AQUA-AEROBIC SYSTEMS, INC.
A Metawater Company

No-Break Fiber Solves Membrane Integrity Problems at Four Water Treatment Plants

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American Water Works Association

DBIA DESIGN-BUILD INSTITUTE OF AMERICA

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Presentation Outline

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- The Problem
- The Alternatives
- A Better Membrane
- Tale of Three Cities and a Village
- Summary

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The Problem

The Problem

Broken Fibers

- Increased risk of pathogens in the drinking water!
- Integrity test failures = less capacity
- Solids in the backwash water could mean irreversible fouling
- Solids in the filtrate = higher disinfection costs

The Problem

"The Real Cost of Fiber Repairs"

- Black & Veatch studied (16) water plants:
  - Averaged 12 fiber repairs/yr/MGD (max was 81!)
  - Projected an average of 6.5% of equipment cost over 20 years (max was 22%!)

– Doesn't include downtime losses or the "nuisance" factor

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The Problem

Broken Fibers

- Many large plants have had to:
  - Create a "pinning station"
  - Hire a person whose sole job is to pin fibers!

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The Alternatives

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The Alternatives

Replace with Same Membrane

- **Pro's:**
  - **No other changes required**
  - **Least-expensive capital cost**
    - **Manufacturer will often give good price to make up for poor product**
- **Con's:**
  - **Continued fiber breaks and integrity test failures**
  - **Most-expensive operating cost**
    - **Pinning costs continue**
    - **Membranes will likely have to be replaced prematurely**

The Alternatives

Replace with Different Modules

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- Pro's:
  - Could reduce fiber breaks and integrity test failures
  - Can reuse most of the existing equipment
- Con's:
  - May have to purchase additional equipment
    - New modules will likely require different backwash, air, and chemical flows/times
  - Typically requires some piping/skid modifications
    - New modules often have different dimensions and connection locations

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The Alternatives

Replace with Universal Skids

- Pro's:
  - Could reduce fiber breaks and integrity test failures
  - Can accept modules from several different manufacturers
- Con's:
  - Will have to purchase additional equipment
    - Must be able to handle a wide range of backwash, air, and chemical flows/pressures
  - Less efficient design means higher operating costs
    - Equipment must be designed for the module with the highest flows/pressures

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The Alternatives

Replace with Different System

- Pro's:
  - Could reduce fiber breaks and integrity test failures
  - Lower operating costs
- Con's:
  - Will have to purchase additional equipment
  - Less options if membrane fails

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A Better Membrane

A Better Membrane

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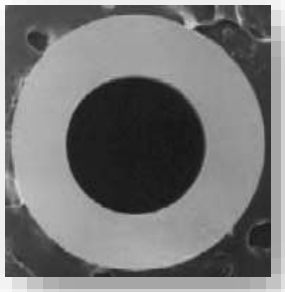
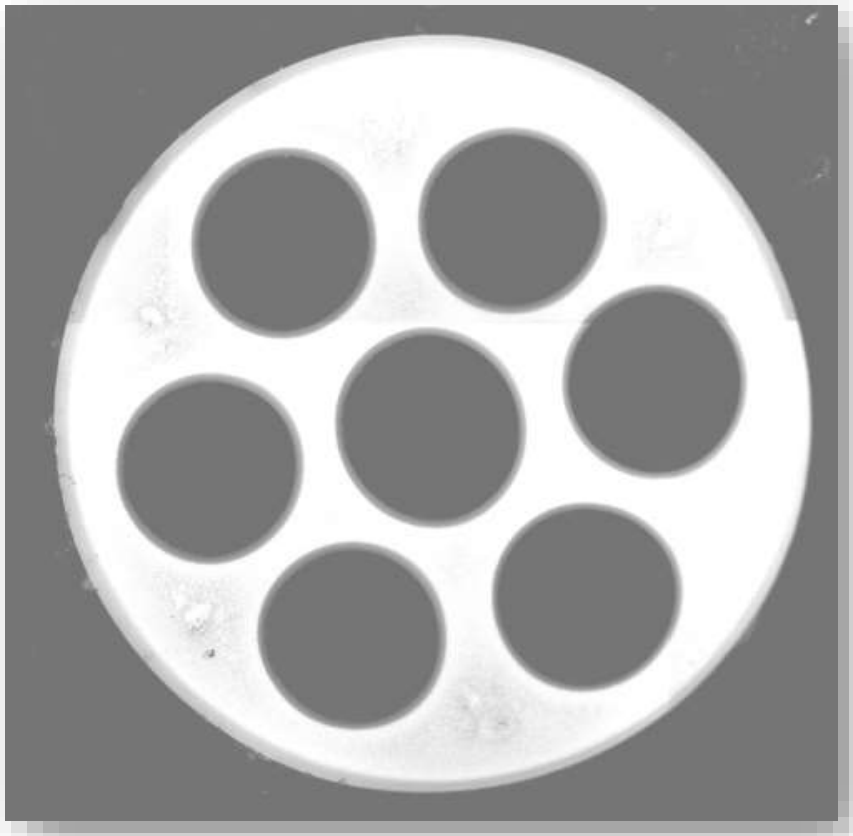
Robust Fibers

- (7) capillaries in one fiber
- Made from one material in one process step
- Superior fiber strength = no fiber breaks



Fiber with single bore (0.7 mm)



