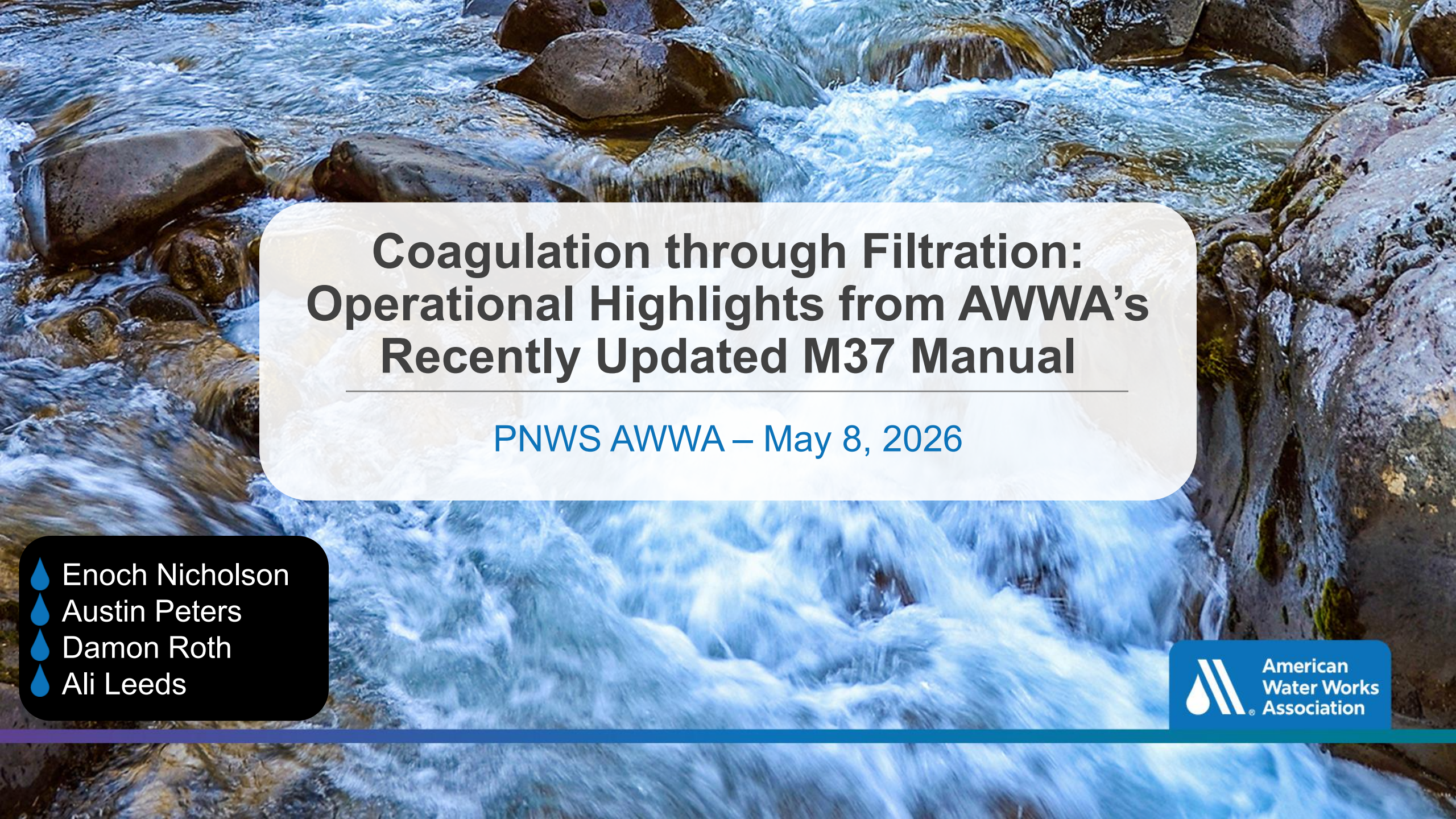


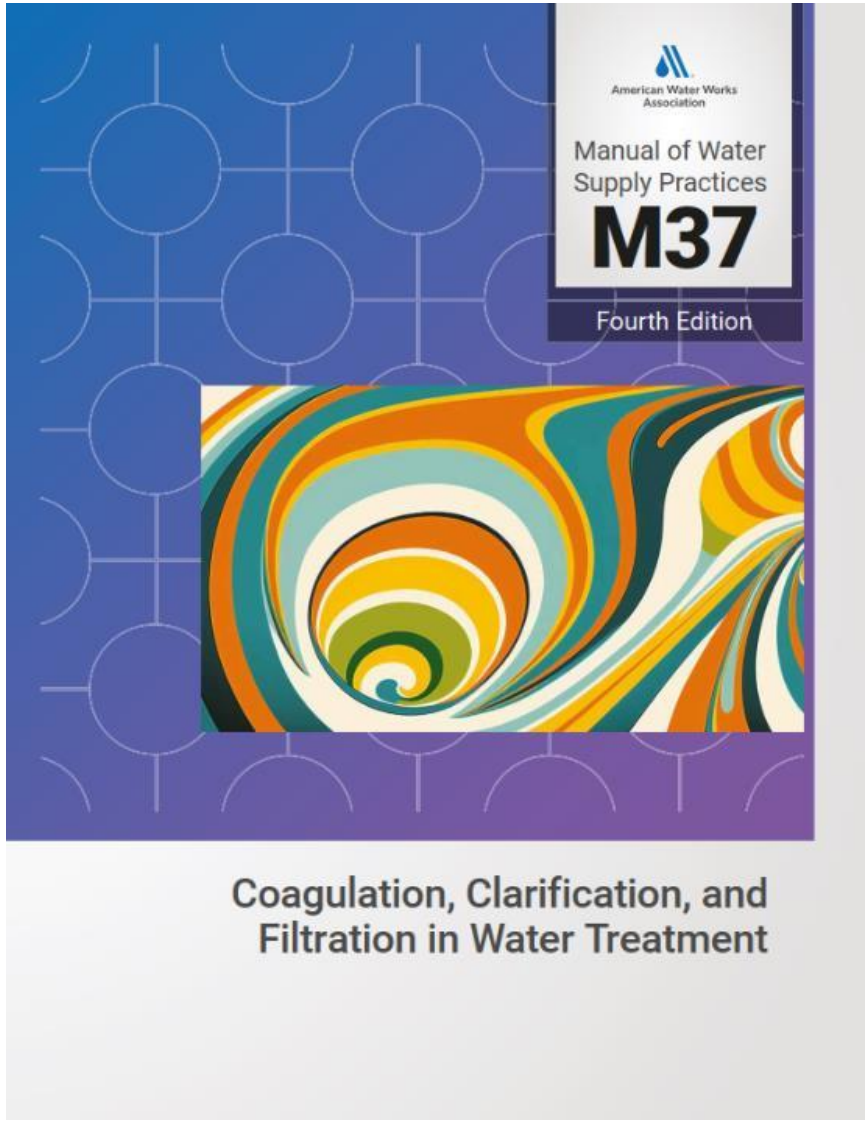
Coagulation through Filtration: Operational Highlights from AWWA's Recently Updated M37 Manual

PNWS AWWA – May 8, 2026

- Enoch Nicholson
- Austin Peters
- Damon Roth
- Ali Leeds

American Water Works Association

Coagulation, Clarification, and Filtration in Water Treatment



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Jeff Cochran, Birmingham Water Works Board, Birmingham, Ala.
Jason Curl, Hazen and Sawyer, Greenwood Village, Colo.
Ashley Kent, Arcadis, Austin, Tex.
***Ali Leeds,* Carollo Engineers, Seattle, Wash.**
William Pennock, New Jersey Institute of Technology, Newark, N.J.
David J. Pernitsky, Stantec Consulting, Pasadena, Calif.
***Robert (Austin) Peters,* Carollo Engineers, Hood River, Ore.**
***Damon Roth*, Brown and Caldwell, Ritzville, Wash.**
Ayman Shawwa, Stantec, Walnut Creek, Calif.
Rebecca Venot, Jacobs, Anchorage, Alaska

4th Edition M37 Updates

> “The purpose of this edition of this manual is focused on *enabling operations staff at existing water treatment plants to get the most effective and optimized treatment* reasonably possible from the systems and facilities they have at their disposal. This is intended to be *not a design manual* but rather a tool for operators and engineers who support operators.”

Chapter 1 – Coagulation Chemistry

Chapter 2 – Rapid-Mixing and Flocculation Process

Chapter 3 – Clarification Processes

Chapter 4 – Granular Media Filtration

Chapter 5 – Coagulation for Membrane Filtration

Chapter 6 – Coagulation and Filtration in Wastewater, Water Reuse, Seawater, and Stormwater Treatment

Chapter 7 – Jar Testing and Bench Testing

Chapter 8 – Testing for Process Evaluation and Control

Chapter 9 – Instrumentation for Monitoring and Control

Chapter 10 – Case Studies

The Big Picture

Provide safe, aesthetically pleasing drinking water by…



removing particles, including pathogens



improving effectiveness of disinfection



reducing organics to lower disinfection byproducts



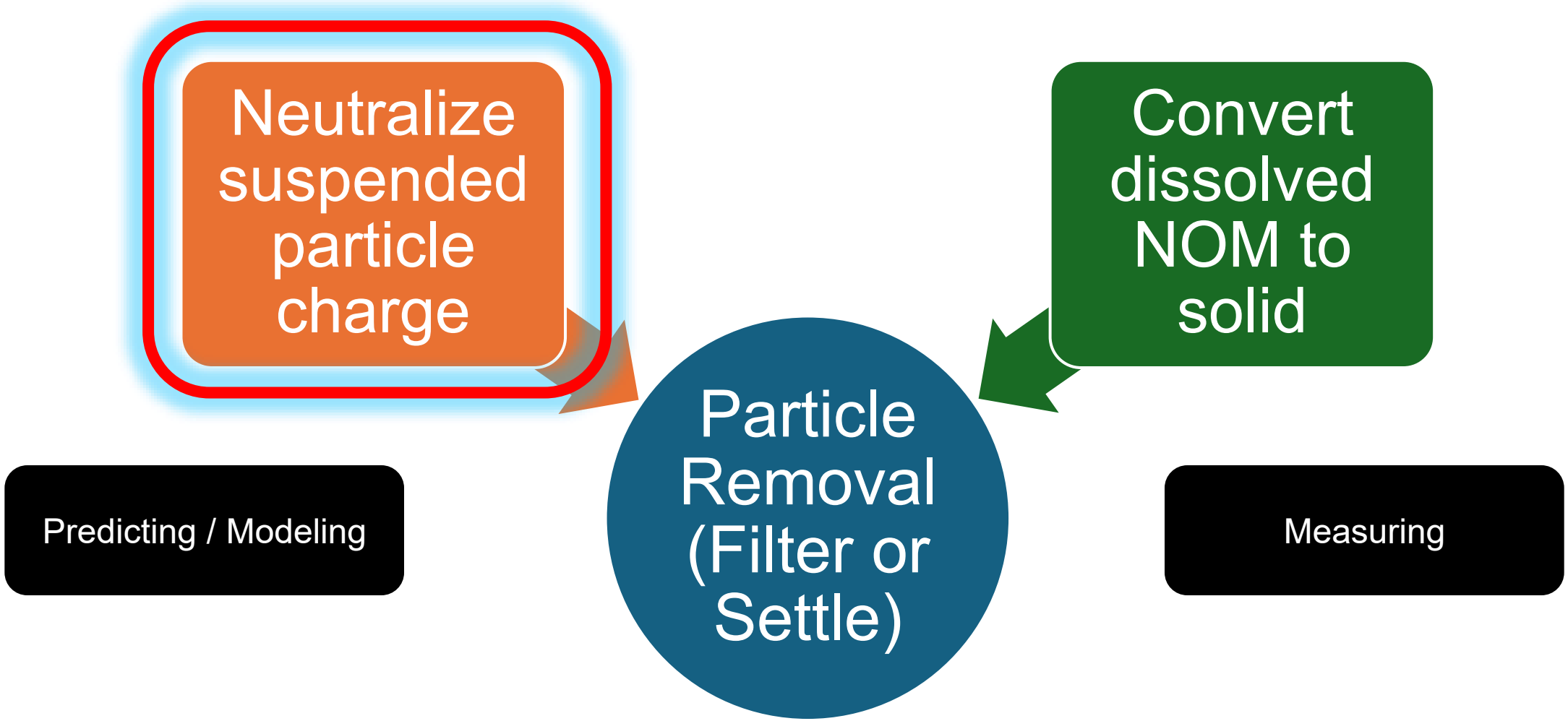
improve aesthetics (color and taste and odor)

