Benefits of Hydraulic Model Development at MSDGC WWTPs

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Hazen and Sawyer
Presentation Overview

• Project Background
• Hydraulic Profile Model Background
• Model Development and Calibration Process
• Using the Model
• Lessons Learned
• Questions
MSDGC Summary

- 43 of 49 of political subdivisions in Hamilton County, and parts of Butler, Clermont, and Warren Counties as well
- Service area of 290+ square miles
Approximately 230,000 residential and commercial users

System includes:
- 3,000 miles of sanitary and combined sewers
- 7 Wastewater Treatment Plants Treating ~184 mgd
- 120 Pump Stations
Project Background

- Development of models for MSDGC WWTPs
  - Calibrated Hydraulic Profile Model
  - Calibrated Process Model
- Provide a tool for ops/maintenance planning and future scenario evaluation
- Minimize “reinventing” the hydraulic profile and process model when work is performed.
- Profile is intended to be a “living” tool for MSDGC
Two+ Different Models

- **GPS-X:**
  - Process Engineering Model
  - Process Operations Tool

- Hydraulic Profile Model
Hydraulic Model -- HazenPro

- Gravity components of main liquid stream
  - Does not include pump stations
- Platform – HazenPro
  - Excel based
  - All modules accessible / usable by MSDGC
- Can be modified by other consultants by removal of modules
Why develop a WWTP Hydraulic Profile Model?

- Hydraulics are rarely assessed after plant design
- Understand as-built plant hydraulic performance:
  - Potential changes in channel and pipe conditions
  - Potential flow split imbalances
  - Changes in units operating
  - Hydraulic bottlenecks
- Understand plant failure modes:
  - Clarifier weir submergence
  - Channel overtopping
- Provide operators a “what-if” tool for training and scenario evaluation
What Can We Evaluate With WWTP Hydraulic Models?

- Average and peak flow rates
- Effect of taking tanks out of service
- Impact of new processes on upstream and downstream (with insertion of new modules)
- Impact of high river levels
Four Plants Modeled in 2011-2012
Little Miami WWTP

- Conventional Activated Sludge Secondary Treatment
- Preliminary Treatment Process Includes:
  - Mechanical Screening
  - Grit Removal
  - Primary Clarification
- Chlorine Disinfection
- Combined Sewer Collection System
- Rated Capacity: 55 mgd
- Peak flows up to 100 mgd
- Flow bypass capabilities
- Discharge to the Ohio River
Polk Run WWTP

- Conventional Activated Sludge Secondary Treatment
- Preliminary Treatment Processes Include:
  - Cylindrical Fine Screens
  - Grit Removal
  - Primary Clarification
- UV Disinfection
- Separate Sanitary Sewer Flows
- Rated Capacity: 8.0 mgd
- Peak flows up to 18 mgd
- Discharge to the Little Miami River
Taylor Creek WWTP

- Counter-Current Aeration Activated Sludge Secondary Treatment (Manufactured by Schreiber)
- Preliminary Treatment Processes Include:
  - Mechanical Screens
  - Grit Removal
- UV Disinfection
- Separate Sanitary Sewer Flows
- Rated Capacity: 5.5 mgd
- Peak flows up to 13.75 mgd
- Discharge to the Great Miami River
Indian Creek WWTP

- Counter-Current Aeration Activated Sludge Secondary Treatment (Manufactured by Schreiber)
- Preliminary Treatment Processes Include:
  - Mechanical Screens
  - Grit Removal
- UV Disinfection
- Separate Sanitary Sewer Flows
- Rated Capacity: 1.5 mgd
- Peak flows up to 7.5 mgd
- Discharge to the Ohio River
Hydraulic Model Development

- Review of as-built plant drawings
- Development of initial hydraulic profile
- Identification of key survey points
  - Structures and water surface
- Surveyed ~100-200 points per plant
  - MSDGC survey crews
- Calibration
  - Survey crew HGL data
  - H&S field measurements during dry and wet weather
  - QA/QC by recognized hydraulic expert
- Report
Hydraulic Model Assumptions

- Flow splits assumed equal
- Not all flow paths modeled (worst case chosen)
- Calibrated to available data (tanks in service)
- Flow restrictions (i.e. grit)
- Surface turbulence (i.e. at splitter boxes)
- Gate / opening adjustments
- Specialized structures / process (i.e. UV)
Hydraulic Model Development

- **Step 1 – Review of As-Builts**
  - Age of plant and construction history
    - Taylor Creek – Newer plant – no upgrades since original
    - Little Miami – 20+ Record Drawing Sets with at Least 3 Major Plant Upgrade Projects
  - Consistency between construction phases and upgrade projects
  - Internal consistency in record drawing sets
Hydraulic Model Development

