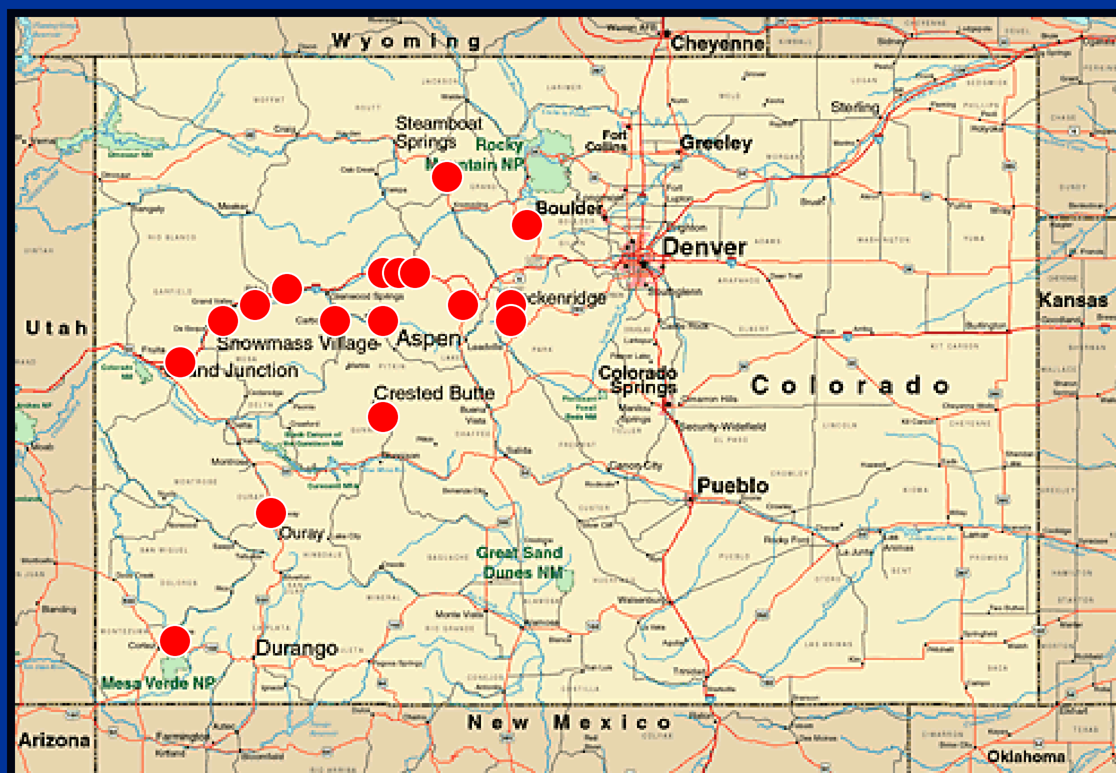
Case Studies:
GAC & Coagulation to Control DBPs at Membrane Filtration Plants

SGM Fall Forum

October 30, 2009

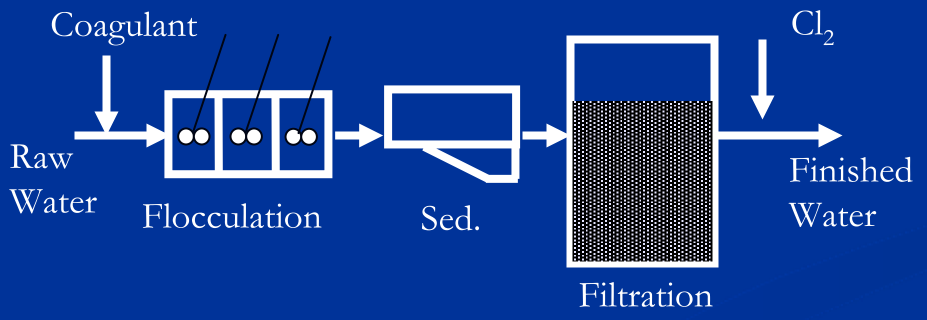
Define the Problem

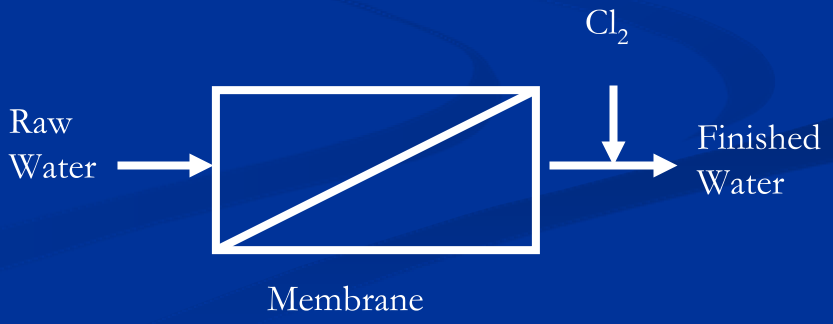
- Many Western Slope utilities installed MF/UF membranes in the early 2000's…



Define the Problem

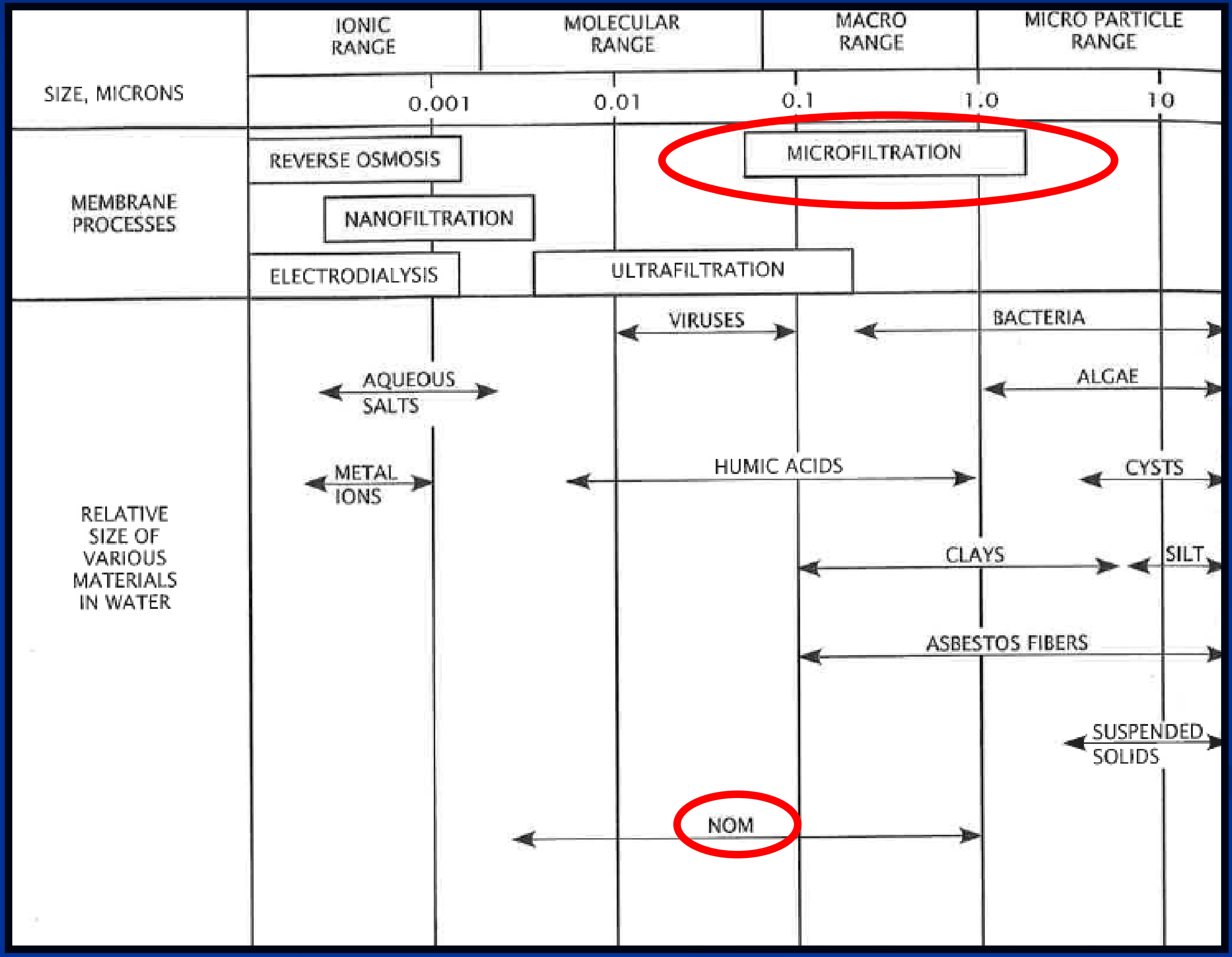
- The coagulation/flocculation process was often removed…





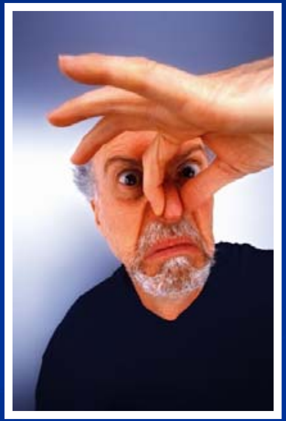
Define the Problem

- So was the barrier for NOM removal…



Define the Problem

- NOM (or TOC) causes treatment issues…
  - Objectionable T&O
  - Color
  - Impart high oxidant demand
  - Facilitate transport of organic and inorganic pollutants
  - Impede process performance
  - DBP precursor



Define the Problem

- DBPs are regulated…

.	Disinfection Byproduct	MCL (mg/L)	MCLG (mg/L)
(1)	Total trihalomethanes (TTHM)	0.080[1]	
(a)	Bromodichloromethane	.	Zero
(b)	Bromoform	.	Zero
(c)	Chloroform	.	0.07
(d)	Dibromochloromethane	.	0.06
(2)	Haloacetic acids (five) (HAA5)	0.060[1]	.
(a)	Bromoacetic acid	.	N/A
(b)	Dibromoacetic acid	.	N/A
(c)	Dichloroacetic acid	.	Zero
(d)	Monochloroacetic acid	.	0.07
(e)	Trichloroacetic acid	.	0.02
(3)	Bromate[2]	0.010	Zero
(4)	Chlorite[3]	1.0	0.8

Define the Problem

- DBP regulations became stricter (Stage 2 D/DBP Rule)…

Table 7-30 Compliance Dates

If the system is a…….	The system must comply with section 7.8 monitoring by[1]
Systems that are not part of a combined distribution system and systems that serve the largest population in the combined distribution system	
(1) System serving ≥ 100,000	April 1, 2012
(2) System serving 50,000 – 99,999	October 1, 2012
(3) System serving 10,000 – 49,999	October 1, 2013
(4) System serving < 10,000	October 1, 2013 if no Cryptosporidium monitoring is required under section 7.4.2(a)(3) or October 1, 2014 if Cryptosporidium monitoring is required under sections 7.4.2(a)(3) and 7.4.2(a)(4)
Other systems that are part of a combined distribution system	
(5) Consecutive system or wholesale system	At the same time as the system with the earliest compliance date in the combined distribution system

