

# Biological Phosphorus Removal Technology

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# Overview

- What is phosphorus and why do we care?
- How can you remove phosphorus?
- Biological phosphorus removal
- Biological phosphorus removal facilities
  - Tomah, WI
  - Dane-Iowa, WI
  - Cross Plains, WI
  - Reedsburg, WI
  - Rhinelander, WI

# Phosphorus



# Phosphorus Regulation

- Technology based effluent limits
  - Typical = 1.0 mg/L
  - Alternative phosphorus limits (APL)
    - Biological – maximum 2.0 mg/L
    - Economics - variance
- Water quality based effluent limits
  - Based upon target concentration in receiving water
  - Total Maximum Daily Load (TMDL)
  - Can be as low as 0.100 - 0.075 mg/L for streams and 0.040 – 0.015 mg/L for lakes

# Chemical Phosphorus Removal

- Coagulant
  - Alum
  - Ferric Chloride
  - Ferric Sulfate
  - Poly aluminum chloride (PAC)
- Advantages
  - Simple
  - Lower capital cost (sometimes)
- Disadvantages
  - Sludge production
  - Operational costs
  - Chemical handling
  - Consumes alkalinity

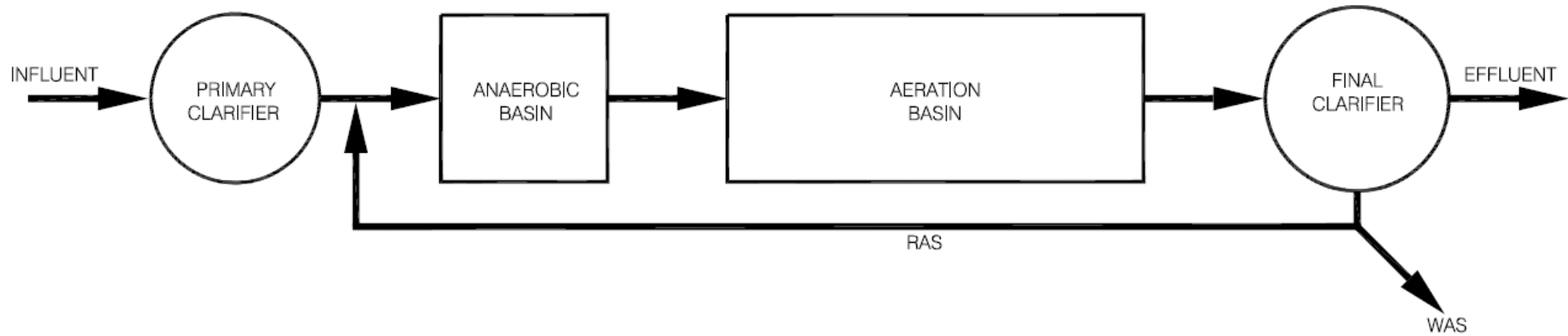
# Biological Phosphorus Removal (BPR)

- Create an environment to select for organisms that will store phosphorus
- Requirements
  - Readily biodegradable BOD in the form of volatile fatty acids
  - Phosphorus
  - Cycling between anaerobic and aerobic environments
- Advantages
  - Low operational costs
  - Improved treatment performance
- Disadvantages
  - Capital cost
  - More complicated treatment

# BPR Microbiology

- Phosphorus accumulating organisms (PAOs)
  - Store excess phosphorus inside cells
  - Release phosphorus for energy in anaerobic environment
  - Take in phosphorus in aerobic environment
- Identifying PAOs and biological phosphorus removal
  - Anaerobic batch testing
  - Staining techniques
  - DAPI
  - Florescence In-Situ Hybridization (FISH)
  - DNA sequencing

