

URS

Nitrate and/or TOC Removal by RO Membranes, Anion Exchange and GAC – Case Studies

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Presentation Summary

- Introduction
- TOC Removal Strategies
- Nitrate Removal Strategies

- Case Studies:
  - Archbold, OH
  - Paulding, OH
  - Devola (PCWC), OH

TOC Reduction Strategies

- Enhanced Coagulation / Filtration
- Strong Base Anion Exchange
- Granular Activated Carbon (GAC)
- Nanofiltration / Reverse Osmosis

Nitrate Reduction Strategies

- ~~Enhanced Coagulation / Filtration~~
- Strong Base Anion Exchange
- ~~Granular Activated Carbon (GAC)~~
- ~~Nanofiltration /~~ Reverse Osmosis

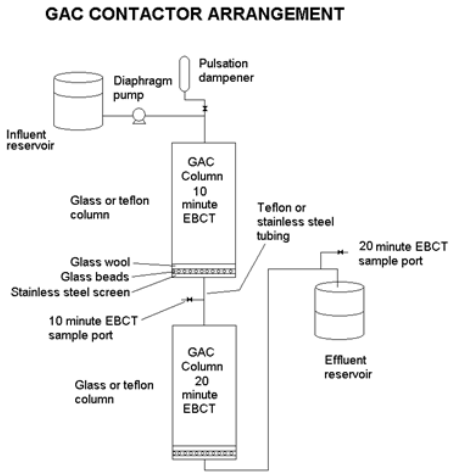
Case Study: Archbold WTP

- 7.5 MGD Surface Water Plant (Lime Softening)
  - Source: Tiffin River
  - 2 Reservoirs: 200 MG and 100 MG
- Compared GAC with Four (4) SBA Resins

Case Study: Archbold WTP

- IDSE (2009-2010) Revealed Potential Difficulty Meeting Stage 2 Rule Limits for THMs
- URS and PMG Consulting Performed Demonstration Study Utilizing
  - Four (4) Anion Exchange Resins
  - GAC

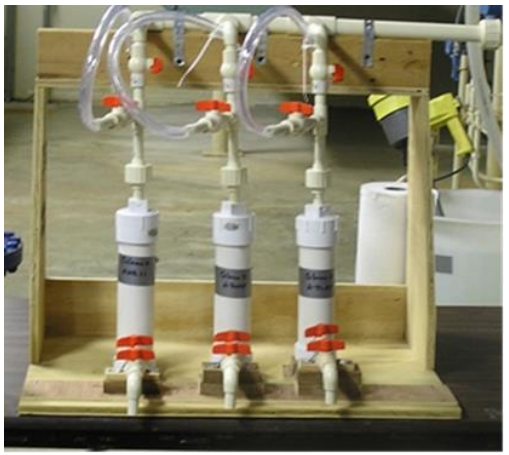
Dr. R. Scott Summers (Univ. of Colorado Boulder) Performed GAC RSSCT studies



Case Study: Archbold WTP

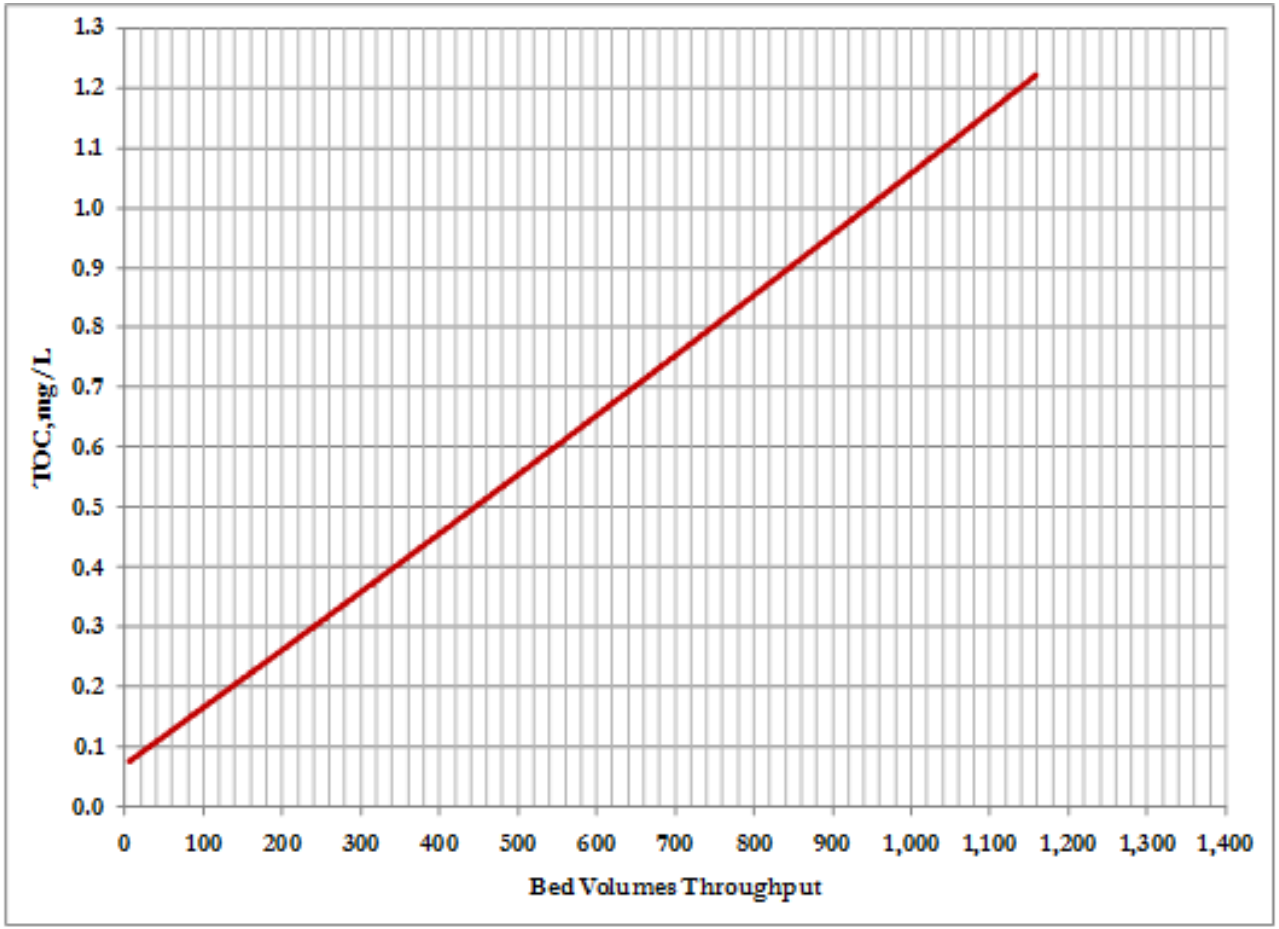
- Anion Exchange Resins Tested

Resin Manufacturer	Exchange Capacity	Salt Regenerant, lbs/ft^3
Dow DOWEX TAN-1	0.7 eq/L	2.92
Dow DOWEX MARATHON 11	1.3 eq/L	4.74
Thermax Tulsion A-30 MP	0.7 eq/L	2.92
Thermax Tulsion A-72 MP	1.1 eq/L	4.00



