Optimization Cases - Rapid Sand and Tertiary Filtration

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OTCO Procrastinator's Workshop

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Agenda

- Common Optimization Criteria
- Wastewater Filtration Case Study
- Water Filtration Case Study
- Summary

Common Filter Optimization Criteria

- Effluent turbidity (solids)
- Run time
- Gross water production
- Washwater usage
- Floc retention
- Media conditions
  - Grain size
  - Acid solubility
  - Organic/inorganic deposits
  - L/D_{10} ratio and bed depth

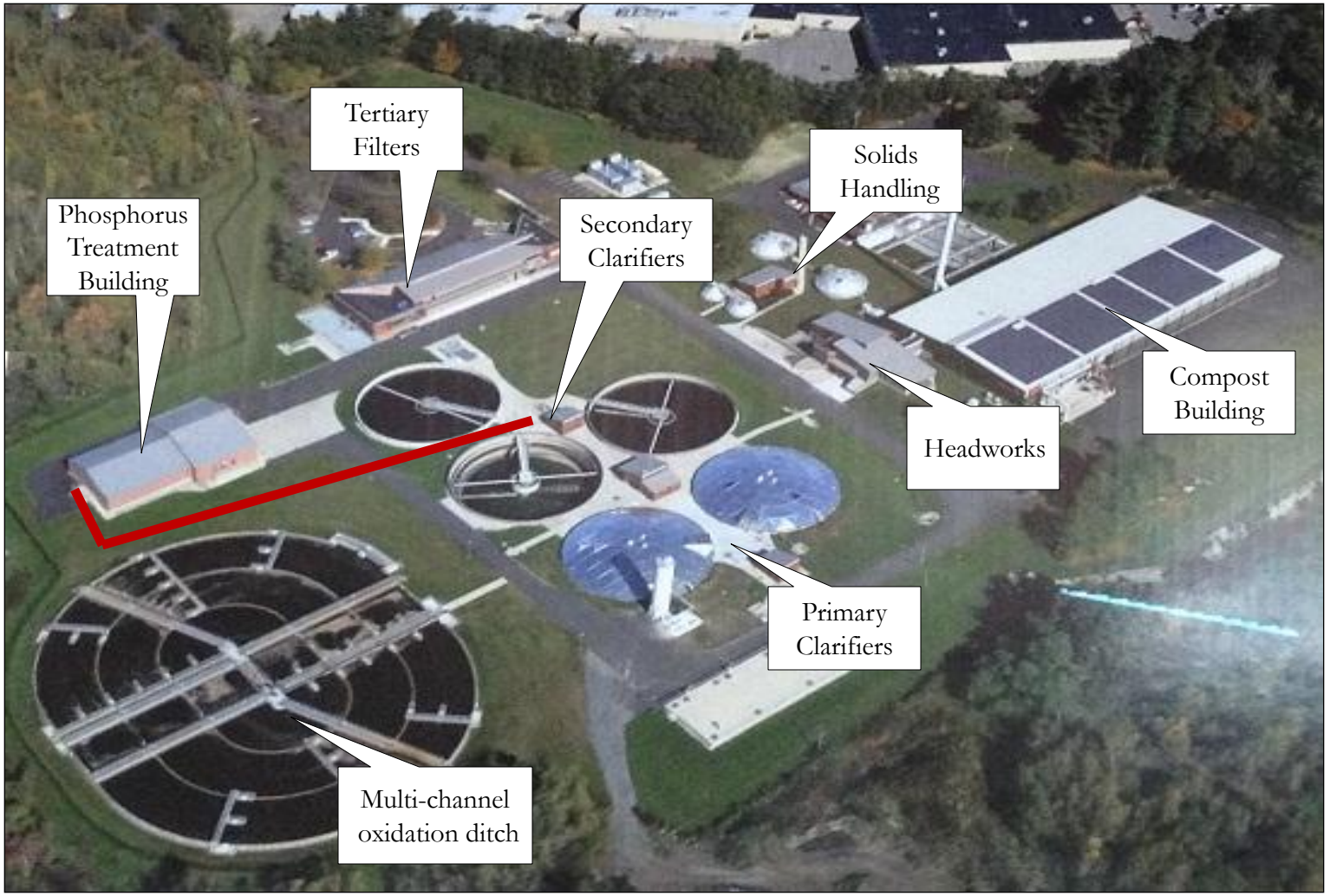
Wastewater Case Study

Westborough, MA Wastewater Plant - Case Study

NPDES Permit Requirements	
Peak flow, mgd design	14.33
Daily average flow, mgd design	7.68
Average daily flow, mgd	5.5
Water pH, s.u.	6.5 - 8.5
BOD, mg/L	10 ave / 15 max day
SS, mg/L	15 ave / 25 max day
Phosphorus, mg/L	0.1 ave / 0.2 max day

Flow equalization, primary treatment and phosphorus removal, oxidation ditch and secondary settling, tertiary phosphorus and filtration treatment, disinfection, solids handling, composting

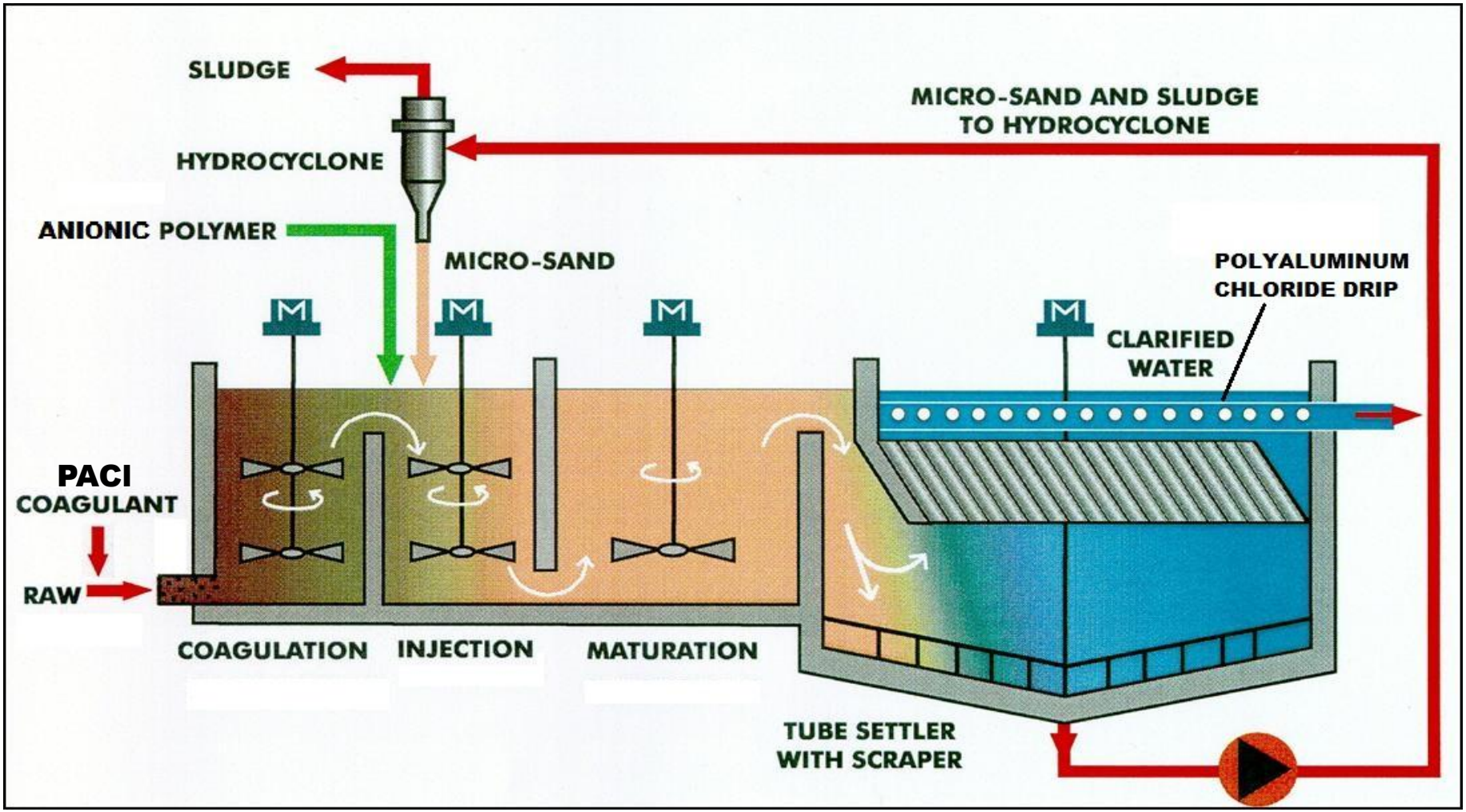
Westborough Wastewater Treatment Plant



Current Phosphorus Treatment

- 1° and 2° treatment reduce phosphorus
  - Phosphorus range - 0.12 mg/L to 0.6 mg/L
- Actiflo high rate chemical precipitation and settling
  - Start-up May 2012
  - 58 mg/L PACl
  - 0.4 mg/L anionic polymer
  - 15 gpm/ft^2 hydraulic loading
  - 3 mg/L PACl drip to settled water channel
    - Effluent phosphorus 0.03 mg/L to 0.08 mg/L
    - Filterability index - **6.6**

Actiflo Process Treatment

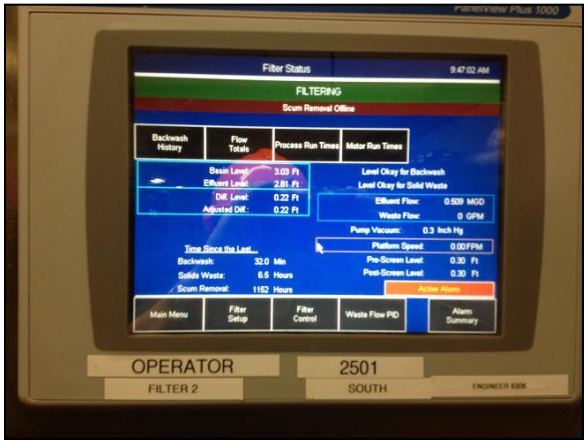


Current Filtration Treatment

- AquaDiamond cloth media filters
  - 0.1 micron polyester cloth
  - Backwashed **every 60 minutes** (350 gpm)
    - Vacuum system traveling bridge
    - Frequent high vacuum issues
  - Chemical cleaning every month
    - Sodium dithionate and orange clean
    - 2 operators, 4 hrs/filter

