Metropolitan Water Reclamation District of Greater Chicago

Welcome to the December Edition of the 2025 M&R Seminar Series

NOTES FOR SEMINAR ATTENDEES

- Remote attendees' microphones are muted at entry to minimize background noise.
  For attendees in the auditorium, please silence your phones.
- A question and answer (Q/A) session will follow the presentation.
- For remote attendees, please use "**Chat**" only to type questions for the presenter. For other issues, please send emails to MnRseminars@mwrd.org.
  For attendees in the auditorium, please raise your hand and wait for the microphone to ask a verbal question during the Q/A session.
- The presentation slides will be posted on the MWRD website after the seminar.
- This seminar has been approved by the Engineering Society of Illinois (ESI) for one PDH and approved by the IEPA for one TCH. Certificates will be issued only to participants who attend the entire presentation. For PDH certificate seekers, **completing a brief course evaluation and submitting it are required**.

Weizhe (William) An, Ph.D., P.E.
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Dr. William An is a professional engineer who focuses on odor management, wastewater treatment, watershed hydrology/ hydraulics modeling, and Geographical Information System (GIS) application in the water and wastewater industry. Dr. An obtained his Bachelor of Engineering and Master of Science from Tianjin University, China. He obtained his Ph.D. degree in Civil and Environmental Engineering from the University of Pittsburgh, Pennsylvania. Dr. An has been a research scientist in the District since 2014. Before joining the District, he worked at CDM Smith Inc., KLH Engineering, Inc., and MWH Global Inc for many years. Besides working and studying, Dr. An and his family enjoy sports, traveling, and reading.

Metropolitan Water Reclamation District of Greater Chicago

Sewer Modeling for South Park Interceptor to the Calumet WRP

William An
M&R Department
December 12, 2025

OVERVIEW

1. Background and Objectives
2. Sewer Process Model Components
3. Model Development and Data Collection
4. Model Calibration and Validation
5. Sensitivity Analysis
6. Scenario Analysis
7. Summary and Conclusion
8. Acknowledgement

Background and Objectives

- **A model is a simplified representation of something in the real world.**
- **Models help us understand, explain, or predict how the real world works. We should use model's benefits but always be aware of model's limitation.**
- **All models are wrong, but some are useful.**

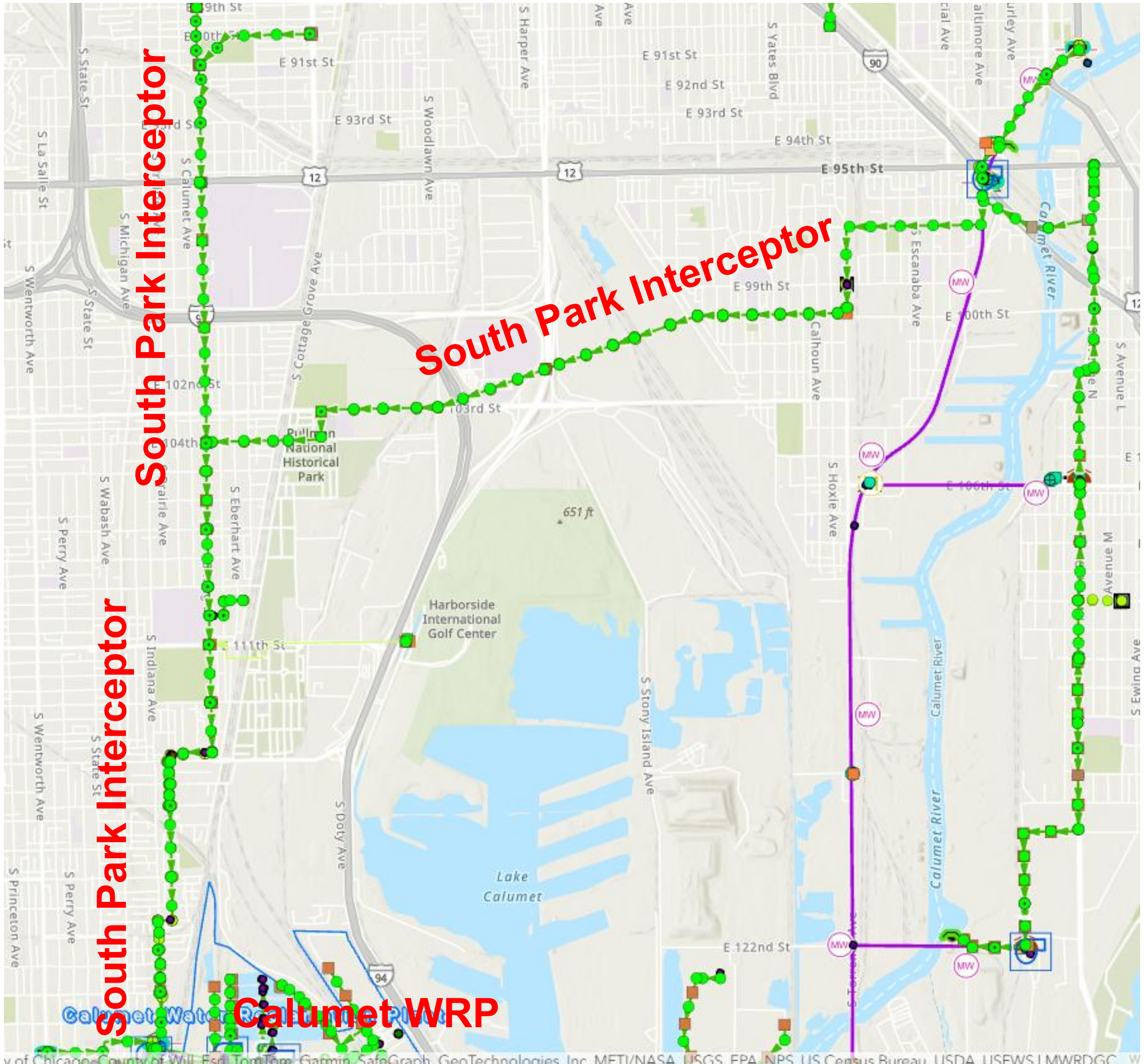
---- George Box (British statistician)

Background and Objectives

- Calumet WRP serves 305.4 square miles and 1.006 millions population in Cook County. The service area has 183.86 miles of interceptors.
- South Park is one of the four sewersheds and interceptors contributing to Calumet WRP. South Park area covers 42 square miles, 16 miles of interceptors, about 285,000 population.
- South Park is “famous” for its industrial waste and odors.

Background and Objectives

Calumet WRP and South Park interceptor



Objectives

- **Develop and calibrate a sewer process model for the studied area.**
- **Simulate H_2S and corrosion conditions in the studied area.**
- **Evaluate control strategies to mitigate H_2S and corrosion.**

Sewer Process Model Components

A Sewer Process Model simulates biological and chemical processes in sewer networks. It predicts how wastewater constituents are transformed and degraded as the wastewater flows. We used the software, Mega-WATS.

Main (not all) Components

Physical Networks	Hydraulics	Biological and Chemical Reactions	Air Flows

Physical Networks

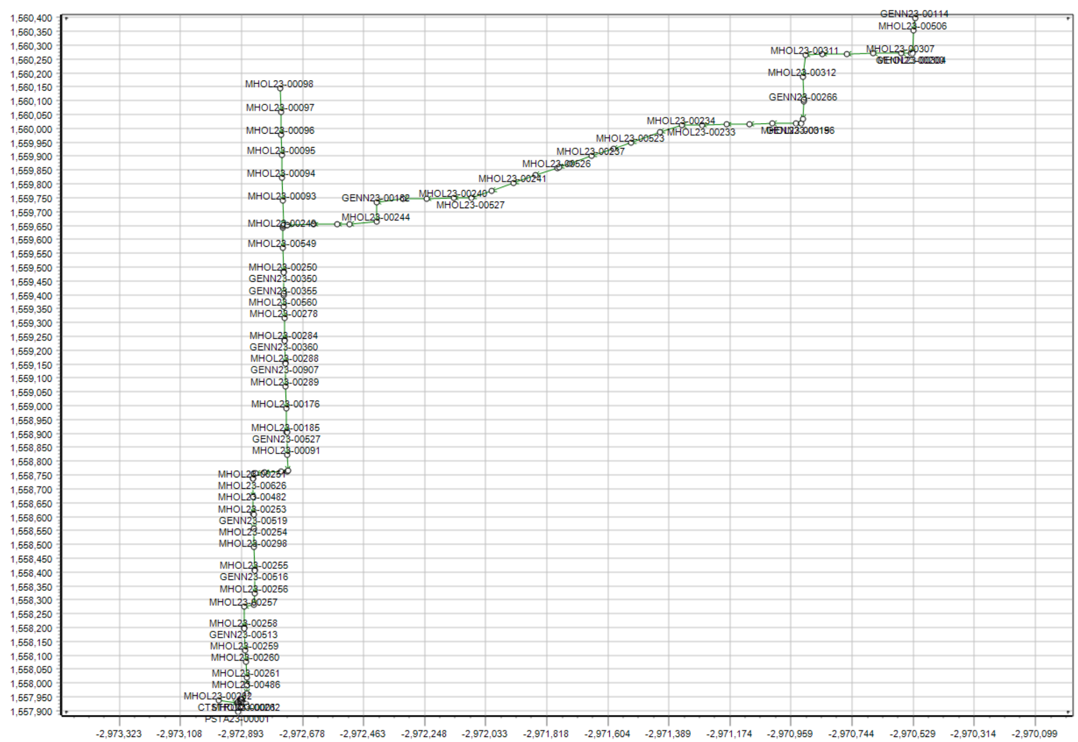
The networks include pipes, manholes, weirs, orifices, storages, etc. with right shapes, dimensions, and elevations.

They are the backbone of the process model.