Take Home Message #1

✓ NOM can pass through MF and UF membranes resulting in DBP problems

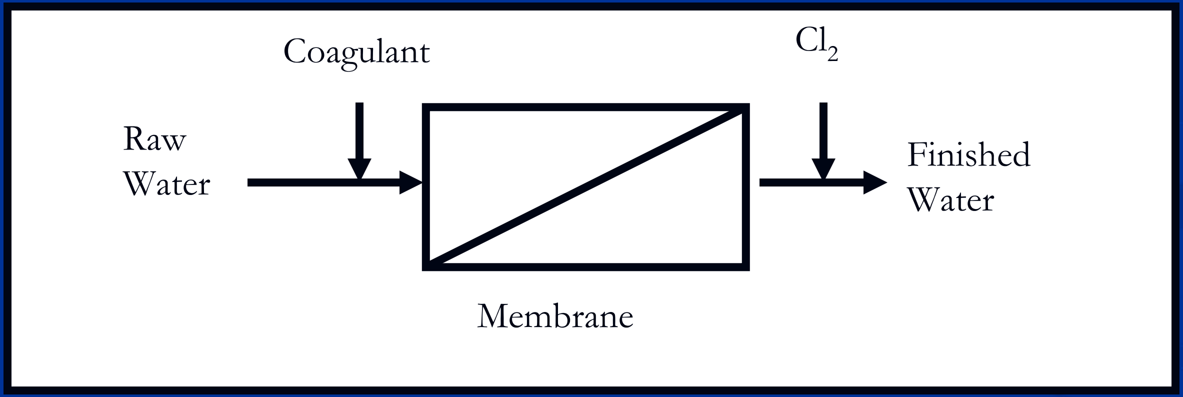
Treatment Techniques for NOM Removal or DBP Reduction

- DBP reduction
  - Distribution System Flushing
  - Blending
  - Change Point of Chlorination

- NOM Removal
  - Enhanced Coagulation
  - Enhanced Softening
  - Membrane Filtration (NF, RO)
  - GAC

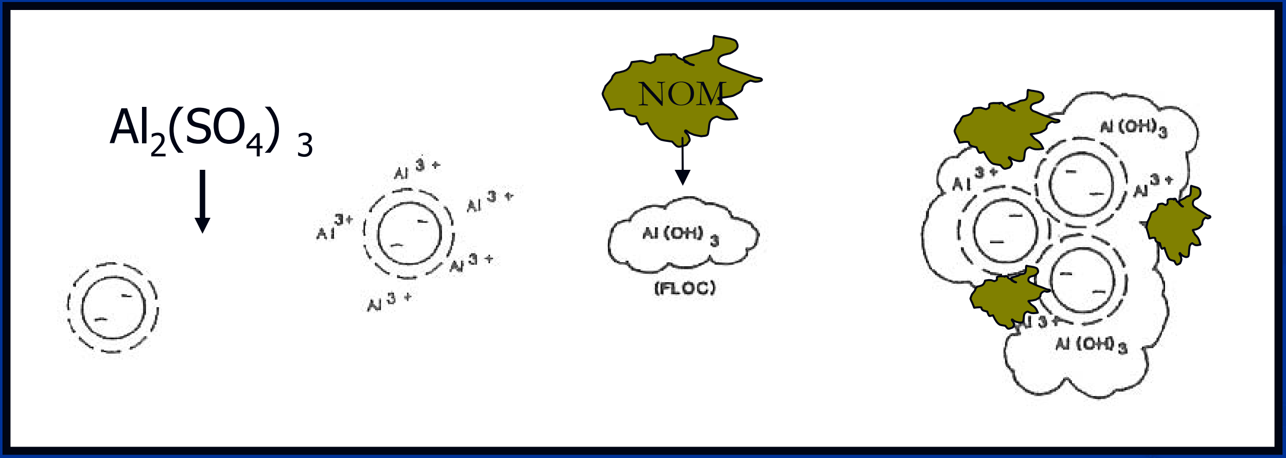
Coagulation Overview

- Coagulant fed upstream of membrane



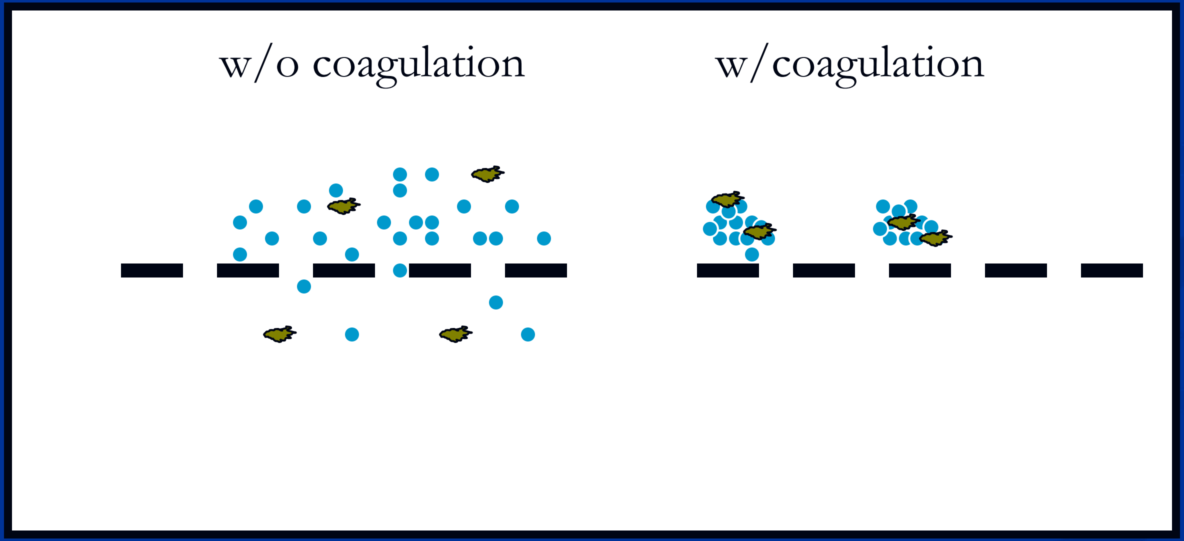
Coagulation Overview

- NOM adsorbed on floc particles



Coagulation Overview

- Rejection of particles & NOM improved



Coagulation/Flocculation Design Considerations

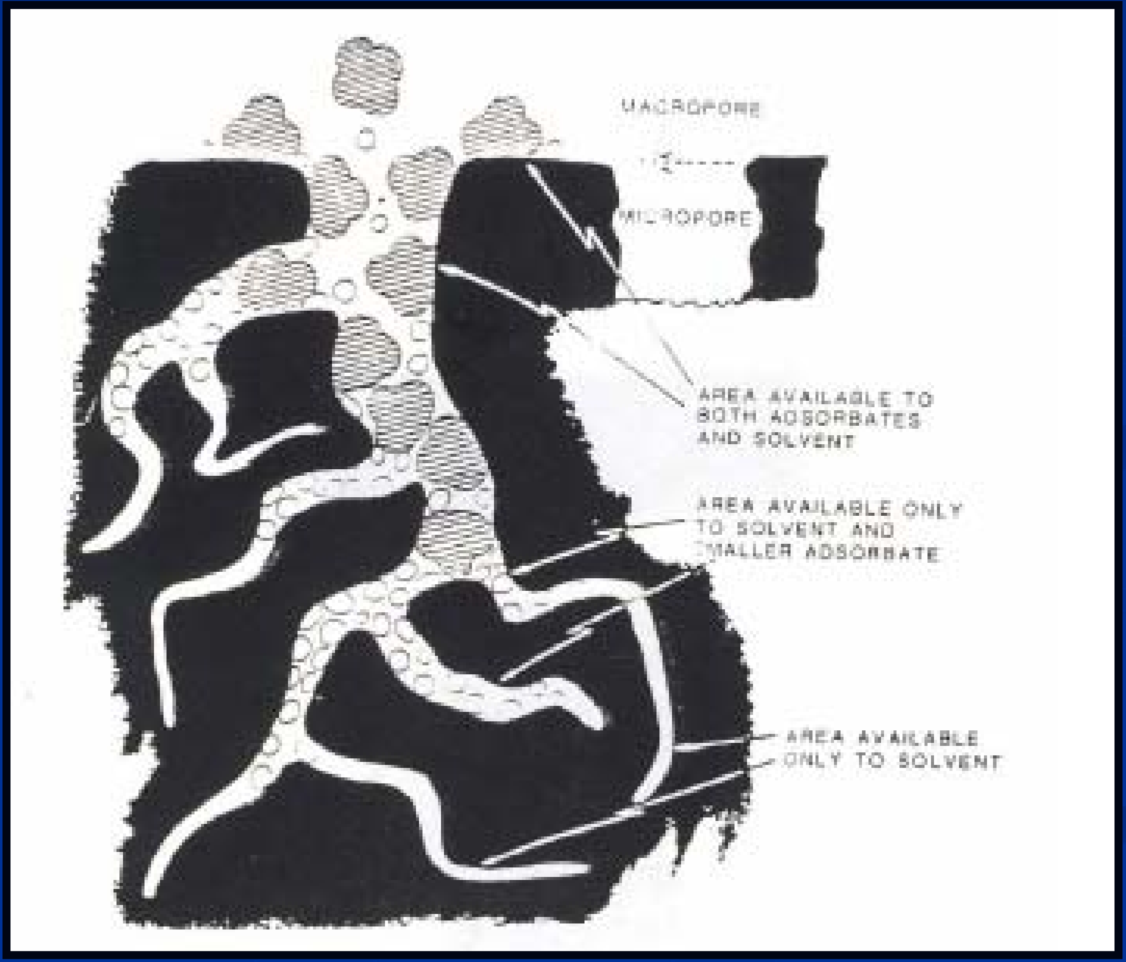
- Water quality
  - Turbidity
  - pH
  - Temperature
- Dosing location
- Coagulant type
- Interactions with membrane

GAC Overview

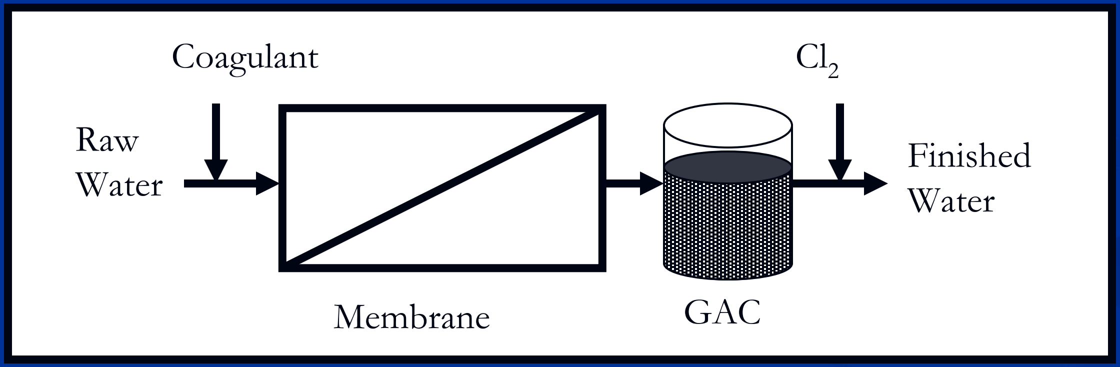
- Activated, porous adsorbent derived from carbonaceous sources:
  - coal (bituminous, lignite)
  - wood
  - coconut shells

- Drinking water applications:
  - taste and odor control
  - trace organic removal
  - total organic carbon removal

GAC Overview



GAC Overview



GAC Design Considerations

- Water quality
  - TOC
  - pH
- GAC size
- Hydraulic loading rate/EBCT
- GAC changeout frequency
- Pressure requirements

Take Home Message #2

- ✓ GAC and Coagulation can effectively remove TOC and reduce DBPs in membrane facilities

Process Selection

GAC

- Advantages
  - Can achieve TOC removal >90%
  - "guaranteed" TOC removal
- Disadvantages
  - Expensive
  - Possibly Frequent Regeneration
  - Difficult to predict GAC usage rates
  - More equipment

