Northeast Ohio Regional Sewer District

Flow and Rainfall Monitoring for Engineering and Construction Projects

Standards and Protocols

Version 2.1
## Version History

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<th>Date</th>
<th>Description of Revisions</th>
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<td>1/16/2015</td>
<td>Draft release for review.</td>
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<td>Major update to all sections of standards.</td>
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<td>Section 2.0 - FMP clarification &amp; FMP Addendum</td>
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<td>Section 4.0 – Uptime Requirement clarification</td>
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1.0 Introduction

1.1 Purpose of the Document

This document describes the standards and protocols to be used for the installation and maintenance of flow monitors and rain gauges in a manner that promotes the collection of sound data to support the needs of the Northeast Ohio Regional Sewer District (NEORSD/the District) Engineering and Construction Department projects. This document will be updated as needed to address the District’s future modeling requirements and to adapt to future software updates throughout the course of modeling efforts.

1.2 District ArcGIS Online Geographical Information System

The District supports all monitoring efforts with the use of an internal ArcGIS Online Geographical Information System (AGOL). This will be made available to all consultants providing flow monitoring services in support of District projects. AGOL is available through any smart phone, tablet, or desktop computer with the use of an internet connection. AGOL training is available, as needed, for project personnel. Consultants will be required to post electronic deliverables to the AGOL.

1.3 Request for Variance

The flow monitoring standards and protocols have been developed to ensure consistency in monitoring practices to support achieving the District’s Engineering and Construction project and Consent Decree objectives. It is understood that monitoring and data collection efforts will vary from project to project, therefore this document may not be suited for all monitoring/data collection efforts. Variances may be granted by the District in special cases if justification for a variance can be demonstrated. Due to the nature of Consent Decree related monitoring projects, variances from these standards are not generally considered for these projects. Any granted variances should be documented with the submittal of the final flow monitoring report.
2.0 Site Selection and Reconnaissance

The following steps must be followed when siting flow monitors and rain gauges.

2.1 Desktop Analysis and Flow Monitoring Plan

- Perform a desktop analysis to identify initial monitoring and temporary rain gauge locations to support project needs. An initial Flow Monitoring Plan (FMP) with a map of preliminary monitoring locations must be submitted to the District in hardcopy and in AGOL for review/approval. (The FMP should also summarize the project that the FMP is supporting and also serve as the work plan for the overall flow monitoring effort which must cover all aspects of the flow monitoring standards.)
  - See Appendix A for Map of District Rain Gauge Network.
  - The use of radar-rainfall to further define the rainfall distribution may be considered depending on project extent and is available through the District’s current contract with Vieux, Inc. Consultants requiring access should contact the District Project Manager Michael Blair at BlairM@neorsd.org.

2.2 Site Reconnaissance

- Upon District approval, perform a detailed site investigation to assess the suitability of each proposed monitoring site (flow meter and rain gauge). The District must notify member communities at least 7 business days prior to conducting site investigations.
  - Field reconnaissance will identify site accessibility, any harmful entry conditions, and any traffic control requirements
  - Manholes will be opened to observe flow pattern, velocity, flow depth, any sediment deposition, any historical surcharge conditions, and potential backwater condition.
  - Measured flow depth and velocity are within equipment tolerances
  - Steady flow with little to no turbulence through manhole
  - Sketches of the proposed site structure will document incoming and outgoing pipe sizes and configurations, overflow lines and/or weir configurations, and manhole depth
  - Do not force installation at a site that will record suspect data

2.3 Reporting and Flow Monitoring Plan Addendum

- If the approved monitoring site(s) is deemed suitable for equipment installation, then a Flow Monitor and/or Rain Gauge Installation Report must be completed. See Appendix B for Flow Monitor and Rain Gauge Installation Report Example Templates and Section 3.0 Installation of Flow Monitors and Rain Gauges for additional information.
- Complete a Flow Monitoring Plan Addendum that details modifications made to the initial Flow Monitoring Plan and explains changes. An example of the Flow Monitoring Plan Addendum can be found in Appendix C.

If the monitoring site is crucial to the monitoring effort, the District must be notified if debris or other
issues are identified that may impact data collection and require cleaning and/or removal. The District will either remove debris, authorize cleaning by others or contact the responsible agency regarding sites not maintained by the District and request any necessary cleaning or repair of a manhole and/or sewer segment. If the responsible agency cannot perform the cleaning or repair, the monitor should be installed at an alternate location and details of the original location must be noted in the Installation Report.
3.0 Installation of Flow Monitors and Rain Gauges

Installation reports for the selected flow monitoring and rain gauge sites should be provided electronically in PDF format to the District after installation and must be uploaded to the AGOL project site. Flow Monitoring and Rain Gauge Installation Report Example Templates can be found in Appendix B.

3.1 Installation Report Details

Flow Monitoring Installation Reports must include, at a minimum, the following information:

- General site location map
- Basic connectivity sketch with pipe sizes
- Manhole depth
- Installation sketch
  - Sensor position/offset
  - Calibration data verifying monitor setup
  - Explanation of any variance from manufacturer recommended procedures
- Physical sewer pipe characteristics in which the sensors are installed
  - Pipe size and shape (diameter other measurements necessary to define the pipe cross-section)
  - Pipe material
  - Depth of silt
  - Depth of flow
- Site Photographs
  - Street View
  - Monitor Installation
  - Sensor Installation
- Weather conditions at time of installation
- Description of any adverse hydraulic conditions
- Flow monitor information
- Adjustments due to initial calibration

Rain Gauge Installation Report must include, at a minimum, the following:

- Location description and site photo(s)
- Contact information and instructions for site access
- Rain Gauge Make/Model and any additional information

3.2 Unique Pipe Geometries

Default pipe geometries in the flow monitoring software for egg-shaped pipes must agree with geometries provided by the District, found in Appendix D, in order to properly calculate flow rates associated with observed depth and velocity readings. If field measurements indicate a deviation from values obtained from Appendix D, adjust the software to reflect the field measurements. If
non-standard shape pipes are encountered, the pipe table generated from field measurements used for flow calculations must be submitted to the District in .csv format, see Section 7.0 Documentation.

