APPLICATION OF REAL-TIME WEATHER FORECAST IN COLLECTION SYSTEM OPERATION

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Huron, OH
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OARS Tunnel Shaft
Agenda

• Columbus Collection System
• OARS Tunnel
• Collection System Operation
• Conclusion and Next Steps
City of Columbus Collection System

- 432,000 Acres
- 24 Contract Service Areas
- One Deep Tunnel
- Two Storm Tanks
  - Whittier St
  - Alum Creek
- Two WWTPs
  - Jackson Pike
  - Southerly
- One CEPT
  - In service end 2019
City of Columbus Current Challenges

- 29 CSOs
- 69 SSOs
- Basement backup complaint areas
- High population growth
Wet Weather Management Plan

Background/Timeline

Wet Weather Management Plan (WWTP Upgrade and 3 Tunnels)

August 2002
SSO
CO

Sept 2004
CSO
CO

July 2005

Sept 2010

July 2010

July 2012

Jan 2013

Dec 2015

Sept 2016

July 2017

Kuyper City Council Welcome Historic Ohio PPA Final Approval
of $2.5 Billion Plan to Reduce Sewage Overflows

"The City has anticipated the need for a comprehensive solution to address the
sheer volume of sewage overflows that have been occurring in the City's
drainage system. This PPA is a significant step forward in helping to
ensure that our city remains healthy and vibrant for future generations." said
Mayor Michael B. Haddad. "Arcadis' work on this project will help to address
issues that have plagued the City for many years, and we are grateful for
their commitment to seeing this project through to completion."
WWTP Improvement

SWWTP: 200 → 330 MGD
JPWWTP: 102 → 150 MGD
OARS Construction

- Aug 2002
- Sept 2004
- July 2005
- July 2010
- Sept 2010
- July 2012
- Jan 2013
- Dec 2015
- Sept 2016
- July 2017

OARS Construction Begins
WWMP Update to Integrated Plan

- Aug 2002
- Sept 2004
- July 2005
- Sept 2010
- July 2010
- July 2012
- Jan 2013
- Dec 2015
- Sept 2016
- July 2017

Request to Explore Integrated Planning

OEPA Approved Request
Blueprint Columbus

Comprehensive I/I Reduction program from public sewers and private properties

- Aug 2002
- July 2012
- Jan 2013
- Dec 2015
- Sept 2016
- July 2017

- BP Approval
- BP Implementation Starts
Agenda

• Columbus Collection System
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OARS Extent

Ends at Henry St.

Downtown CSOs

Starts at Jackson Pike
OARS Tunnel Information

- 4.4 miles of 20’ Diameter Tunnel, 64 MG Storage Capacity
- 180’ Invert Depth
- 6 Shafts – 4 receive flow with special drop shaft structures
- 1 CSO at downstream end of the tunnel
- Dewatering Pumps

- If treatment capacity is available, tunnel can also work as a siphon to convey flow back to the system during large events

Source: https://www.columbus.gov/utilities/projects/OARS-Deep-Sewer-Tunnel/
OARS Tunnel - Level of Service

- Mitigate 10 downtown CSOs points up to 10-year LOS
- Reduce 2 billion gallons of CSOs at Whittier St Storm Tanks during typical year storm (2005 condition)
- Limit CSO overflow to 4 activations (typical year) at OARS downstream end
Agenda

- Columbus Collection System
- OARS Tunnel
- Collection System Operation
  - Operation Controls
  - OARS Weir Gates RTC
  - Rainfall Forecast Operation
- Conclusion and Next Steps
Operation Controls

Key Control Structures:

- OARS Weir Gates (static)
- WSST Gates
- OARS Dewatering Pumps
- OARS West Gates
- Scioto Main Relief Weir
- Big Walnut/BWARI Gates
- CEPT (2019)
## Collection System Operation Matrix

<table>
<thead>
<tr>
<th>Control Structures /Monitoring Points</th>
<th>WSST Reg Gates</th>
<th>SMR Weir</th>
<th>ODS Gate</th>
<th>OARS Pumps</th>
<th>FDS Gate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protect OSIS MHs at Berliner, avoid SSO at DSR083 and avoid bypass at Southerly</td>
<td>Maintain JP wet well at 14 ft after FDS reaches 689 or UC reaches 671</td>
<td>Control OARS flow to avoid bypass at JP and Southerly and avoid flow backup into OARS</td>
<td>Dewater OARS during and after the storm</td>
<td>Avoid bypass at JP</td>
<td></td>
</tr>
<tr>
<td><strong>Default Setting</strong></td>
<td>Open</td>
<td>Setting = 1</td>
<td>Closed</td>
<td>Off</td>
<td>Closed</td>
</tr>
<tr>
<td><strong>UC Head</strong></td>
<td>Close WSST Gates if UC Head &gt;= 678; If UC Head is between 673.5 and 678, modulate to maintain DSR 083 Head at 696; If UC Head is between 669.5 and 673.5, modulate to maintain DSR 083 Head at 700; If UC Head &lt; 669.5, turn DSR 083 pumps off</td>
<td>If UC Head &gt;= 671, maintain FDS Head at 691.5</td>
<td>Close ODS gates if UC Head &gt;= 678</td>
<td>Turn Pumps off when UC Head &gt; 678 Turn Pumps on when UC Head &lt;= 677.5</td>
<td></td>
</tr>
<tr>
<td><strong>DSR 083 Head</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FDS Head</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ODS Head</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Priority 1
- One FDS gate 50% open if FDS Head >= 694.3
- Turn Pumps on when FDS Head <= 692