Physical Networks

asset_id	us_node_id	ds_node_id	link_type	conduit_material	conduit_shape	conduit_width	conduit_height	roughness	conduit_gradient	conduit_length	us_invert_z	ds_invert_z	us_node_x	us_node_y	ds_node_x	ds_node_y
Units:						in	in	Manning n	%	ft	ft	ft	ft	ft	ft	ft
PIPE23-00831	GENN23-00114	MHOL23-00506	gravity	RCP	Arch	132	105.6	0.014	0.00038779	386.81	-7.35	-7.5	-9745807.915	5119415.851	-9745827.357	5119273.569
PIPE23-00835	MHOL23-00506	MHOL23-00304	gravity	RCP	Arch	132	105.6	0.014	0.00040666	688.53	-7.5	-7.78	-9745827.357	5119273.569	-9745839.072	5119004.052
PIPE23-00685	MHOL23-00304	GENN23-00200	gravity	RCP	Arch	132	105.6	0.014	0.00000000	40	-7.78	-7.78	-9745839.072	5119004.052	-9745855.391	5119002.173
PIPE23-00527	GENN23-00200	MHOL23-00307	gravity	RCP	Arch	132	105.6	0.014	0.00038685	284.35	-7.78	-7.89	-9745855.391	5119002.173	-9745971.291	5119001.775
PIPE23-00521	MHOL23-00307	MHOL23-00308	gravity	RCP	Arch	132	105.6	0.014	0.00041001	780.46	-7.89	-8.21	-9745971.291	5119001.775	-9746289.513	5118996.718
PIPE23-00526	MHOL23-00308	MHOL23-00309	gravity	RCP	Arch	132	105.6	0.014	0.00039936	751.2	-8.21	-8.51	-9746289.513	5118996.718	-9746595.752	5118991.606
PIPE23-00522	MHOL23-00309	MHOL23-00310	gravity	RCP	Arch	132	105.6	0.014	0.00039331	686.48	-8.51	-8.78	-9746595.752	5118991.606	-9746875.589	5118986.928
PIPE23-00523	MHOL23-00310	MHOL23-00311	gravity	RCP	Arch	132	105.6	0.014	0.00039240	484.2	-8.78	-8.97	-9746875.589	5118986.928	-9747072.983	5118983.712
PIPE23-00714	MHOL23-00311	MHOL23-00312	gravity	RCP	Arch	132	105.6	0.014	0.00040596	689.73	-8.97	-9.25	-9747072.983	5118983.712	-9747102.964	5118723.596
PIPE23-00525	MHOL23-00312	GENN23-00202	gravity	RCP	Arch	132	105.6	0.014	0.00037986	658.13	-9.25	-9.5	-9747102.964	5118723.596	-9747094.128	5118454.375
PIPE23-00807	GENN23-00202	GENN23-00266	gravity	RCP	Arch	156	124.8	0.014	0.03975265	45.28	-9.5	-11.3	-9747094.128	5118454.375	-9747096.106	5118433.854
PIPE23-00113	GENN23-00266	MHOL23-00522	gravity	RCP	Arch	156	124.8	0.014	0.00019307	517.95	-11.3	-11.4	-9747096.106	5118433.854	-9747097.952	5118221.853
PIPE23-00720	MHOL23-00522	GENN23-00196	gravity	RCP	Arch	156	124.8	0.014	0.00019724	152.1	-11.4	-11.43	-9747097.952	5118221.853	-9747120.934	5118173.628
PIPE23-00817	GENN23-00196	MHOL23-00315	gravity	RCP	Arch	156	124.8	0.014	0.00025651	155.94	-11.43	-11.47	-9747120.934	5118173.628	-9747184.533	5118174.587
PIPE23-00725	MHOL23-00315	MHOL23-00316	gravity	RCP	Arch	156	124.8	0.014	0.00003033	659.48	-11.47	-11.49	-9747184.533	5118174.587	-9747453.358	5118169.687
PIPE23-00742	MHOL23-00316	MHOL23-00231	gravity	RCP	Arch	156	124.8	0.014	0.00019757	658	-11.49	-11.62	-9747453.358	5118169.687	-9747721.577	5118164.698
PIPE23-00746	MHOL23-00231	MHOL23-00232	gravity	RCP	Arch	156	124.8	0.014	0.00020287	640.81	-11.62	-11.75	-9747721.577	5118164.698	-9747982.788	5118159.749
PIPE23-00750	MHOL23-00232	MHOL23-00233	gravity	RCP	Arch	156	124.8	0.014	0.00020416	685.72	-11.75	-11.89	-9747982.788	5118159.749	-9748262.308	5118154.569
PIPE23-00753	MHOL23-00233	MHOL23-00234	gravity	RCP	Arch	156	124.8	0.014	0.00020794	577.09	-11.89	-12.01	-9748262.308	5118154.569	-9748497.687	5118149.199
PIPE23-00754	MHOL23-00234	MHOL23-00521	gravity	RCP	Arch	156	124.8	0.014	0.00019664	661.09	-12.01	-12.14	-9748497.687	5118149.199	-9748753.97	5118064.526
PIPE23-00752	MHOL23-00521	MHOL23-00523	gravity	RCP	Arch	156	124.8	0.014	0.00019536	870.17	-12.14	-12.31	-9748753.97	5118064.526	-9749087.574	5117943.589
PIPE23-00751	MHOL23-00523	MHOL23-00235	gravity	RCP	Arch	156	124.8	0.014	0.00020919	525.84	-12.31	-12.42	-9749087.574	5117943.589	-9749290.556	5117874.294
PIPE23-00758	MHOL23-00235	MHOL23-00237	gravity	RCP	Arch	156	124.8	0.014	0.00019705	659.73	-12.42	-12.55	-9749290.556	5117874.294	-9749544.234	5117784.581
PIPE23-00760	MHOL23-00237	MHOL23-00236	gravity	RCP	Arch	156	124.8	0.014	0.00019745	658.38	-12.55	-12.68	-9749544.234	5117784.581	-9749797.431	5117694.92
PIPE23-00759	MHOL23-00236	INTC23-00153	gravity	RCP	Arch	156	124.8	0.014	0.00065867	440.28	-12.68	-12.97	-9749797.431	5117694.92	-9749919.477	5117648.652
PIPE23-00802	INTC23-00153	MHOL23-00526	gravity	RCP	Arch	198	158.5	0.014	0.00081722	36.71	-12.97	-13	-9749919.477	5117648.652	-9749934.507	5117646.398
PIPE23-00779	MHOL23-00526	MHOL23-00242	gravity	RCP	Arch	198	158.5	0.014	0.00019626	662.38	-13	-13.13	-9749934.507	5117646.398	-9750189.417	5117556.987
PIPE23-00780	MHOL23-00242	MHOL23-00241	gravity	RCP	Arch	198	158.5	0.014	0.00021087	663.91	-13.13	-13.27	-9750189.417	5117556.987	-9750444.685	5117466.535
PIPE23-00774	MHOL23-00241	MHOL23-00528	gravity	RCP	Arch	198	158.5	0.014	0.00019645	661.76	-13.27	-13.4	-9750444.685	5117466.535	-9750698.359	5117374.8

Network input file to the model



Network in the model GUI

Hydraulics

Hydraulics refer to the flow rate, hydraulic load, diurnal variation, water depth etc. in the model system.

They are the blood of the process model.

Hydraulics

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MHOL23-00096 3.8000  4.0448  4.0448  4.0448  4.0448  4.0448  4.0448  4.0067  4.0067  4.0067  4.0067  4.0067
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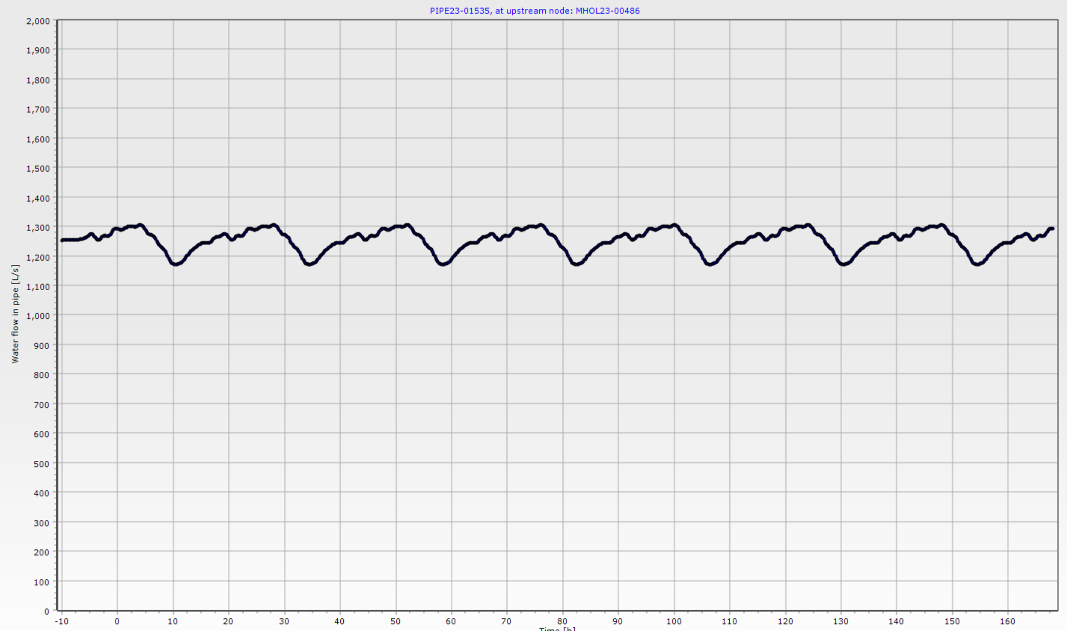


Hydraulics input file to the model

Hydraulics in the model GUI

Biological and Chemical Reactions

Biological and Chemical Reactions refer to various reactions, such as COD degradation, sulfide oxidation, aerobic and anoxic, fermentation, etc. in the model system.

These reactions dominate the process in sewers and are the key components of the process model.

Biological and Chemical Reactions

Many reactions. Here are some key reaction equations.

1. Growth of biomass:

$$\frac{dX_H}{dt} = \mu_{max} \frac{S_O}{K_O + S_O} \frac{S_S}{K_S + S_S} X_H \alpha_w^{T-20} k_{H,pH}$$

Where α_w = An Arrhenius constant

T = The temperature of the wastewater

$k_{H,pH}$ = a function that limits the growth depending on pH

2. Sulfide formation rate:

$$r = r_{max}\left(k_{\tau_0} + \frac{\tau}{K_\tau + \tau}(1 - k_0)\right)$$

Where $k_{\tau 0}$ *is* the fraction of sulfide formation rate (r/r_{max}) at zero shear stress; K_τ is the saturation constant shifting from the zero shear to indefinite shear.

Air Flow

Air flow refers to the air movement in the head space of sewer, which was balanced by the drag of the water and the friction on the pipe wall.

Air flow affects the H2S accumulation , which is typically an indicator of odor, in the sewer.