3.3 Initial Calibration

Initial calibration of each flow monitor must be completed upon installation and activation by taking manual depth and velocity readings using independent instrumentation. The following steps must be followed for calibration:

- Obtain field depth measurements using a method that does not disrupt the flow regime.
- Obtain manual velocity readings of the cross-section of flow (velocity profile) using an industry accepted method to determine the pipe’s hydraulic profile if site conditions allow.
- Compare field depth and velocity measurements to real-time monitor readings to determine if the monitor is recording data representative of field measurements.
- Use best practice methods to verify data in the field and document the methods used, the measurements obtained, and any adjustments made must be detailed in the Flow Monitor Installation Report.

The following protocols must be used for the calibration of temporary rain gauges:

- Perform a field calibration check on each gauge after installation per the manufacturer’s specification.
- If the calibration check falls outside of a tolerance that is acceptable, perform a second test.
- If the second test confirms the gauge is out of tolerance, return the gauge to the manufacturer for recalibration and notify the District as needed.

3.4 Radar Rainfall Coordination

Upon completion of the Rain Gauge Installation Report and upload to the AGOL Project Site the team must coordinate with the Radar Rainfall Consultant Vieux Inc. In order to do this the team must send the following information to Matt Fedak with the Districts System Integration Department at FedakM@neorsd.org and cc the District Project Manager:

- Project Name
- Approximate Monitoring Period Start/End date
- GIS File Geodatabase (preferred) of Rain Gauges or Shapefile
- Monthly Data before the 7th of each month
4.0 Data Collection

4.1 Collection Criteria
Flow monitors must be configured to record depth and velocity readings at five-minute intervals. Rain gauges must be configured to record rainfall in 0.01-inch increments and report data at five-minute intervals.

4.2 Data Collection/Cellular Communication
The flow monitors and rain gauges should be configurable to support automatic communications with a web server and must be supported by the major cellular providers. Data must be uploaded to the web server daily. The District must receive access to the web server at the start of the data collection period. The web server must allow viewing of data as hydrographs and scatter graphs with rain data overlain. See Section 7.0 Documentation for more information on data reporting requirements.

If the consultant does not have a web server available, the District’s Telog Enterprise system in coordination with the District’s System’s Integration Department can be utilized. If monitors do not have cellular communication capabilities or if a site does not allow for cellular communication, the District must be notified prior to installation and data must be collected and uploaded weekly to a web server within 48 hours of collection.

4.3 Uptime Requirements
Monitoring consultants shall collect useable flow data a minimum of 90% of the wet weather period time each month of the monitoring period at each site. The uptime requirement is intended to ensure that the flow monitors are monitored daily, and any issues are flagged immediately and can be addressed within 48 hours. As a general rule, the 90% uptime is violated if flow values are not available nor can be calculated for more than 3 consecutive days.

In order to track uptime, the Data Quality Summary Table should be populated and submitted on a monthly basis or upon request. An example is provided in Appendix E that should be populated to reflect the uptime for each monitor to be included in the monthly deliverables. A thorough explanation must be provided if the monitor is not meeting the up-time requirement. Monitor uptime shall be defined as the number of 5-minute measurement intervals where a flow value can be calculated from a measured depth and a measured or inferred velocity for a common time interval divided by the total number of measurement intervals (monthly).

Reduced payment will be considered for monitors with an uptime between 80% to 90% for wet weather periods. A wet weather period is defined as 6 hrs. prior to and 10 hrs. after a recorded rainfall event recorded by the closest rain gauge to the project area. The payment reduction will be applied to the full day period (12 AM to 12AM) for monitors that did not meet the uptime criteria. In the case of a gap in dry weather data, a dry weather diurnal pattern may be substituted without counting negatively toward the uptime requirement. This data adjustment must be noted in the Data Quality Summary Table.
Monitors with uptime less than 80% may be considered for a reduced payment or no payment for that meter. A thorough explanation must be provided for monitors not meeting the uptime requirement for consideration of a variance to this requirement.

The uptime requirement is to be generally satisfied with actual measured data. However, it is also recognized that there may be occurrences where a velocity measurement may not be required to develop accurate data. Accordingly, inferred data would not be considered downtime, if the monitoring firm documents to the satisfaction of the District that accurate data can be obtained without the velocity measurement and the loss of velocity data was not caused by maintenance neglect. In any case, however, no velocity data shall be inferred for any measurement interval where (1) a corresponding depth measurement has not been obtained for that measurement interval or (2) independent calibration measurements have not been acquired for the site. Monitoring consultant shall clearly identify all inferred data in all reports and other deliverables.
5.0 Monitor Maintenance

A routine monitoring maintenance schedule must be detailed in the Flow Monitoring Plan and followed to comply with the minimum standards and protocols as described below:

5.1 Maintenance Schedule

Daily activities:
- In the case where automatic cellular communications is available, data must be reviewed daily for all sites to identify any potential sensor fouling or equipment malfunctions. Issues are to be remedied as soon as possible to minimize lost or inaccurate data, but within 48 hours of identification.

Weekly activities:
- Weekly site visits are to be performed for flow monitor and rain gauge sites without cellular communication to download data and to assess any maintenance or monitor performance issues.

