Chemicals & Oxides

# Rare Earth Technology for Low Phosphorus Removal

Pam Cornish – Business Development Manager

OWEA Technical Conference & Expo – June 2017

# Discussion Outline

- **Rare Earth Technology Introduction**
  - What are rare earths?
  - Rare earths vs. traditional P removal
  - Product Characteristics
- **Performance of Rare Earth Technology in Wastewater Treatment Facilities**
- **Summary of Benefits of Rare Earth Technology**
  - Ability to achieve low P levels
  - Sludge reduction
  - Improved Dewatering, Coagulation
  - Capital Costs Savings

# What are Rare Earths?

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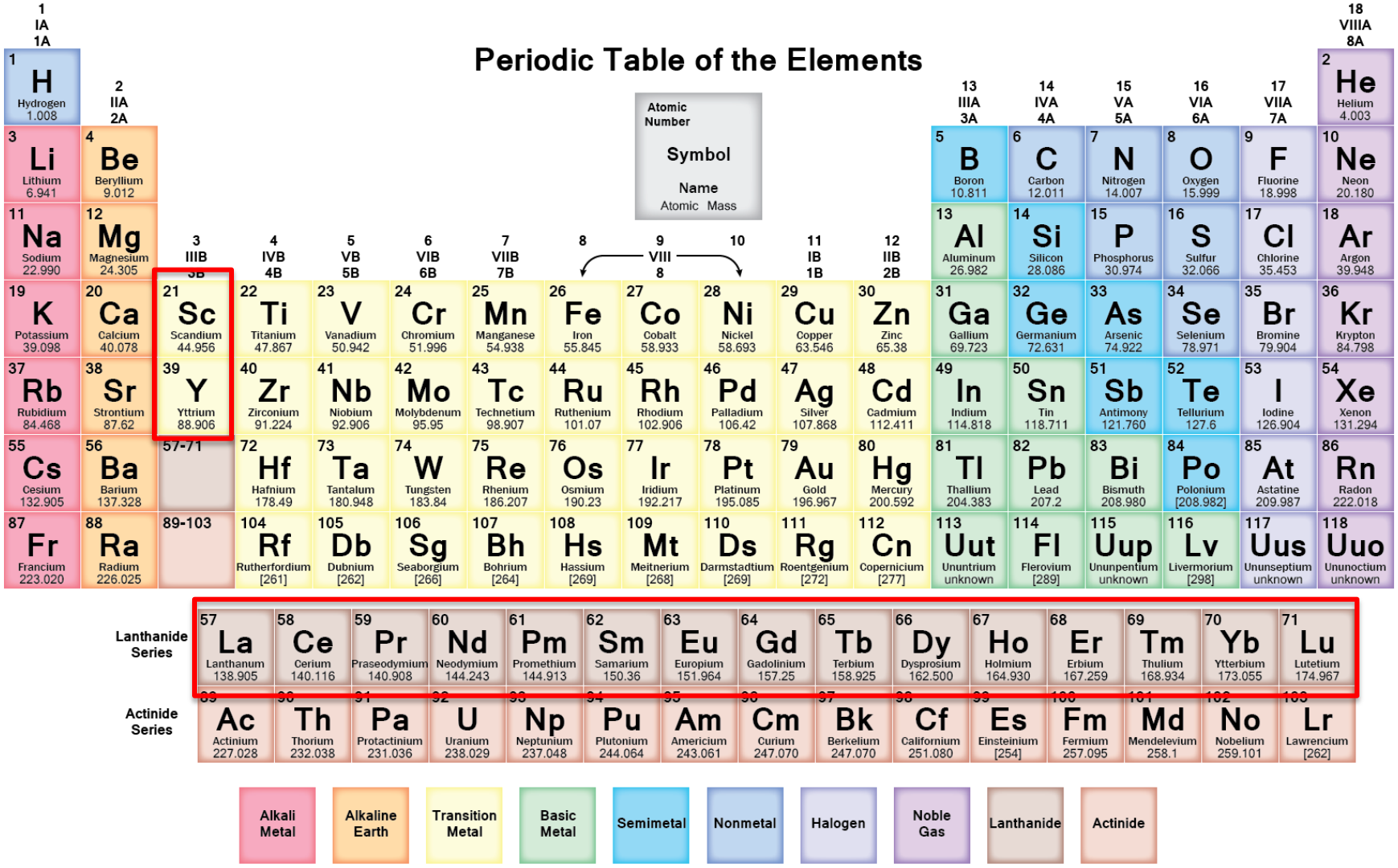

# Rare Earths in Water Treatment Markets

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Recreation Water

Aquarium

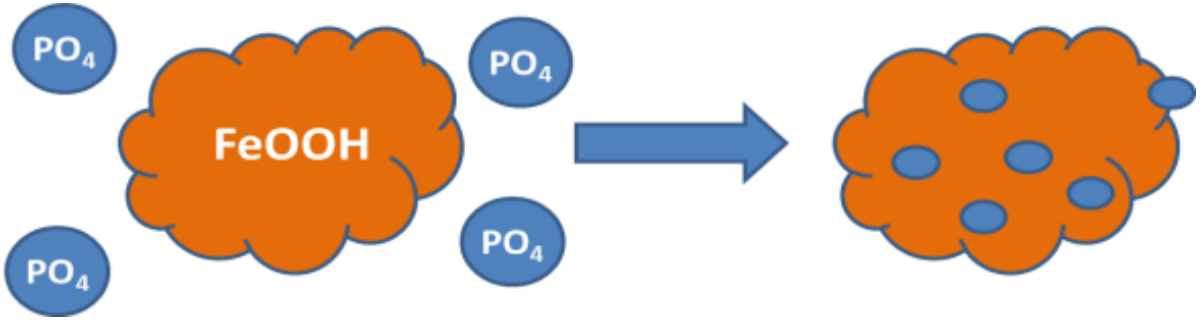
Lake Remediation

**Wastewater**

# Phosphorus Removal Mechanism

- Rare earth elements form strong, crystalline bonds with phosphorus
  - Forms insoluble rhabdophane precipitate


- Iron and aluminum based products form amorphous “cloud” in solution
  - Adsorbs phosphate onto metal hydroxide floc



# Why RE is different than traditional coagulants



- Precipitate is $CePO_4$ / $LaPO_4$ (Rhabdophane)
- Forms ionic bonds
- Preferentially reacts with phosphorus
- Achieves 1:1 molar ratio of La/Ce:$PO_4$ → Reduced chemical sludge

- Forms Fe/AlOOH and Fe/$Al(OH)_3$ intermediates to adsorb P
- Phosphate adsorbs on the surface of the floc (surface chemistry)

# Molar Dose Ratio of Traditional Coagulants

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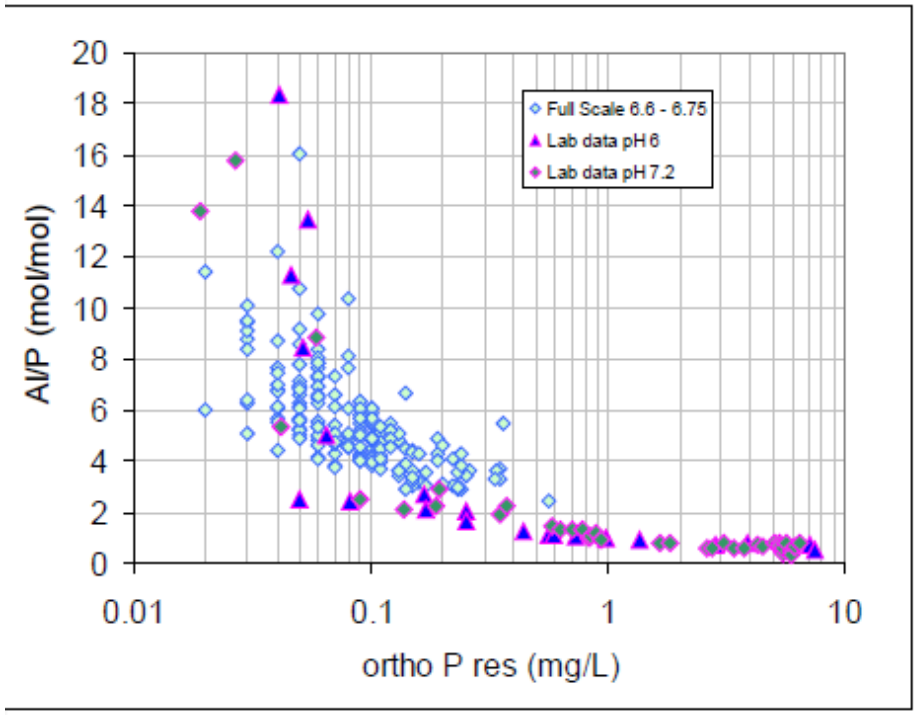
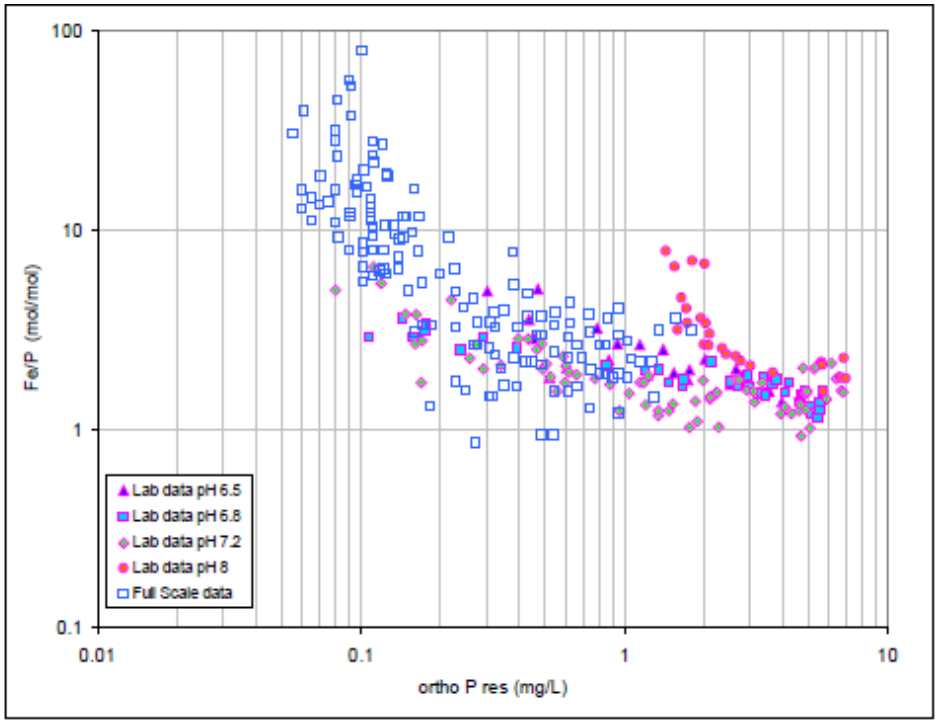
## Aluminum