# Typical Biological Removal Configuration



# Influent Considerations

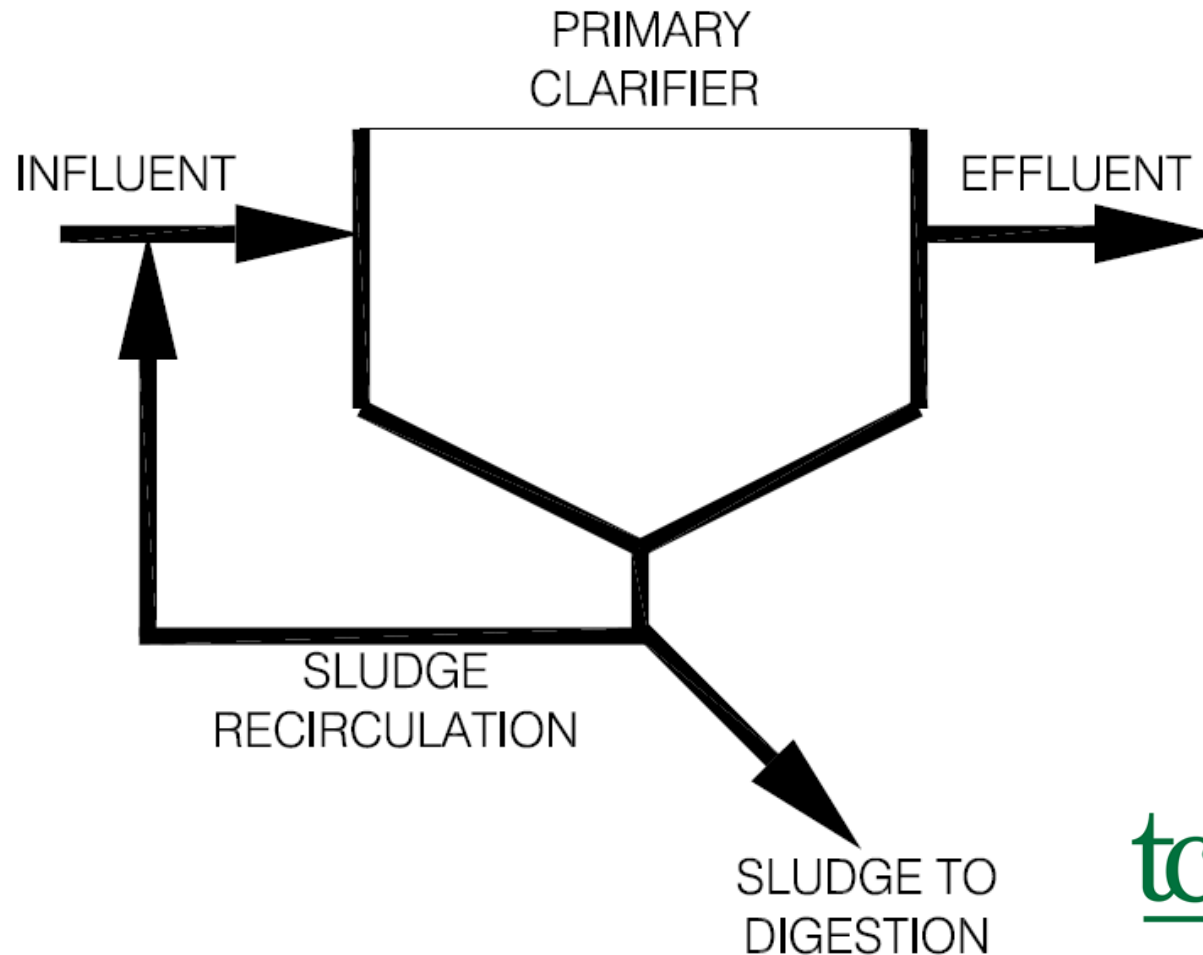
- BOD and phosphorus required for biological phosphorus removal to work
- BOD should be in readily biodegradable form
- Nitrate inhibits biological phosphorus removal
  - High influent ammonia will be converted to nitrate if nitrification occurs
- Frequency and quantity of inflow and infiltration (I&I)

# Primary Clarifier

- Removal of non-biodegradable or difficult to degrade components
- Use as **ACTIVATED** primary for production of VFA's
  - Hold sludge blanket
  - Recirculate sludge - elutriation



# Activated Primary Clarifier

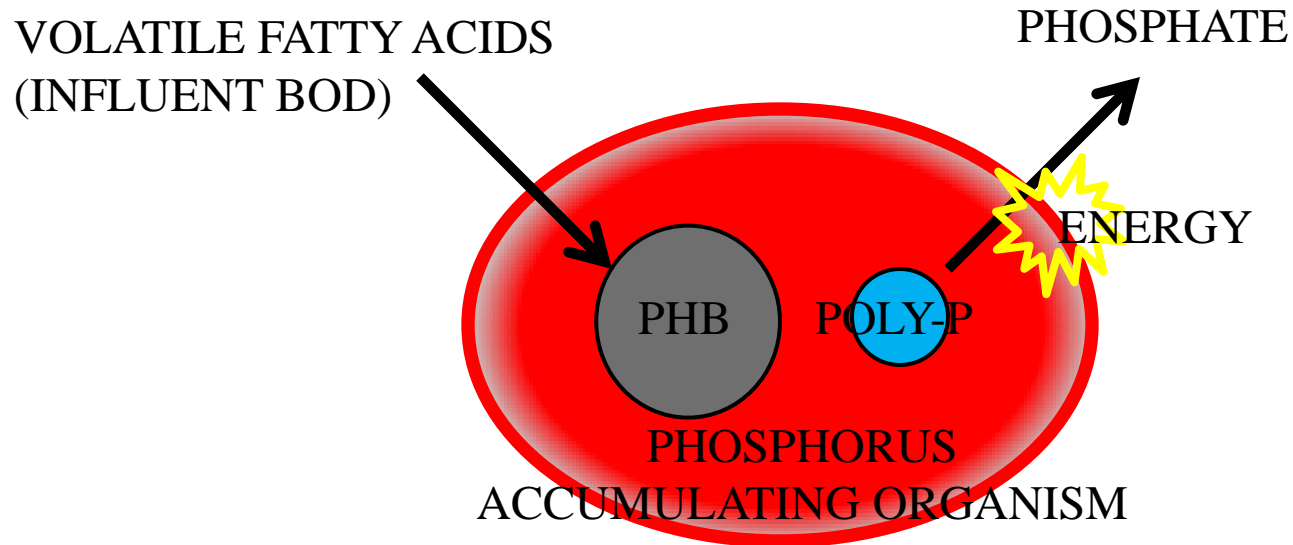


# Selector Basins

- Anaerobic environment
- VFA's formed through fermentation
- Organisms take in VFA's and store VFA's as PHB
- Phosphorus released to give PAO energy