Monthly activities:
- Monthly site visits are to be performed for flow monitoring and rain gauge sites supported by cellular communication to assess maintenance needs and perform monitor confirmations.
- The following preventative maintenance activities must be performed during each site visit (monthly and any time the site is visited) and documented in a Flow Monitor Maintenance Log as appropriate, see Appendix F for example template:
  - Check battery charge, desiccants, and vent tubes
  - Confirm the clock time is accurate
  - Inspect sensors to ensure the installation is intact
  - Clean paper, rags, oil, and/or debris off the sensors in accordance with manufacturer’s instructions
  - Remove sediment and debris when it interferes with proper operation of the monitoring devices
  - Monitor confirmation measurements if the manhole is entered during a site visit
5.2 Confirmation Details

Monitor confirmations must be performed to demonstrate equipment is collecting reliable/accurate data. Based on review of collected data, additional confirmations may be necessary if hydraulic conditions change or if confirmations result in inconsistent measurements. It is preferred that confirmations be scheduled during various flow conditions; this can be achieved by scheduling confirmations at different times of day and during varying weather conditions. This schedule can be adjusted to support the project/monitor site needs, all deviations from the preferred monthly confirmations must be approved by the District. Monitor confirmations must include the following activities similar to the initial calibration of the monitor during installation as referenced in Section 3.0 Installation of Flow Monitors and Rain Gauges:

- Take manual depth and velocity readings using independent instrumentation and compare to real-time monitor readings to verify that the installed monitor yields data representative of actual field conditions.
- Record the silt level in the pipe
- Log all measurements, adjustments and efforts undertaken in a Flow Monitor Maintenance Log, see Appendix F for example template
- Provide confirmation measurements to the District with data submittals, discussed in Section 7.0 Documentation, documenting the date and time they were performed for each monitoring site.
- Promptly notify District if site conditions are impacting data quality and corrective action is required.
6.0 Data Analysis

Periodic data analysis of the rainfall and flow monitoring data collected throughout a project’s monitoring period must be performed to ensure data quality and reliability. This section summarizes the minimum activities and responsibilities in performing data analysis.

6.1 Analysis Activities

Data analysis must include a comprehensive review of collected data and should consist of, but not be limited to, the following activities:

- Identify and document periods of data gaps or equipment malfunctions
- Monitor service needs and resolutions
- Utilize weekly hydrographs of depth, velocity, and flow rate with rainfall and all calibration and confirmation measurements overlain
- Utilize scatter graphs of depth and velocity/flow readings with all calibration and confirmation measurements overlain
- Check for data anomalies or unusual trends
- Independent data check using Q=VA
- Check for regular diurnal patterns
- Check for reasonable depths and velocities using data diagnostic tools such as hydrographs and scatter graphs (i.e. how noisy is the site).
- Check continuity (mass balance) between meters, if there is an imbalance use gallons per capita-day to support the evaluation and include the incremental area
- If there is suspect open channel data use the Manning Equation to help determine any issues

6.2 Final Data and Data Quality Summary

Edited data must be created from the monthly raw data, see Section 7.0 Documentation. Major edits must be documented in a Data Quality Summary Table, see Appendix E for example. Edits to the raw data may include but is not limited to the following:

- Adjustments to the level/velocity based on field verified measurements
- Adjustments of the average/peak velocity ratio based on field verified measurements
- Insertion of dry weather diurnal patterns in the case of data drop outs or poor data quality during confirmed dry weather conditions
- Removal of a recorded level/velocity that is not typical to the flow pattern and is not recorded for a duration that would indicate an actual reading.
- Identify data gaps/poor data quality due to equipment malfunction that cannot be edited due to a known rain event that took place during the data gap/poor data quality period. When these data cannot be edited the District recommends using null values.
### 7.0 Documentation

Periodic data submittals throughout the project’s monitoring period must be provided to the District for review and to document progress. This section summarizes the monitoring documentation and submittal schedule that must be followed. If this deliverable format does not support the needs of the project refer to Section 1.3 regarding variances. The District Flow Monitoring Deliverables Reference Guide is provided in Appendix G.

#### 7.1 Documentation Available Upon Request

The following data must be made available upon request within two (2) weeks of the request:

- **Hydrographs**: Time series plots of the entire month of depth, velocity, flow, and rainfall with confirmation measurements overlain
- **Scatter graphs**: Edited depth-velocity readings with confirmation measurements overlain
- **Flow Monitor Maintenance Log**: Summary table of calibration and confirmation measurements, documenting the date and time they were performed for each monitoring site, see Section 5.0 Monitor Maintenance for more information
- **Data Quality Summary Table**: Table of major edits made to the data and major data quality issues. An example template of the Data Quality Summary Table Example is available in Appendix E. See Section 6.0 Data Analysis for more information.
- **Edited continuous time series including depth, velocity, calculated flow (.csv)**.
- **Monthly rainfall data in electronic format (.csv)**. Additionally, email the electronic (.csv) file for any temporary rain gages to the Districts Matt Fedak at FedakM@neorsd.org before the 7th of each month, to support the radar rainfall contract.

