Coagulation Zones

1. Zone 1: no destabilization (coagulation) occurs
2. Zone 2: destabilization (coagulation) occurs by charge neutralization
3. Zone 3: restabilization occurs (particle charge is reversed)
4. Zone 4: destabilization (coagulation) occurs in form of colloidal entrapment or “sweep floc”

Figure 2-4 Coagulant Dose Versus Very Low Colloidal Concentrations (Residual Turbidity)

Source: O'Melia, 1972.

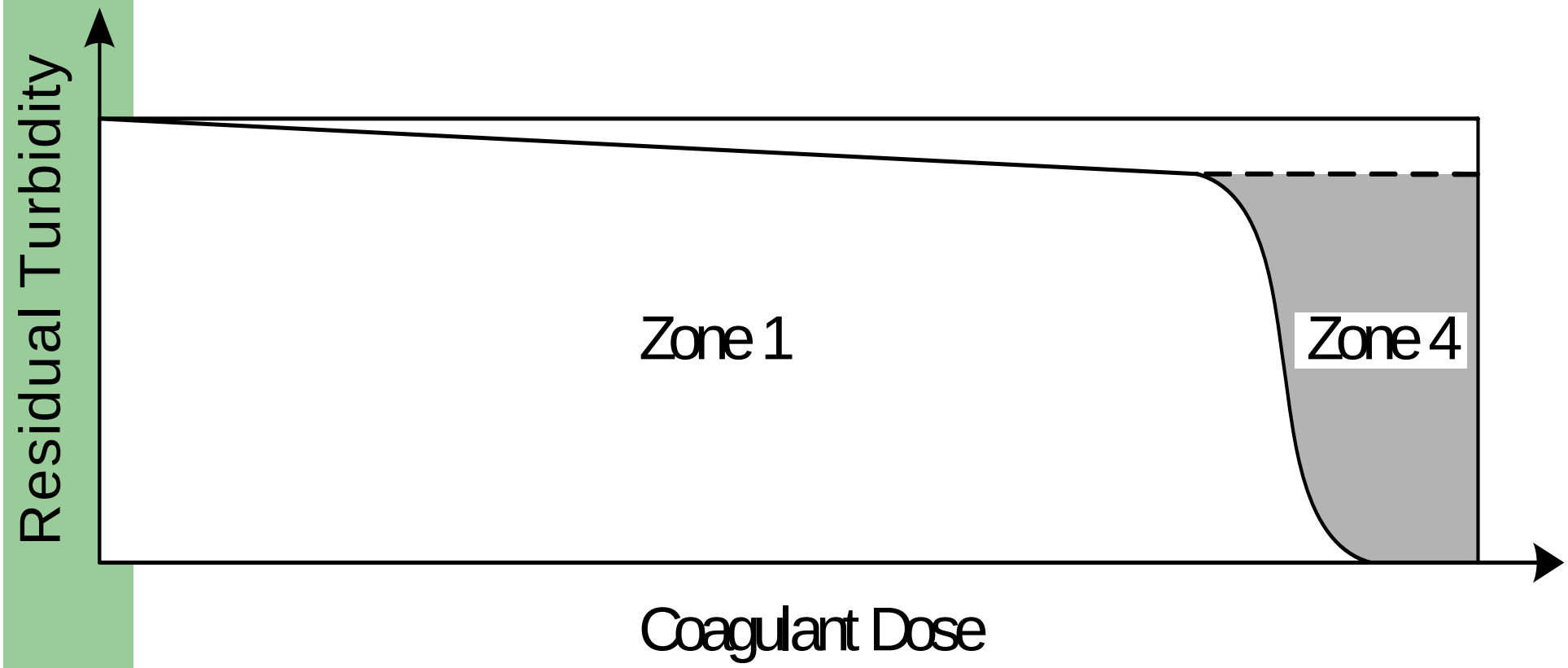


Figure 2-5 Coagulant Dose Versus <u>Moderate Colloidal Concentrations</u> (Residual Turbidity)

Source: O'Melia, 1972.