- Step 2 – Development of Initial Hydraulic Profile Model
  - Identification of flow path to simulate
  - Framework for representing hydraulic elements at plant
  - Identification of hydraulic control points
  - Site visits for initial verification of plant record drawing information
Hydraulic Model Development

- Step 2 – Development of Initial Hydraulic Profile Model
  - Flow Path Selection
Hydraulic Model Development

• Step 2 – Development of Initial Hydraulic Profile Model
  • Framework for representing hydraulic elements at plant
  • Identification of hydraulic control points
Hydraulic Model Development

- **Step 2 – Development of Initial Hydraulic Profile Model**
  - Site visits for initial verification of plant record drawing information
Hydraulic Model Development

- Step 3 – Plant Surveying
  - Verification of hydraulically important plant elevations
    - Weir Elevations
    - Channel Invert Elevations
    - Top of Structure Elevations
  - Measurement of Water Surface Elevations
  - Freeboard Measurements
Hydraulic Model Development

- Step 3 – Plant Surveying

<table>
<thead>
<tr>
<th>Number</th>
<th>Location</th>
<th>Measuring Point</th>
<th>No. of Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR.1.1</td>
<td>Plant Influential Channel</td>
<td>Invert</td>
<td>1</td>
</tr>
<tr>
<td>PR.1.2</td>
<td>Plant Influential Channel</td>
<td>Top of Wall</td>
<td>1</td>
</tr>
<tr>
<td>PR.1.3</td>
<td>Plant Influential Channel</td>
<td>Water Surface</td>
<td>1</td>
</tr>
<tr>
<td>PR.1.4</td>
<td>Screen Influential Channel Distribution Box</td>
<td>Invert</td>
<td>1</td>
</tr>
<tr>
<td>PR.1.5</td>
<td>Mechanical Screen Structure</td>
<td>Top of Wall</td>
<td>1</td>
</tr>
<tr>
<td>PR.1.6-8</td>
<td>Mechanical Screen Channels - Upstream of Screen</td>
<td>Invert</td>
<td>1</td>
</tr>
<tr>
<td>PR.1.9</td>
<td>Mechanical Screen Channels - Upstream of Screen</td>
<td>Water Surface (1 of 3 Screen Channels)</td>
<td>1</td>
</tr>
<tr>
<td>PR.1.10-12</td>
<td>Mechanical Screen Channels - Downstream of Screen</td>
<td>Invert</td>
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<tr>
<td>PR.1.14-16</td>
<td>Mechanical Screen Channels - Effluent (3 Screens)</td>
<td>Invert</td>
<td>1</td>
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<tr>
<td>PR.1.17</td>
<td>Mechanical Screen Channel</td>
<td>Invert</td>
<td>1</td>
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<tr>
<td>PR.1.18</td>
<td>Screen Effluent Channel</td>
<td>Water Surface</td>
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<tr>
<td>PR.1.19-20</td>
<td>Grit Tank Overflow Weirs (2 Weirs) [Sharp-Crest]</td>
<td>Top of Weir (2 Locations)</td>
<td>1</td>
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<tr>
<td>PR.1.21</td>
<td>Grit Tank Wall</td>
<td>Top of Wall</td>
<td>1</td>
</tr>
<tr>
<td>PR.1.22</td>
<td>Grit Tank Baffle Wall</td>
<td>Top of Wall</td>
<td>1</td>
</tr>
<tr>
<td>PR.1.23</td>
<td>Grit Tank Effluent Box</td>
<td>Invert</td>
<td>1</td>
</tr>
<tr>
<td>PR.1.24</td>
<td>Grit Tank Effluent Box</td>
<td>Water Surface</td>
<td>1</td>
</tr>
<tr>
<td>PR.2.1</td>
<td>Primary Clarifier Influential Channel (Combined)</td>
<td>Invert</td>
<td>1</td>
</tr>
<tr>
<td>PR.2.2</td>
<td>Primary Clarifier Influential Channel (Split to Tanks 1-3)</td>
<td>Invert</td>
<td>1</td>
</tr>
<tr>
<td>PR.2.3</td>
<td>Primary Clarifier Influential Channel (Split to Tanks 4-6)</td>
<td>Invert</td>
<td>1</td>
</tr>
<tr>
<td>PR.2.4</td>
<td>Primary Clarifier Influential Channel (Weirs to Tanks 1-3)</td>
<td>Invert</td>
<td>1</td>
</tr>
<tr>
<td>PR.2.5</td>
<td>Primary Clarifier Influential Channel (Weirs to Tanks 4-6)</td>
<td>Invert</td>
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</tr>
<tr>
<td>PR.2.6</td>
<td>Primary Clarifier Influential Channel (Weirs to Tanks 4-6)</td>
<td>Water Surface</td>
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<tr>
<td>PR.2.7</td>
<td>Primary Clarifier Influential Channel (Weirs to Tanks 4-6)</td>
<td>Water Surface</td>
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</tr>
</tbody>
</table>
Hydraulic Model Development