#### 7.2 Final Flow Monitoring Report

Within 6 weeks of the end of the project flow monitoring period, a Final Flow Monitoring Report must be submitted and include the monthly deliverables referenced above and the following items for each flow monitoring site for the entire flow monitoring period. An outline of the preferred Final Flow Monitoring Report can be found in Appendix H:

- **Flow Monitoring Installation Reports** and **Rain Gauge Installation Reports** (if applicable) see Section 3.0 Installation of Flow Monitors and Rain Gauges
- **Summary of each rainfall event including total rainfall depth, duration, peak 5-minute, and 1-hour intensities**
- **Pipe Tables used for flow calculations for non-standard pipes**, see Section 3.0 Installation of Flow Monitors and Rain Gauges, in hardcopy and digital attachment to the flow monitoring report
- **Final data in standard electronic format (.csv)**
  - **Note**: If data is edited during the modelling phase or beyond 6 weeks from the end of the monitoring period final data must be resubmitted to the District
- **Raw data in standard electronic format (.csv)**
- **Documentation of any variances that were granted**

Within 6 weeks of the end of the flow monitoring period, the Final Data (.csv) and final Installation Reports (.pdf) should be uploaded to the project AGOL for each monitoring site.
Appendix A
Map of District Rain Gauge Network
Appendix B
Flow Monitor Installation Report
Rain Gauge Installation Report
Example Templates
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SITE ID: ________________________

Additional Site Photos:

VICINITY MAP

SITE LOCATION
# RAIN GAUGE INSTALLATION REPORT

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## Location Description:

## GPS Coordinates:

## Building Contact Person:

- Title: 
- Telephone #: 

## Additional instructions for access:

## Rain Gauge Hardware Information

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## LOCATION MAP

- N

## Site/Installation Photos:

Rain Gauge Setup
Appendix C
Flow Monitoring Plan Addendum Example
(Pages of Example have been Removed)
The purpose of this memorandum is to document modifications to the preliminary Flow Monitoring Plan (FMP) for the London Road Relief Sewers (LRRS) Project and provide explanations for the changes.

The 2014 Easterly Advanced Facilities Plan recommended improvements to the tributaries of the Ivanhoe-Holmes Branch Interceptor along Holmes Avenue and London Road. The project will provide relief for Intra-Community Relief Sewers on Roseland Drive and Cliffview Roads. Lastly, the project will increase CSO control to Green Creek (CSO 214) and Nine Mile Creek (CSOs 211 and 212) via regulator modifications and relief sewers. The purpose of this FMP is to collect and monitor data to assess model performance of the District’s current master CSO models and support recalibration if needed.

The preliminary FMP was developed via desktop analysis of the NEORSD GIS and available record drawings and field inspection data. The list of installed meters, specific dates, goals, and comments for each meter installed is seen in Attachment 1: Reconnaissance Summary Table. WRCE and ADS Environmental Services investigated 13 preliminary locations on April 13, and determined two needed to be relocated (I-09A and I-12) and one needed to be investigated further (I-20). The remainder of the sites were found to be hydraulically acceptable for monitoring.

Flow Divider I-09A: Field investigations determined the 8” sewer connecting from the northeast to this structure was flowing in instead of out as a high pipe relief as indicated by GIS. Since this structure is not actually a flow divider, the recommendation to install a meter was no longer critical for the LRRS model assessment or design. An alternative monitor location was identified further
downstream and renamed I09A-D1. The purpose of the new alternative site is to confirm system performance in a local No. 3 Egg combined sewer along Ivanhoe Rd near Regulator I-10. Attachment 4 provides a photo of manhole I-09A taken during field investigation.

Regulator I-12: Field investigations determined that the 15” pipe from the northwest of Regulator I-12 was not diverted around it and is flowing into the manhole. The 15” line on the north side of Belvoir Rd, originally thought to be diverted from the regulator, was seen with active dry weather flow while the 15” line on the south side of Belvoir was found to have very stagnant flow. To get a better understanding of flows into the regulator, the recommendation was made to move the meter installation to the north side of the road to capture more flows. The field investigation summary is shown in Attachment 5.

Regulator I-20: During investigation, Regulator I-20 was found to have a constructed bulkhead that caused all flow to be routed into the Green Creek Culvert. After additional District investigation, it was noted that they had no record of this installation and they removed the bulkhead on May 8. On May 17, a meter was installed here to monitor the dry weather flow in the sewer. The photos and investigation for this are seen in Attachment 6.

Attachment 2: Map Book Marked-Up with Field Investigation Summary presents the preliminary FMP that lists the pre-investigation flow monitors and locations as well as comments regarding the purposes of the flow monitors in those locations. If the meters were installed in a different location, they are marked up in Attachment 2.

Attachment 3: Site Installation Reports, presents ADS Site Installation Reports of all thirteen meters installed between April 22 and 27.

