Optimization Stories from the Field (3rd in a Series)

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PMG Consulting, Inc.

58th Annual Water Workshop

March 10, 2020

Agenda

- Optimization practices used in the field
  - Short synopsis
- Optimization stories
  - Evaluations made
  - Technical solutions developed
  - Implementation and verification
  - Results achieved
- Questions

Optimization Practices Used in Field

- Define objectives/goals
  - Why should this project be initiated
- Develop baseline characteristics
  - Current operations and metrics
- Benchmark industry standards or best practices
  - Compare where things are to where you believe they should be
- Conduct gap analysis
  - How do I get to the goals?
  - Tools, capital, training, operating adjustments that might be needed to achieve the goals

Optimization Practices Used in Field

- Establish Implementation strategy
  - Capital needs
  - Tools, modeling, etc.
  - Operational changes
  - Adjustment protocols
  - Verification procedures
- Track progress against objectives/goals
  - Did you meet the objectives and goals?
  - Did you exceed the objectives and goals?
  - Did you improve water quality?
  - Did you improve performance?

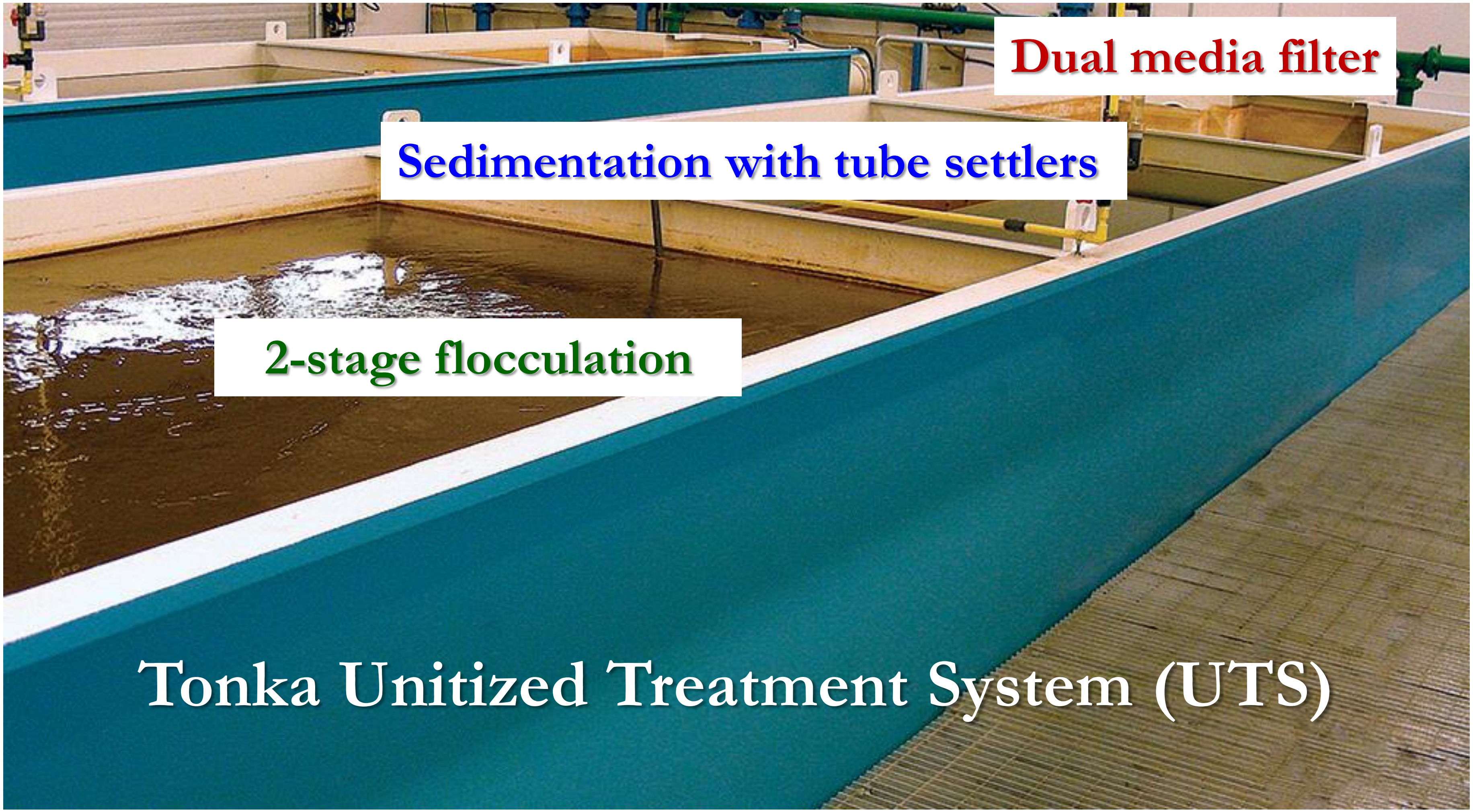
Attica, Ohio

Attica, Ohio

- 0.5 mgd surface water softening plant
  - Average daily production 0.105 mgd (5 hours per day)
- Small reservoir just north of plant
  - Moderate TOC, high hardness, seasonal algae
- Coagulation/pH adjustment/filtration
  - Chemical treatment
  - Solids handling
  - Disinfection and storage
- Finished water pumping to distribution system
  - 900 people