Current Filtration Treatment

- Filtration Issues
  - High filterability index values from Actiflo
    - Blinding from anionic polymer
  - Short run times and frequent backwashing
    - 1 hour run times common
    - 4 hours maximum
  - Expensive chemical cleaning every month
    - Chemical and labor costs



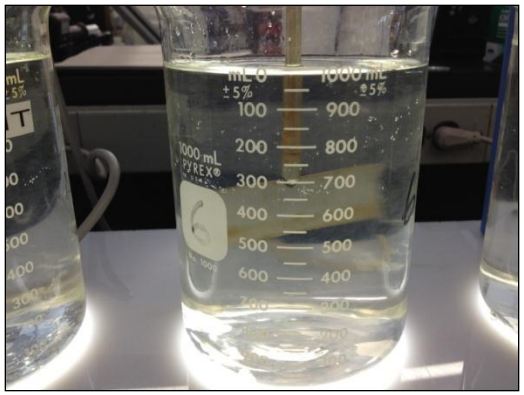
Filtration Investigations

- Poor filterability Actiflo effluent
  - Filterability index typically 6.6
    - 1.6 NTU settled water turbidity
    - SS 2 mg/L average
    - Water pH typically 6.9-7.0
    - Phosphorus about ½ of permit limits

  - PACl drip to settled channel suggested possible overdosing of anionic polymer causing filter blinding
  - Recommended jar testing evaluations to define coagulant and polymer combinations to improve filterability

Investigations to Improve Filtration

- Coagulants/polymers tested
  - Polyaluminum chloride (PACl)
  - Aluminum chlorohydrate (ACH)
  - Polyaluminum chlorosulfate (PACS)
  - Aluminum chlorohydrate with polyDADMAC
  - PolyDADMAC
  - Quaternary polyamine
- Jar testing evaluations
  - Phosphorus reduction
  - Water pH
  - Filterability index



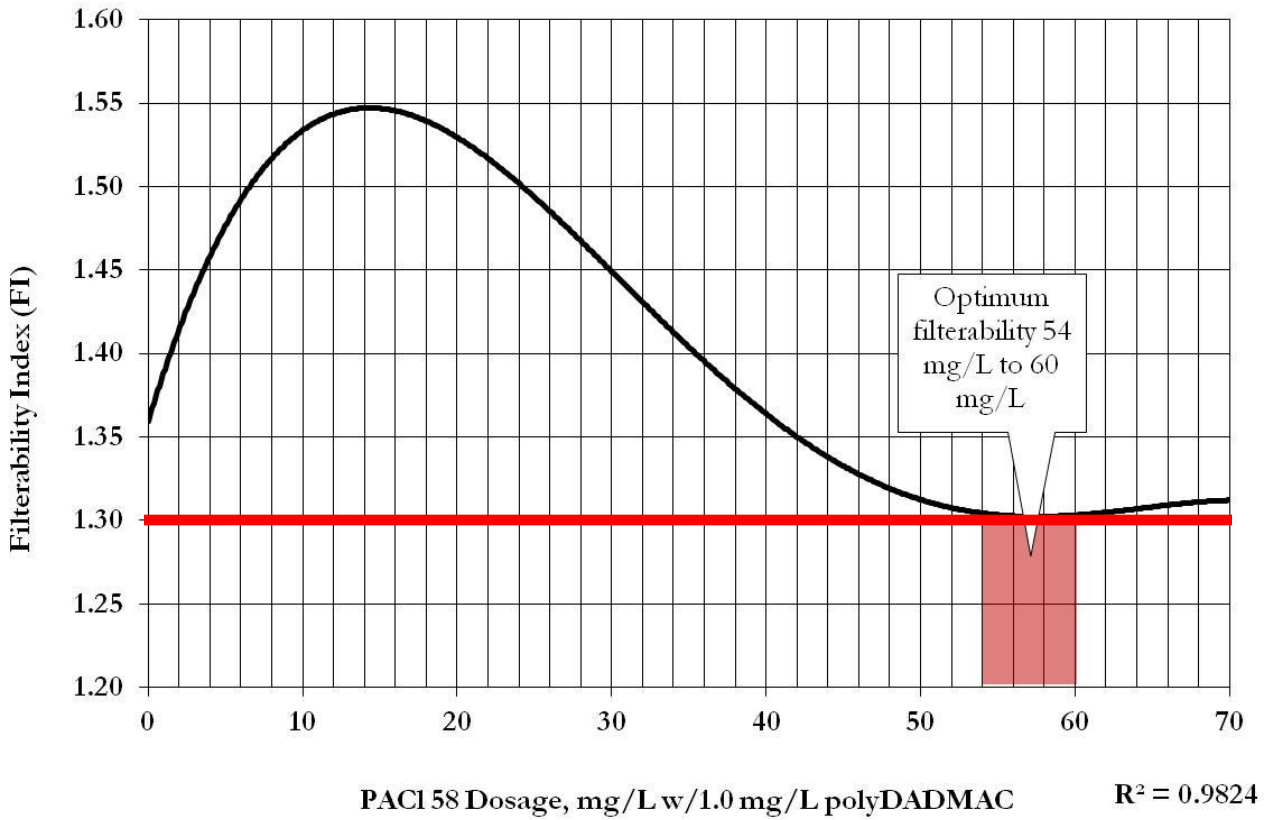
Investigations to Improve Filtration

- Coagulant dosages varied 20 mg/L to 70 mg/L
- Polymer dosages varied 0.4 mg/L to 1.4 mg/L
- Simulated Actiflo operating parameters
- Settled water analyzed
  - Water pH
  - Filterability index (1.3 or less)
  - Phosphorus residual