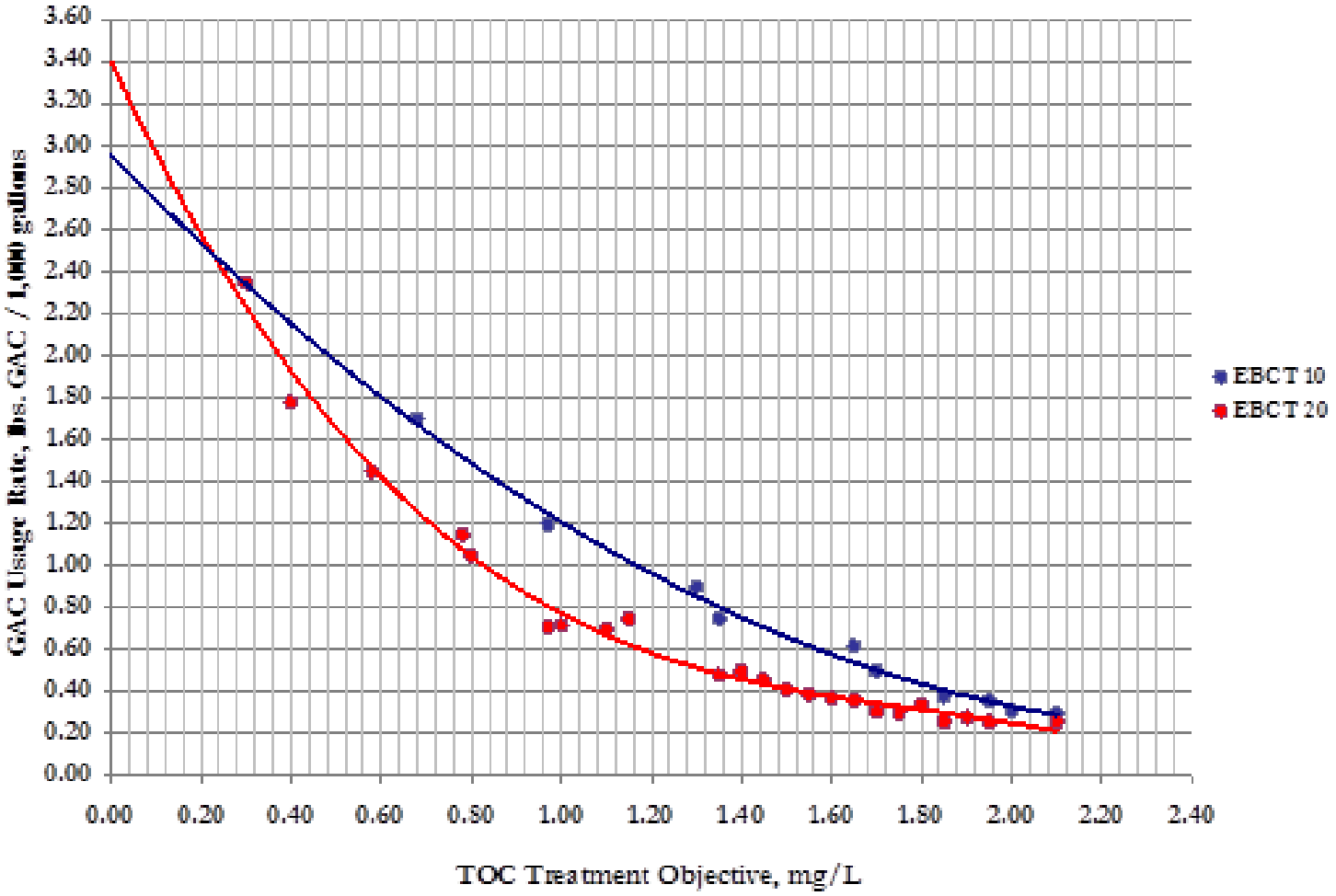
Case Study: Archbold WTP

- Thermax Tulsion A-72MP (Macroporous Resin) Performance Shown Below



Case Study: Archbold WTP

- GAC Performance Shown Below



Study Results: Archbold WTP

- Both GAC and Anion Exchange Demonstrated Compliance with Stage 2 THM Limits.
- 60% Side Stream of Filtered Water Through Anion Exchange Would Reduce TOC to Required Levels of 1.7 mg/l.
- Alkalinity Reductions in Anion Exchange Column Requires Additional Lime and CO_2
- **Annual Operating Costs for Anion Exchange Appear to Be 1/3 the Cost of GAC**

Cost Evaluation: Archbold WTP

COMPARISON OF OPERATING COSTS FOR ADSORPTION TECHNOLOGIES STUDIED (TREATING UP TO 2 MGD)

Costs are in October 2010 dollars per day except as noted.

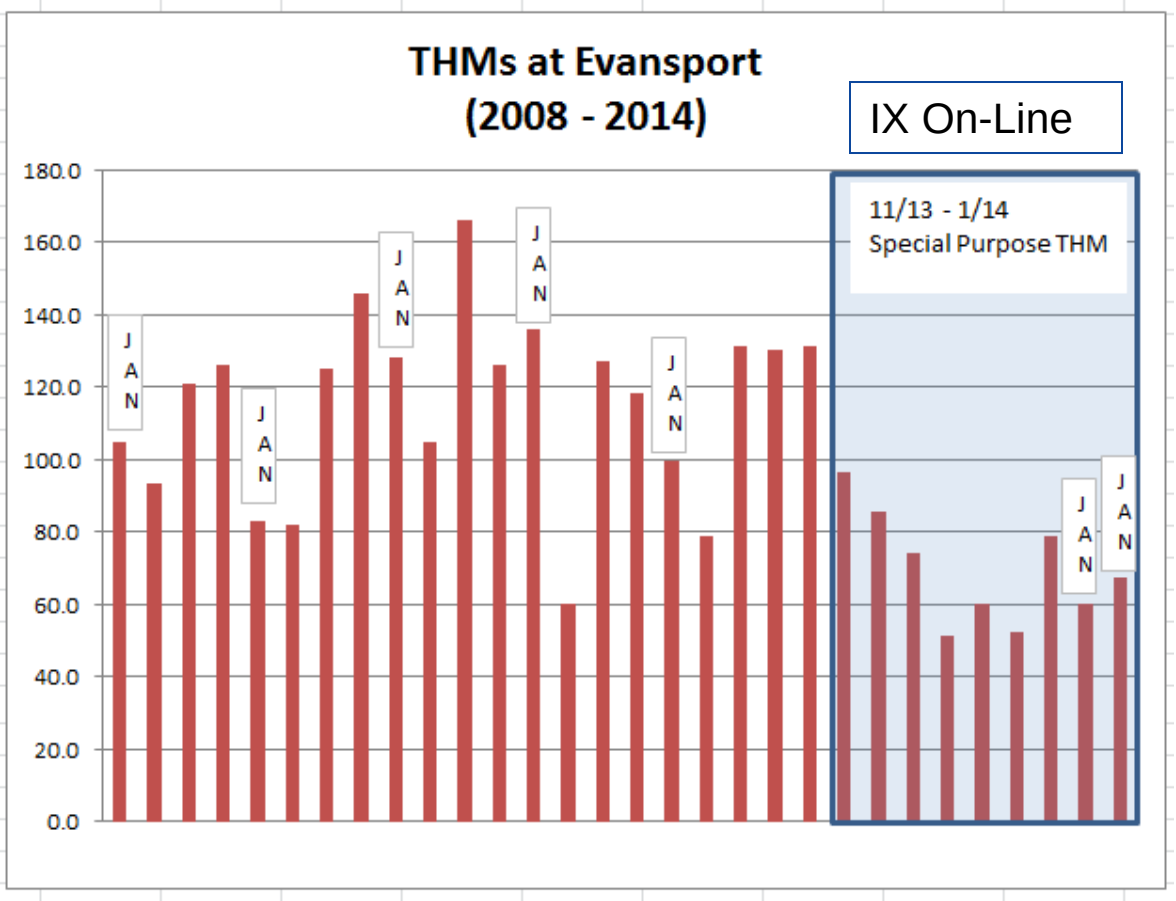
MATERIAL	TAN-1	MAR 11	A-30 MP	A-72 MP	GAC
Lime	$41.20	$41.20	$41.20	$41.20	$0.00
Carbon dioxide	$16.10	$16.10	$16.10	$16.10	$0.00
Salt	$62.40	$30.42	$40.02	$26.64	$0.00
Water	$3.30	$1.53	$2.01	$1.35	$2.40
Power	$28.03	$28.03	$28.03	$28.03	$28.03
Resin or media	$20.22	$79.22	$56.22	$44.04	$449.51
Predicted Daily Costs	$171.25	$196.50	$183.58	$157.36	$479.94
Predicted Annual Costs	**$62,507**	**$71,723**	**$67,006**	**$57,436**	**$175,179**
Cost per million gallons (MG)	$90.13	$103.42	$96.62	$82.82	$252.60
Costs per 1,000 gallons	**$0.0901**	**$0.1034**	**$0.0966**	**$0.0828**	**$0.2526**

