetts to perform flow accuracy tests on the Flo-Dar sensor with an electromagnetic surcharge sensor. The Flo-Dar was subjected to a flow range of 400 gpm to over 9000 gpm in a pipe size of 23.5 inches. The pipe had a slope of approximately zero. The test results are shown in Figure 4, Figure 5, Figure 6 and Figure 7.

The flow tests showed that the Flo-Dar compared very favorably with the Alden flow standard (weigh tank) over a wide range of flows where the open channel flow ranged from 400 gpm to 6000 gpm, and the surcharge (submerged) flow ranged from 6000 gpm to 9000 gpm.

Tests were also run to depict how Flo-Dar performs under transition conditions where the flow goes from an open channel condition to a surcharge (submerged) condition.

Test results show that the data from the open channel radar sensor and surcharge electromagnetic sensor overlay each other and the Alden Standard. Tests were run under both free flow conditions as well as where the pipe outlet was partially blocked so as to create an entirely different velocity/depth relationship.

Additional flow accuracy tests were run on a 36” pipe at Alden on July 17, 2003. All of the data points were shown to be within 3.5% of the Alden Standard.

Figure 4 compares the Flo-Dar flow vs. the Alden Standard (weigh tank). The flow condition for this test was both open channel flow and surcharge (submerged) flow.
Figure 5 compares the velocity measured by the Radar sensor plotted against flow depth. Note that when the depth reaches approximately 18 inches the EM surcharge sensor has been activated. There is one data point where both sensors are active and then the EM surcharge sensor continues to measure after the radar sensor has become submerged and inoperative.

Figure 6 depicts a second surcharge test where the flow was incremented more slowly in order to achieve additional data points in the area where both the Radar sensor and the EM surcharge sensors are active simultaneously. Note that both the Radar sensor and the EM sensor are active between flow depths of 18 inches and 18.5 inches. Also, note how both the Radar and EM data points overlay each other and the Alden standard.
The accuracy of Flo-Dar under both open channel conditions as well as surcharge (submerged) conditions is more than adequate for the most demanding of metering applications including open channel billing applications.

Additional tests performed at Alden in 2003 on a 36" pipe again validated Flo-Dar's accuracy under open channel and surcharge flow.

Figure 7 depicts the result of a surcharge test at a lower flow rate. In this test, a round plate with multiple holes was placed at the outlet of the test pipe so as to achieve submerged flow at a lower velocity. Note the consistency of both the Radar velocity data and the EM velocity data as compared to the Alden standard.

Figure 8 compares the Flo-Dar flow vs. the Alden Standard (weigh tank) for flow accuracy tests in a 36" pipe. These tests were performed on July 17, 2003. Note that at 17,000 gpm the sensor was under surcharge conditions. All of the data points were shown to be within 3.5% of the Alden Standard.
The Flo-Dar data logger records all four of the flow parameters - open channel surface velocity and depth, and surcharged velocity and depth. When the water depth is below the bottom of the Flo-Dar sensor, only the surface velocity and the flow depth of the open channel flow are used in the flow calculation.

Once the flow depth is such that both the surcharge depth sensor is activated and a conductivity switch is activated, then flow is calculated using the full pipe dimensions for area and the surcharge velocity sensor for velocity.

**Conclusions**

Flo-Dar is a rugged, general purpose flow meter for use in most open channels such as sanitary sewers, storm water sewers and other man-made channels such as aqueducts as well as certain natural channels such as small streams. Flo-Dar measures open channel velocity and depth by non-contact means virtually eliminating the need to periodically clean the sensors as required by all submerged type sensors. Data recovery from Flo-Dar deployments ranges between 98% to 100% even under site conditions that render most submerged sensors inoperable.

The accuracy of Flo-Dar under both open channel conditions as well as surcharge (submerged) conditions is more than adequate for the most demanding of metering applications including open channel billing applications.

*Note 1. The accuracy of open channel flow meters can be affected by adverse conditions present at any metering site. The accuracy specifications of most manufacturers are generally stated under ideal conditions.*
Open Channel Flow Monitoring Study
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1) Locate the following parts (See Figure 1):

1) Flo-Dar Sensor
2) Flo-Dar Logger
3) Flo-Dar Communication Cable
4) Flo-Ware Software CD
5) Sensor Mounting Frame
6) Jack-Bar Assembly
7) Extension Pipe, Tee Fitting, and Bushing
8) Clamp Set with qty. (8) ¼-20 Bolts
9) Desiccant Capsule
10) Laser-Alignment Tool
12) Start-Up Guide (not pictured)
Methods & Procedures

2) Flo-Ware Software Configuration.

1. Insert the “Flo-Ware For Windows Resources CD” into your drive.
2. Select (single-click) “floware4.exe” from the “Software” box on your screen.
4. Select “Save” from the “Save As” screen.
5. Select “Run” from the “Download Complete” screen.
7. An installation wizard will initiate and load the files onto your hard drive.
8. Select the language you want to use from the “Select Language” screen.
9. Select “Next” from the “Welcome” screen.
10. Select “Next” from the “Choose Destination Location” screen.
11. Select “Next” from the “Select Components” screen.
12. Select “Next” from the “Start Installation” screen.
14. Scroll down the screen and find “Flo-Dar / SVS” on the left side of the screen. Select (single-click) “flodar.exe” from that box on your screen.
17. An installation wizard will initiate and install the files onto your hard drive.

NOTE: There are ample help files on the “Flo-Ware for Windows Resources CD”

3) Set up the mounting frame and jack-bar assembly.

A) Install the jack-bar assembly in the manhole. As a general rule, the jack-bar should be approximately 20” to 24” above the crown (top) of the pipe. In order to reduce movement of the jack-bar due to the cantilever action of the sensor, the jack-bar should be located as parallel to the pipe and invert of the manhole as possible.
B) Assemble the frame, clamp-set, bushing, tee, and extension as shown in figure 2. Position the frame as close as possible to the lip of the pipe by sliding the assembly along the jack-bar with the slide. Be sure to secure the set-screw.