Jar Testing Evaluations Conducted Onsite

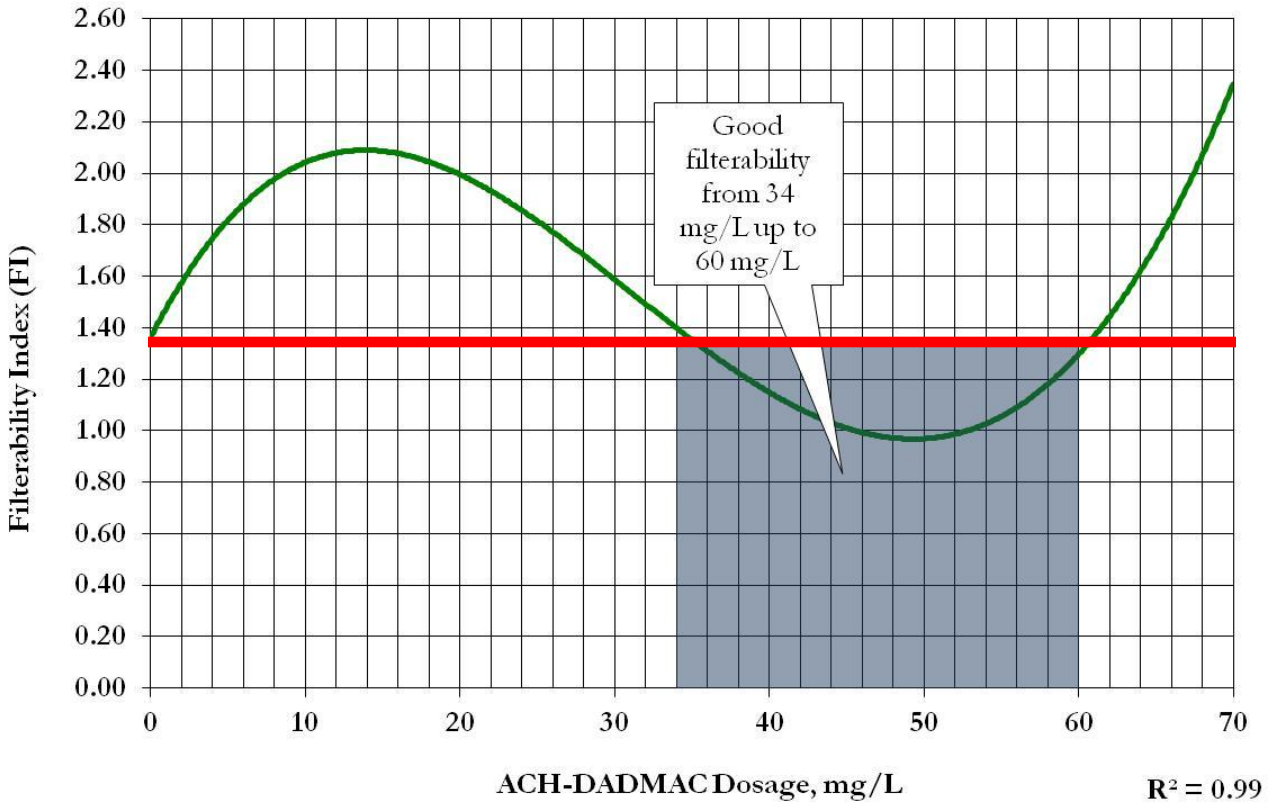
Investigations to Improve Filtration

Current PACl with polyDADMAC polymer

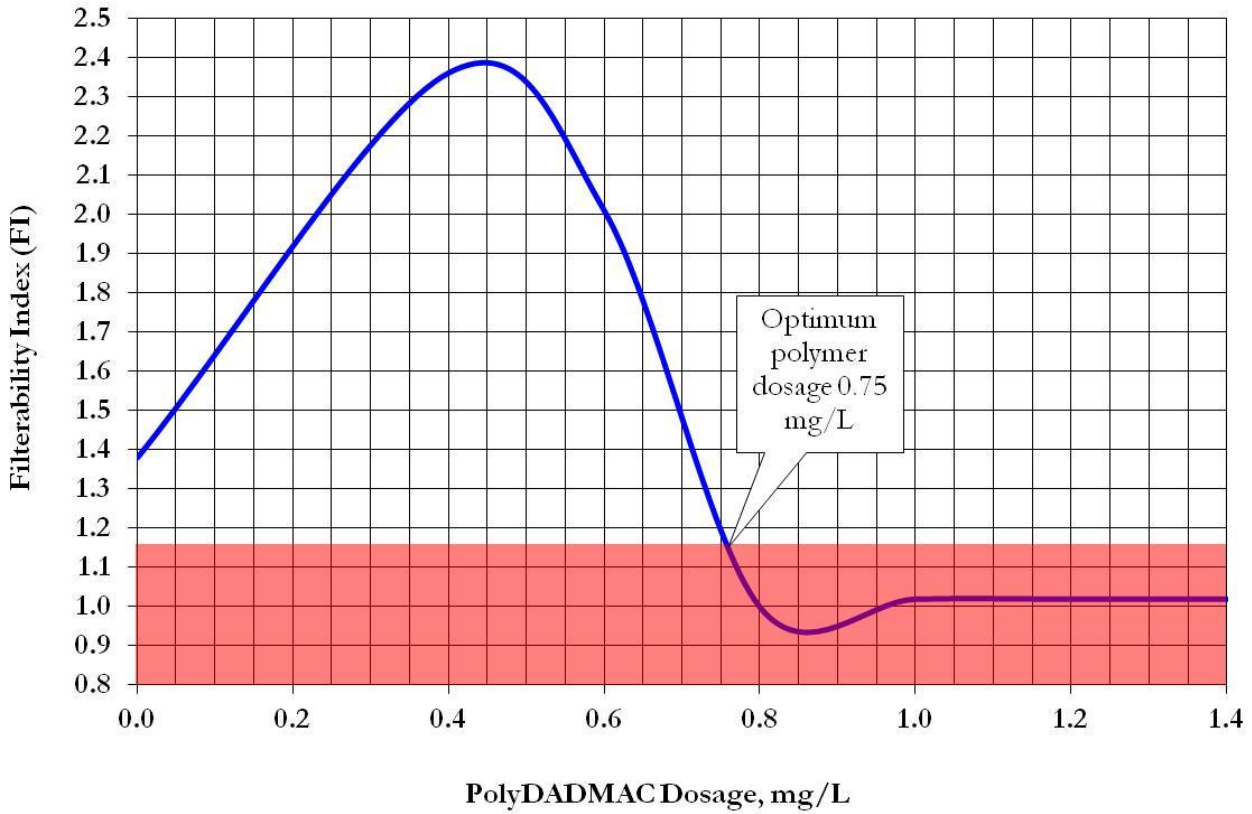


Investigations to Improve Filtration

ACH with polyDADMAC polymer



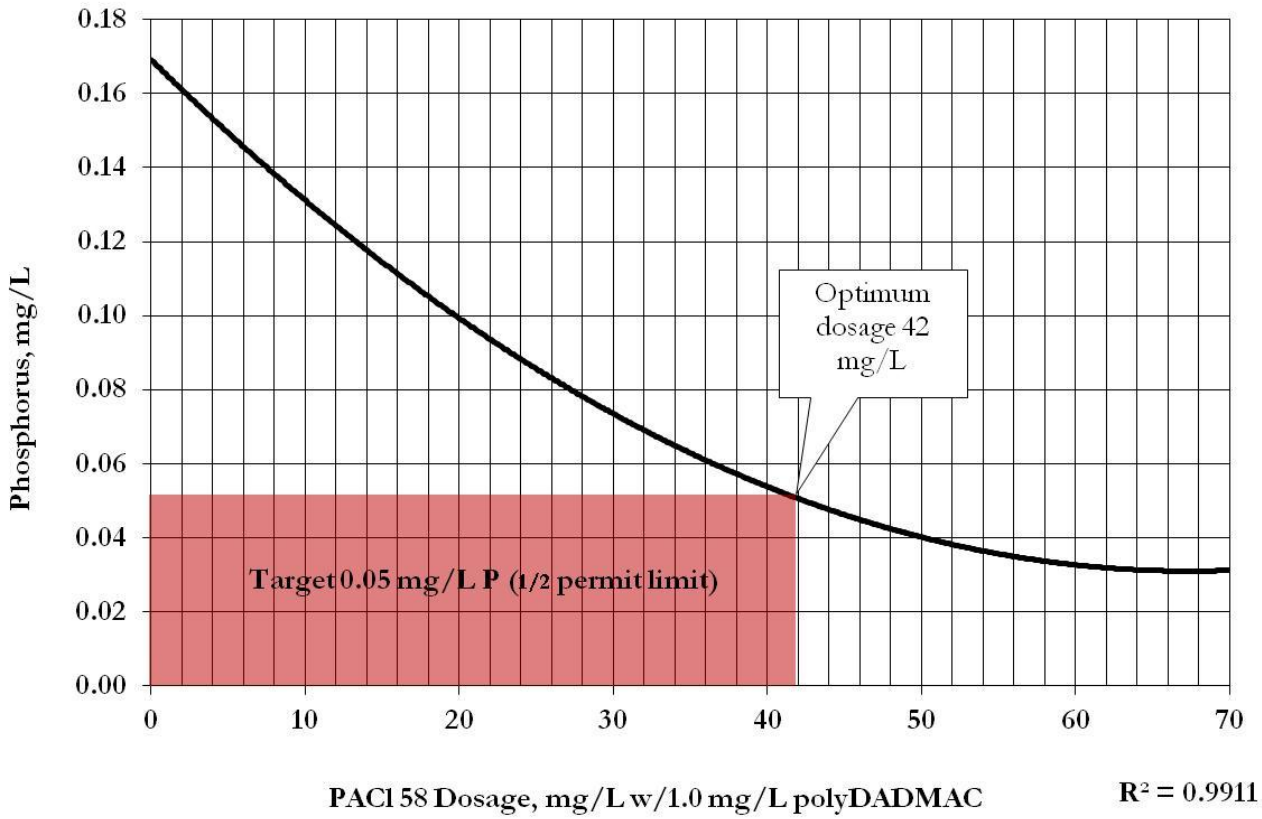
Investigations to Improve Filtration



Polymer dosage optimization

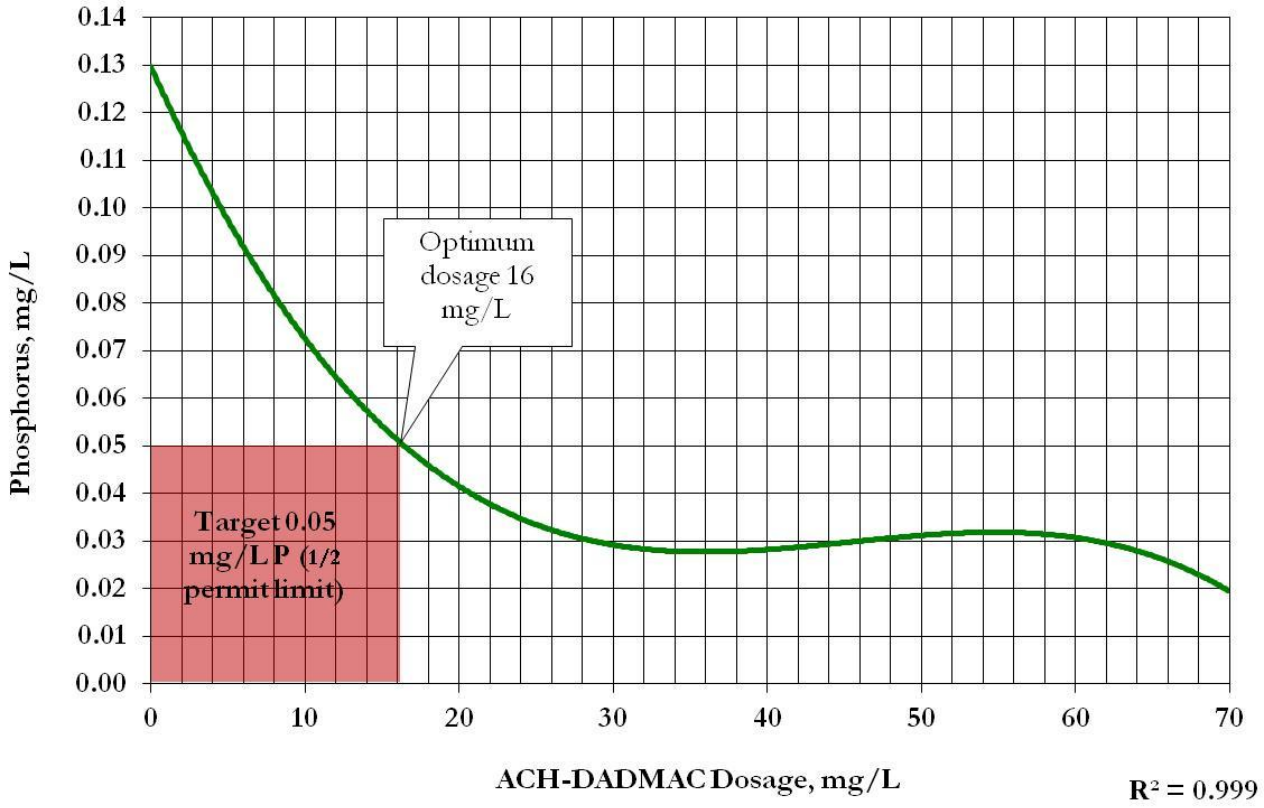
Investigations to Optimize P Reduction

Optimum PACl with polyDADMAC polymer



Investigations to Optimize P Reduction

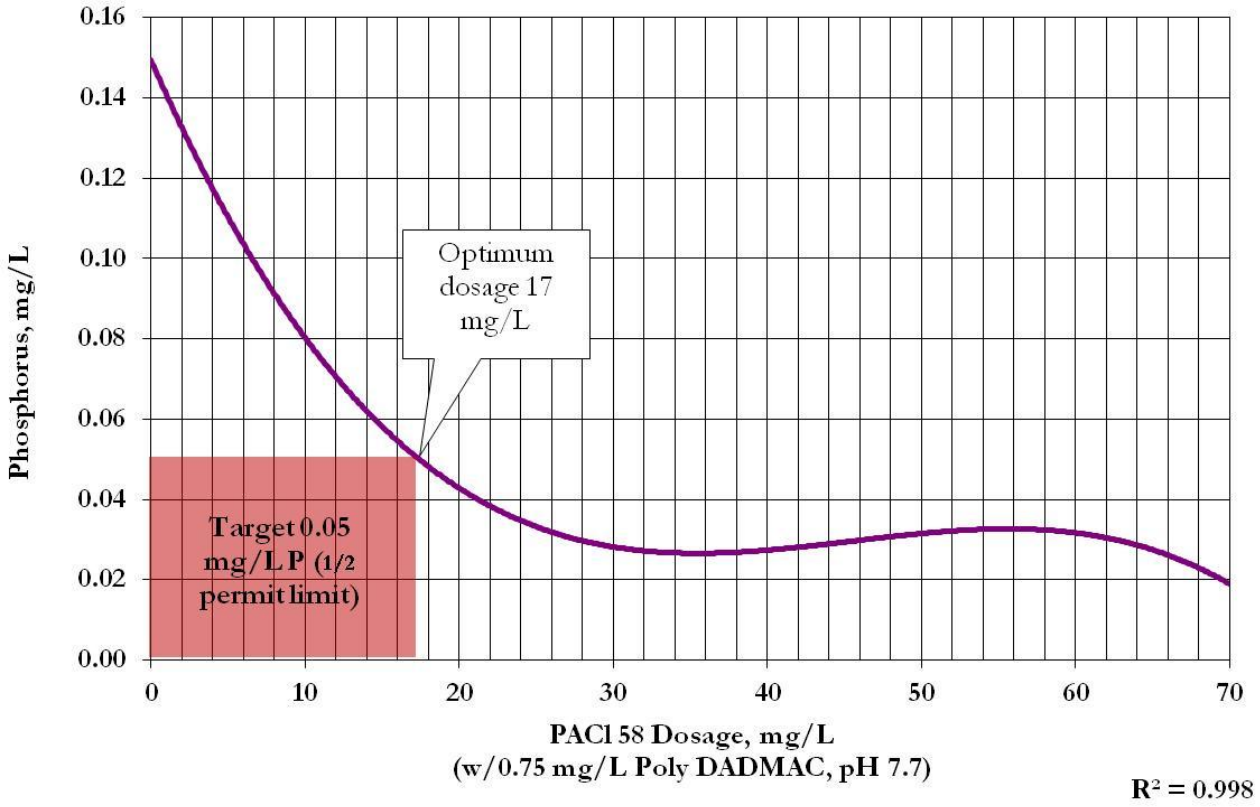
Optimum ACH with polyDADMAC polymer



Impacts from Alkalinity Adjustment

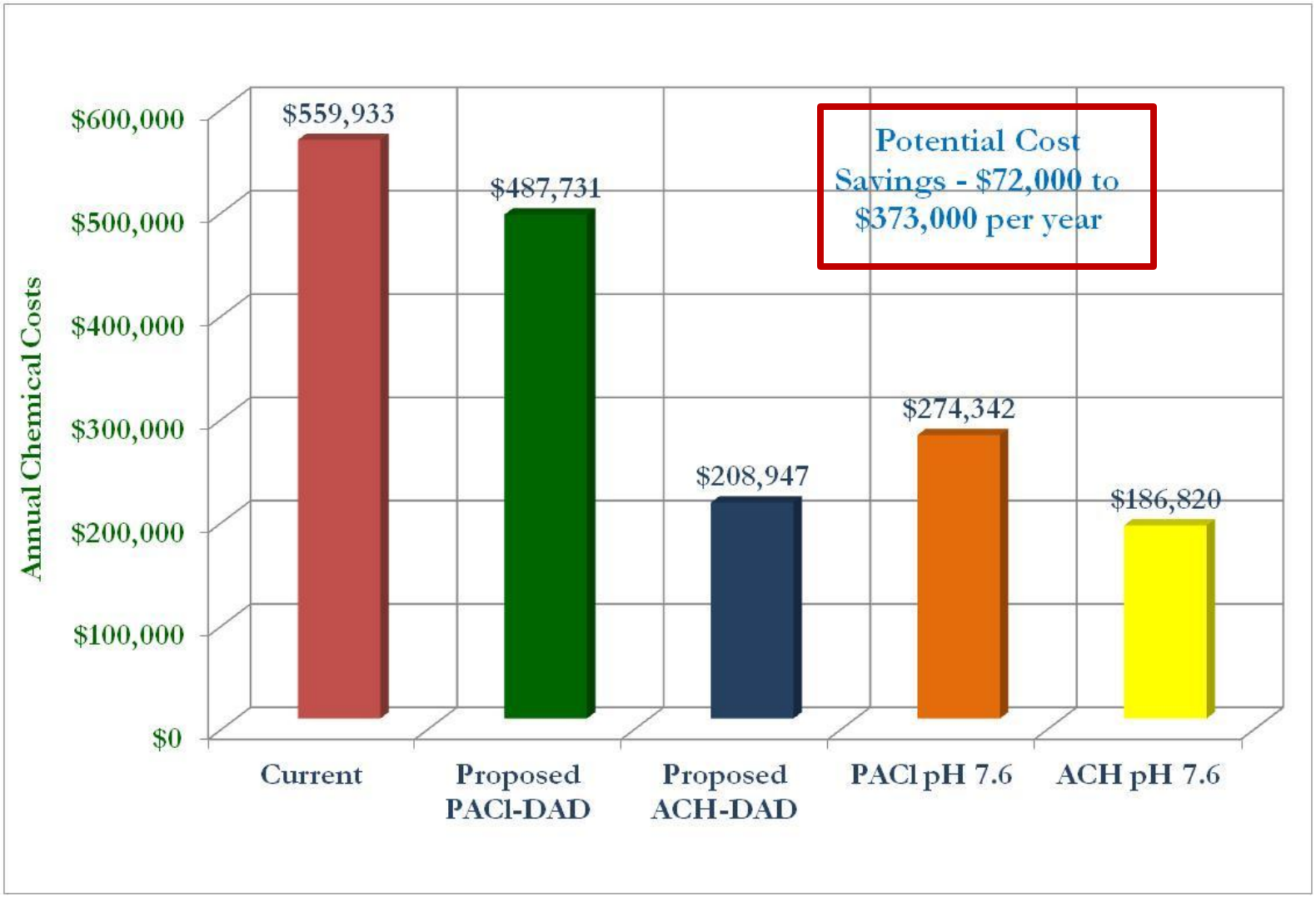
- Increased alkalinity might reduce coagulant dosing for phosphorus removal
  - Proper alkalinity fosters hydroxide floc formation
  - Hydroxide floc responsible for P adsorption during treatment
    - Lime available in pretreatment (increase dosage)
    - Caustic soda available in Actiflo treatment for pH adjustment
- Increased pH to 7.7 with 4 mg/L NaOH
  - Evaluated PACl and polyDADMAC for P reduction