Fiber with (7) 0.9 mm bores

A Better Membrane

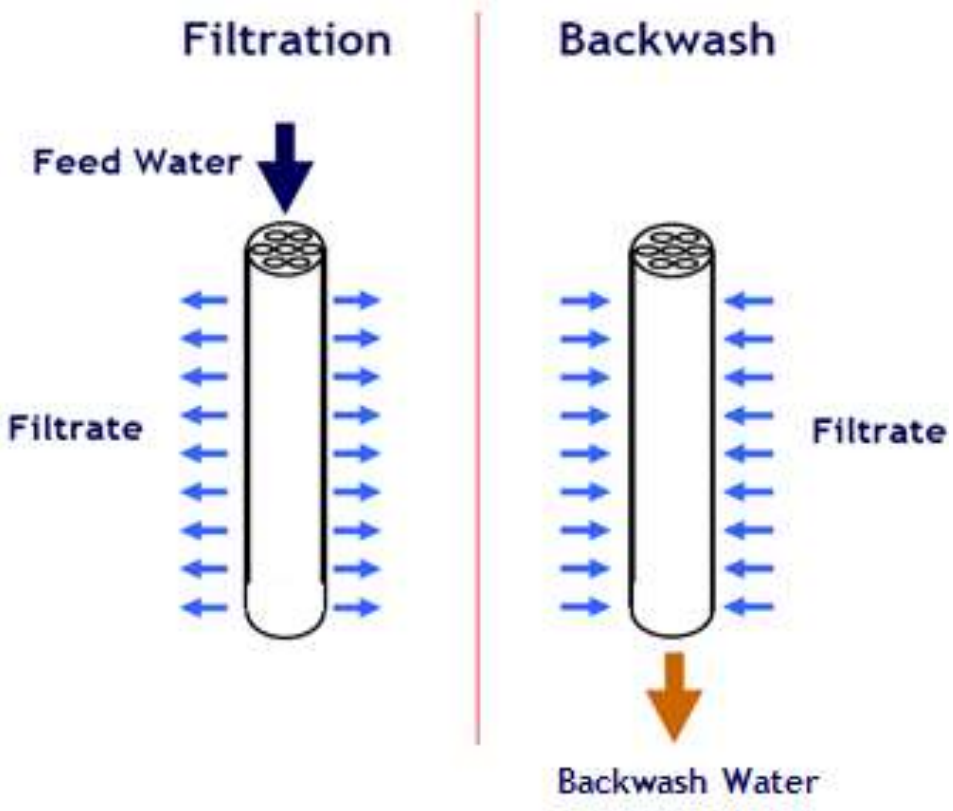
Standard No-Break Warranty

- If a single fiber breaks in the first 5 years…
  - Aqua will replace the entire 2000-fiber module free of charge

A Better Membrane

High Recovery at a Low Operating Cost

- Uses inside-out filtration
  - Solids stay inside bores
  - Backwash flows gives high velocity without air
  - Can handle high solids excursions
- Less water and chemical are required for cleaning



A Better Membrane

Superior Material

- Polyethersulfone (PES) is more hydrophilic than PVDF
  - Minimizes the adhesion of solids to the membrane surfaces

Advantage	PVDF	PES
Stronger		X
More flexible	X	
Can be cleaned with caustic		X
More chlorine-resistant	X	
Less fouling tendency		X
Less trans-membrane pressure		X
Higher permeability		X

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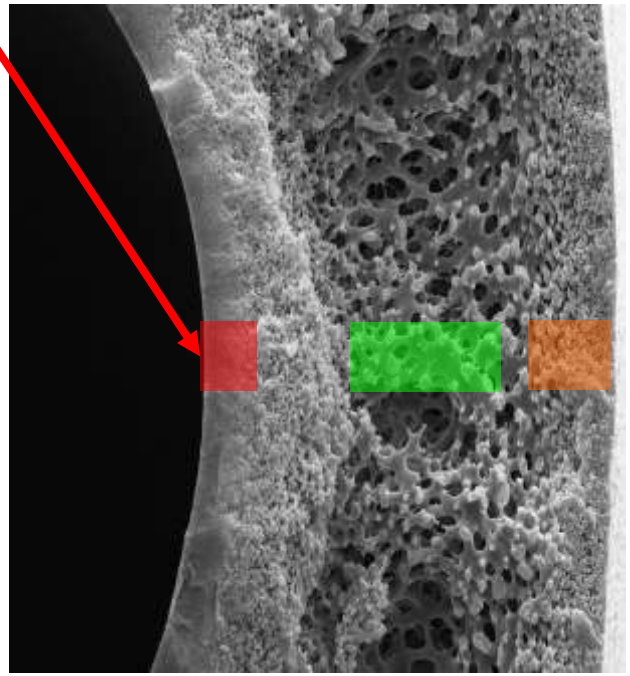
High Flow at a Low Pressure

- Small pores at bore surfaces only
  - Very little pressure drop through rest of membrane
  - Even flow through all 7 bores
- Pores are highly uniform
  - Able to get pores closer together
  - Results in high flow through small area



A Better Membrane

Compact and Accessible Assembly

- Compact and expandable
- External installation
  - Higher fluxes
  - No basins or lifting equipment
  - Accessible

A Better Membrane

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Good Track Record

- The membrane is used in over 700 installations
  - Treating over 1.3 billion gallons per day
  - Extremely low incidence of fiber breakage
    - 14-yr-old German drinking water plant with >54,000 original fibers and no breaks

Abu Dhabi	3,500 m^3/h	Sea Water	Steel Industry
Turkmenistan	2,400 m^3/h	Sea Water	Drinking Water
Ukraine	2,000 m^3/h	Surface water	Chemical Industry
Germany	1,250 m^3/h	Pool Water	Recreation Industry
China	1,200 m^3/h	Waste Water	Petrochemical Industry
Italy	980 m^3/h	Sea Water	Power Industry
China	900 m^3/h	Surface Water	Power Industry
Switzerland	800 m^3/h	Surface Water	Drinking Water
Germany	600 m^3/h	B/w Water	Drinking Water

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Tale of Three Cities and a Village