Attachment 7: Pipe Cross Section Ordinates contains the measurements used by ADS to determine the cross section of each pipe.
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<th>Pipe Size (AGOL)</th>
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<th>Manhole Depth (ADS, App. FT)</th>
<th>Preliminary Site Location Used?</th>
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<th>Purpose</th>
<th>Comments</th>
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<td>I09-S1</td>
<td>38.8&quot; x 30.5&quot; No. 4 Egg</td>
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<td>Reverse</td>
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<td>--</td>
<td>Measure flow split between SWO and DWO</td>
<td>During investigation, the 8&quot; pipe high pipe was seen flowing into this manhole instead of acting as a flow divider as GIS states.</td>
</tr>
<tr>
<td>I09A-D1</td>
<td>33&quot; x 26.76&quot; Egg*</td>
<td>30.5&quot; x 27&quot; Egg*</td>
<td>18</td>
<td>Yes</td>
<td>4/14/2016</td>
<td>4/23/2016</td>
<td>Standard</td>
<td>Measure flow split between SWO and DWO</td>
<td>Good Hydraulic Conditions</td>
</tr>
<tr>
<td>I10-U1</td>
<td>48&quot; Circular</td>
<td>48.75&quot; x 48.5&quot;_ Circular</td>
<td>48.75&quot; x 48.5&quot; Circular</td>
<td>Yes</td>
<td>4/13/2016</td>
<td>4/22/2016</td>
<td>Standard</td>
<td>Measure inflow to I-10 regulator</td>
<td>Good Hydraulic Conditions</td>
</tr>
<tr>
<td>I12-U1</td>
<td>15&quot; Circular</td>
<td>14.75&quot; Circular</td>
<td>10</td>
<td>No</td>
<td>4/13/2016</td>
<td>4/14/2016</td>
<td>4/22/2016</td>
<td>Standard</td>
<td>Measure inflow to I-12 regulator</td>
</tr>
<tr>
<td>I14-U1</td>
<td>42&quot; Circular</td>
<td>42.13&quot; Circular</td>
<td>15</td>
<td>Yes</td>
<td>4/13/2016</td>
<td>4/22/2016</td>
<td>Standard</td>
<td>Measure inflow to I-14 leaper regulator</td>
<td>Good Hydraulic Conditions</td>
</tr>
<tr>
<td>I18-U1</td>
<td>24&quot; circular</td>
<td>20.5&quot; x 20&quot; Circular</td>
<td>20.5&quot; x 20&quot; Circular</td>
<td>Yes</td>
<td>4/13/2016</td>
<td>4/23/2016</td>
<td>Standard</td>
<td>Measure inflows to I-18 regulator</td>
<td>Good Hydraulic Conditions</td>
</tr>
<tr>
<td>I19-U1</td>
<td>36&quot; Circular</td>
<td>40&quot; x 33&quot; Elliptical*</td>
<td>33.25&quot; x 33.38&quot; Circular</td>
<td>Yes</td>
<td>4/13/2016</td>
<td>4/23/2016</td>
<td>Standard</td>
<td>Measure inflows to I-19 leaper regulator with SWO weir</td>
<td>Good Hydraulic Conditions</td>
</tr>
<tr>
<td>I21-U1</td>
<td>38.8&quot; x 30.5&quot; No. 4 Egg</td>
<td>40.75&quot; x 30.38&quot; Egg*</td>
<td>40.75&quot; x 30.38&quot; Egg*</td>
<td>Yes</td>
<td>4/13/2016</td>
<td>4/23/2016</td>
<td>Standard</td>
<td>Measure inflows to I-21 leaper regulator</td>
<td>Good Hydraulic Conditions</td>
</tr>
<tr>
<td>IVH1</td>
<td>66.5&quot; x 52.4&quot; No. 9 Egg</td>
<td>68&quot; x 52.25&quot; Egg*</td>
<td>68&quot; x 52.25&quot; Egg*</td>
<td>Yes</td>
<td>4/13/2016</td>
<td>4/25/2016</td>
<td>Standard</td>
<td>Measure flows in Ivanhoe Interceptor near downstream end of proposed LRRS project</td>
<td>Good Hydraulic Conditions</td>
</tr>
<tr>
<td>IVH2</td>
<td>61&quot; x 55&quot; Basket</td>
<td>62.38&quot; x 54&quot; Inverted Egg*</td>
<td>62.38&quot; x 54&quot; Inverted Egg*</td>
<td>No</td>
<td>4/13/2016</td>
<td>4/27/2016</td>
<td>Reverse</td>
<td>Measure flows in Ivanhoe Interceptor near London Rd and railroad tracks</td>
<td>Good hydraulic conditions were observed at original locations, but ADS had traffic safety concerns</td>
</tr>
<tr>
<td>RSLD</td>
<td>56.3&quot; x 44.4&quot; No. 7 Egg</td>
<td>58.13&quot; x 44&quot; Egg*</td>
<td>58.13&quot; x 44&quot; Egg*</td>
<td>No</td>
<td>4/13/2016</td>
<td>4/27/2016</td>
<td>Standard</td>
<td>Measure flows in combined sewer near Roseland/Wayside Intersection</td>
<td>The initial manhole location was paved over, so there is no access to it anymore</td>
</tr>
</tbody>
</table>

*The cross section ordinates used by ADS are provided in Attachment 7
Attachment 2: Map Book Marked-Up with Field Investigation Summary
Manhole is paved over. Moved down one manhole for sewer access

Installed reverse to avoid an incoming sewer upstream of this manhole. 24" incoming line is not on GIS.

Traffic safety issue coming over railroad tracks. Meter was moved two manholes downstream to accommodate
Figure 4

Pre-Design Flow Monitoring Plan

District removed leaper bulkhead that was found here and ADS later installed a meter here. Additional information in Attachment 6

Measure inflows from 33" sewer

Determined acceptable by ADS/WRCE

Measure inflows & indirectly determine activations
Attachment 3: Site Installation Reports
**Site I.D.**

<table>
<thead>
<tr>
<th>Site Address / Location:</th>
<th>EB center lane of Euclid Ave., between 16200 Euclid and Hillsboro Rd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Access:</td>
<td>Drive / Traffic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monitor Series</th>
<th>Location Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRITON+</td>
<td>Temporary</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pipe Size (H x W)</th>
<th>Pipe Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.5&quot; x 30.63&quot;</td>
<td>Egg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manhole #</th>
<th>System Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Available</td>
<td>Residential</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Access</th>
<th>Traffic</th>
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</thead>
<tbody>
<tr>
<td>Drive</td>
<td>Medium</td>
</tr>
</tbody>
</table>

### Installation Information

- **Installation Date:** Monday, April 25, 2016
- **Installation Type:** Doppler Special Installation
- **Monitoring Location (Sensors):** Downstream 5-10 FT
- **Pressure Sensor Range (psi):** 0 - 5 psi
- **Peak Combo (CS4), Smart Depth (CS5):**

