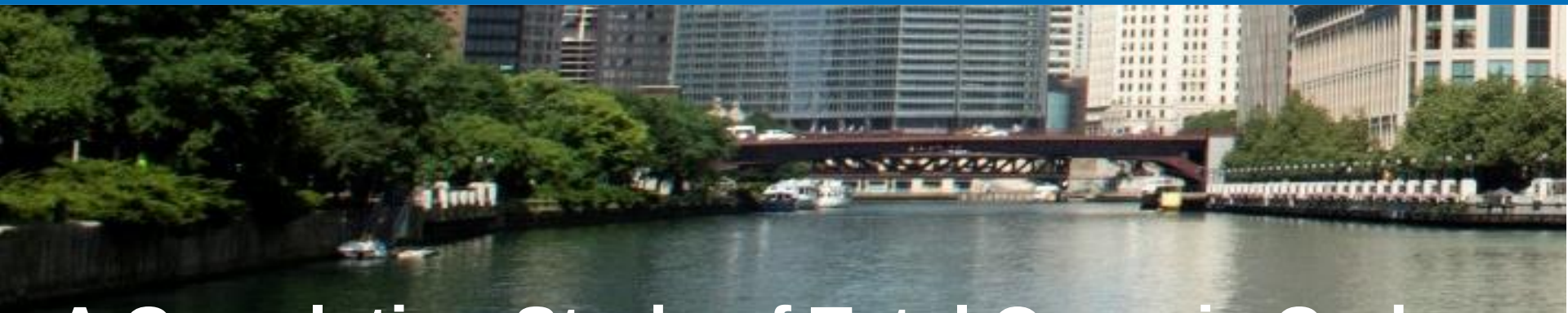
Metropolitan Water Reclamation District of Greater Chicago