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Tale of Three Cities

Module Replacements

- Cities with failing modules
  - Butler, MO
  - Garden City, MO
  - Two Rivers, WI
- Received quick State approval
  - In lieu of pilot, replace modules in one train
  - Run the train in parallel with other train(s)
  - Record effluent and integrity test results for demonstration period
- Modules were replaced with Aqua MultiBore® modules

Butler, MO Water Treatment Plant

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Original Facility

- Commissioned in 1967
  - Sources: Butler Lake, Maris de Cygenes River, Miami Creek
  - Upflow clarifiers with dual-media filters
  - 1 MGD annual average flow in 2000
  - Supplies ~4,100 residents, 4 schools, and 372 medium/large businesses

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Butler, MO Water Treatment Plant

Facility Upgrade

- Replaced filters in 2002
  - Four disk-type strainers with 100-micron openings
  - Four trains of (27) ultrafiltration (UF) membrane modules
  - Membrane backwash and clean-in-place (CIP) systems
  - Design capacity of 3 MGD

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Butler, MO Water Treatment Plant

Module Replacement

- System soon began failing integrity tests due to broken fibers
- Modules were replaced several times with same membrane
- In early 2014, MDNR approved 9-month pilot
  - Using new modules in one of the plant's four trains
- New membrane modules installed in April 2014
  - Train 2 was used for the pilot
  - (27) existing modules were replaced with (21) new modules

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Butler, MO Water Treatment Plant

Module Replacement

- The filtrate piping had to be rerouted.

- The DIT pressure was changed
- (18) unused connections were blinded off

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Butler, MO Water Treatment Plant

Direct Integrity Test Results

- Upper Control Limit (UCL) was calculated at 0.096 psi/min.
- Actual pressure decay during DIT was 0.3 psi/10 min, or 0.03 psi/min.
- UCL was exceeded twice since startup in April 2013
  - Operator error caused severe water hammer

Time Elapsed	Pressure (psi)
0 sec.	15.4
60 sec.	15.4
120 sec.	15.3
180 sec.	15.3
240 sec.	15.2
300 sec.	15.2
360 sec.	15.2
420 sec.	15.2
480 sec.	15.1
540 sec.	15.1
600 sec.	15.1

Butler, MO Water Treatment Plant

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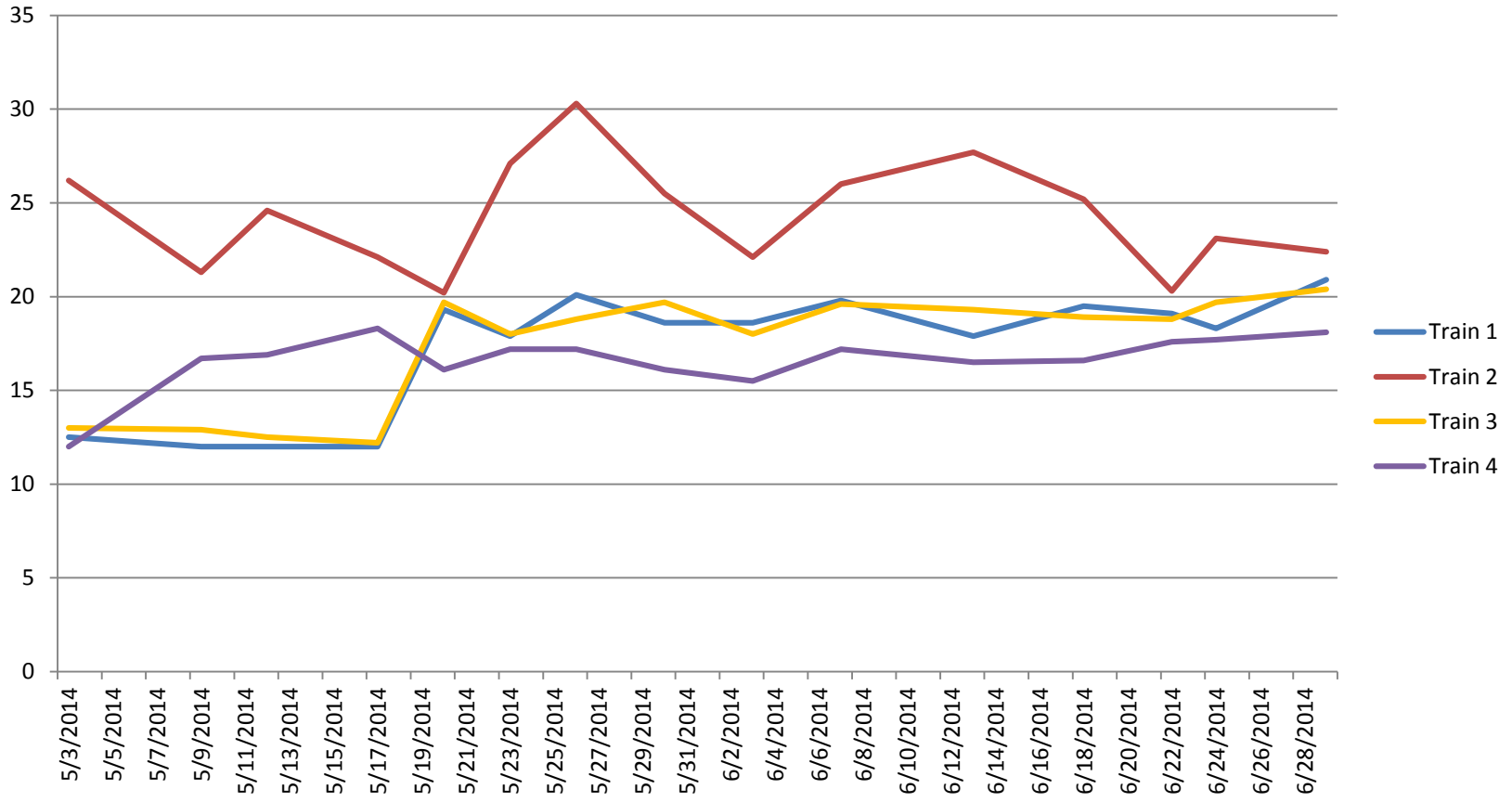
Temperature-Corrected Specific Fluxes (gfd/psi)