### Priority 2
- One FDS gate 5% open if ODS Head > 580 and UC Head < 678
- Turn Pumps on when ODS Head between 535.6 and 692.5

### Priority 3
- Open ODS gate at ODS Head 692, close at ODS Head 691.6. When open, initially open 5% and then open up further if ODS Head continues to build
- Turn Pumps on when ODS Head between 535.6 and 692.5

### Priority 4
- Turn Pumps on when ODS Head between 535.6 and 692.5

### Priority 5
- Turn Pumps on when ODS Head between 535.6 and 692.5
# System Performance Metric Sheet

## 20 Year Model Simulation

<table>
<thead>
<tr>
<th>Description</th>
<th>Number of Overflow Activations</th>
<th>Overflow Volume</th>
<th>Overflow Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>OARS/WWTP/ACST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mainline SSOs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downtown CSOs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olentangy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSOs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manholes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## SSOs
Agenda

• Columbus Collection System
• OARS Tunnel
• Collection System Operation
  ð Operation Controls
  ð OARS Weir Gates RTC
  ð Rainfall Forecast Operation
• Conclusion and Next Steps
Real Time Control – OARS Weir Gates

Modulate the weir gates

- Convey first flush via surface sewers for treatment
- Save tunnel storage for the peak flow duration
- Avoid CSO activation at 10 downtown regulators
OARS Weir Gates Setting – RTC vs Static

Averages Annual
(from 20Y Simulation Results)

<table>
<thead>
<tr>
<th>OARS Fill / Dewater (MG)</th>
<th>OSIS-S6</th>
<th>OSIS-S5</th>
<th>OSIS-S4</th>
<th>Total Inflow</th>
<th>OARS Pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Setting</td>
<td>95</td>
<td>73</td>
<td>600</td>
<td>768</td>
<td>555</td>
</tr>
<tr>
<td>RTC</td>
<td>90</td>
<td>438</td>
<td>212</td>
<td>750</td>
<td>524</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overflow/CEPT (MG)</th>
<th>OARS OF</th>
<th>SWWTP Bypass</th>
<th>CEPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Setting</td>
<td>206</td>
<td>43</td>
<td>245</td>
</tr>
<tr>
<td>RTC</td>
<td>204</td>
<td>41</td>
<td>245</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activation Frequency</th>
<th>OARS OF</th>
<th>SWWTP Bypass</th>
<th>CEPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Setting</td>
<td>2.20</td>
<td>1.60</td>
<td>4.10</td>
</tr>
<tr>
<td>RTC</td>
<td>2.15</td>
<td>1.55</td>
<td>4.15</td>
</tr>
</tbody>
</table>

Static weirs setting performs as good as a comprehensive weir gates modulation program.
Agenda

- Columbus Collection System
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  - OARS Weir Gates RTC
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OARS Tunnel Operation Modes

Storage Mode
• Dewater after the storm
• Start dewatering when flow at WWTPs has been less than treatment capacity for 30 minutes

Conveyance Mode
• Dewater during the storm
  • Use dewater pumps as the tunnel is filling
  • Switch to a siphon mode when tunnel is full
## Storage vs Conveyance Operation Modes

### Averages Annual (from 20Y Simulation Results)

<table>
<thead>
<tr>
<th>Operation Mode</th>
<th>OARS Overflow (MG)</th>
<th>Gravity Bypass (MG)</th>
<th>CEPT (MG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage</td>
<td>317</td>
<td>26</td>
<td>98</td>
</tr>
<tr>
<td>Conveyance</td>
<td>292</td>
<td>26</td>
<td>104</td>
</tr>
</tbody>
</table>

Conveyance mode could reduce OARS overflow by sending more water to CEPT.

<table>
<thead>
<tr>
<th>Activation Frequency</th>
<th># OARS Overflow</th>
<th>Gravity Bypass</th>
<th>CEPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage</td>
<td>3.2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Conveyance</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
OARS Tunnel Operation Improvement

Can we use rainfall forecast to switch between operation modes?

- Is there a storm threshold above which OARS is expected to overflow?

- What is the condition during the back-to-back storms?