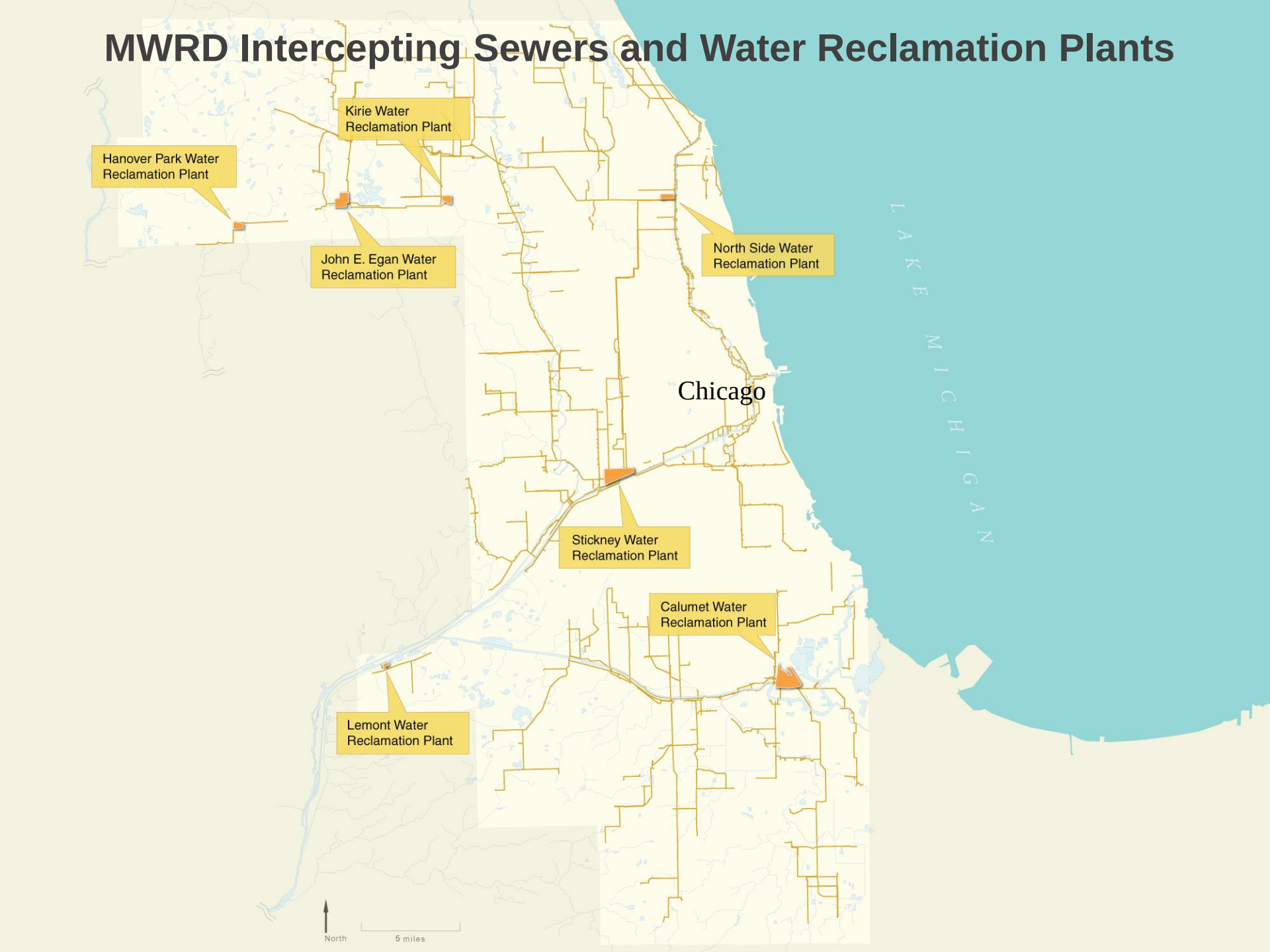


A Correlation Study of Total Organic Carbon and the Five-Day BOD and CBOD Tests in Water Reclamation Plant Influent and Effluent

Dominic Brose

February 16, 2021

MWRD Intercepting Sewers and Water Reclamation Plants



$CBOD_5$ and BOD_5 NPDES Limits

WRP	Daily Outfall $CBOD_5$	Weekly Outfall $CBOD_5$	Monthly Outfall $CBOD_5$	30-day BOD_5 removal
	--- mg/L ---			%
Stickney		15	10	85
O'Brien		12	10	85
Calumet		20	10	85
Kirie	20		4	85
Egan	20		10	85
Hanover Park	20		10	85
Lemont		40	20	80

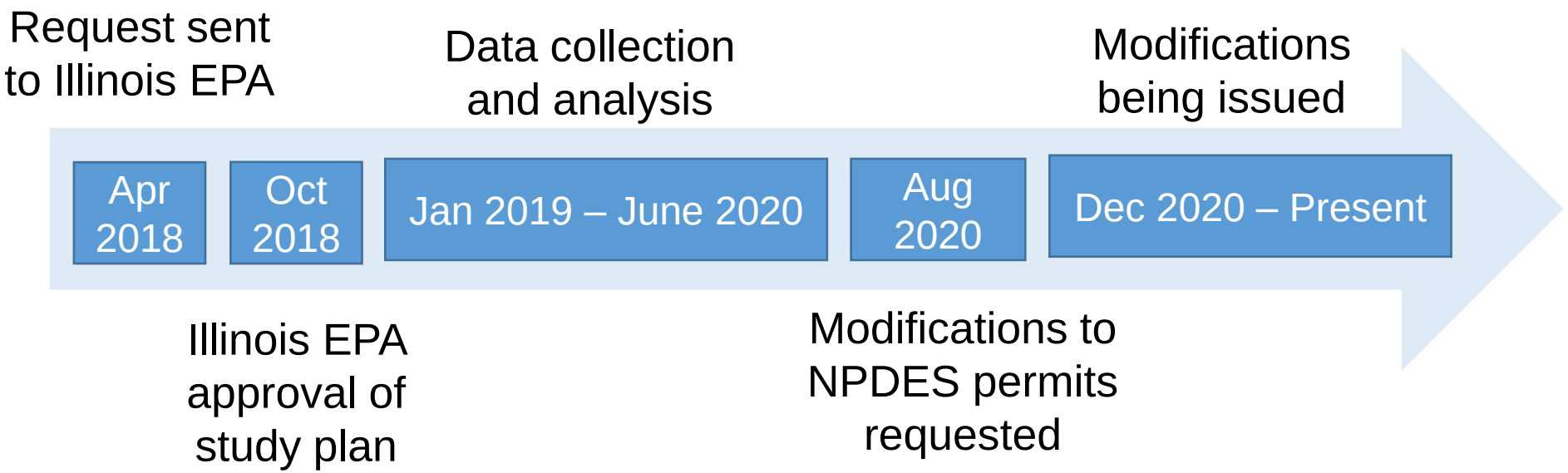
Why are we interested in the correlation between BOD and TOC?