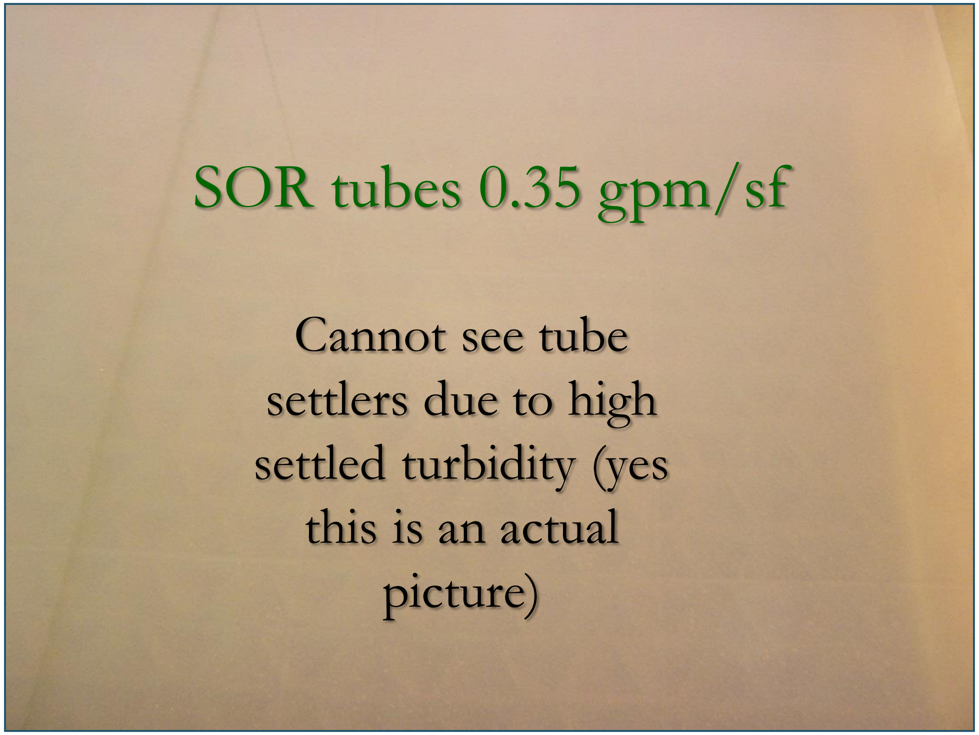
Attica, Ohio

Attica Floc Speed Adjustment

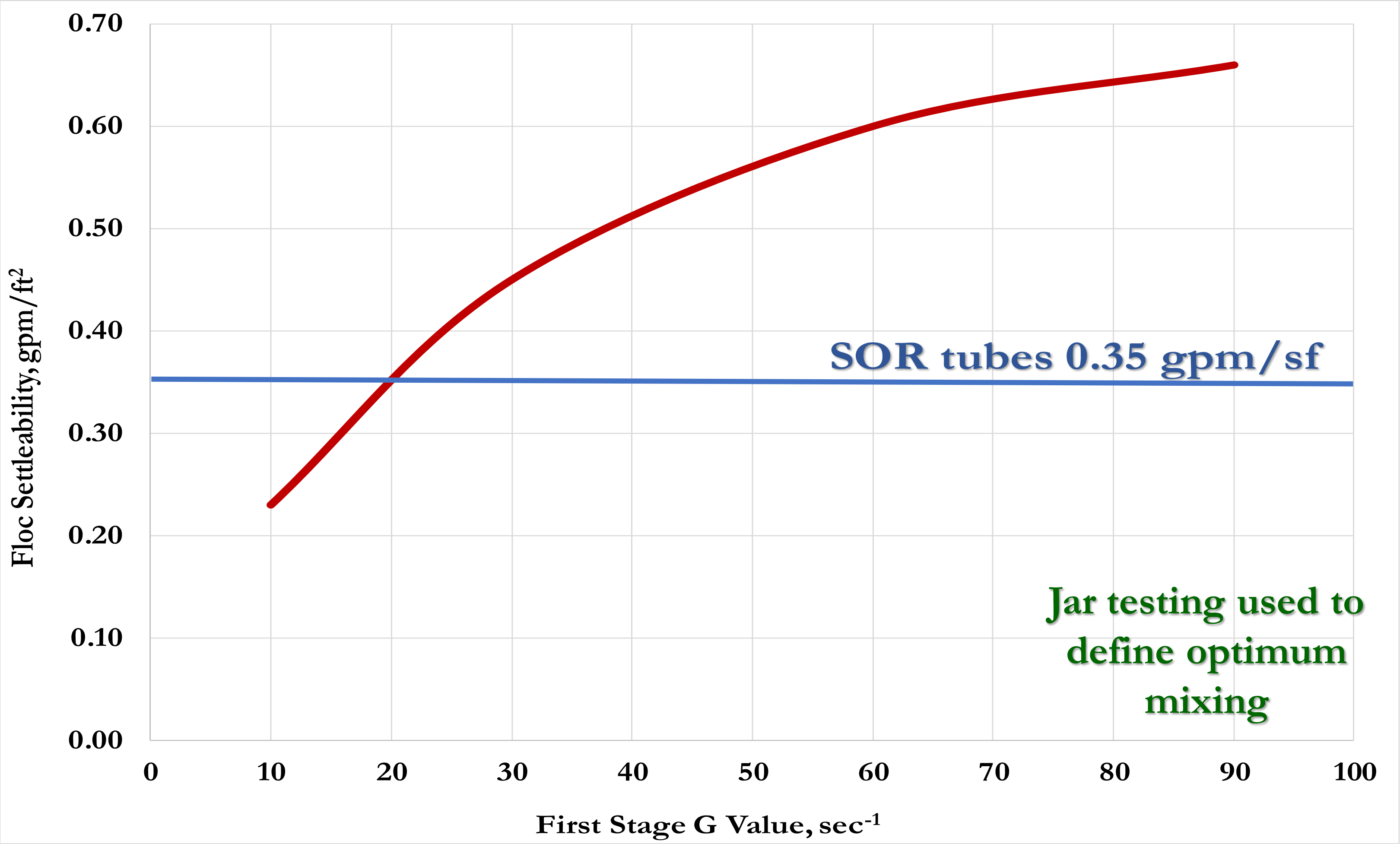


Attica Floc Speed Adjustment

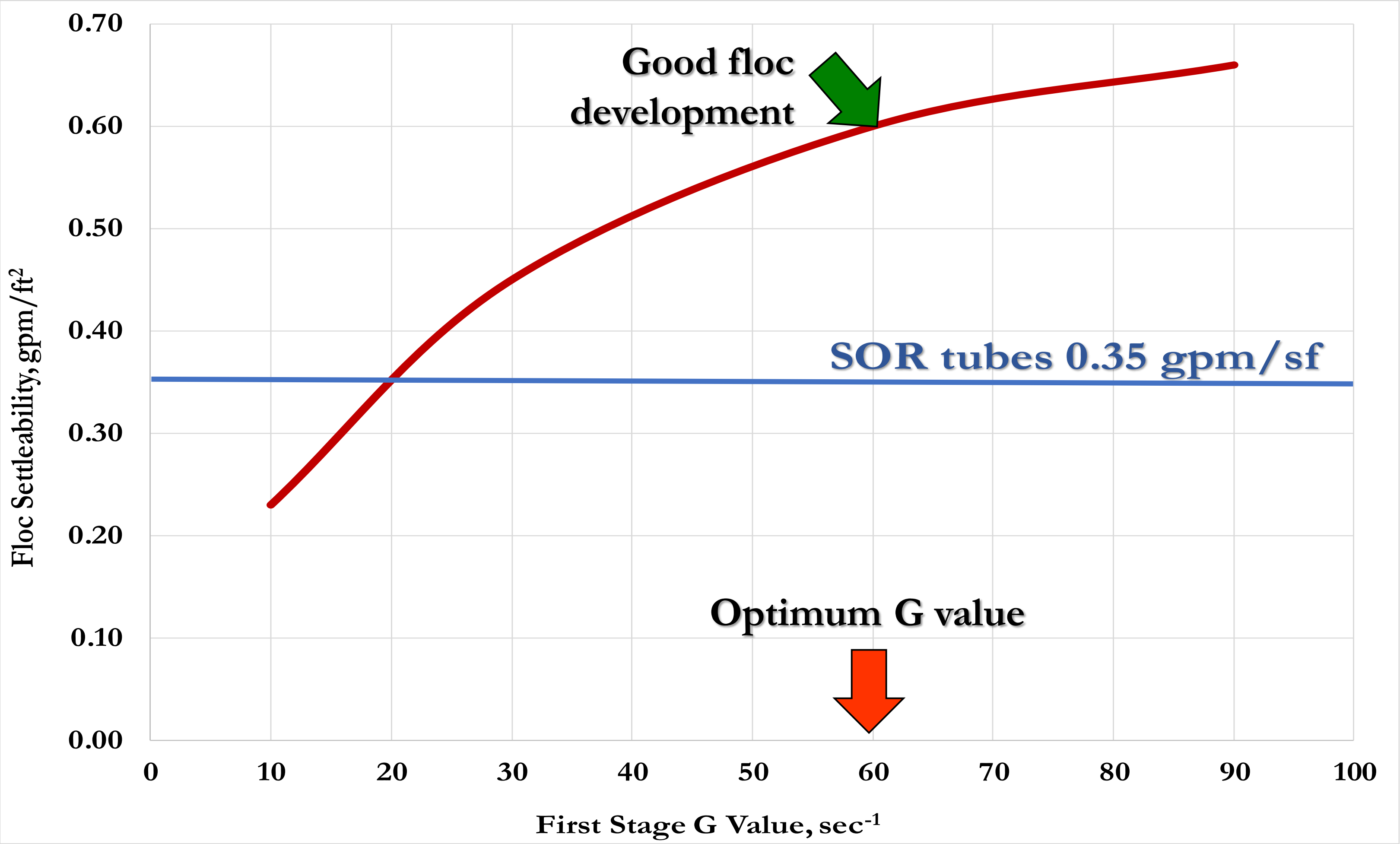
- Initial floc mixer operation
  - **20%** speed
  - G value stage 1 - **10 sec**$^{-1}$
  - G value stage 2 - **7 sec**$^{-1}$
- Floc characteristics
  - 0.6 mm diameter
  - Settleability 0.22 gpm/sf
- Settled water turbidity
  - 8 NTU
  - Poor water clarity
  - High filter solids loading



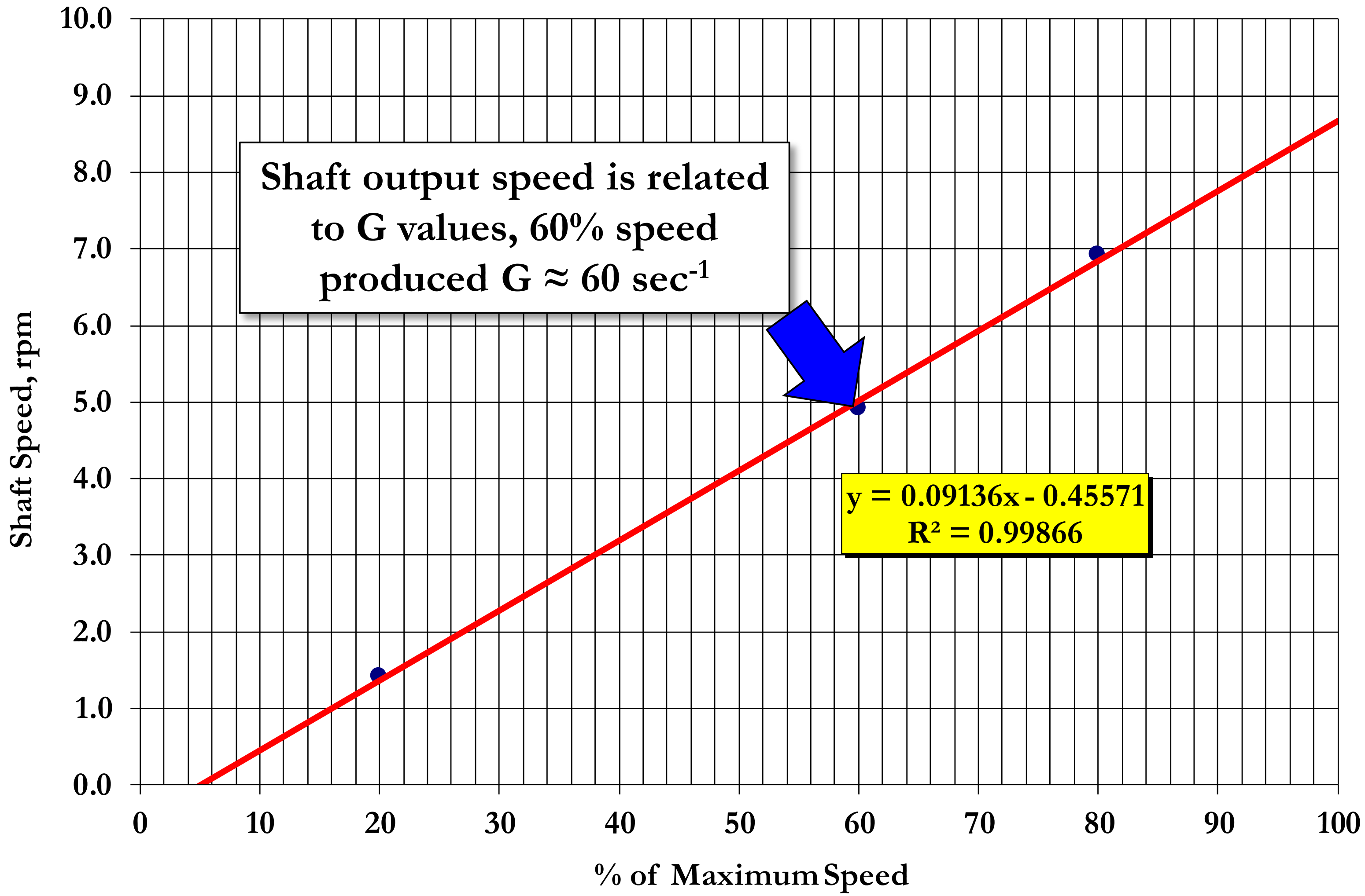
Attica Floc Speed Adjustment



Attica Floc Speed Adjustment



Attica Floc Speed Adjustment

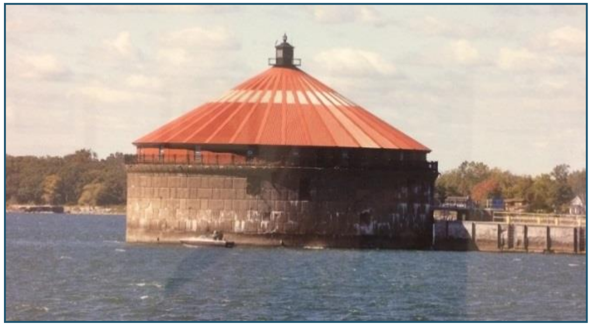


Attica Floc Speed Adjustment

- Adjusted floc speed to 60%
  - G values
    - Stage 1 - 61 sec^{-1}
    - Stage 2 - 43 sec^{-1}
  - Floc size increase to 1.2 mm diameter
  - Floc settleability increased to 0.6 gpm/sf
  - Settled water turbidity decreased to 0.63 NTU
  - Extended filter run times

Buffalo Water

- 120 mgd surface water plant, originally 1922
  - Average daily production 71 mgd
- Direct draw from eastern basin Lake Erie
  - Just upstream of Niagara River
- Coagulation/filtration plant
  - Chemical treatment
  - Solids handling
  - Disinfection and storage
- Finished water pumping to distribution system
  - 257,00 people