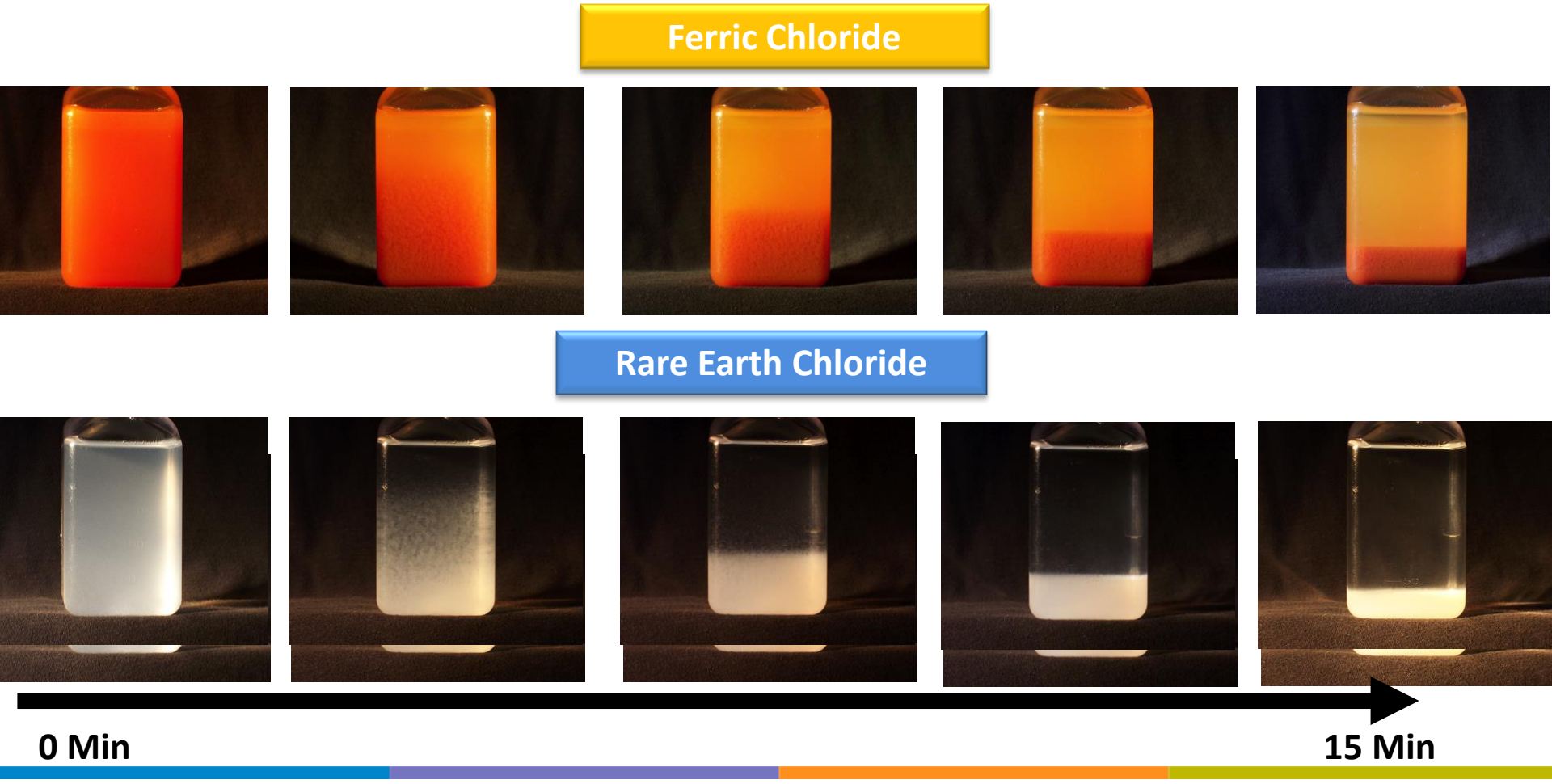

## Iron



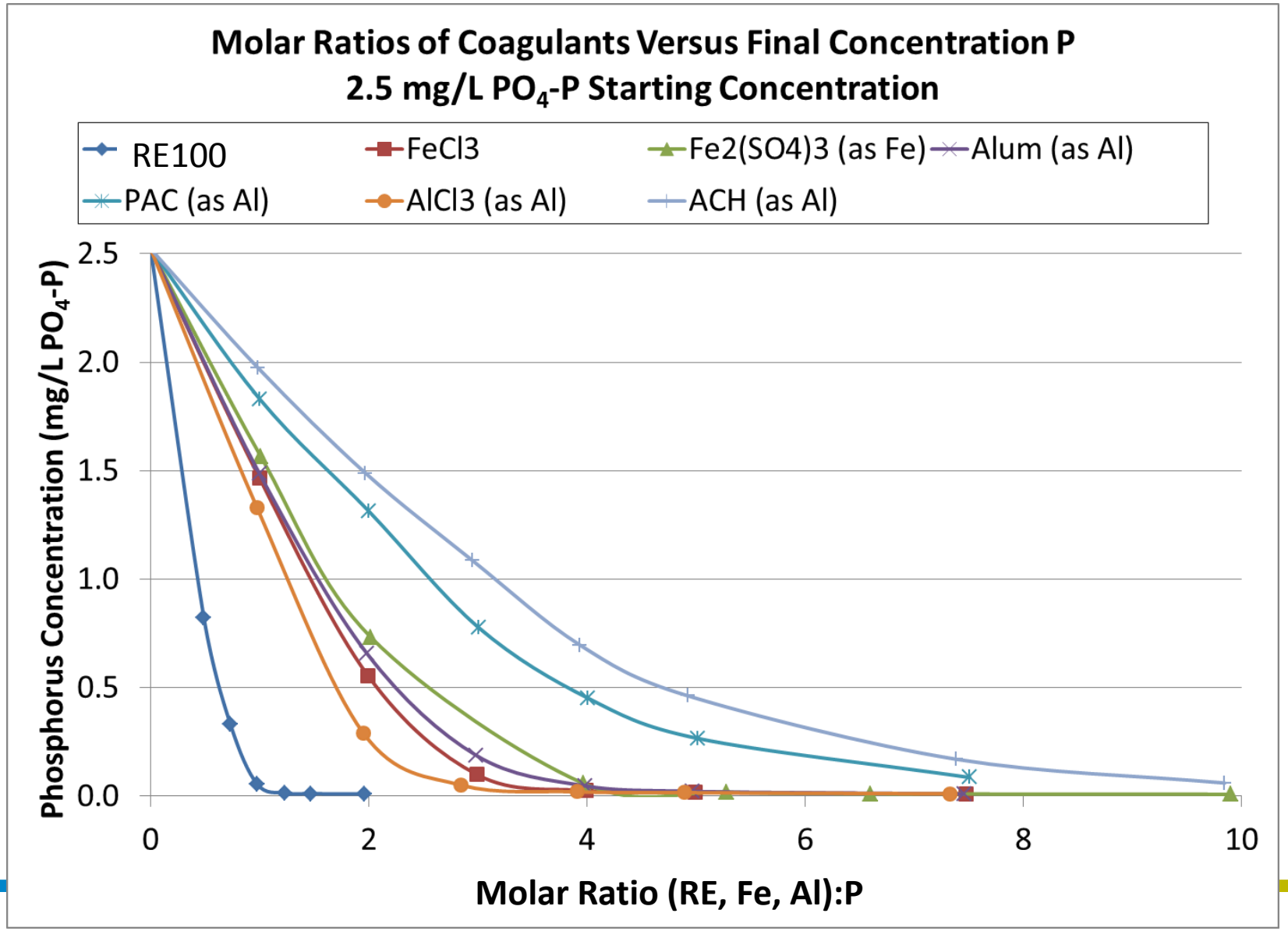

Slav Hermanowicz, Chemical Fundamentals of Phosphorus Precipitation, WERF Boundary Condition Workshop, Washington DC 2006

# Phosphorus Removal Demonstration

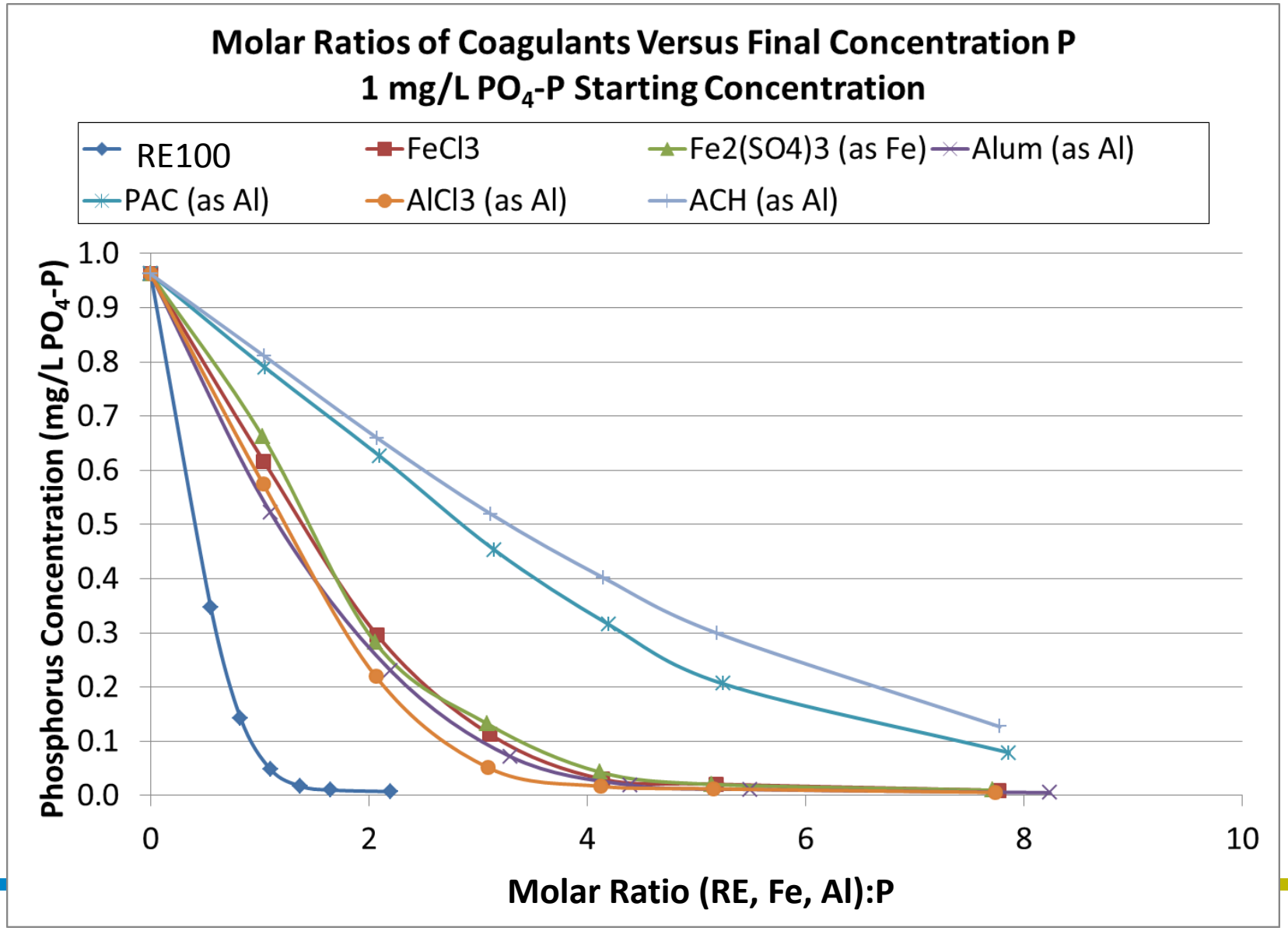
- Rare earth chloride quickly reacts to form a dense precipitate which readily settles out of solution