Construction: Archbold WTP

- City Constructed Anion Exchange Facilities (Nov. 2013)
- Three (3) – 11 foot diameter vessels (one or two future units)
- Designed for 3 MGD (40%- 60% of Flow)

Results at Archbold WTP

- Construction Cost: $2,000,000
- Performance (Shown Below)



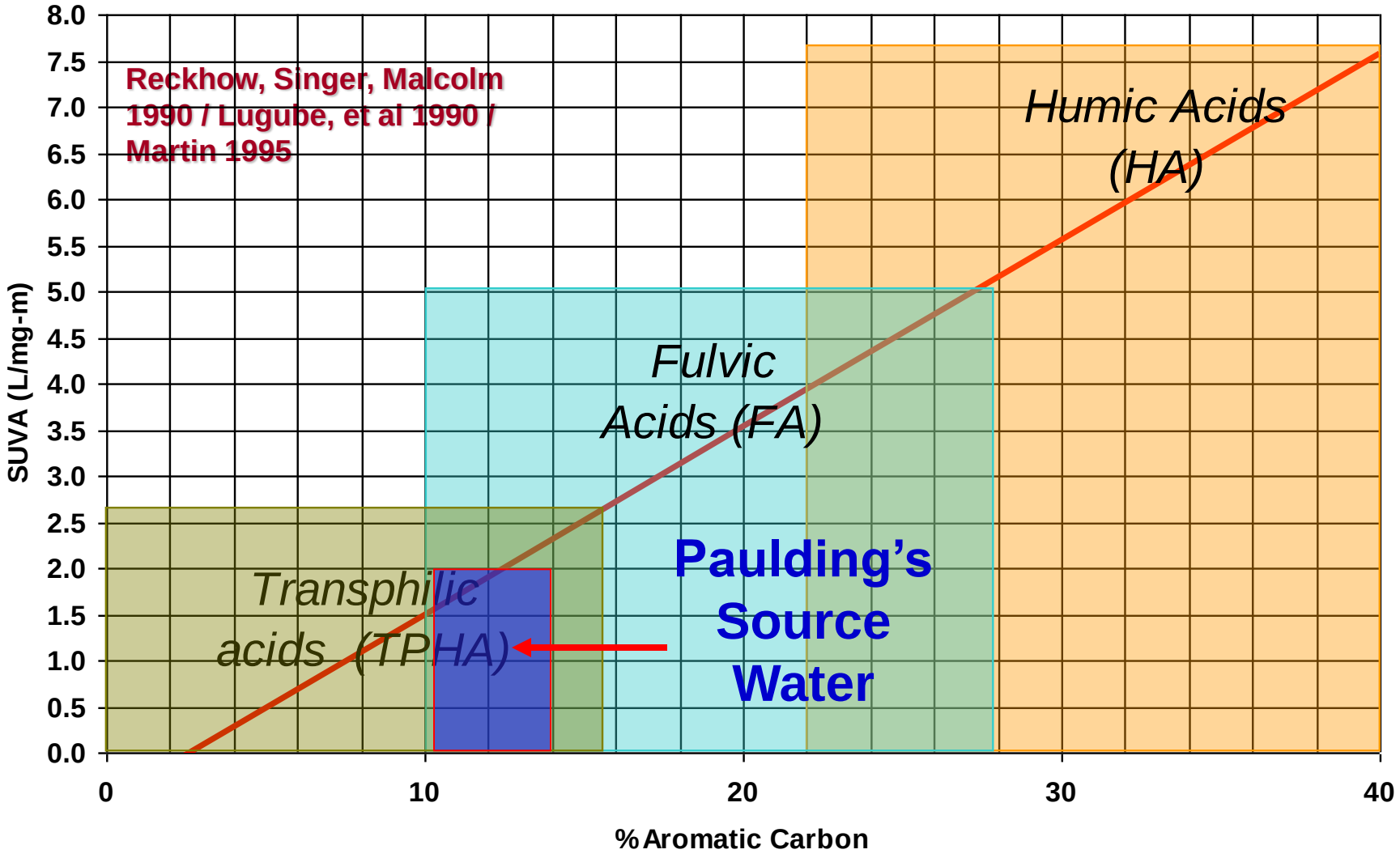
Case Study: Paulding WTP

- 2.2 MGD Surface Water Plant (Was Lime Softening)
  - Source: Flat Rock Creek
  - Reservoir: 420 MG

Case Study: Paulding WTP

- Existing Plant Built in 1966
- High Raw Water TOC: 3 mg/l- 9.1 mg/l (5.6 mg/l ave)
  - Stage 2 D/DBP Rule Compliance Not Likely
  - No Redundant Process / Trains