C) Set the elevation of the frame (measured to the top of the frame tubes) to be 6” above the inside crown of the pipe (for pipe I.D. under 25”) or 5” above the inside crown of the pipe (for pipe I.D. of 25” and greater). An easy way to set the frame elevation is to measure the distance from the bottom of the manhole invert to the top of the mounting frame tubes. (This assumes that there is no drop or hydraulic jump from the lip of the pipe to the invert) Set the dimension to equal the pipe I.D. plus 6” (for pipe I.D. under 25”) or the pipe I.D. plus 5” (for pipe I.D. of 25” or greater).

D) If you are not interested in measuring flow under surcharge conditions, or if you are sure the site will not surcharge, you can mount the sensor at any elevation above the surface of the water as long as the frame is within 60” of the water surface. When the sensor is mounted at higher elevations than those shown in Figure 3, it will still read normal velocity and level readings. Surcharge level will still be recorded properly, but surcharge velocity readings will not be possible. If you are mounting the sensor at higher elevations, it is still necessary to confirm the location of the velocity radar beam as described on pages 5 & 6 of this guide.
E) Align and level the frame by placing the laser alignment tool in the frame as shown in figure 4. Utilize the bubble-level on the tool to level the frame.

F) Snap the laser-pointer into the laser alignment tool as shown below in figure 5. It is a tight fit. Make sure the pointer is firmly and evenly seated in its slot as shown.

G) With the laser-pointer snapped into the tool, as shown, place the alignment tool back into the frame. The laser is now set up to duplicate the velocity radar beam angle. Use the laser-pointer to shine the beam onto the surface of the water. Ideally, the beam should be aligned so that it lands in the middle of the surface of the water inside the pipe.

NOTE: There are numerous adjustment points on the frame and jack-bar assembly.
H) Remove the laser-pointer from the tool and re-install it into the tool as shown below in figure 6. With the laser-pointer in the position shown, it is now set up to duplicate the ultra-sonic level transducer beam location.

I) Align the beam so that it lands in the middle of the channel you are measuring.

**NOTE:** You may have to check level, velocity laser alignment, and level laser alignment several times to ensure all three are correct. Adjusting one or more of the alignments will often affect one or more of the other adjustments! It is critical to remember to tighten all bolts on the jack-bar and clamp set to assure that the sensor frame does not move, once positioned correctly.

![Figure 6](image)

**Figure 6**

4) **Install the Sensor.**

A) Gently lower the sensor into the mounting frame and lock it in place by rotating the bail assembly (located on top of the sensor) 90 degrees. The two locking arms will extend out to engage the slots in the vertical side webs of the frame ensuring that the sensor will not dislodge from the frame, particularly if the manhole surcharges.

**NOTE:** Make sure the sensor is placed in the frame so that the cables are exiting the sensor on the downstream (manhole effluent) side. (see Figure 7 below)

5) **Connect the Data Logger.**

A) Connect the sensor cables to the data logger. Make sure the grey cable-end connects to the connector marked grey. Connect the yellow cable-end to the connector marked yellow. Tighten the threaded cable connector-ends securely to the data logger connectors.

B) Remove the desiccant capsule from the vacuum-sealed bag and plug it onto the brass A.P.R. fitting (located next to the yellow cable connector) on the data logger. See Figure 8 below.

![Figure 7](image)

**Figure 7**

![Figure 8](image)

**Figure 8**
6) Configure the Data Logger using Flo-Ware Software.

A) Connect the interface cable from the data logger to the laptop’s 9-pin serial port.

   **NOTE:** If your laptop does not have a 9-pin serial port, you will have to use a USB port with a USB-to-serial port adapter (not provided by Marsh-McBirney).

B) Double-click the “Flo-Ware” icon on your computer’s desktop.
C) When Flo-Ware opens, you will see the screen shown below.

D) Place your cursor on the line that says “Communicate with an instrument” and single-click. A small pop-up window will open. Place your cursor over the “Flo-Dar” line and single-click. A second pop-up window will appear. Single-click on the word “communications”. The site set-up screen will appear as shown below.
E) Proceed to enter your specific site information into the appropriate boxes in the site set-up screen. An example of a typical set-up is shown below, along with explanations-actions of the input required from the user.

- Site I.D. and Location are self-explanatory. You MUST enter something in the site I.D. box in order for the program to work.
- Cycle time is the time interval between the start of each sample.
- Number of samples is the number of 1-minute samples that the instrument will take at the beginning of each cycle.
- Flow Units can be selected by using the pull-down arrow to view the available choices.
- Start Type is either immediate or delayed. If you choose a delayed start, you can use the pull-down arrow to reveal a calendar box and time box. You can use the pull down arrow on the calendar box to view convenient calendars which allow you to click on the date you desire. When using a delayed start, the instrument will “sleep” until the desired start-up date and time are reached. It will then “wake up” and start sampling.
- Multiplier should be left at 1.00 for most applications in round pipes. If you have a round pipe greater than 54” in diameter, or you are using the instrument in a square/rectangular channel, or an odd-shaped channel, contact the Customer Support Department at 714-542-1004 for instructions about the multiplier.
- Memory can be either “Fixed” or “Wrapped”. If you choose “Fixed”, the instrument will stop collecting data once the memory is full. In “Wrapped” mode, when the memory becomes full, the instrument will continue collecting data and will over-write the first data point, then the second, etc., with new data. This will continue indefinitely until a new set-up is downloaded to the instrument.

![Diagram of site setup screen]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site I.D.</td>
<td>mandatory entry, program does not function without it</td>
</tr>
<tr>
<td>Location</td>
<td>mandatory entry, explains the site's geographical position</td>
</tr>
<tr>
<td>Cycle Time</td>
<td>interval between sample start</td>
</tr>
<tr>
<td>Samples</td>
<td>number of 1-minute samples taken at beginning of each cycle</td>
</tr>
<tr>
<td>Flow Units</td>
<td>selection from pull-down menu for flow data</td>
</tr>
<tr>
<td>Start Type</td>
<td>immediate or delayed, calendar box visible</td>
</tr>
<tr>
<td>Multiplier</td>
<td>default 1.00 for round pipes; contact support for other configurations</td>
</tr>
<tr>
<td>Memory</td>
<td>fixed or wrapped, fixed stops data collection, wrapped overwrites first data point</td>
</tr>
</tbody>
</table>