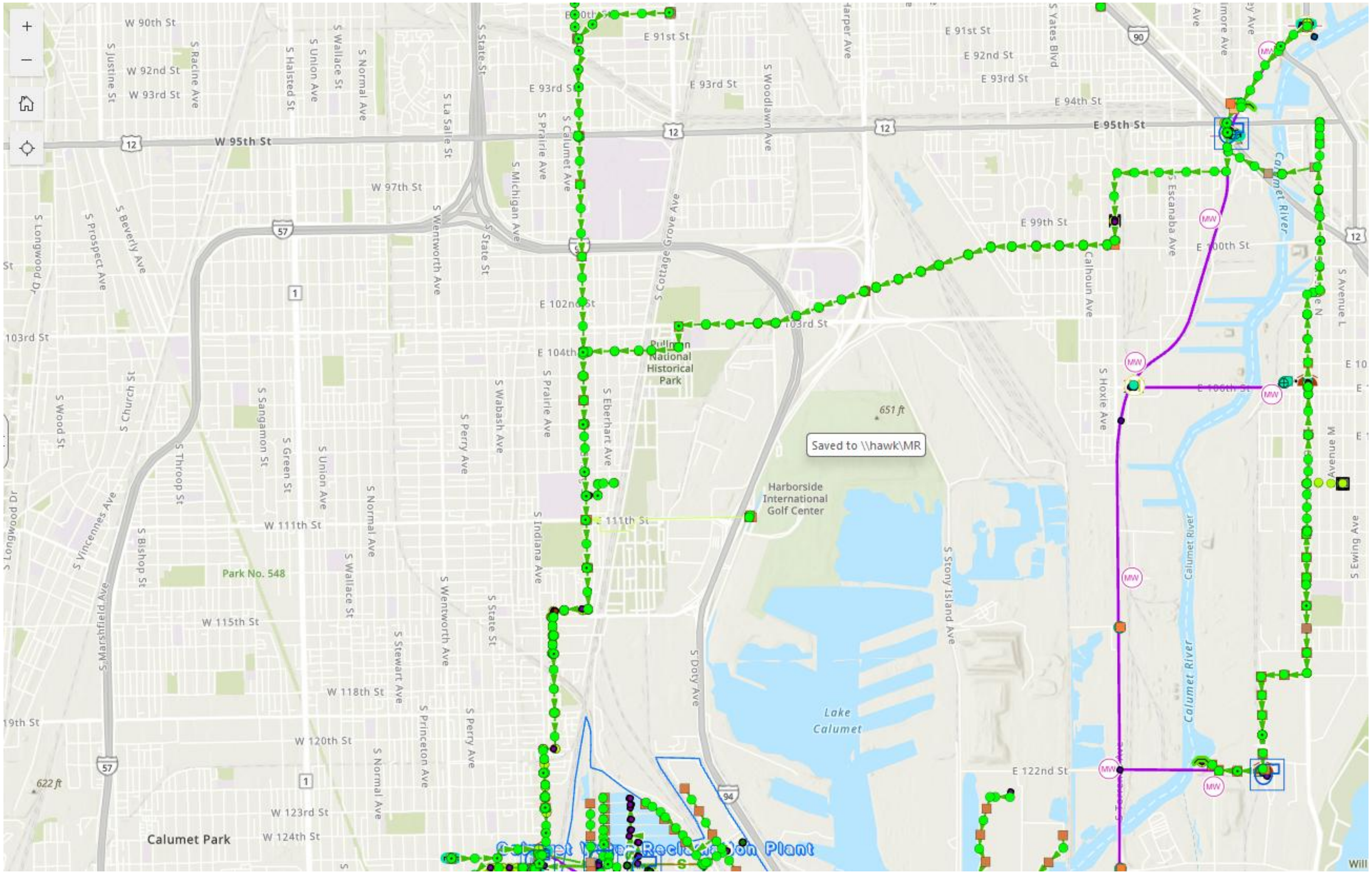
Model Development and Data Collection

Model development includes surveying the sewer / manhole, collecting flow rate, water quality, air quality data, and assembling all components into an executable model.

- Physical Networks
- Hydraulics
- Water Quality Data Collection
- Air Flows

Physical Networks

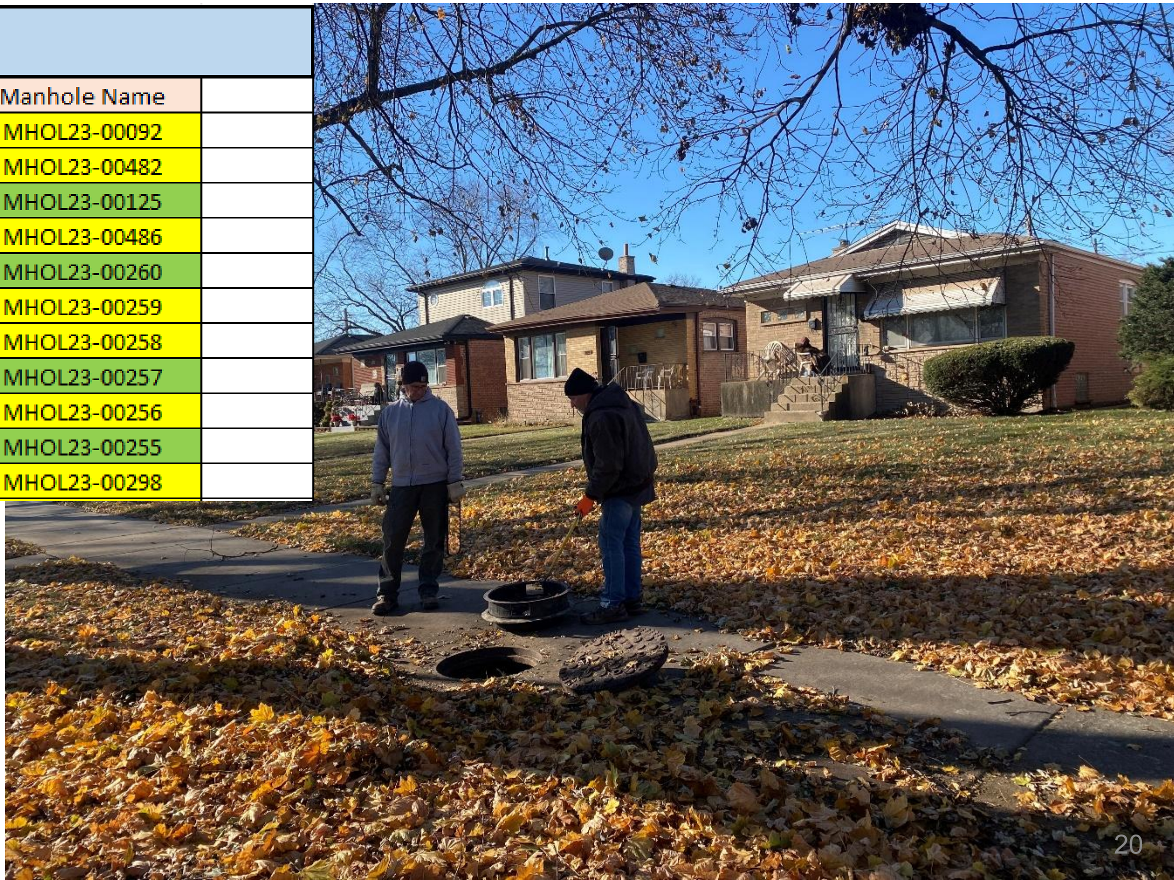
Use IMGIS data to develop the network file.



Physical Networks

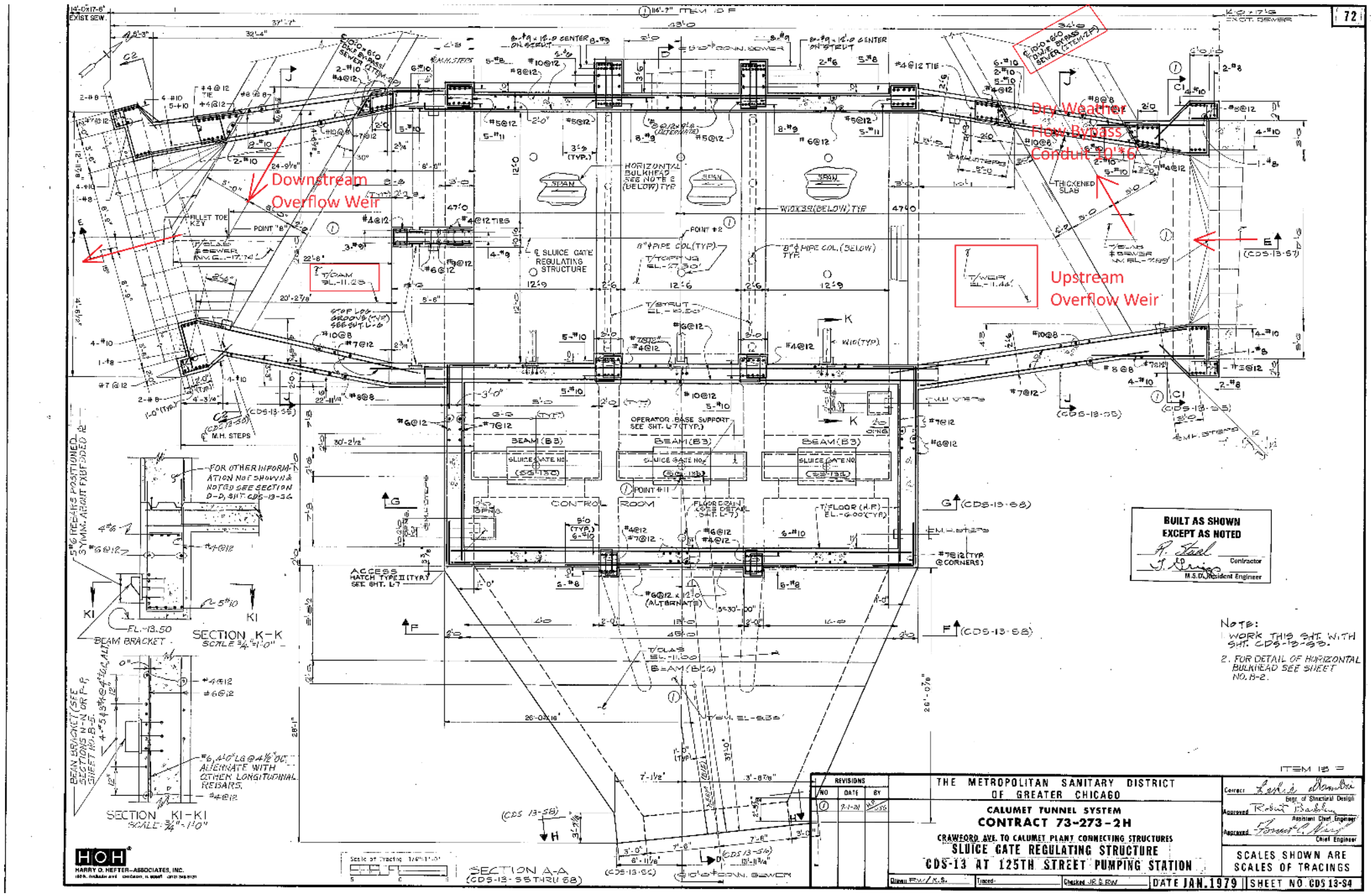
Survey (Engineering Dept.) manhole if IMGIS data are missing.

