

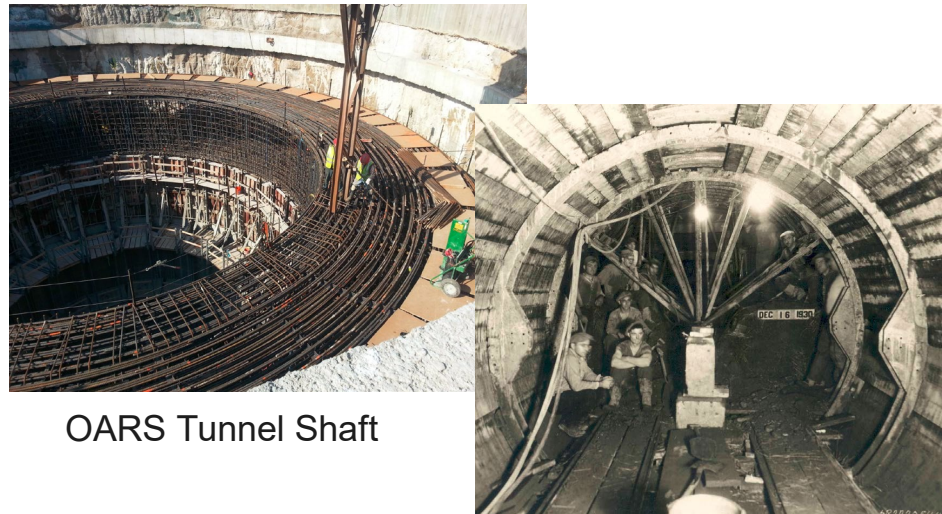
# APPLICATION OF REAL-TIME WEATHER FORECAST IN COLLECTION SYSTEM OPERATION

Hazem Gheith, Qiuli Julie Lu and Tiantian Xiang

OWEA Annual Conference 2019

Huron, OH

Hazem Gheith, Ph.D., P.E.  
Qiuli Julie Lu, Ph.D., P.E.  
Tiantian Xiang, Ph.D., EIT

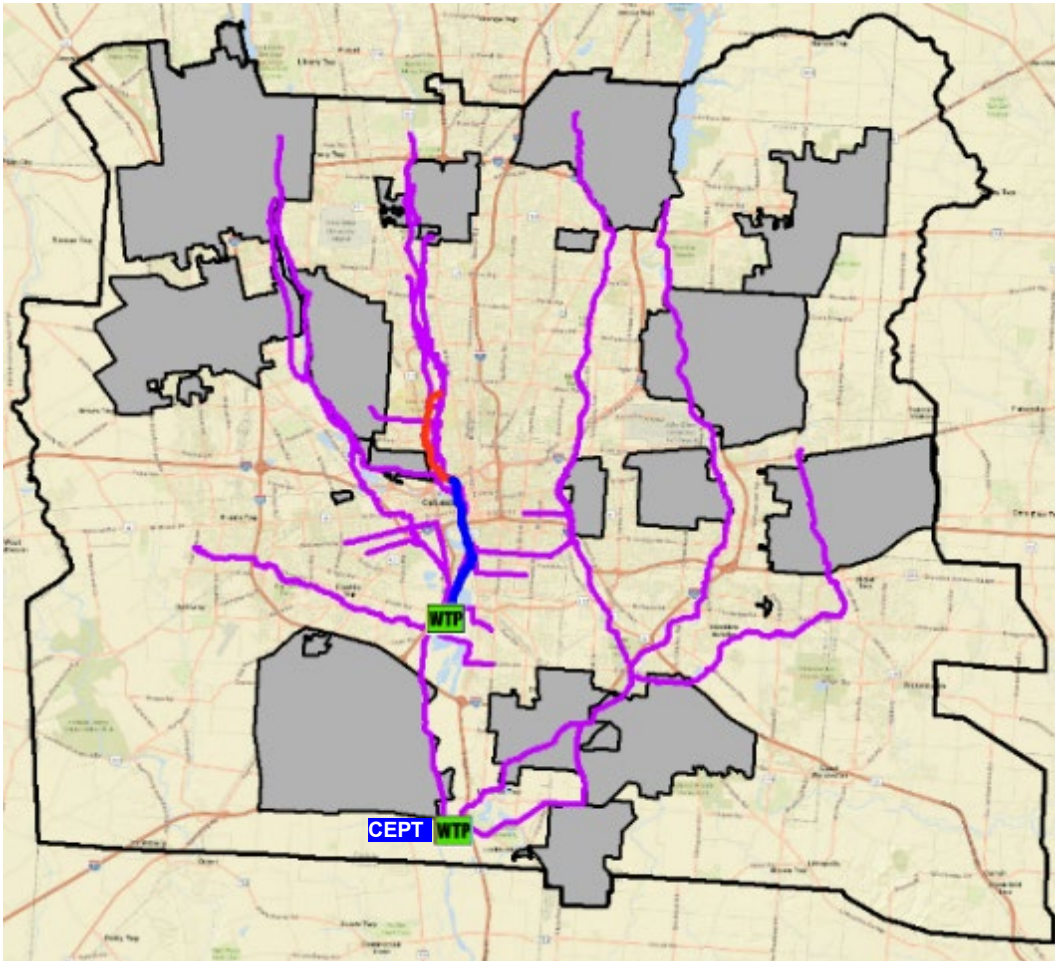


OARS Tunnel Shaft

# Agenda

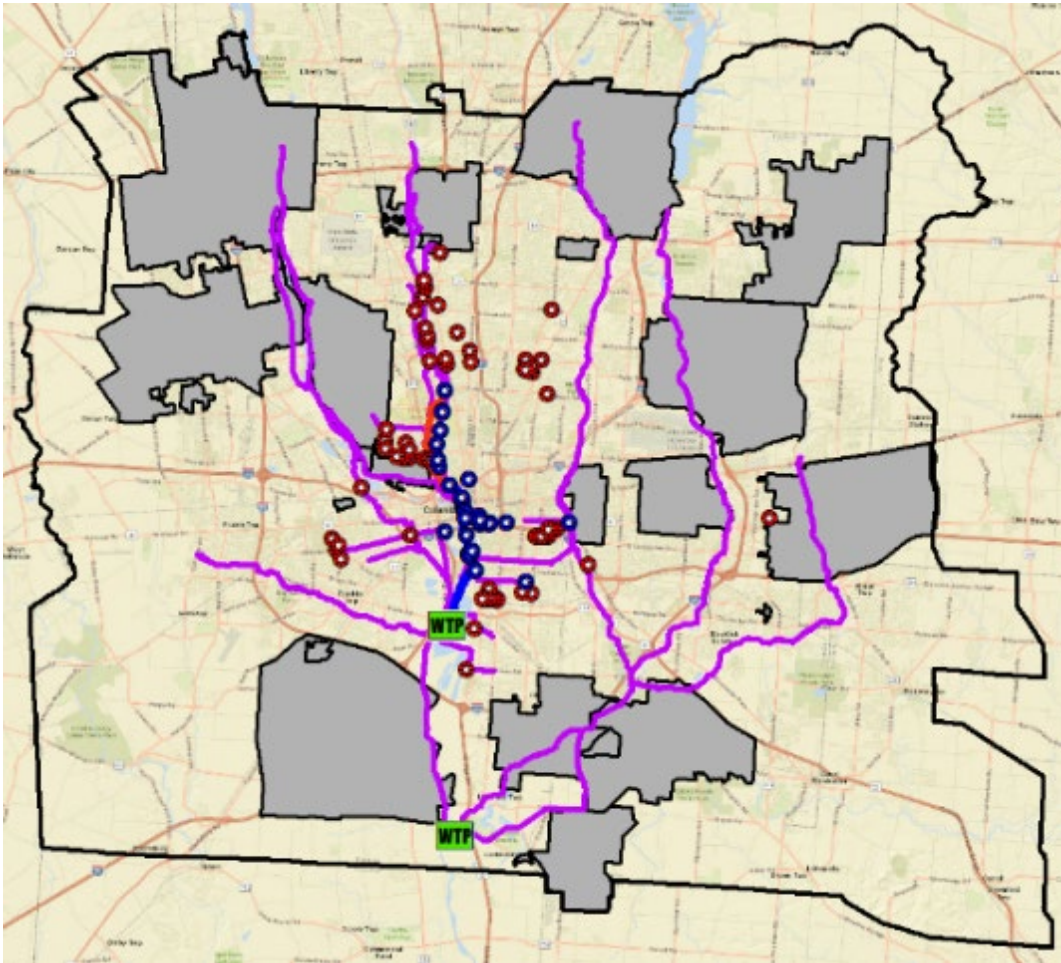
- Columbus Collection System
- OARS Tunnel
- Collection System Operation
- Conclusion and Next Steps

# 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

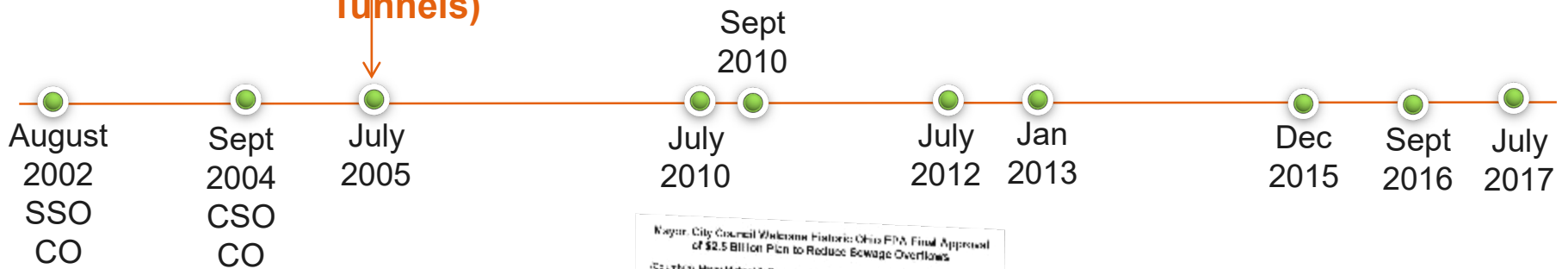


- 29 CSOs
- 69 SSOs
- Basement backup complaint areas
- High population growth

# Wet Weather Management Plan

## Background/Timeline

### Wet Weather Management Plan (WWTP Upgrade and 3 Tunnels)



**Nagar, City Council Welcomes Historic Ohio EPA Final Approval of \$2.5 Billion Plan to Reduce Sewage Overflows**

City Mayor Michael S. Costner and City Council have passed the City's Environmental Policy Statement (EPS) for the final review of the City's \$2.5 billion Wet Weather Management Plan (WWMP). The plan, now completed, will dramatically reduce sewage overflows and improve the city's water and sewer systems. The WWMP, adopted in July 2005, and being re-approved, is the largest infrastructure project in the city's history since 2000 and 2001.