- The image of the site setup screen is shown with specific input values filled in. The screen displays options for site information, cycle time, number of samples, flow units, start type, multiplier, and memory settings.
• Shape is self-explanatory. If you are measuring flow in an odd-shaped conduit, please call the US3 at 714-542-1004 for detailed instructions.
• Diameter is the INSIDE diameter of the pipe. This dimension should be measured in the field. Often, the pipe diameter is not what one assumes from the specs on a given pipe. Always measure the inside diameter to be sure of the dimension.
• Sediment is the amount of non-flowing sediment that may be in the bottom of the pipe. The software will take sediment into account when calculating cross-sectional area for the flow calculation. If there is no sediment, leave the number at 0.00.
• Sensor offset is the dimension from the top surface of the horizontal sensor mounting frame tubing, to the bottom of the invert or cannel. (see Figure 3, page 4) If you want to measure flow in a surcharge condition, or if you want to set the instrument up to measure flow in case the manhole surcharges, then the mounting frame should be located so that the sensor offset dimension is equal to the pipe diameter plus 6 inches for pipe diameters up to 24”, or equal to the pipe diameter plus 5 inches for pipe diameters greater than 24”.
• Single-click on the “Extended Setup” button.
• Single-click on “Surcharge Level Cal”
• A window marked “Calculate Surcharge Level Cal will appear as shown below.

![Calculate Surcharge Level Cal window](image)

• Type 0.00 in the box marked “known”.
• Single-click on the “Take Sample” box.
• Allow the unit to perform a real time sample of the surcharge pressure transducer. This will take approx. 45 seconds. The software will fill in the box marked “Sensor” and the box marked “Level Cal” with the proper values automatically.
7) Save the site information to your hard drive by clicking on the “Save Site” button near the upper left-hand corner of the set-up screen.

8) Download the site information to the data logger by clicking on the “Send Setup” button near the upper right-hand corner of the site set-up screen.

9) Turn on (check the boxes) both of the SVS channels as shown above.

10) Adjust the instrument clock to match your laptop computer clock as shown below. Use the pull-downs next to the date and time to help you set the instrument clock time. Click OK.
11) A warning screen will appear as shown below. Select whether or not you want to reset the logger flow totalizer, then click OK.

![Warning Screen]

12) The “Send setup complete” screen (shown below) will appear, indicating that you have successfully sent the setup data to the instrument. The instrument will now begin collecting data.

![Send Setup Complete Screen]
13) Collect real-time readings to confirm proper operation of the instrument before leaving the metering site.

A) Single-click on the “Real Time” tab on the Communications Screen. The real time screen will appear as shown below.

B) Single-click on the “Sample” button. You may or may not see the following pop up window appear.
C) Single-click the “Sample” button. It will take about 45 to 60 seconds for the meter to sample velocity, level, and send the data packet to the data logger. It will then display the real time sample on the screen (see below).

D) Confirm the level reading on the screen matches the actual water level in the pipe. Confirm that the velocity reading on the screen matches the velocity you approximate in the pipe.

14) Close the real time window and Flo-Ware main screen.

15) Disconnect the communications cable from your laptop to the data logger.

16) Screw the protective metal cap onto the communications port connector. in order to protect the connector from damage due to water or dirt.

17) Coil the sensor cables and secure them to the top ladder rung. Hang the data logger from the top ladder rung. (See Figure 9 next page.)
You have successfully installed the Flo-Dar Flowmeter. Please remember to secure the manhole lid prior to leaving the site.

If you have any questions regarding this flowmeter, please contact US3. Please note that telephone support is available Monday through Friday between 9:00 AM and 5:00 PM U.S. Pacific Standard Time.

Figure 9
Marsh-McBirney FLO-DAR® Area/Velocity Radar Flow Meter Sensor

Features and Benefits

The Flo-Dar Area/Velocity Radar Flow Meter provides an revolutionary approach to open channel flow monitoring. The sensor combines advanced Digital Doppler Radar velocity sensing technology with ultrasonic pulse echo depth sensing to remotely measure open channel flow. Use with FL900 Series Flow Logger or Flo-Logger/Logger XT for portable monitoring; for permanent monitoring sites, the Flo-Dar can be connected to the Flo-Station which displays flow rate, velocity, and level. (See Lit. No. 2709 [standard] or Lit. No. 2711 [wireless] for Flow Logger product information, or Lit. No. 2616 for Flo-Station product information). Intrinsically safe models available.

Accurate Flow Measurement
Flo-Dar provides the user with highly accurate flow measurements under a wide range of flows and site conditions. By measuring the velocity of the fluid from above, Flo-Dar eliminates accuracy problems inherent with submerged sensors including sensor disturbances, high solids content and distribution of reflectors.

Non-Contact Sensor Eliminates Lost Data
No lost data with non-contact, above the flow sensor that is unaffected due to debris and grease.

Easy Installation and Maintenance
As the sensor is mounted above the flow, personnel have little or no contact with the flow during installation. Future sensor removal can be done without the need for confined space entry.

Independent Accuracy / Long-Term Stability Verification
Flo-Dar sensor accuracy and long-term stability (up to 3 years without need for site calibration) from low flow depths up to surcharge conditions has been independently verified many times over the years including a formal evaluation by the Alden Research Laboratory, Inc. and recent field evaluations done by municipalities and consulting engineering firms.

Perfect Solution for Difficult Flow Conditions
Operates in the most difficult conditions including flows with high solids content, high temperature, shallow and caustic flows, large man-made channels, and high velocities up to 20 ft/s.

Optional Surcharge Velocity Sensor
During surcharge events Flo-Dar’s optional electromagnetic sensor will continue to provide uninterrupted and accurate flow monitoring through dry and wet weather flows without the need for routine sensor cleaning or maintenance.

Applications

Municipal
- Sanitary Sewer Evaluation Studies
- Collection Systems
- Capacity Studies
- Combined Sewer Overflows
- Inflow and Infiltration (I&I) Studies
- Billing / Custody Transfer
- Plant Influent and Effluent

Industrial
- Process Waste
- Plant Influent
- Plant Effluent
- Non-contact Cooling Water
- Stormwater Monitoring and Compliance
**Specifications**

**FLO-DAR SENSOR**

*Enclosure*
IP68 Waterproof rating, Polystyrene

*Dimensions*
160.5 W x 432.2 L x 297 D mm (6.32 x 16.66 x 11.7 in.), with SVS, D = 387 mm (15.2 in.)