# Coagulant Comparison – 2.5 mg/L



# Coagulant Comparison – 1 mg/L



# Rare Earth Technology for Wastewater Industry

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- Introduced in 2013
- Has been used in over 50 facilities in over 10 states, including Virginia, Pennsylvania, New York, Vermont, Ohio, Illinois, Wisconsin, Indiana, Texas, Washington
- Proven effective for meeting low phosphorus permit levels
- Additional benefits include sludge reduction & dewatering of biosolids

# Product Characteristics

- Rare earth chloride solution
- Active Ingredient: $CeCl_3$ / $LaCl_3$

| | RE 100 | RE 300 |
|---|---|---|
| % active ingredient (w/w) | 33% | 40.5% |
| Density (lbs/gal) | 11.9 | 13.2 |
| pH | 3 - 4 | |
| Freezing Point | -40°C | |

- Non-hazardous rating


- Compatible with existing equipment
  - 275 gallon totes / 3500 gallon tankers

# Freezing Temp -40°C

- Outside storage @ -30°F in Northeast US during Winter 2015

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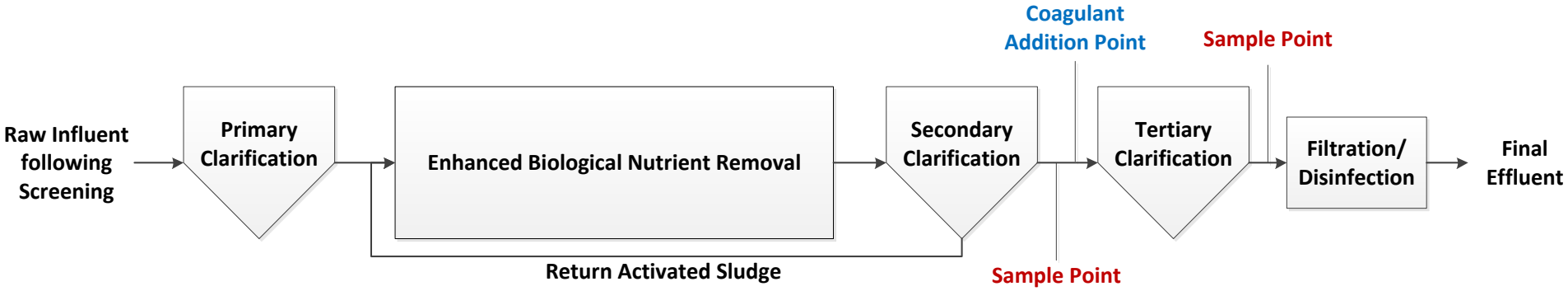
  - Improved Dewatering, Coagulation
  - Capital Costs Savings

# Noman Cole VA WWTF

- 45 MGD municipal WRF located in Chesapeake Bay region
- Total phosphorus limit of 0.18 mg/L P
  - Target of 0.10 mg/L P
- Interested in seeking new coagulant with lower consumption rate, less chemical solids produced, and less staining of UV



# Noman Cole VA WWTF

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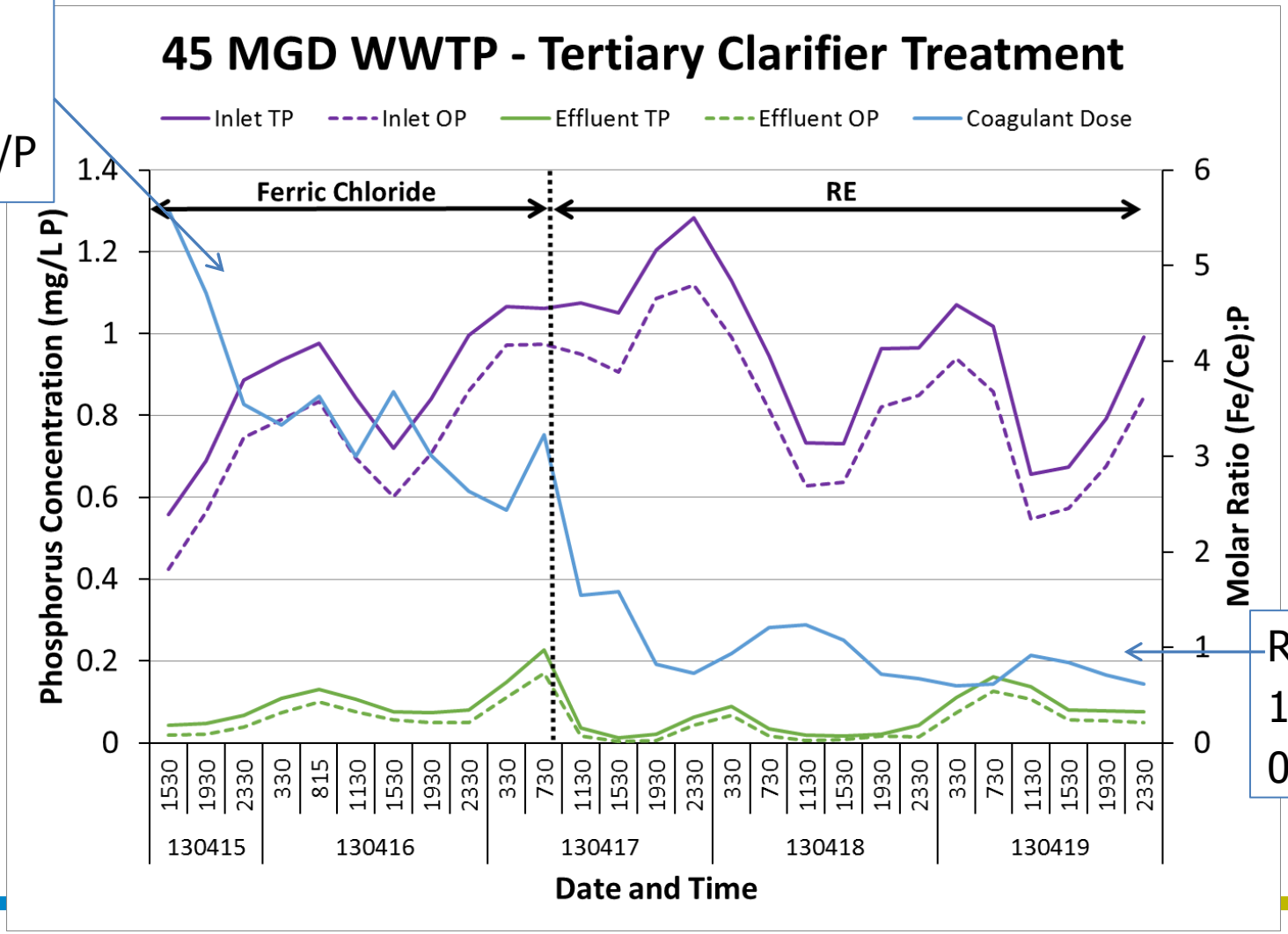
## Rare Earth technology maintained phosphorus below limit with a dosage rate 3x less than $FeCl_3$