# Anaerobic Environment

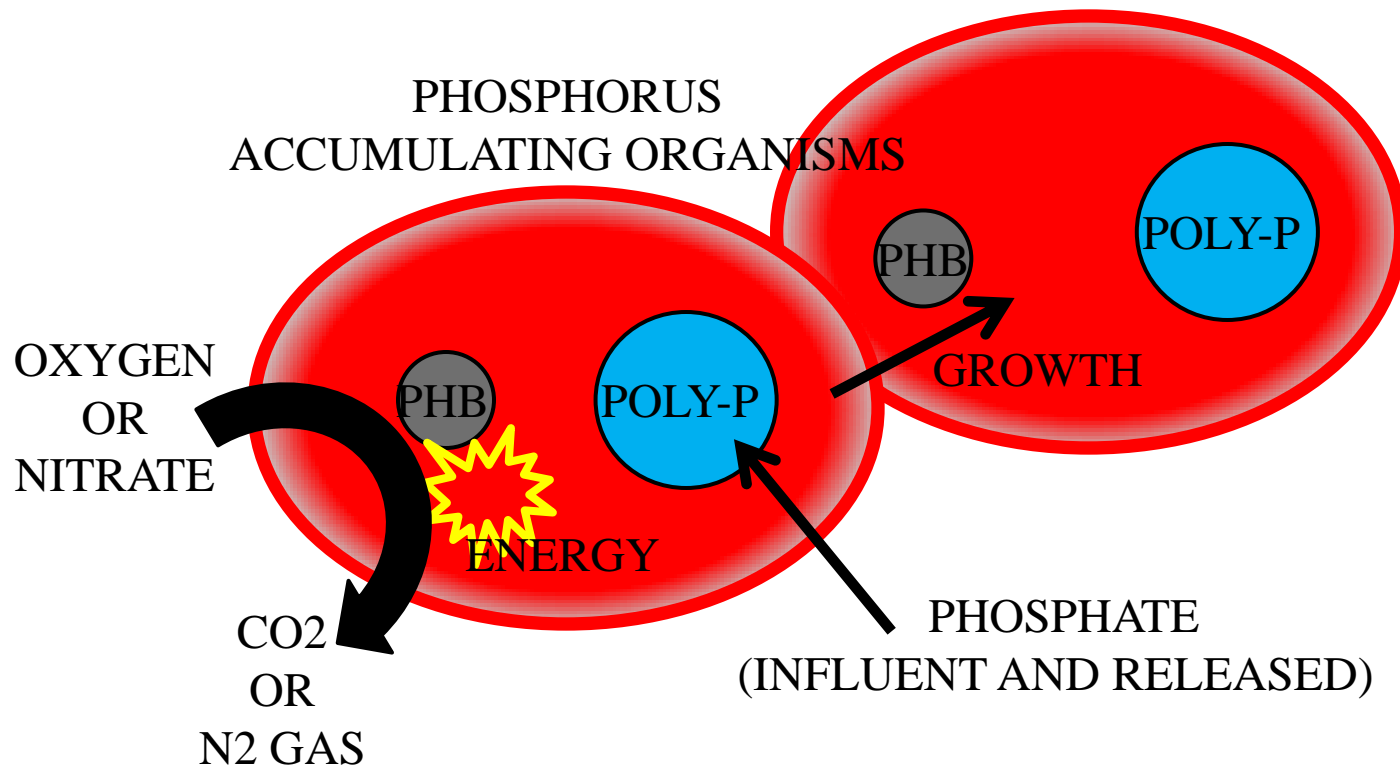


# Aeration Basins

- Stored PHB is consumed (BOD)
- Influent and released phosphorus is taken up to provide energy for future reactions
- Micro organisms grow and reproduce
- Higher phosphorus content in cells (>4% vs. 1% - 2%)



# Aerobic Environment



# Final Clarifiers, RAS, and WAS

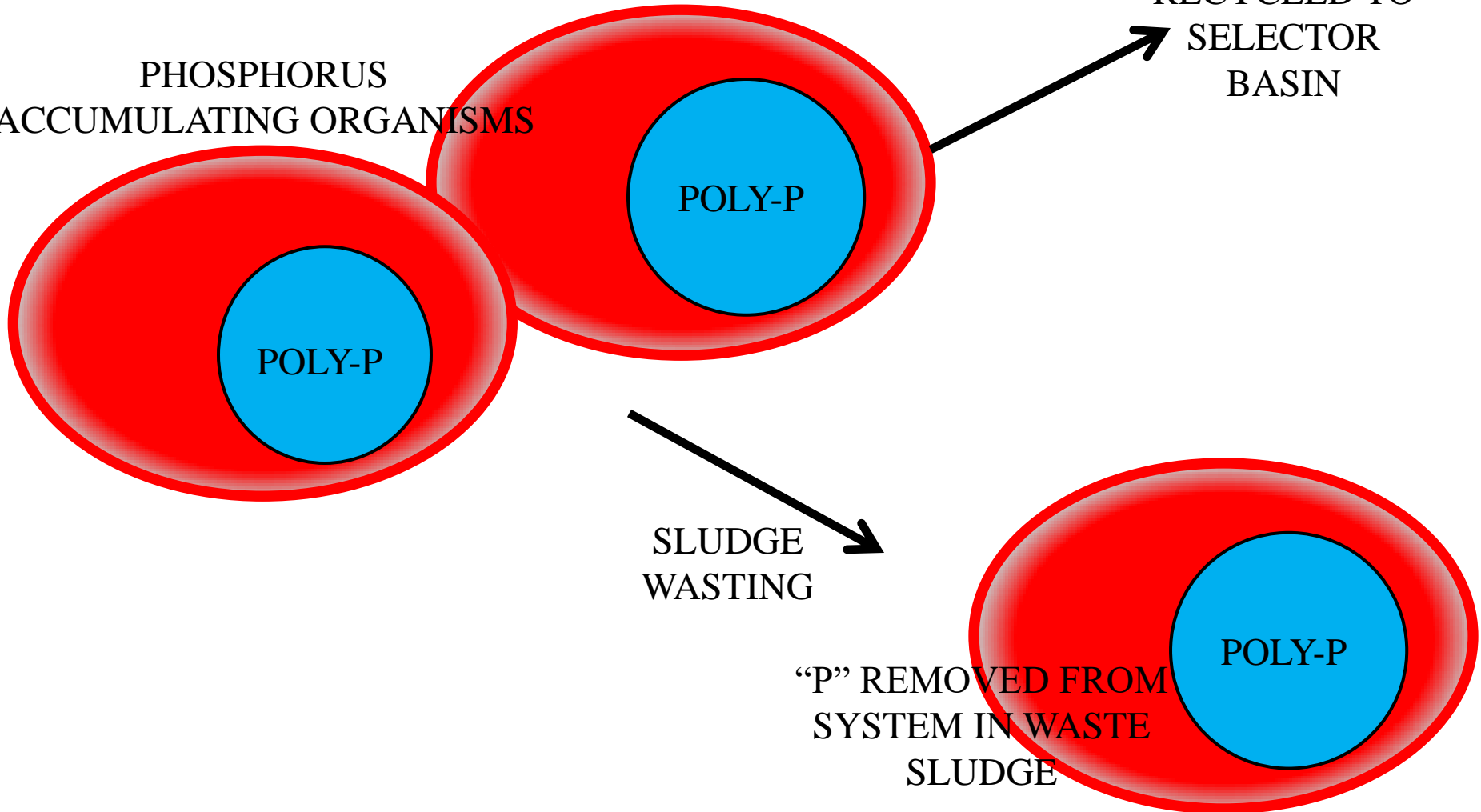
- Phosphorus laden organisms settle
- Rapid sludge removal (avoid secondary release)
- Sludge wasting removes organisms and phosphorus from system