"I congratulate the city on making history and leading the nation thanks to our partnership with Ohio EPA to develop our innovative plan to reduce sewer overflows and improve our waterways and water resources for Columbus families," said Mayor Costner. "This is a significant step toward better facilities, greater protection, and a more sustainable project, so we must stay vigilant to do it all we can to keep our city and sewer lines affordable."

To date, the City has received nearly \$100 million in state and federal grants, including a \$40 million grant from the Ohio EPA, to fund the City's WWMP. The plan, which includes upgrades to the city's sewer system, construction of three new tunnels, and other infrastructure projects, will reduce overflows and improve the city's water and sewer systems. The City's WWMP is the largest infrastructure project in the city's history since 2000 and 2001.

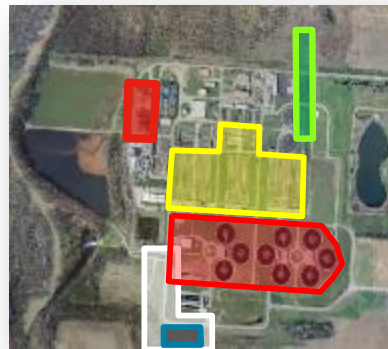
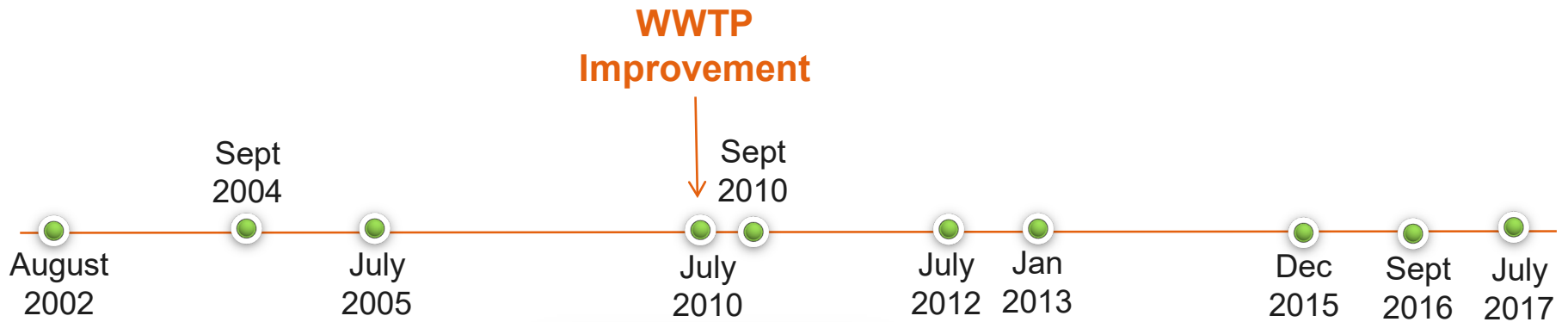
"This historic approval will help the City of Columbus meet the increased demand for clean and safe water infrastructure in an environmentally friendly way," said City Council Public Utilities Committee Chair Eileen Palfrey.

Ohio EPA's approval of the WWMP is a significant milestone for the city's water and sewer systems. The City's WWMP is the largest infrastructure project in the city's history since 2000 and 2001. The City's WWMP is the largest infrastructure project in the city's history since 2000 and 2001.

"This historic approval is the result of the City's hard work and leadership," said Mayor Costner. "We must continue to invest in our infrastructure to ensure the city's future and the health of our waterways. We must stay vigilant to do it all we can to keep our city and sewer lines affordable."

© 2005 The City of Columbus. All rights reserved. The City of Columbus has provided a summary of the project to the public. For more information, please contact the City of Columbus at (614) 462-1000.