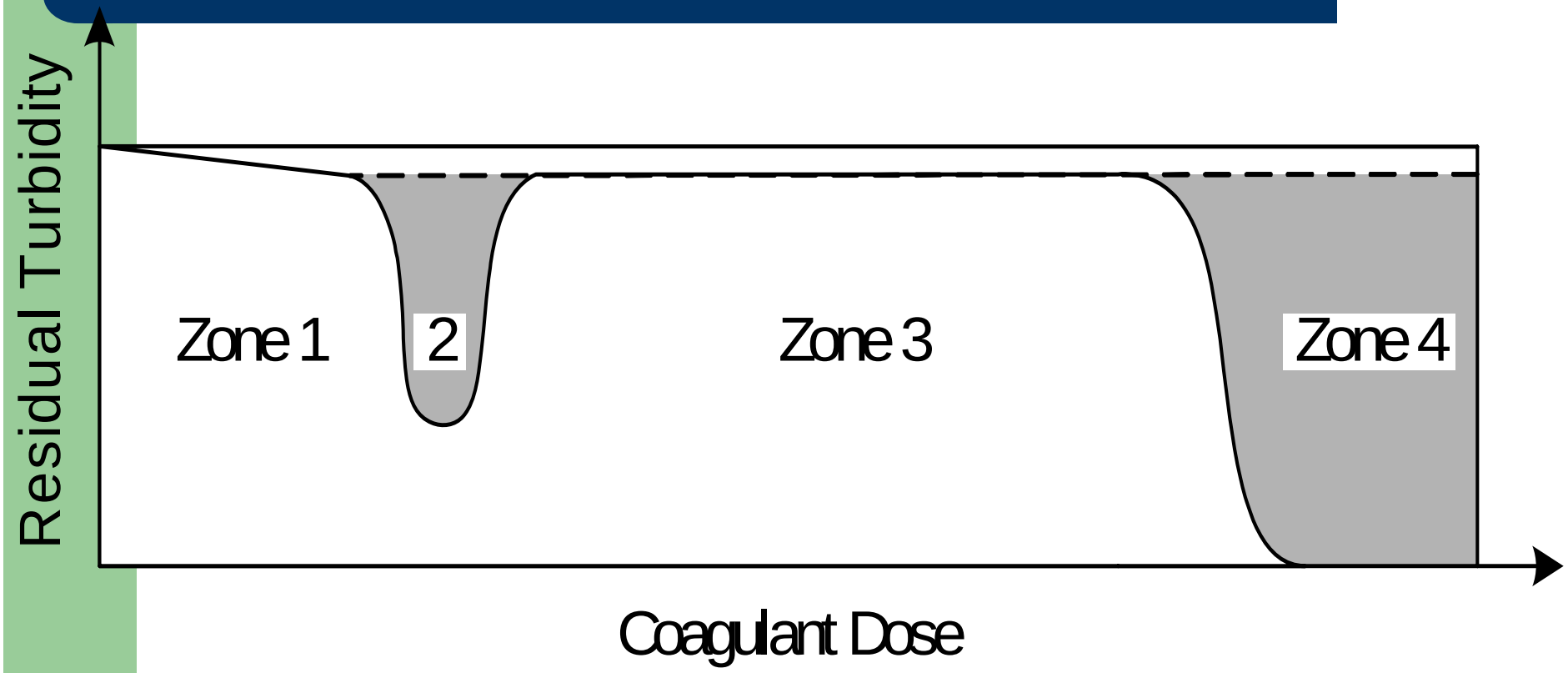


Figure 2-6 Coagulant Dose Versus High Colloidal Concentrations (Residual Turbidity)