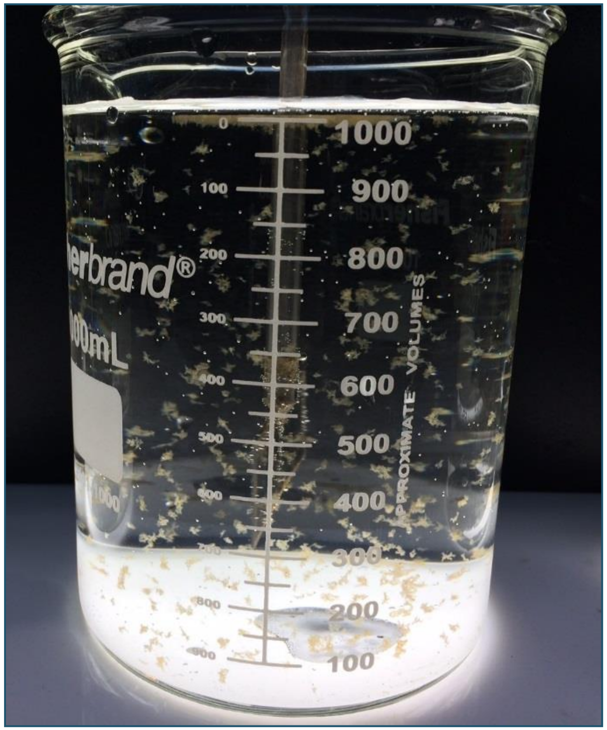


Lake Intake Structure

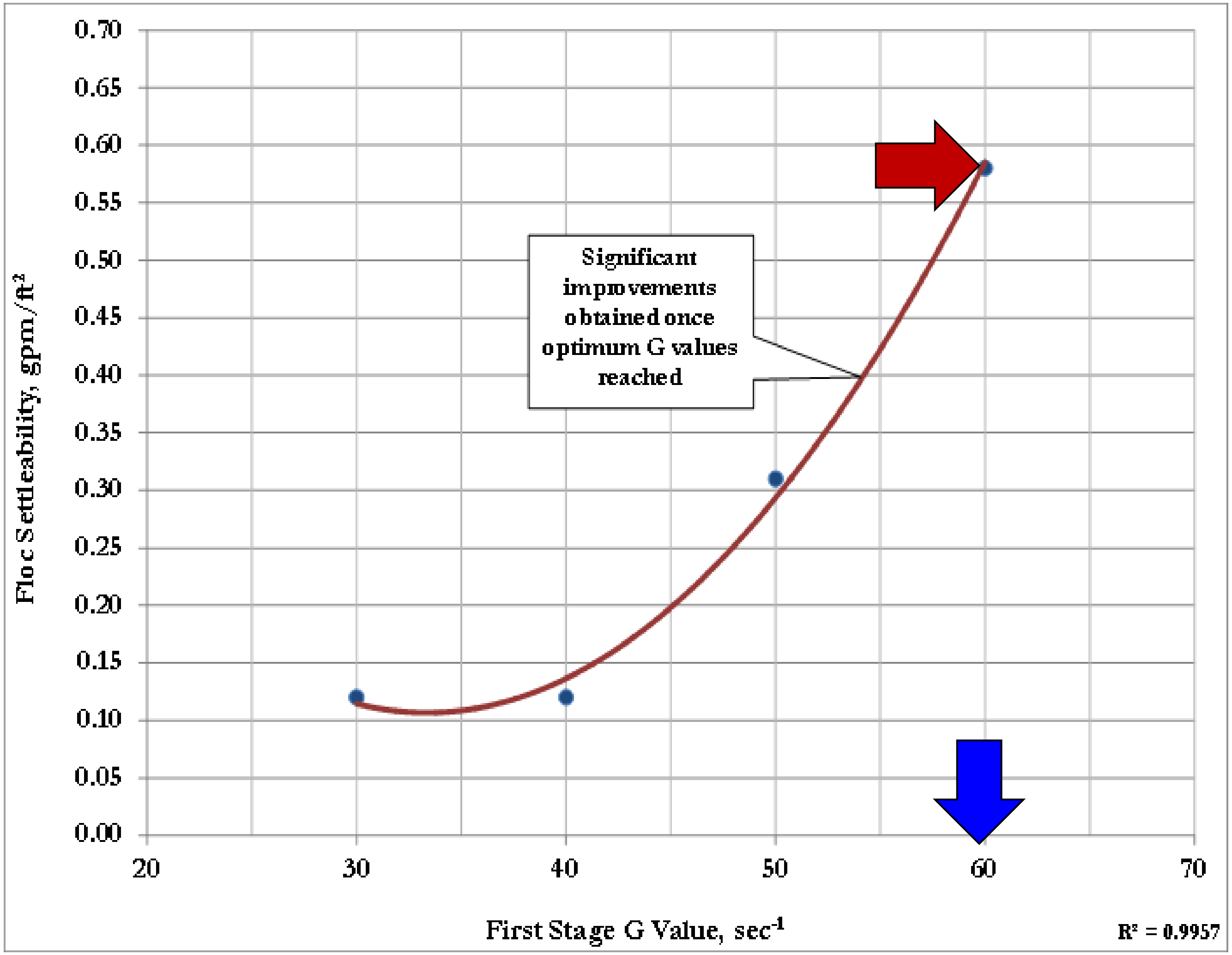
Buffalo Water

Buffalo Floc Speed Adjustments

- SternPac coagulant used since 1990’s
  - Raw water turbidity averages 2 NTU
  - 2016 Settled water turbidity averaged 0.28 NTU
    - Previous coagulant mixing improvements
  - Filter run times 72 hours
    - Low head loss
- Initial floc drive operations
  - 4 stages, VFDs
    - Stage 1 - 18 Hz, 30 G
    - Stage 2 - 12 Hz, 16 G
    - Stage 3 - 10 Hz, 14 G
    - Stage 4 - 8 Hz, 12 G



Buffalo Floc Speed Adjustments

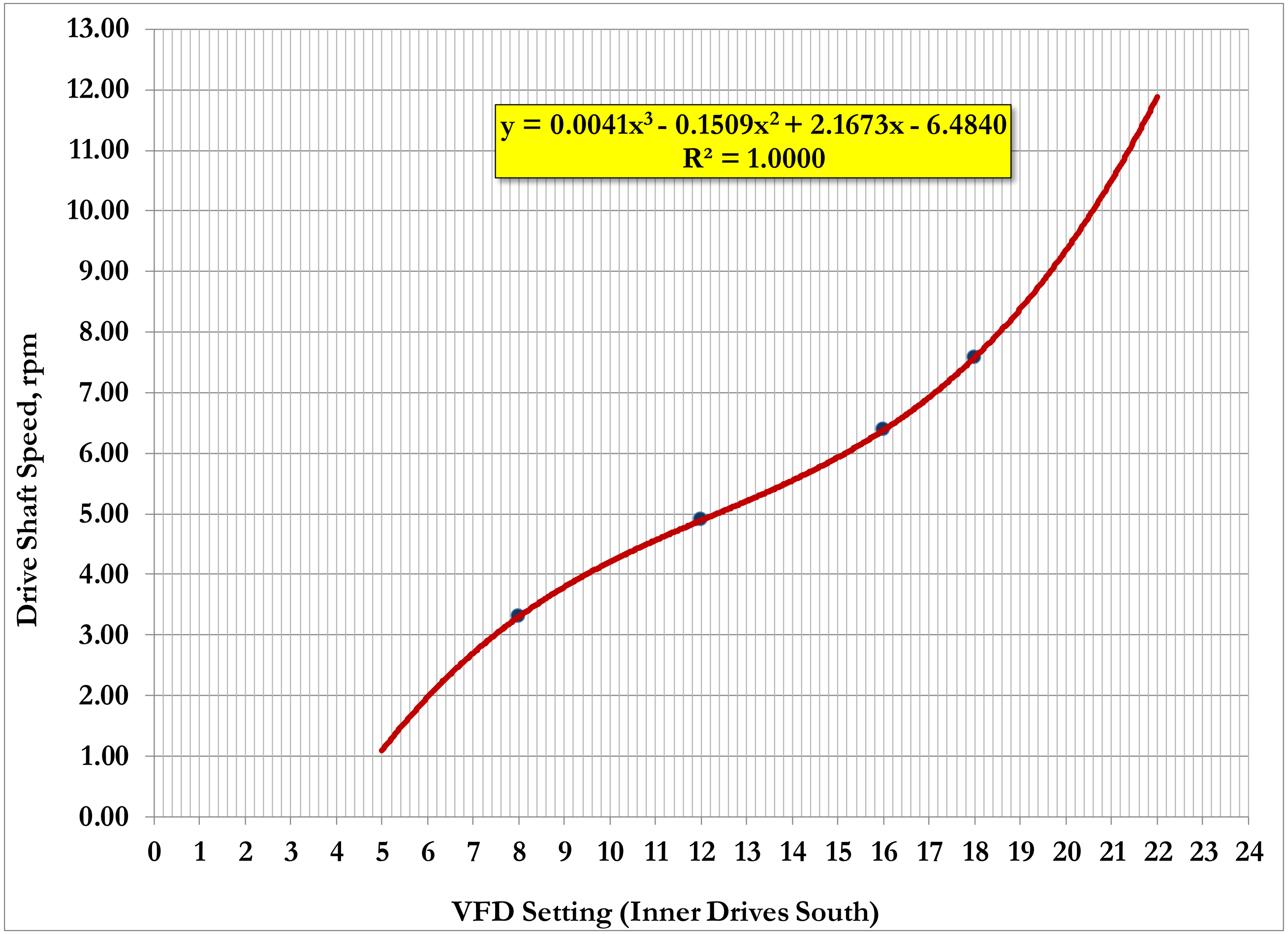


Jar testing suggested that higher G values in flocculation could improve floc development and settleability

Floc size improvement from 0.3 mm to 0.6 mm

Buffalo Floc Speed Adjustments

- Floc drive settings and rotational speeds verified in field



Buffalo Floc Speed Adjustments

- Floc speed adjustments suggested from G values calculations based on temperature variations
  - Stage 1 - 20.2 Hz, 60 G
  - Stage 2 - 19.4 Hz, 50 G
  - Stage 3 - 18.4 Hz, 40 G
  - Stage 4 - 16.6 Hz, 30 G
- Implemented floc speed adjustments late in 2016
  - Adjust floc drive speeds twice per year (temperature-based)
- Verified target settled water turbidity
  - 0.7 NTU to 1.0 NTU

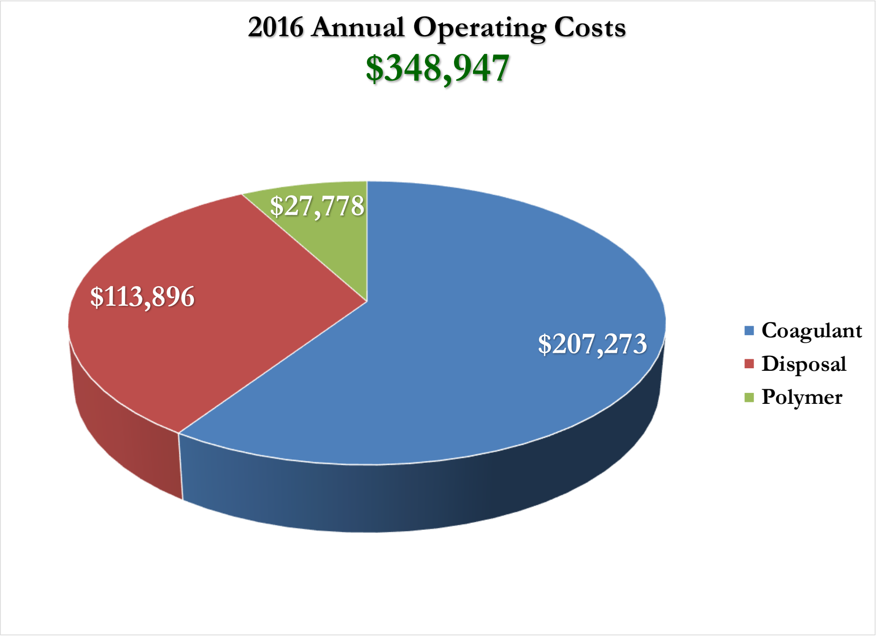
Buffalo Floc Speed Adjustments

- Floc speed adjustments immediately led to 13% average reduction in coagulant dosage
  - 8.5 mg/L 2016
  - 7.4 mg/L 2017
    - Settled water turbidity averaged 0.83 NTU
    - Target turbidity 0.7 NTU to 1.0 NTU
- Coagulant reduction also impacted
  - Sludge dewatering
  - Polymer conditioning
  - Cake disposal
  - Operating costs