- Step 3 – Plant Surveying
  - How well did survey measurements match record drawing elevations?
Hydraulic Model Development

- Step 3 – Plant Surveying
  - Polk Run WWTP Plant-Wide Discrepancies

Differential Between Survey Measurement and Expected Record Drawing Elevation (Feet)
Hydraulic Model Development

- Step 3 – Plant Surveying
  - Polk Run WWTP Plant-Wide Discrepancies
  - Polk Run WWTP Primary Clarifier Influent Weirs
  - Indian Creek WWTP – Secondary Clarifier Compound Distribution Weir

3 Sharp Crested Weirs
579.30 feet (+/- 0.02 feet)

3 Sharp Crested Weirs
579.53 feet (+/- 0.01 feet)
Hydraulic Model Development

- **Step 3 – Plant Surveying – Flow Conditions Captured**

<table>
<thead>
<tr>
<th>Plant</th>
<th>Survey Measurement Flow Rates</th>
<th>Freeboard Measurement Flow Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little Miami WWTP</td>
<td>20 mgd to 67 mgd</td>
<td>27.7 mgd, 43.6 mgd, and 81.7 mgd</td>
</tr>
<tr>
<td>Polk Run WWTP</td>
<td>4.0 mgd to 4.5 mgd</td>
<td>4.5 mgd, 4.7 mgd, and 8.9 mgd</td>
</tr>
<tr>
<td>Taylor Creek WWTP</td>
<td>2.1 mgd to 3.2 mgd</td>
<td>2.4 mgd, 2.8 mgd, 5.4 mgd, and 5.5 mgd</td>
</tr>
<tr>
<td>Indian Creek WWTP</td>
<td>0.2 mgd to 0.6 mgd</td>
<td>0.4 mgd, 0.8 mgd, 2.9 mgd, and 3.0 mgd</td>
</tr>
</tbody>
</table>
Hydraulic Model Development

- Step 4 – Hydraulic Model Calibration
  - Incorporate survey elevation data
  - Compare model predictions to measured water surface elevations
  - Broader considerations:
    - LOTS OF DATA
      - Little Miami WWTP: 112 Water Surface Measurements
      - Polk Run WWTP: 135 Water Surface Measurements
      - Taylor Creek WWTP: 115 Water Surface Measurements
      - Indian Creek WWTP: 68 Water Surface Measurements
  - How to match the model to ALL the data collected?
  - Criteria and Threshold for Calibration
Hydraulic Model Development

- Step 4 – Hydraulic Model Calibration
  - Threshold for calibration
    - Survey measurements
    - Freeboard measurements
      - Tape measure accuracy
      - Chamfered channel corners
      - Hitting a “moving target”
  - 0.05-feet (~1/2 inch) desired
  - 0.10-feet as upper threshold
Step 4 – Hydraulic Model Calibration

- Parameters for adjustment
  - Adjustment of Manning’s “n” coefficients
  - Modification of k-values for fittings, entrances, exits, etc.
  - Addition or deletion of energy grade line to hydraulic grade line conversion

\[ V = \frac{k}{n} \times R_h^{2/3} \times S^{1/2} \]

\[ H_m = k \times \frac{V^2}{2g} \]
Hydraulic Model Development

- Discoveries during model development:
  - Little Miami WWTP
  - Suspected process unit flow imbalances
Discoveries during model development:

- Little Miami WWTP
- Suspected process unit flow imbalances
Hydraulic Model Development

- Discoveries during model development:
  - Little Miami WWTP
  - Suspected air entrainment
Hydraulic Model Development

- Discoveries during model development:
  - Polk Run WWTP
  - Primary Clarifier Flow Split Cause
Hydraulic Model Development

- Discoveries during model development:
  - Polk Run WWTP
  - Secondary Clarifier Flow Split Imbalance
Hydraulic Model Development

- Discoveries during model development:
  - Taylor Creek WWTP
  - Secondary Clarifier Influent Piping Air Entrainment
Hydraulic Model Development

- Discoveries during model development:
  - Taylor Creek WWTP
  - UV System Hydraulics

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Graph: Observed Headloss (ft) vs. Flow (mgd) for HazenPRO MFR Module Fit.
Hydraulic Model Development

- Discoveries during model development:
  - Taylor Creek WWTP
    - Rapidly Fluctuating Flow Rates – Influent Pump Cycling
Hydraulic Model Development