CAL-6,CAL-5 AND CAL-4				
Point #	Northing	Easting	Rim Elevation	Manhole Name
1	1836093.758	1180775.987	593.9643	MHOL23-00092
2	1828235.298	1179975.989	590.7043	MHOL23-00482
3	1828944.348	1180297.249	590.0957	MHOL23-00125
5	1822779.572	1179837.996	591.2896	MHOL23-00486
6	1823475.14	1179829.823	591.3168	MHOL23-00260
7	1823779.877	1179780.233	589.6774	MHOL23-00259
8	1824441.379	1179758.966	589.6589	MHOL23-00258
11	1825062.761	1179746.133	589.0412	MHOL23-00257
12	1825448.013	1180061.179	588.8503	MHOL23-00256
13	1826113.224	1180043.235	588.9253	MHOL23-00255
14	1826777.394	1180024.894	588.6018	MHOL23-00298



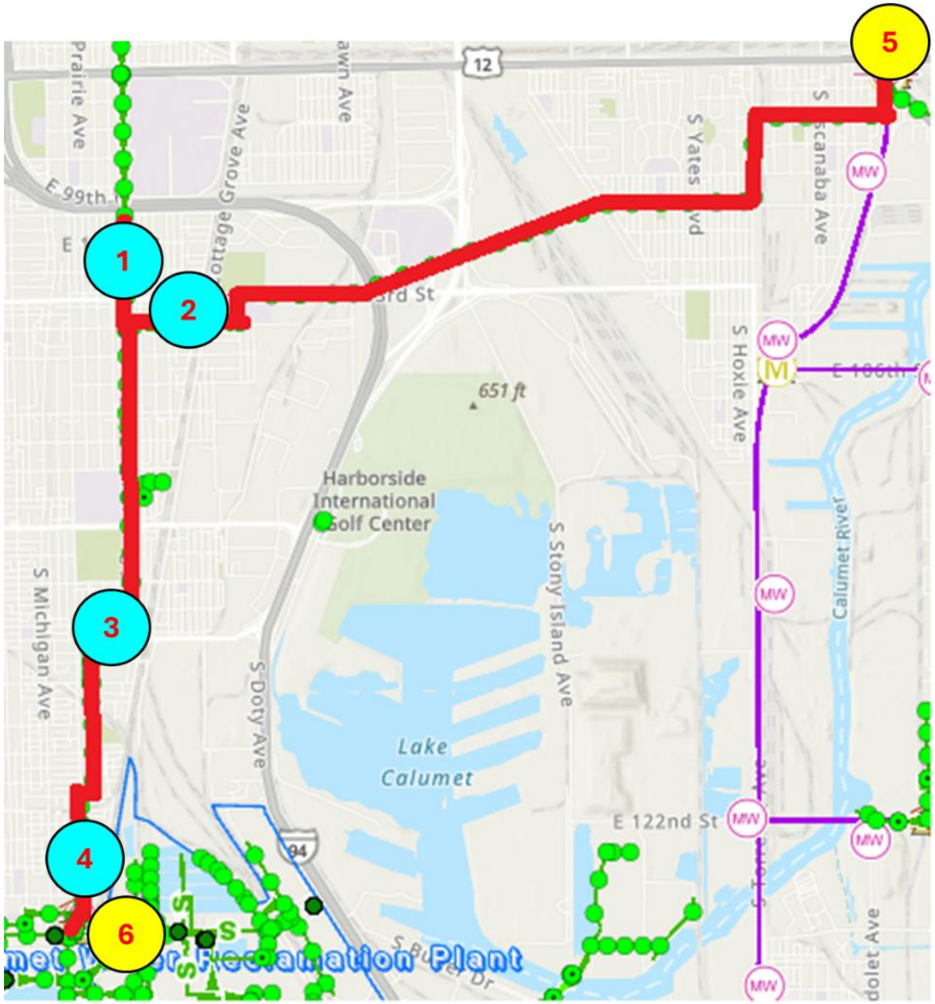
Physical Networks

Read record drawing details for complex structure.



Hydraulics

M&R conducted water depth monitoring and flow monitoring at four locations – Locations 1, 2, 3, 4.



Hydraulics

M&R installed SmartCover monitoring system to monitor water depth for two years.

Hydraulics

M&R hired a contractor to monitor flow rate for 30 days.

Hydraulics

City of Chicago and Jacobs provided hydraulic model showing the local connection between City sewer and District interceptor

Object ID	ds_flow[MGD]
4A1925.1	4.78977
4B0902.1	0.28796
4B0902.2	0
4B1063.1	0
4B1063.2	0.28646
4B1083.1	0
4B1083.2	0.08457
4B1431.1	4.78977
4B1433.1	0
4B1469.1	0
SDM000160767.1	0.04983
SJS000154178.1	1.06619
SMA000093507.1	4.78977
SMA000094503.1	0.03316
SMA000094515.1	0.00373
SMA000094560.1	0
SMA000094560.2	0.00502
SMA000094561.1	0.03318

Hydraulics

The District conducted and reviewed hundreds sewer videos to double check the local connection and flow.

Water/Air Quality Data Collection

M&R collected various COD, pH, sulfide, sulfate, alkalinity, headspace H_2S data, etc. at various locations.

In September and October 2024, M&R collected grab samples from Locations 1, 2, and 4 for two weeks – intensive field sampling.

Water/Air Quality Data Collection

- **Gas phase H_2S**

Locations	Days	Frequency
Location 1	9/16/2024 – 10/11/2024	5 mins
Location 2	9/16/2024 – 10/11/2024	
Location 4	9/16/2024 – 10/11/2024	

- **COD, sCOD, ffCOD, VFA, dissolved sulfide, sulfate, alkalinity**

Locations	Days	Frequency
Location 1	9/18/24 and 10/9/24	2 hrs interval; 4 samples per day
Location 2	9/17/24 and 10/8/24	
Location 4	9/19/24 and 10/10/24	

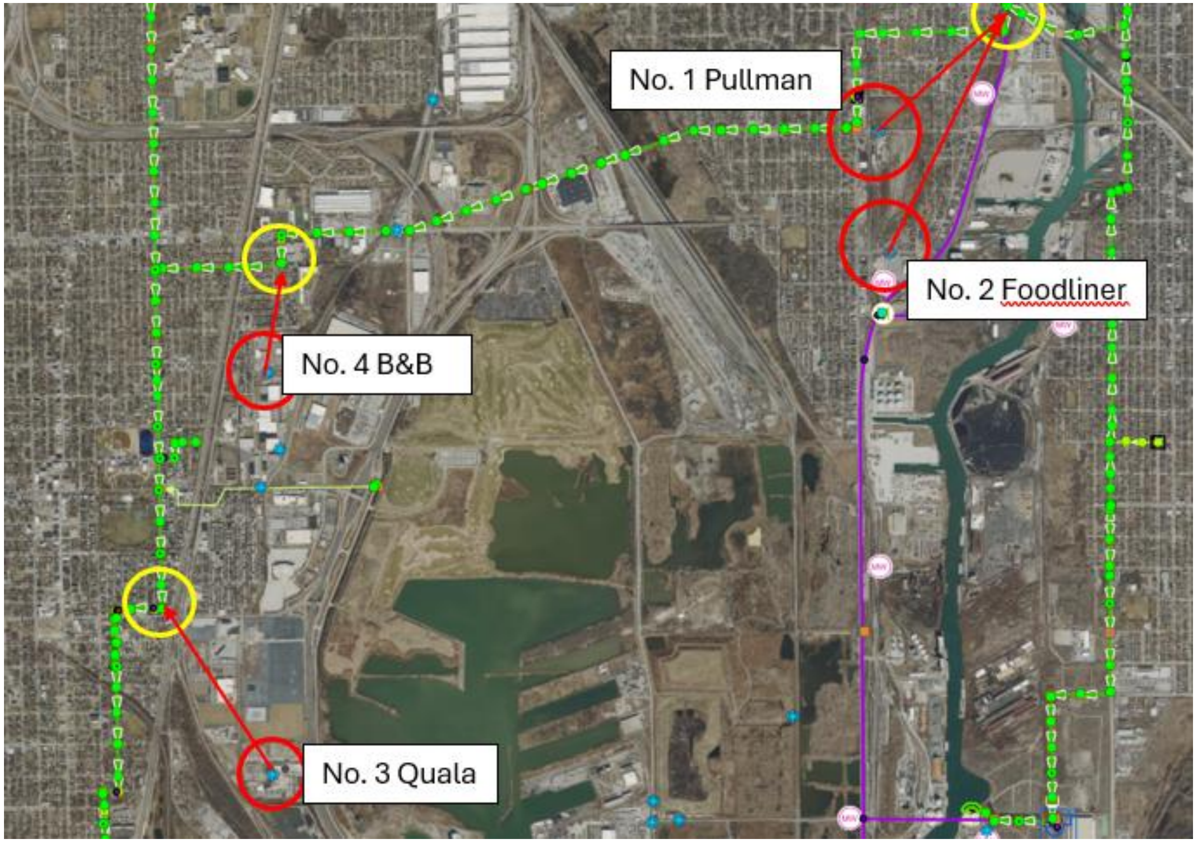
- **pH**

Locations	Days	Frequency
Location 1	9/18/24 and 10/9/24	5 mins interval; 6 hours readings
Location 2	9/17/24 and 10/8/24	
Location 4	9/19/24 and 10/10/24	

Water/Air Quality Data Collection

Local industrial waste had significant impact on sewer system

Collected continuous samples for largest industrial waste loading location.



Water/Air Quality Data Collection

In July 2025, M&R collected continuous samples and grab samples from Locations 2, 3, 4, and 5 for one week – very intensive field work.

Model Calibration and Validation

1. Use data collected in 2024 to calibrate the sewer process model.
2. Key kinetic parameters are hydrogen sulfide formation rate and hydrogen sulfide concrete uptake rate.
3. Key state parameters are CODs, dis sulfide, gas phase H2S, etc.
4. Calibrate kinetic parameters by inputting and matching state parameters.