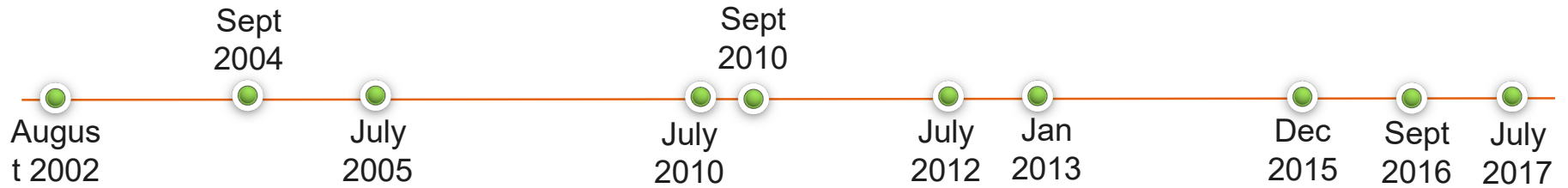
# WWTP Improvement



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

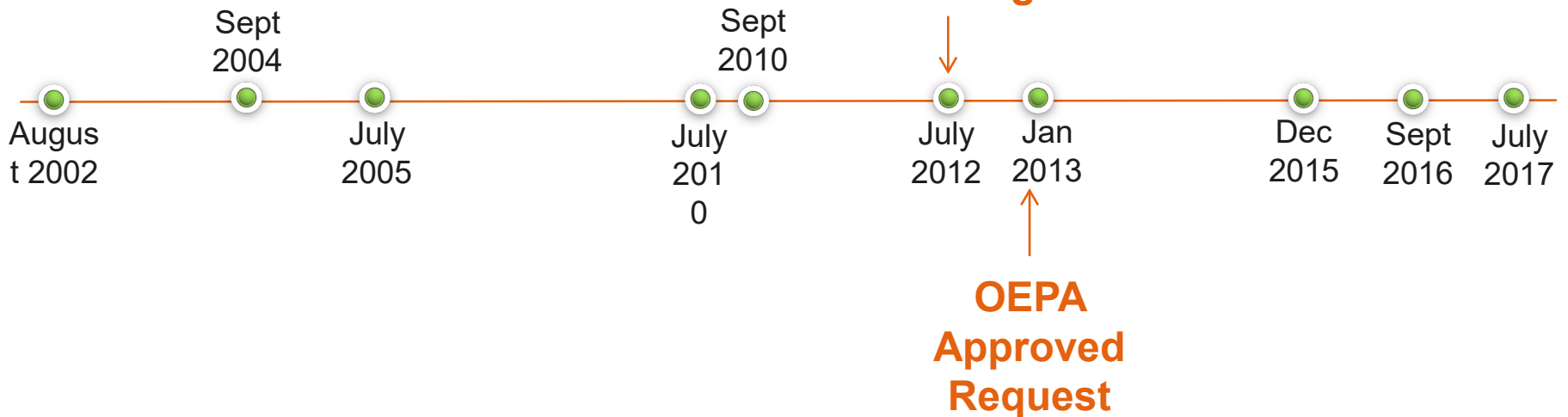
# OARS Construction

**OARS  
Construction  
Begins**



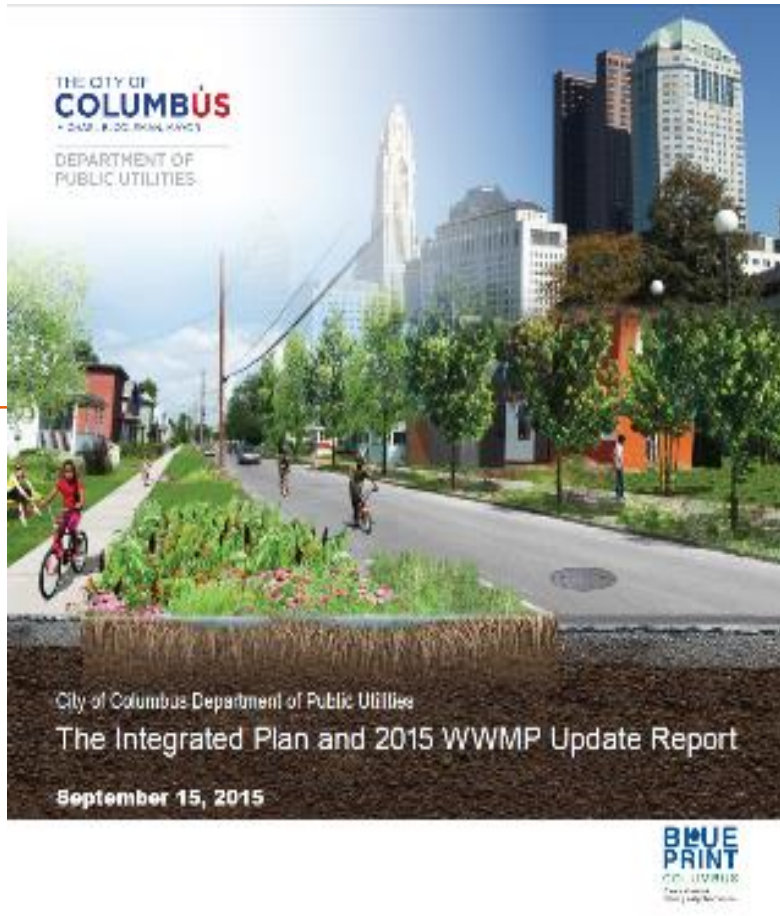


# WWMP Update to Integrated Plan

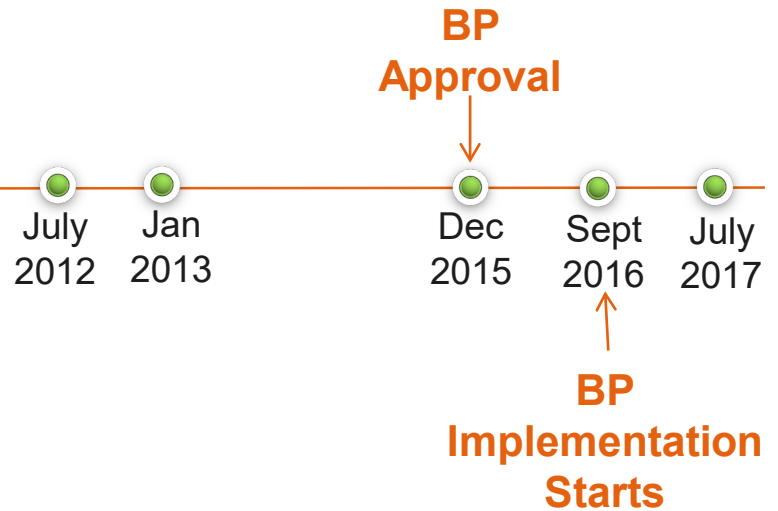


# Blueprint Columbus

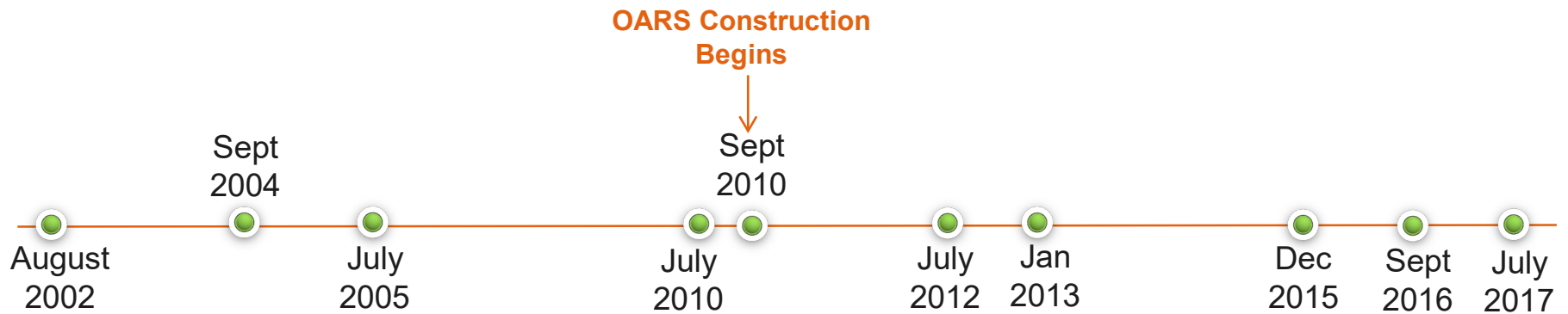
August 2002



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



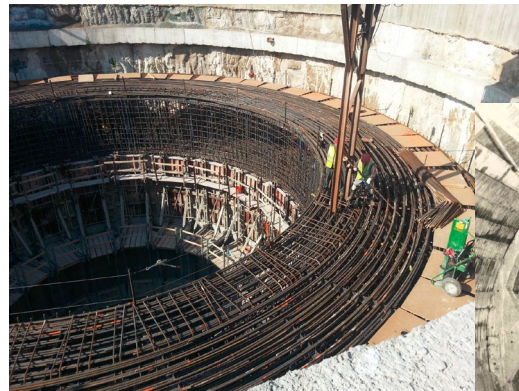
# OARS in Service - 2017



**OARS Construction Begins**

Sept 2010

**OARS Construction Completed**



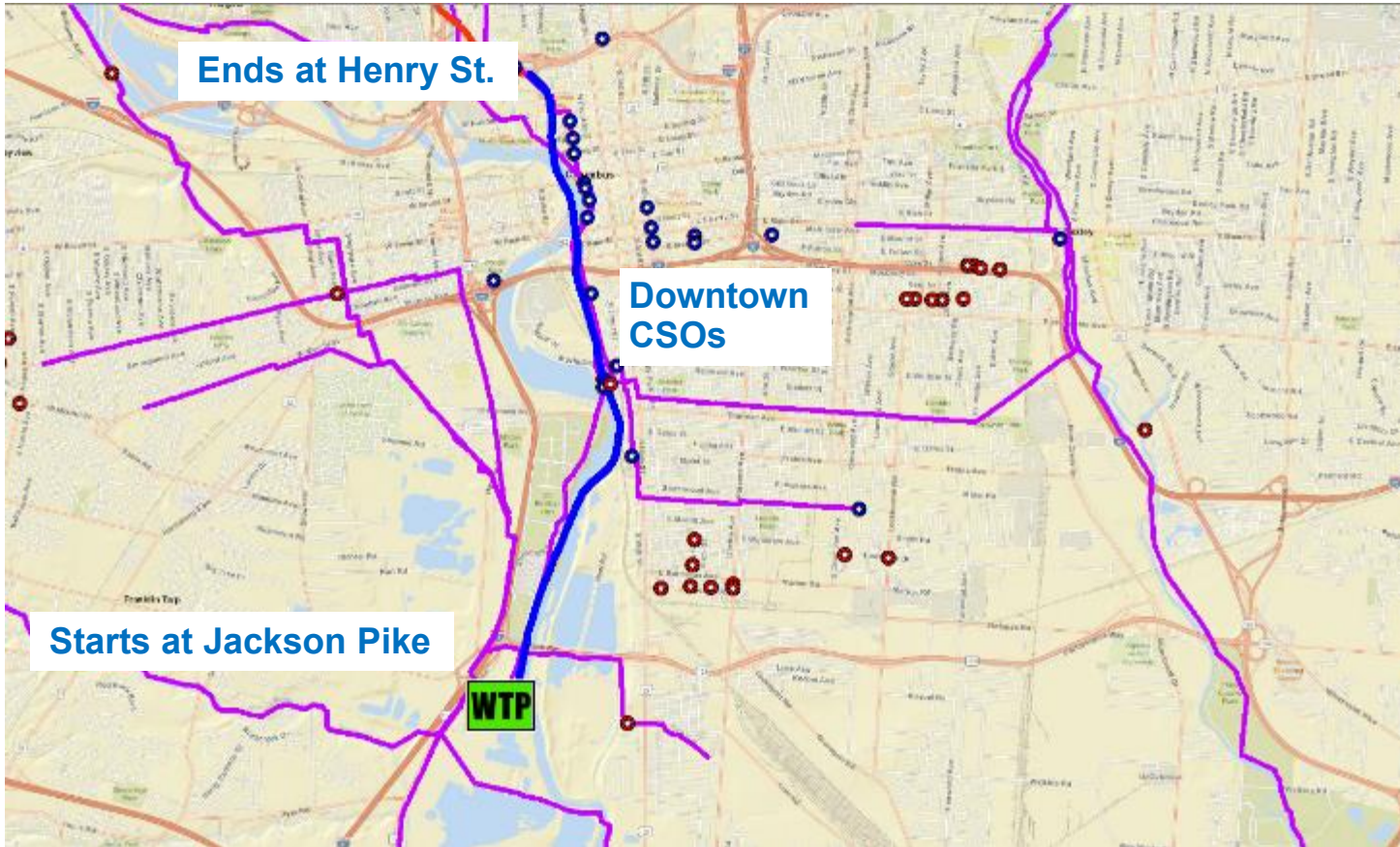
OARS Tunnel Shaft



# Agenda

- Columbus Collection System
- **OARS Tunnel**
- Collection System Operation
- Conclusion and Next Steps

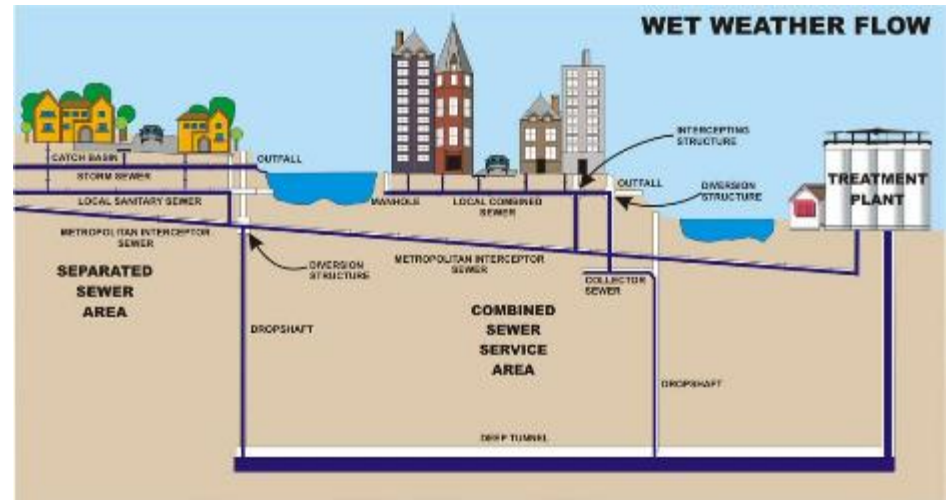
# OARS Extent



# 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

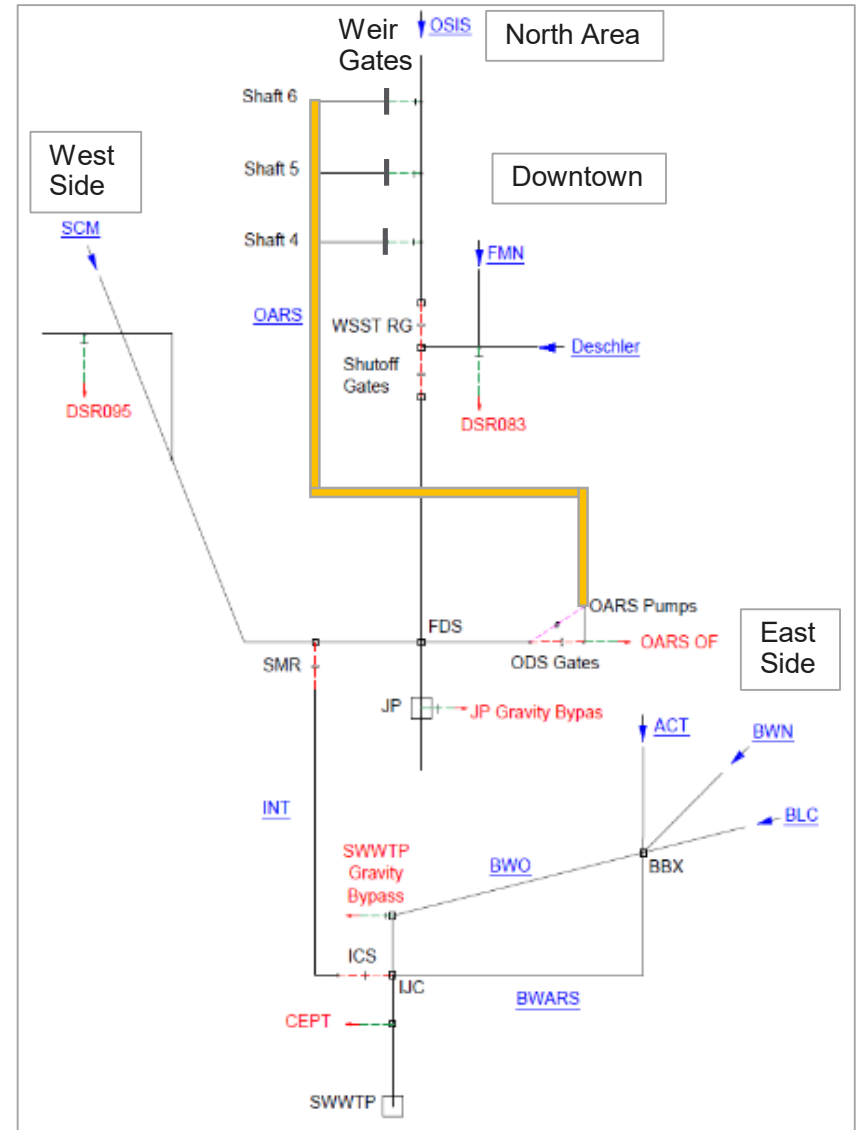
- If treatment capacity is available, tunnel can also work as a siphon to convey flow back to the system during large events