- Discoveries during model development:
  - Indian Creek WWTP
  - Vortex Grit Removal Sample Collection Stop Plate

- Widely Fluctuating Flow Rates (Suspected)
Hydraulic Model Development

- Building on the Basic Model
  - Tailor to use for a wide variety of users
    - Operations Staff
    - Planning
    - Engineers
  - Ease of Use
  - Ease of Interpretation
## 1.4 Outfall Pipe From Sampling/Metering Chamber to MH-Y

**Module PIPH**

<table>
<thead>
<tr>
<th>Piping by Hazen-Williams Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter = 72 in</td>
</tr>
<tr>
<td>Length = 190 ft</td>
</tr>
<tr>
<td>Hazen &amp; Will. C = 120</td>
</tr>
<tr>
<td>Minor Loss K’s : Entr / Exit</td>
</tr>
<tr>
<td>45 Bends</td>
</tr>
<tr>
<td>Branch Tee</td>
</tr>
<tr>
<td>Sum K = 1.5</td>
</tr>
</tbody>
</table>

**EGL/HGL at** 458.92  459.84  458.07

## 1.5 Outfall Pipe From Outfall Control Box to Sampling/Metering Chamber

**Module PIPH**

<table>
<thead>
<tr>
<th>Piping by Hazen-Williams Equation</th>
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<tbody>
<tr>
<td>Diameter = 72 in</td>
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<tr>
<td>Length = 100 ft</td>
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<tr>
<td>Hazen &amp; Will. C = 120</td>
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<tr>
<td>Minor Loss K’s : Entr / Exit</td>
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</tr>
<tr>
<td>Branch Tee</td>
</tr>
<tr>
<td>Sum K = 1.5</td>
</tr>
</tbody>
</table>

**EGL/HGL at** 459.91  461.02  458.89

## 2.1 Final Effluent Conduit From Chlorine Contact Tank to Outfall Control Box

**Module CCR**

<table>
<thead>
<tr>
<th>Rectangular Closed Conduit by Mannings Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q_{secondary} (mgd) = 110.0</td>
</tr>
<tr>
<td>Width = 5.0 ft</td>
</tr>
<tr>
<td>Height = 5.0 ft</td>
</tr>
<tr>
<td>Length = 32 ft</td>
</tr>
<tr>
<td>Manning n = 0.013</td>
</tr>
<tr>
<td>SumK = 2.1</td>
</tr>
</tbody>
</table>
Hydraulic Profile Model Features

**INPUTS**

- Input Up to 3 Flow Scenarios
- Take Tanks In and Out of Service
- Input River Elevation at Discharge
Hydraulic Profile Model - Features

SUMMARY RESULTS

Visual Water Surface Elevation Output

Create PDF of Inputs and Results

Summary of Water Surface Elevations and Weir Conditions
Hydraulic Profile Model - Features

### Summary of Predicted Water Surface Elevations

<table>
<thead>
<tr>
<th>Predicted Water Surface - Scenario 1 (ft)</th>
<th>Predicted Water Surface - Scenario 2 (ft)</th>
<th>Predicted Water Surface - Scenario 3 (ft)</th>
<th>Top of Structure Surface (ft)</th>
<th>Estimated Freeboard (inches) - Flowrate 1</th>
<th>Estimated Freeboard (inches) - Flowrate 2</th>
<th>Estimated Freeboard (inches) - Flowrate 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>578.01</td>
<td>577.98</td>
<td>578.38</td>
<td>579.66</td>
<td>20</td>
<td>20</td>
<td>15</td>
</tr>
</tbody>
</table>

**Location of Survey Point**

**Summary of Predicted Water Surface Elevations**

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[Image: Aeration Basin Distribution Box]

SUMMARY RESULTS – PHOTOS
Lessons Learned

- **Plant Hydraulics**
  - Calibration – Only as good as the flow rate data
  - Air entrainment a suspected problem at several of the plants
  - Flow split inequalities common - hydraulic and process implications

- **Modeling**
  - Accounting for turbulence and air entrainment key
  - Survey data not as accurate as expected
  - Accounting for vastly differing flow paths

- **Unexpected Challenges**
  - Balancing the needs of all model users – usability vs. accuracy

- **Importance of Keeping Internal Users Interested and Informed**
  - Producing a product that will be utilized by MSDGC staff for years to come
Project Team Acknowledgements

- MSDGC
  - Rick Reiss
  - Tom Kutcher
  - Bruce Smith
  - WWTP Superintendents
  - WWTP Operators

- Hazen and Sawyer
  - Jamie Gellner
  - Richard Claus
  - Will Martin
  - David Nailor
Thank You! Questions?

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