Case Study: Paulding WTP



Case Study: Paulding WTP

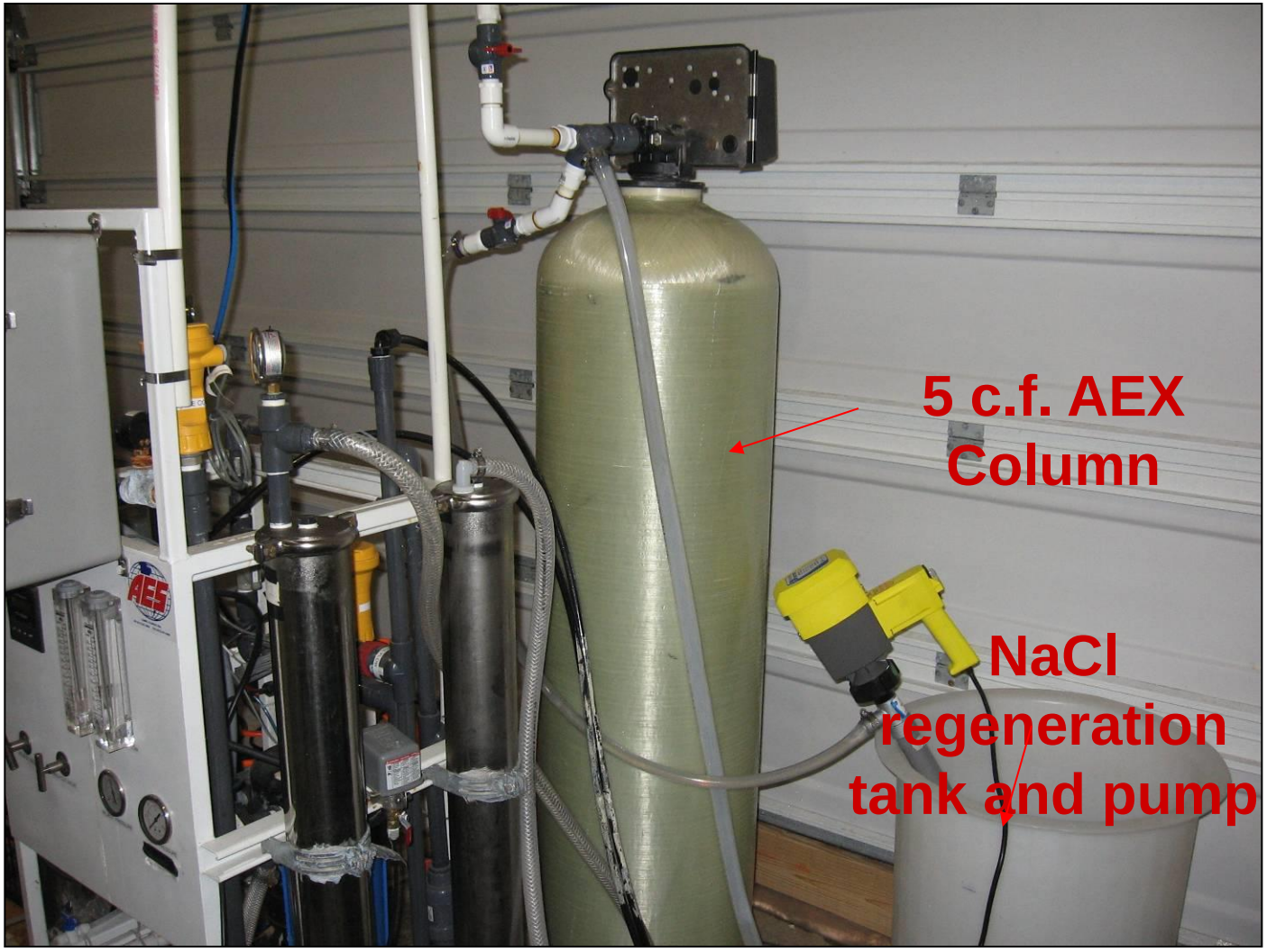
- Village Decided to Build New Plant
  - Piloted:
    - Anion Exchange (for TOC Removal)
    - UF Membranes - GE Zenon
    - NF Membranes, and
    - RO Membranes

Case Study: Paulding WTP

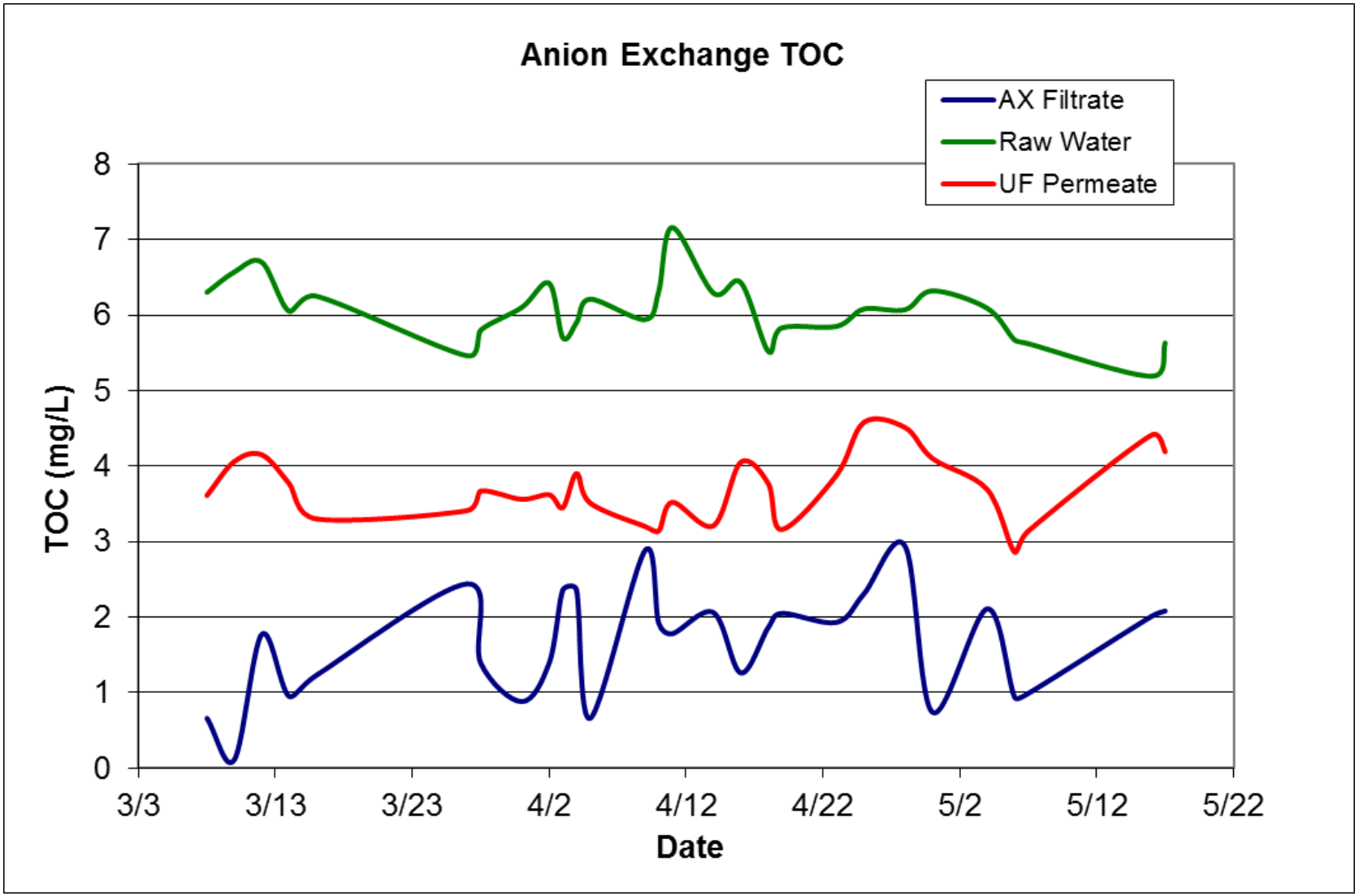
Pilot Work in Paulding

- Anion Exchange (DOW TAN-1)
  - Exchange capacity 0.8 eq/L
  - Regenerate 2.9 lbs/ft^3 NaCl
    - TOC reached about 2 mg/L end of each cycle
  - Hydraulic loading ~ 4.2 gpm/ft^2
  - February 2008 - July 2008 pilot period