40 CFR 133.104 (b):

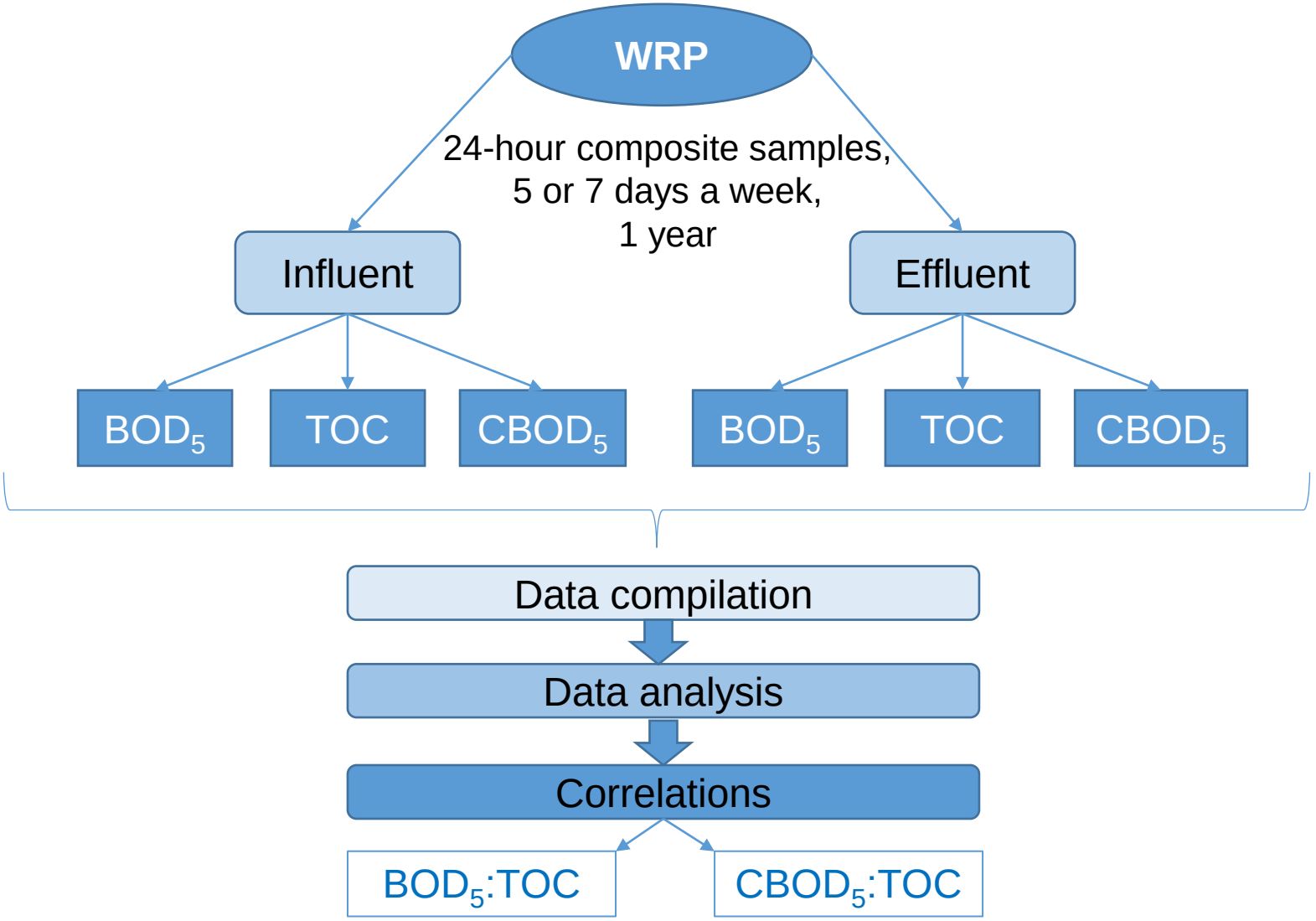
"Chemical oxygen demand (COD) or total organic carbon (TOC) may be substituted for BOD5 when a long-term BOD:COD or BOD:TOC correlation has been demonstrated."