#### Installation Confirmation:

- **Confirmation Time:** 12:32:00 PM
- **Pipe Size (HxW):** 40.5" x 30.63"
- **Depth of Flow (Wet DOF) (in):** 25.75
- **Range (Air DOF) (in):** 13.5
- **Downlooker Physical Offset (in):** 1.38
- **Measurement Confidence (in):** 0.38"
- **Peak Velocity (fps):** 0
- **Velocity Sensor Offset (in):** 0
- **Silt (in):** 0
- **Silt Type:**

**Hydraulic Comments:**
- Dry pipe.

### Manhole / Pipe Information:

- **Manhole Depth (Approx. FT):** 12
- **Manhole Configuration:** Leaping Weir
- **Manhole Material:** Brick
- **Manhole Condition:** Good
- **Manhole Opening Diameter (in):** 24
- **Manhole Diameter (Approx.):** 36
- **Manhole Cover:** Vented
- **Manhole Frame:** Normal
- **Active Drop Connections:**
  - Yes, Inside: Yes
  - Yes, Outside: No
- **Pipe Material:** Brick
- **Pipe Condition:** Good

### Communication Information:

- **Communication Type:** Wireless
- **Antenna Location:** Manhole Pick / Vent Hole

**Additional Site Info. / Comments:**
- Box test used to verify depth sensor.
<table>
<thead>
<tr>
<th>Upstream</th>
<th>Downstream</th>
<th>Sanitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Upstream Photo]</td>
<td>![Downstream Photo]</td>
<td>![Sanitary Photo]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>24&quot; Connection</th>
<th>From Top</th>
<th>Location</th>
</tr>
</thead>
<tbody>
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<td>![24&quot; Connection Photo]</td>
<td>![From Top Photo]</td>
<td>![Location Photo]</td>
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</table>

<table>
<thead>
<tr>
<th>24&quot; connection</th>
<th>24&quot; connection</th>
<th>Plugged 12&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>![24&quot; connection Photo]</td>
<td>![24&quot; connection Photo]</td>
<td>![Plugged 12&quot; Photo]</td>
</tr>
</tbody>
</table>
Attachment 4: I09A-D1 Field Investigation Notes
Euclid & Ivanhoe sewer connectivity investigation 4-13-16
At I-09A

- Expected the 8” pipe to the northwest to be relief pipe, as per GIS
- Observed flows entering manhole from 8” combined flow pipe from the northwest during field investigation
- I-09A is not a flow divider and therefore nor critical for LRRS flow monitoring
Attachment 5: I12-U1 Field Investigation Notes
Belvoir sewer connectivity investigation 4-14-16

Investigated connectivity of sanitary and combined sewers along Belvoir

Located and Opened Manholes
1. Sanitary manhole upstream SSO I-13
2. Sanitary manhole on DWO from SSO 1-13
3. Sanitary manhole north of Lancaster
4. Combined manhole east side Belvoir
5. Combined manhole west side Belvoir
6. SSO SWO west side of Belvoir
7. Sanitary manhole south of Lancaster

ArcGIS Online (AGOL) connectivity generally correct. Could not locate manhole where sanitary sewer ties into combined sewer. AGOL connectivity in agreement with IMP-345. Could not locate a sanitary manhole south of intersection

County plan IMP-345 - Plan associated with 36” Belvoir trunk line
Belvoir sewer connectivity investigation 4-14-16
Lancaster & Belvoir

Located and Opened Manholes
1. Sanitary manhole upstream SSO I-13
2. Sanitary manhole on DWO from SSO 1-13
3. Sanitary manhole north of Lancaster
4. Combined manhole east side Belvoir
5. Combined manhole west side Belvoir
6. SSO SWO west side of Belvoir
7. Sanitary manhole south of Lancaster

Flow present in combined sewers

ArcGIS Online (AGOL) connectivity generally correct. Could not locate manhole where sanitary sewer ties into combined sewer. AGOL connectivity in agreement with IMP-345. Could not locate a sanitary manhole south of intersection

County plan IMP-345 - Plan associated with 36" Belvoir trunk line
Belvoir sewer connectivity investigation 4-14-16
Groton & Belvoir

Located and Opened Manholes
8. AGOL shows continuous combined sewer south of Belvoir. Opened manhole, no flow, full of leaves.

9. Clear, low flow in 12” combined sewer

10. Flow in 36” sanitary sewer

ArcGIS Online (AGOL) shows continuous combined sewer south side of Belvoir. No flow in south line.

County plan IMP-345 - Plan associated with 36” Belvoir trunk line
Belvoir sewer connectivity investigation 4-14-16
Groton & Belvoir

Located and Opened Manholes
8. AGOL shows continuous combined sewer south of Belvoir. Opened manhole, no flow, full of leaves.
9. Clear, low flow in 12” combined sewer
10. Flow in 36” sanitary sewer

ArcGIS Online (AGOL) shows continuous combined sewer south side of Belvoir. No flow in south line.

County plan IMP-345 - Plan associated with 36” Belvoir trunk line

Belvoir sewer connectivity investigation 4-14-16
Near I-12

Located and Opened Manholes
11. Flow in sanitary sewer
12. Clear, low flow in 15” combined sewer
13. Connected to combined sewer from northeast Very low, clear flow from combined South of Belvoir. 24” storm sewer from catch basin connected as high pipe above incoming 15” combined sewers

ArcGIS Online (AGOL) connectivity in agreement with 4/13 & 4/14 field investigation findings

County plan IMP-345 - Plan associated with 36” Belvoir trunk line

WPC plan R-526 – Plan associated with combined sewers and regulator I-12
Belvoir sewer connectivity investigation 4-14-16
Near I-12

Located and Opened Manholes

11. Flow in sanitary sewer

12. Clear, low flow in 15” combined sewer

13. Connected to combined sewer from northeast
Very low, clear flow from combined South of Belvoir. 24” storm sewer from catch basin connected as high pipe above incoming 15” combined sewers