- Aqua train (#2) had higher fluxes than other trains

Butler, MO Water Treatment Plant

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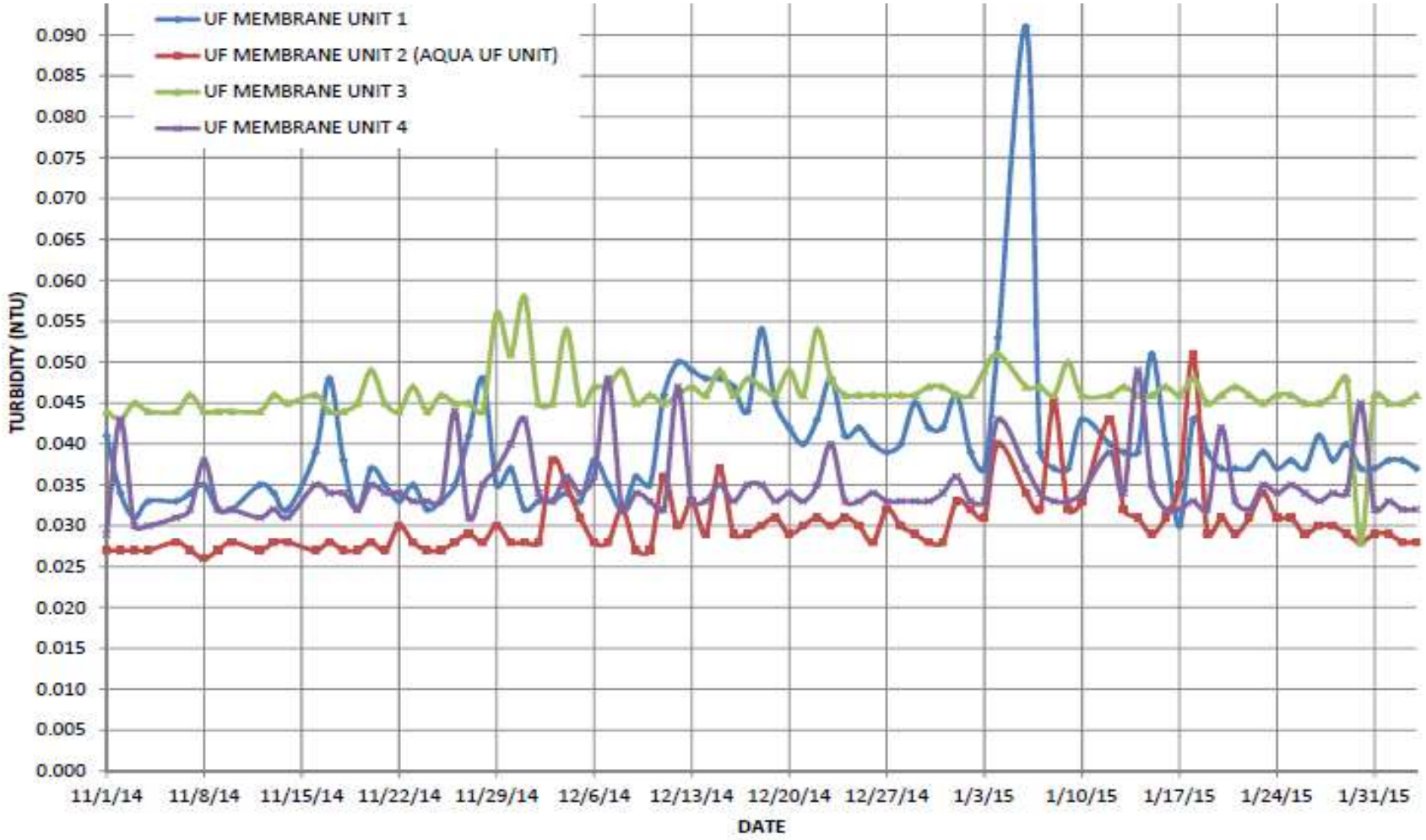
Effluent Turbidities



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Garden City, MO Water Treatment Plant (WTP)

Module Replacement

- Existing 0.15 MGD drinking water plant
  - Had (2) 8-module trains with same membranes as Butler
  - Had similar integrity problems
- Replaced Train 1 membranes in 2014
  - With (7) Aqua MultiBore® modules
- Replaced Train 2 membranes in 2015