# Waste Activated Sludge

ORGANISMS  
RECYCLED TO  
SELECTOR  
BASIN

PHOSPHORUS  
ACCUMULATING  
ORGANISMS



SLUDGE  
WASTING

“P” REMOVED FROM  
SYSTEM IN WASTE  
SLUDGE

# Special Considerations for BPR

- Secondary release – selector basins and clarifiers
- Nitrates – RAS
- Recycle streams – especially with anaerobic digestion
- ORP and DO control

# Tomah, WI WWTP

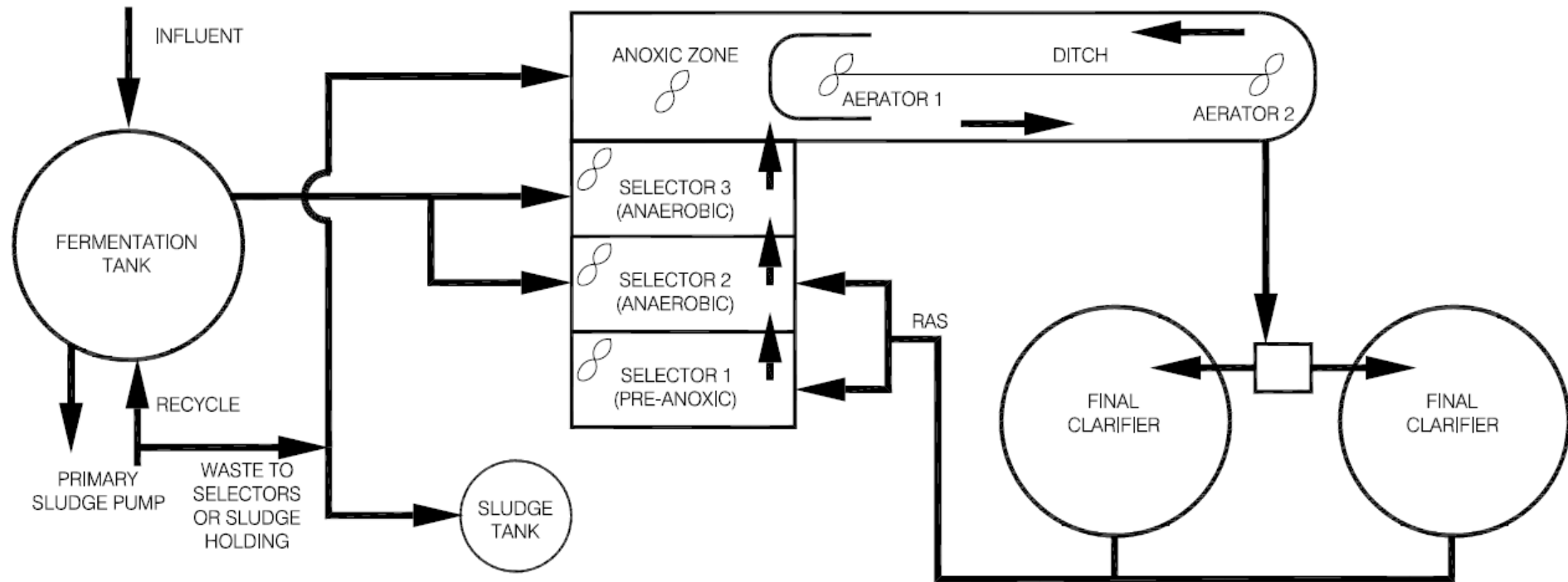
- Design Conditions

▫ Design Flow	2.3 MGD
▫ Peak Hourly Flow	8.0 MGD
▫ BOD	4,500 lbs/day
▫ TSS	4,750 lbs/day
▫ TKN	540 lbs/day
▫ Phosphorus	190 lbs/day