ArcGIS Online (AGOL) connectivity in agreement with 4/13 & 4/14 field investigation findings

County plan IMP-345 - Plan associated with 36” Belvoir trunk line

WPC plan R-526 – Plan associated with combined sewers and regulator I-12

Belvoir sewer connectivity investigation 4-14-16
At I-12

Located and Opened Manholes

11. Flow in sanitary sewer

12. Clear, low flow in 15” combined sewer

13. Connected to combined sewer from northeast
Very low, clear flow from combined South of Belvoir. 24” storm sewer from catch basin connected as high pipe above incoming 15” combined sewers

ArcGIS Online (AGOL) connectivity in agreement with 4/13 & 4/14 field investigation findings

County plan IMP-345 - Plan associated with 36” Belvoir trunk line

WPC plan R-526 – Plan associated with combined sewers and regulator I-12
Attachment 7: Pipe Cross Section Ordinates
Appendix D
Egg-shaped Sewer Geometries
EGG SHAPED SEWERS

<table>
<thead>
<tr>
<th>NO.</th>
<th>H FEET</th>
<th>W FEET</th>
<th>S FEET</th>
<th>AREA 50 SQ FT</th>
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<td>1</td>
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<td>4.04</td>
<td>2.71</td>
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<td>6</td>
<td>3.14</td>
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<tr>
<td>7</td>
<td>4.09</td>
<td>3.80</td>
<td>2.76</td>
<td>1612.5</td>
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</tbody>
</table>

SEWER: \(\text{SEWER}\#X+1+2=\L_c\times E_{\text{FIN. EQUIV.}}\)

TIMBER GRILLAGE WHERE SPECIFIED

USE 8 20 ga STEEL WIRE NAILS FOR EACH RIB

TYPES OF EGG SHAPED SEWERS

A - 1 RING OF BRICK ALL AROUND.
B - 1 RING EXTRA ON ARCH.
C - 2 RINGS OF BRICK ALL AROUND.
D - 2 RINGS EXTRA ON ARCH.
E - 3 RINGS OF BRICK ALL AROUND.

TABULAR DIMENSIONS FOR EGG SHAPED SEWERS, NO. 2 TO NO. 8

<table>
<thead>
<tr>
<th>NO.</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
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</tr>
</tbody>
</table>

CITY OF CLEVELAND

ENGINEERING DIVISION

RALPH C. FAULK-DIRECTOR OF PUBLIC SERVICE

STANDARD PLAN FOR EGG SHAPED SEWERS

DIMENSIONS & AREAS

NO SCALE

DRAWN BY:  SHEET: 8 2-28 6
SUBMITTED BY:  SHEET: 8 2-28 6
APPROVED:  SHEET: 8 2-28 6
APPROVED DATE:  SHEET: 8 2-28 6

FILE NO.: 73 M

REV. 11-25-49
Appendix E
Data Quality Summary Table Example
## Appendix F Data Quality Summary Table Example

**Figure 5. DRRS Pre-Design Flow Monitoring Program Performance and Data Quality Summary - July 2016**

<table>
<thead>
<tr>
<th>Data Quality Codes</th>
<th>Reliable Data</th>
<th>Questionable Depth</th>
<th>Questionable Velocity</th>
<th>Questionable Depth &amp; Velocity</th>
<th>No Data /Equip. Malfunction</th>
<th>Unusual Observation</th>
<th>Data Quality not in Question</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Quality Codes</th>
<th>Edited Data</th>
<th>Monitor Installed /Reinstalled/Replaced</th>
<th>Sensor Adjusted /Scrubbed</th>
<th>Sensor Replaced</th>
<th>Daily Total Rainfall (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Temporary Monitor</th>
<th>July 2016</th>
<th>Uptime %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Week 11</td>
<td>Week 12</td>
</tr>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31</td>
<td></td>
</tr>
<tr>
<td>Rain Gauges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>REA</td>
<td>0.1 0.2 0.0 0.0 0.2</td>
<td>0.2 0.0 0.4 0.2</td>
</tr>
<tr>
<td>RSO</td>
<td>0.1 0.1 0.0 0.1</td>
<td>0.1 0.0 0.1</td>
</tr>
<tr>
<td>Flow Meters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D64A-U1</td>
<td></td>
<td>(1) A</td>
</tr>
<tr>
<td>D64A-U2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D76A-U1(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D76-S1 (3)</td>
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<td></td>
</tr>
<tr>
<td>D77A-U1(4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D77-U1</td>
<td></td>
<td>(4) A</td>
</tr>
<tr>
<td>D85-U1(5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D86-U1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E39-D1</td>
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<td></td>
</tr>
<tr>
<td>E39-U1(6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1). Possible debris on sensor, velocity data were edited using scattergraph editor
(2). Pressure depth used for the entire month, velocity edits throughout the month to address pops/drops with scattergraph editor
(3). Meter in SWO pipe, velocity readings set to zero during dry weather, pressure depth were used during wet weather
(4). Depth shifting while no change in velocity. The drift in depth were manual edited throughout the month
(5). Due to low flows, velocity readings were erratic during in dry weather and were edited using scattergraph editor. Wet period reliable
(6). Velocity edits throughout the month using scattergraph editor to address pops/drops
Appendix F

Flow Monitor Maintenance Log Example Template
# Flow Monitor Field Maintenance Log

## Project: Site ID: Meter Serial #:

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Field Crew Initials</th>
<th>Manual Readings</th>
<th>Real Time/Current Status Meter Sensed</th>
<th>Battery Voltage</th>
<th>Observations/Actions Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Level</td>
<td>Velocity</td>
<td>Level</td>
<td>Velocity</td>
</tr>
</tbody>
</table>