*Weight*
4.8 kg (10.5 lbs.)

*Operating Temperature*
-10 to 50°C (14 to 122°F)

*Storage Temperature*
-40 to 60°C (-40 to 140°F)

*Power Requirements*
Supplied by FL900 Flow Logger, Flo-Logger, or Flo-Station

*Interconnecting Cable*
–Disconnectable at both sensor and logger or Flo-Station
Polyurethane, 0.400 (±0.015) in. diameter; IP68
Standard length 9M (30 ft), maximum 305 m (1000 ft)

Cables are available in two styles:
–connectors both ends
–connector from sensor with open leads to desiccant hub, desiccant hub with connector to logger. A potting/sealant kit will be included. This can be used to run the cable through conduit.

Important Note: The sensor cable assembly with desiccant hub is compatible with either the Marsh-McBirney Flo-Logger/Logger XT or the Hach FL900 Series Flow Loggers. When using this cable assembly with the Marsh-McBirney Flo-Logger, do not disconnect the desiccant cartridge that is attached to the Flo-Logger itself. It is important to keep the air tube plugged.

If using Flo-Dar cable with Flo-Station, the cable will have bare leads to the Flo-Station (30 to 1000 ft. lengths) and there will be no desiccant hub, as the air tube terminates inside of the Flo-Station housing.

*Warranty*
1 year

*Set-up/Data Retrieval*
Flo-Ware for Windows software is the user on-site set-up, data management, and report generation software. It is compatible with desktop/laptop computers utilizing Windows operating system.

*Certification*
The Flo-Dar Transmitter is certified to the following requirements:
- Transmitter type: Field Disturbance Sensor
- Frequency: 24.125 GHz - Doppler pulse
- Maximum rated power output: 128 dbuV (ave) @ 3 meters

Certified to: FCC Part 15.245: FCC ID: VIC-FLODAR24
Industry Canada Spec. RSS210. v7: IC No.: 6149A-FLODAR24

Use of this device is subject to the following conditions:
1. There are no used serviceable items inside this device.
2. The user must install this device in accordance with the supplied installation instructions and must not modify the device in any manner whatsoever.
3. Any service involving the transmitter must only be performed by Hach Company.
4. The user must ensure that no one is within 20 cm of the face of the transmitter when operating.

**SURCHARGE DEPTH MEASUREMENT**

*Method*
Piezo-resistive pressure transducer with stainless steel diaphragm

*Range*
3.5 m (138 in.), overpressure rating 2.5 x full scale

**VELOCITY MEASUREMENT**

*Method*
Radar

*Range*
0.23 to 6.10 m/s (0.75 to 20 ft/s)

*Frequency Range*
24.075 to 24.175 G-Hz, 15.2mW (max.)

*Accuracy*
±0.5%; ±0.03 m/s (±0.1 ft/s)

**DEPTH MEASUREMENT**

*Method*
Ultrasonic

*Standard Operating Range from Flo-Dar Housing to Liquid*
0 to 152.4 cm (0 to 60 in.)

*Optional Extended Level Operating Range from Transducer Face to Liquid*
0 to 6.1 m (0 to 20 ft.) with 43.18 cm (17 in.) dead band, temperature compensated.

*Accuracy*
±1%; ±0.25 cm (±0.1 in.)

**FLOW MEASUREMENT**

*Method*
Based on Continuity Equation

*Accuracy*
±5% of reading typical where flow is in a channel with uniform flow conditions and is not surcharged, ±1% full scale max.

**SURCHARGE CONDITIONS DEPTH/VELOCITY**

**DEPTH (Std with Flo-Dar Sensor)**
Surcharge depth supplied by Flo-Dar sensor.

** VELOCITY (Optional Surcharge Velocity Sensor)**

*Method*
Electromagnetic

*Range*
±4.8 m/s (±16 ft/s)

*Accuracy*
±0.15 ft/s or 4% of reading, whichever is greater.

*Zero Stability*
> ±0.05 ft/s

**CERTIFICATION INTRINSICALLY SAFE**
The Flo-Dar and Surcharge Velocity Sensors are certified to Class I, Zone 1 Standards. They conform to ANSI/UL 60079-11 and are certified to CAN/CSA E60079-11 and EN 60079-11 standards.

The Flo-Dar sensor meets CE requirements.

*Specifications subject to change without notice.*
1. The flow meter shall be capable of measuring level, average velocity and surcharge depth.
2. The method of velocity measurement shall be Doppler radar.
3. The sensor shall combine advanced Doppler Radar velocity sensing technology with ultrasonic pulse echo depth sensing to remotely measure open channel flow.
4. Flow shall be calculated based on the Continuity Equation \( Q = V \times A \), where \( Q \) = Flow, \( V \) = Average Velocity and \( A \) = Area.
5. The range of velocity measurement shall be 0.23 to 6.10 m/s (0.75 to 20 ft/s).
6. The method of depth measurement shall be ultrasonic.
7. The standard operating range for depth measurement shall be 0 to 152.4 cm (0 to 60 in.) with an optional operating range of 0 to 6.1 m (0 to 20 ft.) with 43.18 cm (17 in.) deadband, temperature compensated.
8. The flow meter shall have a surcharge condition velocity sensor option.
9. Exterior dimensions of the sensor shall not exceed 160.5 W x 432.2 L x 297 D mm (6.32 W x 16.66 L x 11.7 D in.) or 160.5 W x 432.2 L x 387 D mm (6.32 W x 16.66 L x 15.2 D in.) with Surcharge Velocity option.
10. The sensor shall be able to measure bi-directional surcharge flow.
11. Optional Intrinsically Safe models available for flow monitoring in hazardous locations.
12. The model shall be the Marsh-McBirney Flo-Dar Open Channel Flow Meter Sensor.