  - Good filterability maintained up to 70 mg/L

Investigations to Optimize Process pH



PACl and polyDADMAC at pH 7.7 produced significant reduction in dosage for P removal (17 mg/L vs. 42 mg/L)

Economic Analyses



Current Operations

- Replaced anionic polymer with polyDADMAC
  - 0.75 mg/L optimum dosage
- Optimized PACl dosage for phosphorus removal
- Filter performance and cleaning intervals
  - Filterability 1.35 vs. 6.6
  - Backwash 16 hours vs. 1 hours
  - Chemical cleaning every 3 months vs. every month
- Future pilot work at pH 7.6
  - Largest cost savings, good phosphorus reductions, filterability index expected <1.2
  - Significant coagulant dose reduction at elevated pH
  - Up to $373,000 annual cost savings

Water Case Study

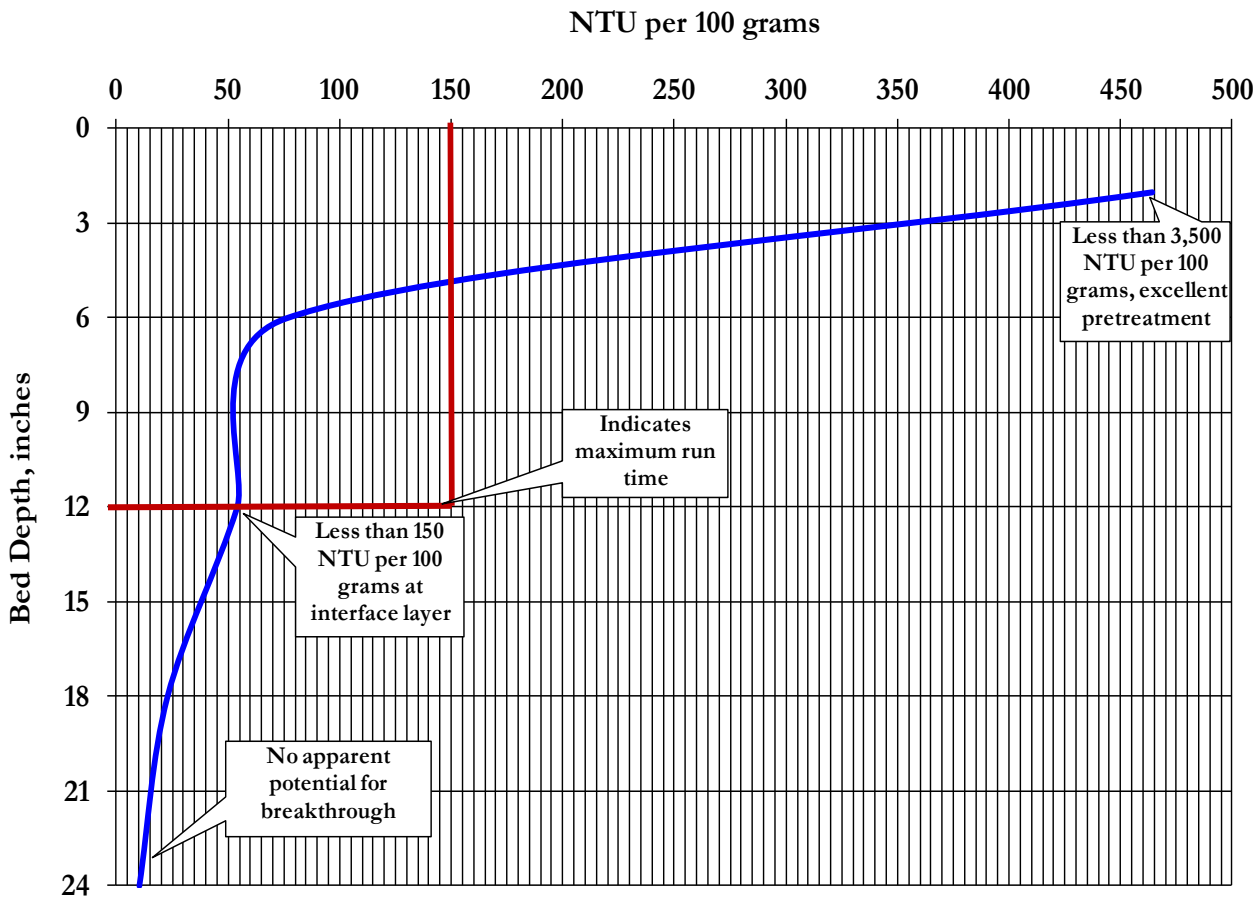
Elyria, Ohio Filtration Case Study

- 22 mgd surface water plant, Lake Erie source
- Conventional treatment
  - $KMnO_4$ pretreatment
  - ACH/polymer blend coagulant
  - No pH adjustment
  - Carbon, fluoride
- Settled water quality
  - 0.5 NTU (<1 mg/L SS)
  - 7.4 to 7.8 pH
  - Alkalinity 30 mg/L to 55 mg/L