---

**Northeast Ohio Regional Sewer District**

Flow Monitor Maintenance Report
## Flow Monitor Field Maintenance Log - Velocity Profile

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Field Crew Initials</th>
<th>Velocity Profile (fps)</th>
<th>Average Velocity (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>D T1 D T2 D T3 D M1 D M2 D M3 D B1 D B2 D B3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### PIPE PROFILE

- T1
- T2
- T3
- M1
- M2
- M3
- B1
- B2
- B3
Appendix G
District Flow Monitoring Deliverables Reference Guide
## District Flow Monitoring Deliverables Reference Guide

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Deliverable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Installation</td>
<td>Flow Monitoring Plan and the shapefile of monitor locations</td>
</tr>
<tr>
<td>Post-Installation</td>
<td>Flow Monitoring Plan Addendum and the shapefile of monitor locations. Upload installation reports to AGOL project site.</td>
</tr>
<tr>
<td>Available Upon Request (within 2-weeks of request during monitoring period)</td>
<td>Hydrographs (Edited Data) (1-month increments): Depth, Velocity, Flow and Rainfall/field confirmation measurements overlain</td>
</tr>
<tr>
<td></td>
<td>Scatter Graph (Edited Data): Depth vs. Velocity Readings with field confirmation measurements overlain</td>
</tr>
<tr>
<td></td>
<td>Summary of Site Visits: Confirmation measurements, date/time, and site/monitor observations</td>
</tr>
<tr>
<td></td>
<td>Summary Table of Daily Min/Max/Avg. and Rain Totals</td>
</tr>
<tr>
<td></td>
<td>Edited Flow Data (.csv): Depth, Velocity, and Flow</td>
</tr>
<tr>
<td></td>
<td>Rain Data (.csv) (EMAILED to <a href="mailto:FedakM@neorsd.org">FedakM@neorsd.org</a> before the 7th of each month)</td>
</tr>
<tr>
<td></td>
<td>Data Quality Summary: Identify major data collection issues or monitor/equipment issues. Uptime percentage.</td>
</tr>
<tr>
<td>With-in 6 Weeks of End of Flow Monitoring</td>
<td>Site Installation Reports</td>
</tr>
<tr>
<td></td>
<td>Scatter Graph (Final Data) (Entire Monitoring Period): Depth vs. Velocity Readings with field confirmation measurements overlain</td>
</tr>
<tr>
<td></td>
<td>Hydrographs (Final Data) (1-month increments): Depth, Velocity, Flow and Rainfall/field confirmation measurements overlain</td>
</tr>
<tr>
<td></td>
<td>Summary Table of Daily Min/Max/Avg. and Rain Totals (Presented on a per calendar month basis)</td>
</tr>
<tr>
<td></td>
<td>Summary of Rain Fall Events: Total rainfall depth, duration, peak 5-minute and 1-hour intensities.</td>
</tr>
<tr>
<td></td>
<td>Summary of Site Visits: Confirmation measurements, date/time, and site/monitor observations</td>
</tr>
<tr>
<td></td>
<td>Data Quality Summary: Identify major data collection issues or monitor/equipment issues. Uptime percentage.</td>
</tr>
<tr>
<td></td>
<td>Pipe Tables used for flow calculation for any non-standard pipe dimensions</td>
</tr>
<tr>
<td></td>
<td>Final Flow Data (.csv): Depth, Velocity and Flow</td>
</tr>
<tr>
<td></td>
<td>Final Rain Data (.csv)</td>
</tr>
<tr>
<td></td>
<td>Raw Flow Data (.csv): Depth, Velocity and Rain</td>
</tr>
<tr>
<td></td>
<td>Raw Rain Data (.csv)</td>
</tr>
<tr>
<td></td>
<td>Upload Installation Report and Final Data (.csv) to the District GIS</td>
</tr>
</tbody>
</table>
Appendix H
Final Flow Monitoring Report Outline
Final Flow Monitoring Report Outline

This attachment provides the recommended flow monitoring report outline. A summary of the information to be discussed but not limited to in each section.

Report Outline

Overview
- Detail the project the monitoring effort is supporting
- Intended use of the data
- Monitoring duration
- Monitoring firms involved and their respective responsibilities
- Description of data handling
- Any key findings from the monitoring

Site Selection, Installation, and Operation
- Describe the site selection process
- Flow monitoring and rain gauge map
- Site naming convention used
- Installation methodology
- Description of equipment used to perform monitoring
- Summary table of all the meters installed illustrating installation type, manhole ID, pipe size/shape (AGOL vs. field measured), and purpose.

Data Collection and Analysis
- Describe the rainfall data collected
- Description and summary table of the rain events based on an inter-event duration of 12-hours, event duration, total rainfall, peak 1-hr intensity and peak 5-min. intensity
- The Data Quality Summary (example presented in Attachment E) summarizing the flow monitoring data quality should also be presented and discussed in this section
• Description of the editing of flow data and any flow volume analysis/mass balance reviews that were performed
• A flow meter schematic should be included to support the mass balance analysis
• Discussion of individual monitoring issues
• Discussion of on whether the 90% uptime requirement was met

Presentation of Final Flow Data
• Describe what data will be shared as part of this report

Summary and Key Findings

Attachments
Attachment A – Monitoring Equipment, Installation, and Operation
Attachment B – Confirmation Points and Service History Reports
Attachment C – Dry and Wet weather mass balance review for selected meters and events
Attachment D – Meter Installation report, Daily Summary, Time Series plots and Scattergraphs
Attachment E – Pipe Tables

Digital Submittal
• Meter Raw Data in CSV Format
• Meter Final Data in CSV Format
• Pipe Tables in excel Format