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

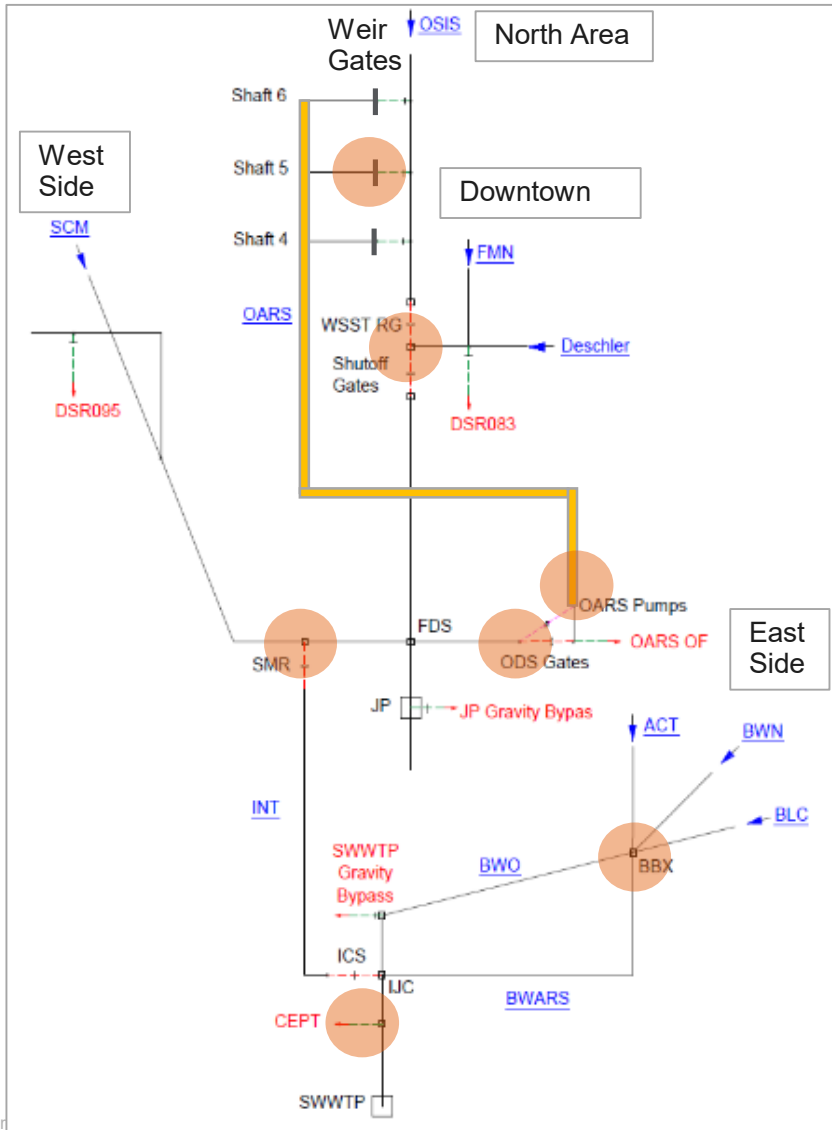


# Agenda

- 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

Control Structures /Monitoring Points	WSST Reg Gates	SMR Weir	ODS Gate	OARS Pumps	FDS Gate
Purpose	Protect OSIS MHs at Berliner, avoid SSO at DSR083 and avoid bypass at Southerly	Maintain JP wet well at 14' after FDS reaches 689 or IJC reaches 671	Control OARS flow to avoid bypass at JP and Southerly and avoid flow backup into OARS	Dewater OARS during and after the storm	Avoid bypass at JP
Default Setting	Open	Setting = 1	Closed	Off	Closed
IJC Head	Close WSST Gates if IJC Head >= 678; If IJC Head is between 673.5 and 678, modulate to maintain DSR 083 Head at 696; If IJC Head is between 669.5 and 673.5, modulate to maintain DSR 083 Head at 700; If IJC Head < 669.5, modulate to maintain DSR 083 Head at 702	If IJC Head >= 671, maintain FDS Head at 691.5	Close ODS gates if IJC Head >= 678	Turn Pumps off when IJC Head > 678 Turn Pumps on when IJC Head <= 677.5	
DSR 083 Head					
FDS Head		If FDS Head >= 689, maintain FDS Head at 691.5	Close ODS gates if FDS Head >= 693.3	Turn Pumps off when FDS Head > 693.3 Turn Pumps on when FDS Head <= 692	One FDS gate 50% open if FDS Head >= 694.3 <b>Priority 1</b>
ODS Head			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 533.6 and 692.5	Open one FDS gate 5% if ODS Head > 580, and IJC Head < 678

←  
Five  
Control  
Structures

↑  
Four  
Monitoring  
Locations

# System Performance Metric Sheet

20 Year Model Simulation

Number of Overflow Activations  
 Overflow Volume  
 Overflow Duration

Category	Overall Summary				OARS/WWTP/ACST				Mainline SSOs				Downtown CSOs				Olentangy CSOs				CSOs Manholes																																
	Total SSO (MG)	Total CSO (MG)	Total Bypass (MG)	Total System Overflow (MG)	QARS OF	WEST WWRQ OF	WEST Emergency/Canals	ACST	SWWTP Mech Bypass	SWWTP Gravity Bypass	SWWTP Gravity Bypass	CPPT	SSR 003 Discharge	SSR 005 West Side Sanitary	SSR 009 Mobility	SSR 013 Francisco Telebridge	SSR 204 FMM Recount Dr	SSR 115 FMM North of Hill Ave	SSR 204 (L) Longview Arches	SSR 202 Credit Rd PS	SSR 222 Williams Rd PS	Markham	Dejeu Park	Town	State	Capital	Broad	Lang	Spring	Chastnut	Leary	West	Trial	King	Irishola	Franklin	One Albery	Madison	Wood/Grant	Mobile/Garrett	Town/Fairfax	McVey/FB	Cherry/Leath	Mobile/Fourth	Wood #73	Henry/Laurel							
Level of Service	N/A	N/A	N/A	N/A	4/TY	TY	TY	TY	10Y	10Y	10Y	N/A	10Y	10Y	10Y	10Y	10Y	10Y	10Y	10Y	10Y	TY	TY	10Y	10Y	10Y	10Y	10Y	10Y	TY	TY	TY	TY	TY	TY	TY	TY	TY	TY	TY	TY	TY	TY	TY	TY	TY	TY						
20Y Total Overflow Volume (MG)					3909	8.80	4.90	46.7					507	3065	1.34				0.93			9.47	2.85																														
20Y Total Overflow Duration (hrs)					441	124	83	34					121	714	6.75				6.26			6.5	6.75																														
20Y Total Number of Activations					37	5	3	16					9	50	2				2			9	7																														

## SSOs

Category	Mainline SSOs - Flow by Structure												Mainline SSOs - Station Volume												Mainline SSOs - Station Volume												Mainline SSOs - Station Volume												Mainline SSOs - Station Volume												Mainline SSOs - Station Volume											
	SSR 003	SSR 005	SSR 009	SSR 013	SSR 204	SSR 115	SSR 204 (L)	SSR 202	SSR 222	Markham	Dejeu Park	Town	State	Capital	Broad	Lang	Spring	Chastnut	Leary	West	Trial	King	Irishola	Franklin	One Albery	Madison	Wood/Grant	Mobile/Garrett	Town/Fairfax	McVey/FB	Cherry/Leath	Mobile/Fourth	Wood #73	Henry/Laurel																																						
Level of Service	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y	30Y																						
20Y Total Overflow Volume (MG)	0.04																																																																							
20Y Total Overflow Duration (Hrs)	1.75																																																																							
20Y Total Number of Activations	2																																																																							
20Y LOS (in years)	37.5																																																																							
20Y LOS Target Volume (MG)	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar																	
20Y LOS Target Peak Flow (MGD)	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar	Mar															

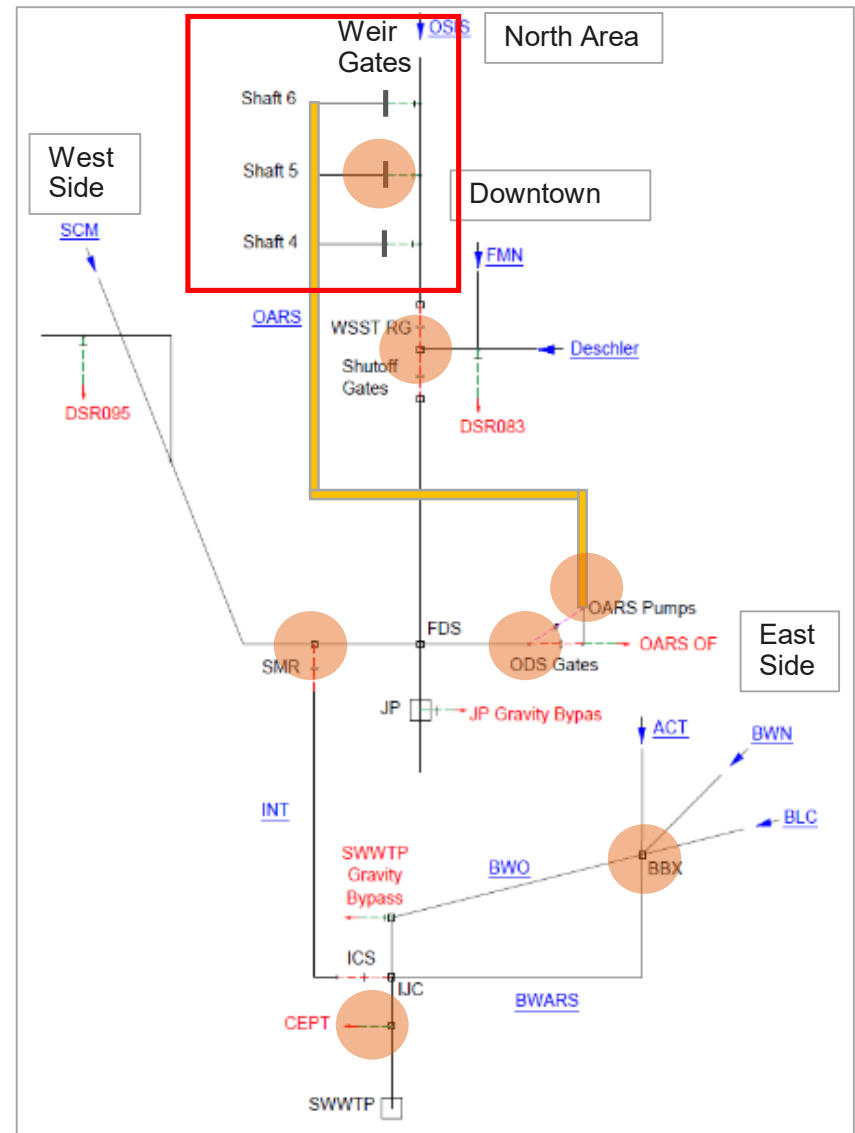
# Agenda

- Columbus Collection System
- OARS Tunnel
- **Collection System Operation**
  - Operation Controls
  - **OARS Weir Gates RTC**
  - 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)