Coagulation

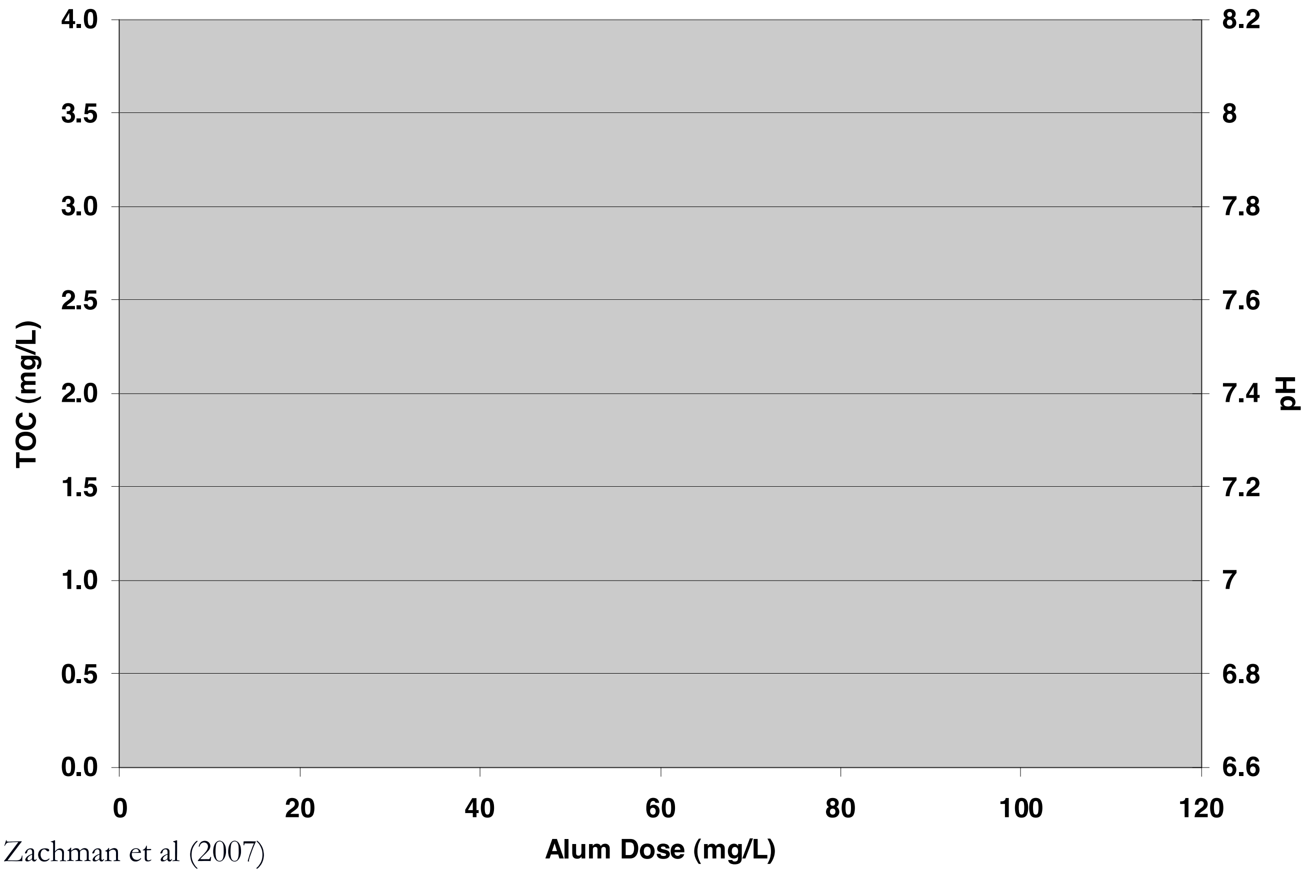
- Advantages
  - Cost effective
  - May be able to make use of existing equipment
- Disadvantages
  - Possibly increase membrane fouling
  - Typically removes only up to ~30% TOC

A Couple of Considerations…

- GAC usage rate (UR) improves at lower TOC and pH conditions
  - TOC: UR increases ~15% for every 0.5 mg/L drop in TOC
  - pH: UR increases ~10% for every 0.5 unit drop in pH

A Couple of Considerations…

- Coagulation can improve GAC performance



Zachman et al (2007)

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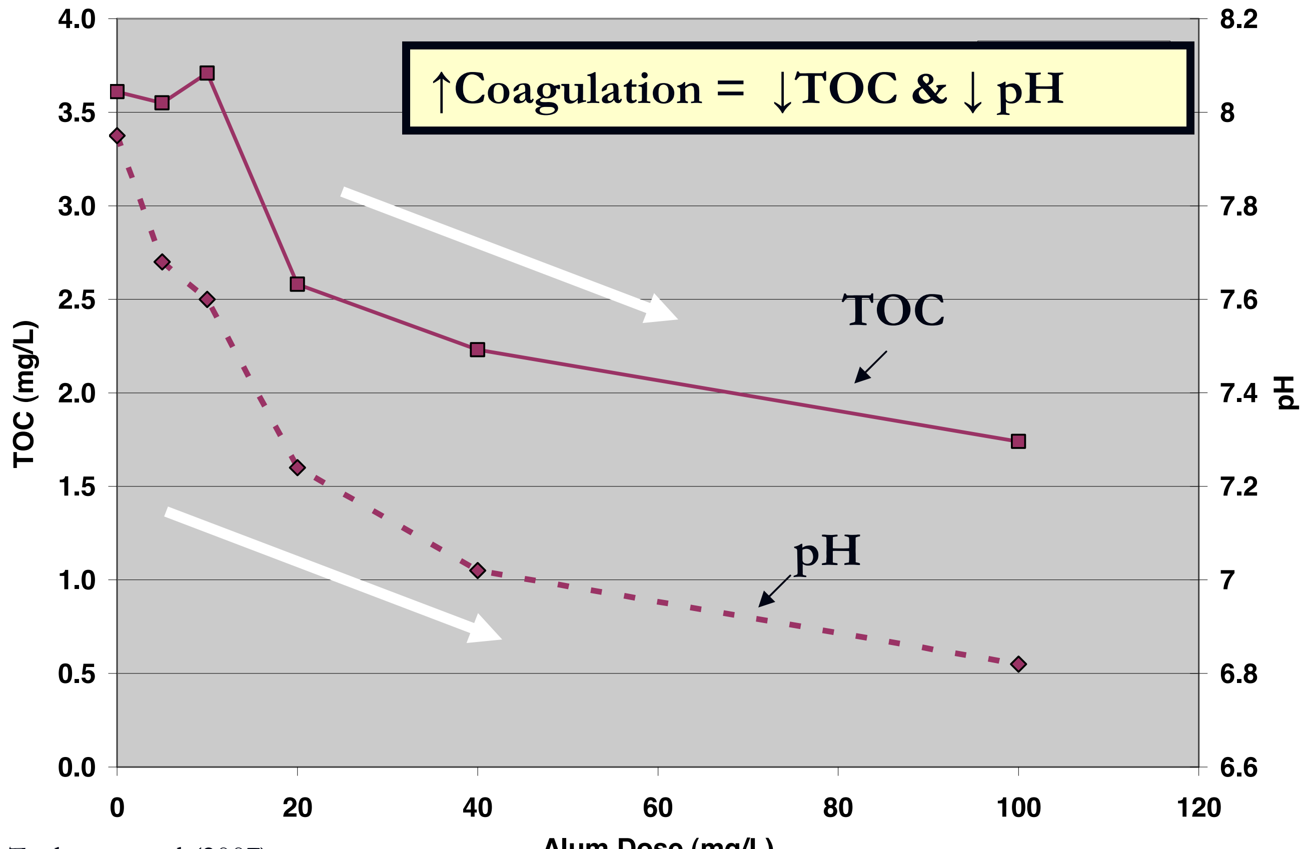

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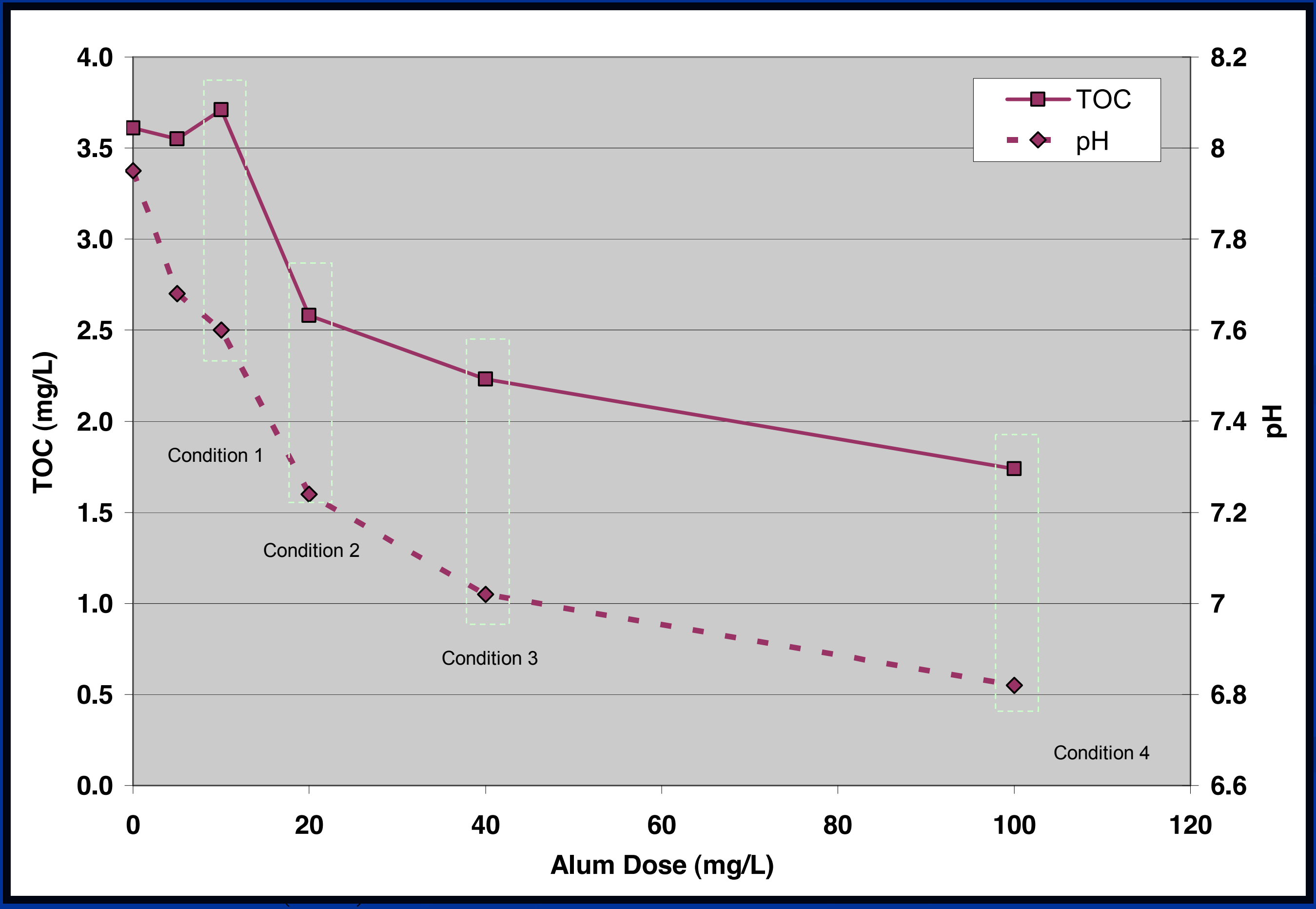
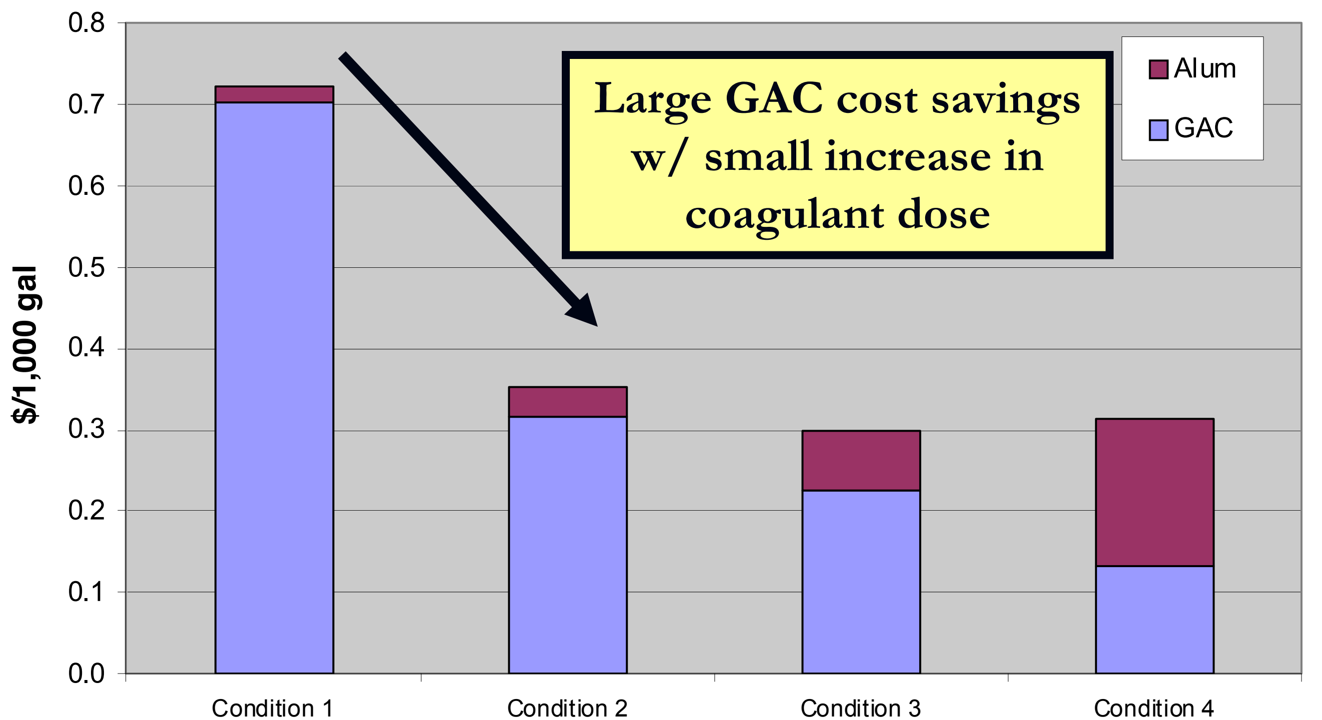