- *BOD and CBOD analyses followed the Standard Method 5210 B*
- *TOC followed the Standard Method 5310 B (High-Temperature Combustion Method)*

Our Study Timeline

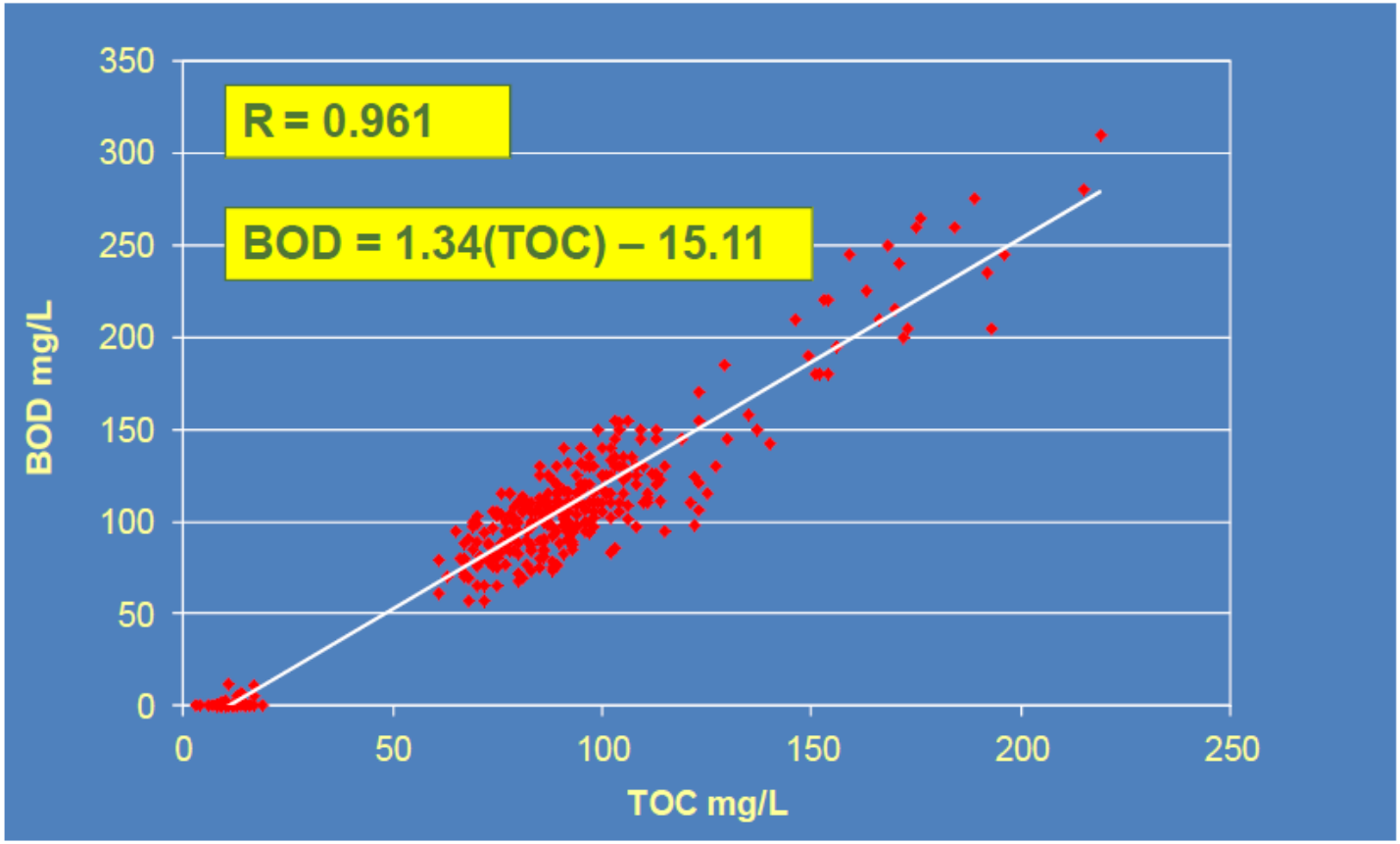


Study Scope


WRP
24-hour composite samples,
5 or 7 days a week,