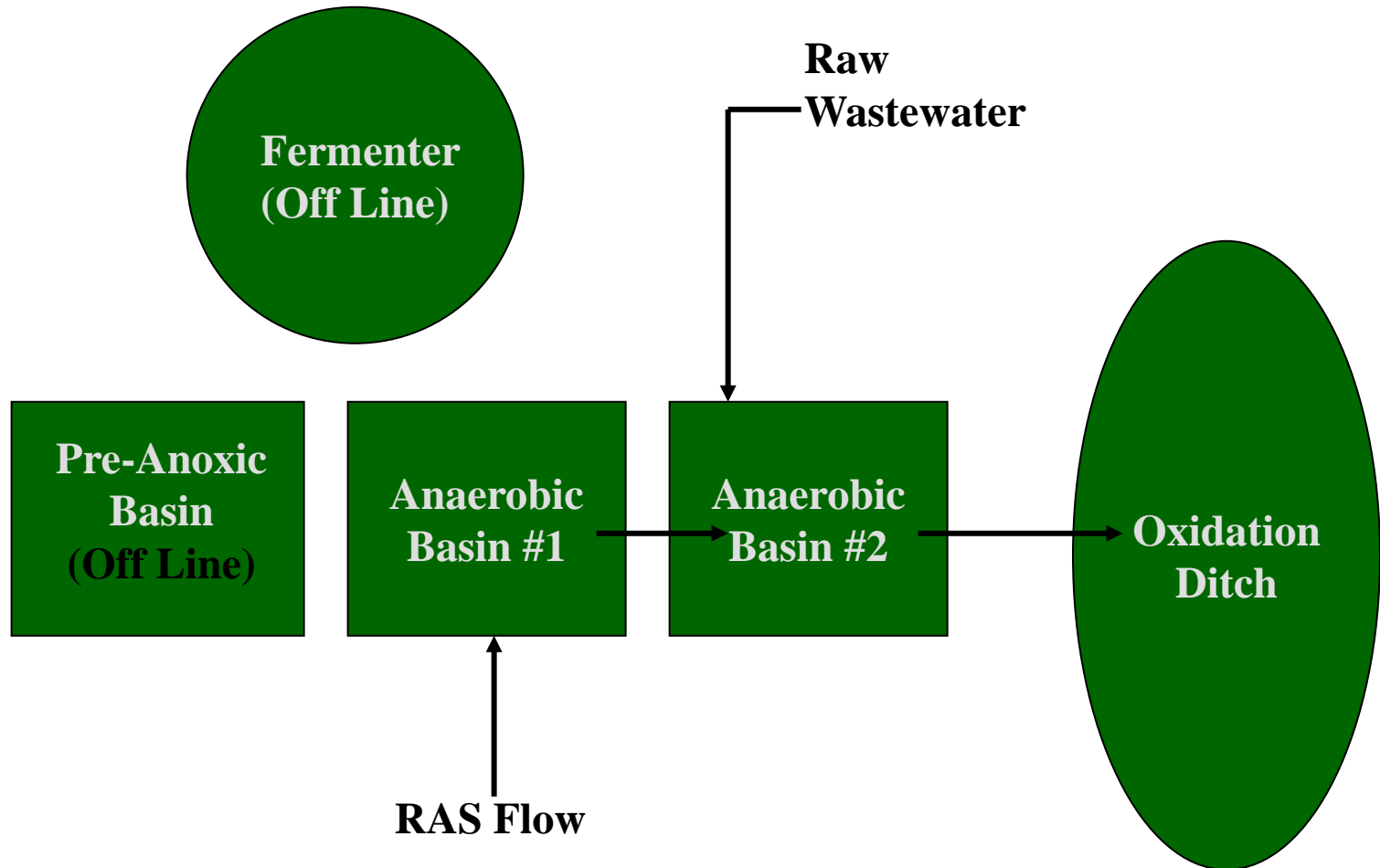
- Unique features

- High influent phosphorus load – Concentration 10 mg/l to 20 mg/l
- Difficult chemical treatment