Source: O'Melia, 1972.

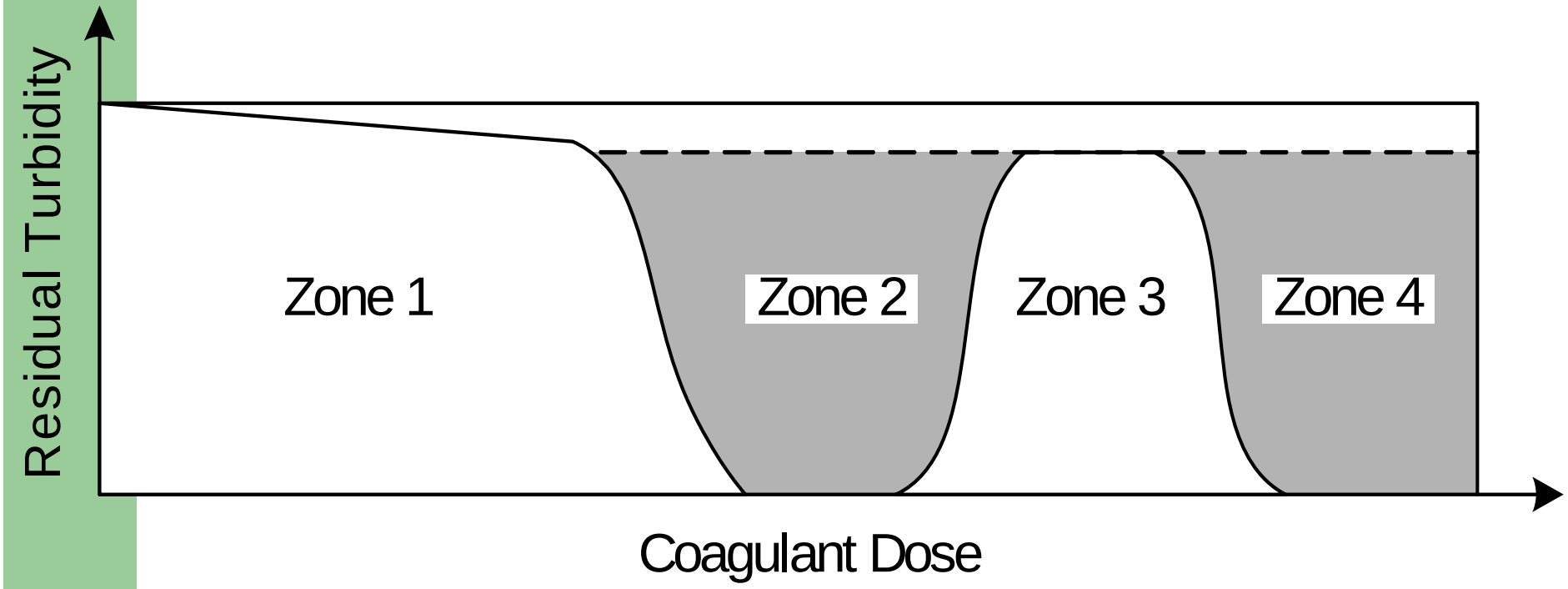
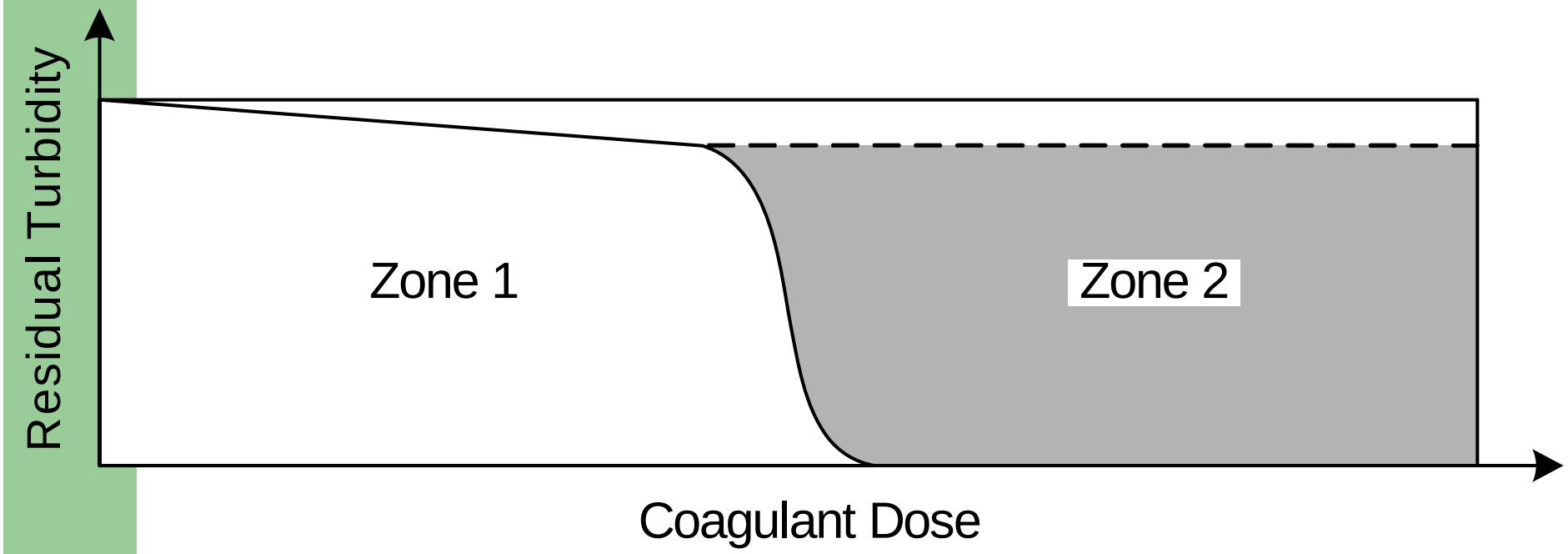
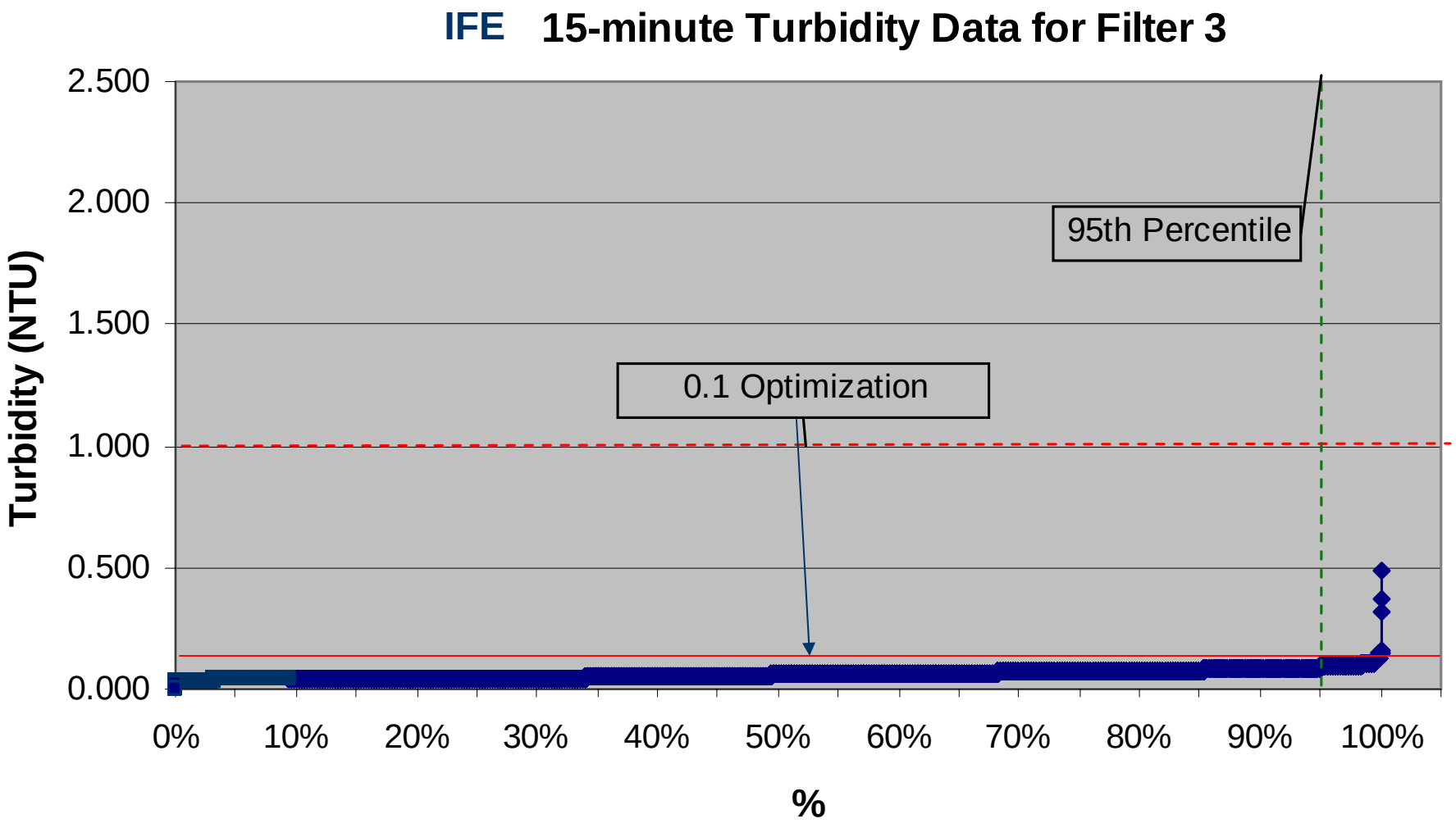