Garden City, MO WTP

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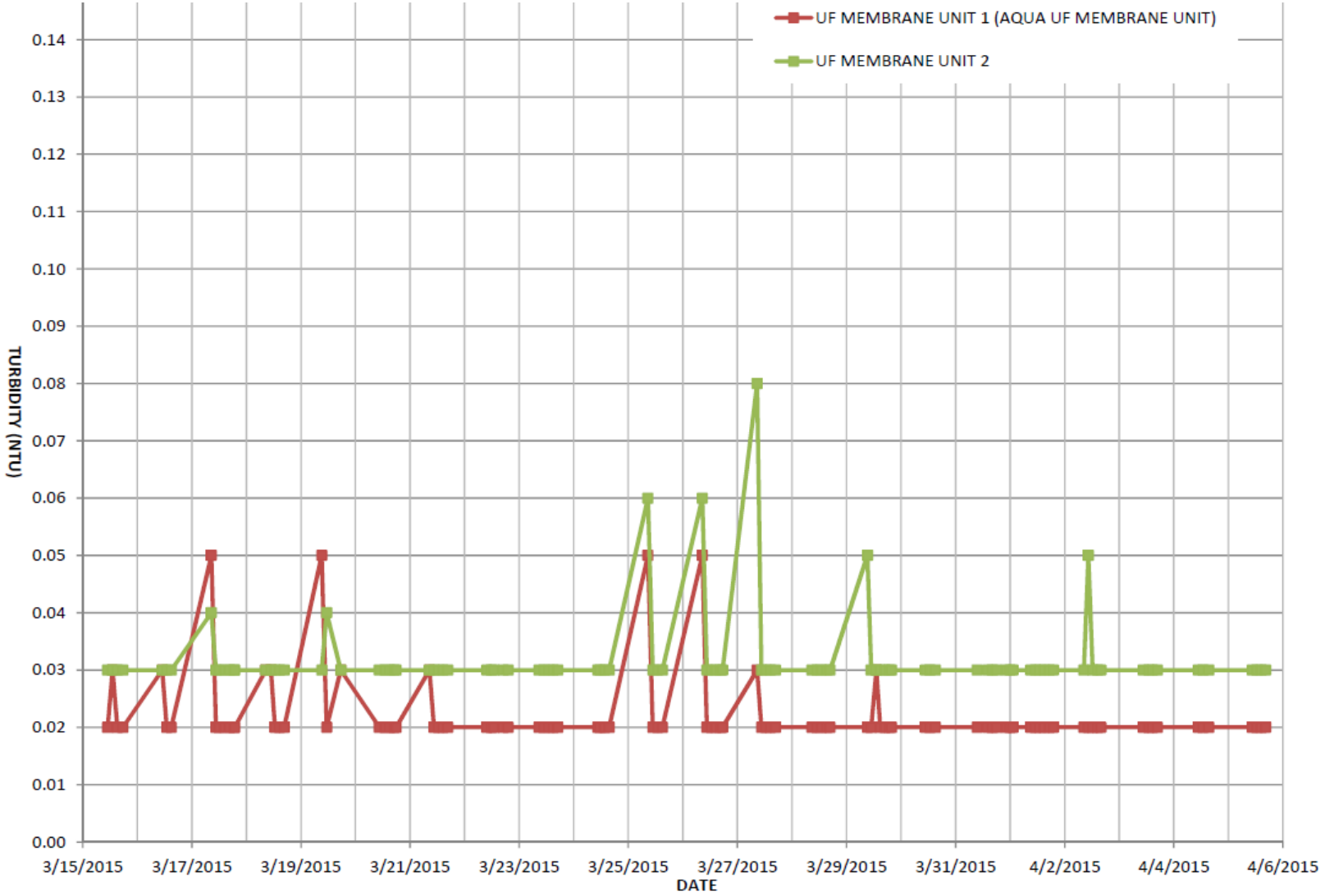
Performance



Two Rivers, WI WTP

Module Replacement

- Existing 3 MGD drinking water plant
  - Had (5) 45-module trains with same membranes as Butler
  - Had similar integrity problems
- Replaced Train 5 membranes in 2017
  - With (35) Aqua MultiBore® modules
- Ready to replace second train

Two Rivers, WI WTP

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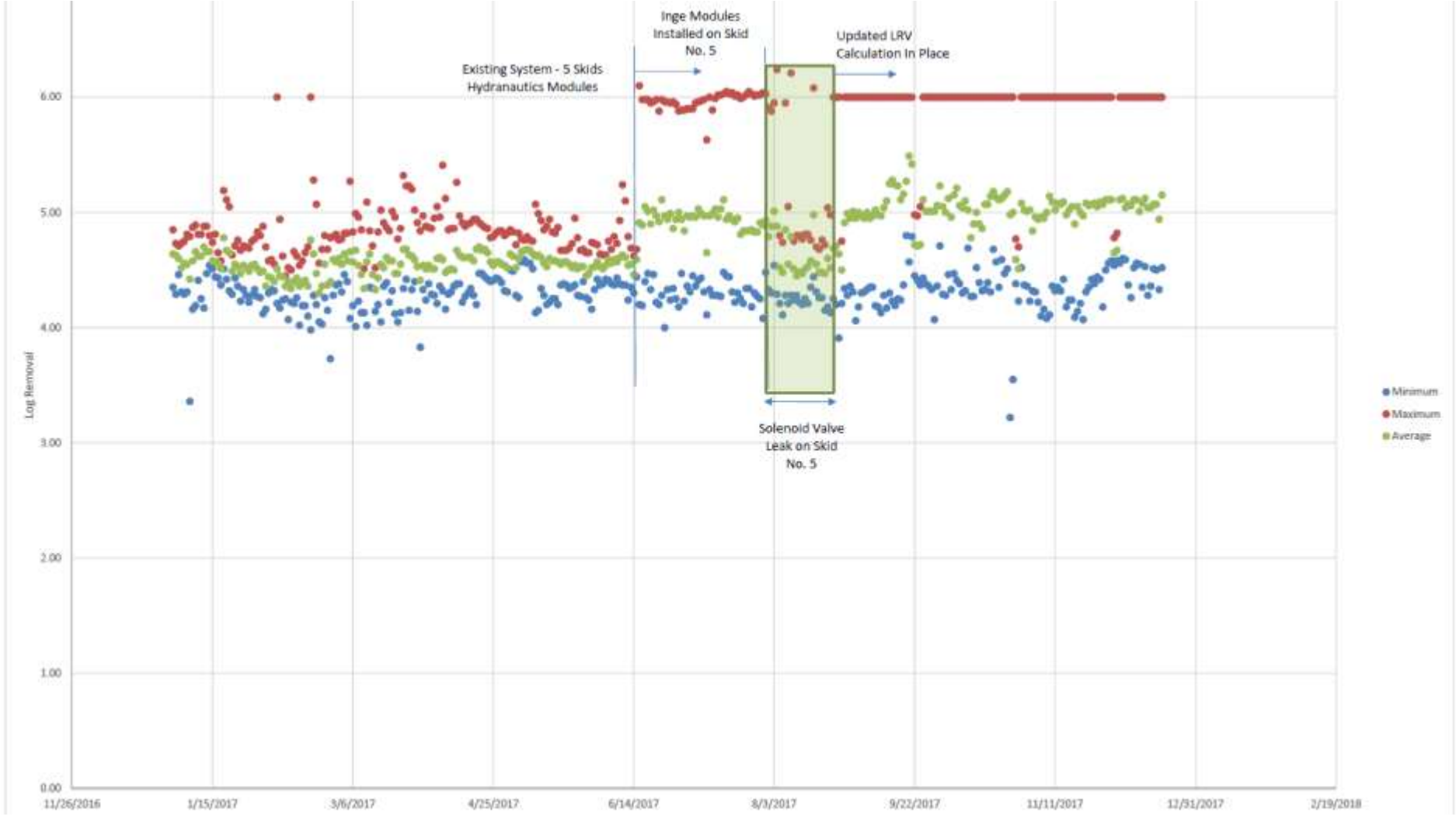
Performance