Performance Goals

- Low filter effluent turbidity and particle counts
- Reduced organics levels
- Least practical DBP formation
- Long filter runs
- Minimal color
- Limited oxidant demand
- Tasty water

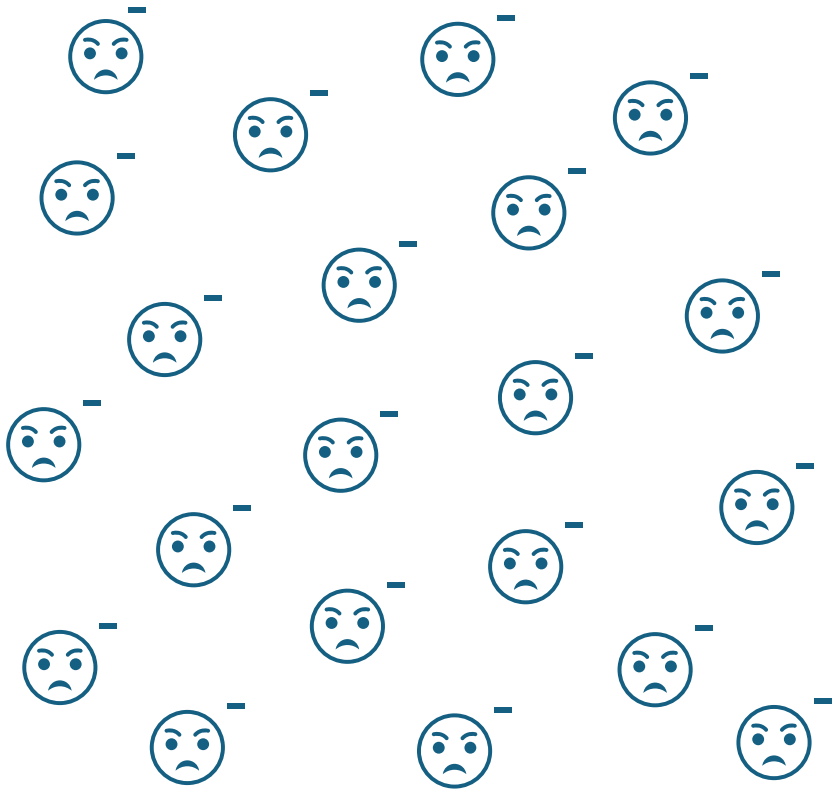
Coagulation Chemistry

The Process

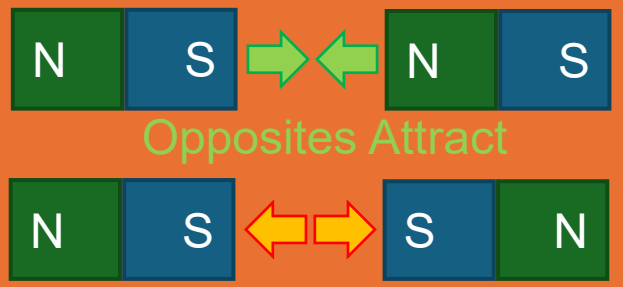


Why it works… Charge Neutralization

Particles in Nature



It's sort of like magnets!

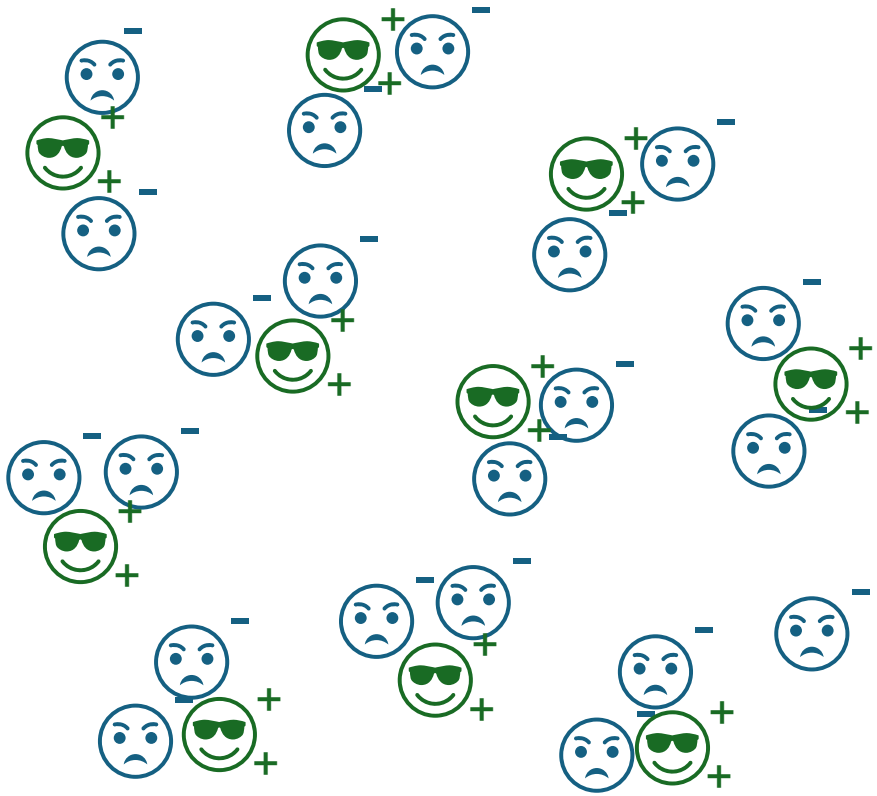


Legend:

Negative Particles

Positive Coagulant

Neutralized Particles
(aka, Effectively Coagulated)



Particles, Particles Everywhere!

Don't be so NEGATIVE!

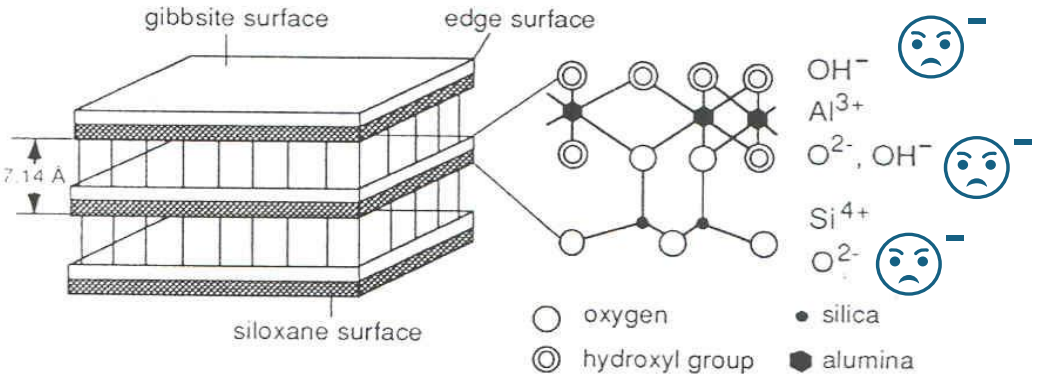
Clays, minerals, algae, and organic matter…. all come naturally negatively charged

All have pH dependent surface chemistry

Turbidity rarely controls coagulant dose!

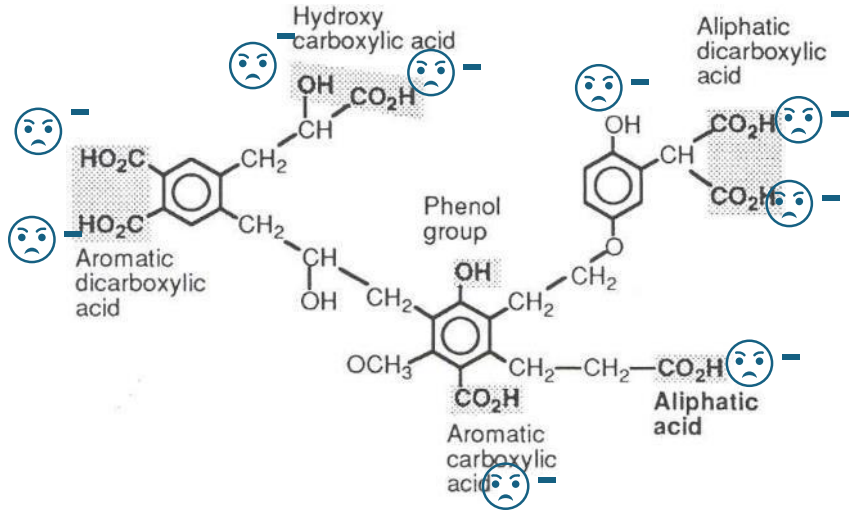
Particle Charge

$$10\frac{mg}{L}\ TSS\ (10\ NTU) \times 0.5\frac{\mu eq}{mg} \rightarrow 5\ \frac{\mu eq}{L}$$