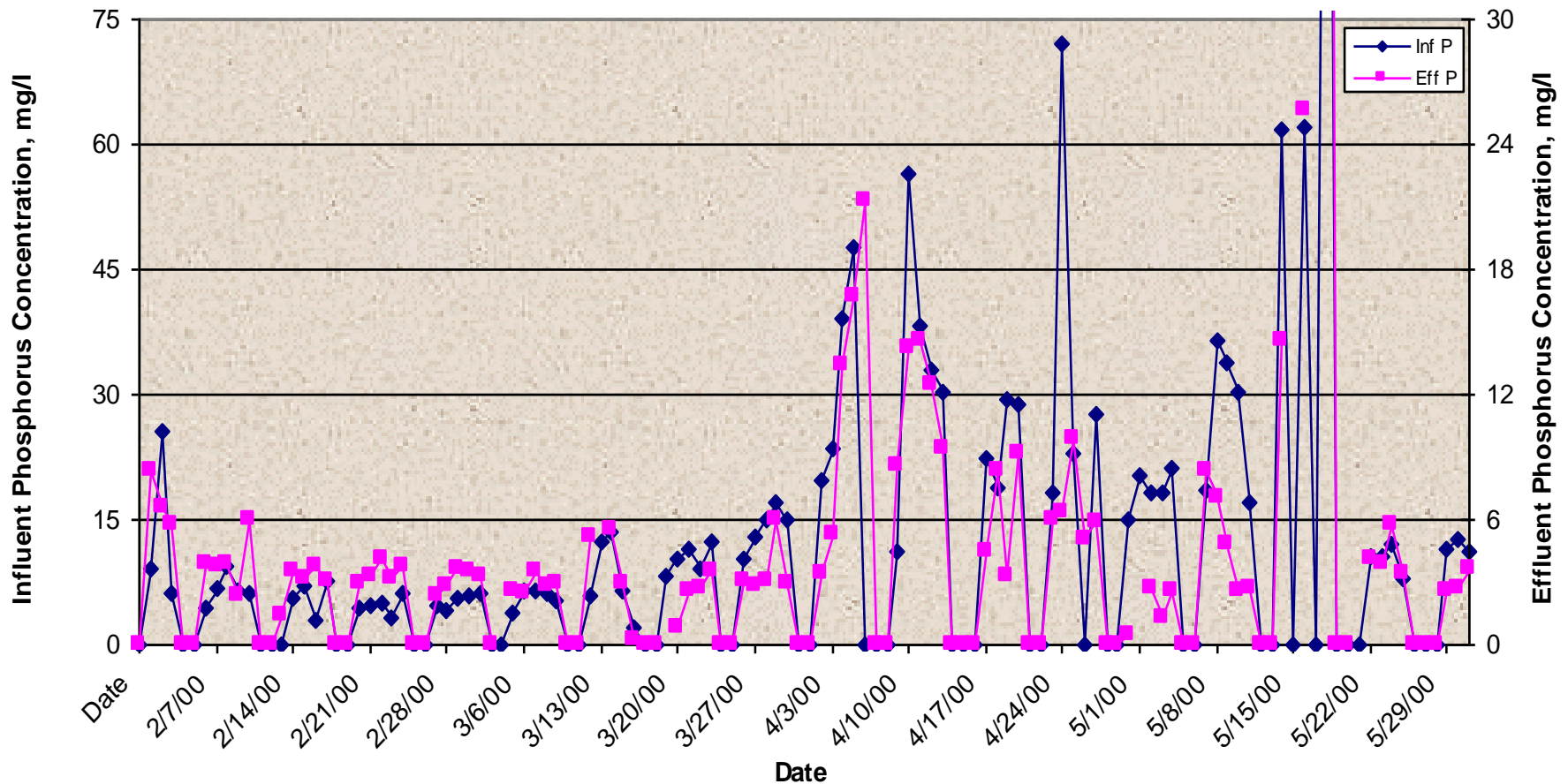
# Tomah, WI WWTP



# Tomah Start-Up (February – May, 2000)

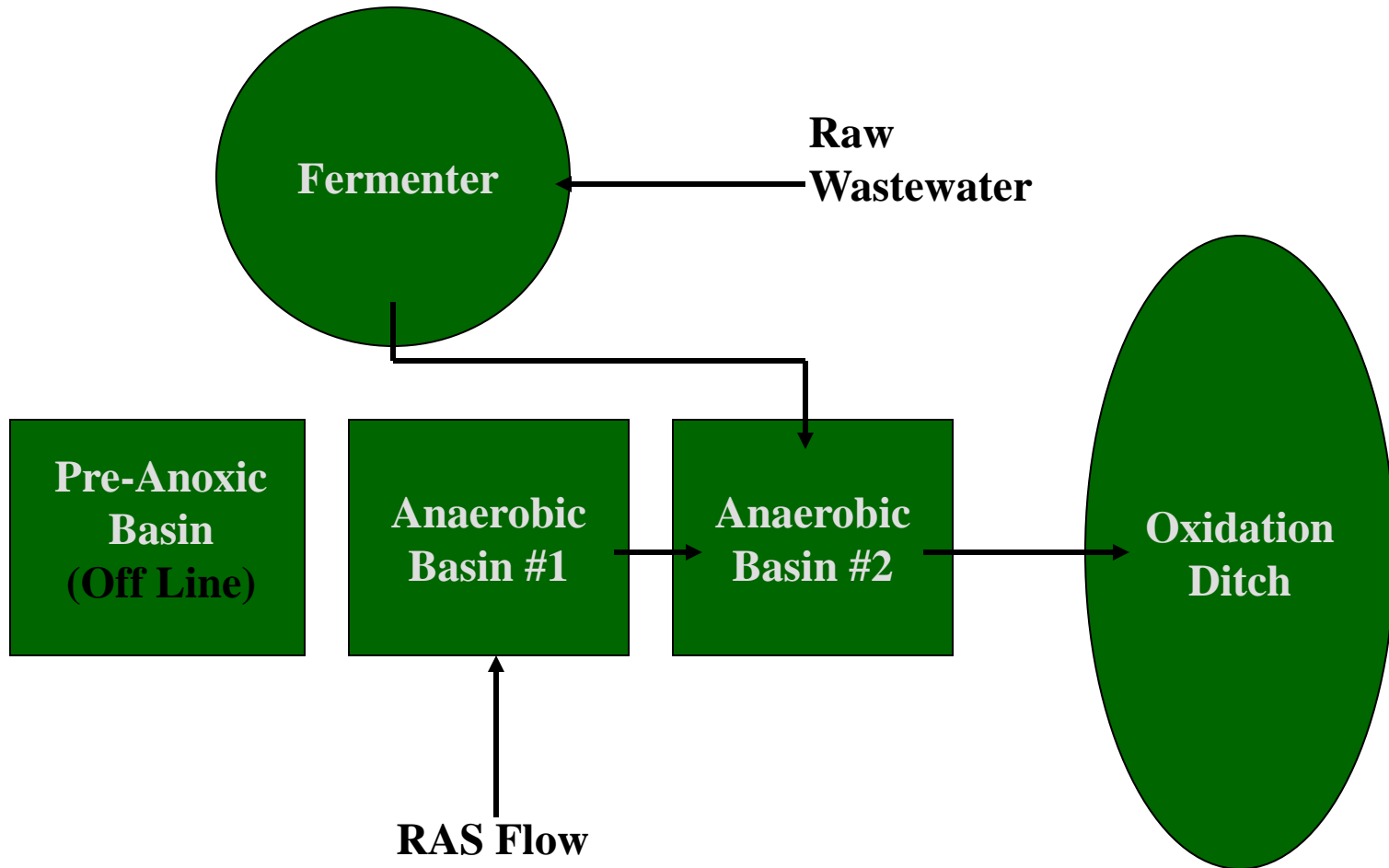


# Tomah February – May 2000 Results