Elyria, Ohio Filtration Case Study

- 10 dual media filters
  - Rebuilt 2009
    - 12-inches anthracite, 12-inches filter sand
  - Filtration rate - 1.25 gpm/ft^2
  - Effluent turbidity - 0.067 NTU average
  - Run times - 72 hrs to 96 hrs
  - Gross water production (GWP) - 5,270 gal/ft^2/run
  - Head loss < 2 feet at backwash
  - Filter Efficiency (FE) 97.8%
  - L/D_{10} ratio 1,035
  - Washwater consumption 120 gal/ft^2
  - Backwash duration - 11 minutes

Floc Retention Analyses



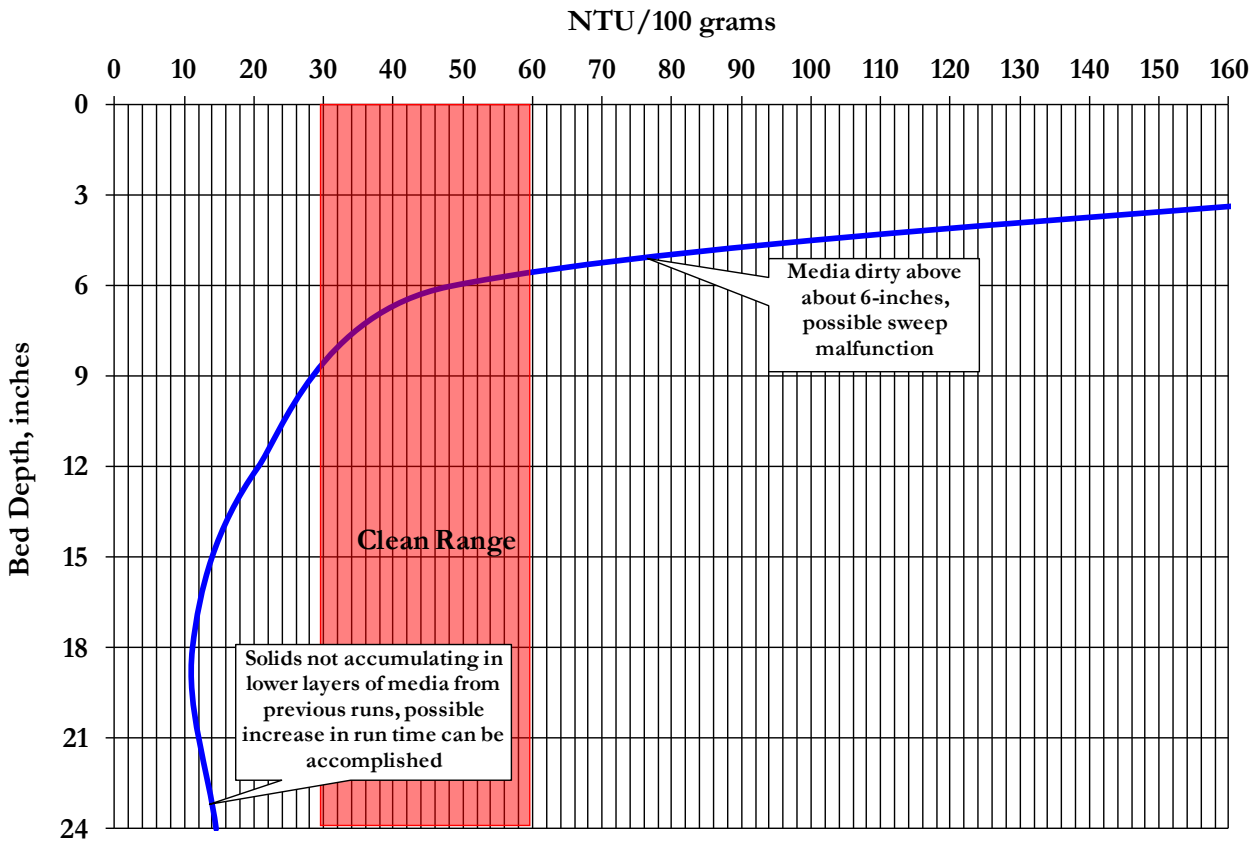
Floc Retention Before Backwash

Confirmed low solids loadings from settled water (0.5 NTU)

Indicated longer run times possible

No indication of breakthrough during filter run

Floc Retention Analyses



Floc Retention After Backwash

Potential issues with surface wash sweeps

Much of top layers remained dirty after backwash

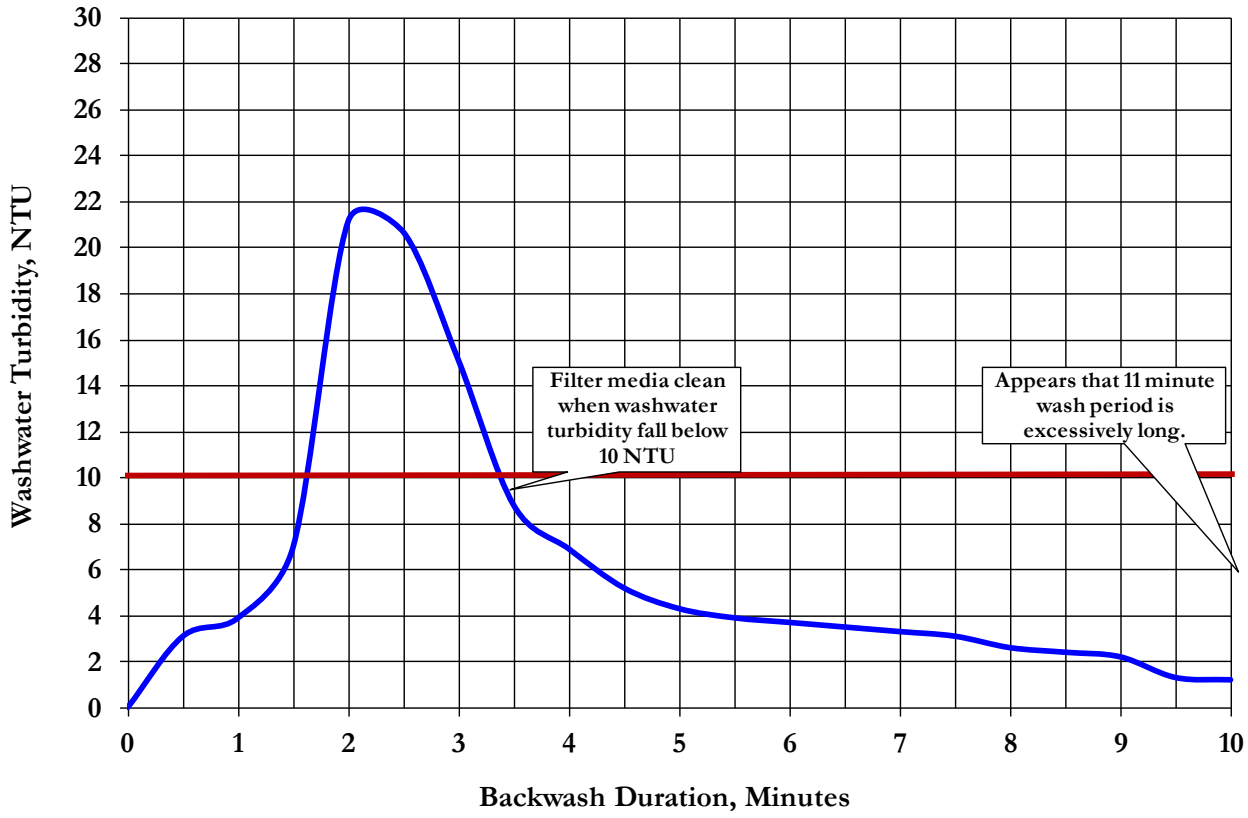
Lower layers below clean range - likely due to low solids loading

Backwash Duration Tests

11 minute wash period too long - 3.5 minutes needed this wash cycle

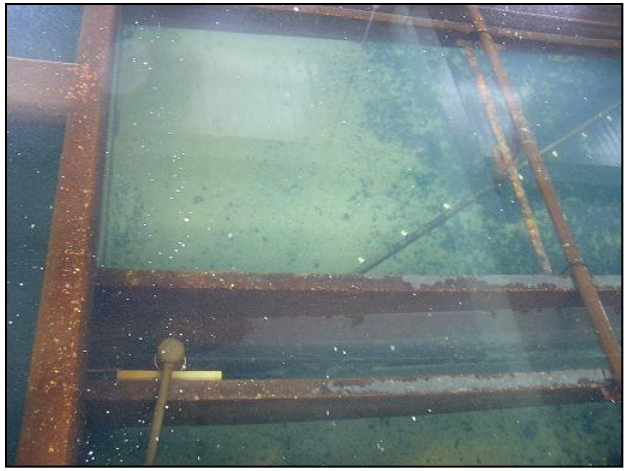
Much less than 10 NTU in washwater at end of wash period (1.1 NTU end of cycle)

Bed expansion 25% at 22°C



Filter Operations Assessment

- Optimization potential
  - Increase filtration rate
  - Increase run times
  - Reduce backwash duration
  - Possible Improvements
    - GWP
    - FE
    - Washwater consumption
    - Effluent NTU