A Couple of Considerations…

- Coagulation can decrease GAC usage cost

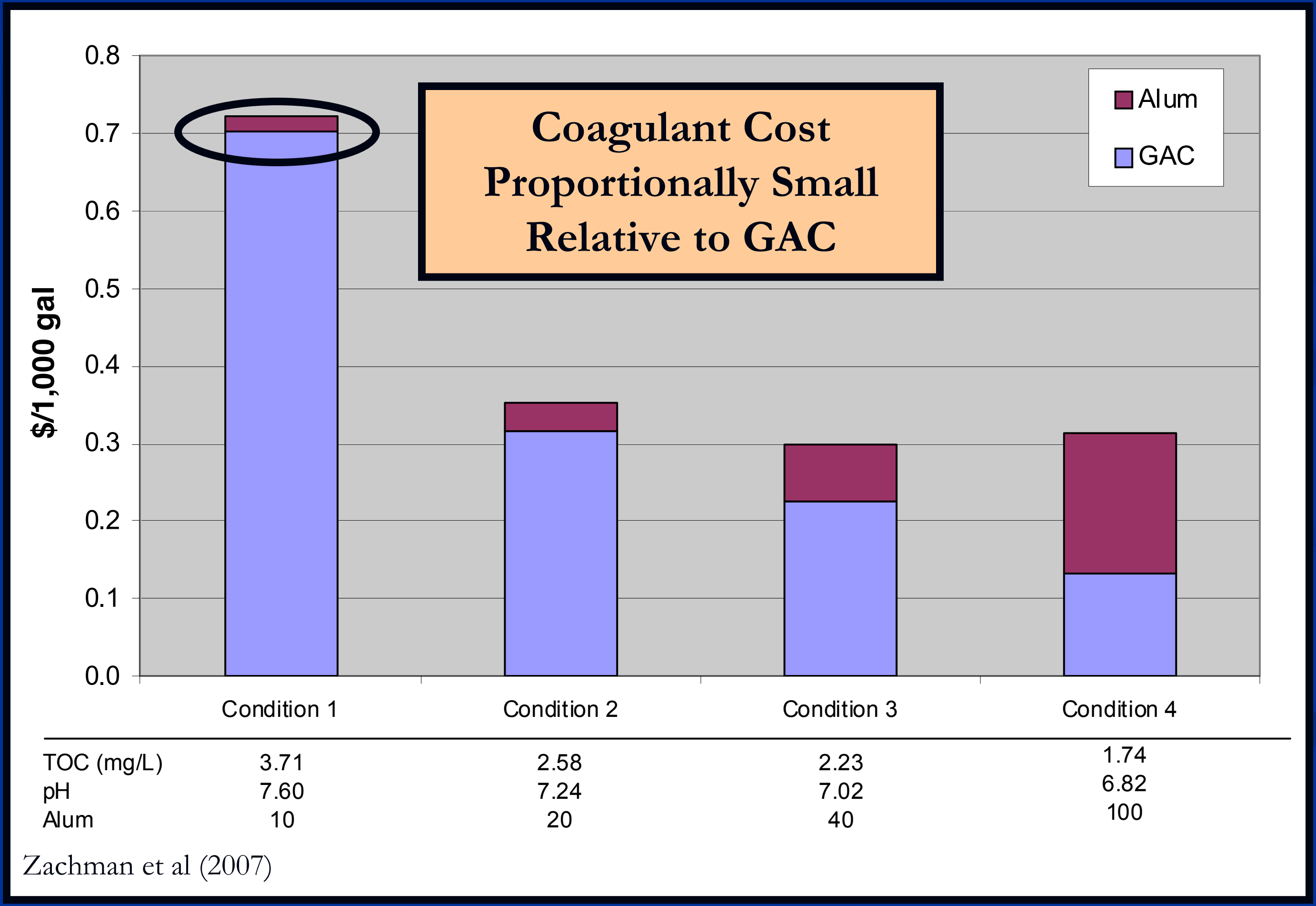


	Condition 1	Condition 2	Condition 3	Condition 4
TOC (mg/L)	3.71	2.58	2.23	1.74
pH	7.60	7.24	7.02	6.82
Alum	10	20	40	100

Zachman et al (2007)

A Couple of Considerations…

- Coagulation more cost effective than GAC



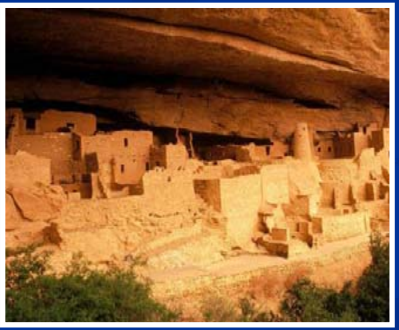
Take Home Message #3

- ✓ Coagulation is relatively inexpensive and may resolve the DBP problem--try it 1st!!!

- ✓ GAC can be later added if needed

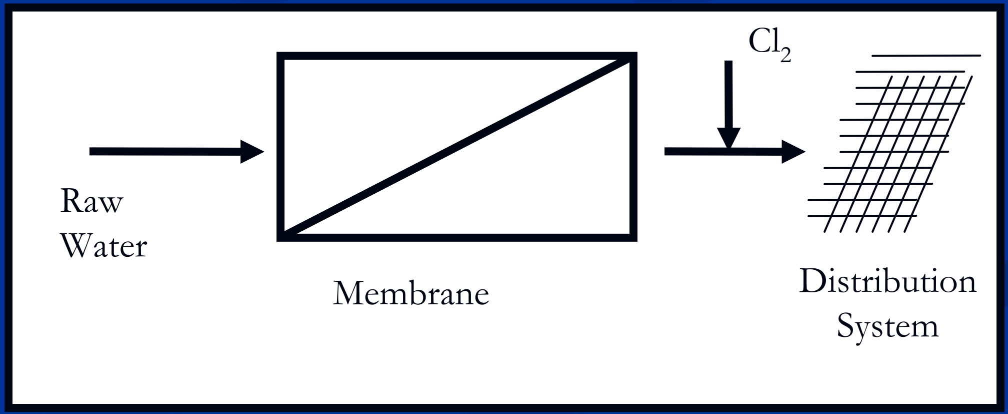
Case Study #1

Mesa Verde National Park WTP


MVWTP Overview

- Source: Mancos River
  - TOC: ~1 to 4 mg/L
  - Turbidity <3 ntu
- Capacity: 350 gpm
  - Seasonal demand
- MF Membranes
  - Installed in 2006
  - Replaced conventional packaged water treatment plant

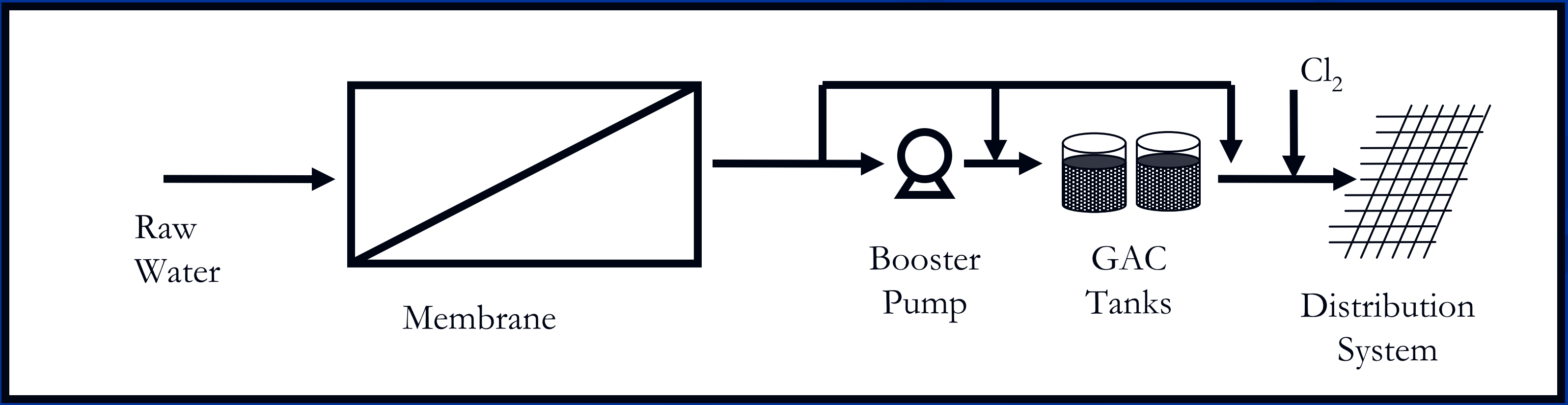


MVWTP Overview

- Problems:
  - Long distribution system residence times (>30 days)
  - High temperatures
  - TTHM levels exceed MCLs
  - Likely would not comply with Stage 2 D/DBPR
- Distribution System Flushing had Limited Success
- Additional Chemical (Coagulant) Addition not Desirable
  - Jar tests showed coagulation not effective