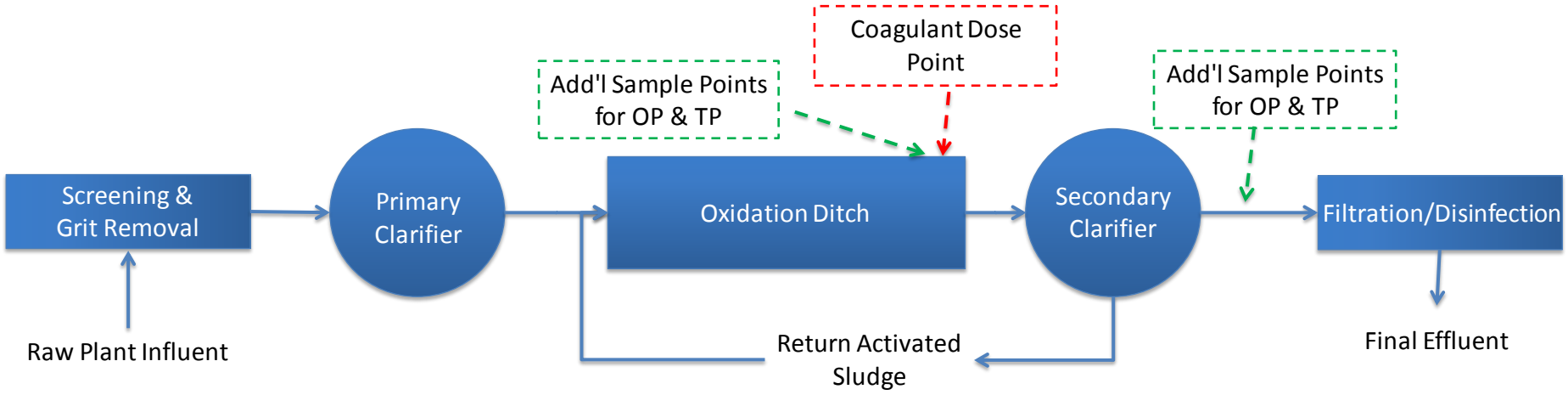
Ferric
34 $ppm_v$
3.5:1 Fe/P



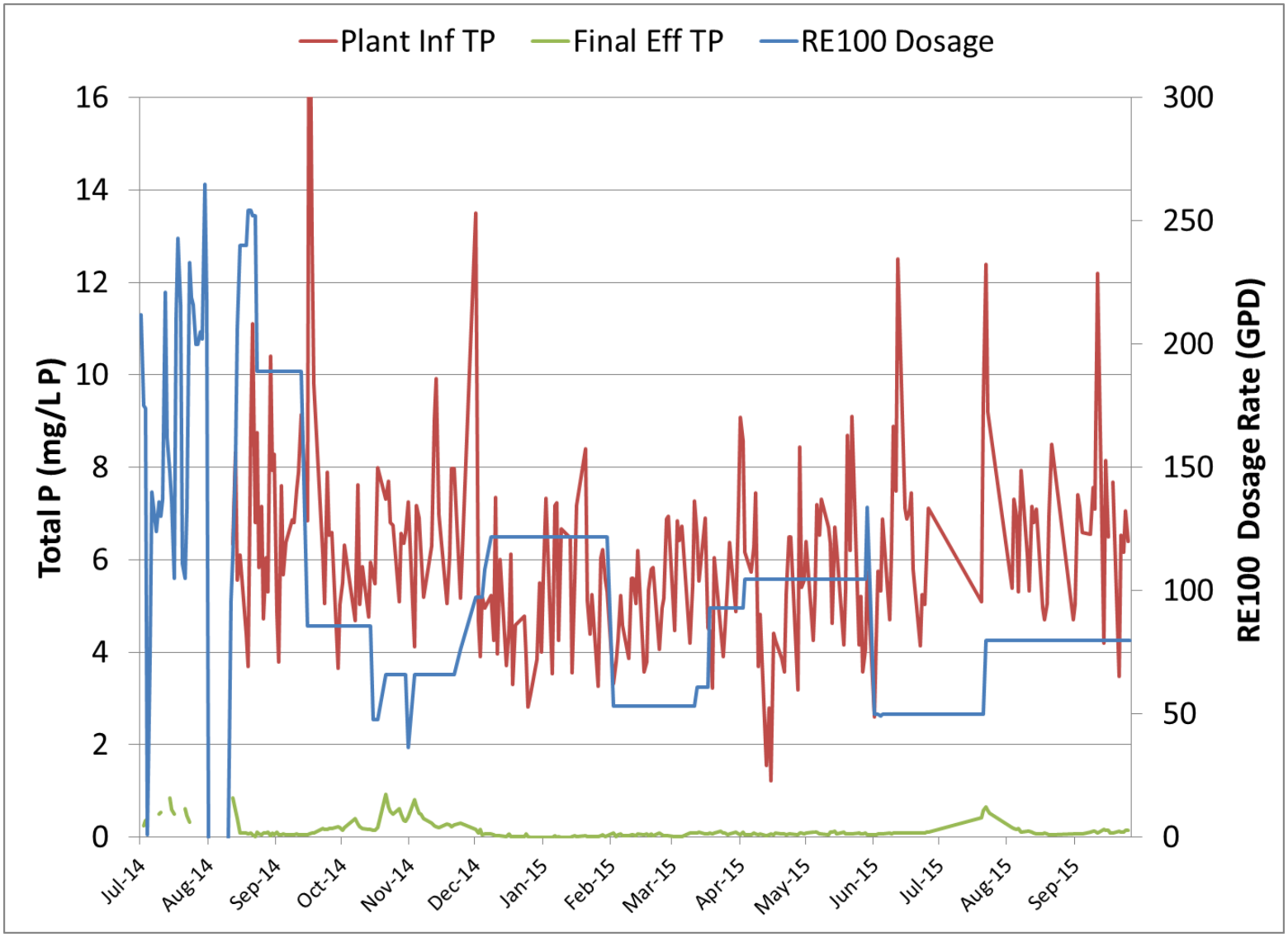

RE Dose
11 $ppm_v$
0.7:1 RE/P

# City of Hartford WI WWTF

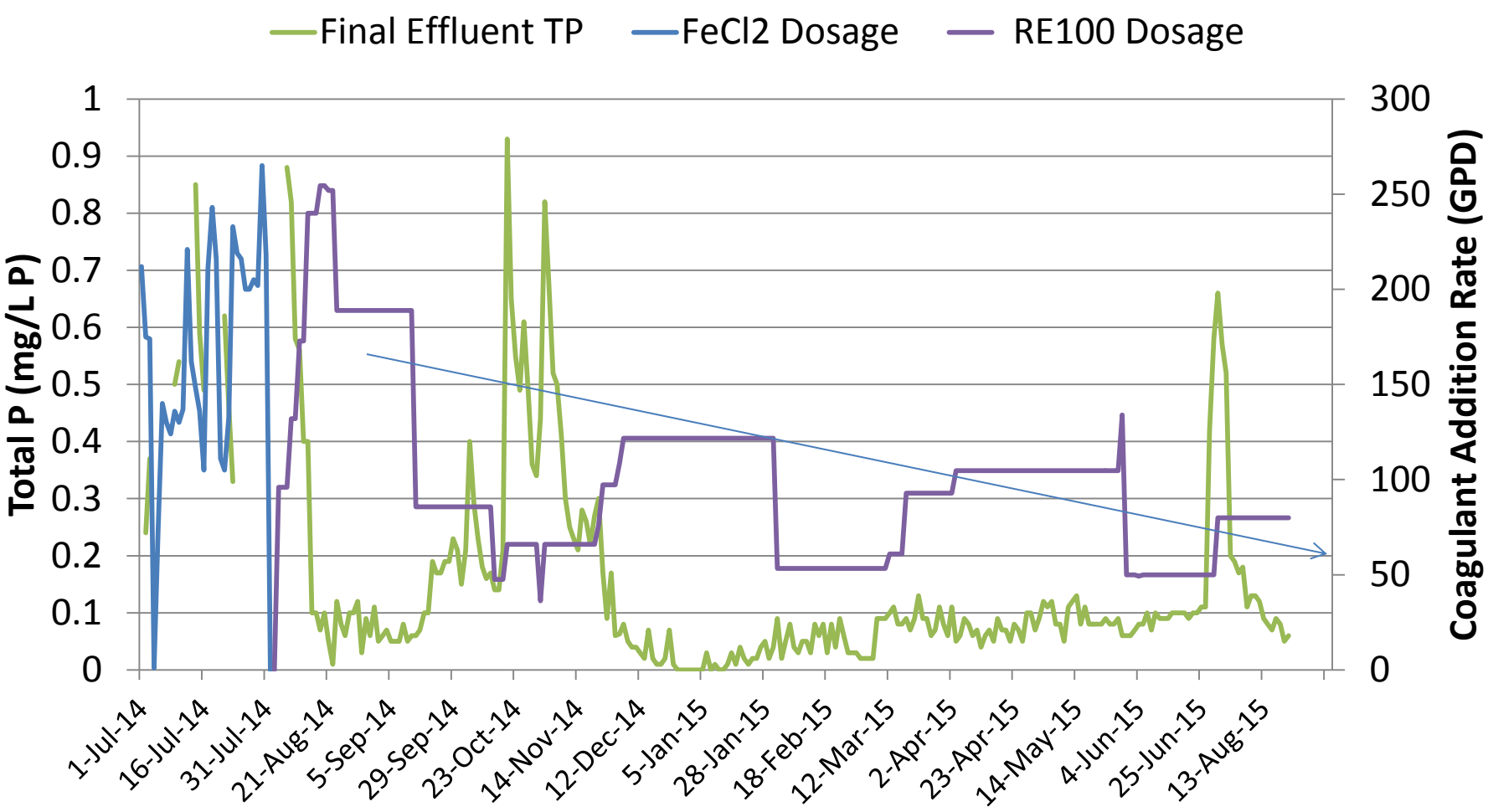
- 3.4 MGD municipal WWTF located in Wisconsin
  - Activated Sludge, Extended Aeration / Tertiary Filtration
- Current limit 1.0 mg/L-P / Upcoming limit of 0.075 mg/L-P
  - Final Compliance Report submitted July 2016
- Previously used ferrous chloride ($FeCl_2$) for chemical P removal
  - 200 GPD achieved ~0.8 mg/L (~ 100 ppmv)
  - Lowest TP level achieved with $FeCl_2$ was 0.3 mg/L



# Hartford achieved < 0.075 mg/L effluent



# Hartford Plant Effluent TP vs. Dose




- RE 100 dose in 2016 was 69 GPD to achieve < 0.075 mg/L-P (36 ppmv)
- → 0.97:1 Molar Ratio (Rare Earth:Phosphorus)

# CSWEA 88th Annual Meeting (May 18-20, 2015)
# Hartford WI Permit Compliance Schedule

## Hartford WPCF Preliminary Facilities Planning

| Process | Equipment Cost |
|---|---|
| Ultrafiltration | $4,567,000 |
| Disk Filtration (cloth) | $974,000 |
| Disk Filtration (membrane) | $1,026,000 |
| Ballasted Sedimentation | $1,153,000 |
| Continuous Backwash Filter | $1,950,000 |
| Rare Earth Product/Biological | $0 |

**Use Anthracite Filters Concrete Superstructure**
**No new Building**

Ruekert · Mielke

# Rare Earth Technology Benefits – Hartford WI WWTP

- Able to reach ultra low phosphorus level without capital costs
- Significant reduction in sludge volume (~ 40%)
  - $FeCl_2$ Sludge Volume = 6 MG/year (dose rate to meet 1 mg/L-P)
  - RE Sludge Volume = 3.7 MG/year (dose rate to meet 0.075 mg/L-P)
- Thicker MLSS concentration

| $FeCl_2$ | RE 100 |
|---|---|
| 1800-2000 mg/L | 2600 – 2800 mg/L |

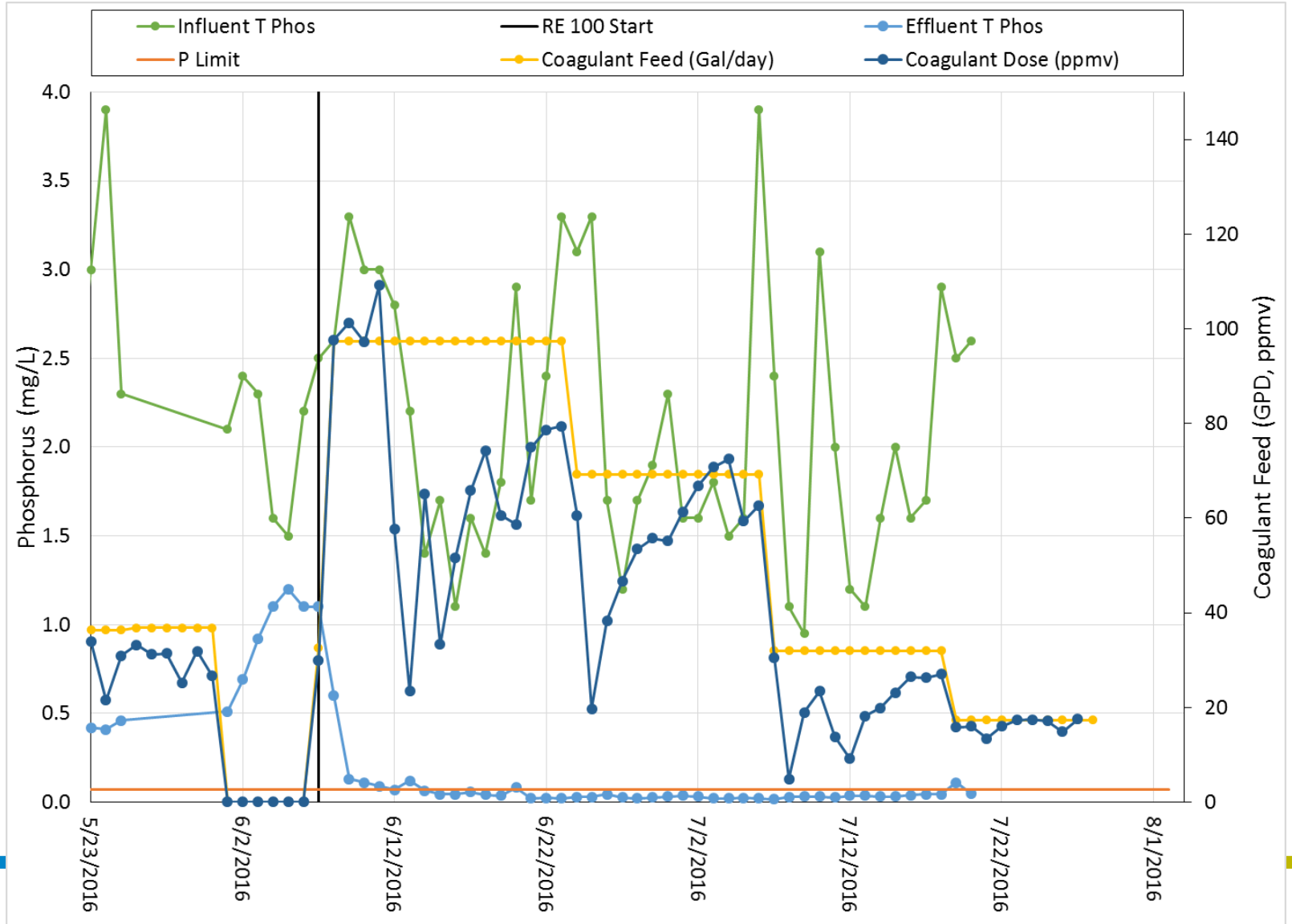
- Lower SVI
- Non-potable water has no smell
- Plant runs more smoothly
  - RE creates a buffer in the process to withstand large spikes in influent P