Pilot Work in Paulding

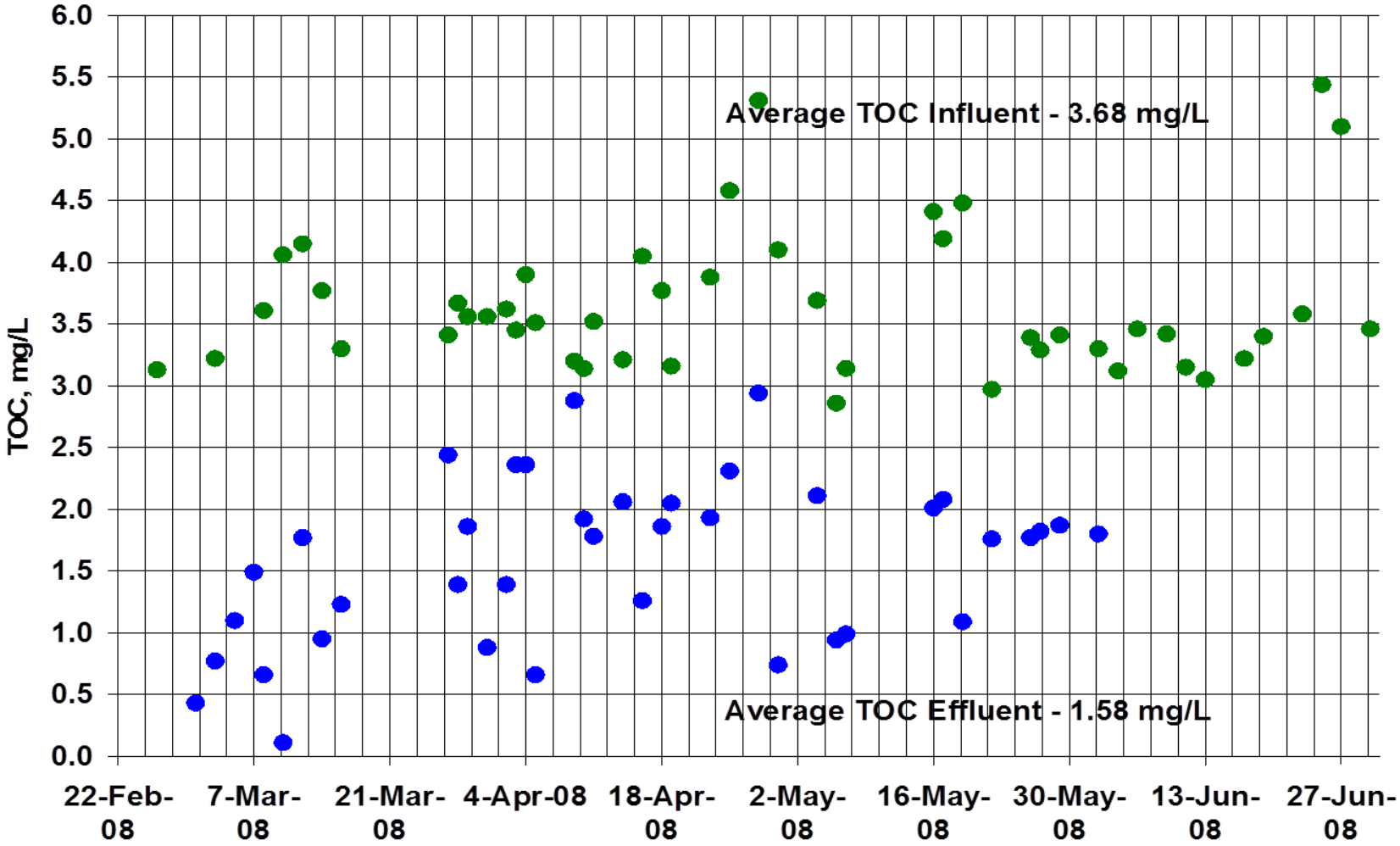


Case Study: Paulding
Comparison of TOC in UF and SBA



Case Study: Paulding WTP

Anion Exchange Pilot Data



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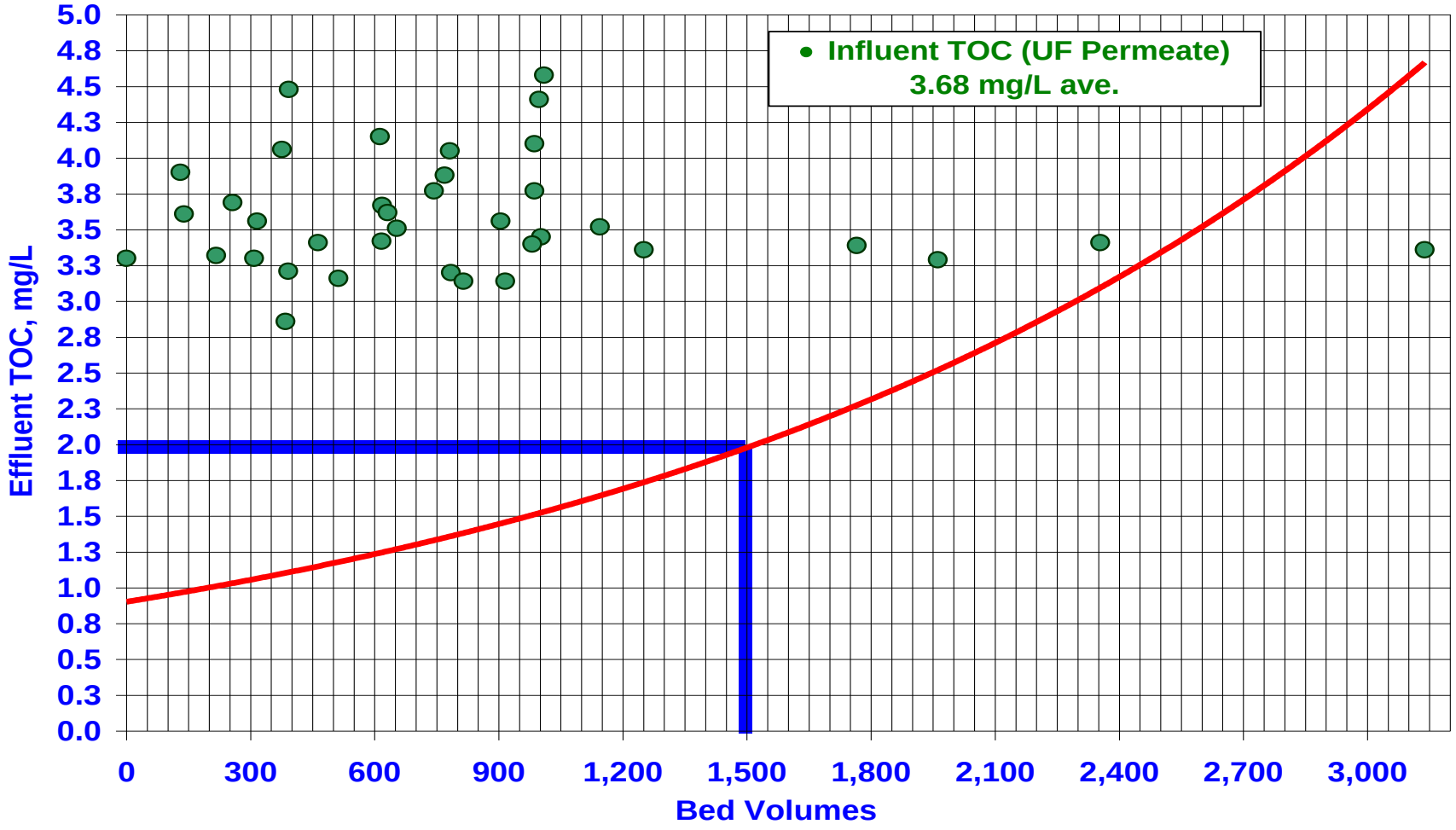


Case Study: Paulding WTP

Anion Exchange Pilot Data

UV_{254} Reduction, %	57.3 - 85.3
TOC Reduction,%	46.0 - 96.2
THMFP Reduction,%	51.2 - 78.6
Bed Volumes	744 - 3,130
Resin dose, $1ft^3$ / 1,000 ft^3	1.44
Life Expectancy	5 years
Operating Cost	4.5¢ per 1,000 gallons

Case Study: Paulding WTP

Anion Exchange Pilot Data

Parameter	Average	Range
Hydraulic Loading, gpm/ft^2	4.2	3.2 - 4.6
Bed Volumes	1,200	744 - 3,130
Cycle Time, hours	150	91 - 384
Cycle Time @ 7.5 gpm/ft^2, days	9.9	6.2 - 26