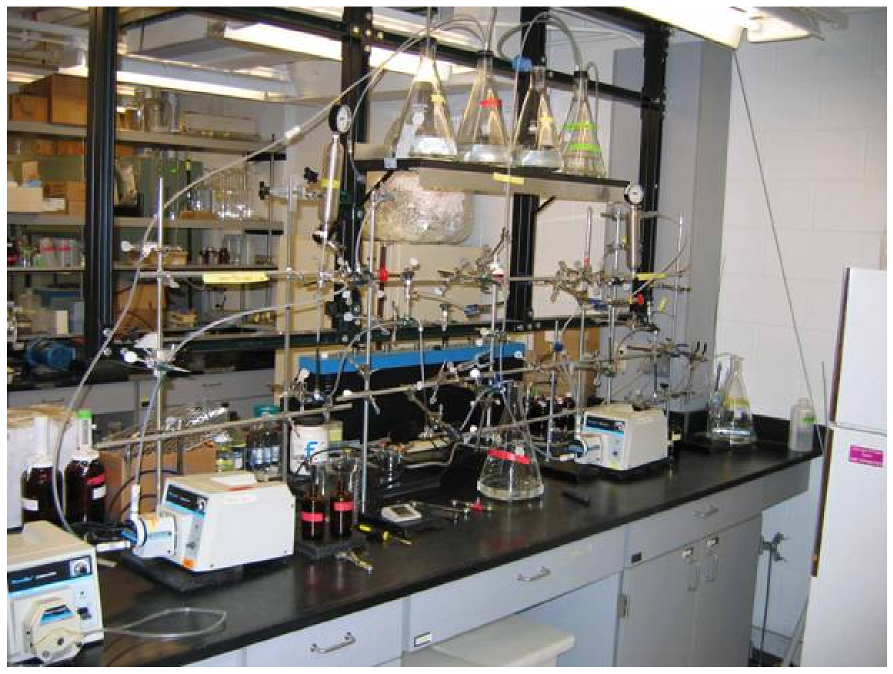
GAC Improvements

- GAC System
  - fully automated
  - Integrated into existing SCADA
- Split Flow Capabilities
- Backwash System
- Booster Pump w/ bypass option



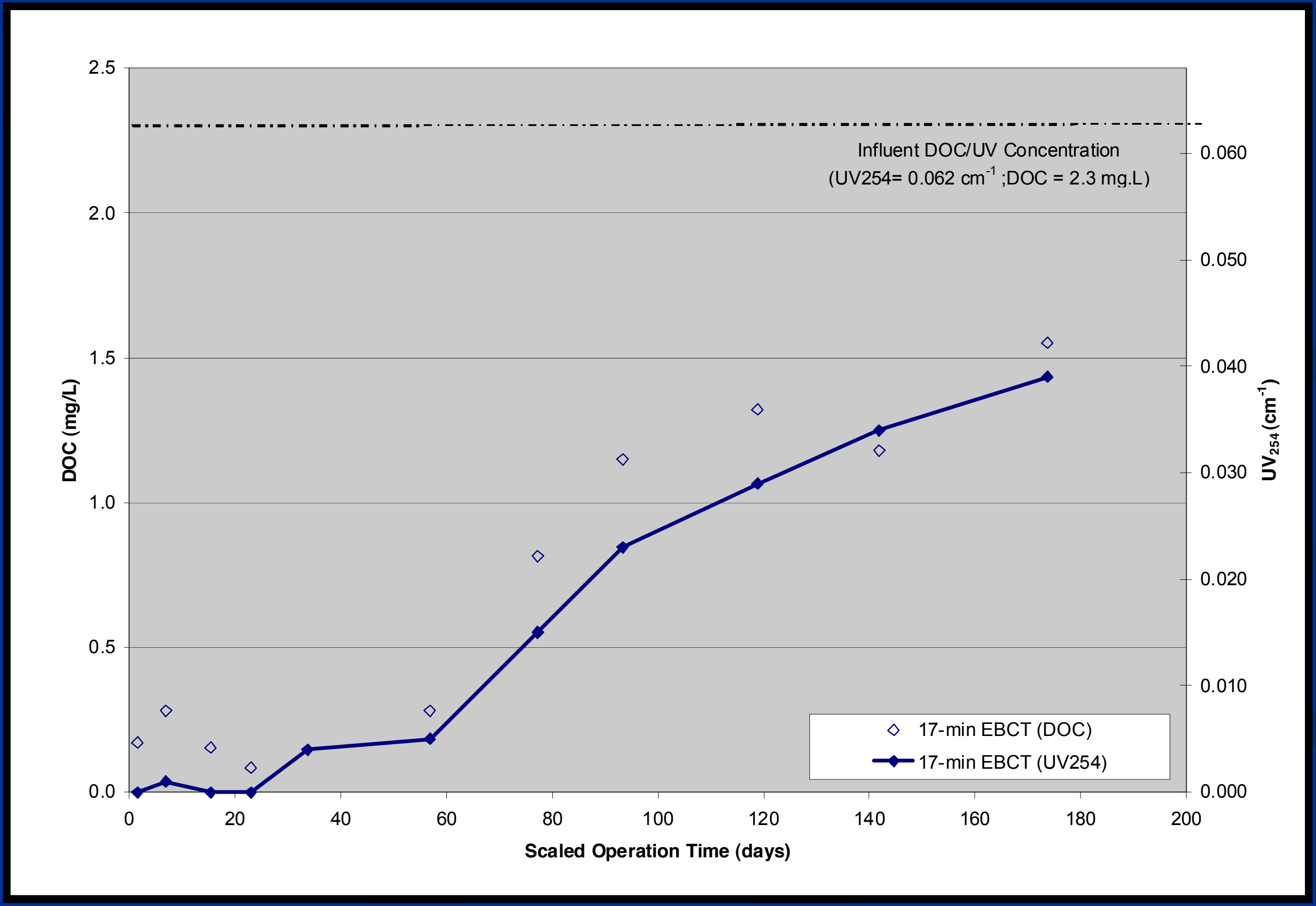
GAC Performance Testing

- Pilot Testing not Feasible
- Rapid Small Scale Column Test (RSSCT) Performed
  - Water collected during runoff period
  - Predict TOC breakthrough in 2-3 weeks
  - Small volume of water requirement



GAC Performance Testing

- RSSCT Breakthrough Results

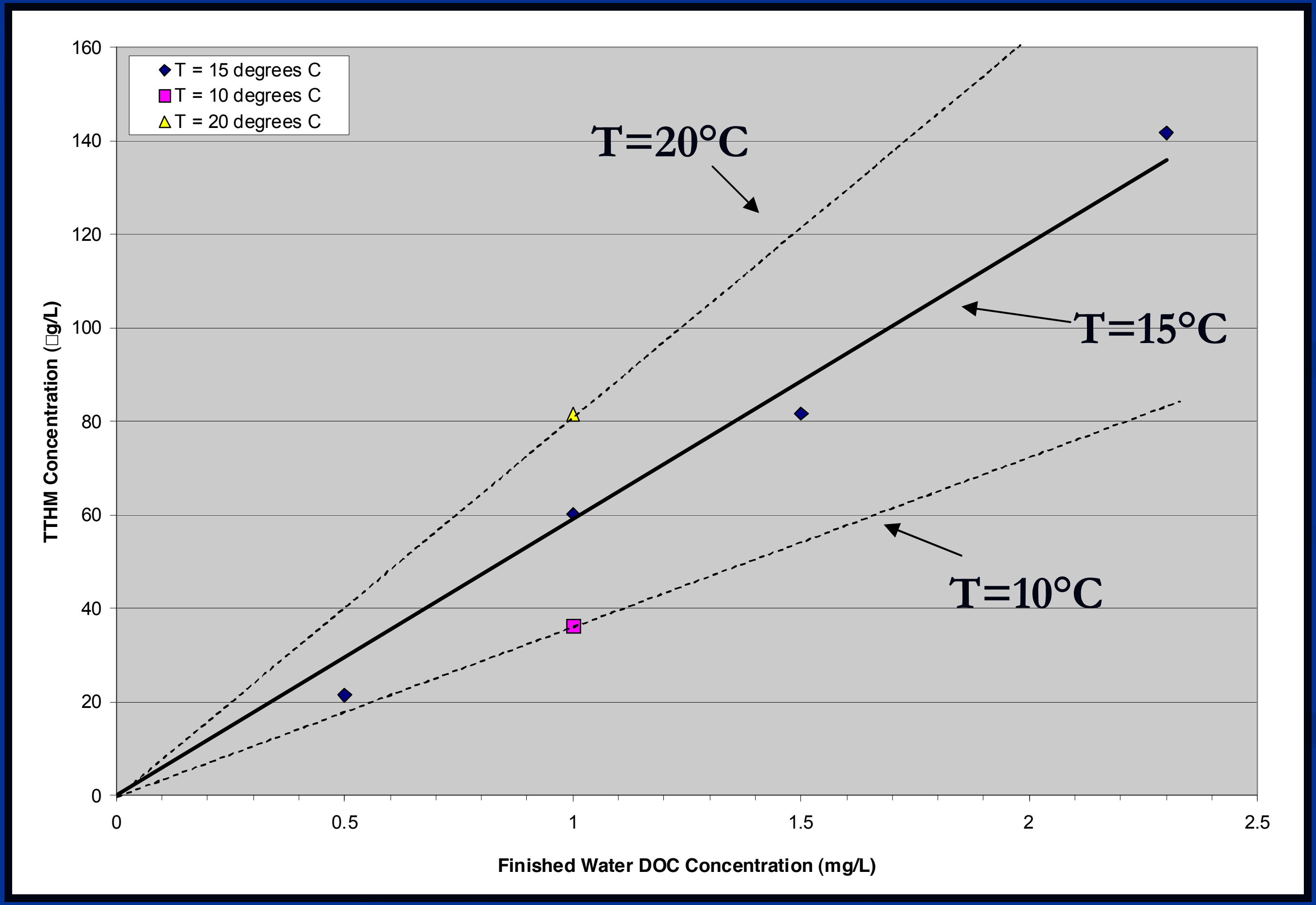


SDS-DBP Formation Testing

- Controlled Hold Study
- Simulates Distribution System Conditions
- "Predicts" TTHM & HAA5 concentrations