### Dimensions

- **Top View**
- **Side View**
- **Desiccant Hub Assemblies for use with portable FL900 Series Loggers and Flo-Logger. (Sensor cable for use with Flo-Station will not contain a desiccant hub and will have bare wires on cable end.)**

The desiccant hub assembly includes a junction box to connect sensor cable to the desiccant and subsequently to the FL900 Logger. The desiccant can easily be replaced without need to purchase a separate desiccant module.
**Ordering Information**

Configure FLO-DAR Sensor to Logger (Portable)

<table>
<thead>
<tr>
<th>Flo-Dar Sensor</th>
<th>Model 4000</th>
<th>-</th>
<th>4</th>
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<tr>
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<tr>
<td>Non Extended Range</td>
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<tr>
<td>Extended Range Option—Allows use in flow depths up to 18 feet. Allow for 18” deadband. Standard unit max depth is 60”</td>
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<td></td>
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<tr>
<td>Remote Extended Range Option with 6” sensor cable—Flow depths up to 18 feet. Allow for 18” deadband. Standard unit max depth is 60”</td>
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Configure FLO-DAR Sensor to Flo-Station (Permanent)

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<tr>
<td>Surcharge Velocity Sensor Option (IMPORTANT NOTE: SVS cable length MUST MATCH FloDar Sensor Cable length)</td>
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<tr>
<td>Non Extended Range</td>
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<tr>
<td>Extended Range Option— Allows use in flow depths up to 18 feet. Allow for 18” deadband. Standard unit max depth is 60”</td>
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<tr>
<td>Remote Extended Range Option with 6” sensor cable—Flow depths up to 18 feet. Allow for 18” deadband. Standard unit max depth is 60”</td>
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Cables

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<th>Description</th>
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</thead>
<tbody>
<tr>
<td>FD9000CBL-XXX*</td>
<td>FL900 Series Logger to Flo-Dar sensor. Cable w/two connectors.</td>
</tr>
<tr>
<td>FDJCTBOXCBL-XXX*</td>
<td>FL900 Series Logger to Flo-Dar sensor. Cable with connector to sensor; open end to desiccant hub, desiccant hub with connector to sensor. Includes finishing kit for potting/sealing desiccant hub. For use with conduit.</td>
</tr>
<tr>
<td>6000062XX*</td>
<td>SVS Sensor with connector for use with FL900 Series Logger.</td>
</tr>
<tr>
<td>570011800-XXX*</td>
<td>Flo-Station to Flo-Dar sensor Cable with one connector and bare leads.</td>
</tr>
<tr>
<td>6000059XX*</td>
<td>SVS Sensor with bare leads for use with Flo-Station.</td>
</tr>
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</table>

Available Cable Lengths (in feet)

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<th>Length</th>
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<td>1000</td>
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</table>

See Lit. No. 2709 (standard models) and Lit. No. 2711 (wireless models) for FL900 Series Flow Logger ordering information. See Lit. No. 2616 for Flo-Station ordering information.

Mounting Hardware

800016701 Permanent Sensor Mount-Includes sensor frame & all mounting hardware. Portable Sensor Mounts Available (Sizes 34-107”) Contact Sales.

Accessories & Spares

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>245000501</td>
<td>Sensor Retrieval Pole - Used to place and retrieve sensor from mounting bracket. Pole extends to 7.3 m (21 ft.)</td>
</tr>
<tr>
<td>510012701</td>
<td>Sensor Retrieval Hook - Used with Sensor Retrieval Pole</td>
</tr>
<tr>
<td>570011401</td>
<td>Grounding Strap (required with Retrieval Pole and Hook when used with IS units)</td>
</tr>
<tr>
<td>8755500</td>
<td>Bulk desiccant beads (1.5 pounds)</td>
</tr>
</tbody>
</table>

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In the interest of improving and updating its equipment, Hach Company reserves the right to alter specifications to equipment at any time.
Hach FL900 Series
Cellular Wireless Flow Logger

NEW!

When combined with the Flo-Dar or Flo-Tote 3 sensor, the Hach FL900 Series Wireless Flow Logger takes flow monitoring to a whole new level. With features that reduce site time and increase crew safety, the wireless flow monitoring system allows you to easily manage your flow data 24/7, as well as your budget.

Features and Benefits

The FL900 Wireless Flow Logger provides users with a reliable, budget saving open channel wireless flow monitoring solution for open portable flow monitoring applications. Flow data is accessible 24/7 with Hach FSDATA web-based software. When combined with the Flo-Dar or Flo-Tote 3 sensor, the system will drastically reduce site time and increase safety for monitoring crews.

Increase Monitoring Crew Safety
With the time saving features designed into the FL900 Wireless Flow Loggers, crews spend less time in the manhole and less time on site to decrease monitoring costs while increasing the safety of flow monitoring crews.

Plug and Play Sensor Ports
The FL900 Series Flow Logger is available with 1, 2 or 4 sensor ports. The sensor ports are “plug and play”; the logger auto-detects the type of sensor connected (Flo-Dar, Surcharge Velocity Sensor or Flo-Tote 3) to allow customers maximum flexibility for their Hach flow sensor inventories.

Flow Monitoring Data at Your Fingertips with FSDATA™ Web-Based Software
Hach FSDATA web-based flow meter software is the ideal time-saving and economical solution for the management of your Hach wireless flow meters and data 24/7. With FSDATA routine site visits to collect flow data are eliminated keeping flow monitoring crews safe. (See Lit. No. 2707 for additional information on FSDATA.)

Easy Installation/Versatile Mounting Options
The logger can be quickly attached to a wall, pole or manhole ladder in minutes. Users can choose to hang logger from standard carabiner or optional 4-bolt wall mount for pole, horizontal or vertical wall mount or ladder rung mount.