1 year
Influent
Effluent
BOD5
TOC
CBOD5
BOD5
TOC
CBOD5
Data compilation
Data analysis
Correlations
BOD5:TOC
CBOD5:TOC

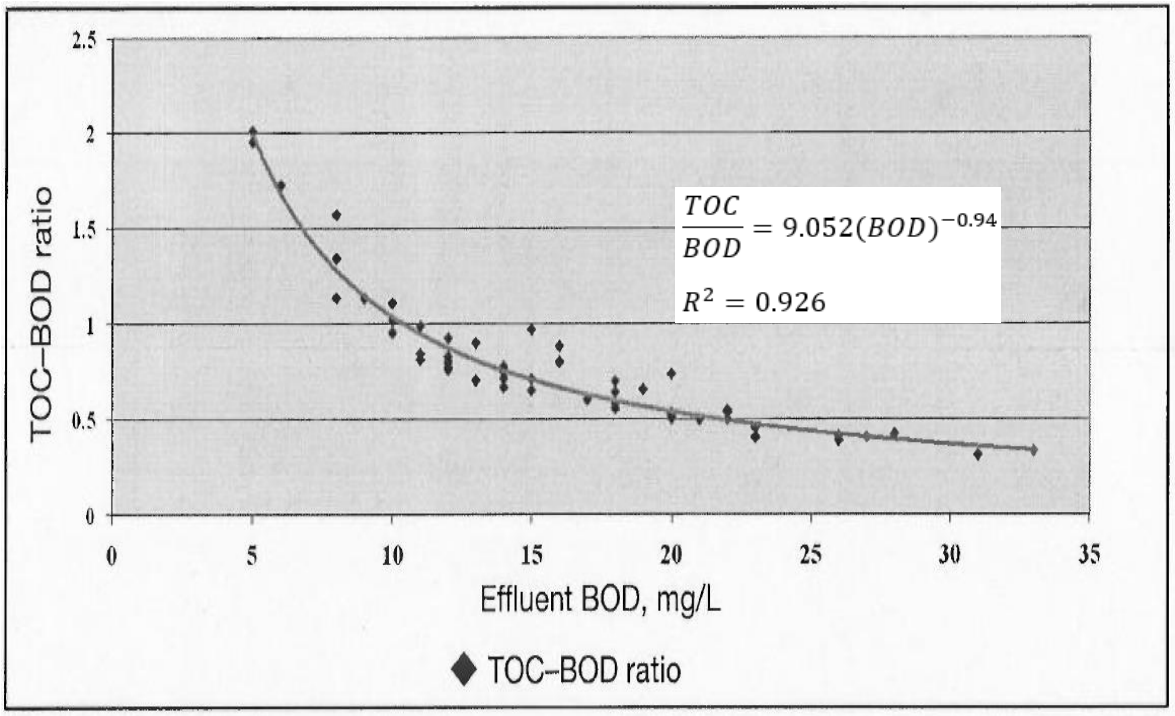
Case Study

- Inland Empire Utilities Agency, CA
  - Influent+Effluent BOD ~ Influent+Effluent TOC