OARS Fill / Dewater (MG)	OSIS-S6	OSIS-S5	OSIS-S4	Total Inflow	OARS Pumps
Static Setting	95	73	600	768	555
RTC	90	438	212	750	524

Overflow/CEPT (MG)	OARS OF	SWWTP Bypass	CEPT
Static Setting	206	43	245
RTC	204	41	245

Activation Frequency	OARS OF	SWWTP Bypass	CEPT
Static Setting	2.20	1.60	4.10
RTC	2.15	1.55	4.15

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

# Agenda

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

# 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)

Operation Mode	OARS Overflow (MG)	Gravity Bypass (MG)	CEPT (MG)
Storage	317	26	98
Conveyance	292	26	104

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

Activation Frequency	# OARS Overflow	Gravity Bypass	CEPT
Storage	3.2	1	3
Conveyance	3	1	4

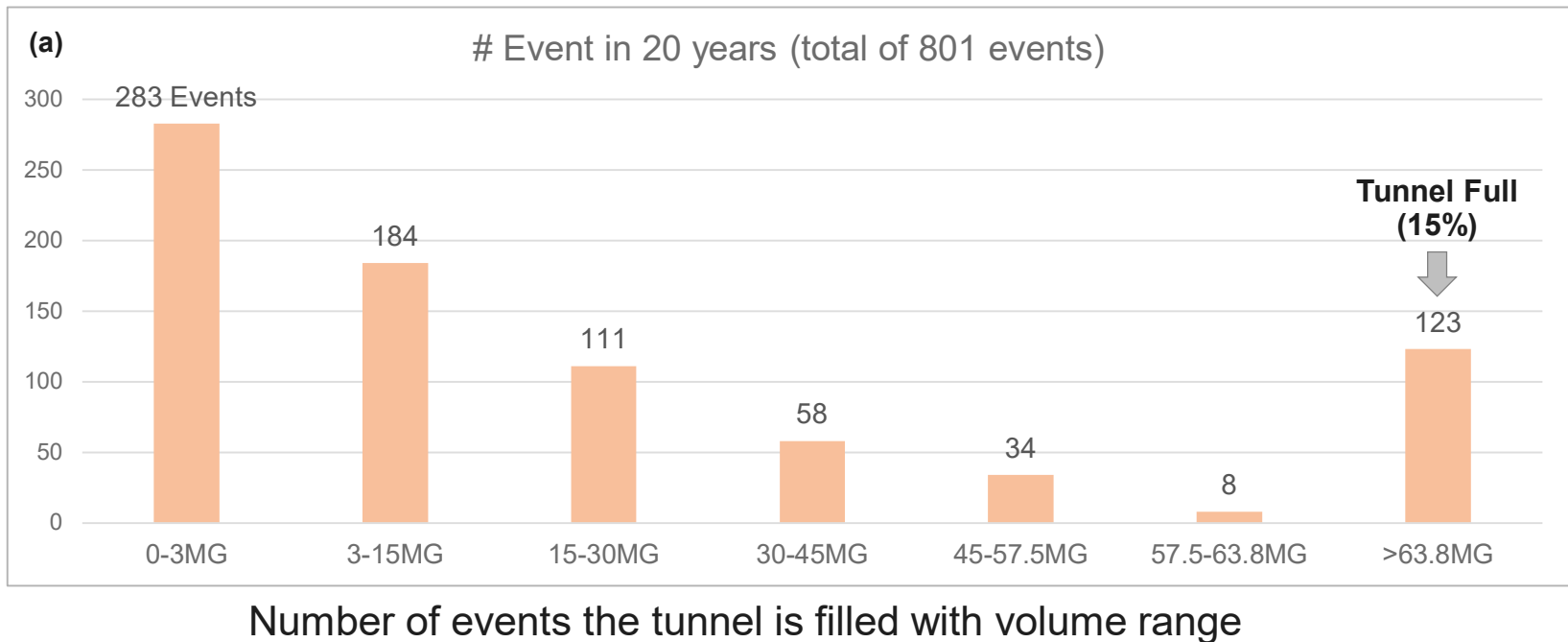
# OARS Tunnel Operation Improvement

Can we use rainfall forecast to switch between operation modes?

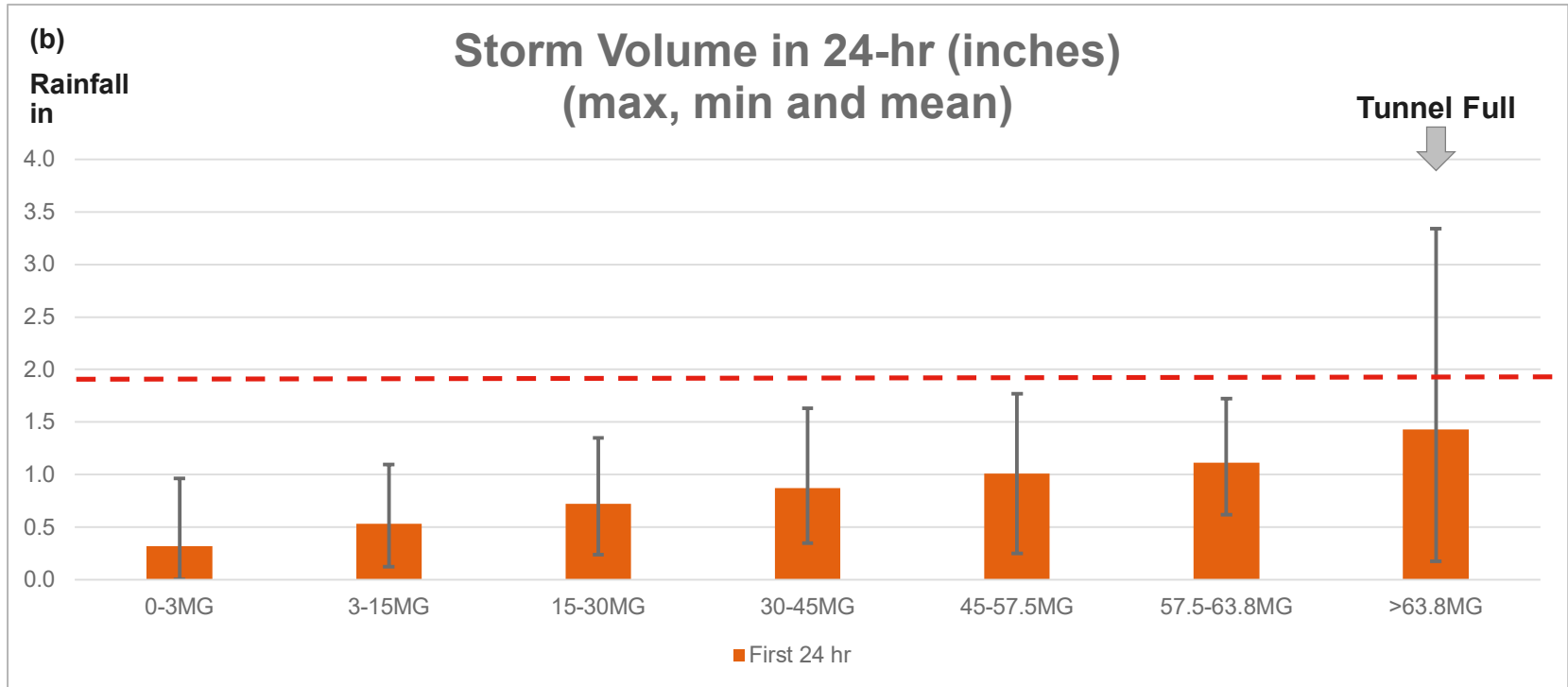
- Is there a storm threshold above which OARS is expected to overflow?
- What is the condition during the back-to-back storms?
- What are the pros and cons for different OARS dewatering strategies?

# 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)



# Storm range Filling OARS



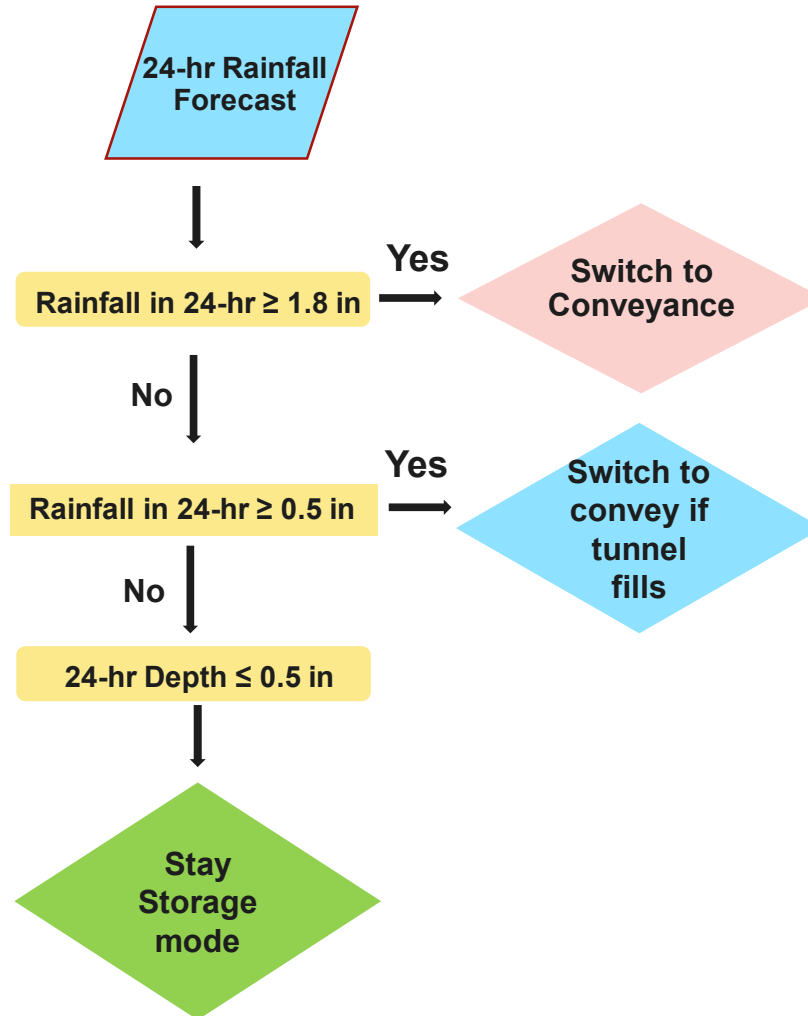
- Tunnel fills when rainfall > 1.8 inches in 24 hours (31 events in 20 years)
- Of the remaining 770 events, tunnel was filled 93 times (12%)