Buffalo Floc Speed Adjustments

Buffalo Floc Speed Adjustments

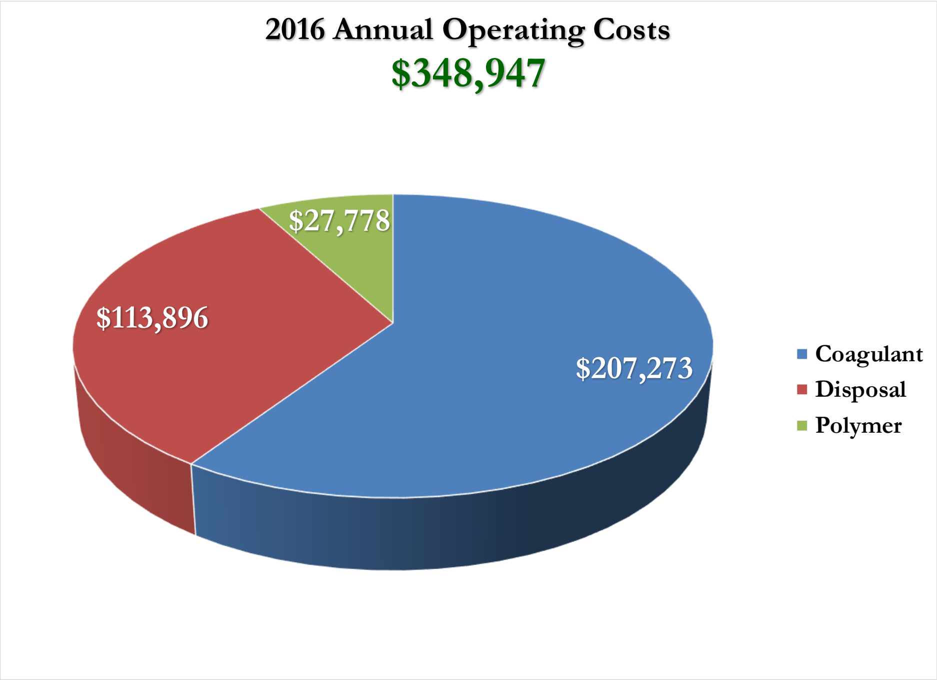
2016 Operating Metrics	
SternPac, mg/L	8.5
Dewatering polymer, lbs/ton	11.9
Cake production, dry tons/yr	173
Cake solids, %	31.8

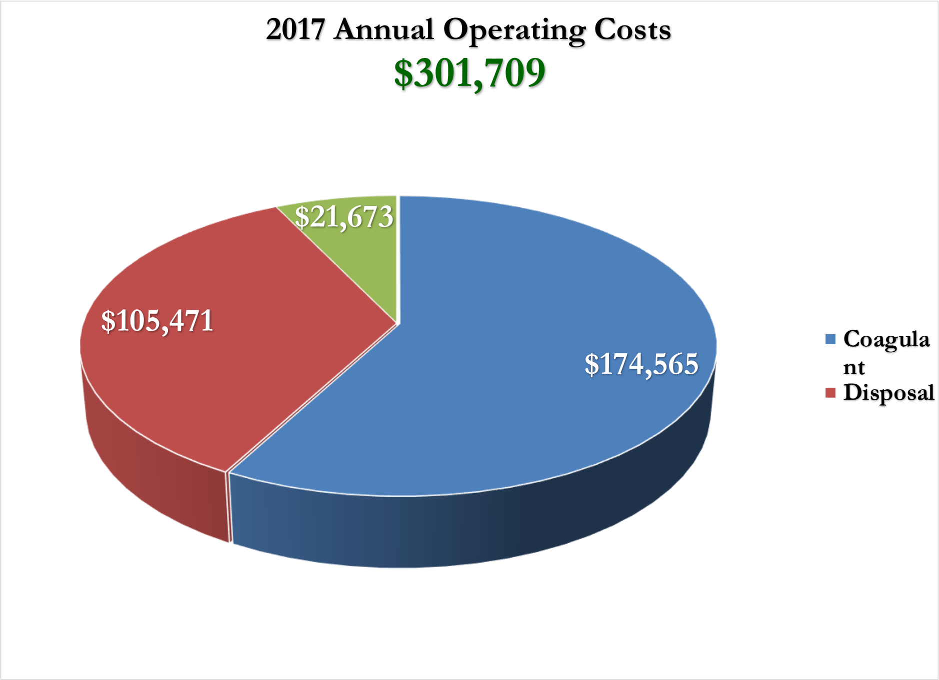


Buffalo Floc Speed Adjustments

2016 Operating Metrics		2017 Operating Metrics	
SternPac, mg/L	8.5	SternPac, mg/L	7.4
Dewatering polymer, lbs/ton	11.9	Dewatering polymer, lbs/ton	10.5
Cake production, dry tons/yr	173	Cake production, dry tons/yr	154
Cake solids, %	31.8	Cake solids, %	32.7