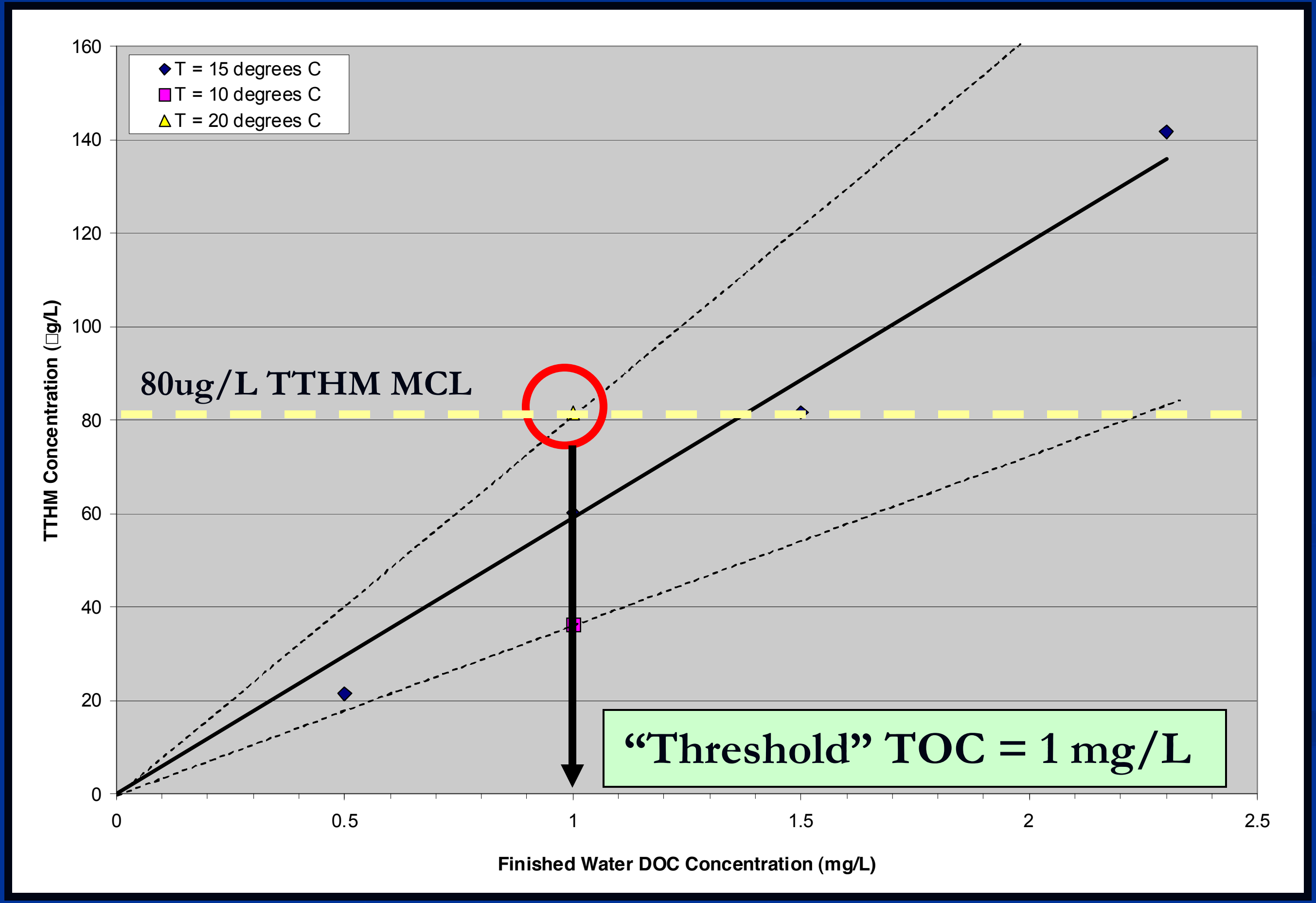
SDS-DBP Formation Testing

- SDS-DBP Testing Results



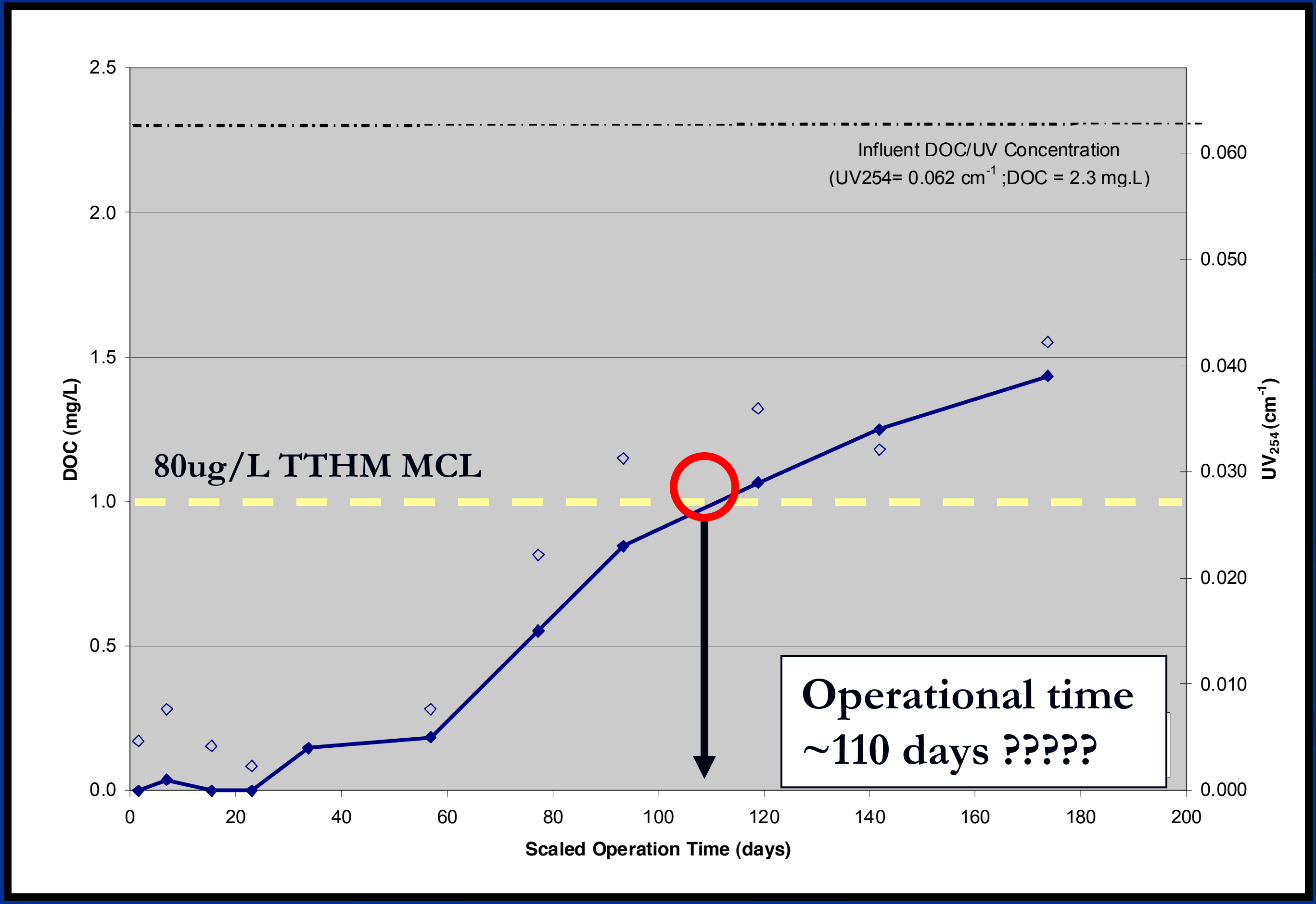
SDS-DBP Formation Testing

- SDS-DBP Testing Results

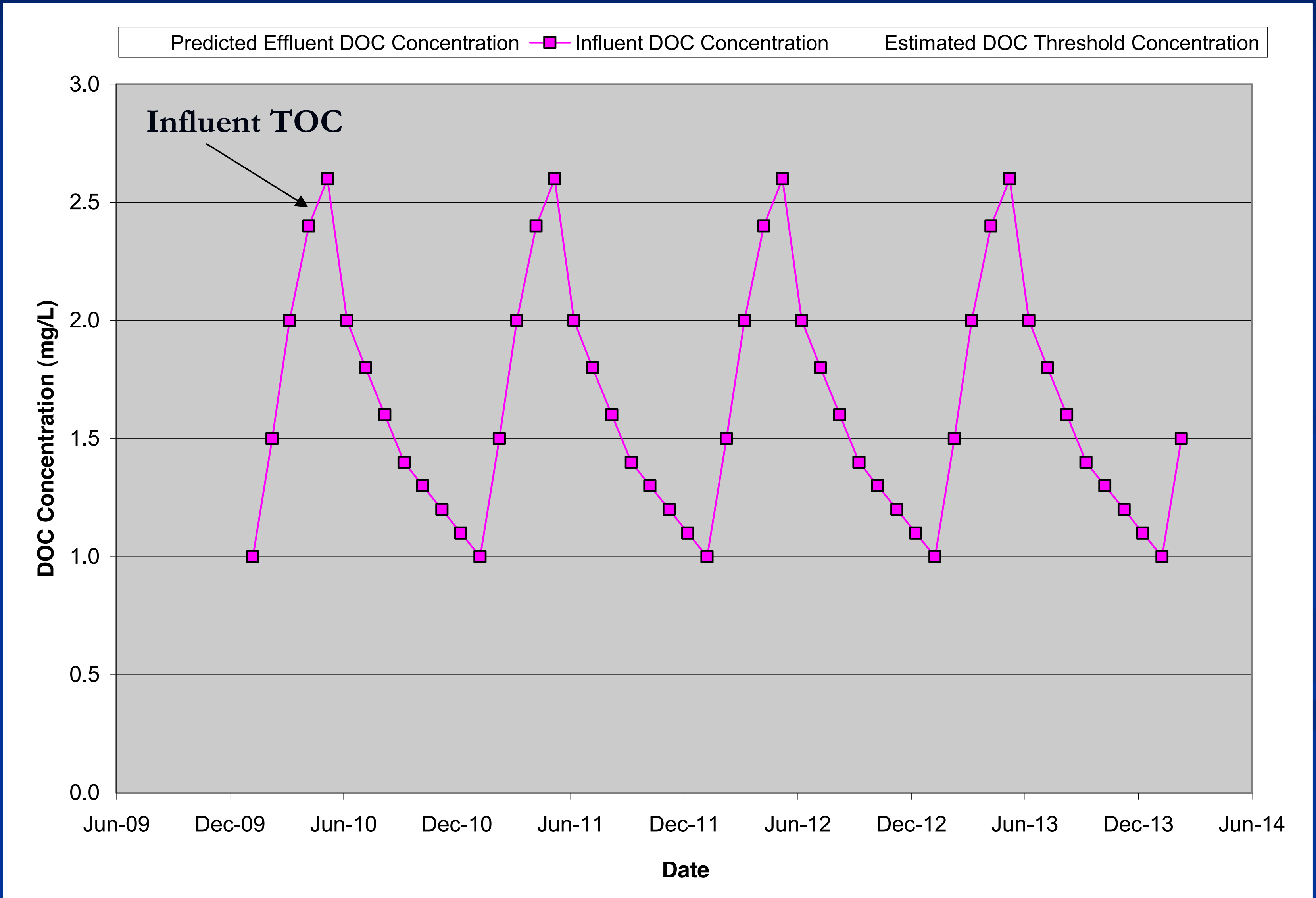


GAC Performance Testing

- RSSCT Breakthrough Results



Predicting "Real" GAC Usage



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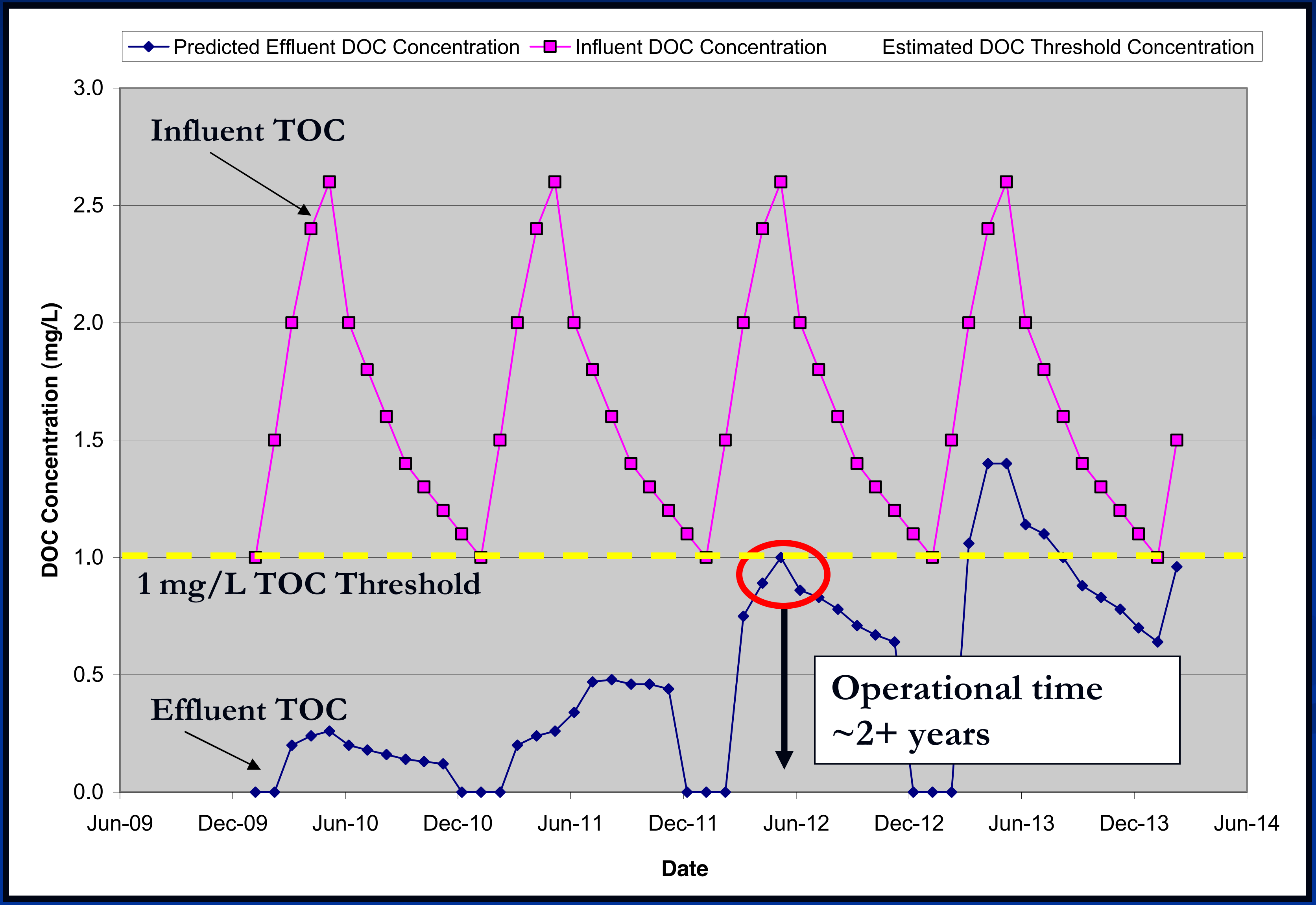