Figure 2-7 Coagulant Dose Versus <u>Very High Colloidal Concentrations</u> (Residual Turbidity)

Source: O'Melia, 1972.




IFE 15-minute Turbidity Data for Filter 3
Turbidity (NTU)
2.500
2.000
1.500
1.000
0.500
0.000
95th Percentile
0.1 Optimization
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
%

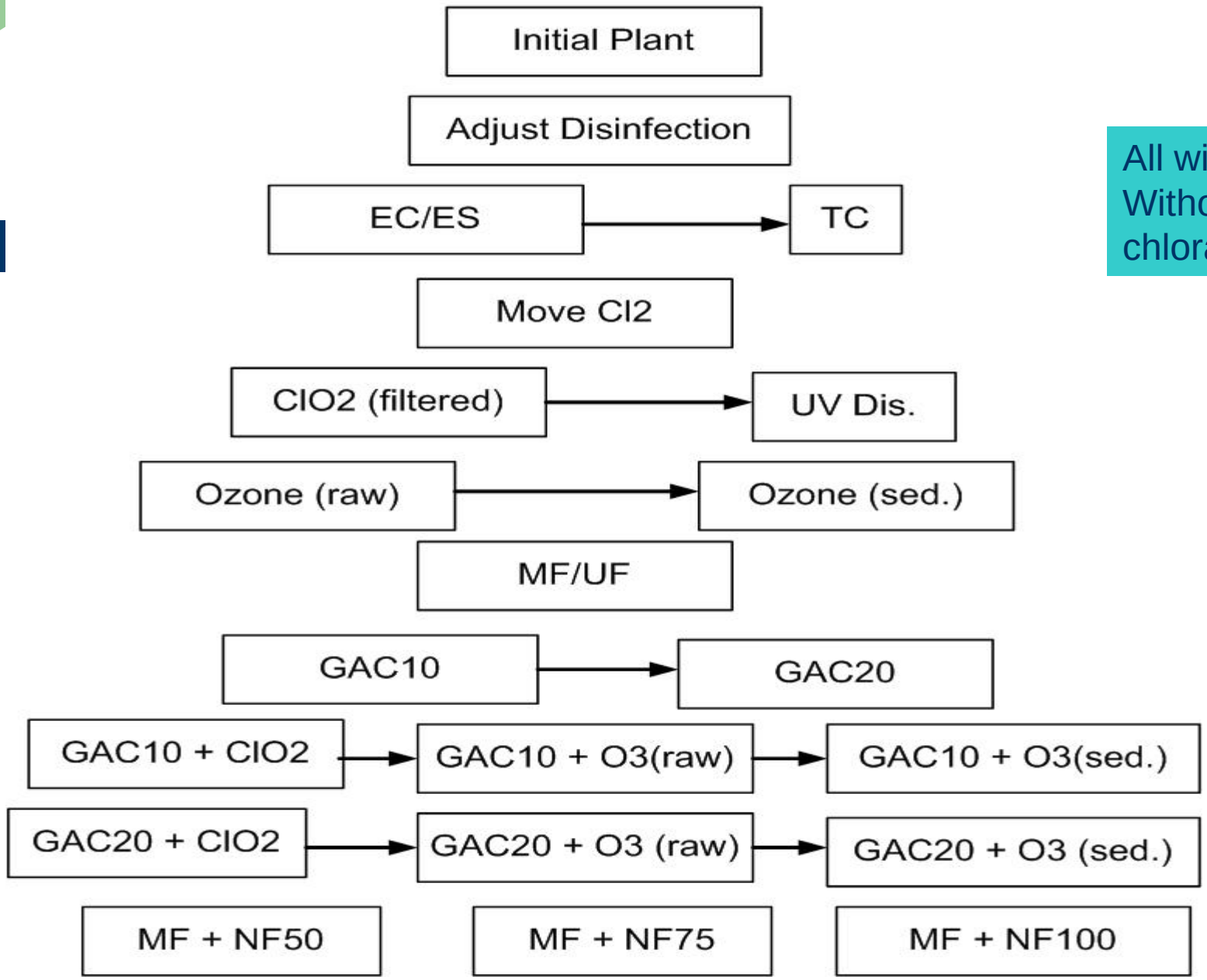
Electron Micrograph of Sand Grains With Attached Floc

Least-cost sorting routine for technology selection for large surface-water systems that filter: Used for Stage 1 Rule development

Treatment Technology

Cl2/conventional
Cl2/NH2Cl
Enhanced Coagulation
Enhanced coagulation + Cl2/NH2Cl
O3/NH2Cl
Enhanced coagulation + O3/NH2Cl
GAC10
Enhanced coagulation + GAC10
Enhanced coagulation + GAC10 + Cl2/NH2Cl
GAC10 + O3/NH2Cl
Enhanced coagulation + GAC10 + O3/NH2Cl
GAC20
Enhanced coagulation + GAC20
GAC20 + O3/NH2Cl
Enhanced coagulation + GAC20 + O3/NH2Cl
Enhanced coagulaton + membranes

Large-system decision tree for Stage 2 and LT2 used in RIA



All with or Without chloramines

Case Studies of Modified Treatment Practices for Disinfection Byproduct Control, **AWWARF, 2003**

"The decision-making process will actually address multiple water quality objectives as well as operational, engineering, and financial issues."

Multiple Water Quality Objectives

- Color
- Taste and Odor
- Arsenic
- VOCs and/or SOCs
- TDS
- Iron/Manganese

Operational and engineering constraints/issues

Retrofit issues
Plant hydraulics
Plant layout
Space availability
Electrical requirements
Infrastructure replacement
Capacity of facility
Compatible with rest of treatment process
Compatible with other plants in system

Financial constraints/issues

Access to capital
Impact on rates
Staged implementation
Uncertainty of future regulations

Comparison of different technologies for the control of multiple water-quality objectives*

Issue	EC	ES	NH_2Cl	ClO_2	O_3	UV	GAC	NF/RO
Regulatory use								
Control THM/HAA formation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Remove/inactivate *Giardia*	Yes	---	---†	Yes	Yes	Yes	---	Yes
Remove/inactivate viruses	Yes	---	---†	Yes	Yes	Yes	---	Yes
Remove/inactivate *Cryptosporidium*	Yes	---	No	Yes	Yes	Yes	---	Yes
Remove/oxidize SOCs	No	No	No	---	Yes	No	Yes	Yes
Remove/biodegrade AOC	Yes	---	No	No	No	No	Yes	---
Biodegrade HAAs	No	No	No	No	No	No	Yes	No
Other water-quality objectives								
Remove/oxidize tastes and odors	No	No	No	Yes	Yes	No	Yes	Yes
Remove/oxidize color	Yes	---	No	---	Yes	No	Yes	Yes
Remove hardness	No	Yes	No	No	No	No	No	Yes
Possible tradeoffs								
Form other regulated DBPs	No	No	No	Yes	Yes	No	No	No
Form other DBPs (non-regulated)	No	No	Yes	Yes	Yes	No	No	No
Form AOC	No	No	No	No	Yes	No	No	No
Kidney dialysis issues	No	No	Yes	Yes	No	No	No	No
Nitrification issues	No	No	Yes	No	No	No	No	No
Residuals issues	Yes	Yes	No	No	No	No	---‡	Yes
Corrosion issues	Yes	Yes	Yes	No	No	No	No	Yes

*This is a general, overall comparison. For specific contaminants, each technology has a different level of efficacy.

†Chloramines are not a strong disinfectant for the inactivation of *Giardia* or viruses.

‡Depending on the GAC usage, there is the need for periodic replacement or reactivation of the GAC.