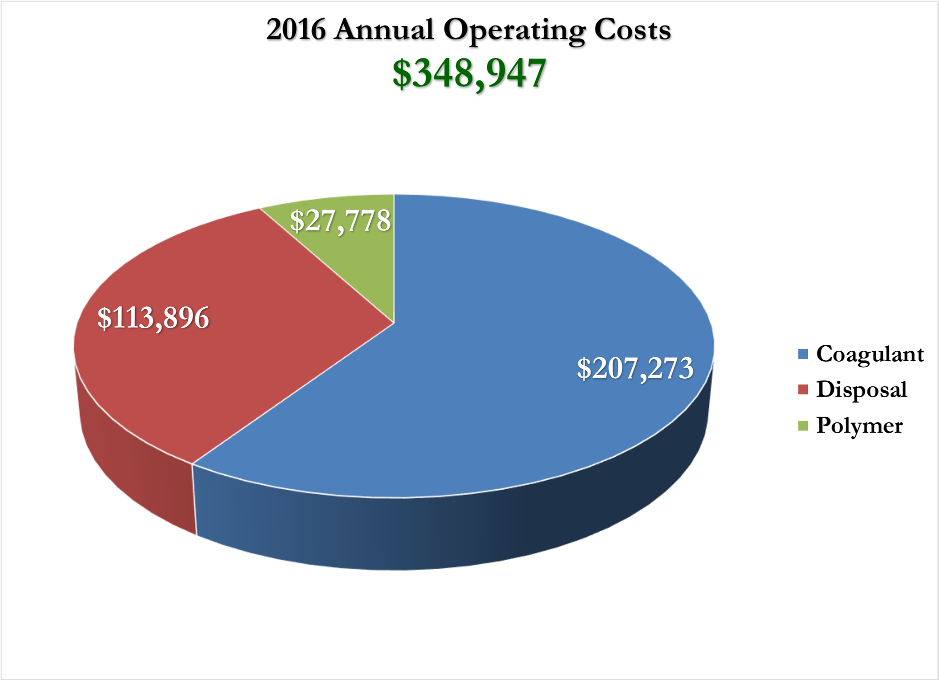
Buffalo Floc Speed Adjustments

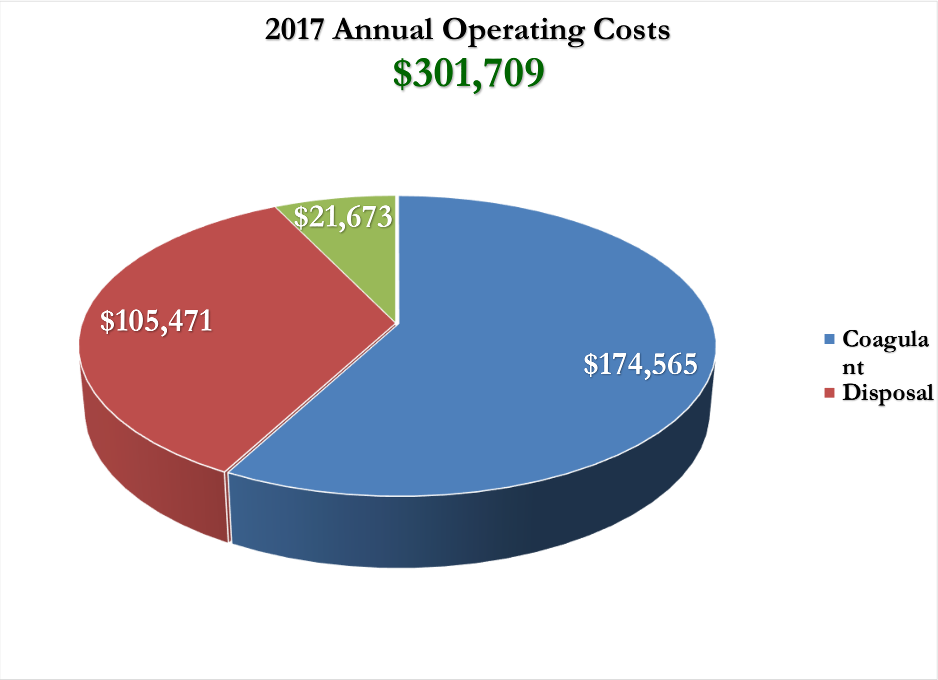




Actual 13.5% reduction realized in annual costs

Buffalo Floc Speed Adjustments





Actual 13.5% reduction realized in annual costs

Annual cost savings $47,238

Fort Recovery, Ohio

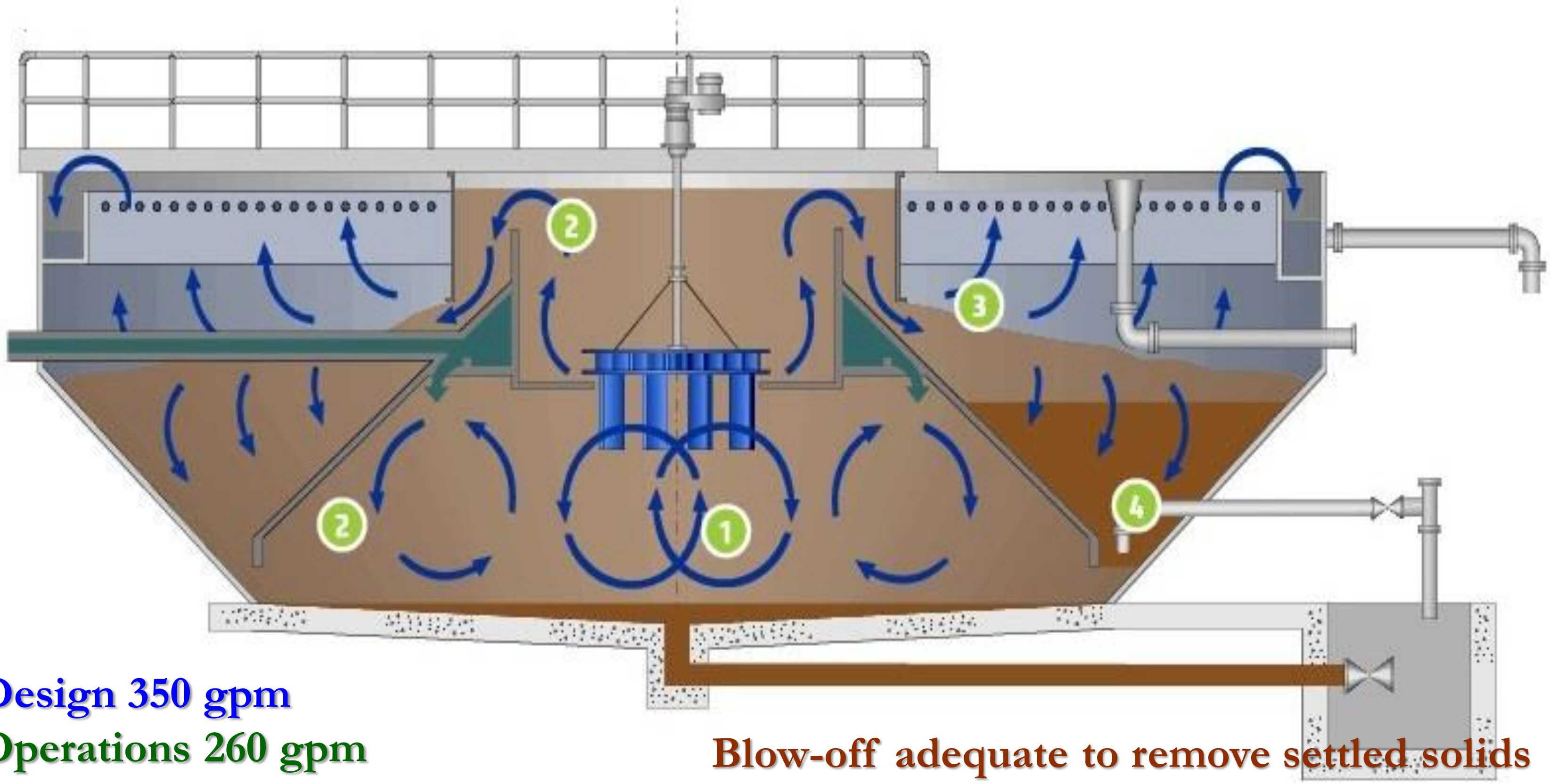
Fort Recovery

- 0.5 mgd ground water softening plant
  - Average daily production 0.11 mgd (7 hours per day)
- Two wells around treatment plant
  - 400 gpm, 370 gpm
- Aeration/lime-soda softening/recarbonation/filtration
  - Chemical treatment
  - Solids handling
  - Disinfection and storage
- Finished water pumping to distribution system
  - 1,400 people

Fort Recovery

Fort Recovery Clarifier Optimization

Infilco (Suez) Accelator



Design 350 gpm

Operations 260 gpm

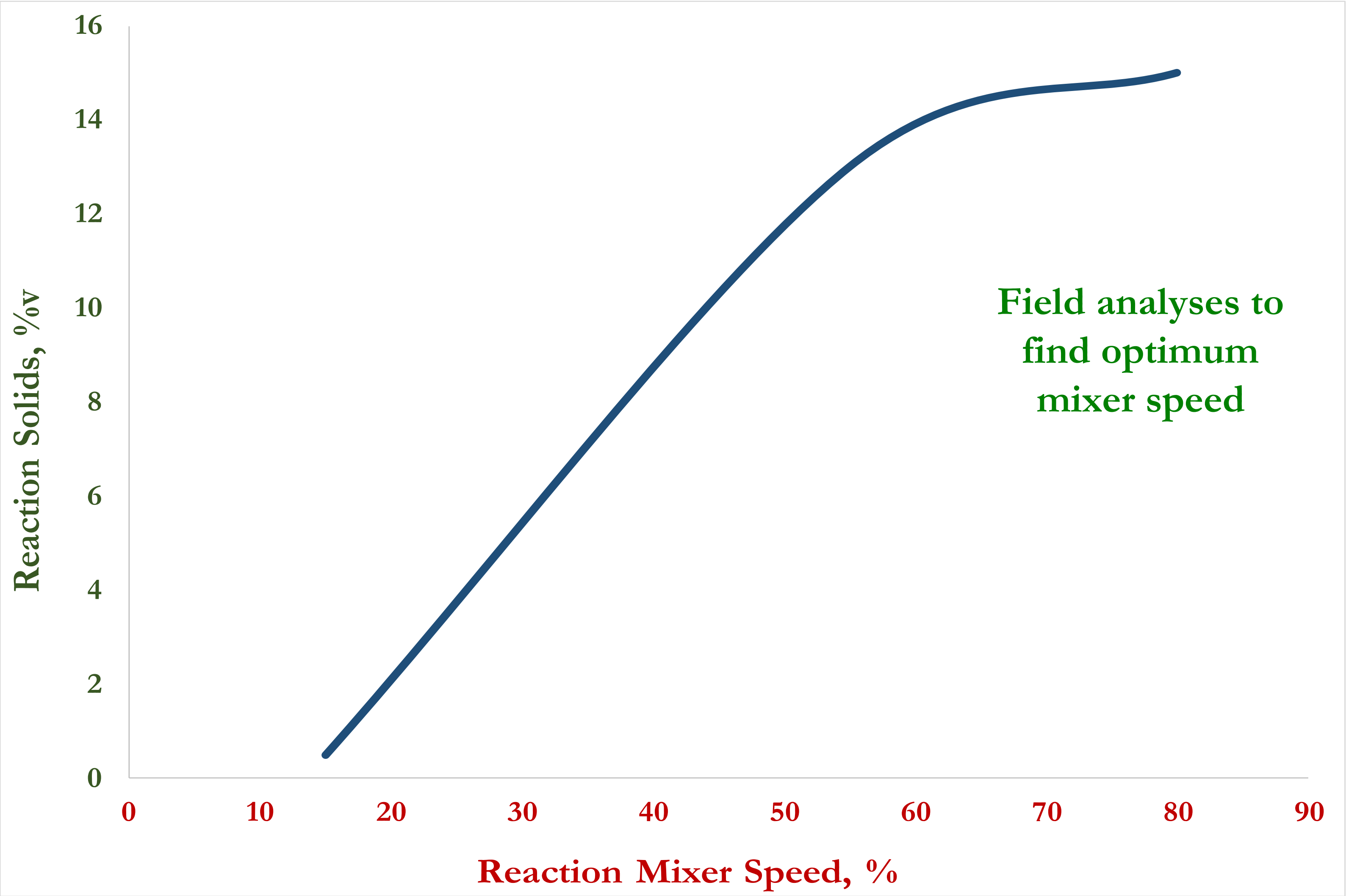
Blow-off adequate to remove settled solids

Fort Recovery Clarifier Optimization

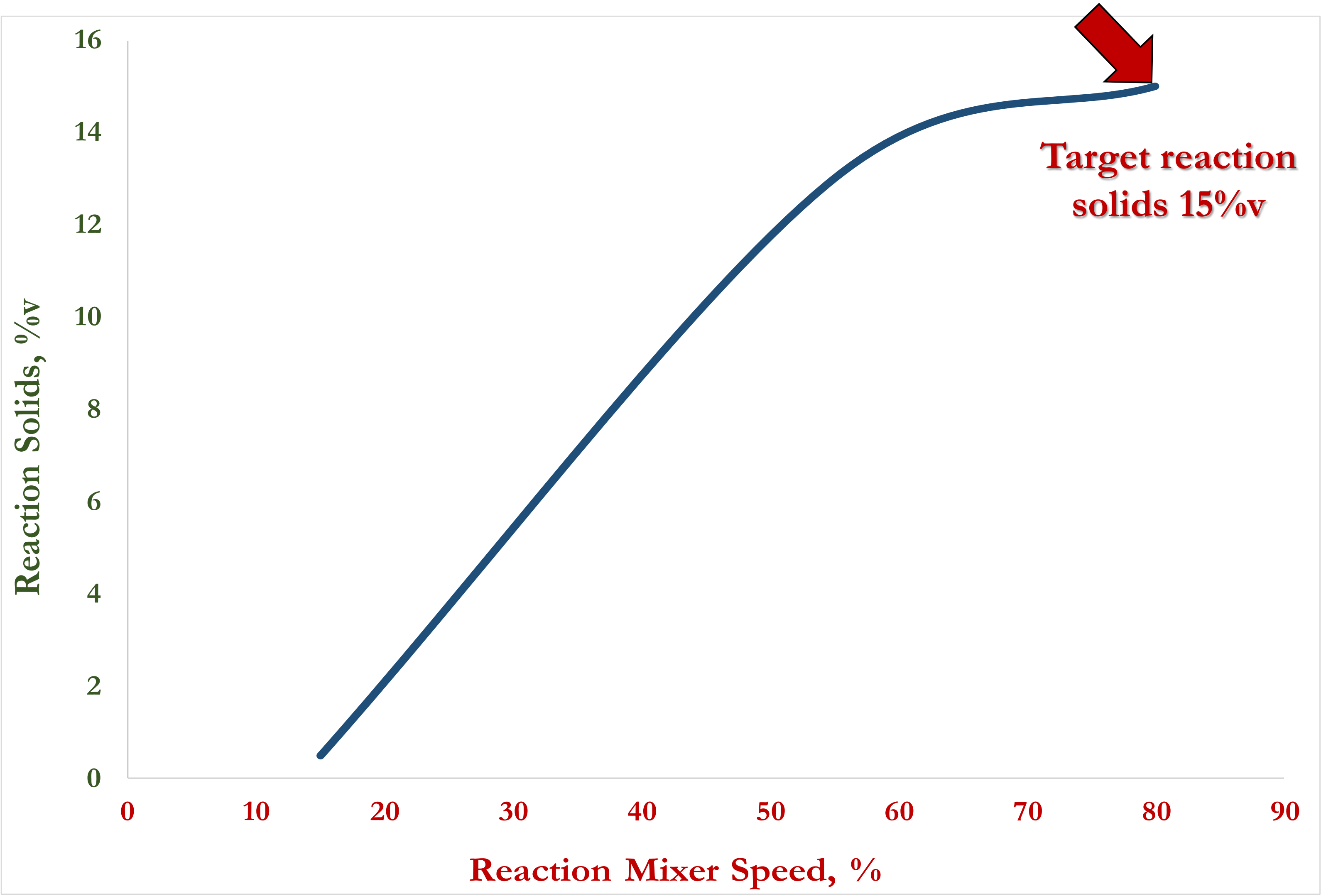
- Clarifier Optimization Initiative
  - Poor water clarity ($CaCO_3$ and OH carryover)
    - 4-inches clear water at sidewall
    - Previously tried ferric chloride and anionic polymers to improve clarity
  - No reaction solids observed
    - Mixer set at 15% speed since 1992 plant start up
  - Excessive OH alkalinity
    - 105 mg/L average
  - Likely need softening improvements as well
    - Average lime dosage 61 mg/L
    - Average NaOH dosage 313 mg/L