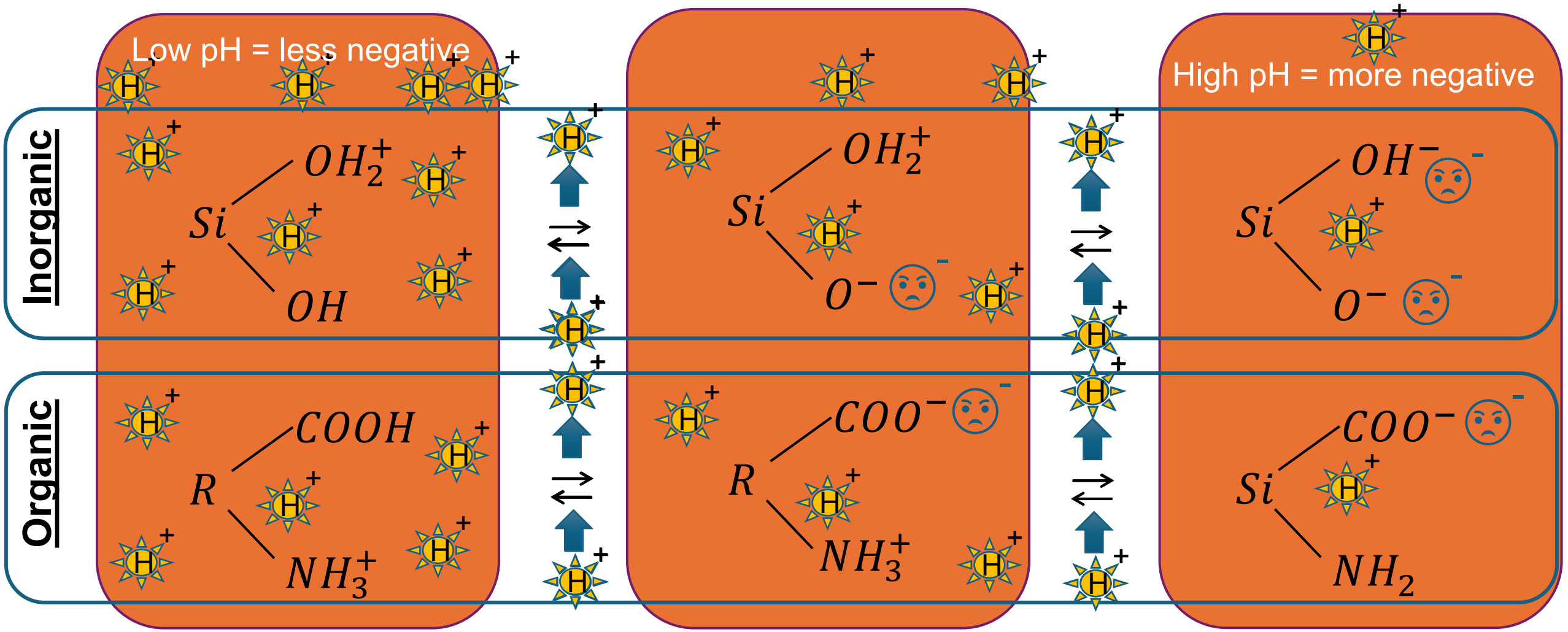


NOM Charge

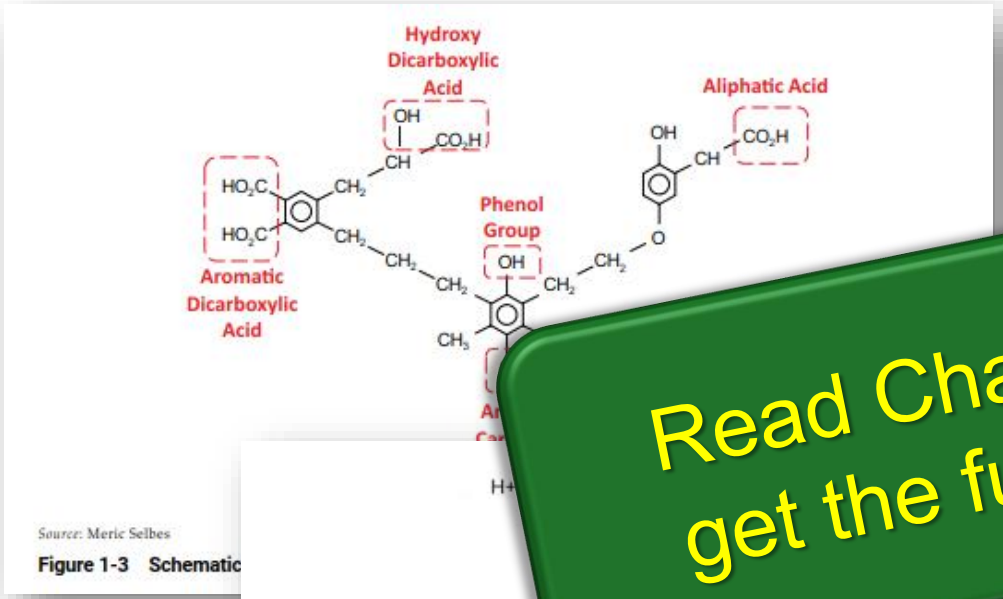
$$3\frac{mg}{L}\ TOC\ \times [10\ \text{to}\ 100]\frac{\mu eq}{mg} \rightarrow [30\ \text{to}\ 300]\ \frac{\mu eq}{L}$$



pH Matters!

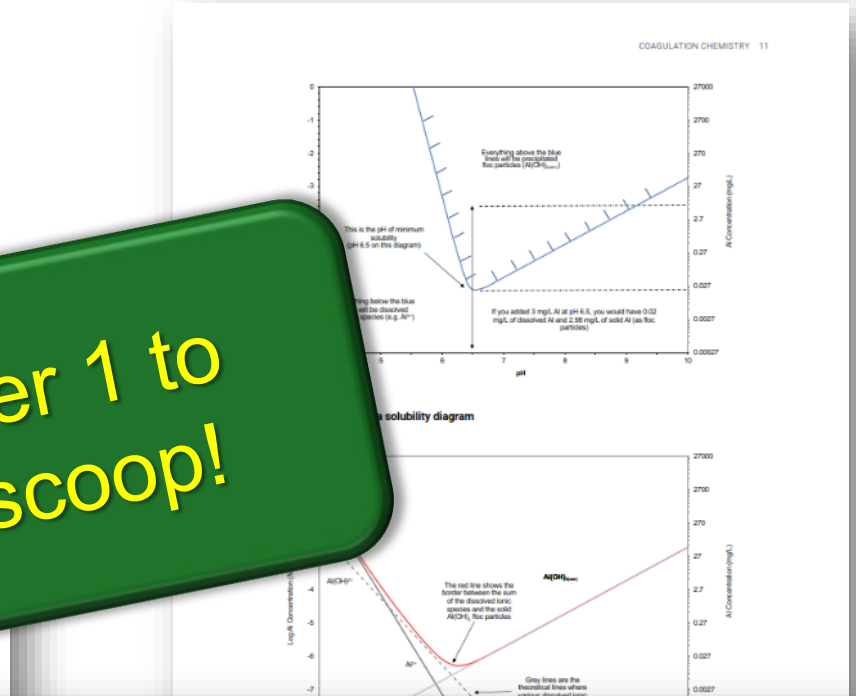

Low pH = less negative
High pH = more negative
Inorganic
Organic
OH_2^+
Si
OH
O^-
OH^-
$COOH$
R
NH_3^+
COO^-
NH_2

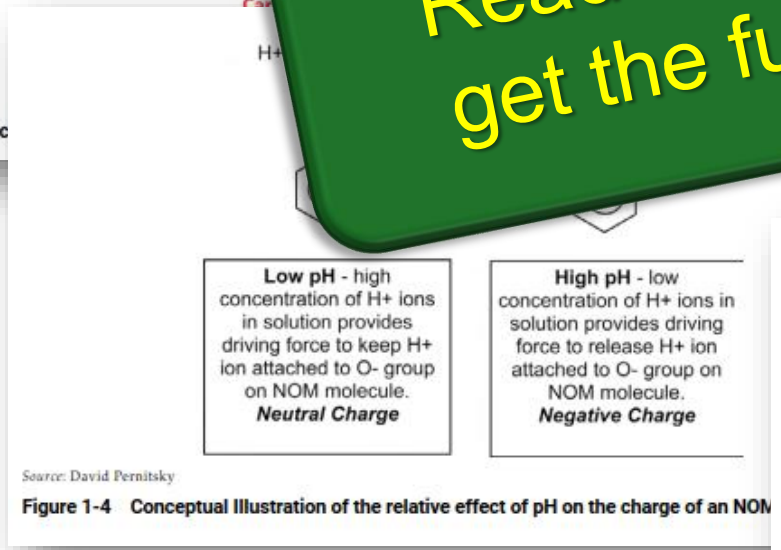
Chemistry of Coagulants…



Source: Meric Selbes

Figure 1-3 Schematic





Low pH - high concentration of H+ ions in solution provides driving force to keep H+ ion attached to O- group on NOM molecule. ***Neutral Charge***

High pH - low concentration of H+ ions in solution provides driving force to release H+ ion attached to O- group on NOM molecule. ***Negative Charge***

Source: David Pernitsky

Figure 1-4 Conceptual Illustration of the relative effect of pH on the charge of an NOM

Read Chapter 1 to get the full scoop!

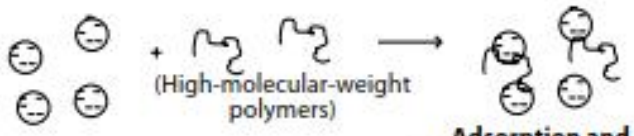
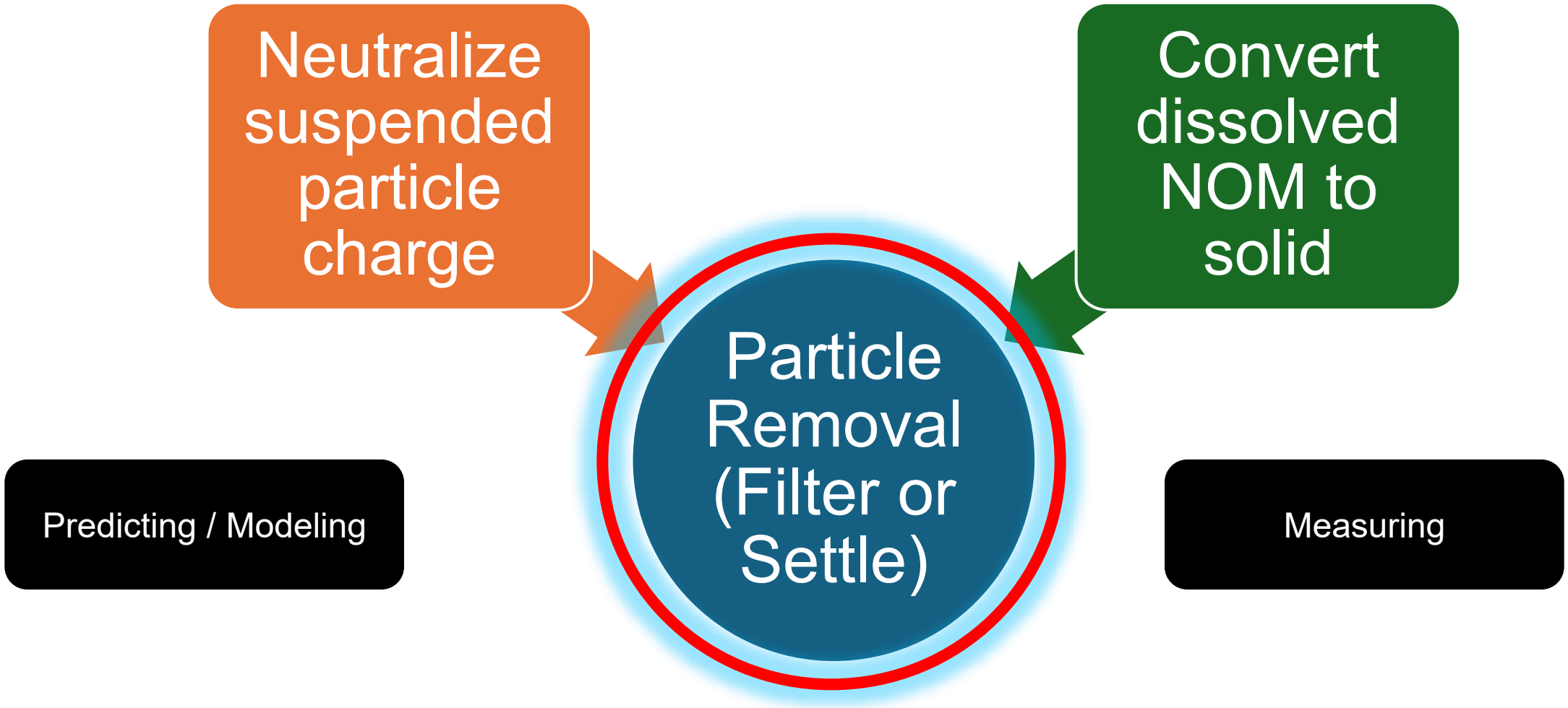