# City of Virginia MN WWTF

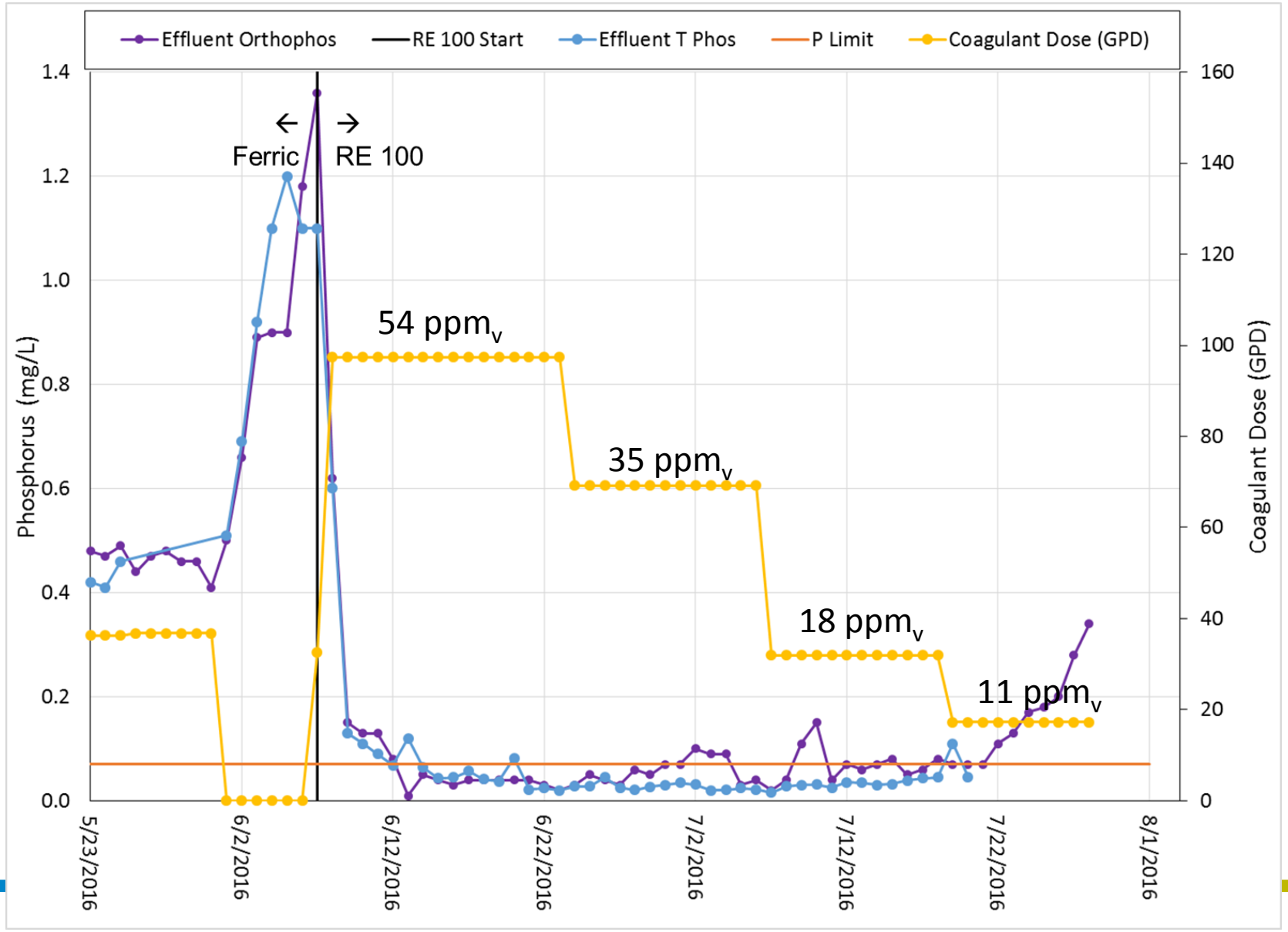
- 2.7 MGD Municipal WWTF located in Minnesota
  - Activated Sludge  Aeration Basins / Secondary Clarification / Filtration
  - Anaerobically digester; belt filter press
- Minnesota Pollution Control Agency (MPCA)
  - Current phosphorus limit of 0.8 mg/L-P (CalMonAvg)
    - 0.5 mg/L 12 month rolling avg
  - New permit of 0.07 mg/L-P (CalMonAvg) – Mar 2023
  - Mgmt Plan with Annual Progress
    - Alternatives Identification Plan (Jan 2017)
- Currently use ferric chloride to meet permit
- Trialed Ferric + PAC in 2015
- Trialed RE 100 in Summer 2016