Case Study

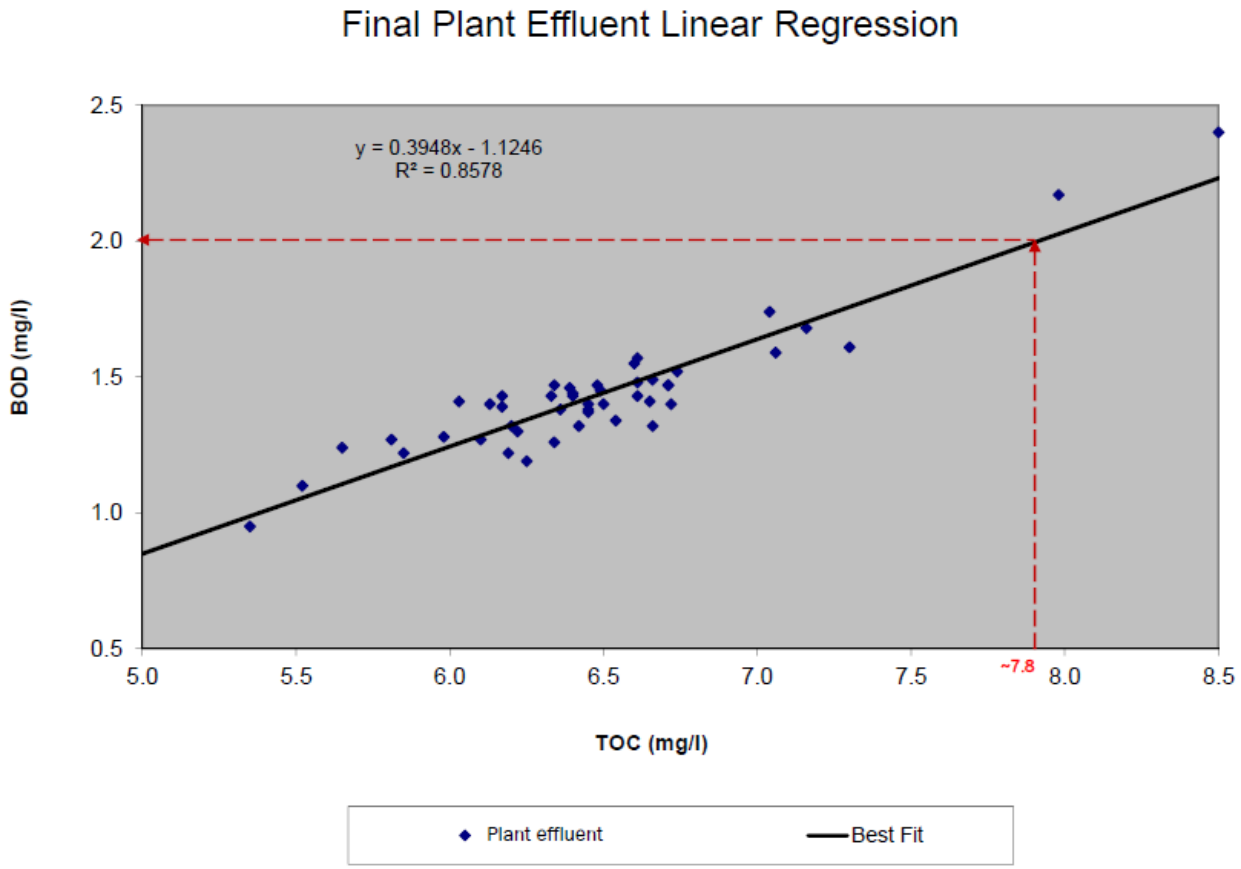
- City of Santa Cruz, CA
  - Effluent TOC:BOD ~ Effluent BOD