# Storms Causing OARS Overflow

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

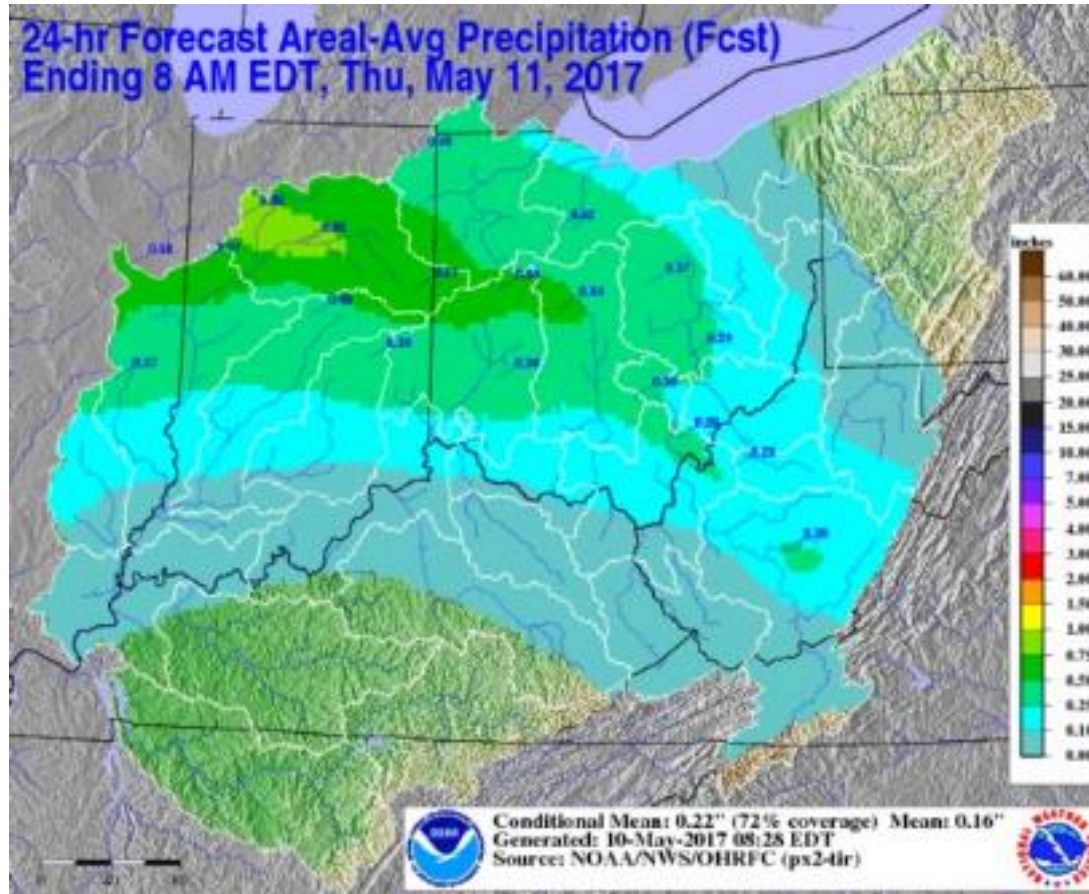
24-hr Rainfall	# OARS Filling	# OARS Overflow	
≥1.8 in	31	29	Use conveyance mode
0.5 - 1.8 in	87	31	If OARS fills, switch to conveyance
<0.5 in	5	0	Stay storage mode

# Operation Based on Real-Time Rainfall Forecast



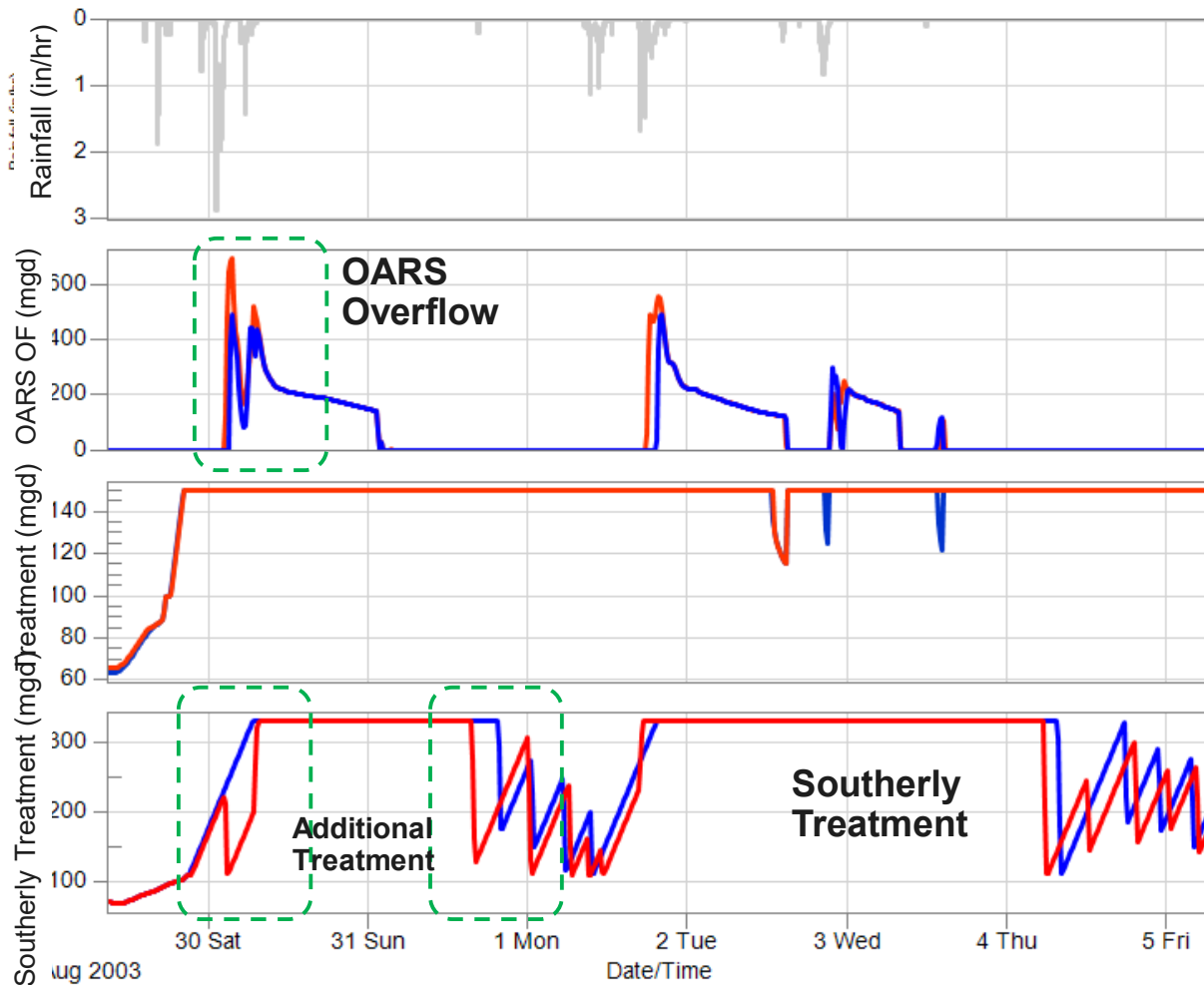
# Rainfall Forecast Source

National Weather Service Ohio River Forecast Center



# Example of Improvements

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



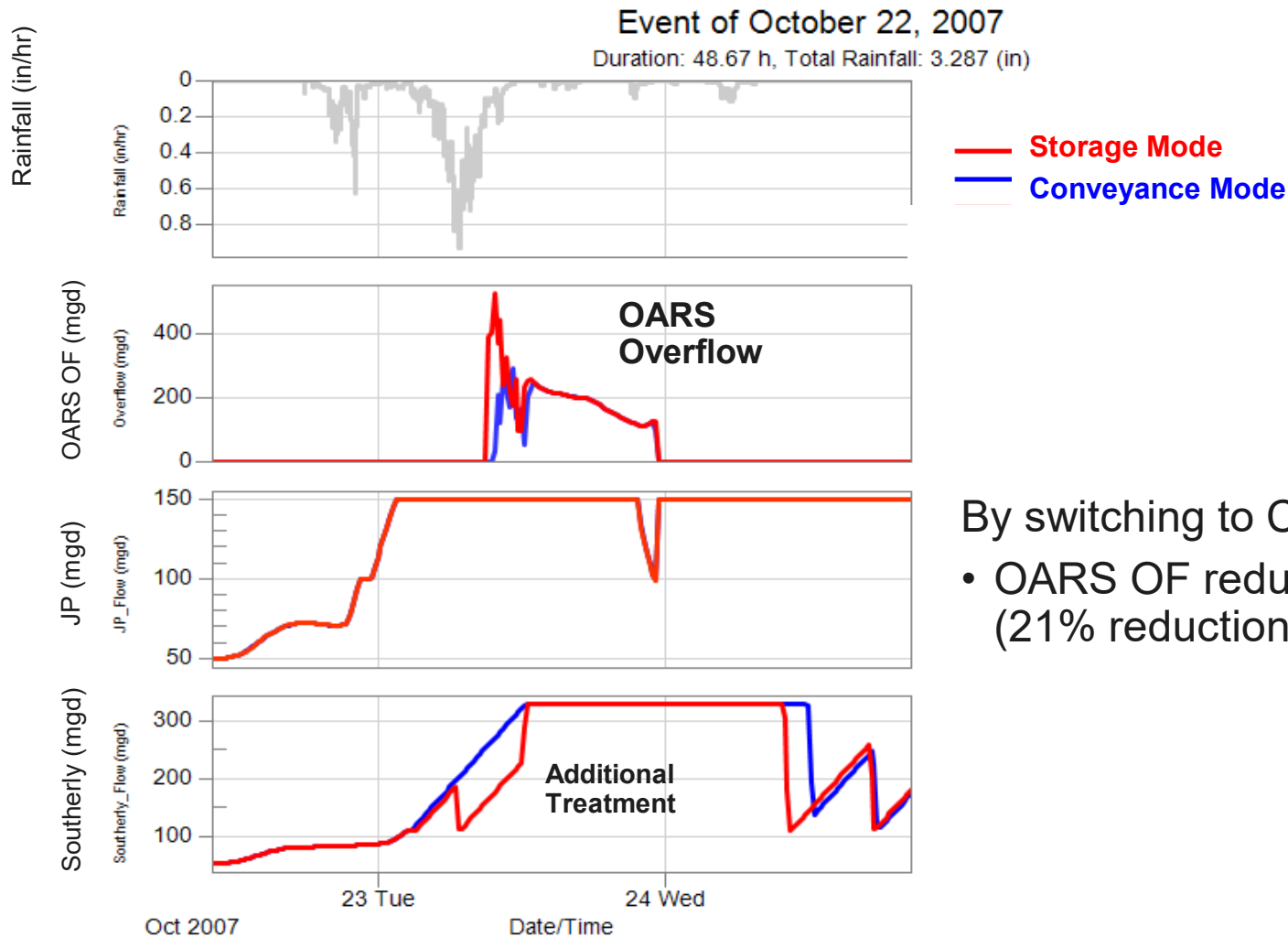
— Storage Mode  
— Improved Mode

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

Operation Mode	Pros	Cons
Storage	<ul style="list-style-type: none"> <li>• Easy Operation Plan</li> <li>• Less Stress on WWTPs</li> </ul>	<ul style="list-style-type: none"> <li>• Under usage of available treatment at start if events</li> <li>• Large overflow volume could have been reduced</li> </ul>
Conveyance (no rainfall forecast)	<ul style="list-style-type: none"> <li>• Keep tunnel storage available for the high peak period of the runoff</li> </ul>	<ul style="list-style-type: none"> <li>• Stressing the WWTPs</li> <li>• Increased potential for bypass</li> </ul>
Conveyance with Rainfall Forecast	<ul style="list-style-type: none"> <li>• Avoid stressing the WWTPs as possible</li> <li>• Allows time for operators to prepare for high flow conditions</li> </ul>	<ul style="list-style-type: none"> <li>• Change operation mode during the storm</li> <li>• Potential need to accelerate dewatering to avoid back-to-back storms condition</li> </ul>