# City of Virginia MN – RE 100 Trial Results

- Despite Influent P variability, effluent TP remains below 0.07 mg/L

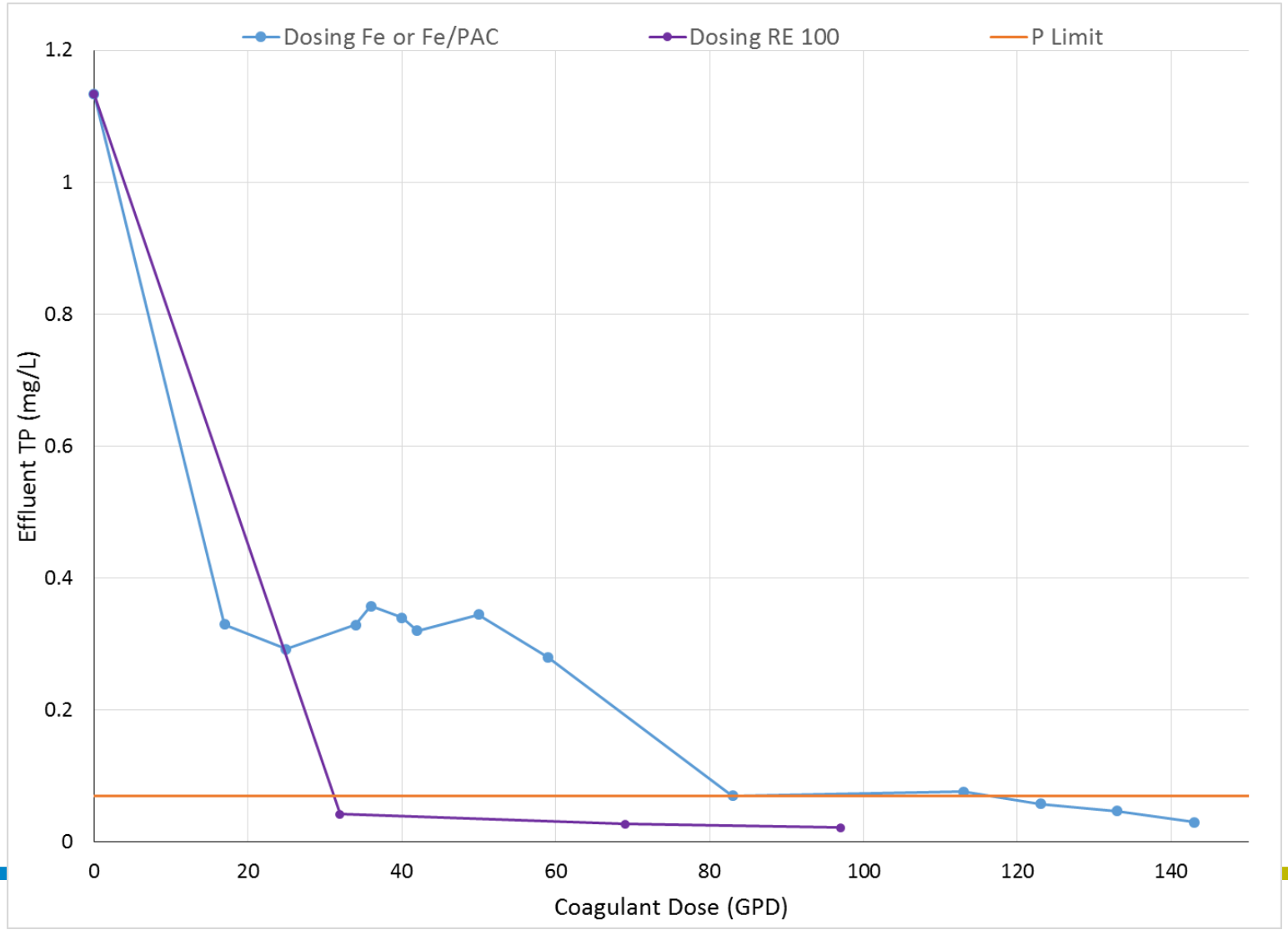


# City of Virginia MN – RE 100 Trial Results



# City of Virginia MN – RE 100 Trial Results

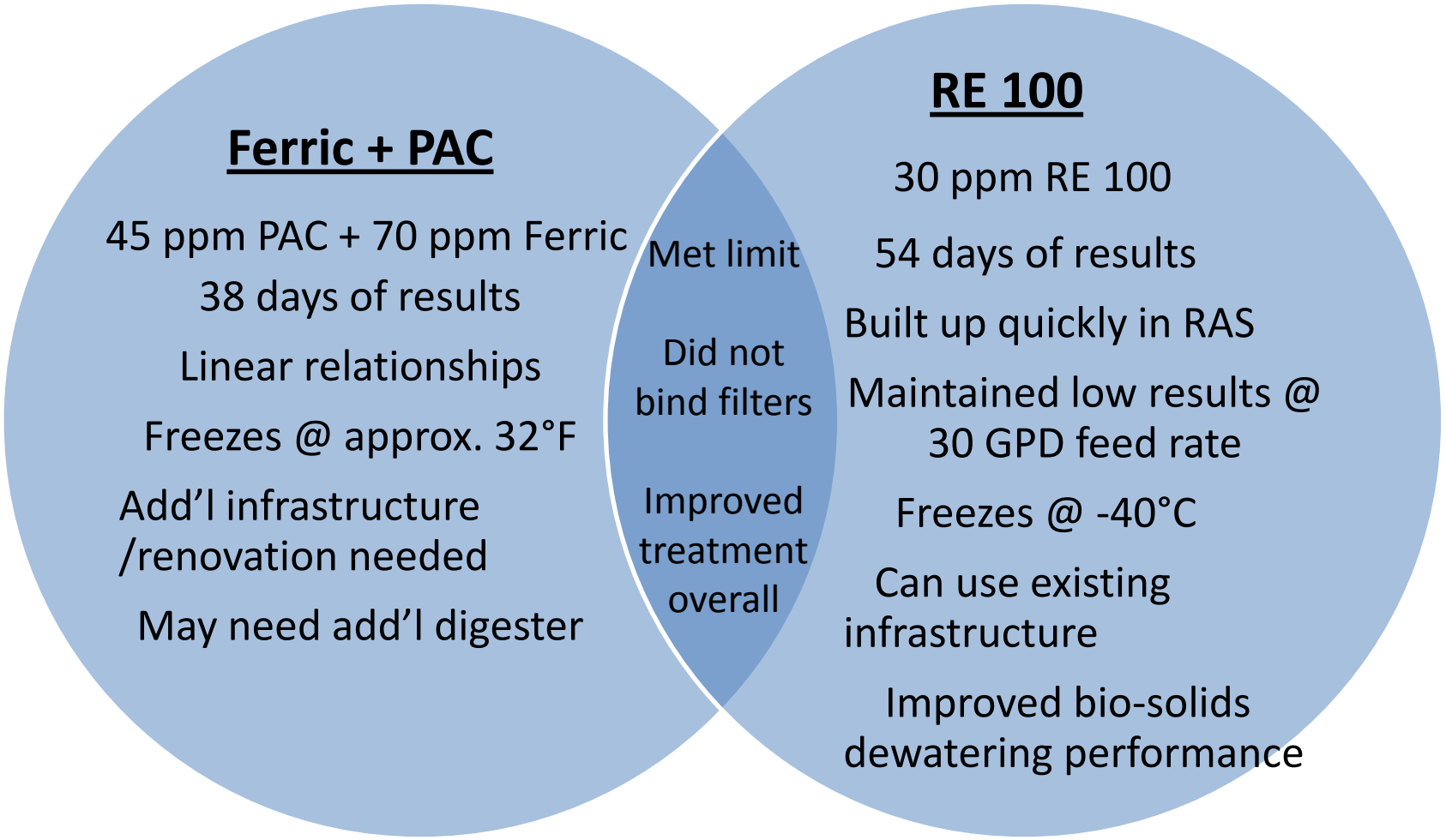
- RE 100 dose of 32 GPD achieved <0.07 mg/L-P



# Virginia MN WWTF - Dewatering Biosolids

- Belt Filter Press results with RE 100
  - ~977 more gallons removed per hour (vs. Ferric)
  - 7,783 more gallons removed per month (vs. Ferric)
  - Ferric + PAC trial – Biosolids production increased by 5000 gpd
- Performance improvement occurred after one month of feeding RE-100. Additional improvement may be evident over longer periods of time.
  - “Perhaps the greatest benefit of RE 100 to biosolids dewatering at the Virginia MN Wastewater Treatment Facility was the avoidance of issues seen with Polyaluminum Chloride during the 2015 Pilot Study that led to over-thickening of biosolids in the anaerobic digester and a dramatic decrease to dewatering efficiency. The fact that RE 100 increased dewatering efficiency at all while achieving effluent total phosphorus results below 0.07 mg/L demonstrates its superiority over other chemicals on the market today.” Brad Bennett, People Services

# City of Virginia, MN WWTF



# RE 100 Benefits – City of Virginia, MN WWTF

- Achieved < 0.07 mg/L-P in final effluent
- Avoidance of capital costs (vs. $FeCl_3$ + PAC)
  - Add'l infrastructure/renovation required for PAC due to freezing point
  - Decreased sludge volumes eliminate need for add'l digester
- Decrease in sludge volume
  - Will better quantify sludge reduction for 2nd trial on-going in 2017
- Improved dewatering of biosolids
- Decrease in chloride levels vs. $FeCl_3$

# Key Benefits of Rare Earth Technology

- ✓ Less coagulant volume required to reach low phosphorus limits
- ✓ Significant reduction in chemical sludge volumes through targeted chemical reaction
- ✓ Improved coagulation – noticable improvement in water clarity
- ✓ Improved dewatering of biosolids
- ✓ Non-hazardous – safer to work with than iron based products
- ✓ Non corrosive – less maintenance costs
- ✓ Eliminates need for settling aids, polymers/flocculants
- ✓ No need for pH adjustment – Low pH of iron and aluminum based products can require addition of pH control chemicals
- ✓ Will not stain or discolor facility structures or equipment
- ✓ Compatible with existing equipment

# Rare Earth Technology Benefits – Fond du Lac WWTP

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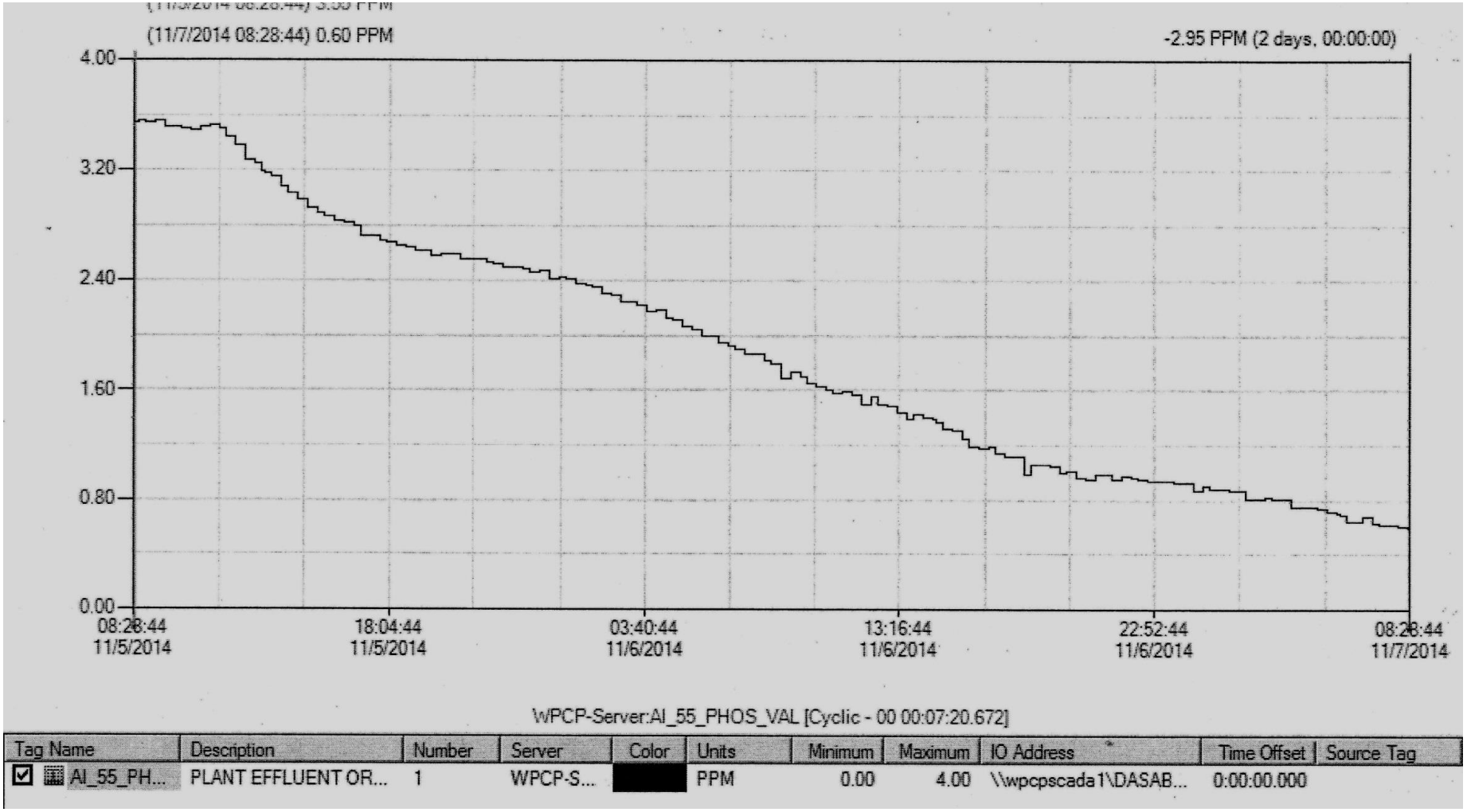
## Fast Coagulation properties




Plant Effluent – from 3.6 mg/L-PO4 to 0.6 mg/L-PO4 in 48 hours

# Rare Earth Technology Benefits

## Fast Coagulation properties

- Mixed Liquor sample - settling

Initial 1 min 2 min 4 min 5 min 10 min

# Fast Coagulation Properties

- Molecular weight of rare earth vs. traditional chemical coagulants is much higher