Model Calibration and Validation

Calibration Results

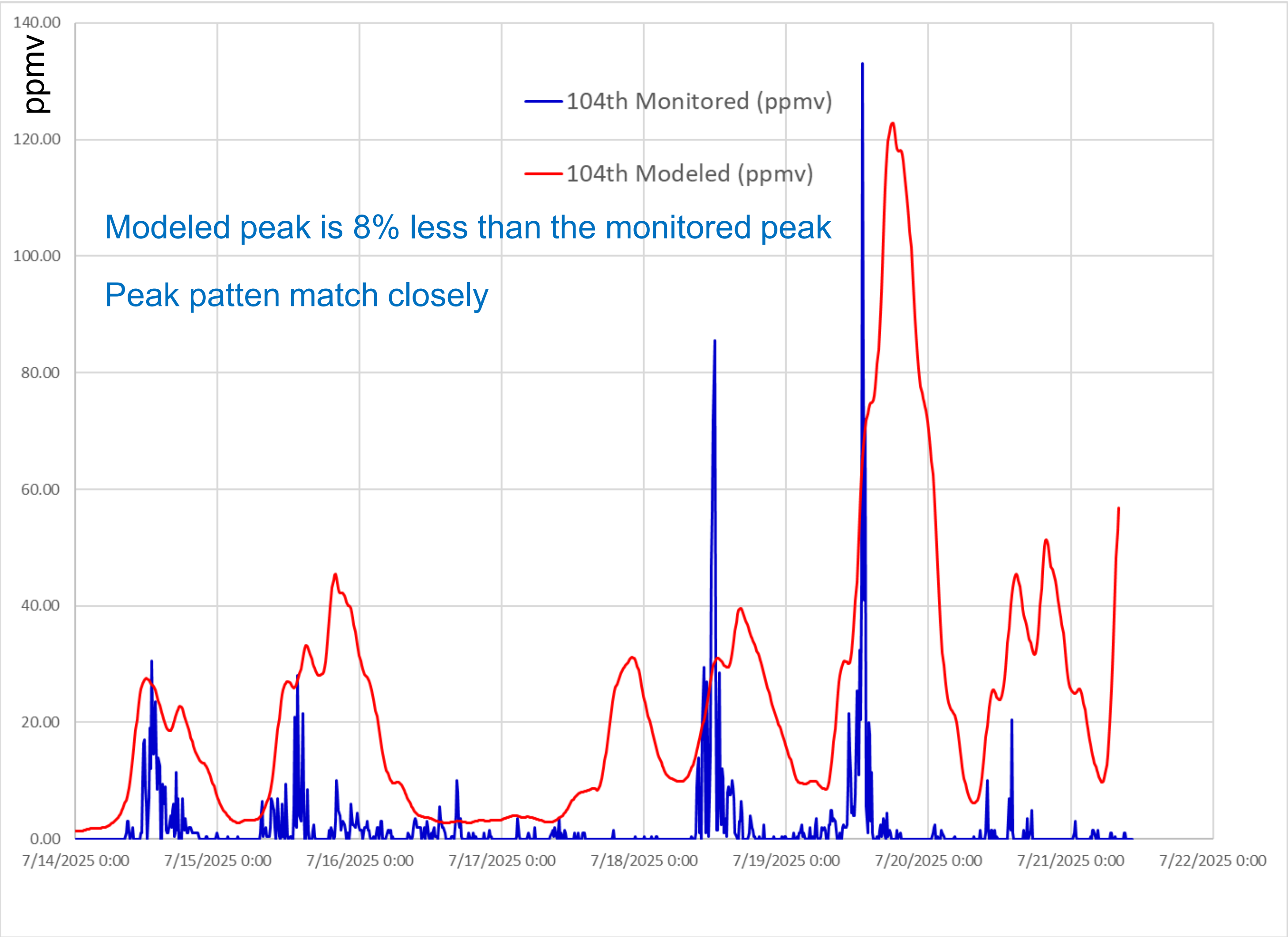
State Parameters At Location 4	Measured	Modeled	Difference
Fermentation products (VFA, mg/L)	168.63	169	0.22%
Fermentable substrates (SF, mg/L)	263.49	264	0.19%
Fast hydrolysable substrates (XSf, mg/L)	63.0	63.5	0.79%
Medium hydrolysable substrates (XSm, mg/L)	64.61	63.5	-1.72%
Slowly hydrolysable substrates (XSs, mg/L)	64.61	64.5	-0.17%
pH value	6.69	6.82	1.94%
Dissolved Carbonate (mg/L)	6.34	6.1	-3.79%
Sulfate (SO4, mg/L)	97.01	97	-0.01%
Dissolved Sulfide (H2Sdisw, mg/L)	0.61	0.64	4.92%
Headspace H2S (pH2Sg, ppmv)	3.843	3.9	1.48%

Model Calibration and Validation

1. Use time series data collected in 2025 to validate the sewer process model.
2. Keep kinetic parameters to reflect the stable biological and chemical condition in the sewer system.
3. Changed state parameters to reflect the input and output scenarios of the sewer system.

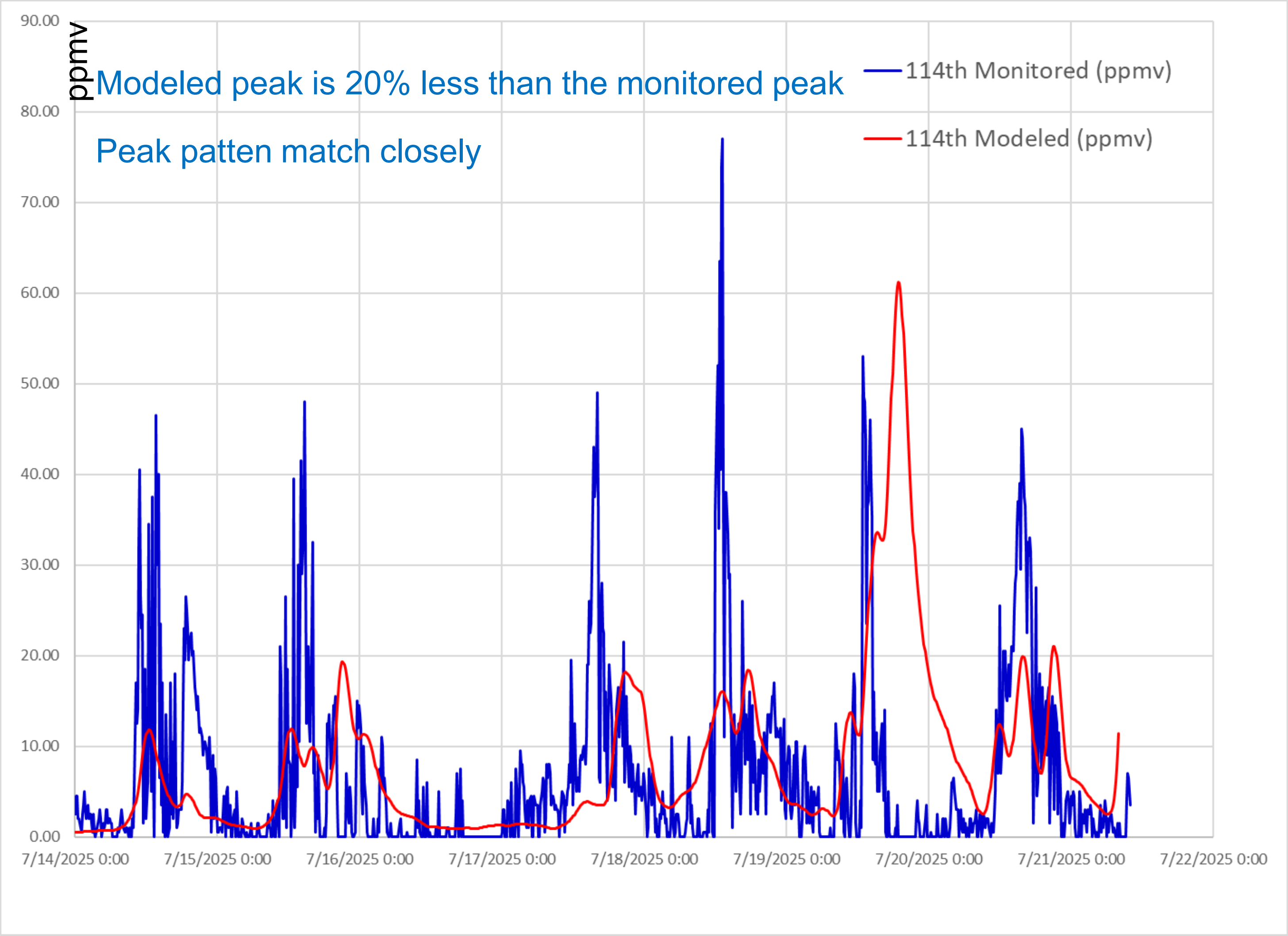
Model Calibration and Validation

Validation Results (H2S level at 104th St)