Fort Recovery Clarifier Optimization

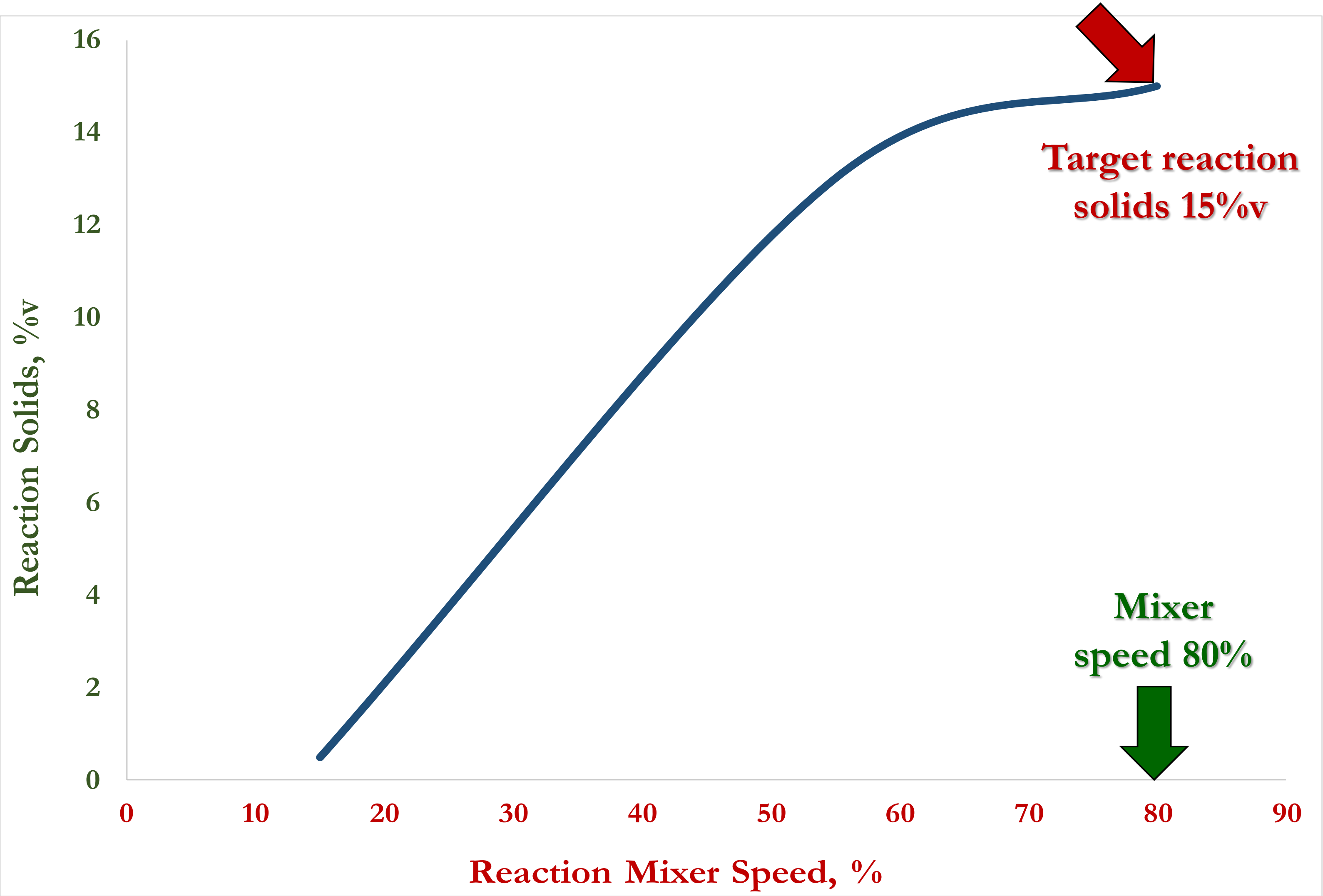
Fort Recovery Clarifier Optimization



Fort Recovery Clarifier Optimization

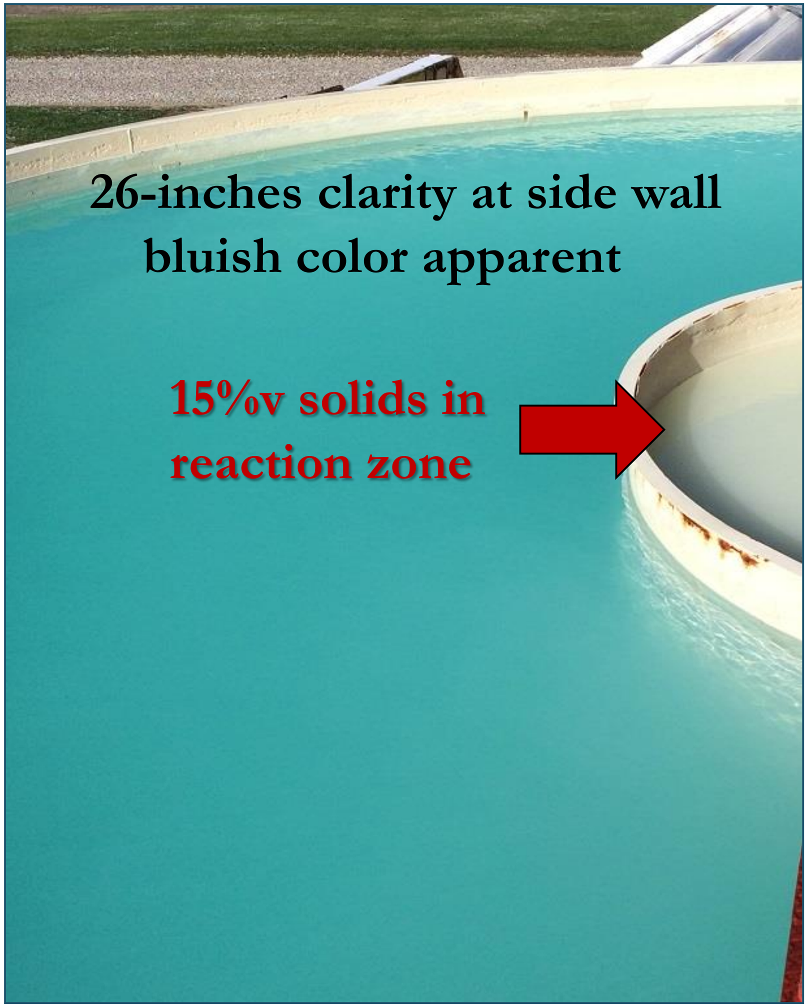


Fort Recovery Clarifier Optimization



Fort Recovery Clarifier Optimization

- Water clarity improved within 2 hours
- Reaction solids observed
- Mixer speed maintained 80%
- Review softening operations
  - Improve stability



Fort Recovery Clarifier Optimization

Parameter	Raw Water	Clarified Water
Water pH, s.u.	7.31	11.27
CO_2, mg/L	16	0
Hardness, mg/L	705	258
Total alkalinity, mg/L	163	109
Phenol alkalinity, mg/L	0	107
CO_3 alkalinity, mg/L	0	4
OH alkalinity, mg/L	0	105
Calcium, mg/L	405	172
Magnesium, mg/L	300	86

Lime 61 mg/L
NaOH 313 mg/L

Fort Recovery Clarifier Optimization

- Computer modeling to simulate softening and recarbonation
  - Significant noncarbonate hardness (540 mg/L)
  - Review Lime/NaOH
  - Investigate Lime/soda ash
- Target hardness 240 mg/L
  - Too expensive to reduce hardness further
  - Finished water stability adjustments (excessive media growth)
    - Bi-annual filter rebuilding

Fort Recovery Clarifier Optimization

Fort Recovery Water Treatment Plant

SETTLED WATER QUALITY

Remaining Compounds	After softening, meq/L
Carbon dioxide	0.00
Calcium carbonate	0.47
Magnesium hydroxide	0.46
Calcium bicarbonate	0.00
Magnesium bicarbonate	0.00
Magnesium carbonate	0.00
Calcium sulfate	2.77
Calcium chloride	0.00
Magnesium sulfate	0.37
Magnesium chloride	0.75
Calcium hydroxide (Excess)	0.37
TA/PA ratio	1.07
CO_3/OH Ratio	**0.15**

Predicted Water Quality	
Calcium - as $CaCO_3$	181 mg/L
Magnesium - as $CaCO_3$	79 mg/L
Hardness - as $CaCO_3$	259 mg/L
Total alkalinity - as $CaCO_3$	64 mg/L
Phenol alkalinity - as $CaCO_3$	60 mg/L
Water pH	11.19
Bicarbonate alkalinity - as $CaCO_3$	0 mg/L
Carbonate alkalinity - as $CaCO_3$	8 mg/L
Hydroxide alkalinity - as $CaCO_3$	56 mg/L

Lime dosage	62 mg/L
Caustic soda dosage	316 mg/L

Model matched current dosages and water quality relatively close to existing treatment on plant visits

Fort Recovery Clarifier Optimization

Fort Recovery Water Treatment Plant

SETTLED WATER QUALITY

Remaining Compounds	After softening, meq/L	Predicted Water Quality
Carbon dioxide	0.00	Calcium - as $CaCO_3$
Calcium carbonate	0.47	173 mg/L
Magnesium hydroxide	0.23	Magnesium - as $CaCO_3$
Calcium bicarbonate	0.00	67.3 mg/L
Magnesium bicarbonate	0.00	Hardness - as $CaCO_3$
Magnesium carbonate	0.00	240 mg/L
Calcium sulfate	2.99	Total alkalinity - as $CaCO_3$
Calcium chloride	0.00	35 mg/L
Magnesium sulfate	0.47	Phenol alkalinity - as $CaCO_3$
Magnesium chloride	0.65	23 mg/L
Calcium hydroxide (Excess)	0.00	Water pH
TA/PA ratio	1.51	10.75
CO_3/OH Ratio	**2.04**	Bicarbonate alkalinity - as $CaCO_3$
		0 mg/L
		Carbonate alkalinity - as $CaCO_3$
		24 mg/L
		Hydroxide alkalinity - as $CaCO_3$
		12 mg/L

Lime dosage	431 mg/L
Soda ash dosage	416 mg/L

Lime/soda ash dosages quite high to meet target hardness, <u>increased operating costs</u>

Fort Recovery Clarifier Optimization

Fort Recovery Water Treatment Plant

SETTLED WATER QUALITY		
Remaining Compounds	After softening, meq/L	Predicted Water Quality
Carbon dioxide	0.00	**Calcium - as $CaCO_3$**
Calcium carbonate	0.47	175 mg/L
Magnesium hydroxide	0.46	**Magnesium - as $CaCO_3$**
Calcium bicarbonate	0.00	66 mg/L
Magnesium bicarbonate	0.00	**Hardness - as $CaCO_3$**
Magnesium carbonate	0.00	240 mg/L
Calcium sulfate	3.02	**Total alkalinity - as $CaCO_3$**
Calcium chloride	0.00	39 mg/L
Magnesium sulfate	0.00	**Phenol alkalinity - as $CaCO_3$**
Magnesium chloride	0.86	35 mg/L
Calcium hydroxide (Excess)	0.00	**Water pH**
TA/PA ratio	1.12	11.14
CO_3/OH Ratio	**0.26**	**Bicarbonate alkalinity - as $CaCO_3$**
		0 mg/L
		Carbonate alkalinity - as $CaCO_3$
		8 mg/L
		Hydroxide alkalinity - as $CaCO_3$
		31 mg/L

Lime dosage	159 mg/L
Caustic soda dosage	293 mg/L

Increase in lime and decrease in NaOH met target hardness, reduced OH alkalinity to about 30 mg/L