Permit	Past	Now
30-day limit	30 mg/L BOD	17 mg/L TOC
7-day limit	45 mg/L BOD	25 mg/L TOC
30-day BOD removal	85%	

Case Study

- Clark County Water Reclamation District, NV
  - Effluent BOD ~ Effluent TOC



Data Analysis Parameters

- **Data compilation:**
  - Only effluent
  - Only influent
  - Influent + effluent

- **Data analysis**:
  - Log-transformed data
  - Ratio-transformed data: log BOD/log TOC
  - Pearson r vs. Spearman rho correlation coefficient
  - Linear regression (Log-transformed)
  - Theil-Sen nonparametric regression (Log-transformed)
    - USEPA recommends non-parameteric methods for trend analysis of non-normally distributed data; less sensitive to outliers
  - Nonlinear least-squares regression (Ratio-transformed)

- **Addressing Reporting Limits:**
  - Robust Regression on Order Statistics (ROS)
  - Actual <RL values
  - Set <RL = ½ RL

Spearman Rho Correlation Coefficients:

WRP	log TOC~ log BOD	log BOD/log TOC ~ log TOC	log TOC ~ log CBOD	log CBOD/log TOC ~ log TOC
Calumet	0.92	0.56	0.89	0.76
Hanover Park	0.89	0.69	0.88	0.71
Kirie	0.91	0.64	0.90	0.62
Egan	0.86	0.61	0.85	0.59
Lemont	0.94	0.36	0.92	0.67
Stickney	0.90	0.57	0.86	0.66
O’Brien	0.90	0.53	0.83	0.53

BOD/TOC Mean Absolute Errors

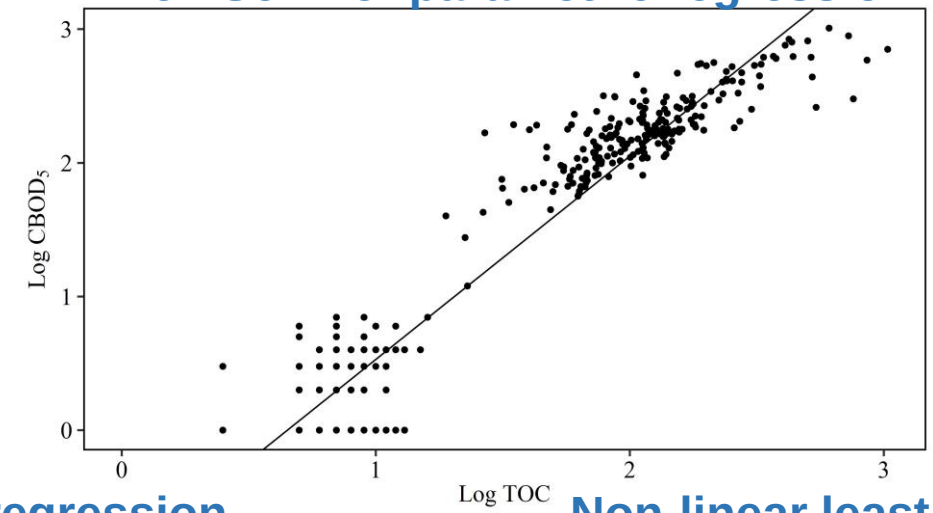
WRP	Linear Regression	Theil-Sen Nonparametric Regression	Nonlinear Least-Squares Regression
Calumet	13	12	28
Lemont	18	16	63
Hanover Park	20	19	43
Egan	20	18	69
Kirie	53	57	107
O’Brien	173	164	510
Stickney	17	16	27