# Next Steps: Summer vs Winter Storms

## Summer Storms

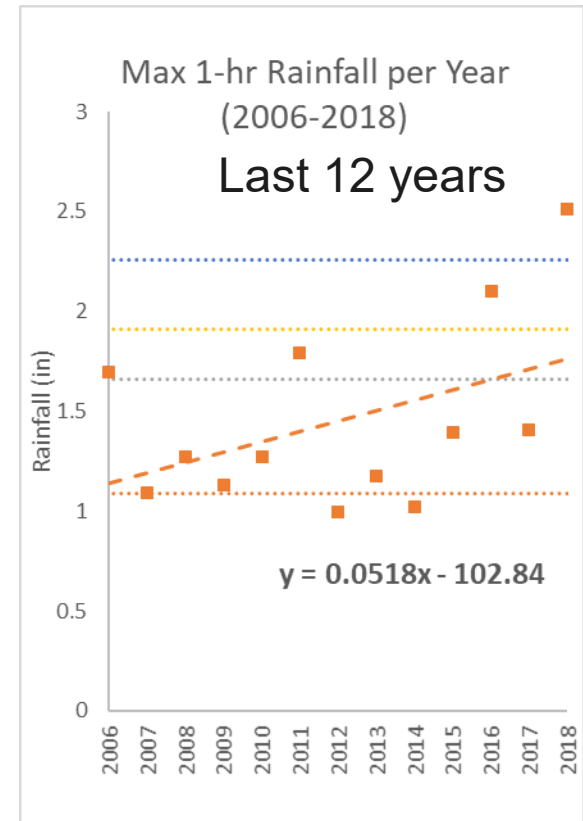
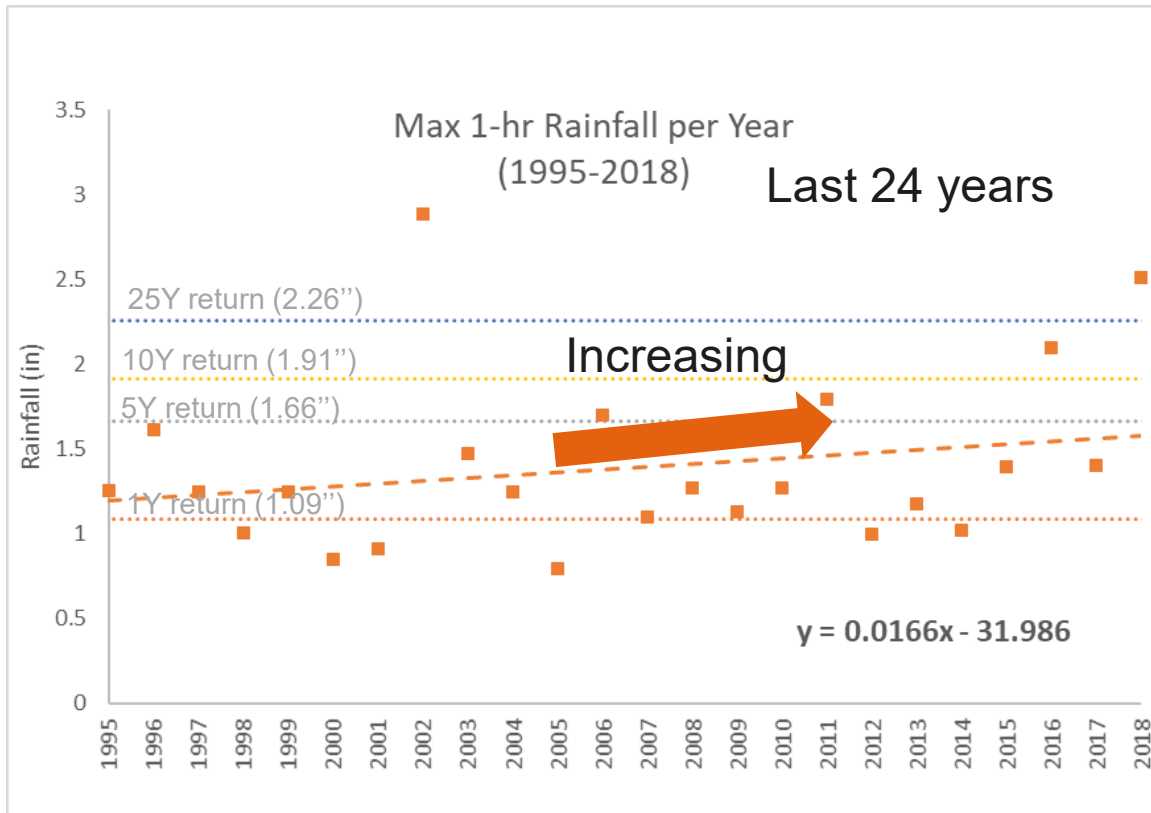
- Sharp peak intensities
- Isolated specially distribution cells

## Winter Storms

- Low intensity, large volume
- Extends over the entire City

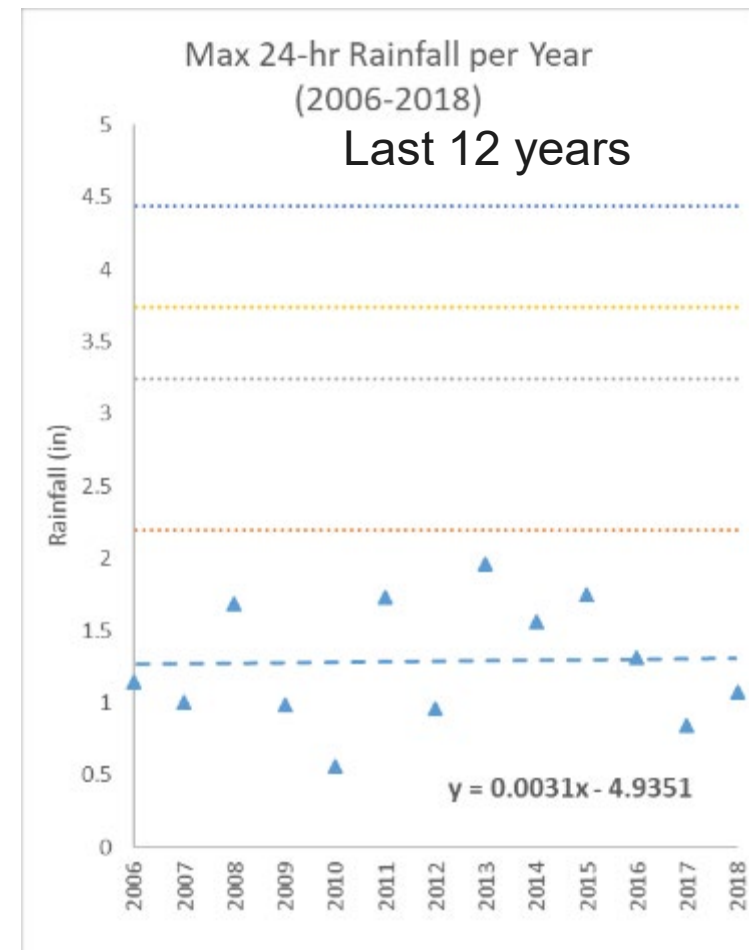
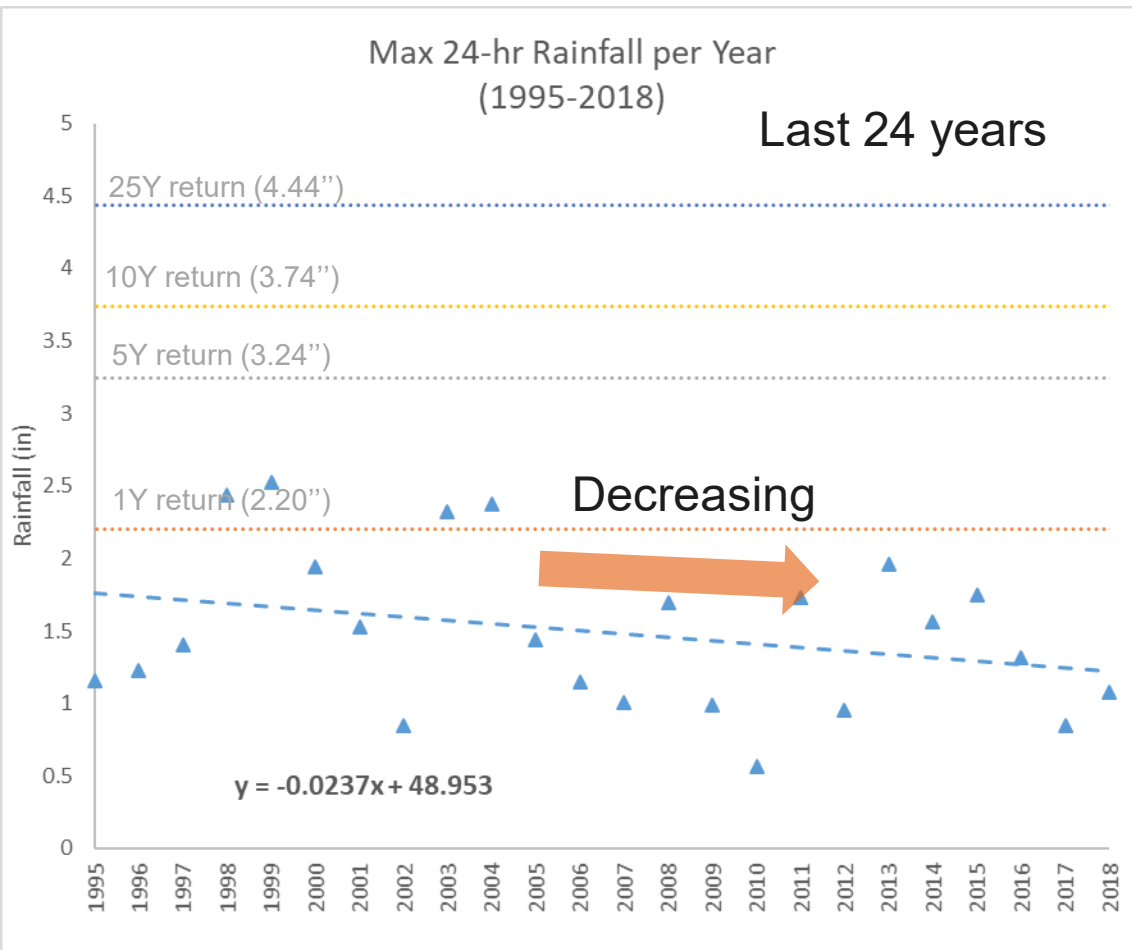
# Next Steps: Summer vs Winter Storms