LED Gives Quick Confirmation of Logger Status
Get peace of mind the logger is ready to capture the next flow event, before you leave the site. The rugged FL900 Wireless Flow Logger includes a status LED panel. The indicator light on the top of the logger shows the status of the instrument and modem (if equipped with wireless option). The user can manually send a call to the server to make sure the network connection is good by simply swiping the magnet over the call initiation target.
<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimensions (W x D x H)</strong></td>
<td>25.4 x 22 x 40 cm (10.0 x 8.7 x 16.0 in.)</td>
</tr>
<tr>
<td><strong>Enclosure</strong></td>
<td>PC/ABS structural foam</td>
</tr>
<tr>
<td><strong>Environmental Rating</strong></td>
<td>NEMA 6P (IP68)</td>
</tr>
<tr>
<td><strong>Weight (Using Model FL900)</strong></td>
<td>4.5 kg (10 lb)—no batteries; 6.3 kg (14 lb)—2 batteries; 8.2 kg (18 lb)—4 batteries</td>
</tr>
<tr>
<td><strong>Operating Temperature</strong></td>
<td>–18 to 60°C (0 to 140°F) at 95% RH</td>
</tr>
<tr>
<td><strong>Storage Temperature</strong></td>
<td>–40 to 60°C (–40 to 140°F)</td>
</tr>
<tr>
<td><strong>Power Requirements</strong></td>
<td>8 to 18 Vdc from batteries or external power source, 2.5W max.</td>
</tr>
<tr>
<td><strong>Battery Life at 15 minute logging intervals</strong></td>
<td>185 days with 4 lantern batteries and a Flo-Dar sensor, 306 days with 4 lantern batteries and a Flo-Tote sensor</td>
</tr>
<tr>
<td><strong>Supported Sensors</strong></td>
<td>Flo-Tote 3, Flo-Dar, Flo-Dar with SVS, Rain Gauge</td>
</tr>
<tr>
<td><strong>Sampler Interface</strong></td>
<td>Compatible with Sigma 900 Standard, Sigma 900 Max, Hach SD900 to support set-point sampling, flow-pacing, and logging sample history.</td>
</tr>
<tr>
<td><strong>Desktop Software</strong></td>
<td>Flo-Ware for Windows software is required for programming the logger, data management, and report generation software. It is compatible with desktop/laptop computers utilizing Windows operating system. Minimum resolution needed is 1024x768.</td>
</tr>
<tr>
<td><strong>Internet Application Software</strong></td>
<td>FisDATA web-based software for flow meter data management and report generation for wireless flow meters and data access 24/7.</td>
</tr>
<tr>
<td><strong>Certifications</strong></td>
<td>Logger: CE; optional AC power supply: UL/CSA/CE</td>
</tr>
<tr>
<td><strong>Warranty</strong></td>
<td>1 year</td>
</tr>
</tbody>
</table>

*Specifications subject to change without notice.
1. Exterior dimensions of the Flow Logger shall be 25.4 W x 22 D x 40 cm H (10.0 W x 8.7 D x 16.0 in. H)
2. The Flow Logger enclosure material shall be PC/ABS structural foam with NEMA 6P (IP68) rating.
3. The operating temperature for the Flow Logger shall be –18 to 60ºC (0 to 140ºF) at 95% relative humidity and storage temperature of –40 to 60ºC (~40 to 140ºF).
4. Power requirements of the Flow Logger shall be 8 to 18 Vdc from batteries or external power source, 2.5W max.
5. When used with a Flo-Dar sensor, the Flow Logger shall have a battery life of 185 days utilizing 4 6v alkaline batteries at a 15 minute logging interval (at room temp.). When used with a Flo-Tote sensor, the Flow Logger shall have a battery life of 306 days utilizing 4 6v alkaline batteries at a 15 minute logging interval (at room temperature). A long-life battery for longer deployments shall be available option.
6. The Flow Logger shall have 1, 2 or 4 sensor ports with stainless steel connector, 1 communications port and 1 auxiliary port.
7. The Flow Logger shall have primary logging intervals of 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 or 60 minutes.
8. The Flow Logger shall have secondary logging intervals available to modify the logging rate based on a defined channel alarm condition or trigger.
9. Optional remote communication shall be available on the FL900 Series Loggers via Wireless modem; CDMA2000 1xRTT or GPRS.
10. The Flow Logger data storage event log shall be 1,000 events maximum in non-volatile flash memory.
11. Timebase Accuracy of the Flow Logger shall be 0.002% synchronized every 24 hours with server software and modem.
12. The Flow Logger shall support the Flo-Dar, Flo-Dar with SVS, Flo-Tote 3 Sensors and Rain Gauge.
13. The Flow Logger shall be compatible with Sigma 900 Standard, Sigma 900 Max and Hach SD900 to support set point sampling, flow-pacing and sample history logging.
14. The Flow Logger shall be able to connect to a lap top or desk top PC using either USB or RS232 serial connection.
15. The Flow Logger shall have an LED indicator for operating /programming status visible on the topmost horizontal surface of the logger.
16. The internet data management software shall indicate sites in alarm condition in either a map view or list view.
17. When connected to an external power source, the FL900 series logger shall be capable of power switching, i.e. drawing power from the external source and conserving the alkaline batteries inside the logger base. At the time the external power source reaches a low alarm condition, it will then switch the power draw to the alkaline batteries mounted inside the base of the logger.
18. The internet software for flow data management shall be Hach FSDATA.
19. The logger will be a Hach FL901, FL902, or FL904 Flow Logger.

**Dimensions**

**Installation/Mounting Options**

- Flow Logger Suspension Cable with Carabiner (Standard)
- Flow Logger Wall Mount
  - Prod. No. 8542700
  - (Optional)
- Flow Logger Ladder Rung Mount
  - Prod. No. 854450
  - (Optional)
### Ordering Information

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<th>Sensor Connector(s)</th>
<th>Country Code</th>
<th>Modem</th>
<th>Rain Gauge</th>
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<td>Sprint (Activated)</td>
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<tr>
<td>No Rain Gauge Connector</td>
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<td>With Rain Gauge Connector</td>
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</table>

#### Cables
- 8528700: Cable, External power, 2 wire, 9 ft.
- 8528200: Cable, Communication, RS232
- 8528300: Cable, Communication, USB
- 8528400: Cable, Aux, 7 pin MIL 5015 (Connect to Sigma Sampler), 9 ft.
- 8528401: Cable, Aux, 7 pin MIL 5015 (Connect to Sigma Sampler), 25 ft

#### Antennas
- 6241804: Antenna, Mini-Wing, Quad (824-960, 1710-2170 MHz) —US for Verizon, Sprint, AT&T, T-Mobile (Customer to Mount)
- 6683000: Antenna, Traffic Rated In Road/Burial (1850-1990 MHz) —US for use with Sprint only wireless service
- 6246200: Antenna, Traffic Rated In Road/Burial (824-896 MHz) —US for use with Verizon only wireless service