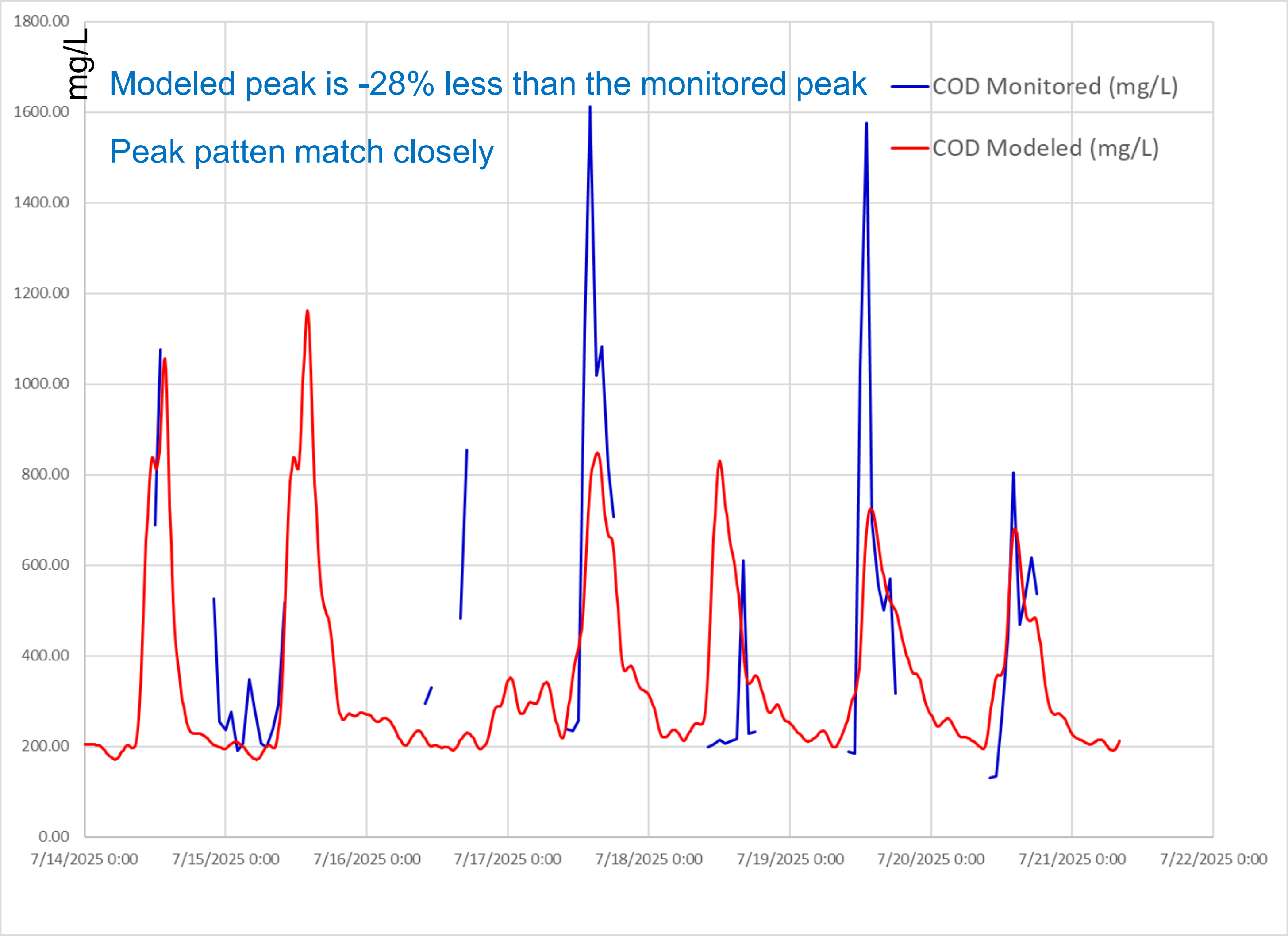


Model Calibration and Validation

Validation Results (H2S level at 114th PI)

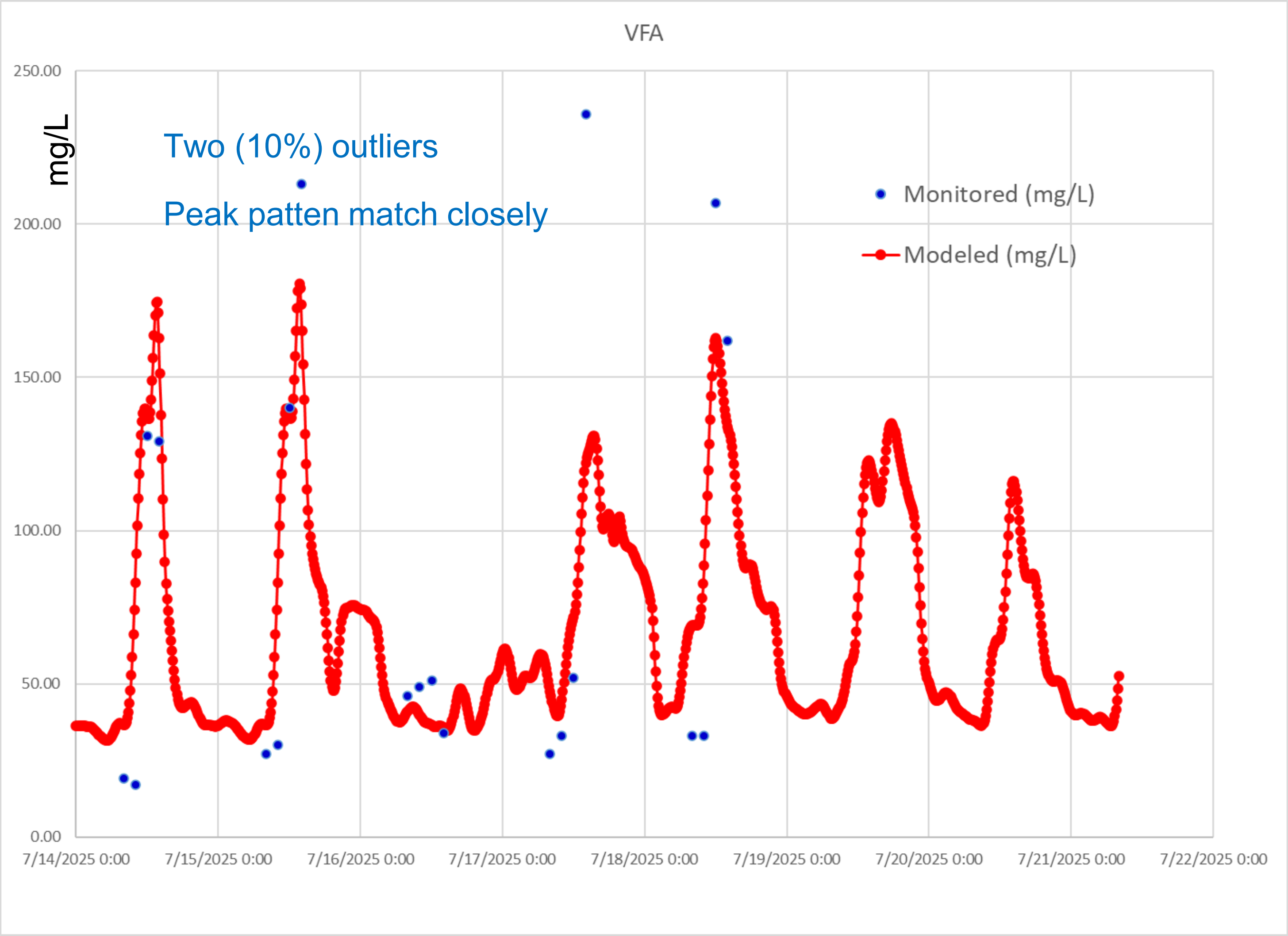


Validation Results (COD at 124th St)



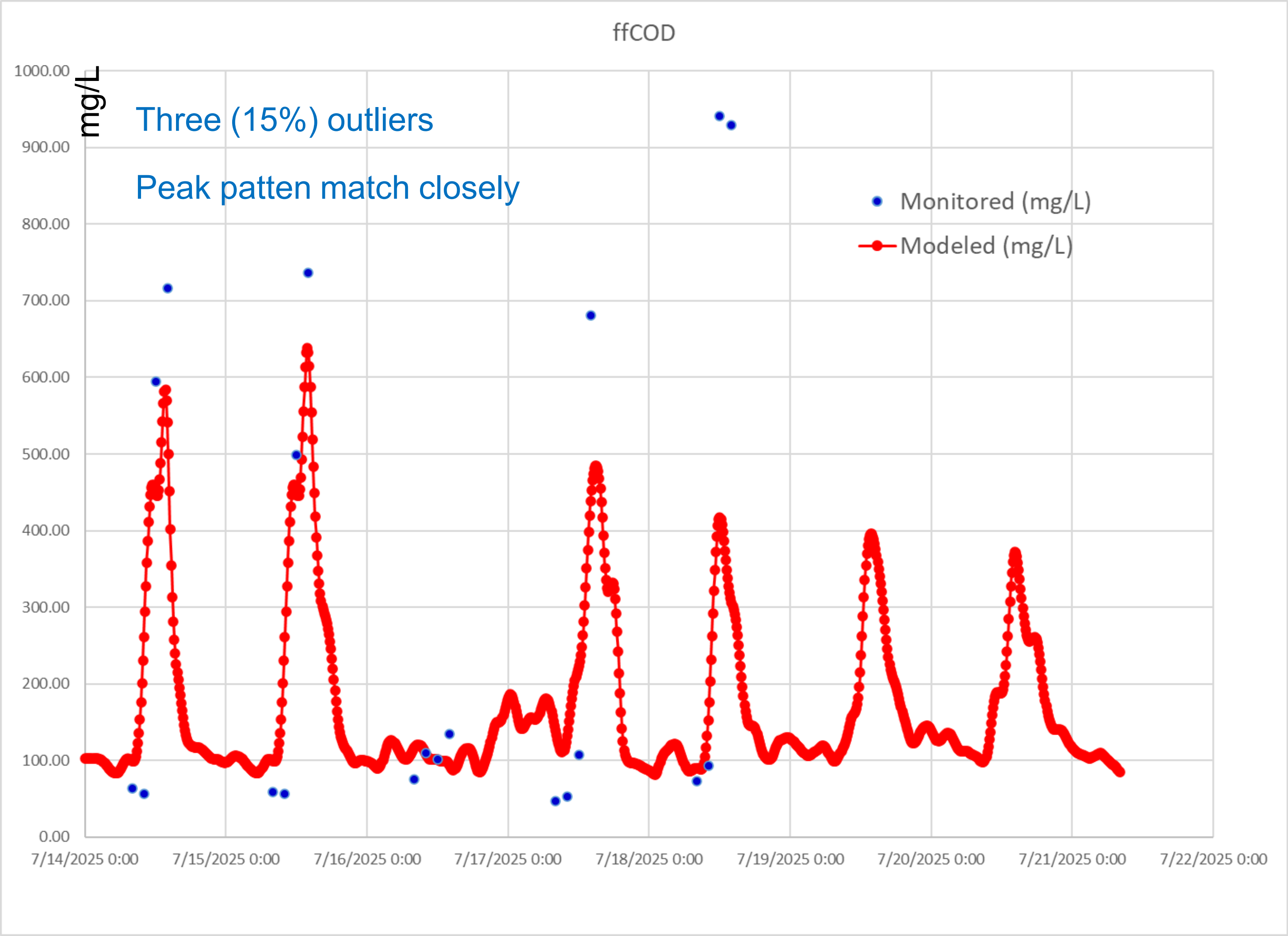
Model Calibration and Validation

Validation Results (VFA at 124th St)