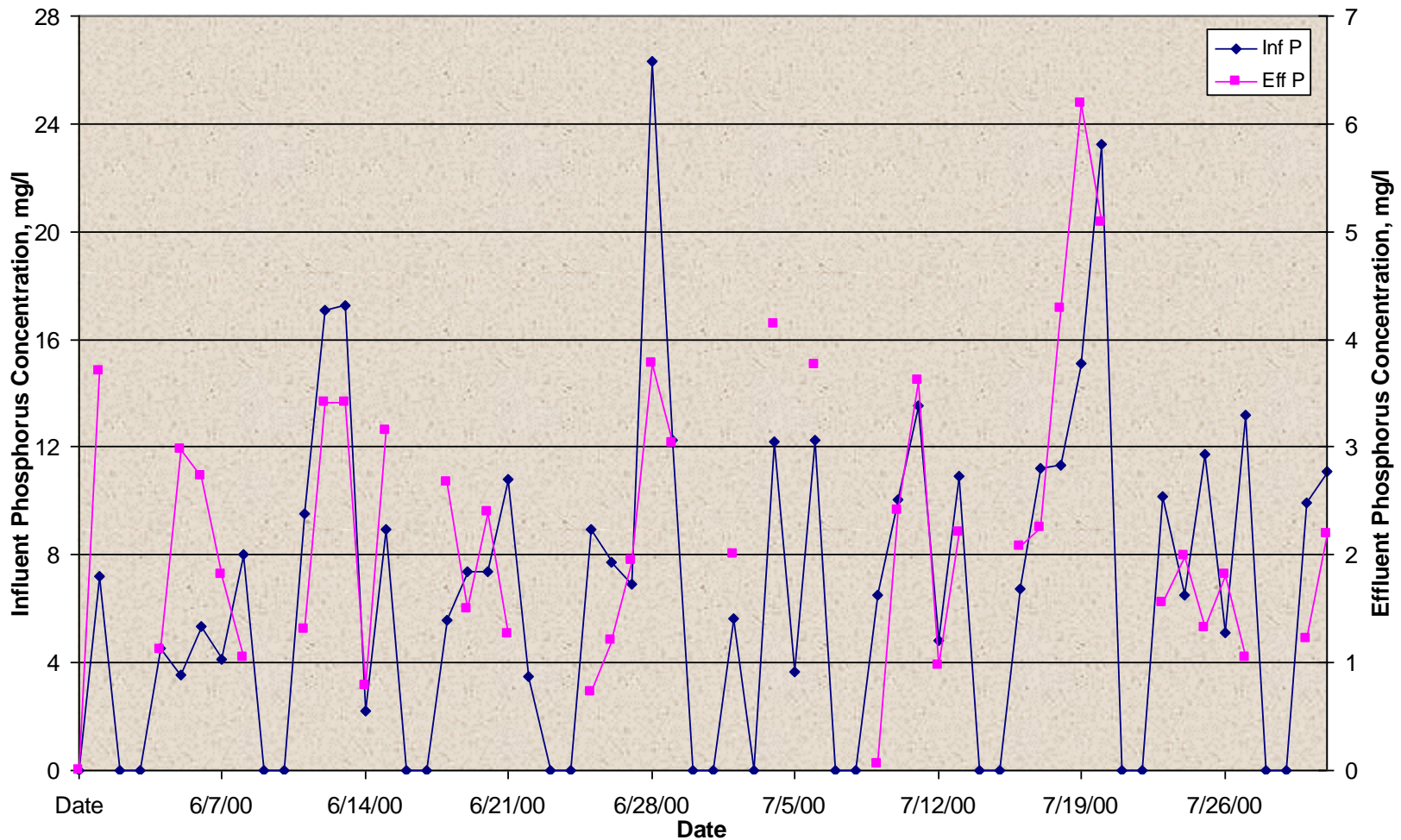


(Note: May 18 Influent P 184.29 mg/l, Effluent P 102.76 mg/l)

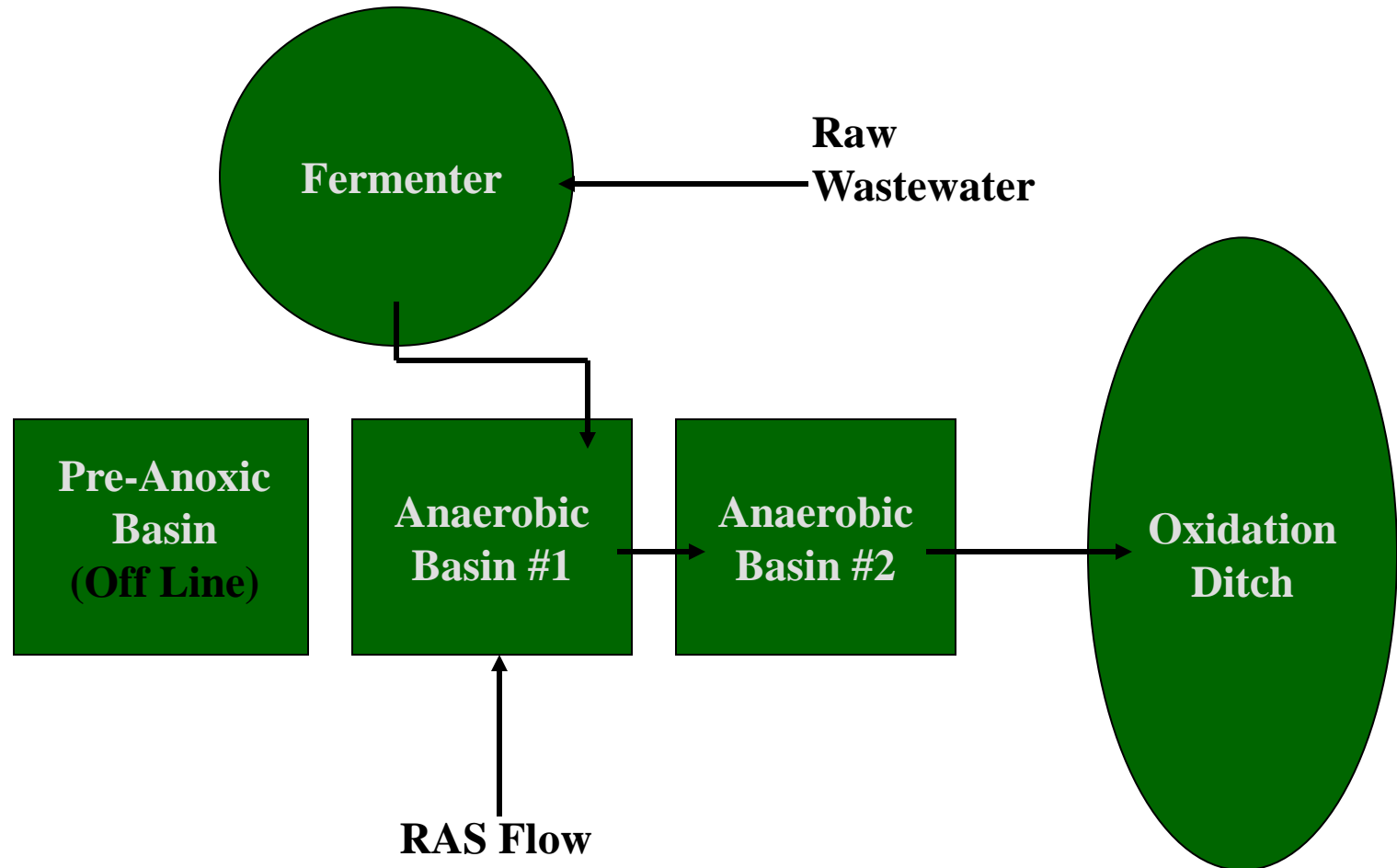
# Tomah Start-Up (June – July 2000)