CBOD/TOC Mean Absolute Errors

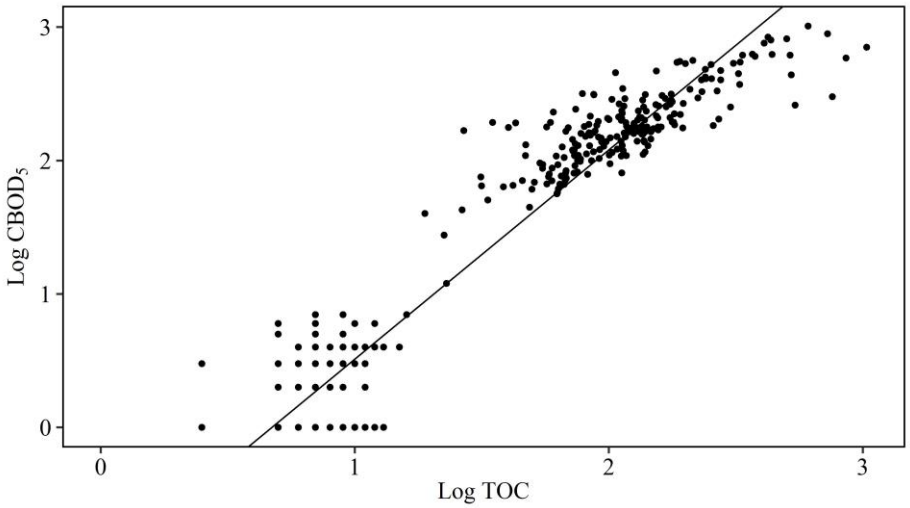
WRP	Linear Regression	Theil-Sen Nonparametric Regression	Nonlinear Least-Squares Regression
Calumet	14	12	12
Lemont	12	11	11
Hanover Park	15	16	14
Egan	10	9.3	10
Kirie	41	44	45
O’Brien	67	59	57
Stickney	11	11	11

Stickney WRP CBOD ~ TOC

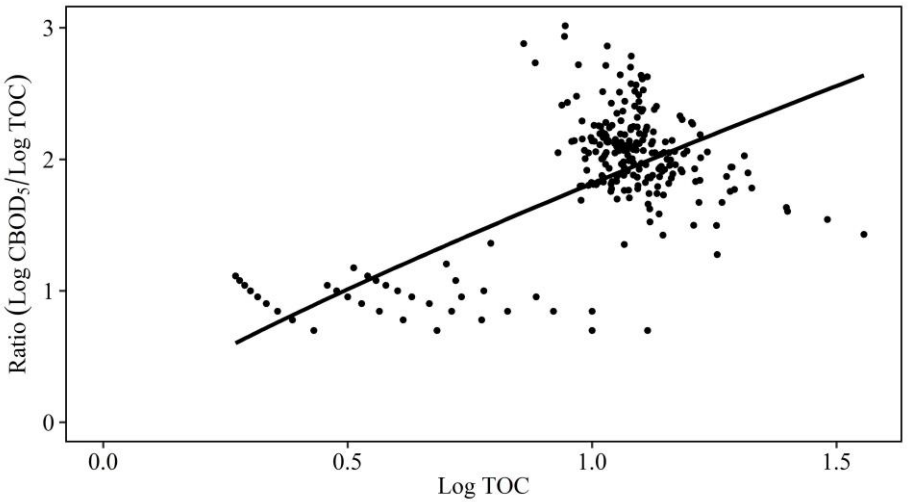
Theil-Sen nonparametric regression



Linear regression



Non-linear least squares regression



Conclusions

- **Data Compilation:**
  - Combined Influent + effluent for each plant
  - Only used dates with matching TOC/BOD or TOC/CBOD data
  - Log-transformed all data

- **Models**:
  - Spearman rho correlation coefficient
  - Theil-Sen nonparametric regression

- **Addressing Reporting Limits:**
  - Set <RL = ½ RL

Metropolitan Water Reclamation District of Greater Chicago

Questions?

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