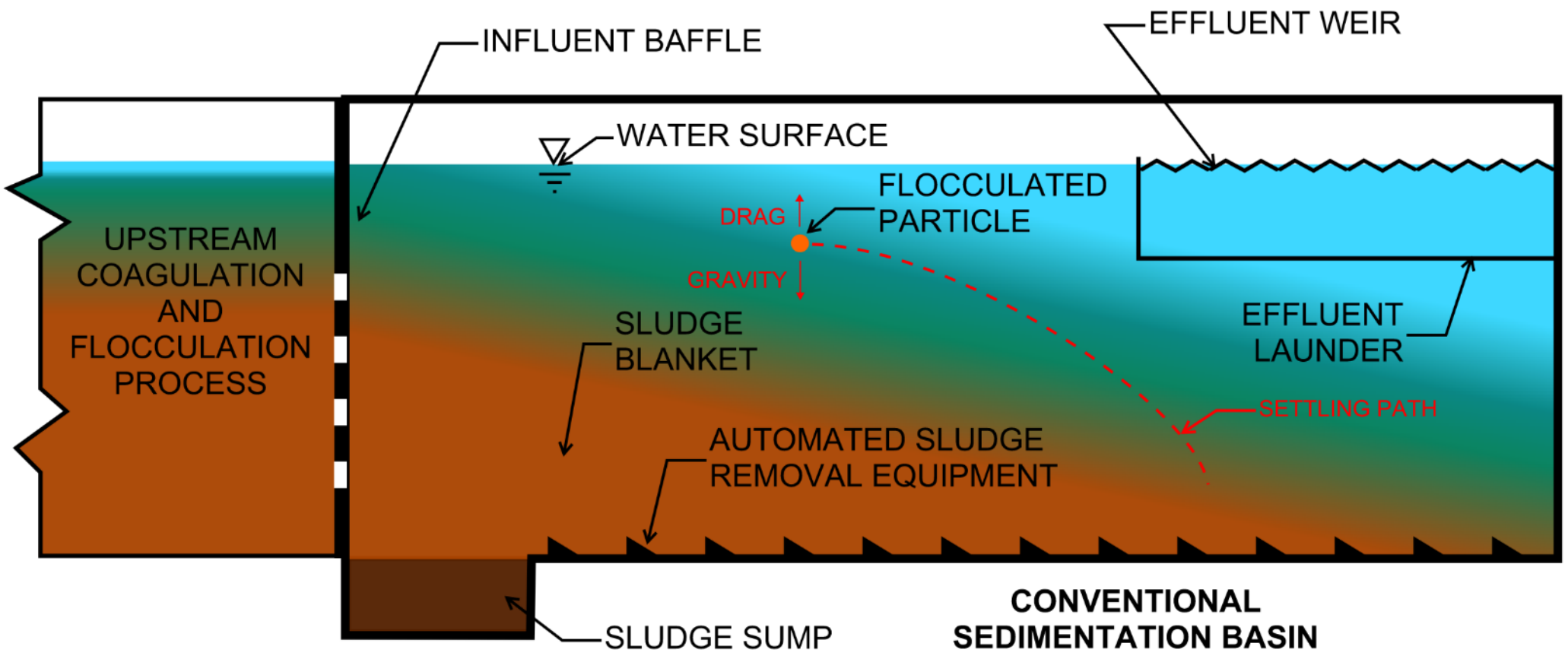
Figure 1-12 Conceptual view of adsorption and interparticle bridging coagulation mechanism

Particle Removal

The Process



The Basic Principle: Conventional Sedimentation Basins



Source: Carollo Engineers

Newer Technologies: Same Process - Intensified

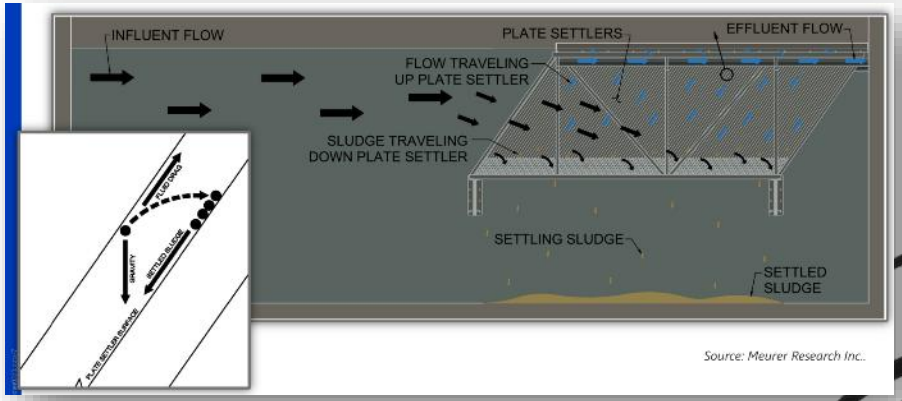
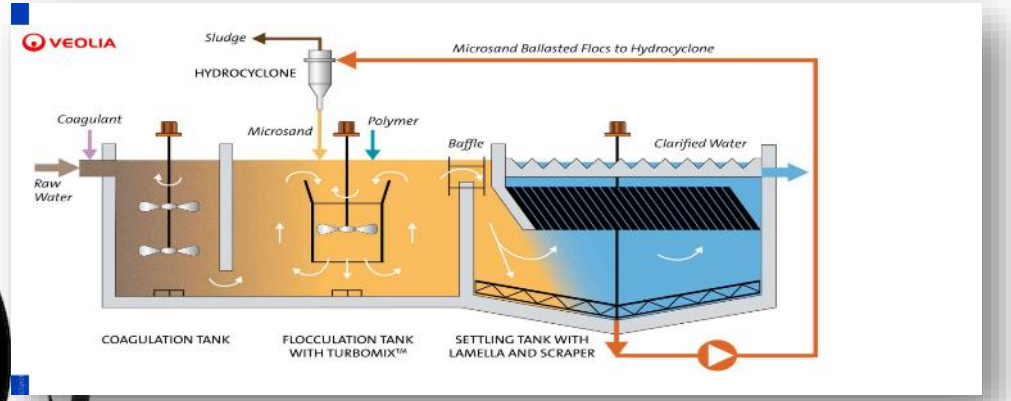
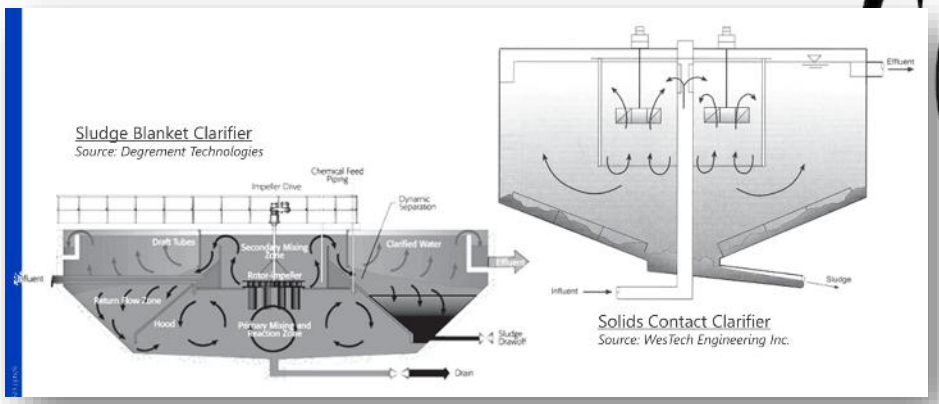


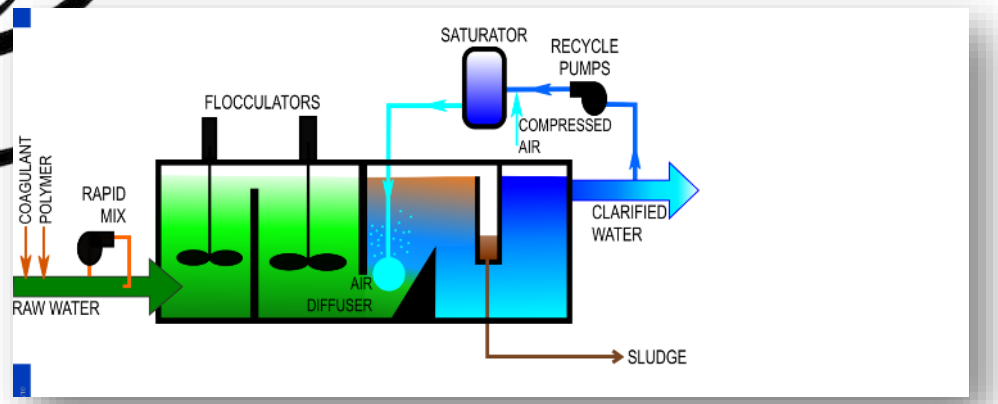
PLATE SETTLERS



BALLASTED FLOCCULATION



SLUDGE BLANKET / SOLIDS CONTACT



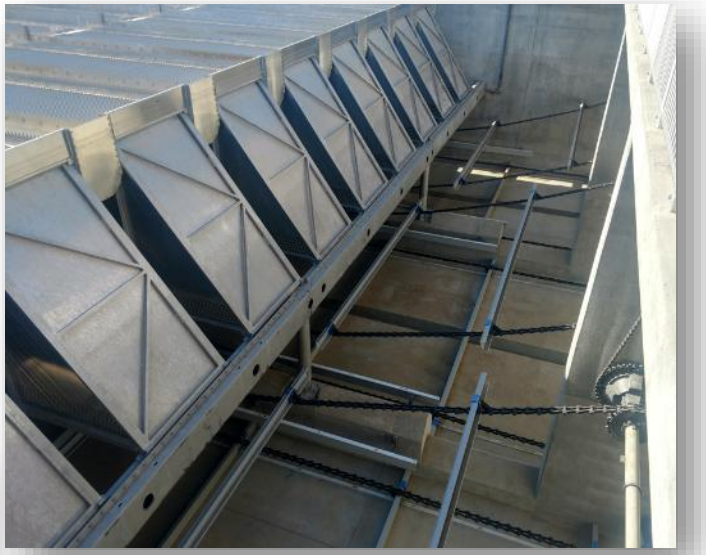
DISSOLVED AIR FLOTATION

Clarification Optimization Strategies

Why Optimize?