Case Study: Paulding WTP

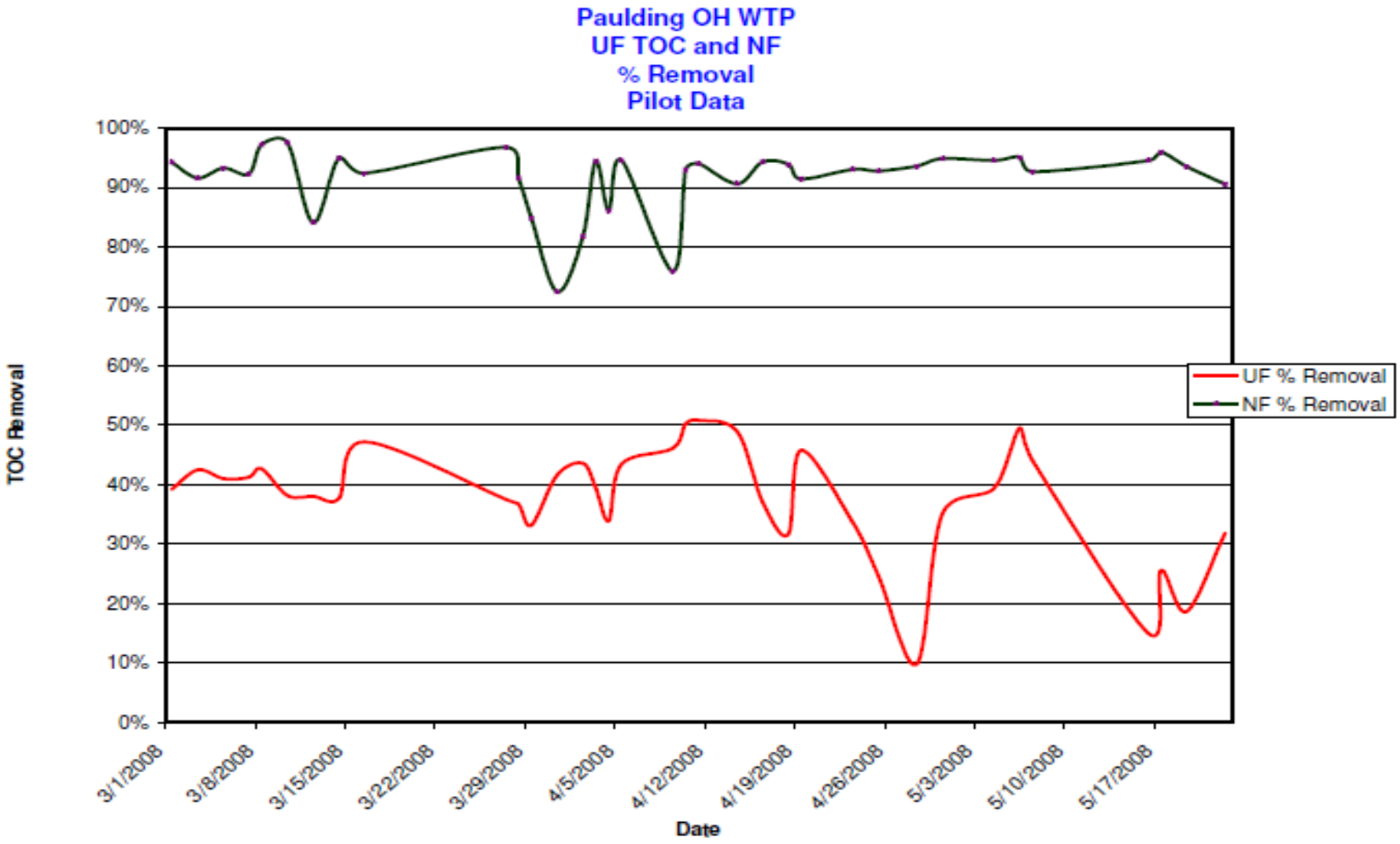
Anion Exchange Pilot Data

Parameter	Average	Range
Water pH, s.u.	8.05	7.65 - 8.47
Temperature, ^{o}C	14	6 - 26
Total Alkalinity, mg/L	119	89 - 169
TOC, mg/L	1.59	0.11 - 2.94
UV_{254} Absorbance, cm^{-1}	0.017	0.006 - 0.035
THMFP, µg/L	77.7	28 - 151
SDS-THM, µg/L	22.1	11.9 - 33.2

Case Study: Paulding WTP

- SBA AEX resins good organics treatment
  - Improve TOC and UV_{254} removal
  - Reduce THMFP and DBP's
- Side stream treatment applications cost effective
  - Treat what is needed to meet regulatory limits
  - About 4.5¢ to 7.3¢ per 1,000 gallons treated (resin and salt)
- High removal efficiencies depending on cycle time
- Moderate life cycle depending on organic load
  - Typically 5 years or greater
- Regeneration cycles similar to ion exchange softening

Case Study: Paulding
Comparison of TOC in UF and NF



Construction: Paulding WTP

- NF Membranes Removed Significantly More TOC (90+%) AND Provided Softening
- Village Constructed UF-NF Membrane Facility (2012-2013)
  - GE Zenon ZW-1500 UF Membranes
  - Dow NF-270 NF Membranes (Very Loose NF Membrane)

Success at Paulding WTP

FROM OLD....

Old Plant in 1909

Water Plant—Gravity Filters (1966-2013)

Water Plant— Lime Softening (1966-2013)

The Village of Paulding has owned and operated a water system that has been servicing the Village for more than 100 years.

The former water plant at this current site was completed in 1966 and had served the Village well for 47 years but was beyond its useful life. In addition, it would not have been able to meet the upcoming Ohio EPA regulations.

The new state-of-the-art water treatment plant will serve the Village meeting the ever-stringent regulations for years to come. The new plant has already made a significant improvement in water quality for the Village residents and has complied with all Ohio EPA drinking water regulations.

Former Water Plant (1966—2013)

TO NEW...