#### Software
- Model T200-200: Flo-Ware Desktop Software
- FS-HOSTING: Monthly data hosting service for rsDATA
- FS-DATAFR: Monthly wireless service

#### Mounting Hardware
- 8543800: Wall mount bracket (304 Stainless)
- 8545600: Wall mount bracket with ladder hanger (304 Stainless)
- 8542700: Wall mount bracket with AC Power Supply shelf (304 Stainless)
- 8544500: Wall mount bracket with AC Power Supply Shelf with ladder hanger (304 Stainless)

#### Replacement Parts
- 8755500: Desiccant refill beads, Bulk 1.5 lb
- 11013M: Battery, 6V lantern
- 8542900: Battery, long-life alkaline
- 8543000: Battery pack top cap adaptor and cable (for long-life alkaline battery pack 800017701)
- 8542800: Rain Gauge with 100 ft. cable

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In the interest of improving and updating its equipment, Hach Company reserves the right to alter specifications to equipment at any time.
User Instructions
Antennas for flow products

Precautionary labels

Read all labels and tags attached to the instrument. Personal injury or damage to the instrument could occur if not observed.

Electrical equipment marked with this symbol may not be disposed of in European public disposal systems after 12 August of 2005. In conformity with European local and national regulations (EU Directive 2002/98/EC), European electrical equipment users must now return old or end-of-life equipment to the Producer for disposal at no charge to the user.

Note: For return for recycling, please contact the equipment producer or supplier for instructions on how to return end-of-life equipment, producer-supplied electrical accessories, and all auxiliary items for proper disposal.

Product components

Make sure that all components have been received. If any items are missing or damaged, contact the manufacturer or a sales representative immediately.

Required equipment/software

Make sure that the following requirements are available:

- FL900 Series flow logger with modem option or Sigma 930T
- Remote host computer operating FSDATA or Telogers for Windows server software
- Portable computer operating FSDATA, FloWare or Telogers for Windows
- Activated wireless account

FL900 Series Flow Logger

Verify the telemetry (wireless option)

The user can manually send a call to the server to make sure that the network communication is good.

1. Temporarily attach the antenna to the logger to test the antenna and the cell coverage at the site location before installation.
2. Touch the magnet to the call initiation target (Figure 1). The modem LED indicator changes to green.
3. Look at the modem LED indicator during the call (45 to 90 seconds) and wait for a change:
   - LED goes off—the connection to the server is good.
   - LED flashes red—the connection to the server failed.

Note: If the connection failed, refer to the instrument user manual for more information.
Verify the wireless connection

The tamper button is used to examine if the wireless connection is working.

1. Temporarily attach the antenna to the logger to test the antenna and the cell coverage at the site location before installation.
2. Attach the tamper module to the RS232 connector on the flow meter (Figure 2).
3. Push the tamper button to start a cellular call from the flow meter to the remote host computer.
4. Go to the event log in Telogers for Windows to make sure that the data was successfully downloaded from the flow meter to the remote host computer. Refer to the 930T documentation for further information about telemetry troubleshooting.
Installation

WARNING
Electromagnetic radiation hazard. To meet the requirements of the FCC Grant, CE Mark and other regulatory bodies, do not use or install the device with an antenna that is not supplied by the manufacturer. Make sure that all antennas are kept at a minimum distance of 20 cm (7.9 in.) from all personnel in normal use.

NOTICE
Test the antenna and cell coverage at the site location before installation.

NOTICE
Make sure that the flow meter is programmed to call the host PC before installation.

Half wave antenna

NOTICE
The half wave antenna is intended for above-ground use.

1. Unpack the antenna (Figure 3).
2. Bend the antenna at the joint to a 90 degree angle between the antenna and the swivel fitting.
3. Put the antenna extension inside of the logger handle (Figure 4).
4. Align the threads from the antenna fitting to the antenna receptacle on the logger. Hand-tighten by turning the swivel end.

Figure 3  Half wave antenna

Figure 4  Half wave antenna attached
Traffic rated manhole lid antenna

Required tools:
- 31.75 mm (1¼ in.) open-end wrench
- Large nylon Ty-wrap cable ties

1. Unpack the antenna (Figure 5) or disassemble the antenna from the instrument.
2. Make sure that the manhole lid has a 25.4 mm (1 in.) hole for the antenna neck to fit into.
   
   **Note:** Do not use the pick hole. Use a drill, motor oil for lubrication and increasing size drill bits to drill the 25.4 mm (1 in.) hole if needed. Make sure that the location of the hole does not coincide with the ribs on the underside of the manhole lid.

3. Remove the manhole lid and put the lid in a stable position where the lid top and bottom are accessible.
4. Remove the nut and washers from the threaded neck on the base of the antenna (Figure 6).
5. Put the antenna cable and neck through a hole on the manhole lid until the base of the antenna is against the top of the manhole lid.
6. Install the flat washer, then the lock washer and then the nut on to the threaded neck of the antenna.
7. Tighten the nut with the open-end wrench until both washers are flush against the base of the manhole lid and the antenna is tight (Figure 6).
8. Connect the antenna cable to the instrument connector labeled “Antenna”. To make sure proper transmission, hand-tighten the connections.
9. Attach any excess cable to the access ladder or another non-obstructing location with Ty-wrap cable ties.
10. Replace the manhole lid.

Figure 5 Traffic rated manhole lid antenna
Wing Quad antenna

The Wing Quad antenna can be attached to an interior wall or to a window for a longer term deployment or the antenna can be attached to a manhole lid for a short term deployment.

**Required tools:**

- Large nylon Ty-wrap cable ties

1. Unpack the antenna (Figure 7).
2. To attach the antenna to a window or a wall, remove the adhesive backing and push the antenna to a clean surface.
3. To attach the antenna to a manhole, make sure that the manhole lid has a hole large enough for the antenna connector to fit into.
   