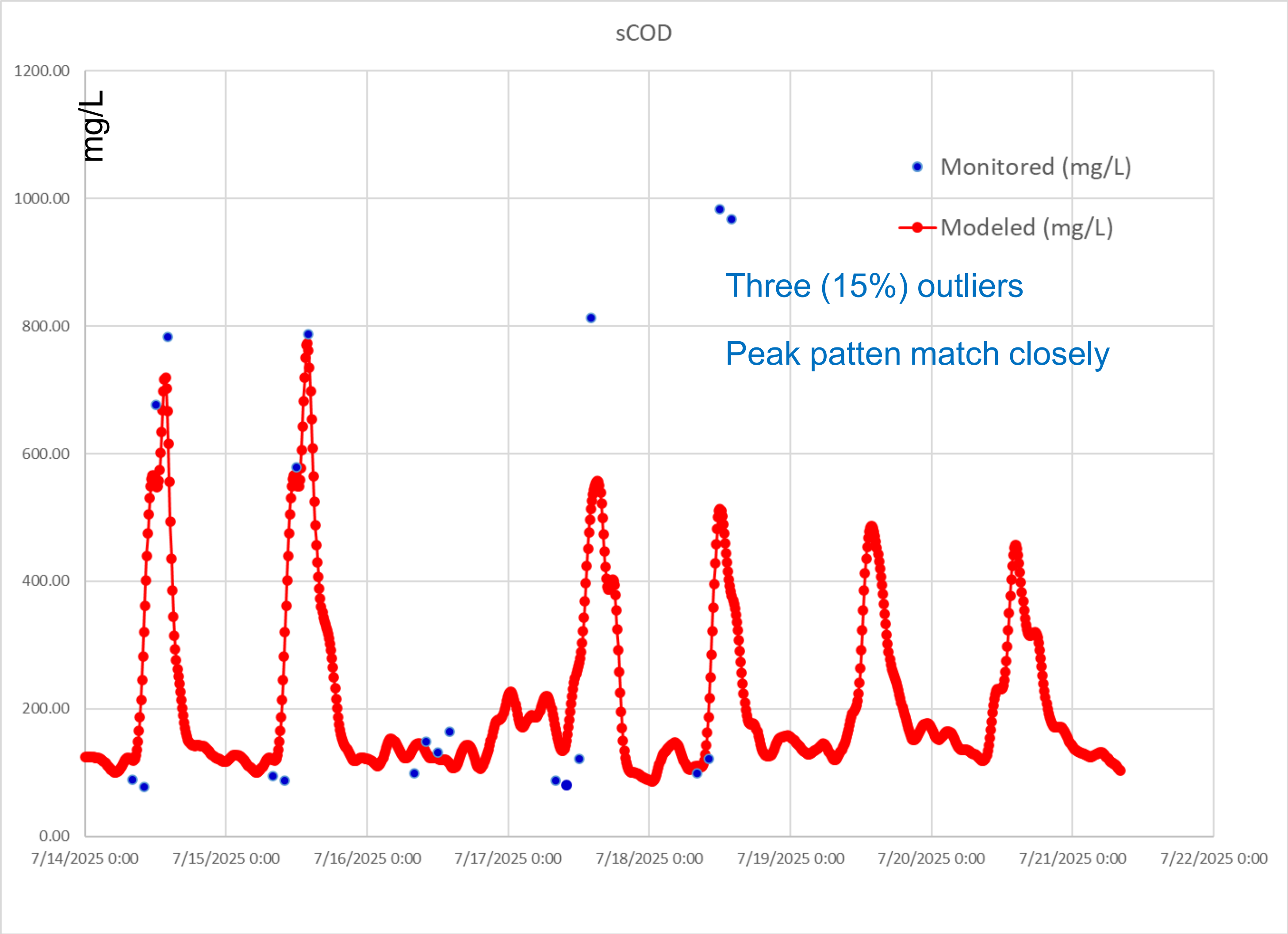
Model Calibration and Validation

Validation Results (ffCOD at 124th St)



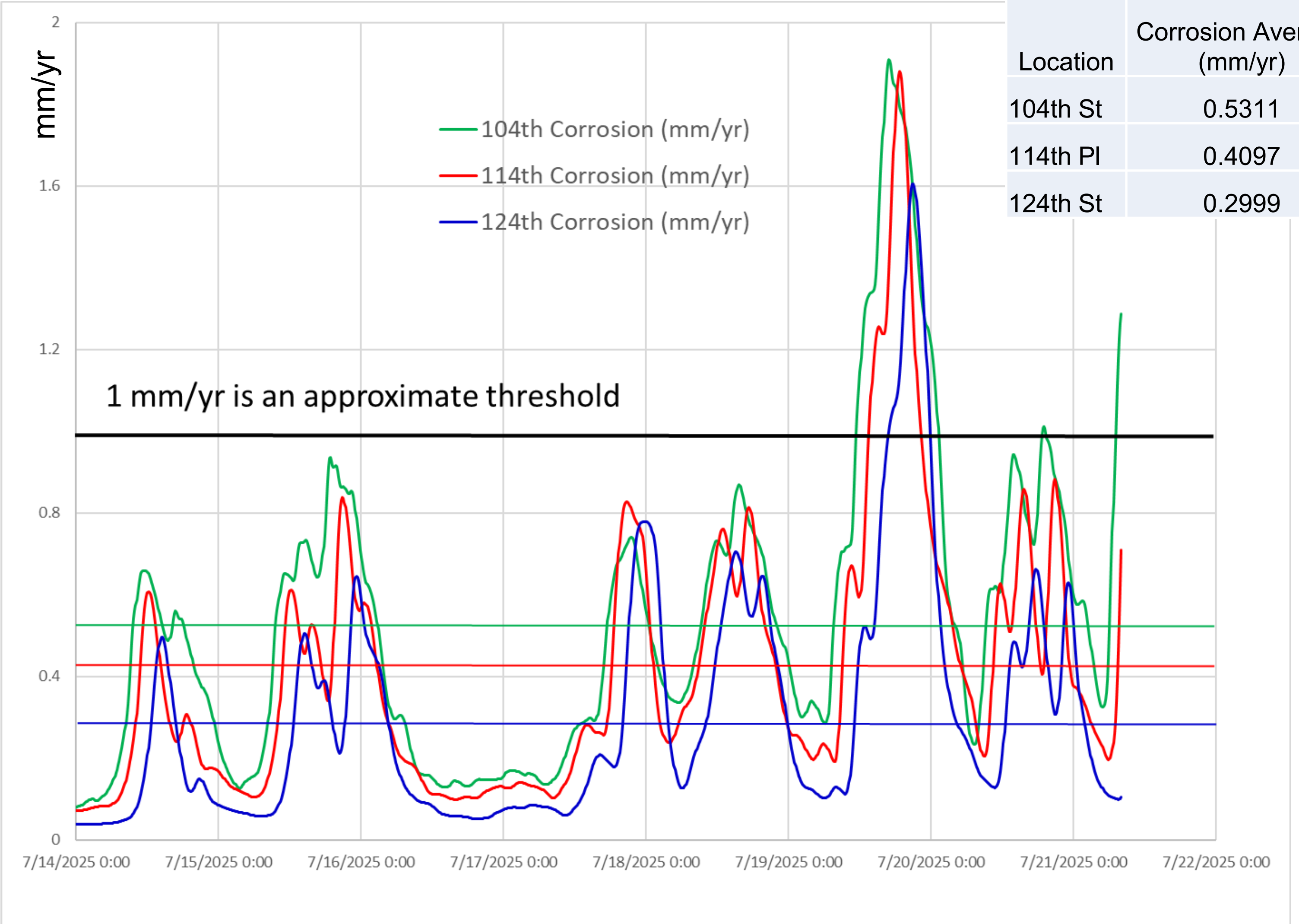
Model Calibration and Validation

Validation Results (sCOD at 124th St)



Model Calibration and Validation

Corrosion



Location	Corrosion Average (mm/yr)
104th St	0.5311
114th Pl	0.4097
124th St	0.2999

Sensitivity Analysis

- Sensitivity analysis shows how different values of input variables affect output variables under a given set of assumptions.
  - Input uncertainty
  - Input variation
- Input: CODs, sulfide, and sulfate in upstream inflows, kinetic parameters.
- Output: gas phase H_2S in downstream.

Sensitivity Analysis Results

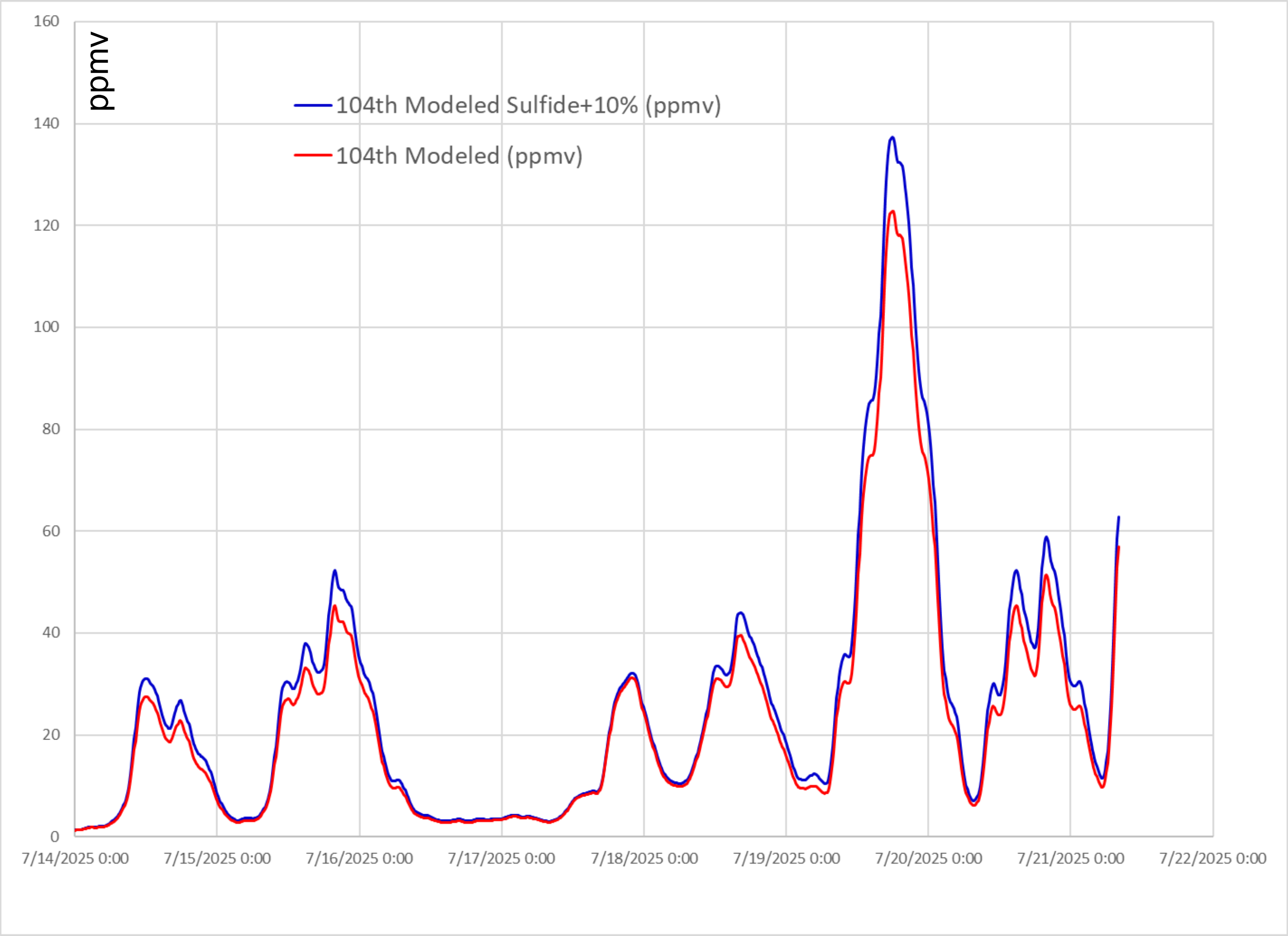
Water Quality Input Change	Location	H2S Change
COD +10%	104th St	1.04%
	114th Pl	1.45%
	124th St	1.96%
COD -10%	104th St	-1.10%
	114th Pl	-1.60%
	124th St	-2.31%
Sulfide +10%	104th St	11.79%
	114th Pl	10.25%
	124th St	10.23%
Sulfide -10%	104th St	-11.76%
	114th Pl	-10.47%
	124th St	-10.28%
Sulfate +10%	104th St	0.09%
	114th Pl	0.13%
	124th St	0.15%
Sulfate -10%	104th St	-0.10%
	114th Pl	-0.15%
	124th St	-0.20%