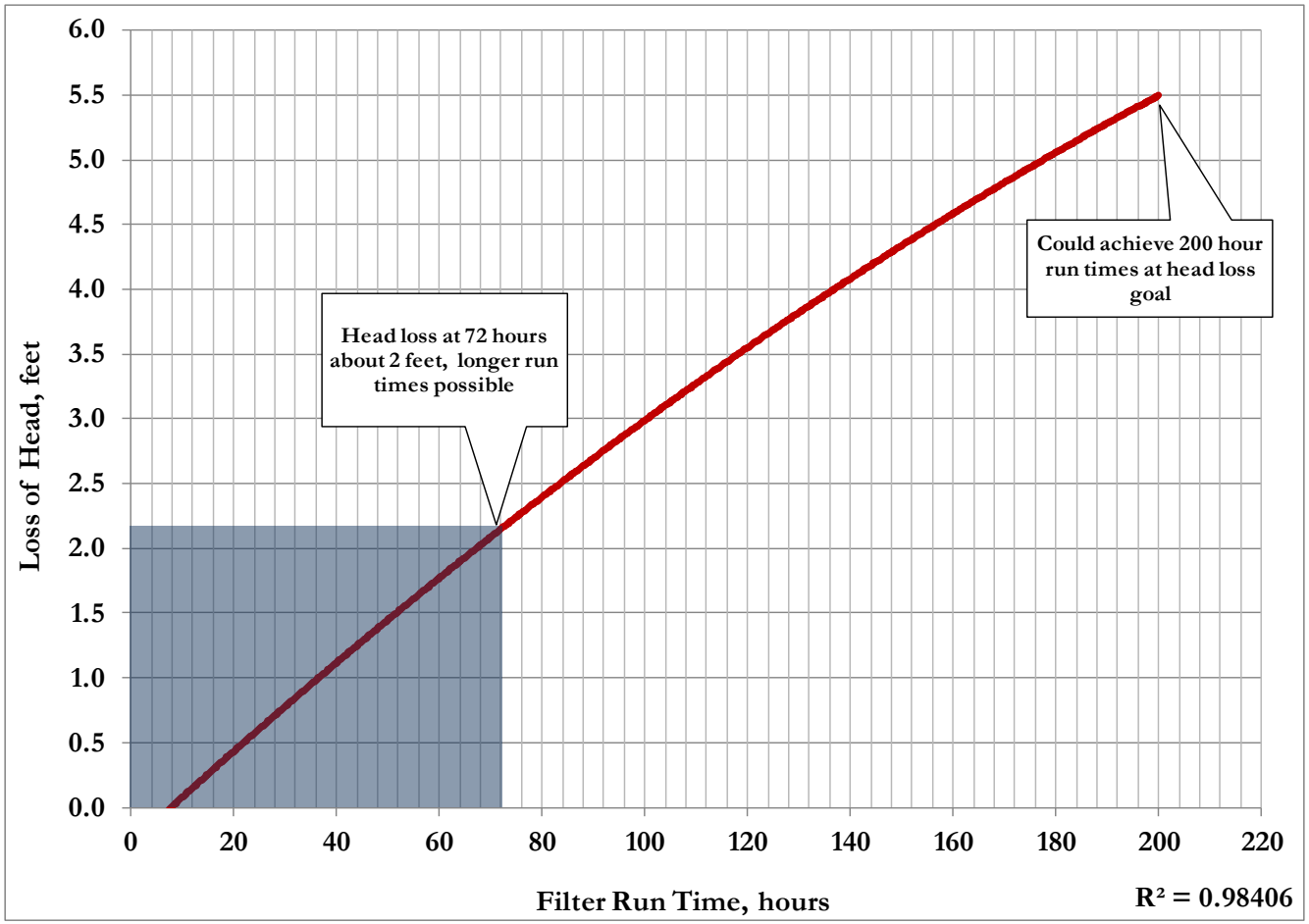
Good settled water clarity - 0.5 NTU average applied turbidity

Head Loss Assessments

Low head loss at backwash confirmed < 2 feet

Extended run time hours increases head loss

Max head loss goal (5.5 feet) indicated longer run times were possible



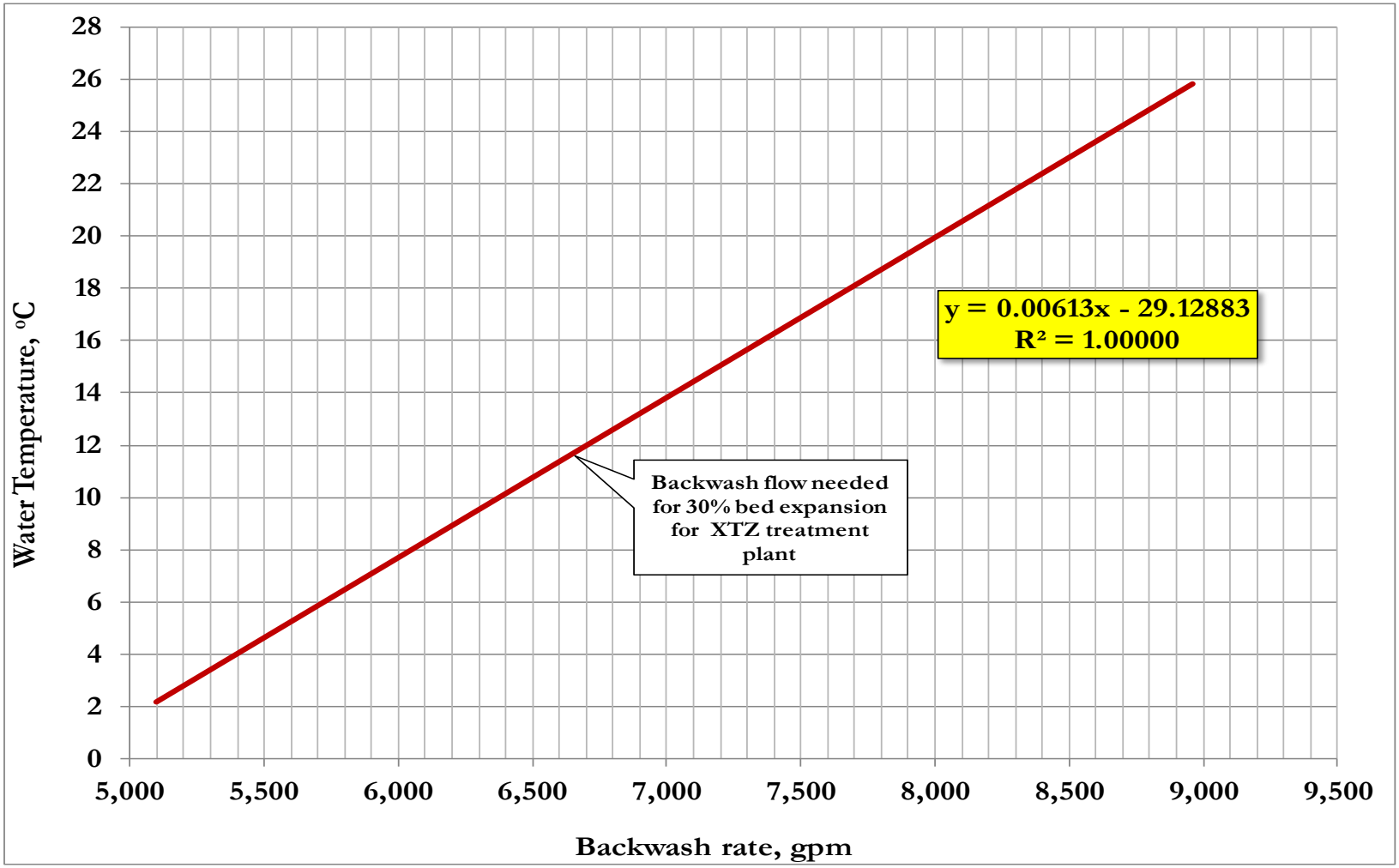
Optimum Filtration / Backwash

- Performance generally increases with filtration rate
  - <1.4 gpm/ft^2 does not produce depth filtration, but surface filtration
  - Filters generally perform better at 2 gpm/ft^2 or higher
- Solids accumulations
  - Media retains solids until head loss indicates void spaces filled (5.5 feet maximum head loss from best practices)
    - Dual media filters can accumulate 0.10 pounds to 0.34 pounds suspended solids per cubic foot of filter media (site specific)
  - Media backwashed when solids retention fills void spaces
    - When maximum turbidity goals reached in filter effluent

Optimum Filtration / Backwash

- Filter-to-waste operations
  - Generally operate lower than normal filtration rate
  - Should produce ripening within 15 minutes or less
  - Should be minimized to reduce wasted water volumes
- Bed expansion
  - Backwash should expand media for most effective cleaning
  - 30% minimum to allow grains to rub against each other
  - 35% maximum to prevent excessive grain separation
  - Same expansion at all water temperatures
    - Higher backwash rates in summer
    - Lower backwash rates in winter
    - 2% flow change for each 1°C change in temperature