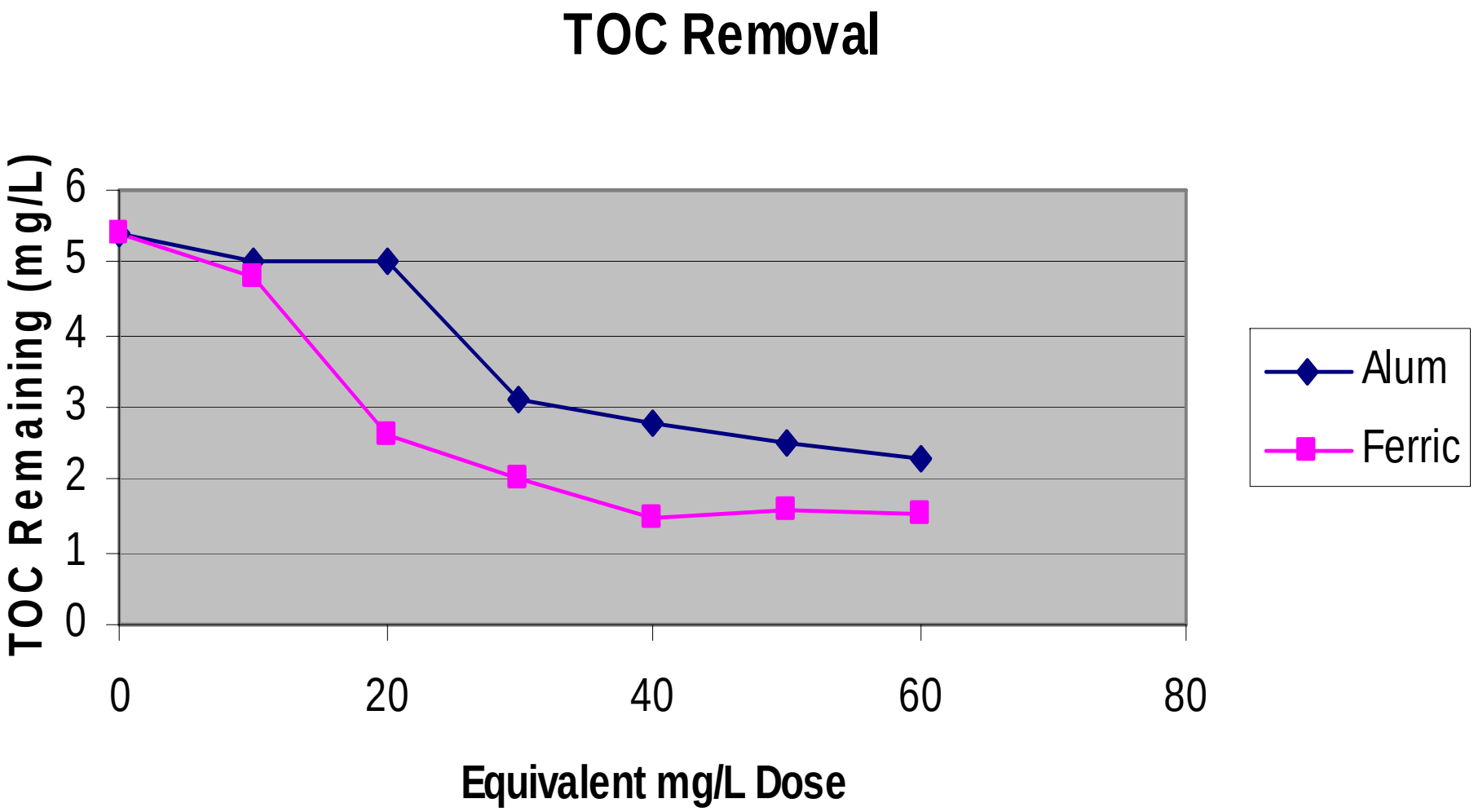
Case 1: Ann Arbor

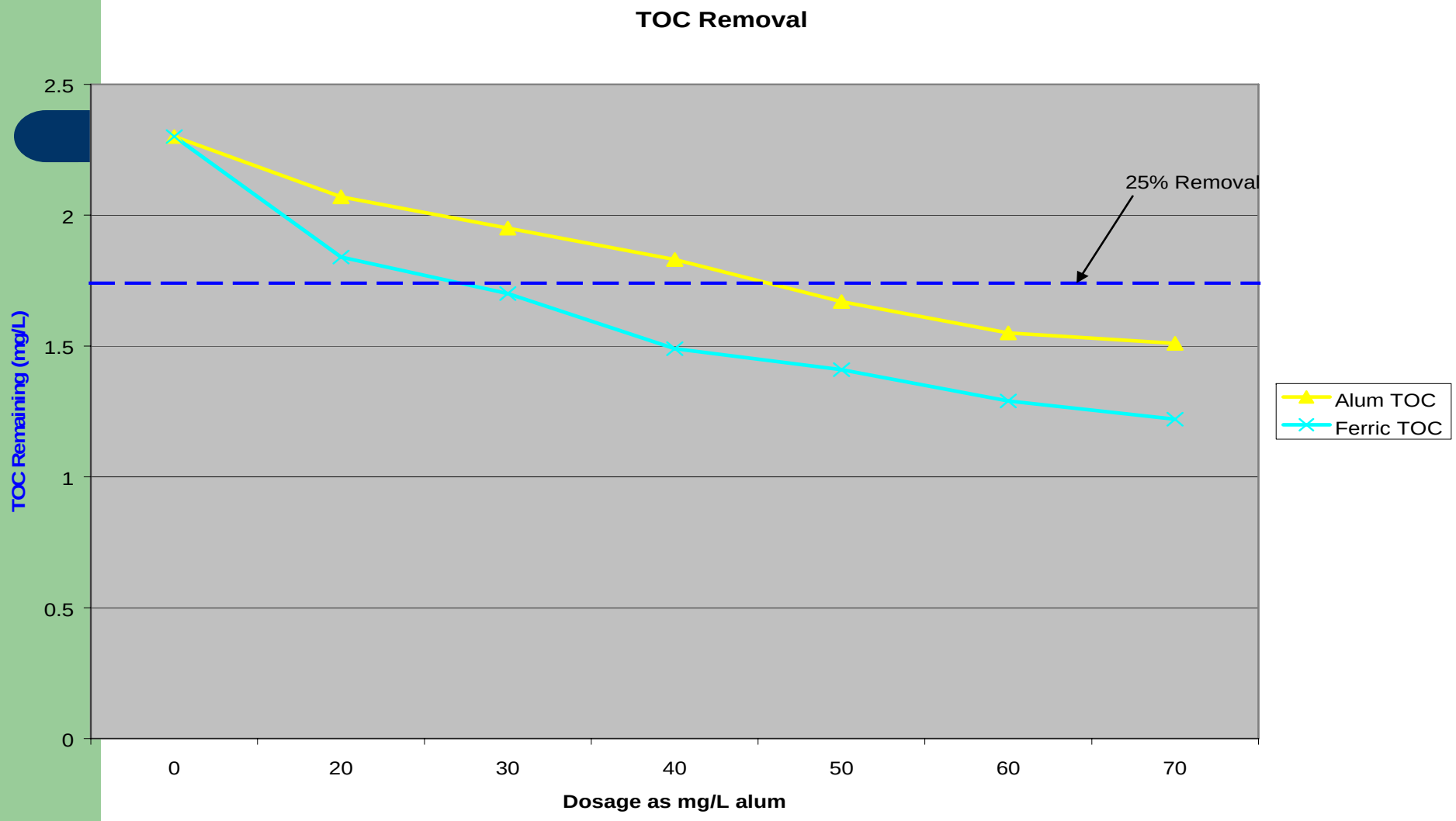
- THMs ok but sometimes out of compliance with SWTR
  - Need to improve disinfection without impacting DBPs
    - Ozone introduced bromate as an issue
      - If bromide was too high, they would have had to pursue another option (or make adjustments to the processes)