- Reduce settled water turbidity / solids loading to filters
- Reduce overall process solids generation
- Reduced water consumption / recycling
- Lowering chemical usage
- Lower energy usage

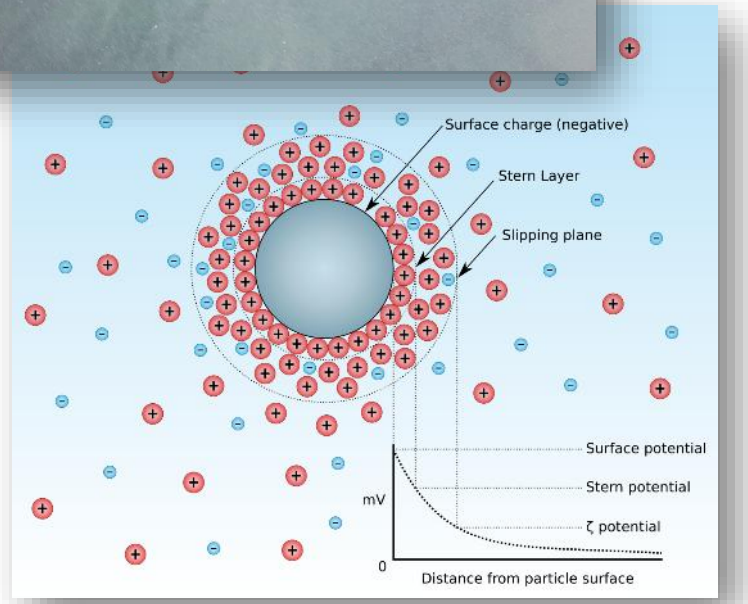






Chemistry is Critical!







pH Adjustment



Coagulants



Polymers

Optimize Floc Size & Integrity

It's not enough just to have floc, it's got to be the right *flavor of floc…*















GOLDIFLOCS



WEAK

STRONG

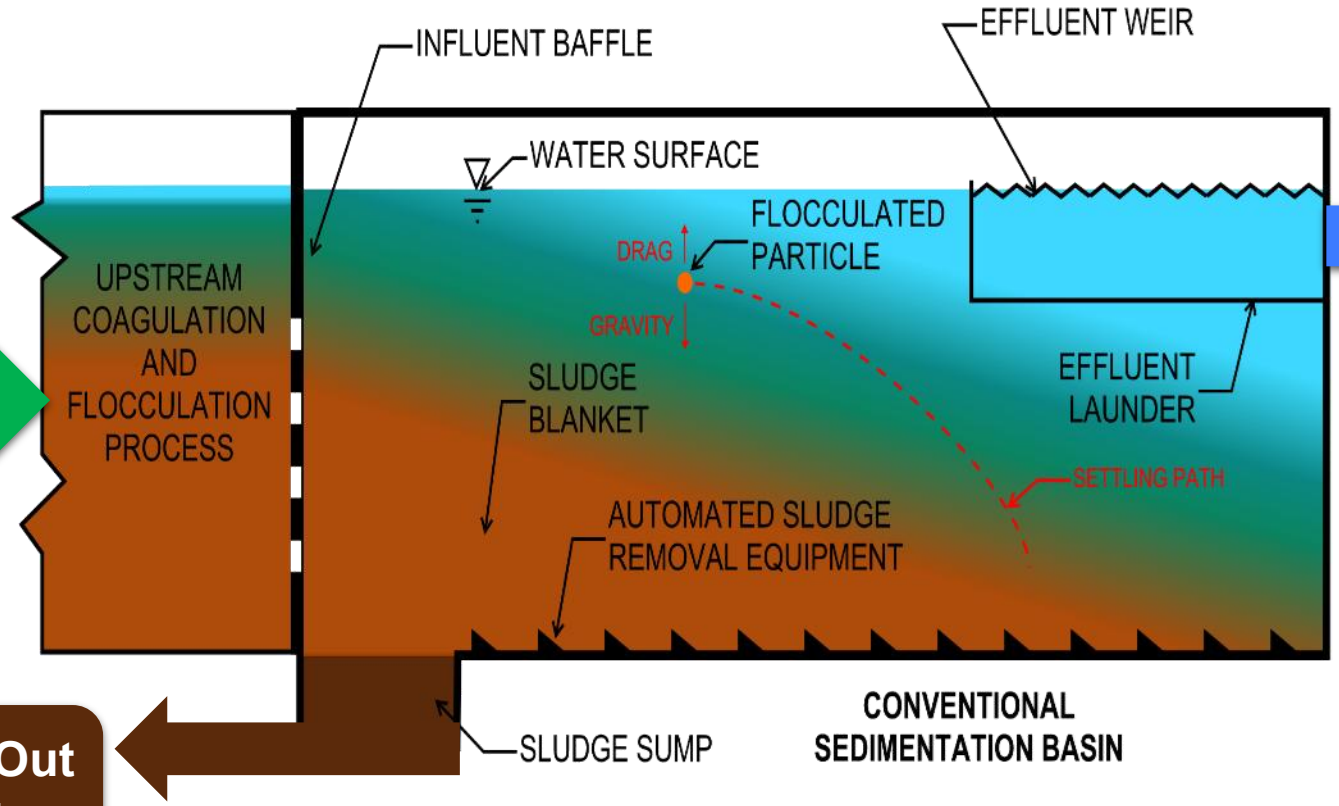
SMALL FLOC

LARGE FLOC

Mind the Mass Balance

Closely Monitor Solids Loading, Sludge Buildup

Solids In
From:
- Raw Water Constituents
- Chemicals
- Recycle



Solids Out
to filters

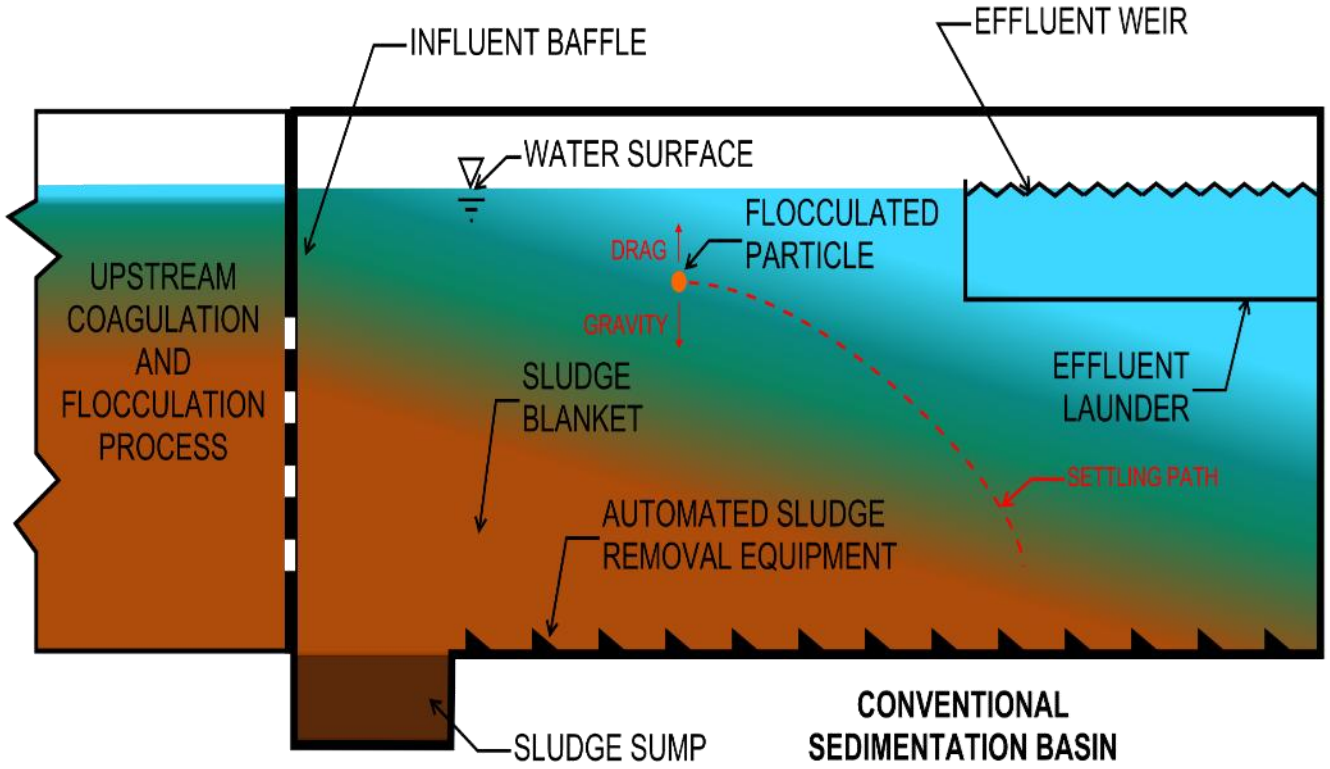
Solids Out
to Solids Handling

$$\text{Solids Production}\ (\text{dry pounds/day}) = 8.34 \times Q \times (F \times \text{Coagulant} + \text{TSS} + \text{Polymer} + \text{TOC})$$

Mind the Mass Balance

Closely Monitor Solids Loading, Sludge Buildup

- Use Instrumentation + SCADA calculations to identify changes in solids loading
- Visually / Physically monitor sludge blanket
- Adjust basin cleaning / sludge removal frequency based on findings



Identify and Eliminate Basin Short-Circuiting

- Plug flow is ideal
- Test impacts at different flow rates, temperatures, and operating schemes
- Also consider external factors like wind and sun, which can trigger short-circuiting
- Drones and tracer studies help detect flow problems and guide fixes