Tale of a Village

Byesville, OH WTP

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- Membrane plant commissioned in 2004
  - Source: two wells drilled into an abandoned underground coal mine
  - 2.25 MGD design flow
  - Supplies ~2,250 residents, 2 schools, and 435 companies

Byesville, OH WTP

Existing Facility

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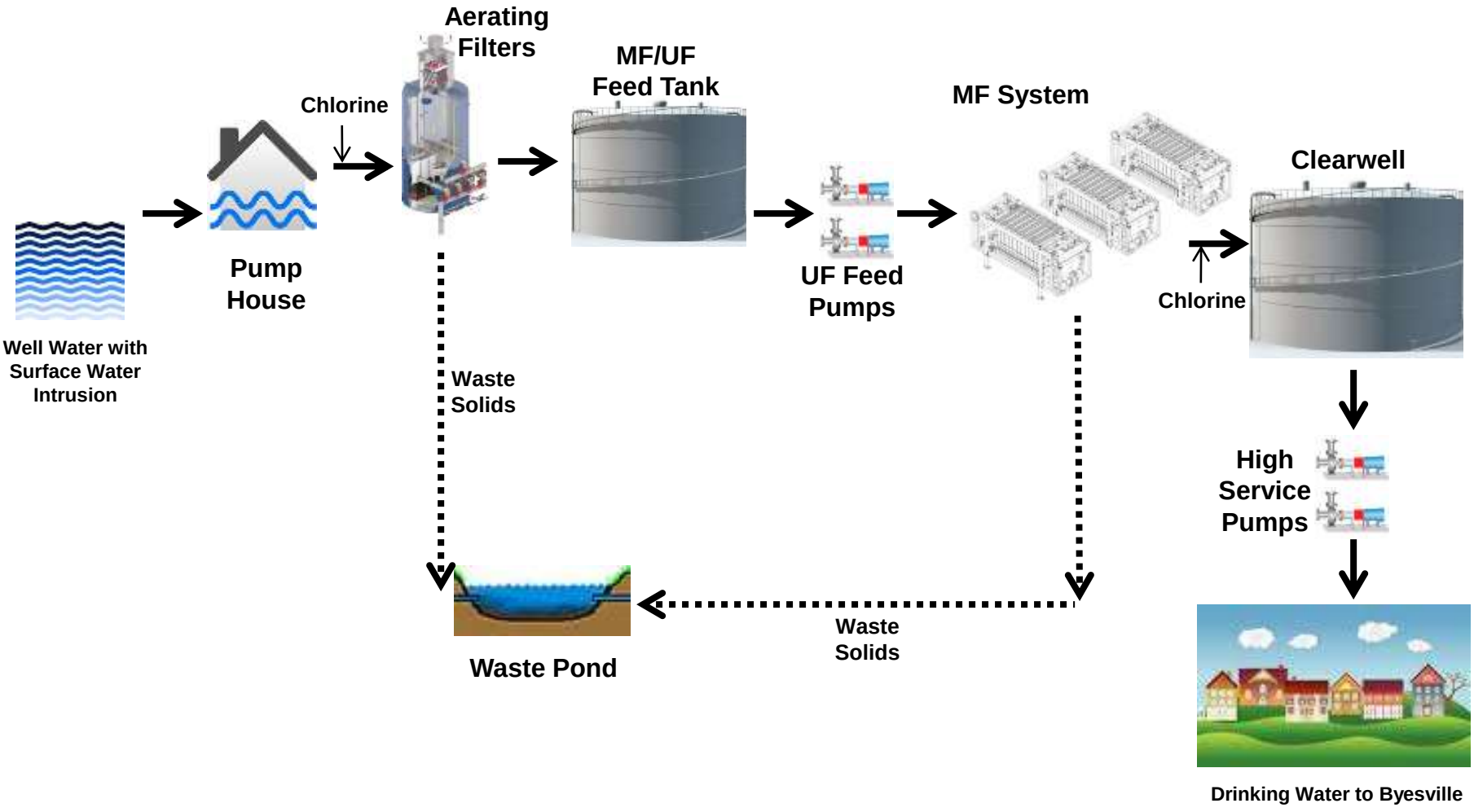