Case 2: Tampa

- Optimization of existing processes
  - Optimized coagulation process to get better TOC removal
    - Had the side benefit of removing more color

Jar Testing to Compare Coagulants



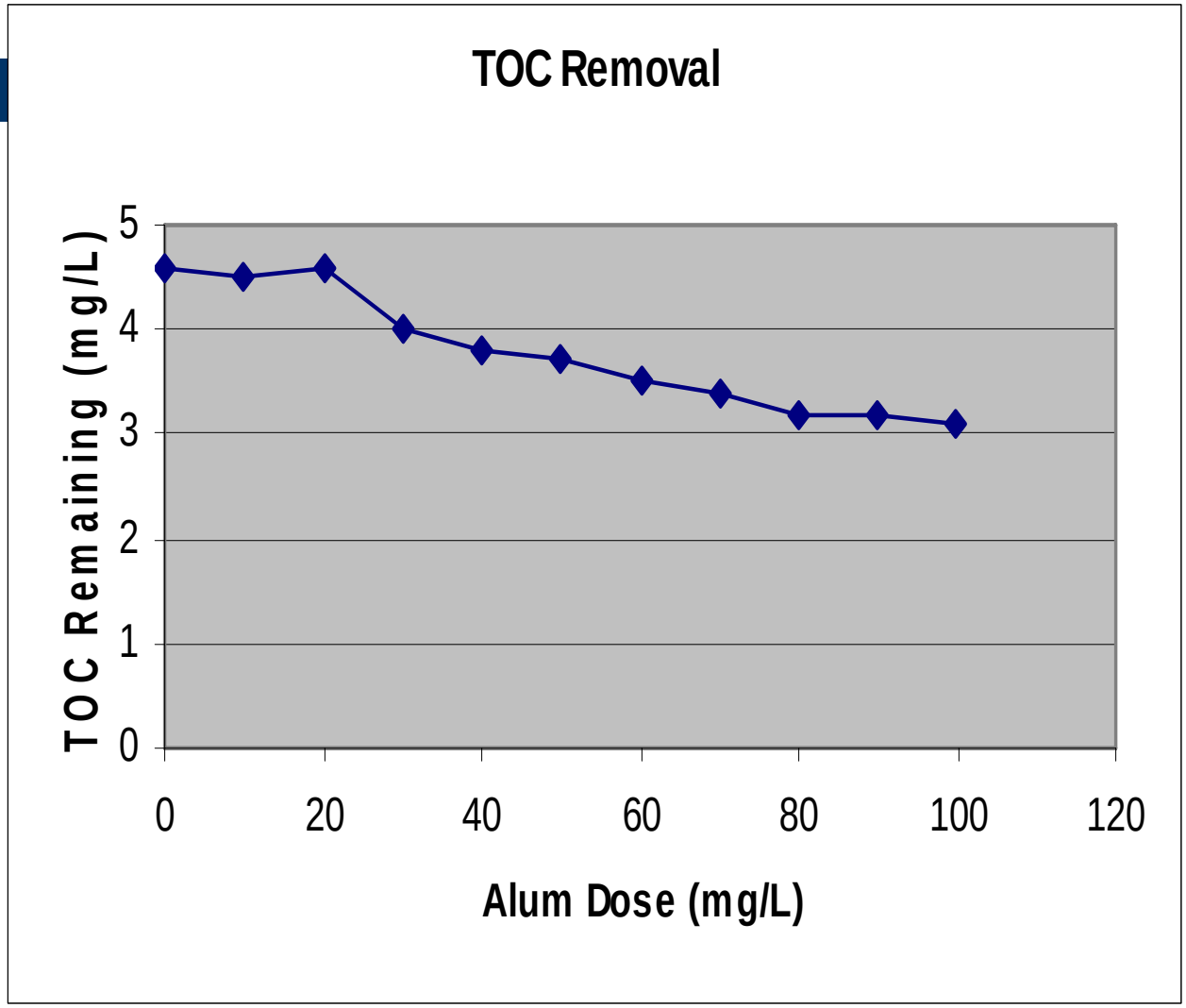

TOC Removal
2.5
2
1.5
1
0.5
0
TOC Remaining (mg/L)
25% Removal
Alum TOC
Ferric TOC
0
20
30
40
50
60
70
Dosage as mg/L alum