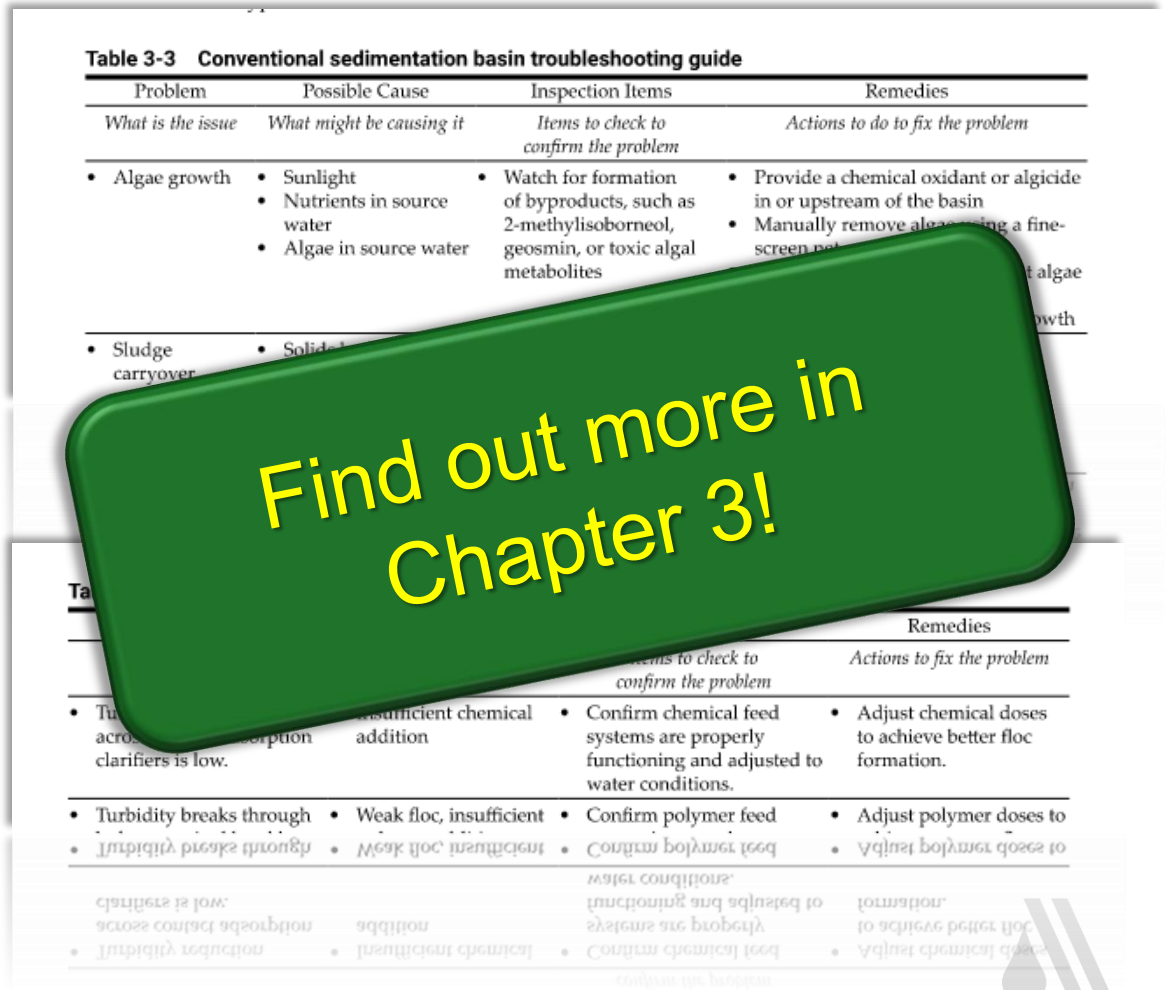




TIP: Turn up the exposure and contrast on aerial photos of basins to help identify short-circuiting issues

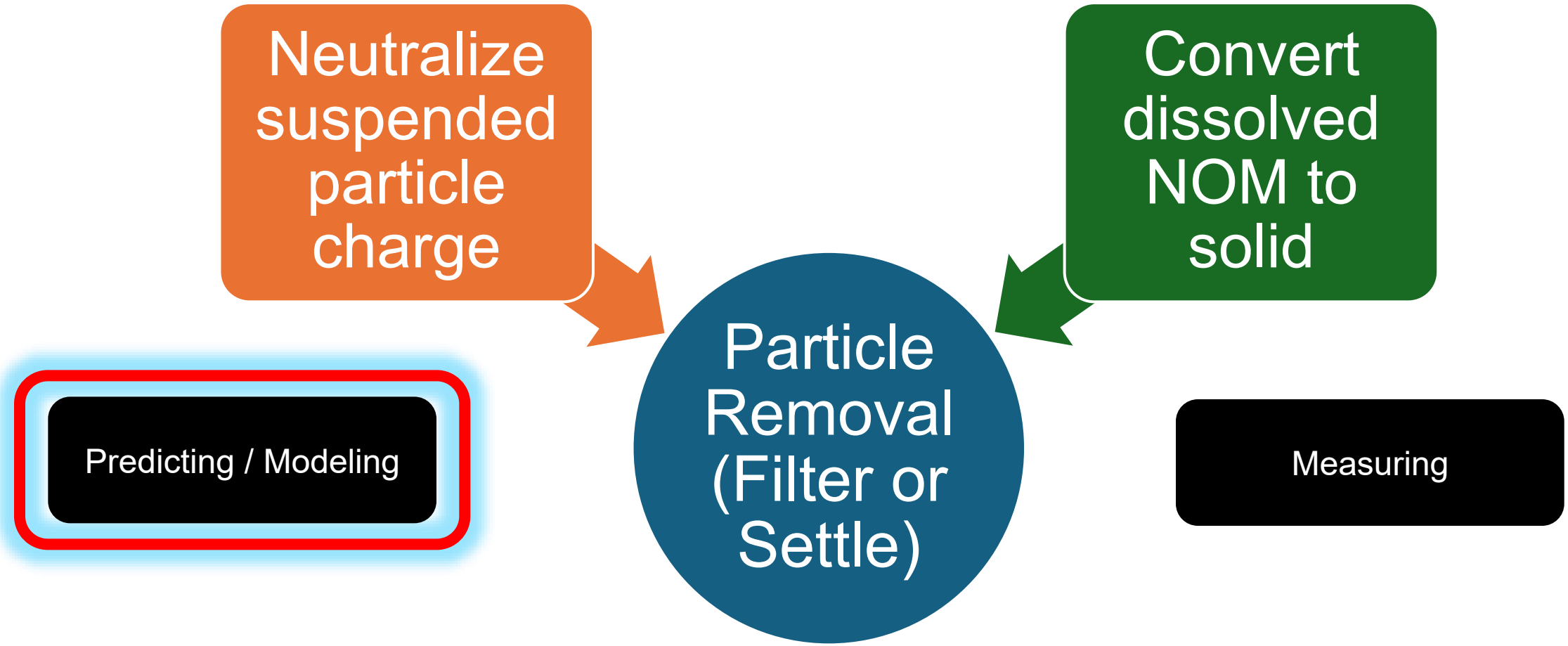
Different Clarification Technologies can have specialized troubleshooting techniques

- A troubleshooting guide for each typical clarification type, featuring:
- Problem
- Possible Cause
- Inspection Items
- Remedies



Bench-Scale Testing

The Process



Why Conduct Testing?

Optimize	Evaluate	Assess
Determine optimum chemical dosing or process parameters	Test process modifications, alternate chemicals, etc.	Assess impacts of source water changes on treatment efficacy

Types of Testing: Bench Scale

- Jar testing is regularly used by many WTPs for process control for coagulation and flocculation
  - Jar testing can also inform evaluations of alternate treatment chemicals
- Other processes can be evaluated at bench-scale
  - Biofiltration
  - Direct filtration
  - Dissolved air flotation (DAF)
  - Ballasted flocculation





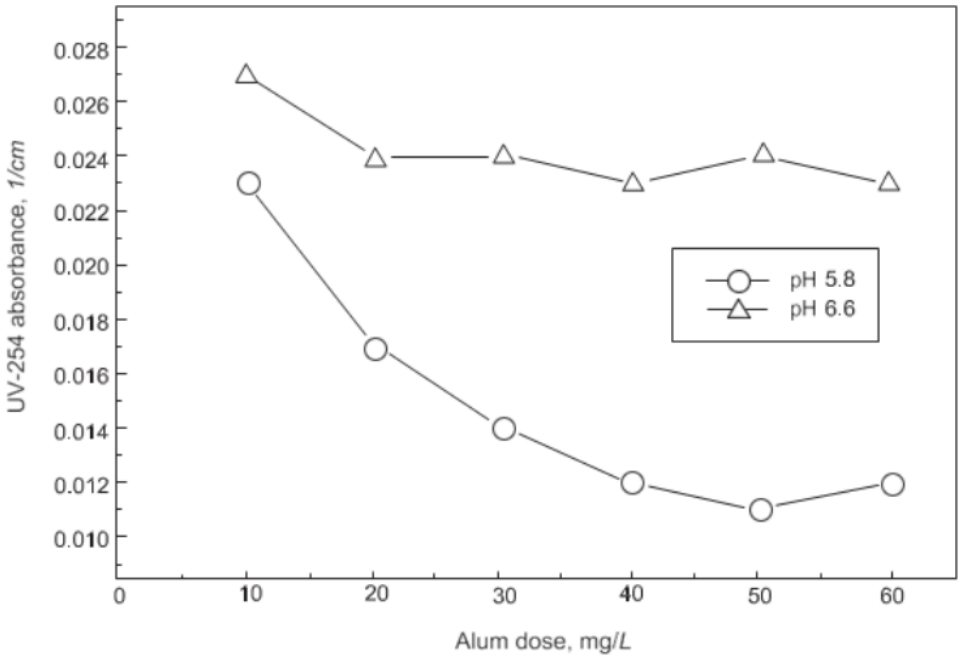
Source: Phipps and Bird

Preparing for Testing

- Define study goals and key performance indicators (KPIs)
- Establish correlation to full-scale treatment
- Prepare necessary testing resources
- Plan for data collection and documentation



Defining Study Goals and KPIs

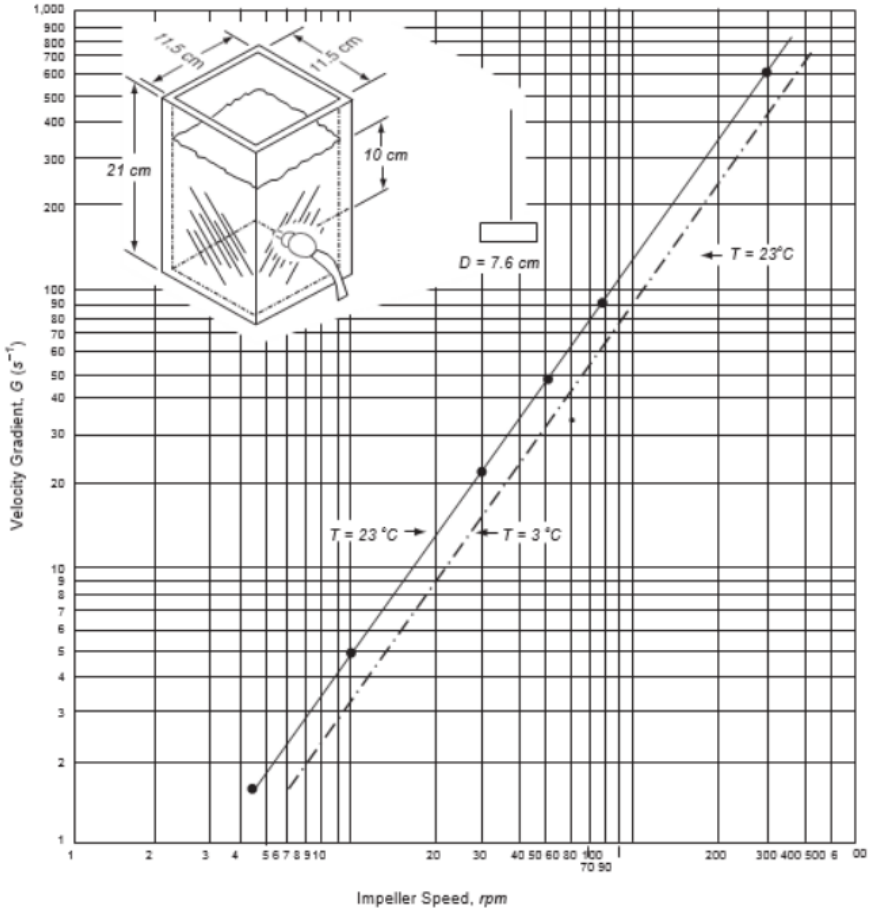


Source: AH Environmental Consultants, Inc. 1997

- Clearly define purpose of testing (e.g., process control, evaluating alternative chemicals, optimizing for TOC removal, etc.)
- Determine what water quality parameters and process data are needed to achieve testing purpose
- Identify Independent and Dependent variables