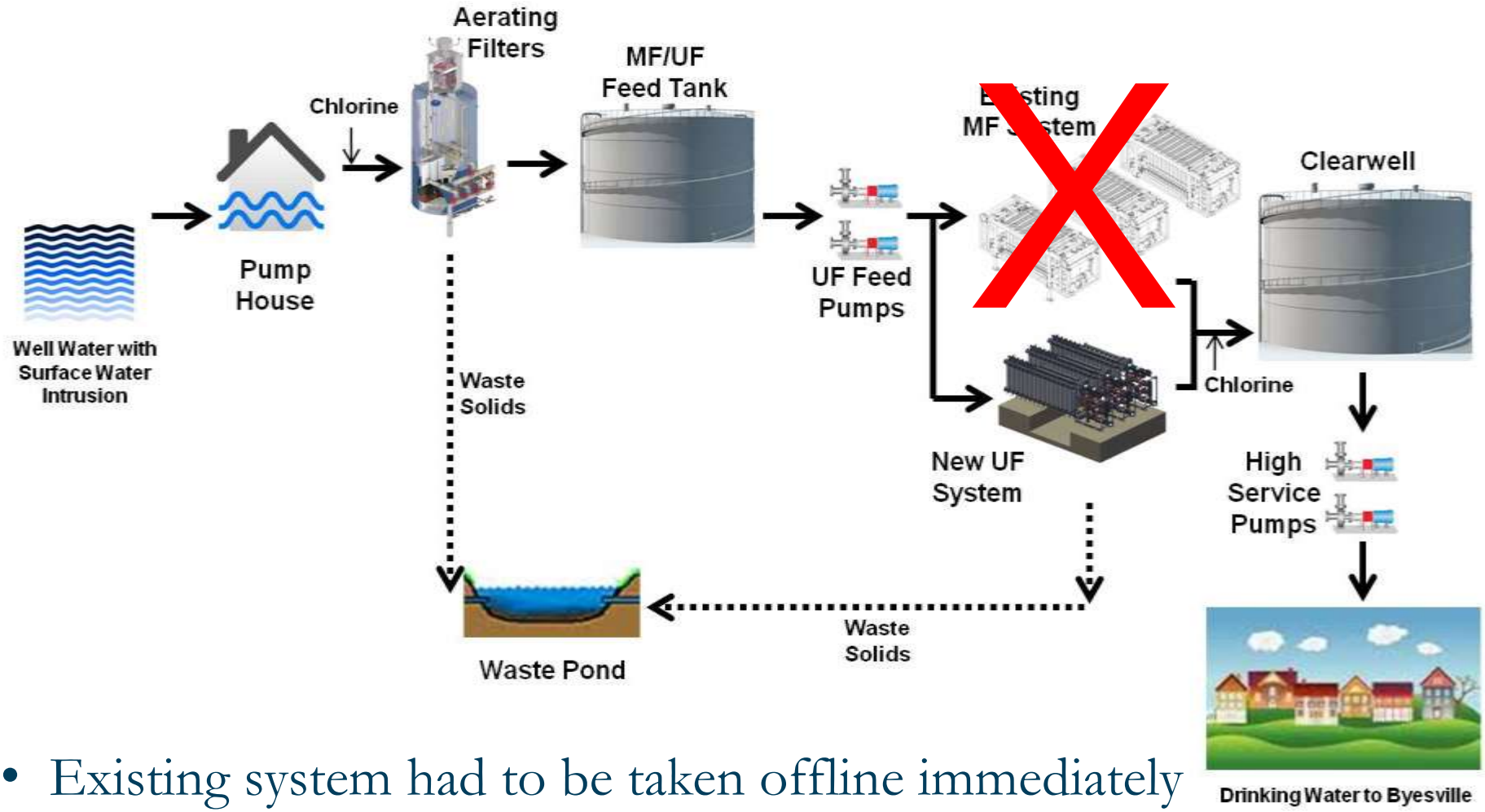
Byesville, OH WTP

System Replacement

- System soon began failing integrity tests due to broken fibers
- Modules were replaced several times with same membrane
- In 2013, OEPA approved a 2,000-hour demonstration period
  - New system to operate in parallel with existing system
- New UF system was placed online in mid-2014
  - (3) 30-module trains