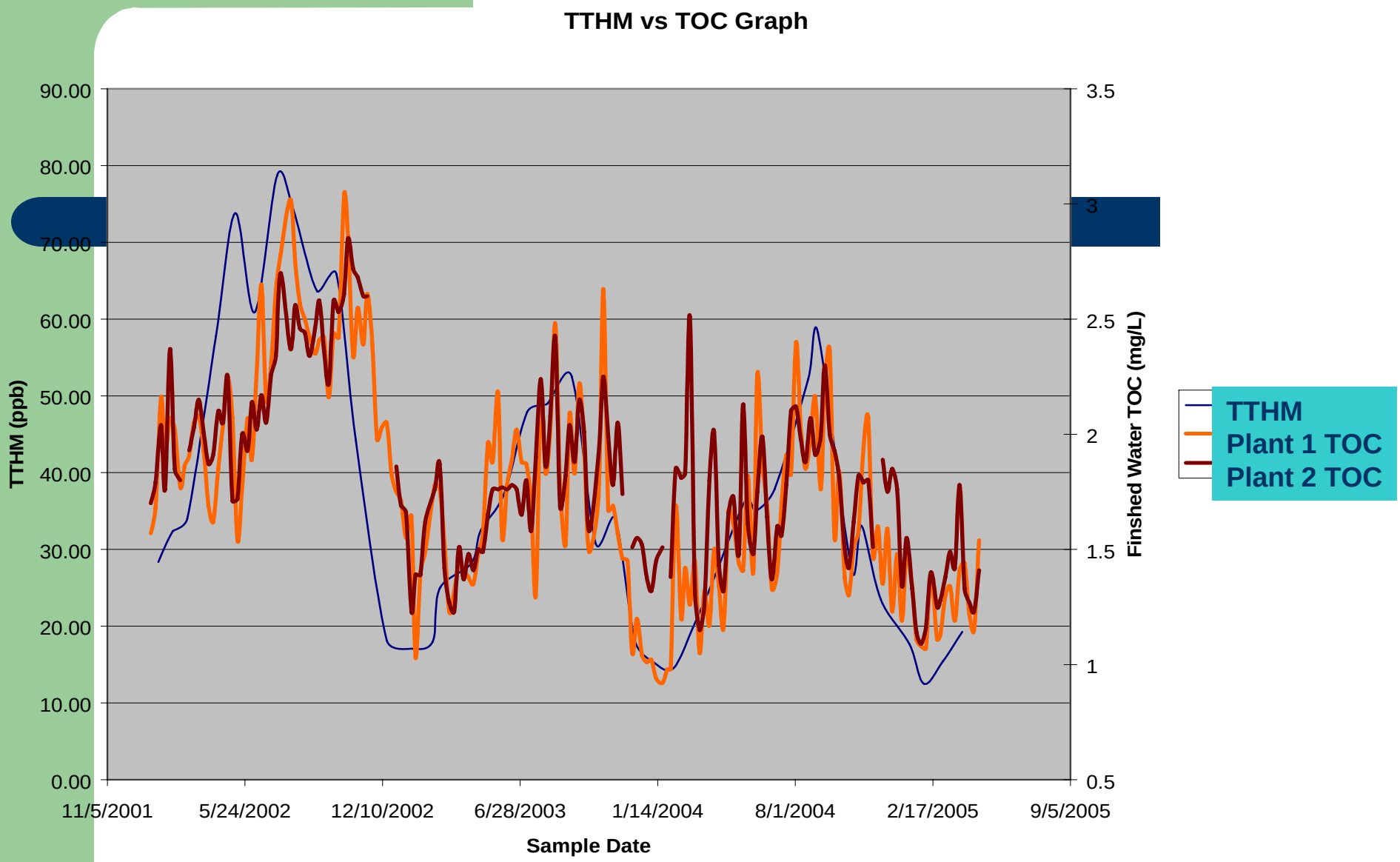
Other Jar Tests

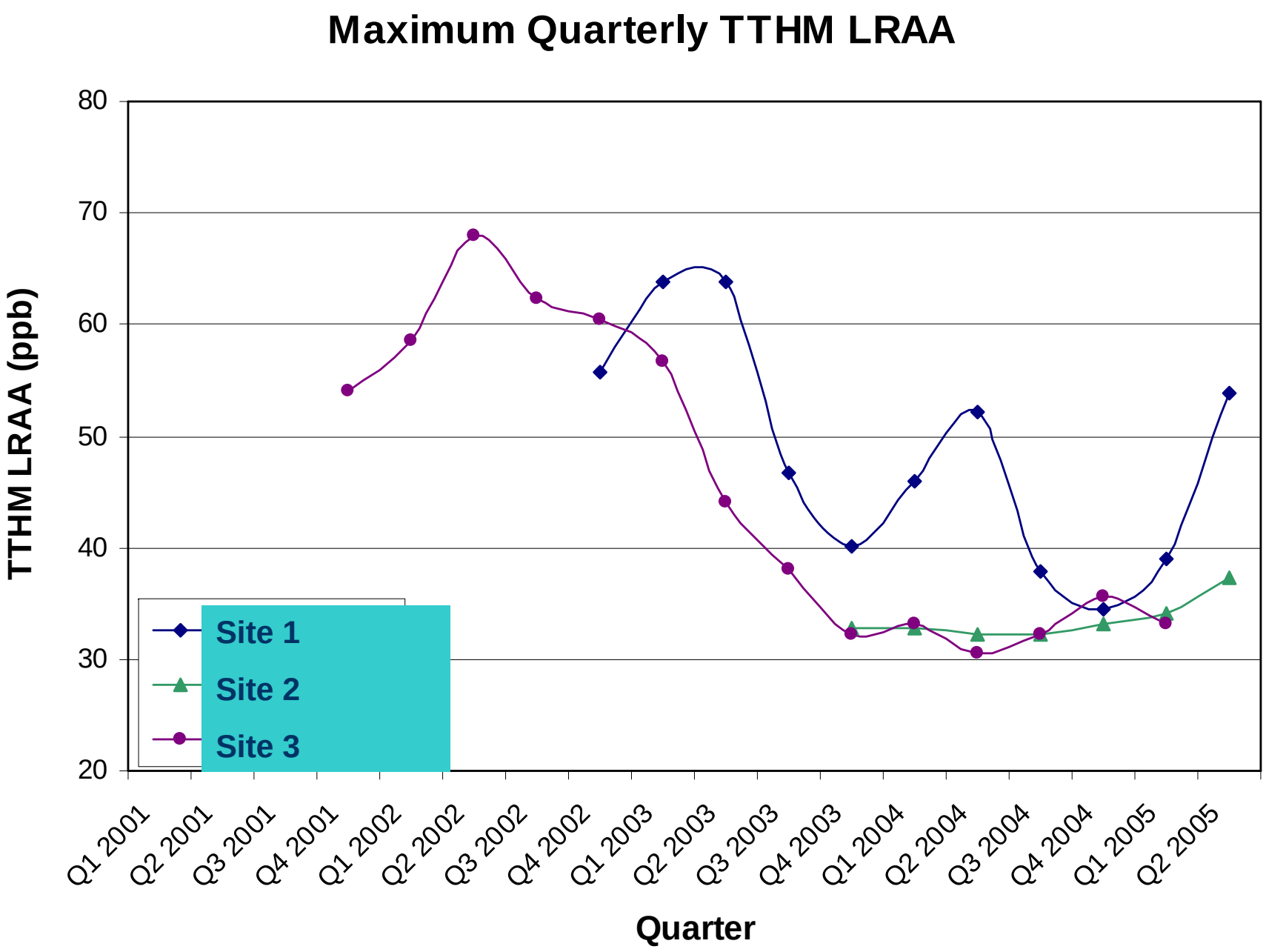
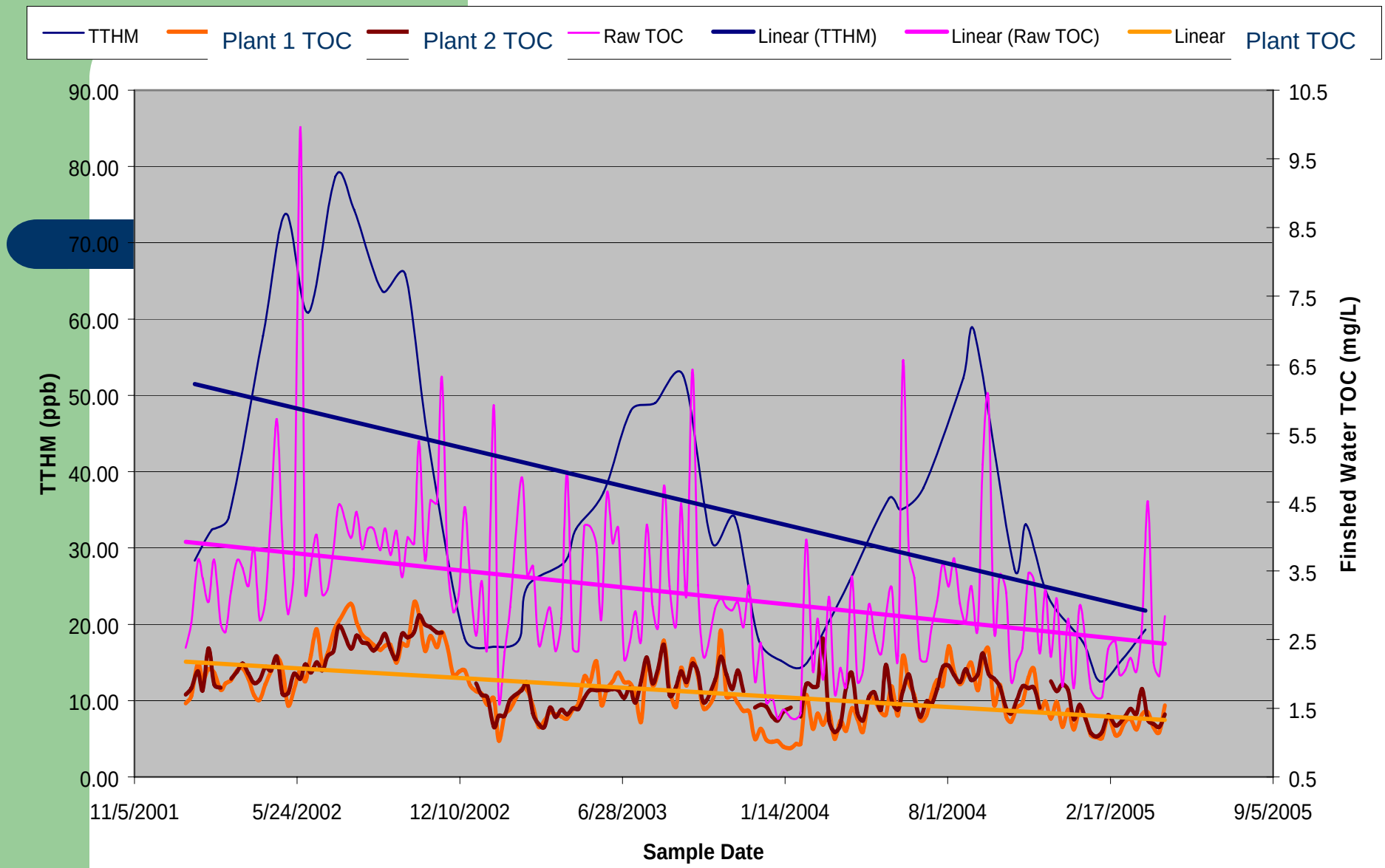
- Optimum Coagulant Dose
- Optimum pH
- Impact of Pre-oxidants
  - Ozone
  - $KMnO_4$
  - Chlorine Dioxide

Jar Testing to Determine Removal Potential

Alum Dose	TOC	Removed
0	4.6	
10	4.5	0.1
20	4.6	0
30	4	0.6
40	3.8	0.2
50	3.7	0.1
60	3.5	0.2
70	3.4	0.2
80	3.2	0.2
90	3.2	0
100	3.1	0.1




TTHM vs TOC Graph
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
TTHM (ppb)
3.5
3
2.5
2
1.5
1
0.5
Finshed Water TOC (mg/L)
11/5/2001
5/24/2002
12/10/2002
6/28/2003
1/14/2004
8/1/2004
2/17/2005
9/5/2005
Sample Date
TTHM
Plant 1 TOC
Plant 2 TOC


Maximum Quarterly TTHM LRAA
TTHM LRAA (ppb)
80
70
60
50
40
30
20
Site 1
Site 2
Site 3
Q1 2001
Q2 2001
Q3 2001
Q4 2001
Q1 2002
Q2 2002
Q3 2002
Q4 2002
Q1 2003
Q2 2003
Q3 2003
Q4 2003
Q1 2004
Q2 2004
Q3 2004
Q4 2004
Q1 2005
Q2 2005
Quarter

TTHM vs TOC Graph