Take Home Message #4 & #5

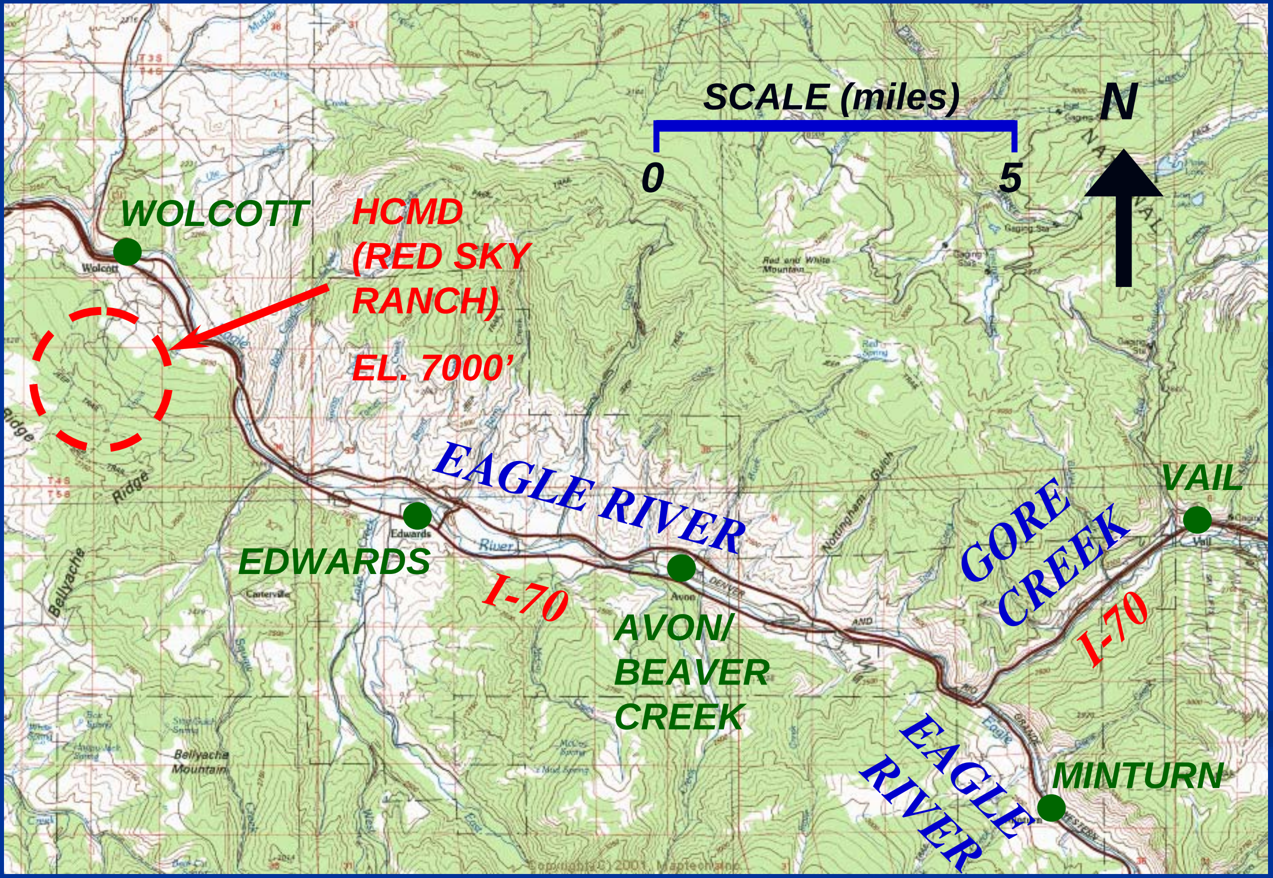
- ✓ GAC usage rates can be reasonably estimated using:
  - RSSCT data
  - SDS-DBP test results
  - TOC breakthrough models

- ✓ Historical TOC data important for accurate prediction

Case Study #2

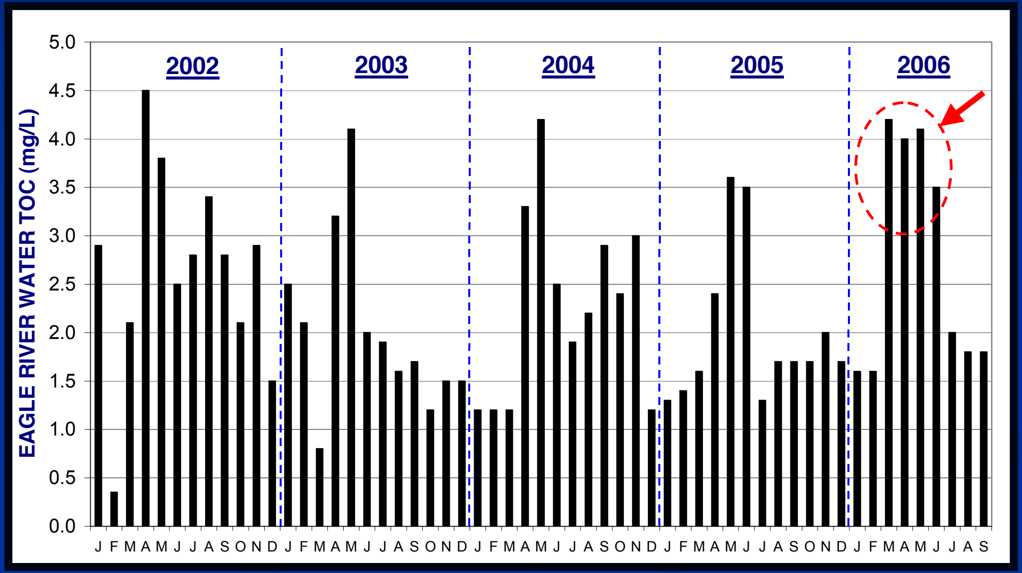
Red Sky Ranch WTP

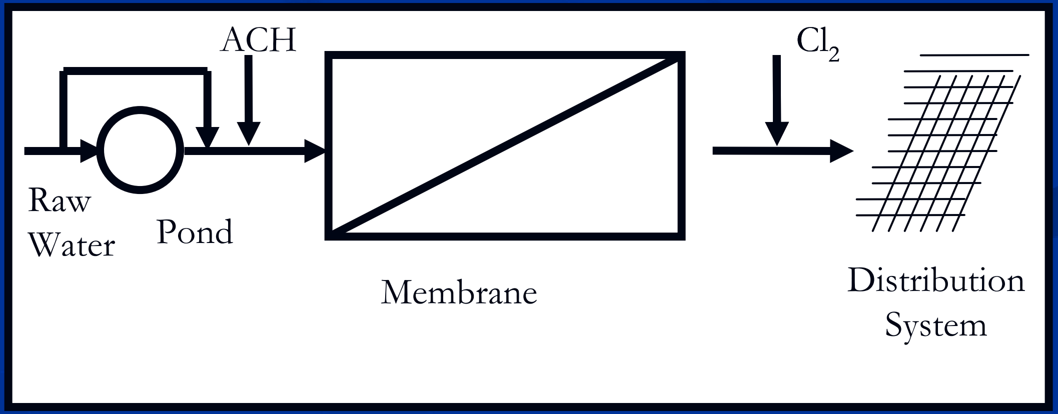
HCMD Owns A Small Surface Water System near Wolcott, CO



RSR WTP Overview

- Source: Eagle River
  - TOC: ~1.5 to 4 mg/L
  - Turbidity: ~5 to 20 ntu
- Capacity: 0.3 MGD
- MF Membranes
  - Installed in 2002
  - New water system



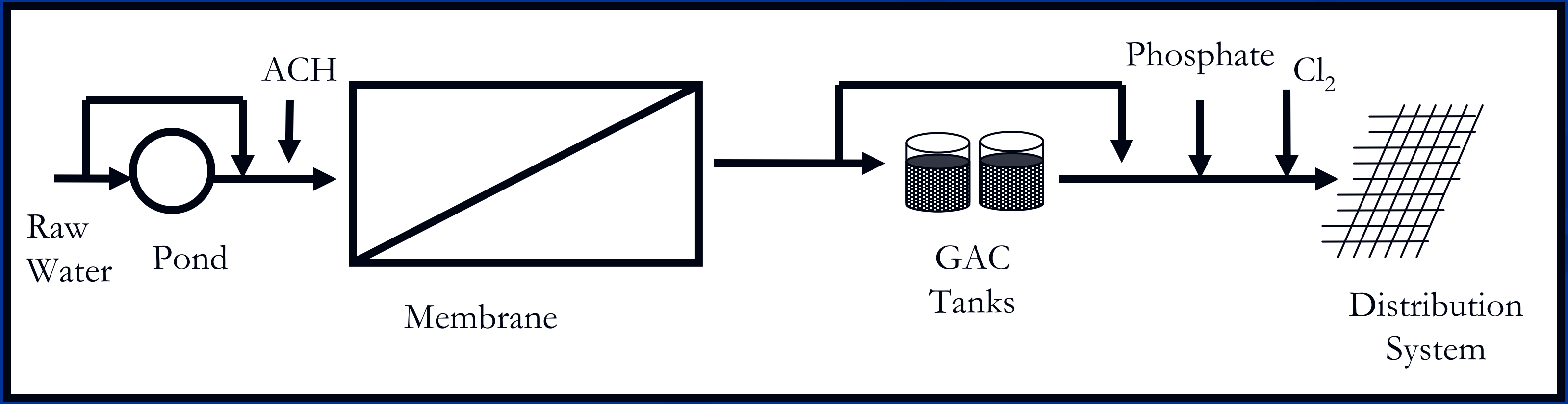


RSR WTP Overview

- Problems:
  - Colored water complaints from customers
  - Manganese (trace)
  - TTHM compliance challenges
    - USEPA finalizes Stage 2 Disinfectants/ Disinfection By-Products (D/DBP) Rule