NEMRWSD - Tupelo, MS

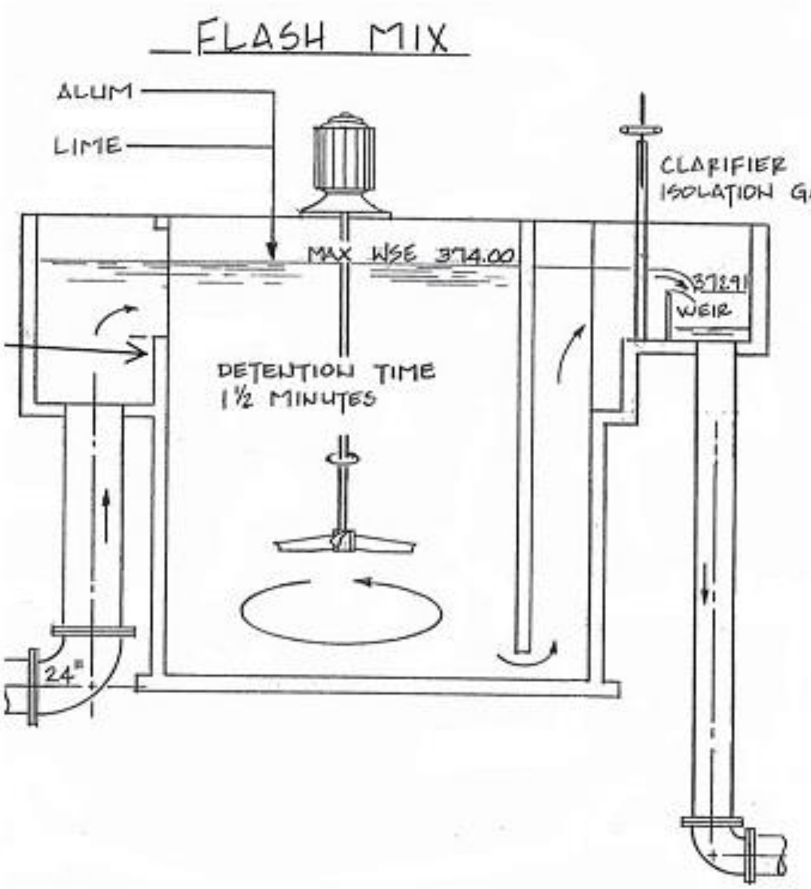
NEMRWD - Tupelo, MS

NEMRWD - Tupelo, MS

- 18 mgd surface water plant drawing from Tombigbee River
  - Average daily production 12 mgd
- Coagulation/pH adjustment/filtration plant
  - Chemical treatment
  - Solids handling
  - Disinfection and storage
    - Final chloramination
- Finished water pumping to four wholesale distribution systems
  - ≈70,000 people

NEMRWD - Tupelo, MS

LACR and TOC Removal Initiative



Tupelo LACR and TOC Removal

- Low alkalinity source water inhibits TOC removals
  - Average annual alkalinity 45 mg/L
  - TOC varies 5 mg/L to 22 mg/L
- Alum coagulation
  - 58 mg/L average dosage
  - 150 mg/L during rain events
    - Due to high color and high TOC
    - Maximum dosage under NSF
    - Often results in elevated turbidity levels
    - Typically insufficient alkalinity to foster coagulation reactions

Tupelo LACR and TOC Removal

- LACR (pr: lacker)
  - **L**ime to **A**lkalinity **C**onsumed **R**atio
    - Lime most common alkalinity supplement
  - Replacement of alkalinity reacted during coagulation to foster optimum metal hydroxide formation
    - Low alkalinity source water <60 mg/L
    - Metal hydroxides adsorb organic contaminants (TOC)
    - Alkalinity control needed for optimum coagulation, corrosion control, and stability control
- LACR maintains control of alkalinity levels and TOC reduction
  - Alkalinity replacement common using lime or other chemicals

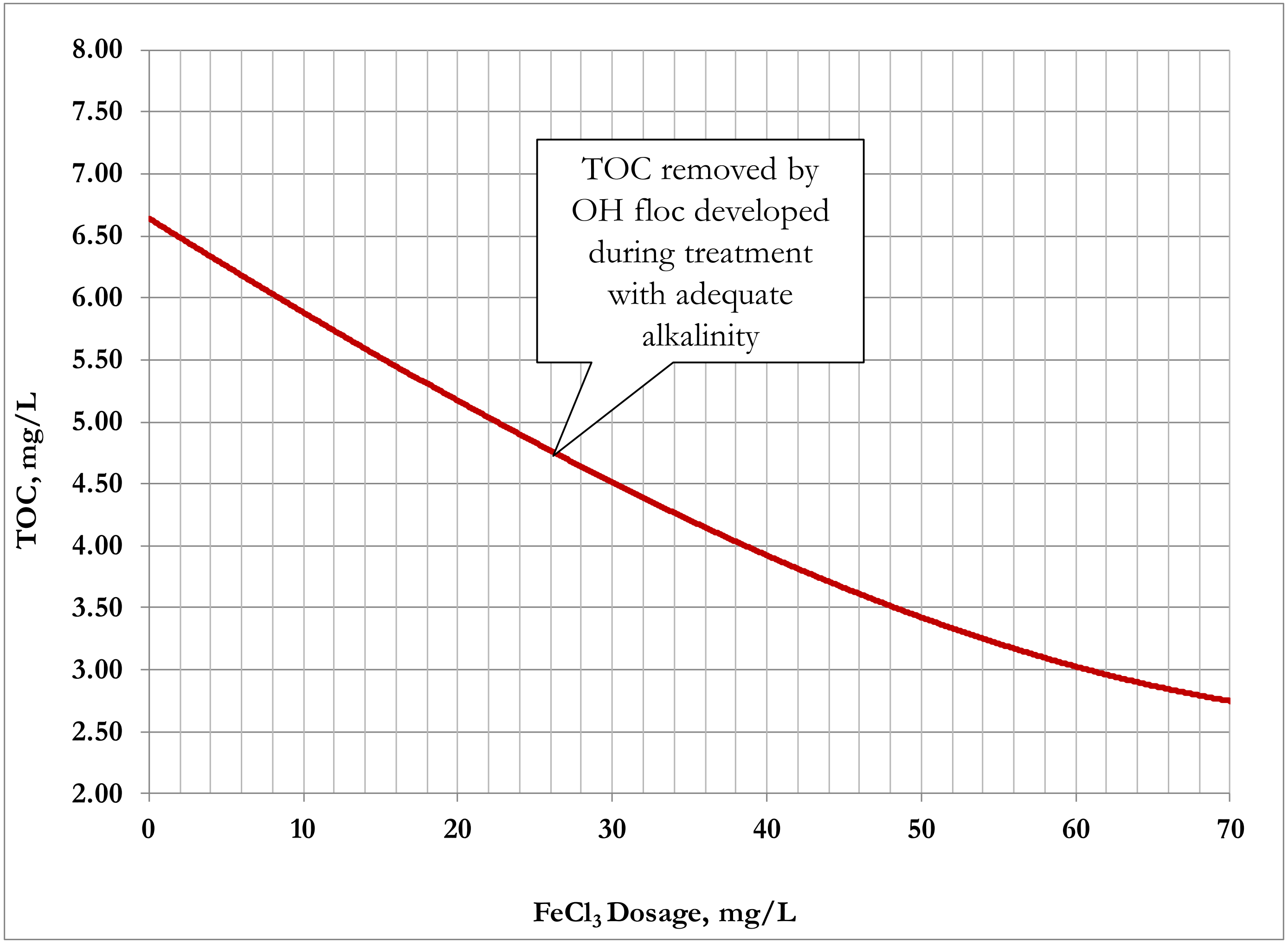
Tupelo LACR and TOC Removal

$$LACR = \frac{alkalinity \quad dosage, mg / L}{k * coagulant \quad dosage, mg / L}$$

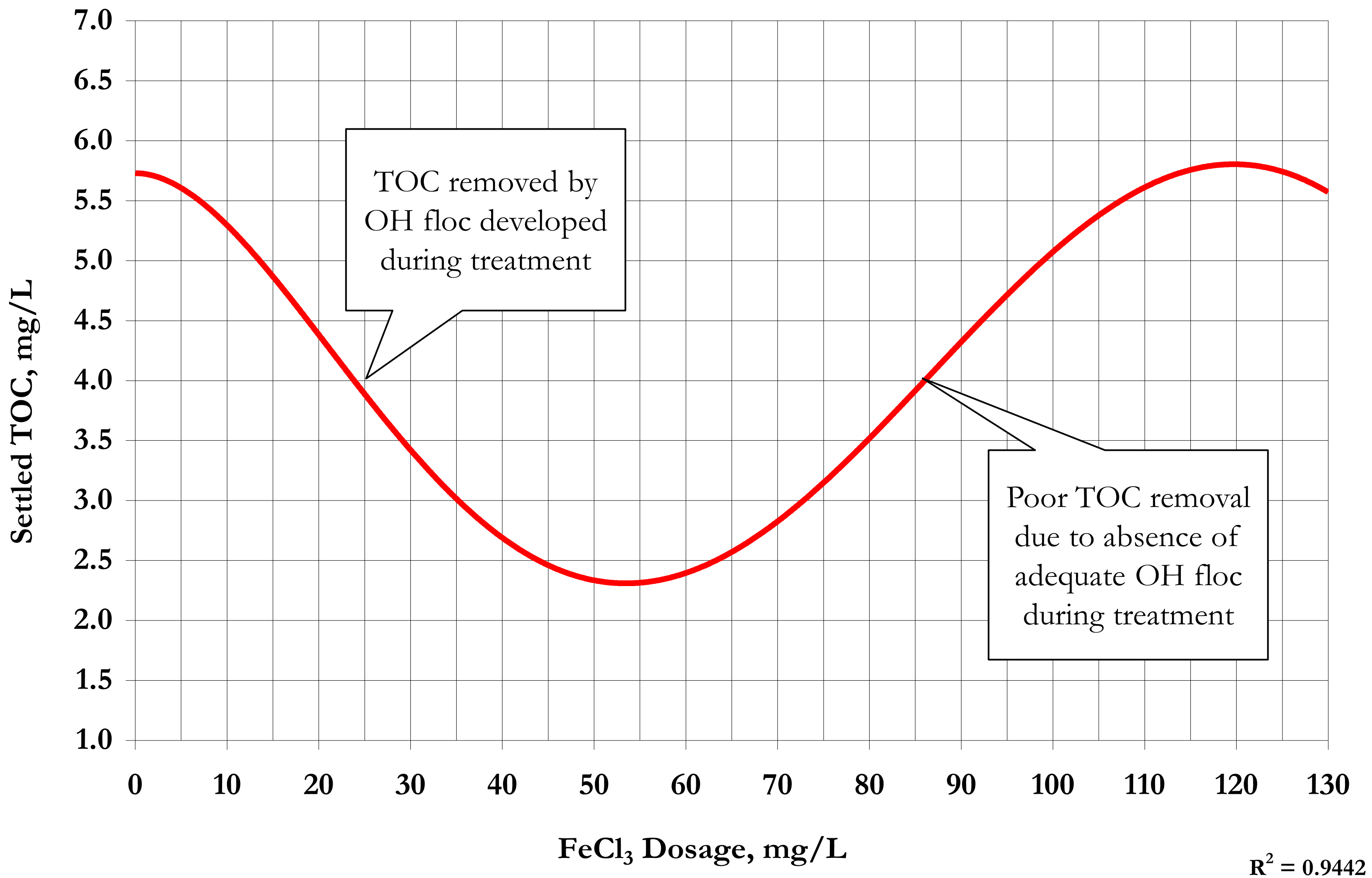
$$k = alkalinity \quad consumption \quad coefficien\,t$$