Optimum Filtration / Backwash



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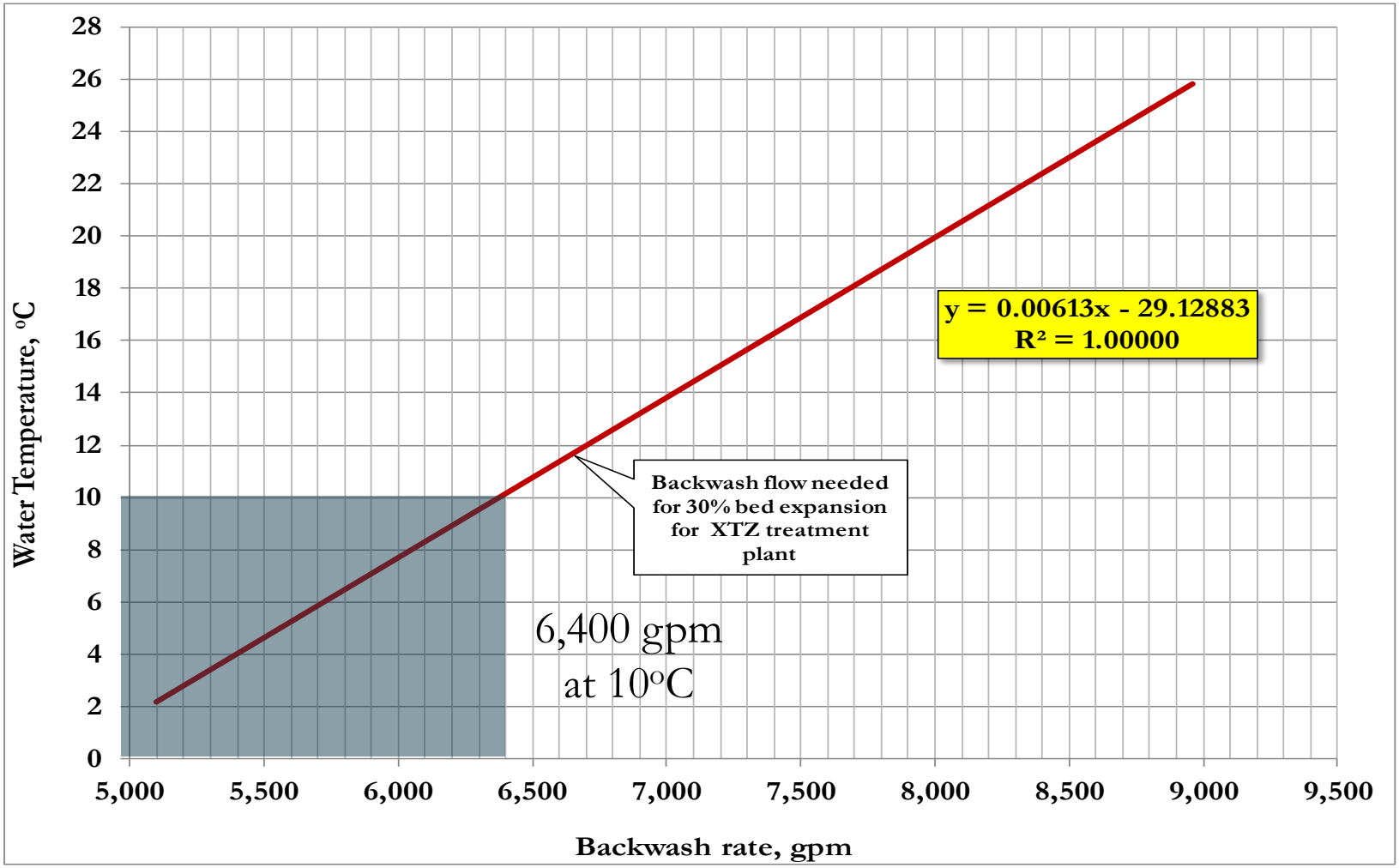
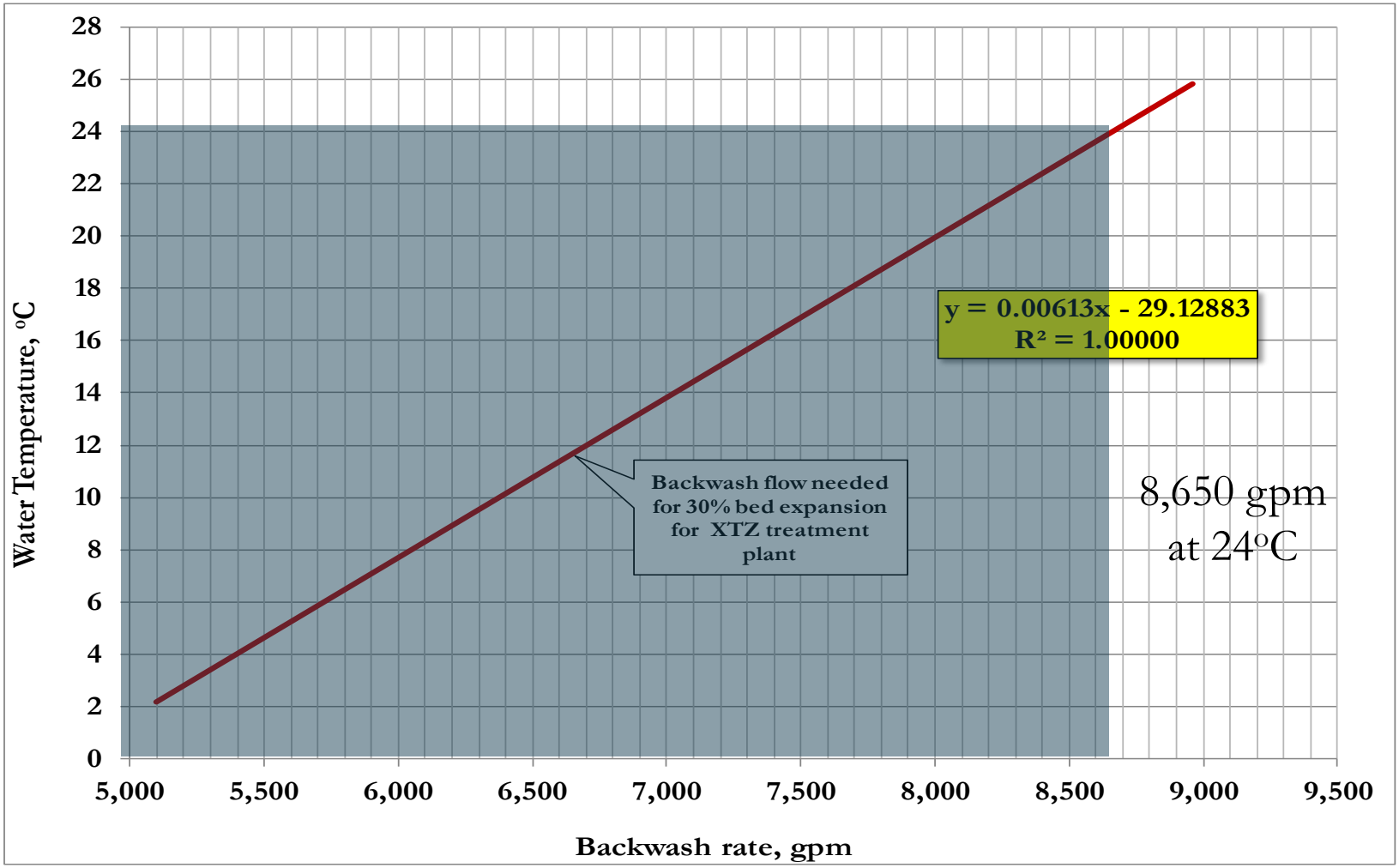


Optimum Filtration / Backwash



Optimum Filtration / Backwash

- Backwash duration
  - Generally 6 minutes to 8 minutes provides effective cleaning
  - Evaluate based on site specific operations and solids loadings
    - Many filters backwashed too long
    - Terminate backwash once washwater falls below 10 NTU
- Filter ripening techniques
  - Filter-to-waste (sometimes called rewash)
  - Retain some solids in filter media after backwash
  - Allow media compaction after backwash by placing filters in standby
    - Most effective based on field studies
    - Stand idle at least 6 hours

Filter Performance Criteria

- Gross Water Production (GWP)
  - Measure of filter performance related to filter throughput
  - 5,000 gal/ft^2/run monomedia filters
  - 10,000 gal/ft^2/run dual media and multimedia filters
  - Up to 20,000 gal/ft^2/run in well optimized filtration and backwash operations
    - Low applied water solids loadings
    - Routine filter coring and floc retention analyses along with backwash evaluations
    - Proper filter ripening operations
    - Operator training and established performance target values

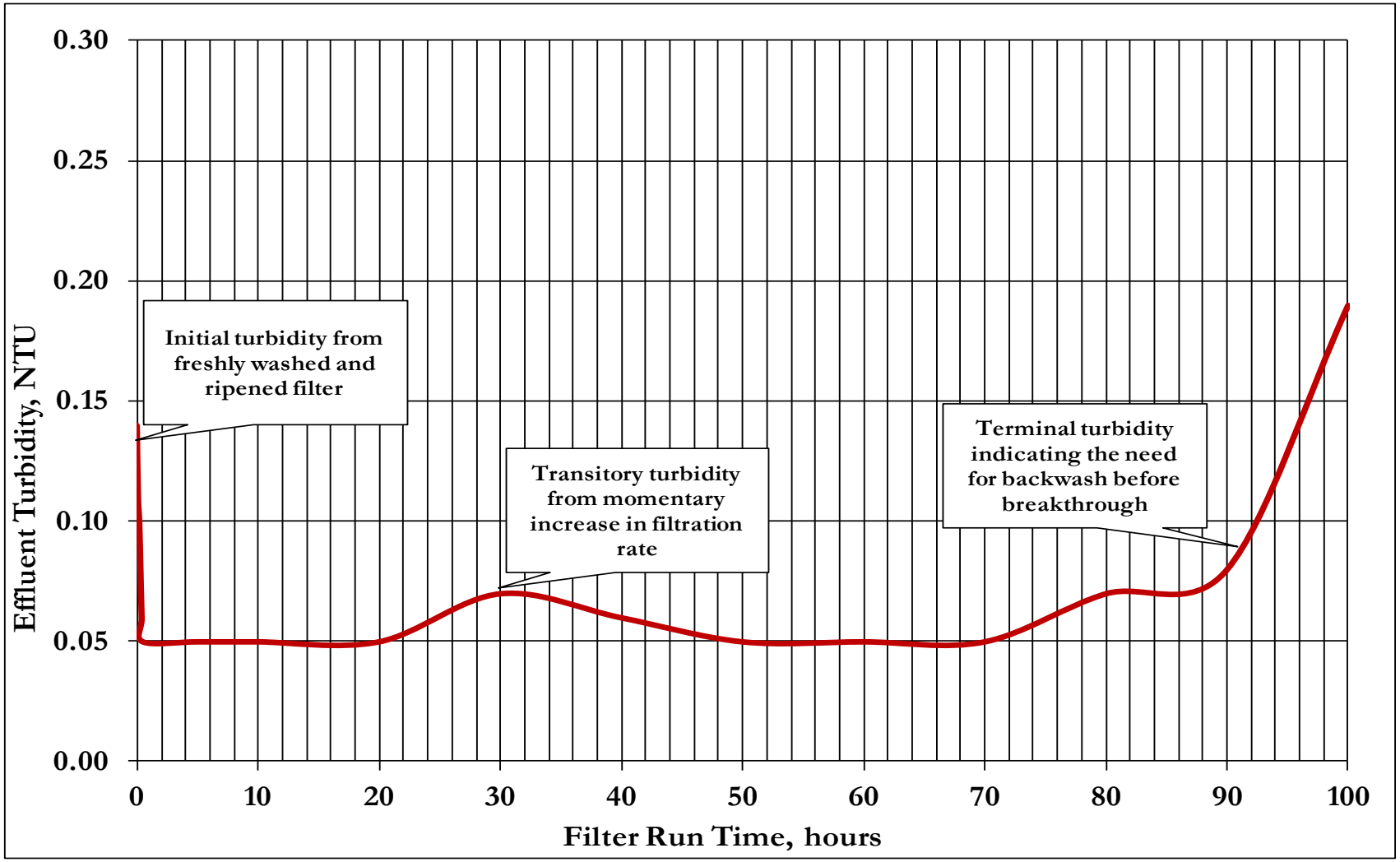
Filter Performance Criteria

- Filtration Efficiency (FE)
  - Measure of filter performance as compared to washwater usage
  - 95% or greater
  - 99% or greater in well optimized filtration and backwash operations
    - Routine filter evaluations
    - Established performance target values

Filter Performance Criteria

- Filter Effluent Turbidity
  - Regulatory levels must be achieved (0.3 NTU, 95% samples)
  - Generally 0.1 NTU or less in first 15 minutes of operation
    - Well optimized filtration and backwash operations
    - Partnership for Safe Water goal
    - Many plants meet 0.1 NTU or less (not always after 15 minutes)
  - Monitored continuously in most cases
    - Data can be used for trending
    - Filter profiling observations
    - Effluent target goals for initiation of backwash