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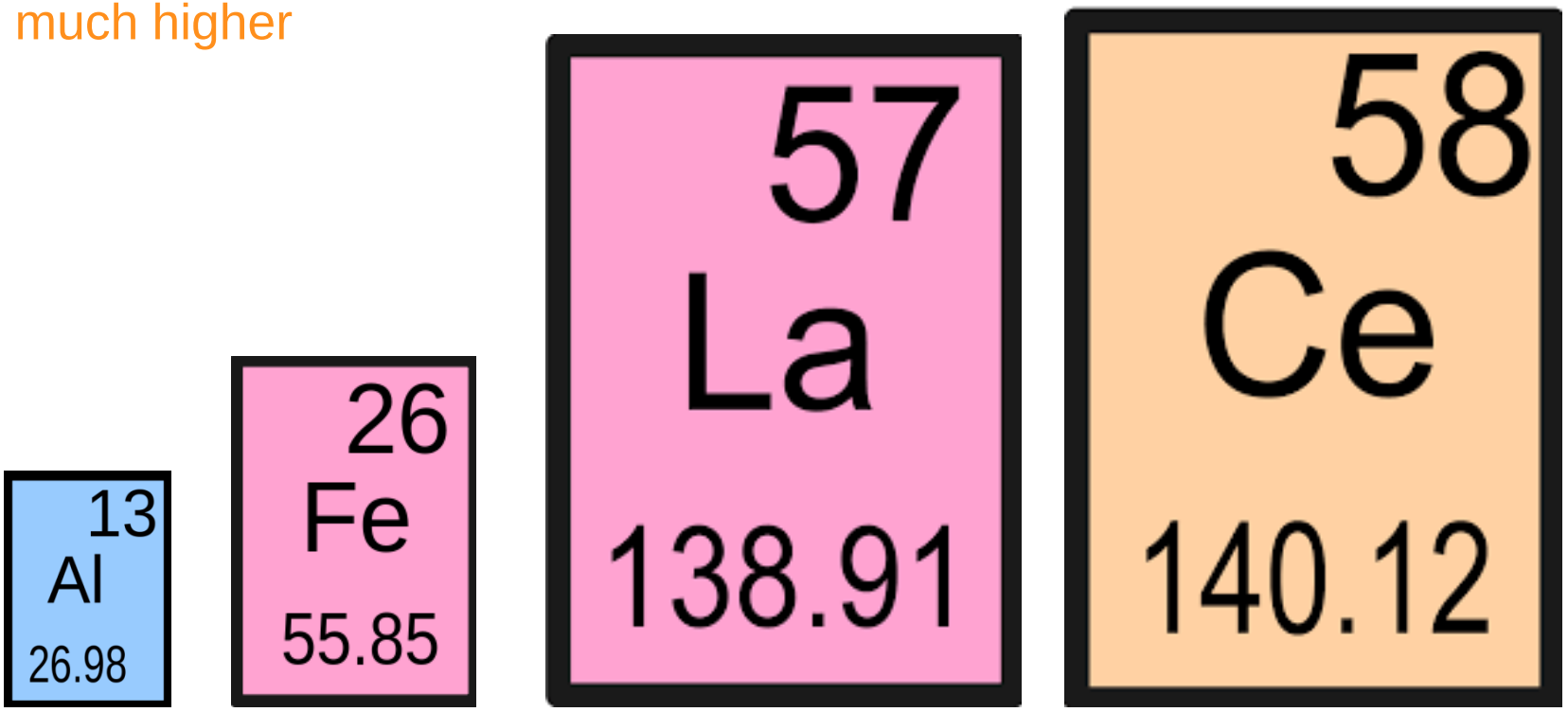



- Forms denser precipitate which settles well in clarifier

# Rare Earth Technology Benefits – Fond du Lac WWTP

- Improved dewatering of biosolids
  - Cake %TS

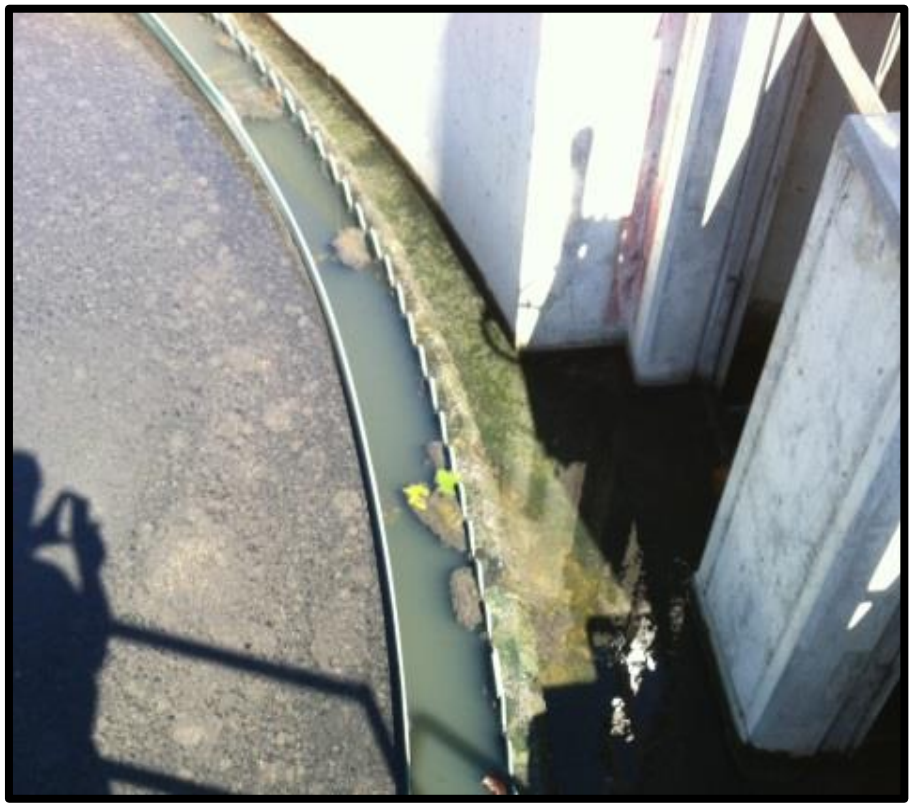
| Before RE 100 | After RE 100 |
|---|---|
| 25 – 26% | 28 – 29% |

- Prevention of struvite formation

- Plant runs more smoothly
  - RE 100 provided a buffer in the process to manage spikes of industrial feed containing high levels of phosphorus

# Rare Earth Technology Benefits – Albion PA

## Improved water clarification



Before RE100 addition

After RE100 addition

# Improved Clarification

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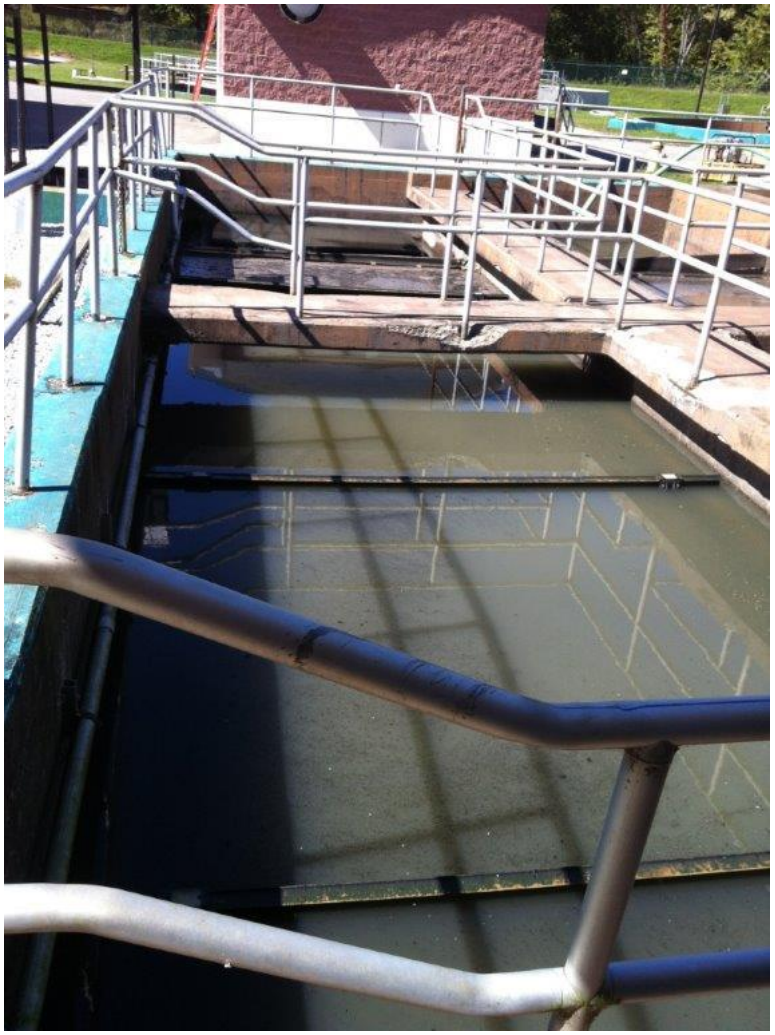
## Before RE 100 addition



## After RE 100 addition

Albion PA“ In 30 years of working here, I have never seen the clarifier look that clear!”

# Improved Dewatering of Biosolids

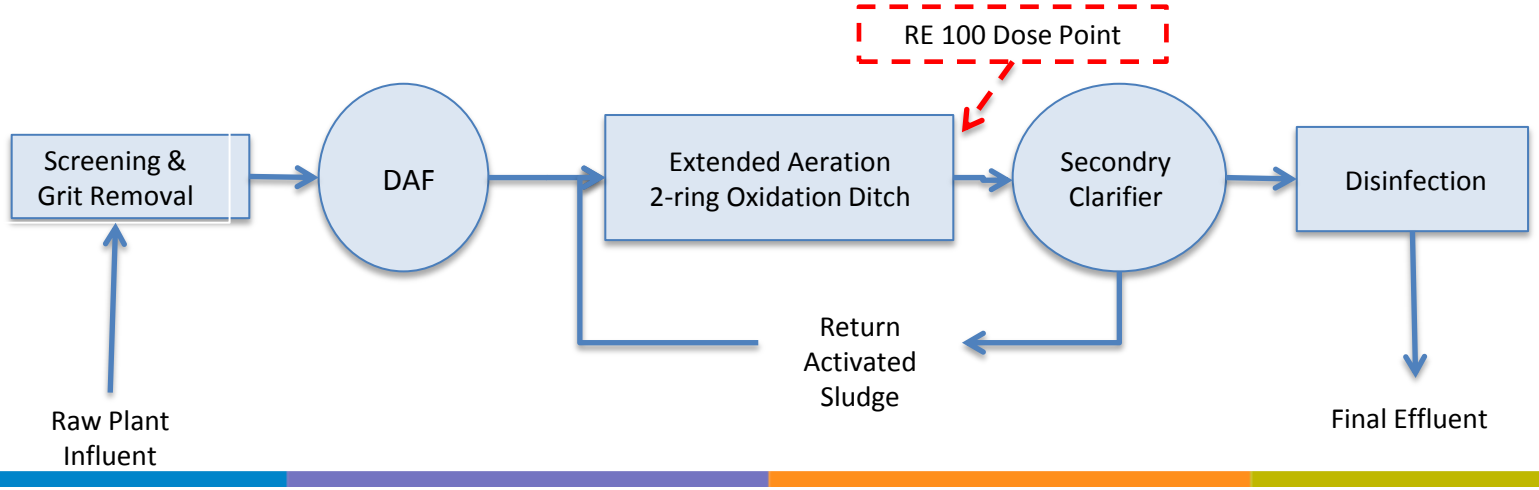

- Albion PA WWTF: “We have doubled our belt filter press throughput, compared to iron and aluminum.”