$$LACR * k * coagulant \quad dosage, mg / L = alkalinity \quad dosage, mg / L$$

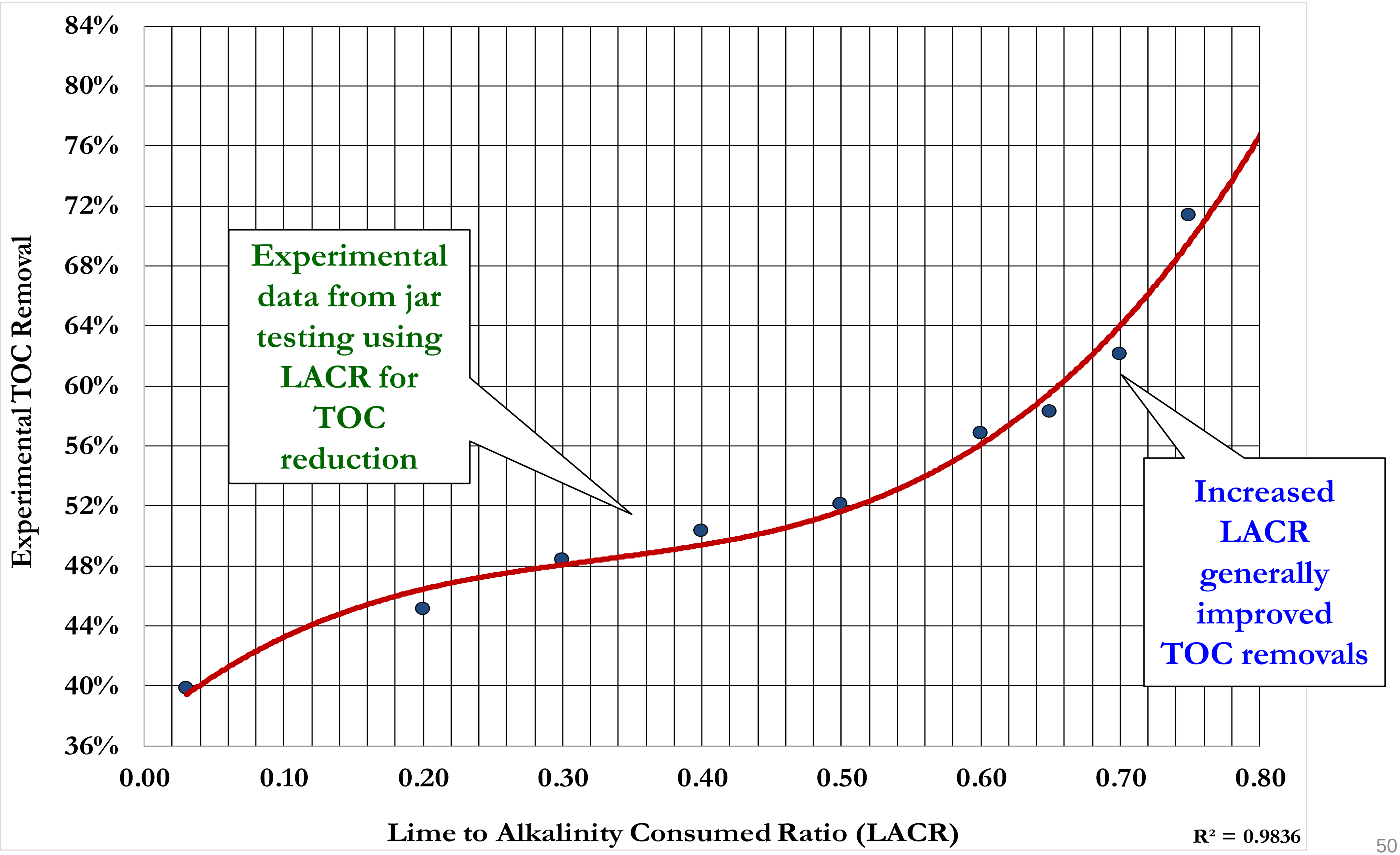
Tupelo LACR and TOC Removal



Tupelo LACR and TOC Removal



Tupelo LACR and TOC Removal



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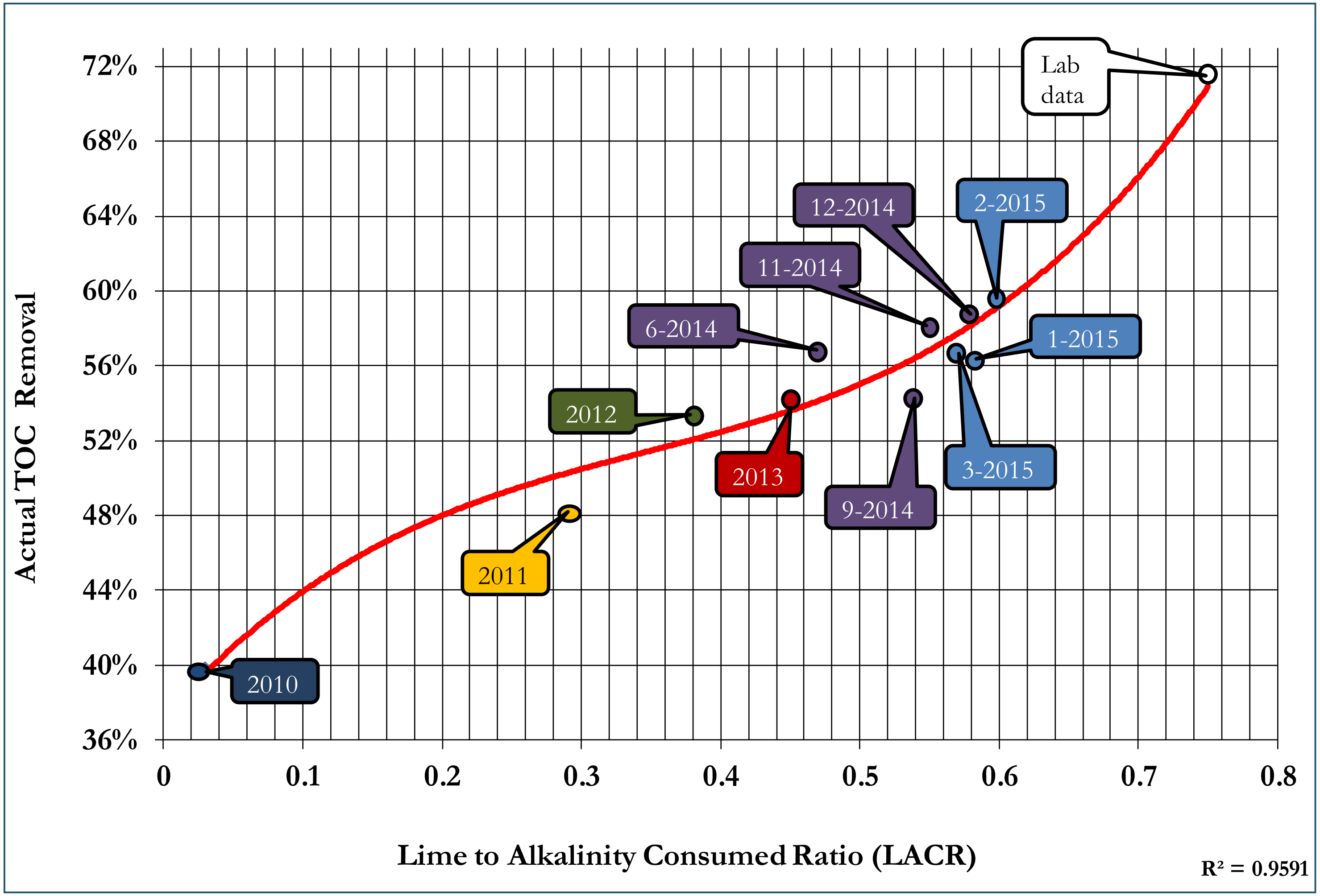

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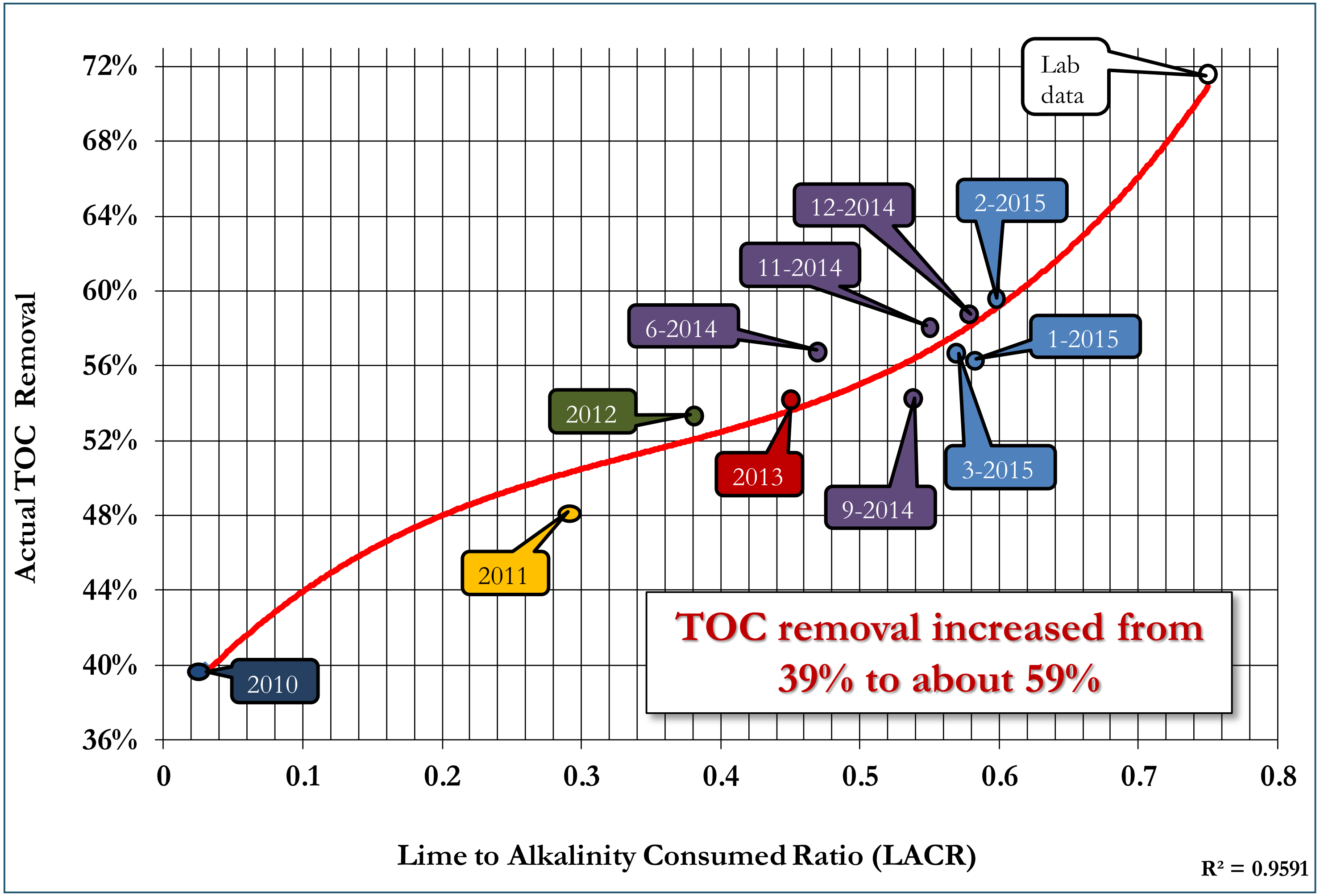

Conclusions

- Optimization can produce excellent results
  - Better performance in many applications
  - Follow scientific principles and established procedures
  - Document findings and projections
  - Verify with first-year field data
  - Often improves water quality and can produce cost savings
- Start making you own stories

Questions

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