## Summer (June-Sept) Rainfall Trend



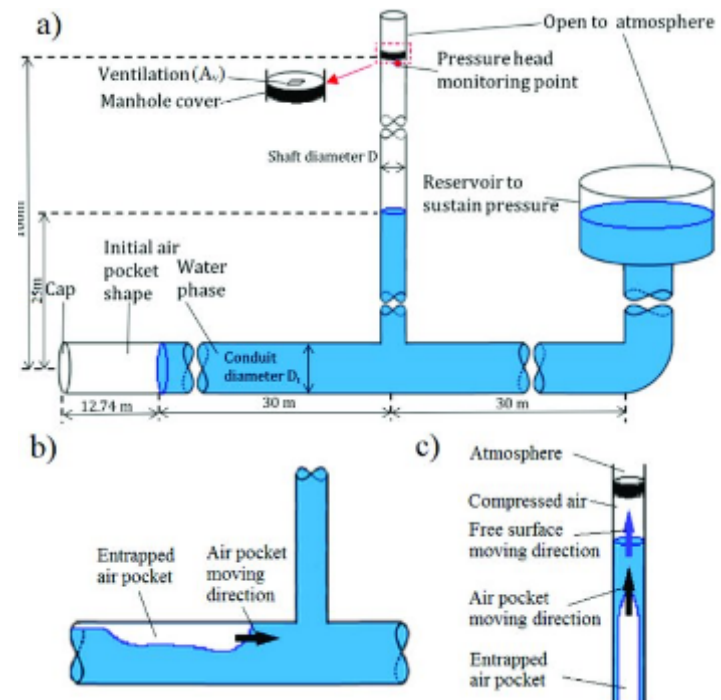
# Next Steps: Summer vs Winter Storms

## Winter (Dec-Jan) Rainfall Trend



# 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



Wang, J., and Vasconcelos, J., 2018, Manhole Cover Displacement Caused by the Release of Entrapped Air Pockets. *Journal of Water Management Modeling*, DOI: 10.14796/JWMM.C444

# 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



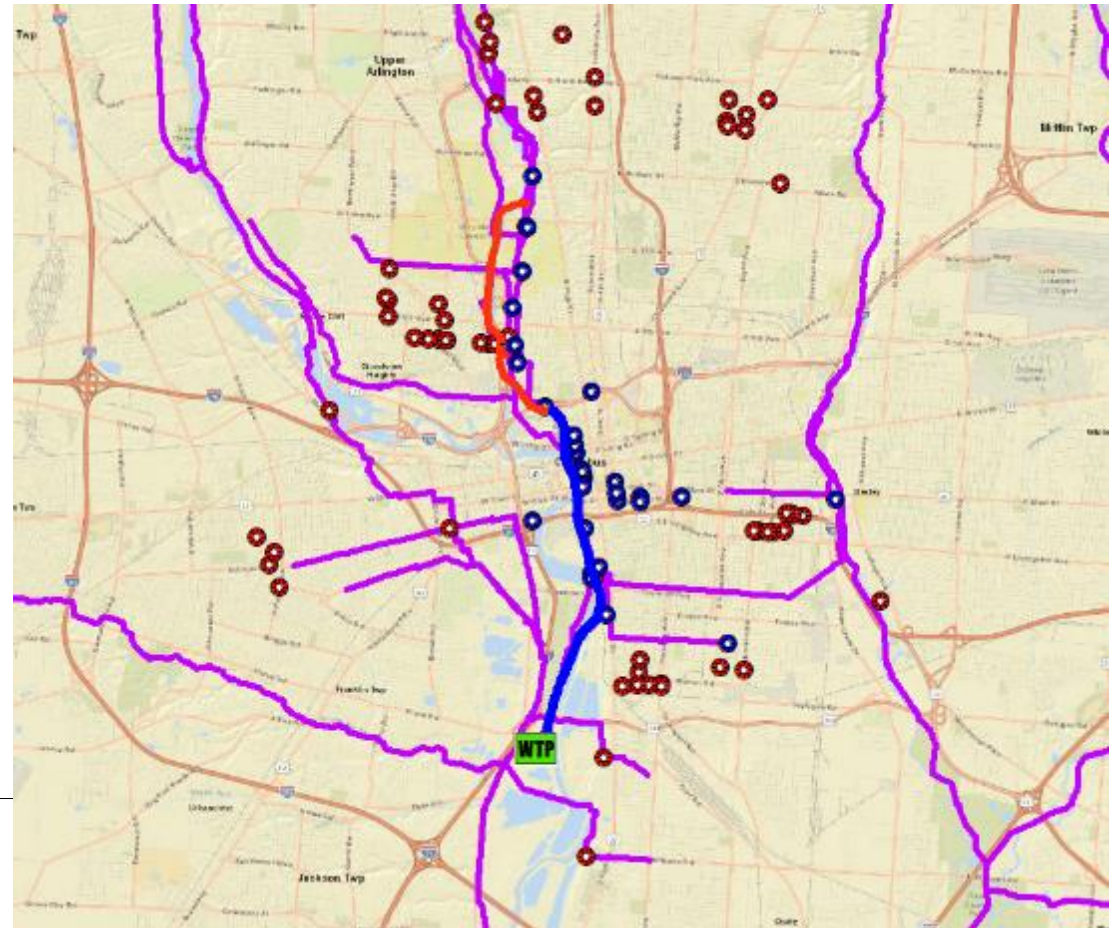


# Next Steps: Lower Olentangy Tunnel

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

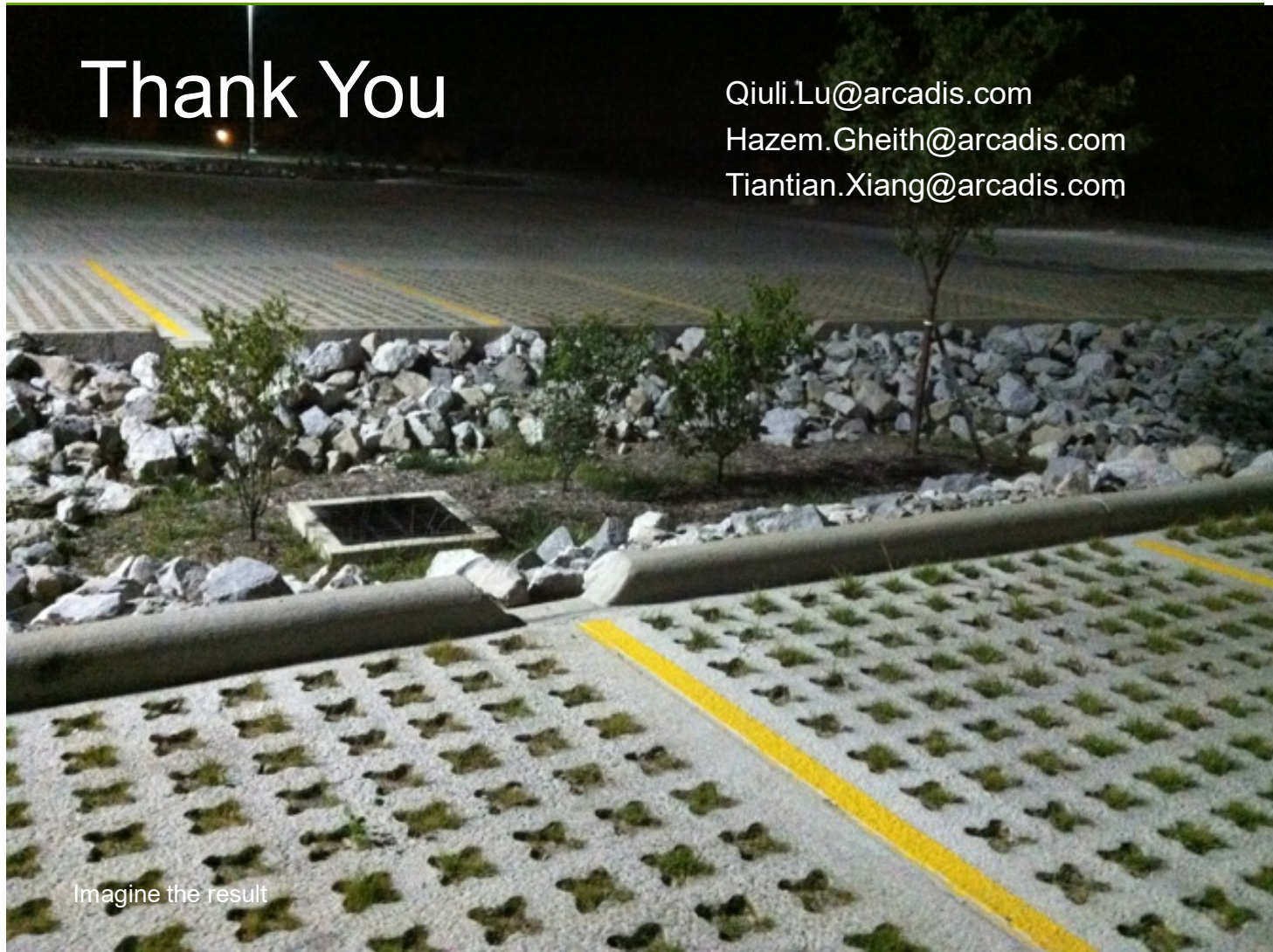
LOT will be connected to OARS through a sluice gate and drop shaft

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



# Thank You

Qiuli.Lu@arcadis.com  
Hazem.Gheith@arcadis.com  
Tiantian.Xiang@arcadis.com



Imagine the result