Correlating to Full-Scale Treatment

- Testing is only useful if it is designed to achieve similitude between the testing apparatus/procedure and the full-scale WTP
- Key parameters include:
  - Velocity gradient/mixing intensity, *G*
  - Retention times
  - Surface loading rates
- M37 includes example calculations and published laboratory *G* curves for reference



Source: Cornwell and Bishop 1983

Preparing Testing Resources



Source: Eppendorf North America

- Testing apparatus (e.g., pilot skid, jar tester, water bath, etc.)
- Required chemicals
  - Chemicals to be tested (independent variables)
  - Chemicals to control test conditions (e.g., pH buffers)
- Stock solutions prepared from the required chemicals
- Lab ware (e.g., glassware, pipettes, analytical equipment, etc.)

Planning for data collection / documentation

- Testing is only useful if relevant test data are documented
  - Source water conditions
  - Test conditions (independent variables)
  - Test results (dependent variables)
  - Visual observations

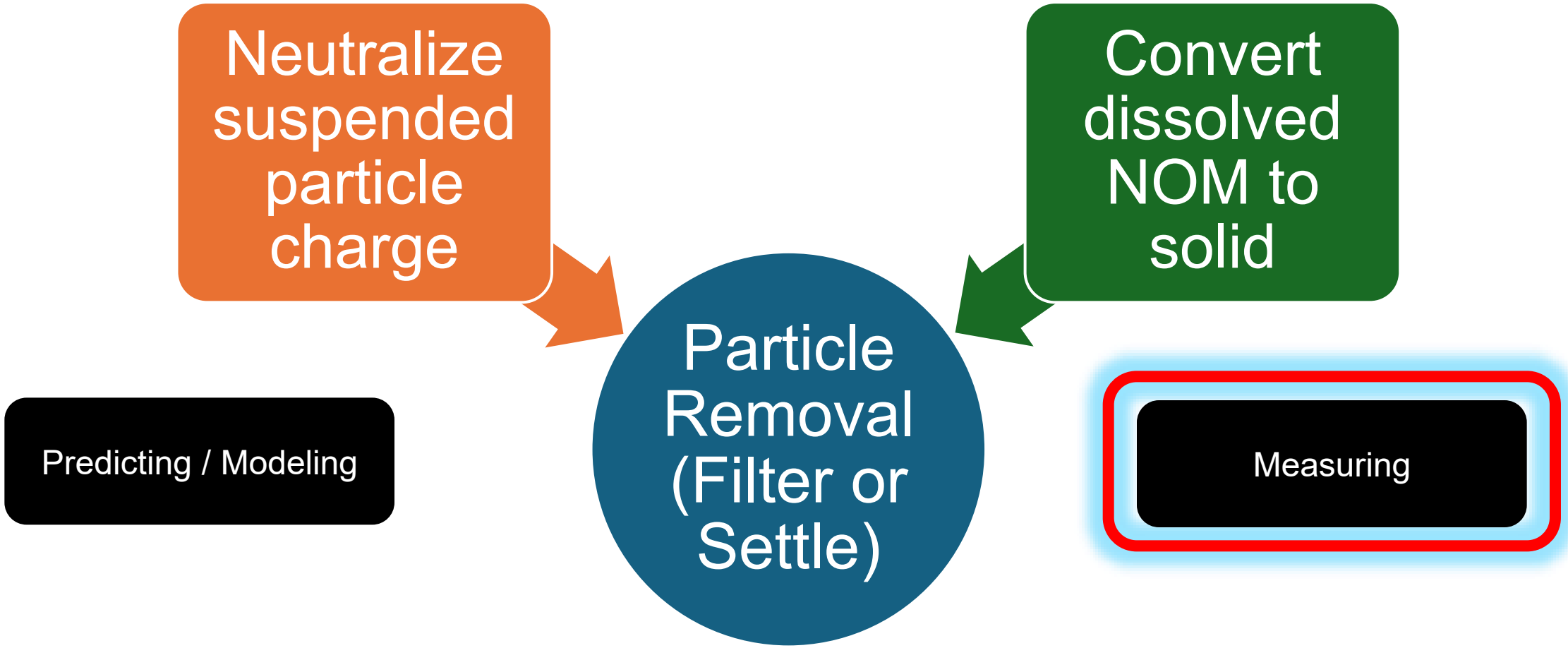
Date:		Concentration (mg/L)
Time:		
Coagulant:		
Oxidant		
Polymer:		

Source Water				
pH	Turbidity (ntu)	Alkalinity (mg/L as $CaCO_3$)	UV254 (cm^{-1})	TOC (mg/L)

Jar Number			1	2	3	4	5	6
Rapid Mix		G (s^{-1})						
		rpm						
		Duration (s)						
Flocculation		G (s^{-1})						
		rpm						
		Duration (s)						
Coagulant Dose (mg/L)								
Volume of Coagulant Added (mg/L)								
Oxidant Dose (mg/L)								
Volume of Oxidant Added (mL)								
Polymer Dose								
Volume of Polymer Added (mL)								
Coagulation pH								
Settling Velocity (cm/min)	Depth of Sampling (cm)	Time of Settling (min)	Turbidity (ntu)	Turbidity (ntu)	Turbidity (ntu)	Turbidity (ntu)	Turbidity (ntu)	Turbidity (ntu)
TOC (mg/L)								
UV-254 (cm^{-1})								