# Rare Earth Benefits - Borough of Albion, PA WWTF

- Improved coagulation & settling in clarifiers
- Significant decrease in sludge volume
  - 68% savings on the sludge disposal costs/ year
    = $70,000/year annual savings
- Improved performance on belt filter press
  - Prior to RE100, ran belt filter press 5 days/week
  - With RE100, run only 1 day/week
  - → 80% decrease in energy savings (estimated to be $7K/year)
- Less maintenance, more steady overall operations

# Northern Morraine Water Reclamation District, Illinois (NMWRD)

- 2 MGD municipal WWTF located in Illinois (Design Max 5 MGD)
- Effluent discharges to Fox River
  - Illinois Environmental Protection Agency's list of impaired waterways
- No current phosphorus permit & not equipped for chemical dosing
  - New limit of **1.0 mg/L-P**
  - Plans & Specifications due May 2017 / Full compliance May 2019
- Trialed RE 100 in Summer 2015



# RE 100 Dose Rates @ NMWRD

- 9 GPD achieve < 1.0 mg/L-P (8 $ppm_v$)
- 12 GPD achieved < 0.5 mg/L-P (11 $ppm_v$)

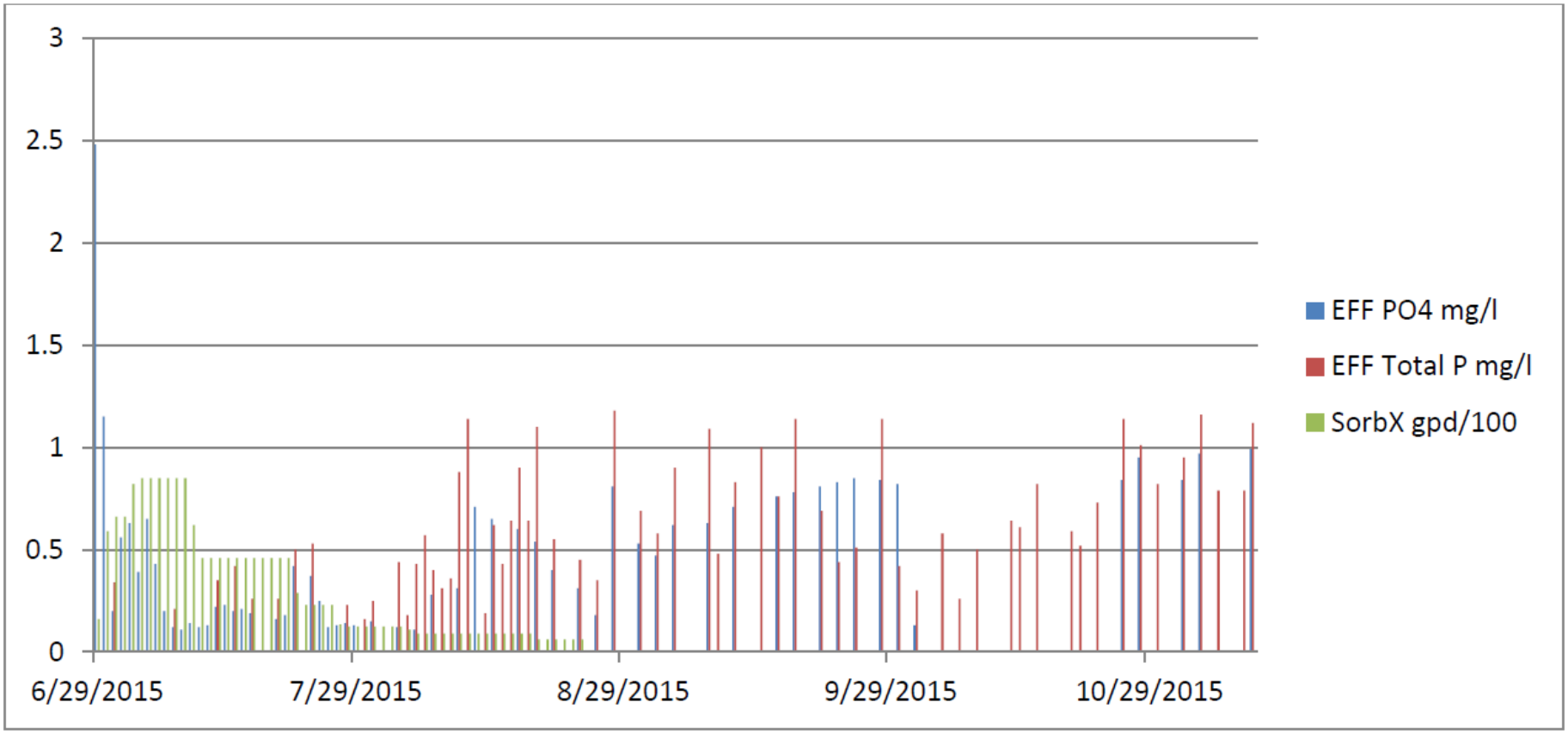



Figure 2. NMWRD Pilot Test Data, SorbX-100 Dosages 6.29.15 to 8.29.15 vs. Effluent P concentrations.

# NMWRD – RE 100 Trial Results

RE100 continued to suppress phosphorus levels for 2+ months after turning off dose

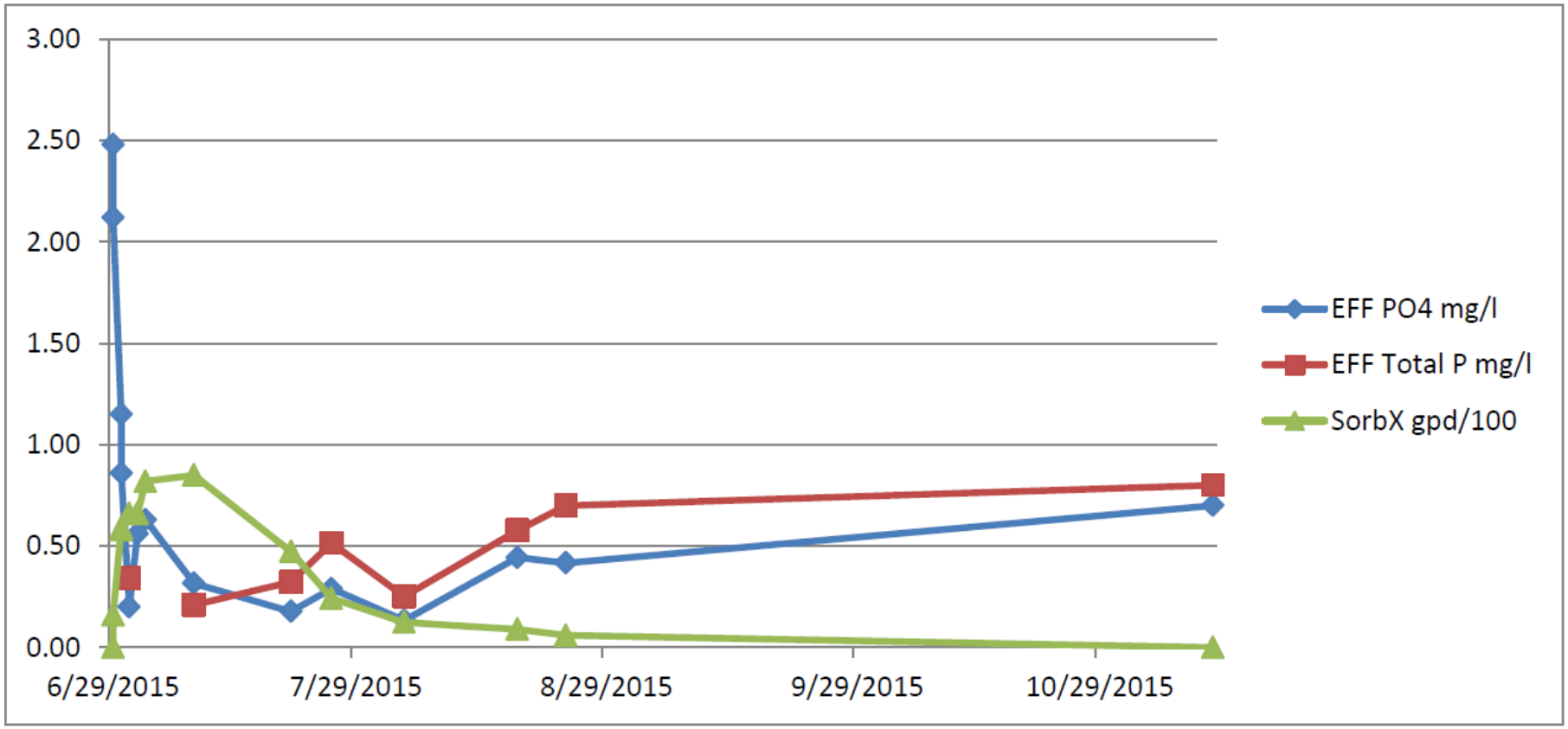



Figure 3. NMWRD Pilot Test Data, SorbX-100 Averages P and PO4 mg/l at each dosing rate.

# NMWRD – RE100 Trial Results

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- Plant Flow = 1.1 MGD
- Influent P = 6.2 mg/L (3.8 – 12.4 mg/L)
  - High P peaks due to side stream impacts from digester decant and dewatering centrifuge concentrations of around 15.7 mg/l TP
- RE100 dose rate
  - 9 GPD achieve < 1.0 mg/L-P (8 $ppm_v$)
  - 12 GPD achieved < 0.5 mg/L-P (11 $ppm_v$)

# Reduction in Capital Costs

Costs for chemical addition facilities needed to meet limits of 0.5 to 1.0 mg/L

| Description | FeCl3* Chemical Feed Building and System | SorbX-100 System |
|---|---|---|
| Construction Subtotal | $358,015 | $100,000 |
| General Conditions | $44,750 | $12,500 |
| Contingency @ 25% | $100,690 | $25,000 |
| Construction total | $503,455 | $137,500 |
| Design Engineering @ 7.5% | $37,760 | $10,312 |
| Construction Engineering @ 7.5% | $37,760 | $10,312 |
| **Total Capital Costs** | **$578,975** | **$158,124** |

* Source: Trotter and Associates 2014 Facility Plan Update

# RE 100 Benefits – NMWRD WWTF

- RE100 quickly achieved target in effluent
- RE100 continued to suppress phosphorus levels for several months after dosing was turned off
- Reduced capital costs to meet 0.5 – 1.0 mg/L-P
  - No need for large chemical storage tanks, buildings and ancillary equipment
  - No need for tertiary filtration
- Preferred a non-hazardous product

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# Plant Trial Recommendations

- Understand phosphorus levels throughout plant
  - TP & OP
- Know the phosphorus speciation in the plant
  - sNRP is important to know if phosphorus permit is < 0.5 mg/L-P
- Minimum trial period is 3 months
  - Unable to quantify overall benefits in less time
- Plant needs the ability to measure phosphorus
  - At a minimum, have ability to measure OP

# Conclusions

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## Observed Benefits of Rare Earth Technology

- ✓ Able to achieve very low TP discharge limits without capital equipment
- ✓ Significant reduction in sludge volumes
- ✓ Faster coagulation and noticeable water clarification
- ✓ Less coagulant volume required to reach low phosphorus limits
- ✓ Reduction in maintenance costs vs. ferric-based coagulants
- ✓ Will not stain or discolor facility structures or equipment
- ✓ Compatible with existing dosing and filtration equipment
- ✓ Rated non-hazardous for DOT regulations

# Questions?


- Pam Cornish
- p.cornish@neomaterials.com
- 734-216-2089