Sensitivity Analysis Results

Kinetic Parameter Change	Location	H2S Change
H2S formation rate +10%	104th St	1.65%
	114th Pl	1.96%
	124th St	2.40%
H2S formation rate -10%	104th St	-1.59%
	114th Pl	-1.94%
	124th St	-2.40%
H2S concrete uptake rate +10%	104th St	-6.43%
	114th Pl	-6.92%
	124th St	-10.59%
H2S concrete uptake rate -10%	104th St	7.22%
	114th Pl	7.82%
	124th St	12.15%
H2S biomass growth rate +10%	104th St	2.73%
	114th Pl	4.07%
	124th St	5.66%
H2S biomass growth rate -10%	104th St	-2.60%
	114th Pl	-3.97%
	124th St	-5.50%

Sensitivity Analysis

Sensitivity Analysis Results



Scenario Analysis

Scenario analysis shows how the gas phase H_2S can be mitigated if we dose chemicals at designated locations.

95th St PS is the ideal dosing location.

We simulated chemicals dosing for – $FeCl_3$, $NaOCl$, $Mg(OH)_2$, and $Ca(NO_3)_2$.

Scenario Analysis

Scenario Analysis Results

From original to 50% reduction costs much less than from 50% reduction to 90% reduction.

Hypochlorite is the most cost-effective solution.

Target H2S Reduction at Location 2	Chemical	Quantity (Gallons/day)	Cost ($/Day)
50%	40% FeCl3	434	$1,242
	12% as NaOCl	418	$807
	55% as Mg(OH)2	2,204	$2,903
	45% as Ca(NO3)2	990	$4,500
90%	40% FeCl3	4,220	$12,085
	12% as NaOCl	2,634	$5,087
	55% as Mg(OH)2	3,526	$4,644
	45% as Ca(NO3)2	19,810 (87% reduction)	$90,000

Scenario Analysis Results

Target H_2S reduction at Location 2 is 50% and 90%, but H_2S reductions at Location 3 and Location 4 vary.

Target H2S Reduction at Location 2	Chemical	H2S Reduction at Location 3	H2S Reduction at Location 4
50%	40% FeCl3	79%	85%
	12% as NaOCl	81%	89%
	55% as Mg(OH)2	37%	31%
	45% as Ca(NO3)2	49%	53%
90%	40% FeCl3	93%	96%
	12% as NaOCl	94%	96%
	55% as Mg(OH)2	63%	51%
	45% as Ca(NO3)2	99%	100%

Scenario Analysis Results

Corrosion Rate Reduction

Target H2S Reduction at Location 2	Chemical	Corrosion Rate Reduction at Location 2	Corrosion Rate Reduction at Location 3	Corrosion Rate Reduction at Location 4
50%	40% FeCl3	23%	37%	43%
	12% as NaOCl	31%	44%	52%
	55% as Mg(OH)2	62%	48%	36%
	45% as Ca(NO3)2	60%	72%	74%
90%	40% FeCl3	62%	62%	65%
	12% as NaOCl	69%	66%	70%
	55% as Mg(OH)2	91%	77%	66%
	45% as Ca(NO3)2	87%	98%	100%

Scenario Analysis

Scenario Analysis Results

Dosing hypochlorite at high sulfide level (S^{2-} >4 mg/L)

The lowest cost option (green highlighted)

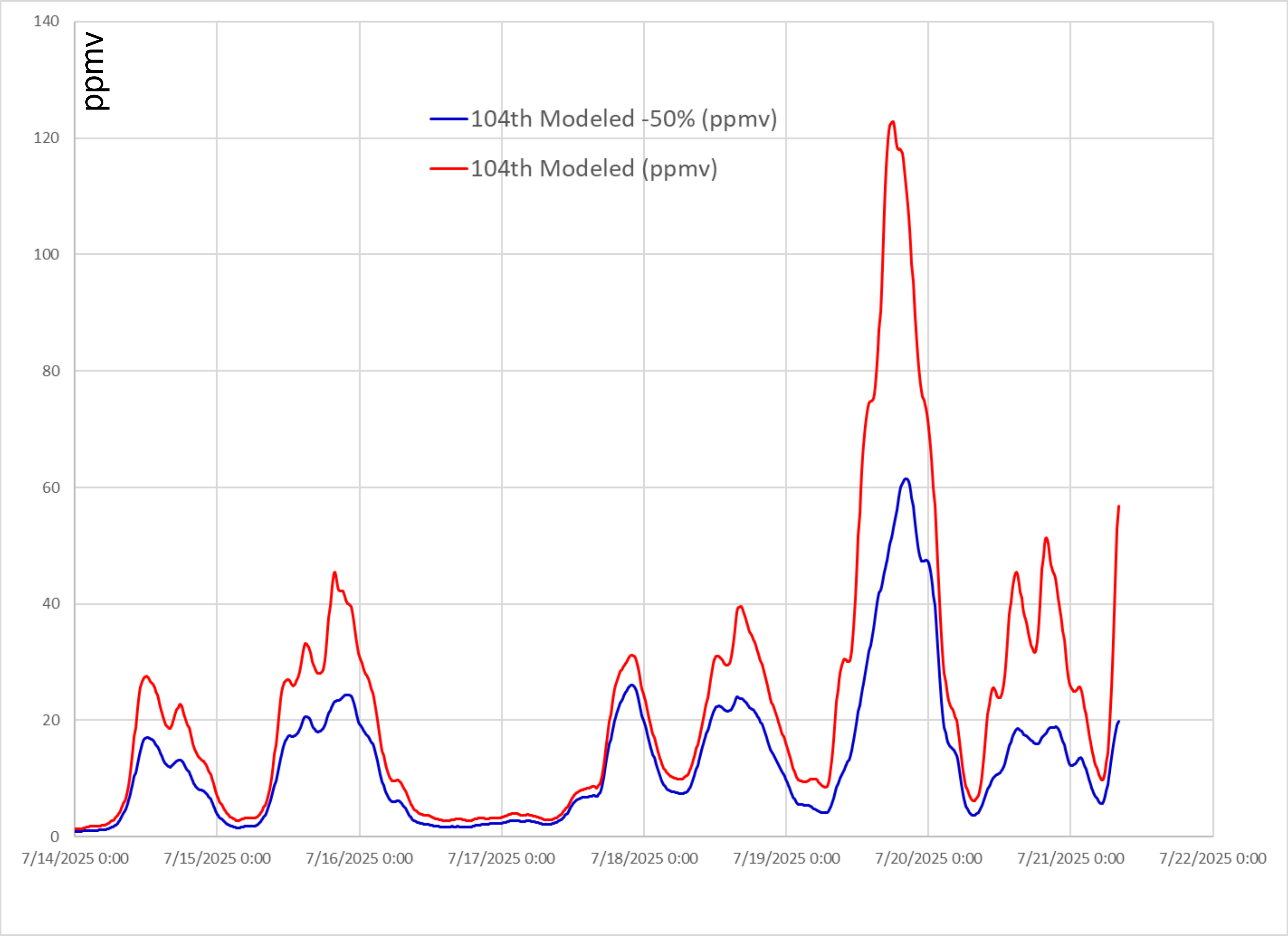
Chemical	Quantity (Gallons/day)	Cost ($/Day)	H2S Reduction at Location 2	H2S Reduction at Location 3	H2S Reduction at Location 4
12% as NaOCl	68	$132	50%	76%	82%
12% as NaOCl	1,301	$2512	84%	84%	89%

Chemical	Quantity (Gallons/day)	Corrosion Rate Reduction at Location 2	Corrosion Rate Reduction at Location 3	Corrosion Rate Reduction at Location 4
12% as NaOCl	68	23%	34%	43%
12% as NaOCl	1,301	48%	49%	54%

Scenario Analysis

Hypochlorite targeting 50% H2S reduction at Location 2

Location 2 H2S reduction



Summary and Conclusion

1. Continuous flow monitoring and water quality sampling are critical for the project success.
2. Sewer process model can simulate head space H2S and water chemistry reasonably well through calibration and verification.
3. Dis sulfide and H2S concrete uptake rate are the most sensitive state parameter and kinetic parameter that affect the head space H2S concentrations.
4. Hypochlorite is a cost-effective odor mitigation chemical according to the model.
5. Targeting H2S reduction by to 50% appears to be optimal option. Higher H2S reduction results in chemical cost to increase exponentially.

Acknowledgement

- Support of Heng Zhang and Ali Oskouie for the valuable advice and directions.
- Support of Adam Chaffin, Evelyn Perez, Syeda Rasheed for preparing equipment and field sampling.
- Support from Section 129 for odor patrol during busy weeks.
- Support from Section 123, 124, 126, IWD, M&O Dept. for the field sampling.
- Support from Engineering Dept. for field survey.
- Support from ALD for the sample analysis.
- Support from City of Chicago and Jacobs for the hydraulics model.


THANK YOU
QUESTIONS

For PDH Certificate seekers,

The link to the new on-line course evaluation form has been posted in the Chat. The link is also available on the District website. The form will only be available online until the start of next month’s seminar. Please be sure to fill it out and submit promptly.