New Water Plant—2013

UF Membrane Filtration —2013

RO Membrane Softening —2013

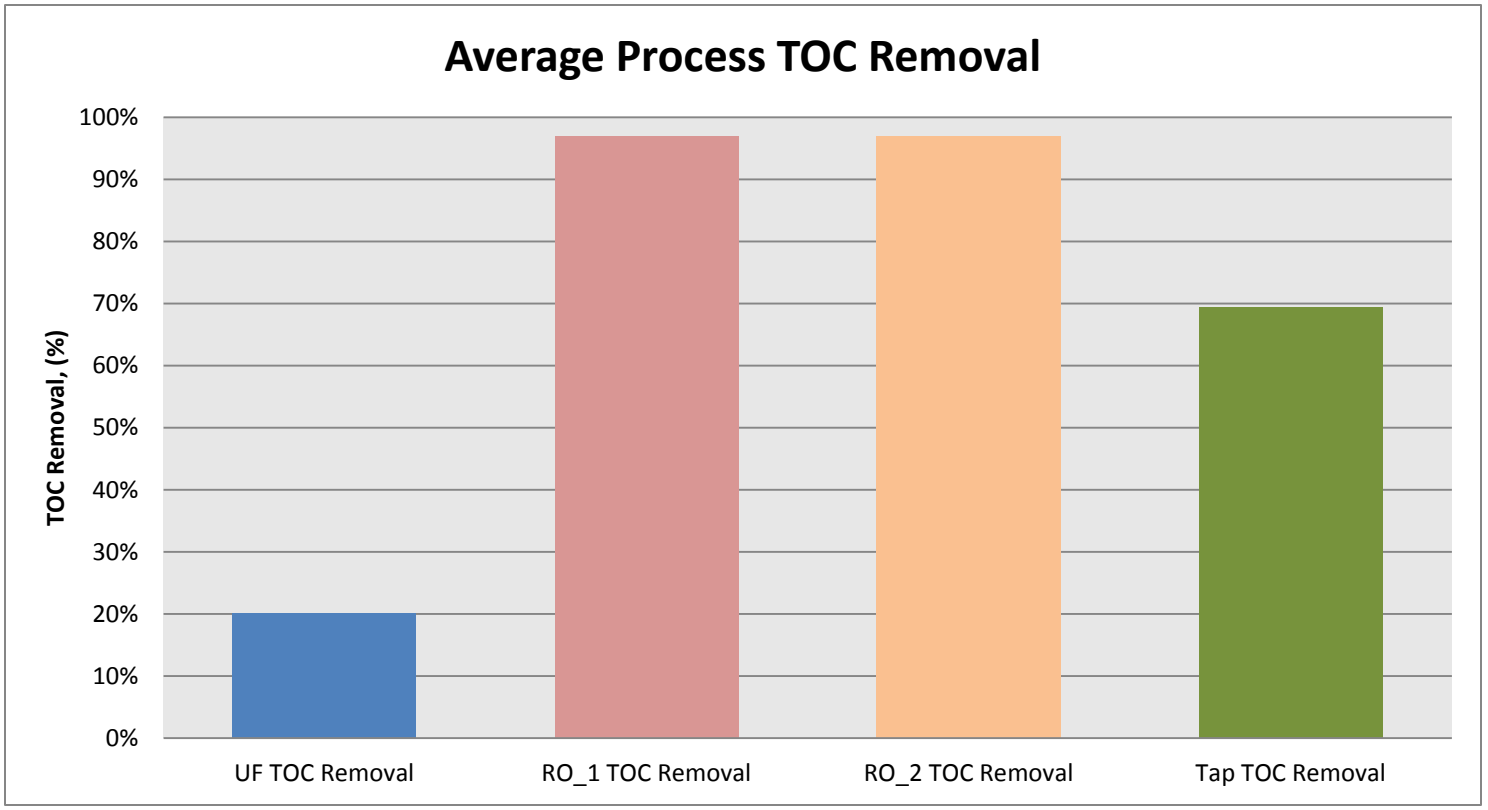
Success at Paulding WTP

- Construction Consisted of:
  - New 12,000 SF Process Building
  - New 4,300 SF Administration Building
    - 2 Laboratories (Water and Wastewater)

Paulding WTP

Success at Paulding WTP

- Construction Cost: $11.5 Million
- Performance (Shown Below):



Case Study: PCWC WTP – Devola, OH

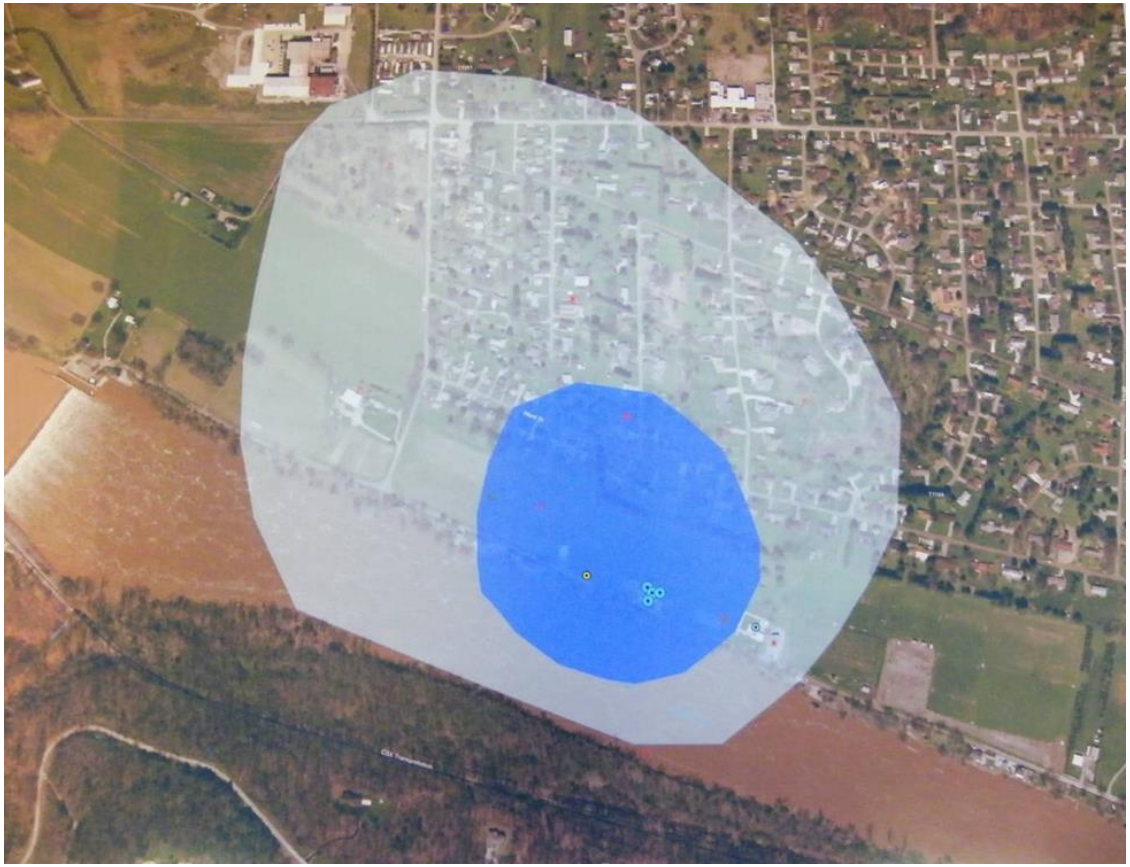
Putnam Community Water Corporation (PCWC) – 0.5 MGD RO WTP (Nitrate Removal)