Analyzery Stuff

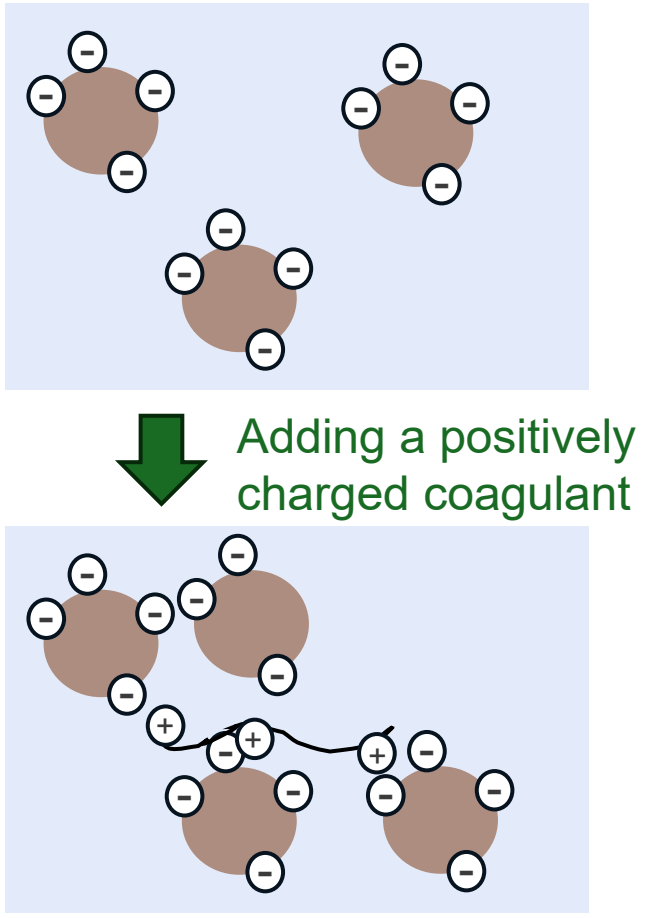
The Process



Measuring Particle Neutralization and Removal

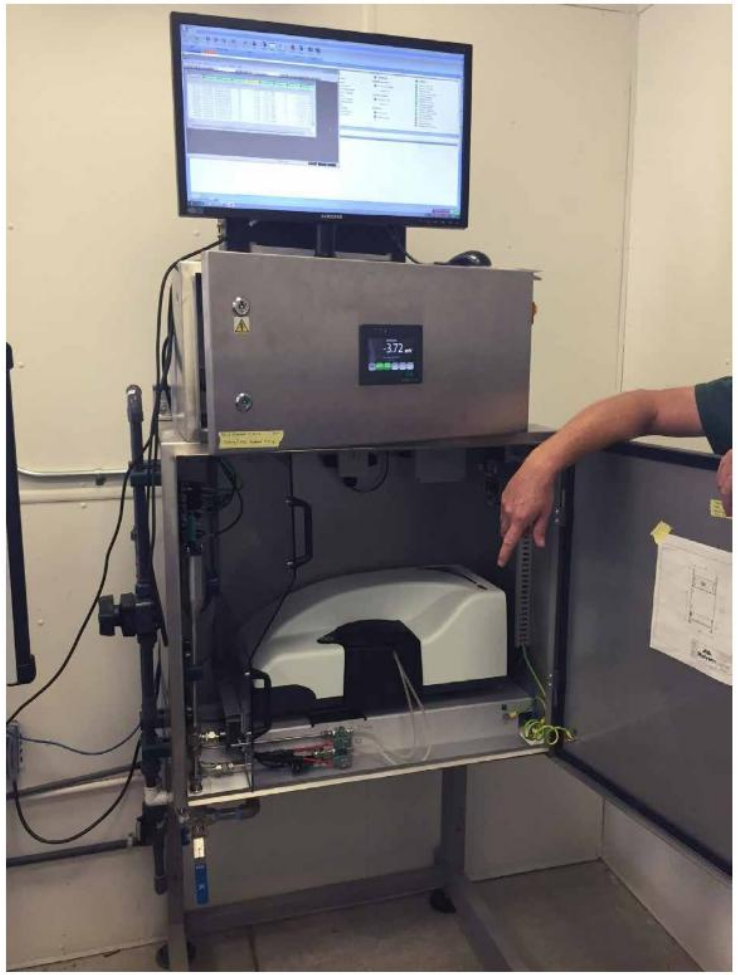


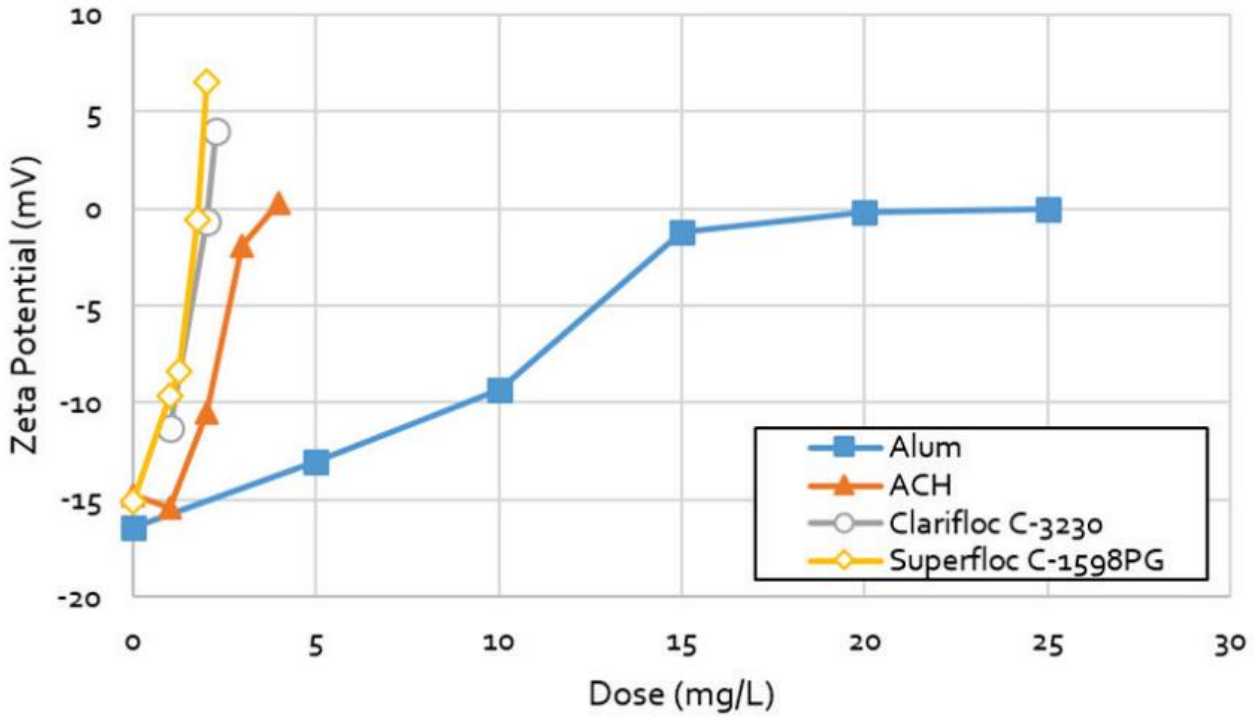
Removal: Turbidimeters



Neutralization: Zeta-Meters

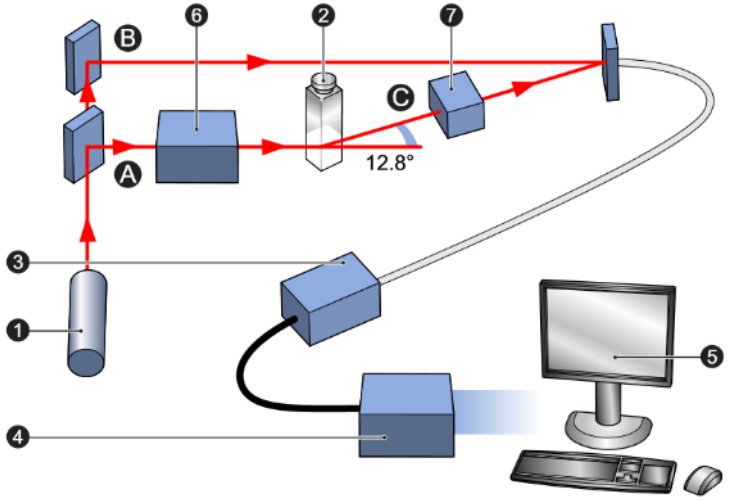
Zeta-Potential: How Do we Measure it?

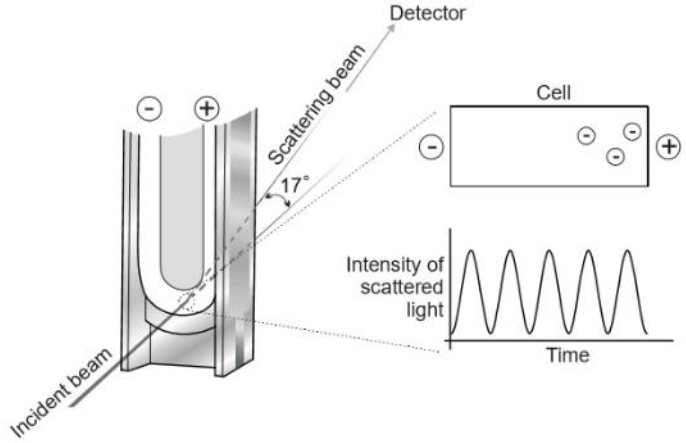




Zeta-Potential: How Does it Work?



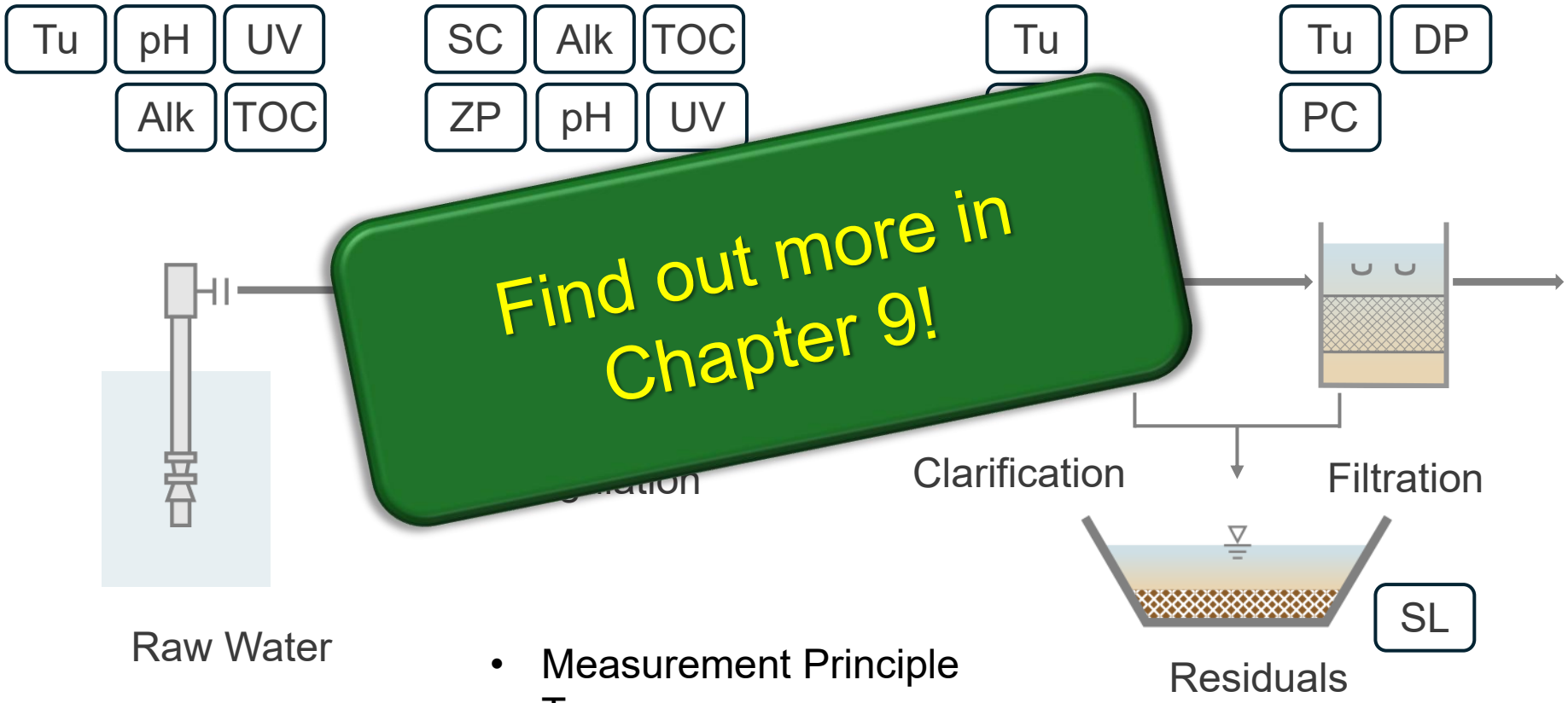




Laser Doppler Electrophoresis!

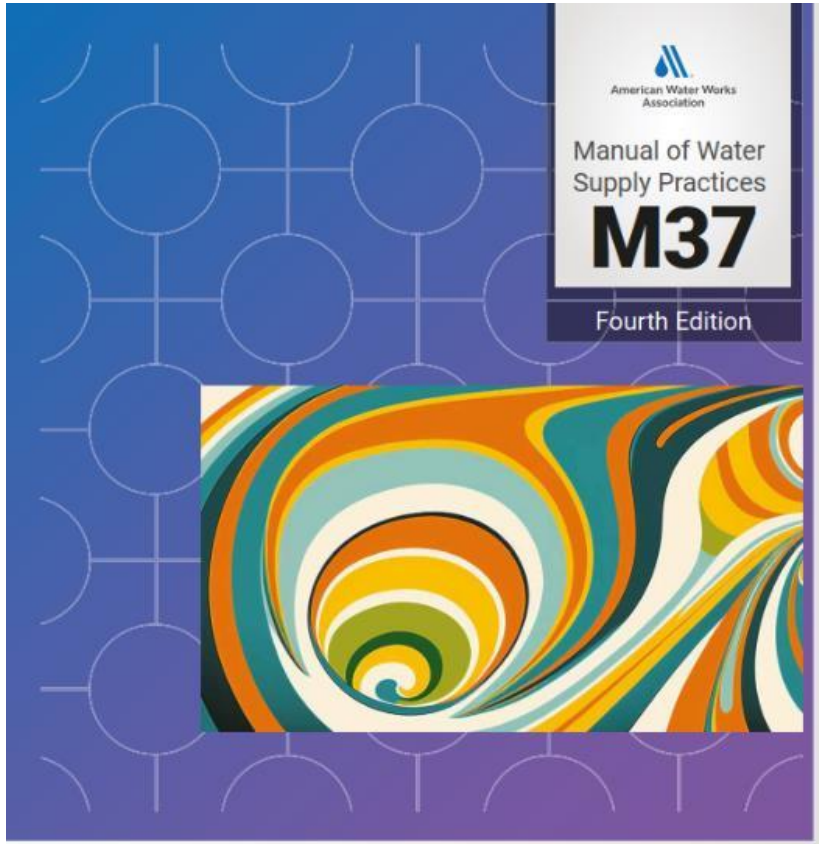
1 – Split the laser beam into A & B
2 – A passes through the sample with particles that moving
3 – Beams are combined and velocity of particle is measured with the doppler effect.
4 – Speed of particle is correlated with the charge.

Analyzers Across the Water Treatment Process



- Measurement Principle
- Types
- Data and Interpretation
- Setup, Standards, and Calibration
- Troubleshooting

Get Yours Now - Available from the AWWA Store!



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- Ali Leeds Aleeds@carollo.com