WTP Improvements

- GAC System
- Manual Control
- Split Flow Capabilities
- Backwash System

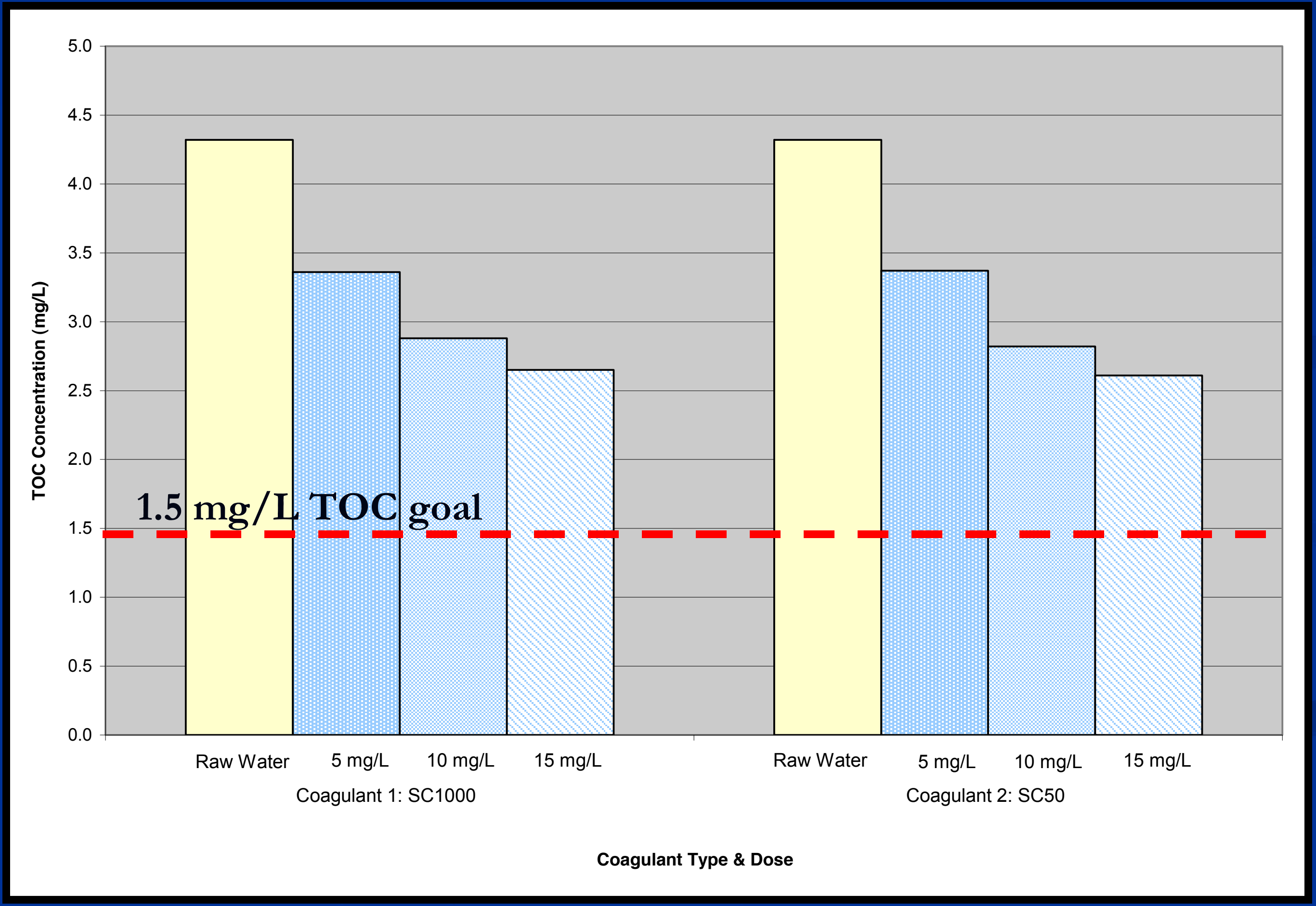


Process Evaluation

- Rapid Small Scale Column Testing
- SDS DBP Formation Testing
- Isotherm testing
- Coagulation Studies
  - Coagulant Dose
  - Coagulant Type
  - Mixing Speed

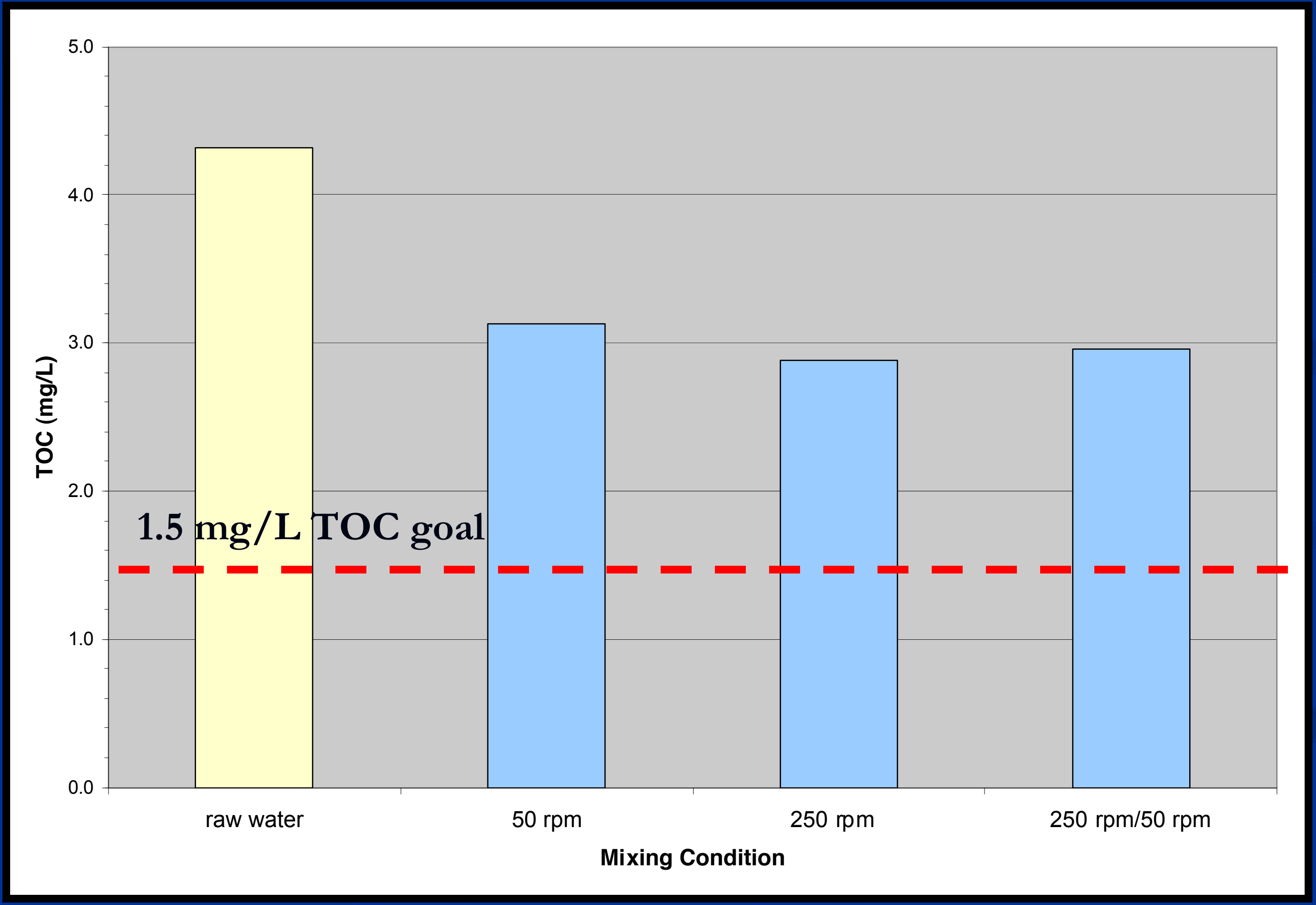
Process Evaluation

- Coagulant Dose and Type

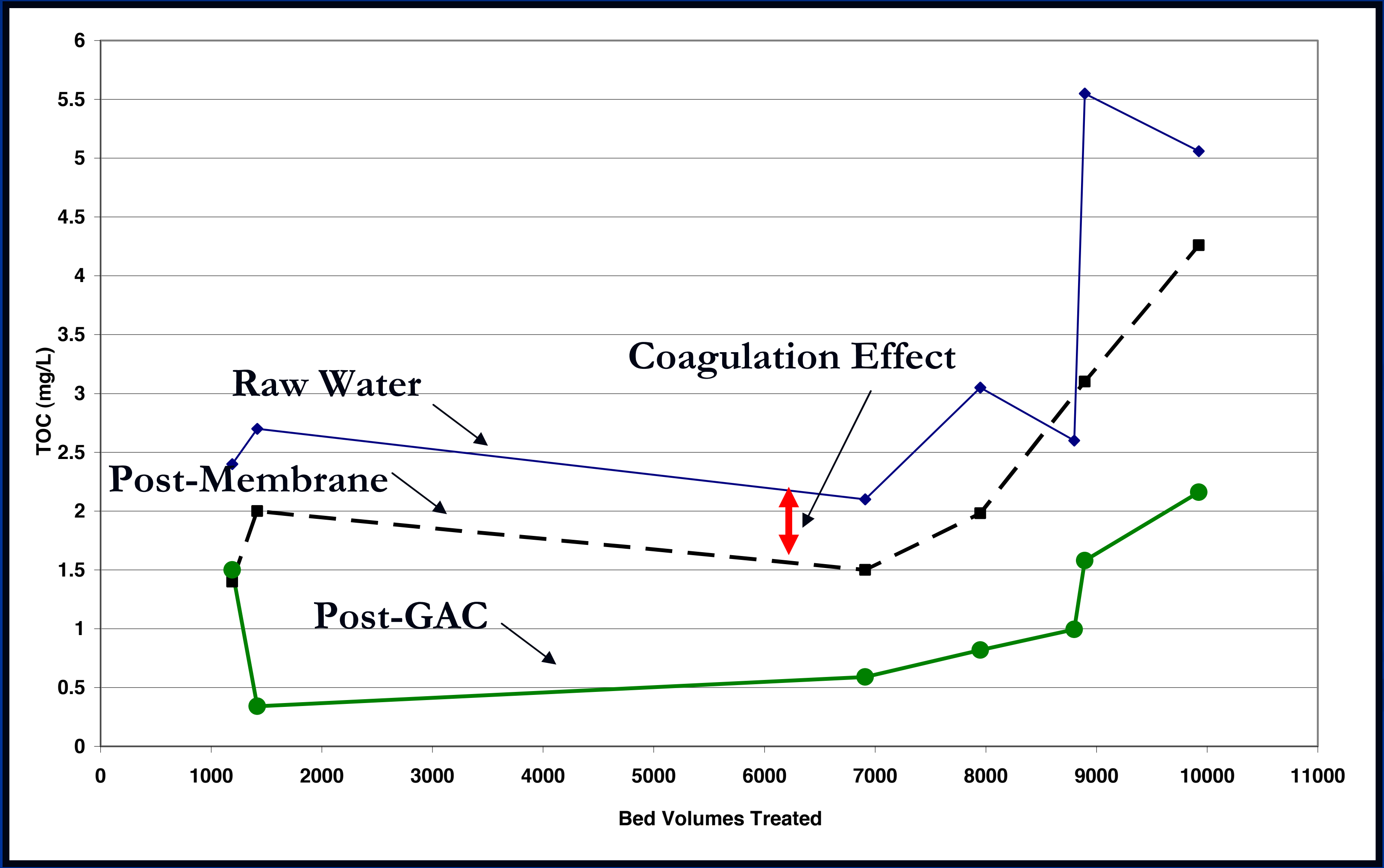


Process Evaluation

- Mixing had little effect on TOC removal



Full-Scale TOC Data



Take Home Message #6

- ✓ Coagulation/GAC Approach can be effective at reducing TOC issues

The Big Picture…

- NOM can pass through MF and UF membranes resulting in DBP problems
- GAC and Coagulation can effectively remove TOC and reduce DBPs
- Try coagulation 1st; GAC can be added if needed
  - Coagulation is cheaper
  - Coagulation can improve GAC performance
- How to Prepare?
  - GAC usage rates can be reasonably estimated but <u>begin collecting</u> historical TOC data!!!