Case Study: PCWC WTP – Devola, OH

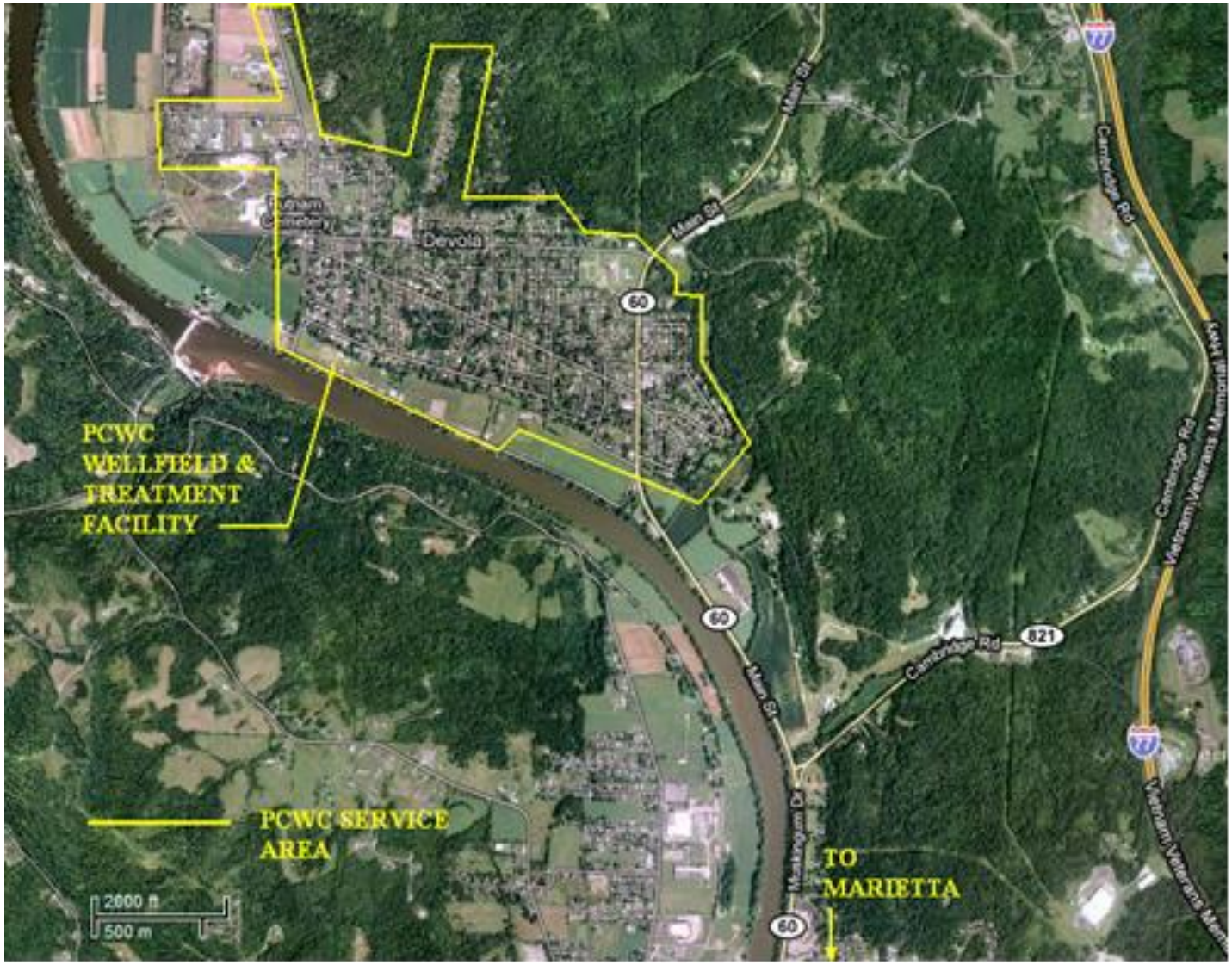
- Putnam Community Water Corporation is a private water utility north of Marietta
- Under Findings and Orders by Ohio EPA due to high nitrate levels (up to 13.8 mg/l)
- URS retained to prepare General Plan to investigate options, including:
  - Tie-in to alternative water systems
  - Alternative raw water supply (new wellfield)
  - Treatment for nitrate

Case Study: PCWC WTP – Devola, OH

- Nitrate in groundwater were found to be coming from septic tanks in unsewered community.



Case Study: PCWC WTP – Devola, OH



Case Study: PCWC WTP – Devola, OH

Alternatives Considered:

1. Purchase Water From Marietta
2. Purchase Water From Warren Community W&S
3. Construct New Anion Exchange WTP for Nitrate Removal – with and without softening
4. Construct New Reverse Osmosis WTP for Nitrate Removal
5. Construct New Wellfield Unaffected by Nitrate

Case Study: PCWC WTP – Devola, OH

Anion Exchange Design Parameters:

Description	Unit	Value
Number of high-rate prefilters	Ea	3
High-rate filter vessel diameter	Ft	4.5
Number of AIX pressure vessels	Ea	3
AIX pressure vessel diameter	Ft	4
AIX resin volume per vessel	cubic feet	50.3
Specific throughput	gpm/ft^2	5.95
Total flow to AIX vessels	gpm	223
AIX vessel bypass flow rate	gpm	127
Finished (blended) water flow	gpm (MGD)	350 (0.5)
Ave. raw water nitrate concentration	mg/L	9.0*
AIX effluent nitrate concentration	mg/L	1.15
Blended water nitrate concentration	mg/L	4.0

Case Study: PCWC WTP – Devola, OH

Cation Exchange Design Parameters (for Softening as well):

Description	Unit	Value
Number of high rate pre-filters	Ea	3
High rate filter diameter	ft	4.5
Number of IX pressure vessels	Ea	3
IX pressure vessel diameter	ft	4
Specific throughput	gpm/ft^2	5.65
Total flow to AIX vessels	gpm	213
IX vessel bypass flow rate	gpm	137
Softened (blended) water flow	gpm (MGD)	350 (0.5)
Raw water hardness	mg/L as $CaCO_3$	356
IX effluent hardness	mg/L as $CaCO_3$	1
Blended water hardness	mg/L as $CaCO_3$	140

Case Study: PCWC WTP – Devola, OH

Reverse Osmosis Alternative - Parameters

Description	Unit	Value
Number of RO skids	Ea	2
Permeate Capacity per RO Skid	gpm	130
Raw (Average) Water Nitrate Level	mg/L	9.0
RO Permeate Nitrate Level	mg/L	0.68
RO Bypass Flow per Skid	gpm	79
Finished Water Nitrate Level	mg/L	3.8
Finished Water Hardness	mg/L as $CaCO_3$	132
Finished Water Flow w/ 1 skid	gpm (MGD)	209 (0.3)
Finished Water Flow w/ 2 skids	gpm (MGD)	418 (0.6)
RO Membrane Flux	gpd/ft^2	13.0
RO Membrane Array (ea. skid)	-	4:2 x 6 long
RO Recovery	%	80

Case Study: PCWC WTP – Devola, OH

- New wellfield was least expensive, but results not guaranteed and time was not available (F&Os).
- Tie-in to Marietta was more expensive due to rates.
- Anion Exchange for nitrate removal was less expensive upfront than RO.
- Water system chose to construct Reverse Osmosis WTP.

Alternative	Capital Cost	Annual Operating Cost	20-Year Present Worth	Average Monthly Cost Per Home
1A - Purchase 100% of water from Marietta	$834,500	$450,000	$6,300,000	$43.88
1B - Blend with water from Marietta	$1,030,000	$338,000	$5,100,000	$35.52
2A- Purchase 100% of water from Warren Water	$823,000	$280,000	$4,200,000	$29.26
2B - Blend with water from Warren Water	$1,018,000	$251,000	$4,000,000	$27.86
3A - New anion exchange facility	$1,813,000	$210,000	$4,100,000	$28.56
3B - New anion exchange facility with softening	$2,195,000	$237,000	$4,800,000	$33.43
4 - New reverse osmosis facility	$2,044,000	$234,700	$4,600,000	$32.04
5 - New wellfield	$1,731,000	$165,000	$3,500,000	$24.38

Case Study: PCWC WTP – Devola, OH

PCWC – Nitrate Removal - Piloting

- RO Pilot (Started October 2011)
  - 4-element pilot with recycle
  - Operating at 13 GFD and 80% recovery
  - Testing (2) membrane manufacturers to assess nitrate removal:
    - CSM BLN (Nitrate removal too low)
    - Hydranautics ESPA2 LD
  - 2,000 hours of piloting required for EPA approval for nitrate removal

Case Study: PCWC WTP – Devola, OH

Used Spectrophotometer and Lab Data for Nitrate Measurements

Date	Raw Water Nitrate (mg/L)	RO Permeate Nitrate (mg/L)
12/23/11	8.24	0.44
12/30/11	7.65	0.54
1/6/12	8.14	0.61
1/13/12	8.04	0.63
1/20/12	7.80	0.61
1/25/12	7.90	0.62
2/24/12	8.47	0.75
3/9/12	-	0.71

Construction: PCWC WTP

- Plant Start-Up: February 2013
- Immediate Compliance
- Softening Provided for First Time
- Actual Construction Cost: $1.9 Million (under projected budget)
- Plant Constructed Adjacent to Muskingum River – with Finished Floor 10 feet Above Grade (Flood Concerns)

Construction: PCWC WTP

- Construction Features
  - Treatment area and generator 10’ above grade (flood elevation)
  - Connected to existing well and office building

Construction: PCWC WTP

- Construction Features
  - Cascade aerator with discharge to Muskingum River (mussel study)

Any Questions?

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