- What are the pros and cons for different OARS dewatering strategies?
OARS Inflow

- 20Y Simulation Results
- Tunnel is expected to be activated 801 times in 20 years
- Tunnel storage capacity is 63.8 MG (123 times tunnel is filled)

![Graph showing number of events (total of 801) in volume range from 0-3MG to >63.8MG]

- **283 Events**
- **184 Events** in 3-15MG
- **111 Events** in 15-30MG
- **58 Events** in 30-45MG
- **34 Events** in 45-57.5MG
- **8 Events** in 57.5-63.8MG
- **123 Events** in >63.8MG

Number of events the tunnel is filled with volume range
Storm range Filling OARS

- Tunnel fills when rainfall > 1.8 inches in 24 hours (31 events in 20 years)
- Of the remaining 770 events, tunnel was filled 93 times (12%)
## Storms Causing OARS Overflow

31 events of those filled the tunnel, rainfall was > 1.8 inches (in 20 years)

<table>
<thead>
<tr>
<th>24-hr Rainfall</th>
<th># OARS Filling</th>
<th># OARS Overflow</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥1.8 in</td>
<td>31</td>
<td>29</td>
<td>Use conveyance mode</td>
</tr>
<tr>
<td>0.5 - 1.8 in</td>
<td>87</td>
<td>31</td>
<td>If OARS fills, switch to conveyance</td>
</tr>
<tr>
<td>&lt;0.5 in</td>
<td>5</td>
<td>0</td>
<td>Stay storage mode</td>
</tr>
</tbody>
</table>
Operation Based on Real-Time Rainfall Forecast

- 24-hr Rainfall Forecast
  - Rainfall in 24-hr ≥ 1.8 in, Yes → Switch to Conveyance
  - Rainfall in 24-hr ≥ 0.5 in, Yes → Switch to convey if tunnel fills
  - 24-hr Depth ≤ 0.5 in, No → Stay Storage mode
  - Rainfall in 24-hr ≥ 0.5 in, No → Stay Storage mode
Rainfall Forecast Source

National Weather Service Ohio River Forecast Center
Example of Improvements

Event of August 29, 2013  (Rank 1 Event for 24-hr Rainfall)

By switching to Conveyance:
• OARS OF reduced 60 MG (12%)
Example of Improvements

By switching to Conveyance:
- OARS OF reduced 27 MG (21% reduction)
Agenda

• Columbus Collection System
• OARS Tunnel
• Operation Controls
• Rainfall Forecast and RTC
• Conclusion and Next Steps
## Conclusion

<table>
<thead>
<tr>
<th>Operation Mode</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
</table>
| Storage                            | • Easy Operation Plan  
• Less Stress on WWTPs                                                | • Under usage of available treatment at start if events  
• Large overflow volume could have been reduced                      |
| Conveyance (no rainfall forecast)  | • Keep tunnel storage available for the high peak period of the runoff | • Stressing the WWTPs  
• Increased potential for bypass                                         |
| Conveyance with Rainfall Forecast  | • Avoid stressing the WWTPs as possible  
• Allows time for operators to prepare for high flow conditions       | • Change operation mode during the storm  
• Potential need to accelerate dewatering to avoid back-to-back storms condition |
Next Steps: Summer vs Winter Storms

Summer Storms

- Sharp peak intensities
- Isolated specially distribution cells

Winter Storms

- Low intensity, large volume
- Extends over the entire City
Next Steps: Summer vs Winter Storms
Summer (June-Sept) Rainfall Trend

Max 1-hr Rainfall per Year
(1995-2018)

- 1Y return (1.09")
- 5Y return (1.66")
- 10Y return (1.91")
- 25Y return (2.26")

Last 24 years

Increasing

\[ y = 0.0166x - 31.986 \]

Last 12 years

\[ y = 0.0518x - 102.84 \]
Next Steps: Summer vs Winter Storms

Winter (Dec-Jan) Rainfall Trend

- 1Y return (2.20”)
- 5Y return (3.24”)
- 10Y return (3.74”)
- 25Y return (4.44”)

Decreasing

Last 24 years

Max 24-hr Rainfall per Year
(1995-2018)

Last 12 years

Max 24-hr Rainfall per Year
(2006-2018)

y = -0.0237x + 48.953

y = 0.0031x - 4.9351
Next Steps: OARS Surge Condition

Delaying water in the tunnel could increase surge and air entrapment conditions in the tunnel due to the back-to-back storms.

Next Steps: High River Operation

During high storms and high river conditions, OARS excessive flow would not be able to overflow to the river, causing backup into the collection system.

Emptying the tunnel at earlier stage could reduce the need to overflow at OARS and would reduce the backup negative impact.
Next Steps: Lower Olentangy Tunnel

City of Columbus is extending OARS with a 12 ft tunnel (LOT) to reduce CSO activation from 7 CSO points at upstream.

LOT will be connected to OARS through a sluice gate and drop shaft.

LOT can add additional storage that could improve the system operation and reduce OARS overflow.
Thank You

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Imagine the result