Filter Profiles



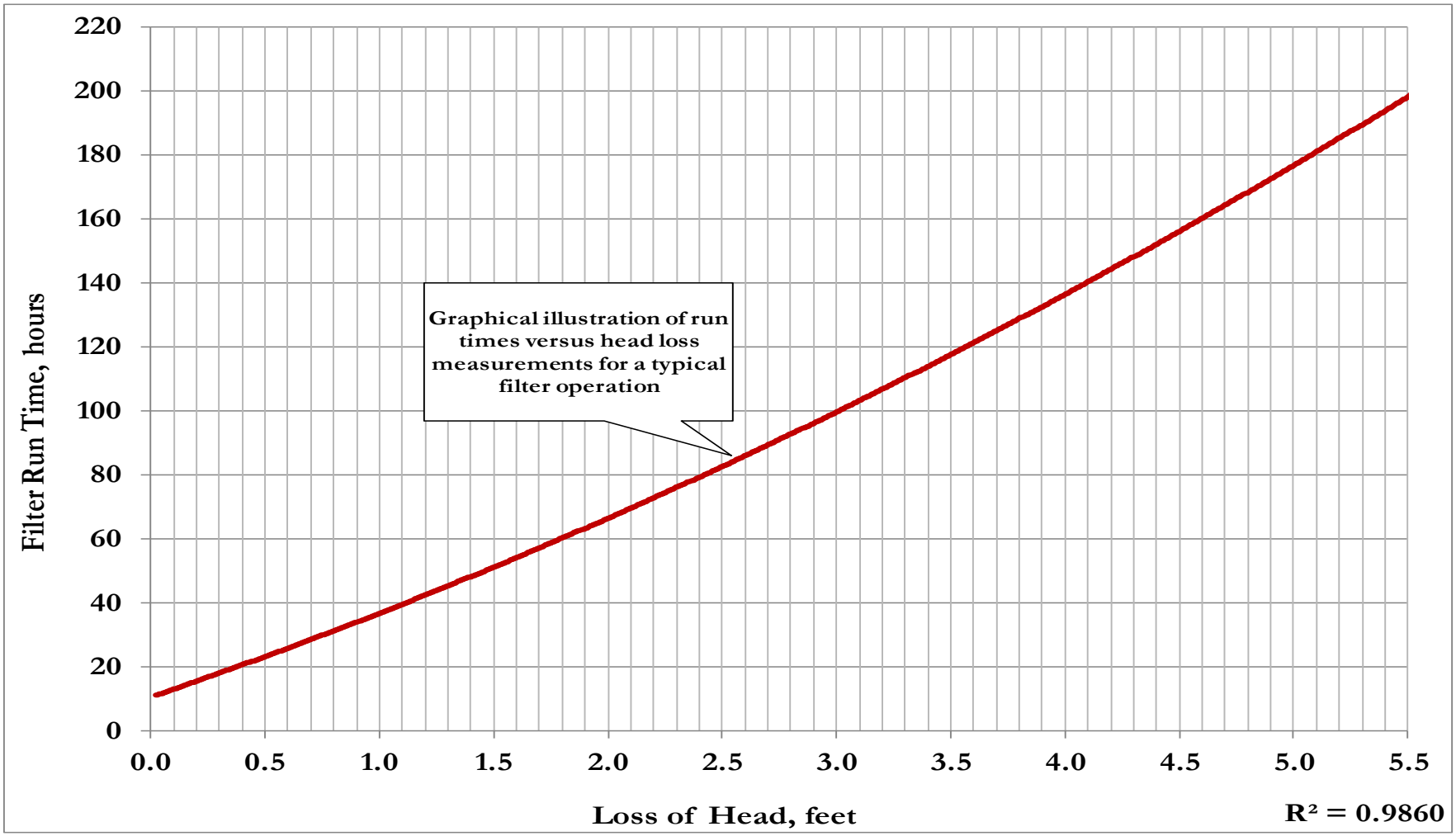
Filter Performance Criteria

- Filter Run Times
  - Generally 48 hours or greater for monomedia filters
  - Generally 72 hours or greater for dual media and multimedia filters
  - Well optimized filtration and backwash operations
    - Maximize filter run times correlated to solids loadings and performance criteria
    - 100 hours to 200 hours common
    - Avoid run times greater than about 225 hours - excessive solids accumulations, backwash problems

Filter Performance Criteria

- Filter Head Loss
  - Terminal head loss established 6 feet to 8 feet
  - Generally 5.5 feet or less established maximum operating head loss
  - Lower turbidity standards have reduced head loss operations
    - Many filters backwashed at 2 feet loss of head or less
    - Correlate head loss to run times
    - Determine maximum run time at 5.5 feet head loss
    - Establish maximum run time based on maximum head loss goal

Head Loss Evaluations



Solids Mass Balance Calculations

- Calculate solids accumulations and solids remaining in the media
  - Average applied water turbidity
  - Average filtration rate
  - Washwater turbidity measurements
  - Washwater volumes used
- Calculate pounds of solids accumulated in media (total and pounds per cubic feet)
- Calculate solids in washwater
- Solids removal efficiency from backwash should be 85% or greater
  - Maintains some solids in media for ripening

Filter Ripening

- Reduces turbidity spikes on freshly washed filters
- Filter-to-waste (FTW) is effective technique
  - Removes initial "slug" of solids from filter media
  - Should be 15 minutes or less
  - Minimize FTW times to reduce waste flows
- Media compaction is most effective technique
  - Media compacts during idle operations to close open spaces
  - Generally at least 6 hours stand-by operations following backwash
  - Does not waste water like FTW
  - Can easily be added to routine operations for filters

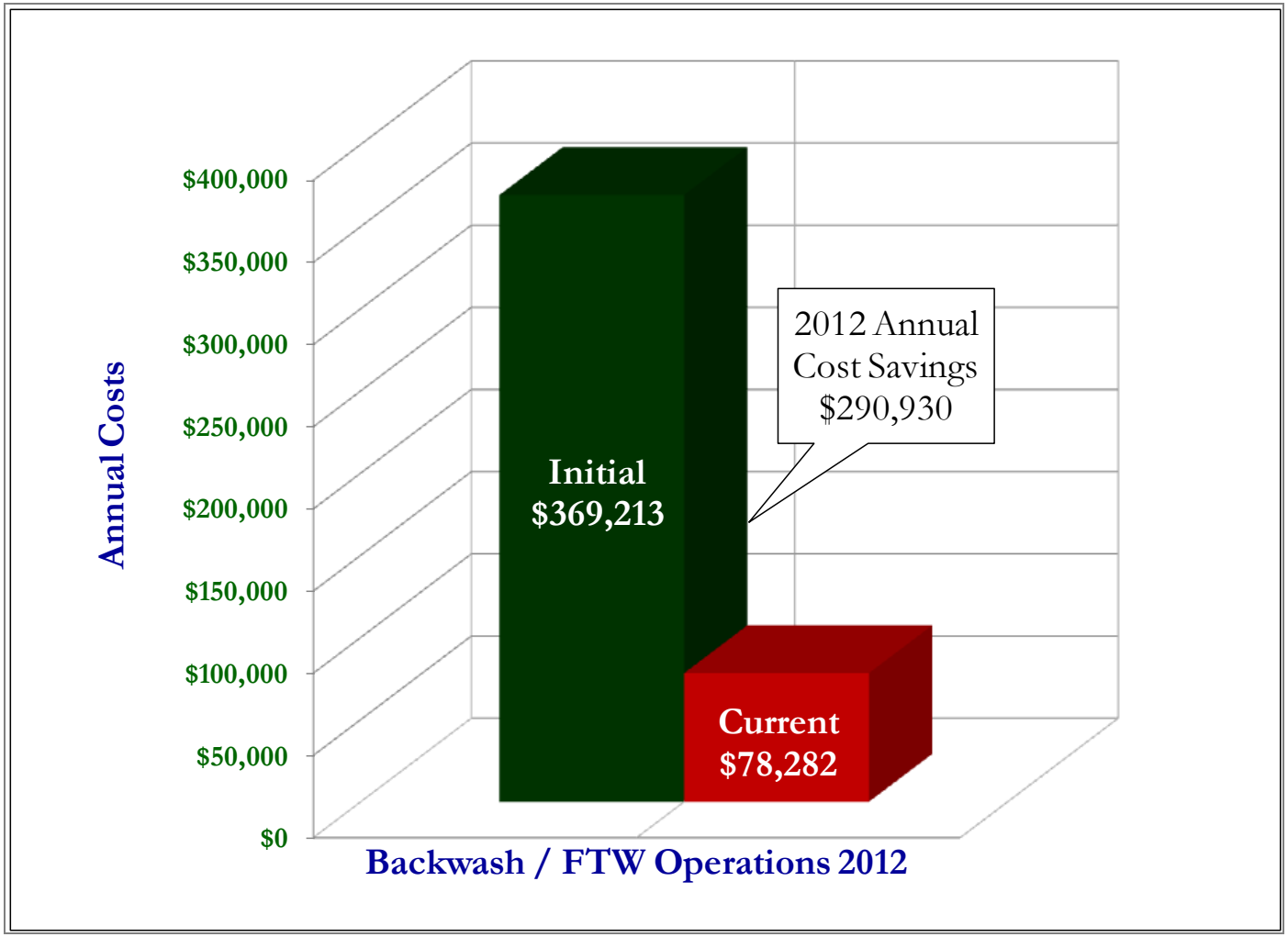
Elyria Filter Operations 2012

Parameter	Before Optimization	Parameter	After Optimization
Filters used	10	Filters used	6
Filtration rate	1.25 gpm/ft^2	Filtration rate	2 gpm/ft^2
Run time	72 hours	Run time	160 hrs to 200 hrs
GWP	5,600 gal/ft^2/run	GWP	19,000 gal/ft^2/run
Filter efficiency	97.8%	Filter efficiency	98.5%
Average NTU	0.067	Average NTU	0.045
Max NTU	0.18	Max NTU	0.085

Elyria Filter Operations 2012

Parameter	Before Optimization	Parameter	After Optimization
Washwater usage	83,500 gal	Washwater usage	47,000 gal
WW consumption	120 gal/ft^2	WW consumption	64 gal/ft^2
Backwash cycles	853 per yr.	Backwash cycles	555 per yr.
FTW usage	86,400 gal	FTW usage	0 gal
Annual water usage	145 MG	Annual water usage	26 MG
Annual water savings	-	Annual water savings	119 MG

Elyria Economic Evaluations 2012



Media Cleaning - Pittsburgh, PA

Before Acid Cleaning	
Effluent Turbidity	0.079 NTU
Run Times	96 hours
Head Loss	1.3 feet at backwash
Effluent Manganese	0.065 NTU

After Acid Cleaning	
Effluent Turbidity	**0.035 NTU**
Run Times	96 hours
Head Loss	1.2 feet at backwash
Effluent Manganese	**0.032 NTU**

Summary

- Relatively simple adjustments in filter operations
- Assessments and evaluations compared to optimization criteria
  - Adjustments made accordingly
- Often improve performance
  - Run times
  - GWP
  - FE
  - Washwater consumption
  - Filter-to-waste
  - Cleaning frequencies
  - Operating costs

Questions

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