Byesville, OH WTP

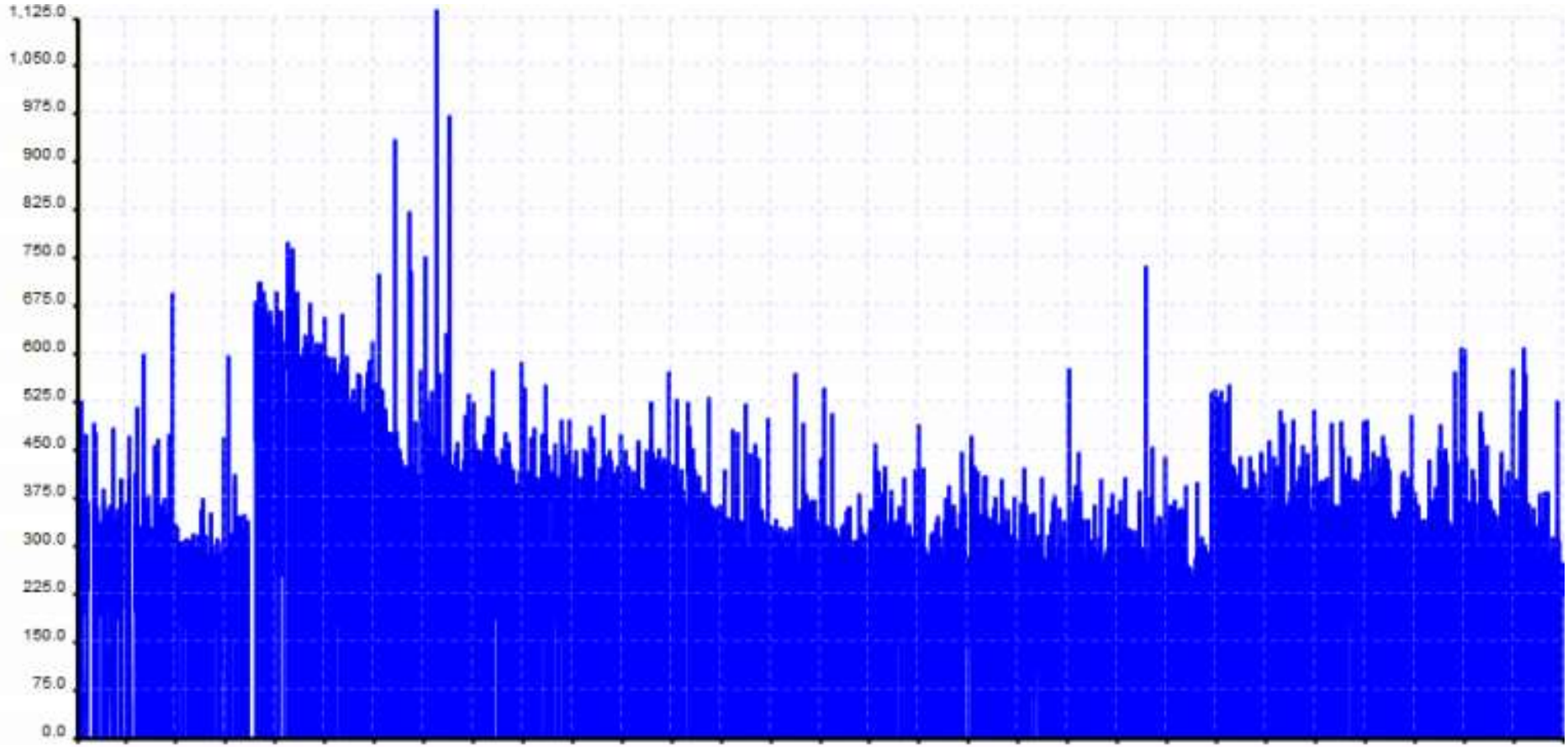
Approved Demonstration Layout



- Existing system had to be taken offline immediately

Byesville, OH WTP

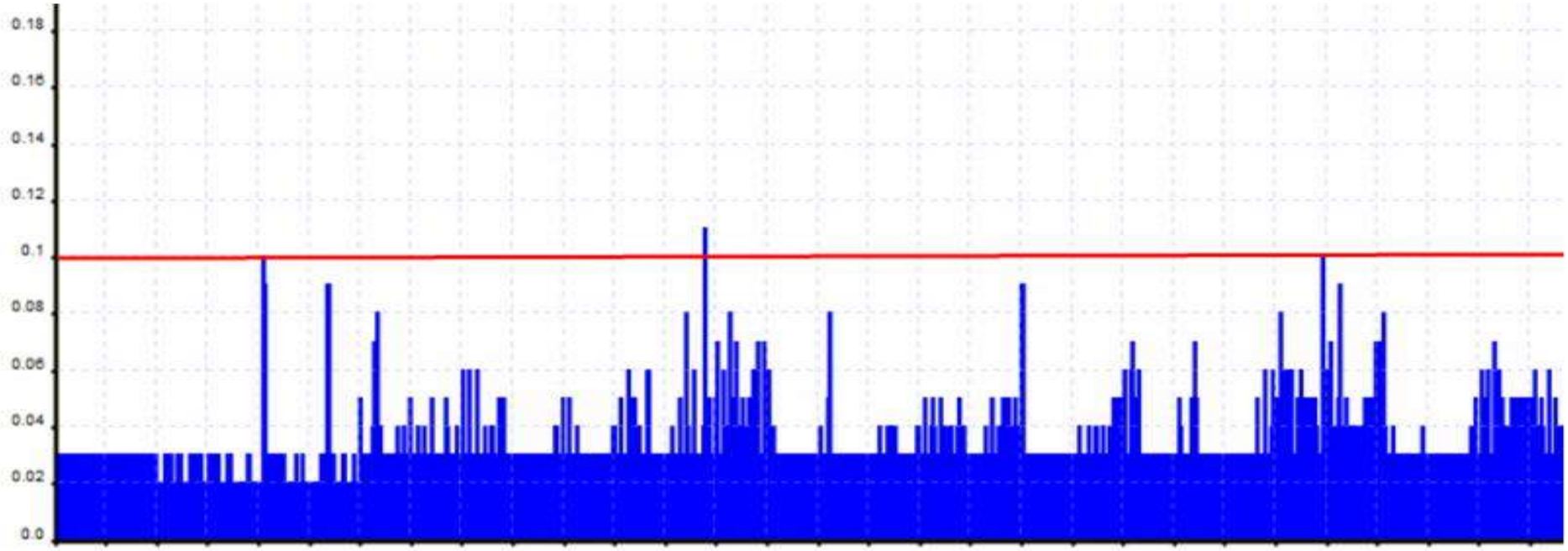
Typical Permeabilities



Monthly average ~ 400 lmh/bar

Byesville, OH WTP

Typical Effluent Turbidity



Monthly average ~ 0.03 NTU

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Summary

Summary

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- Frequent fiber breaks kept plants from passing integrity tests
- Aqua MultiBore® membranes were chosen for their strength and no-break warranty
- Quick State approval was achieved
  - New modules/trains were run in parallel with existing trains for a demonstration period
- New membranes have consistently passed integrity tests
- Turbidities are lower and specific fluxes are higher with the new membranes

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Questions?