   **Note:** Do not use the pick hole. Use a drill, motor oil for lubrication and increasing size drill bits to drill the 1" hole if needed. Make sure that the location of the hole does not coincide with the ribs on the underside of the manhole lid.
4. Remove the manhole lid and put the lid in a stable position where the lid top and bottom are accessible.
5. Put the antenna cable and neck through a hole on the manhole lid until the base of the antenna is against the top of the manhole lid.
6. Attach the antenna to the manhole lid with heavy tape or tar tape.
7. Connect the antenna cable to the instrument connector labeled "Antenna". To make sure proper transmission, hand-tighten the connections.
8. Attach any excess cable to the access ladder or another non-obstructing location with Ty-wrap cable ties.
9. Replace the manhole lid.
Traffic rated in-road/burial antenna

Required tools:
- Asphalt saw or auger: saw capable of cutting 127 mm (5 in.) in diameter and 76.2 mm (3 in.) deep into a road surface or ground
- Asphalt chisel
- Hammer drill with 19.1 to 25.4 mm (¾ to 1 in.) asphalt drill bit (for antenna cable installation)
- Sakrete asphalt mix (Asphalt patch)
- Bondo; Mar-Hyde P606 Traffic Detector Wire Loop Sealer or equal
- Shovel, if placing in the ground

The traffic rated in-road/burial antenna is intended for burial beneath the road surface or ground adjacent to a manhole or vault that is being monitored (Figure 9).

NOTICE

The antenna should be installed in the road approximately 152.4 to 203.2 mm (6 to 8 in.) inches from the manhole or vault containing the flow meter.

1. Unpack the antenna (Figure 8) or disassemble the antenna from the instrument.
2. Excavate a hole or trench in the road surface or ground approximately 127 mm (5 in.) in diameter (or square) and 76.2 mm (3 in.) deep.
3. Select the closest position from the excavated hole to the manhole. Drill a 19.1 to 25.4 mm (¾ to 1 in.) hole from the selected position to the manhole. Make sure to drill the hole below the steel manhole cover support ring (Figure 9, List item. on page 7).
4. Put the antenna cable through the drill hole into the manhole or vault.
5. Install the antenna in the excavated hole. Pull the antenna cable taut. Locate the antenna so that the ceramic side of the antenna is approximately 6.4 (¼ in.) to 12.7 mm (½ in.) maximum below the road or ground surface. Make sure the antenna sits safely in the hole.
6. Attach the antenna cable to the antenna connector.
7. Make sure that the antenna is working by placing a call from the instrument (refer to Verify the wireless connection on page 2).
8. When the operation of the antenna is confirmed, permanently bury the antenna.
   a. Insert asphalt mix around the antenna and pack it in place. Make sure the antenna is sitting firmly on a solid base and cannot be rocked back and forth.
   b. Install the asphalt mix around the antenna. The mix should be level with the road surface but not over the antenna surface.
   c. Pour the Bondo sealer on and over the asphalt mix and over the top of the antenna. There should be no more than 6.4 mm (¼ in.) of Bondo sealer over the top of the antenna.
d. Connect the desired sensors and options to the flow meter. Calibrate the sensors and install the flow meter in the manhole.

Figure 8 Burial antennas

1 Traffic rated in-road/burial antenna (Verizon)  2 Traffic rated in-road/burial antenna (Sprint)

Figure 9 Burial antenna assembly

1 Manhole cover  2 19.1 to 25.4 mm (¾ to 1 in.) hole  3 Antenna  4 Trench or hole for antenna  5 Antenna cable  6 Flow meter
Replacement Parts

**Note:** Product and Article numbers may vary for some selling regions. Contact the appropriate distributor or refer to the company website for contact information.

<table>
<thead>
<tr>
<th>Description</th>
<th>Item no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half wave, 824-894 &amp; 1850-1990 MHz, 3 dBi</td>
<td>5228400</td>
</tr>
<tr>
<td>Half wave European, 870-960 &amp; 1710-1880 MHz, 3dBi</td>
<td>5255300</td>
</tr>
<tr>
<td>Traffic rated manhole lid quad, 824-896 &amp; 1850-1990 MHz, 3 dBi</td>
<td>5255400</td>
</tr>
<tr>
<td>Wing Quad, 824-960 &amp; 1710-2170 MHz, 2.15 dBi</td>
<td>6241804</td>
</tr>
<tr>
<td>Traffic rated in-road/burial antenna (Verizon), 824-896 MHz, 3 dBi</td>
<td>6246200</td>
</tr>
<tr>
<td>Traffic rated in-road/burial antenna (Sprint), 1850-1990 MHz, 3 dBi</td>
<td>6683000</td>
</tr>
</tbody>
</table>
Tab 4: DVD with Raw Flow Monitoring Data
Tab 5: US$^3$ Company Information

US$^3$ is a California Corporation Federal ID No. 33-0729605 and qualifies as a Minority Business Enterprise. US$^3$ has certified as an MBE with the California Public Utility Commission’s authorized clearinghouse, Verification Number: 97ES0008.

US$^3$ is a specialty service company for the Water & Waste Water industry, providing monitoring and control for Utilities since 1996. US$^3$ is in the forefront of this industry by taking the proven technological approaches developed in other high tech industries and applying them to protect one of our most precious natural resources - our water.

US$^3$ engineers and technical personnel have applied advanced instrumentation system technology to water/wastewater open channel flow monitoring, pipeline evaluation, engineering, and data analysis, all coupled to the power of the Internet. This unique integrated systems approach allows the company to bring greater insight and intelligence to gathering information about water/wastewater system performance of our clients, and in turn, to support the fulfillment of their commitments to manage and cost effectively design, operate, and maintain these systems.

Figure: US$^3$ utilizes exclusively Hach March-McBirney Flo-Dar® Meters
Moreover, US$^{3}$ supports Municipalities, Consulting Engineering firms and other water/waste water systems integrators by providing temporary technical services for engineering, software programming and technical site maintenance and calibration site support work, primarily in the Water and Waste Water industries.

**Figure:** All technicians are certified for Confined Space Entry.

**Name, Title, Address and Telephone numbers of persons to contact concerning this report.**

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<th>Tom Williams, PE</th>
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<td>619-546-4281 Work</td>
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<tr>
<td>619-246-5304 Cell</td>
<td>619-398-7799 Cell</td>
</tr>
</tbody>
</table>