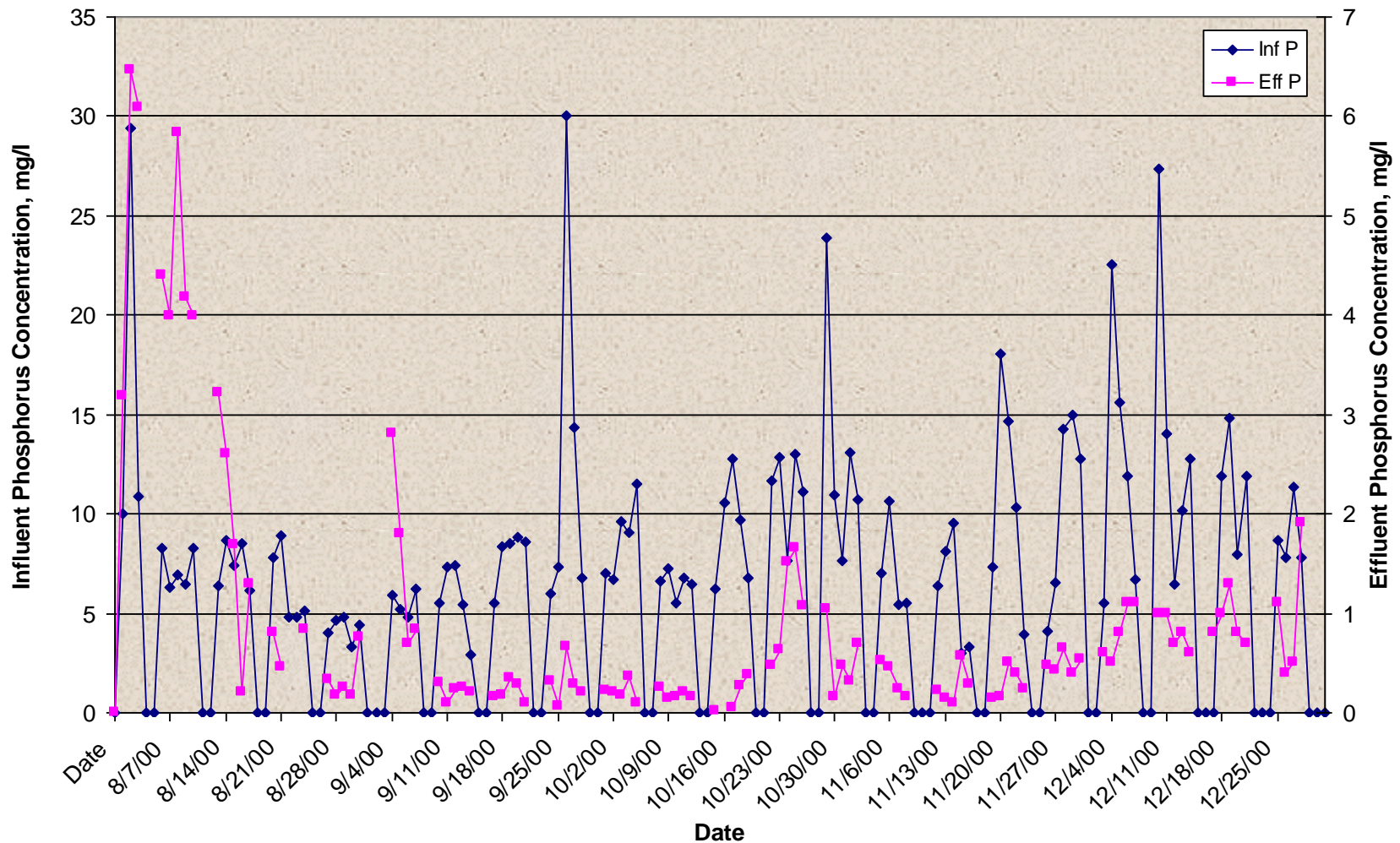
# Tomah June – July 2000 Results



# Tomah Start-Up (August – Dec. 2000)

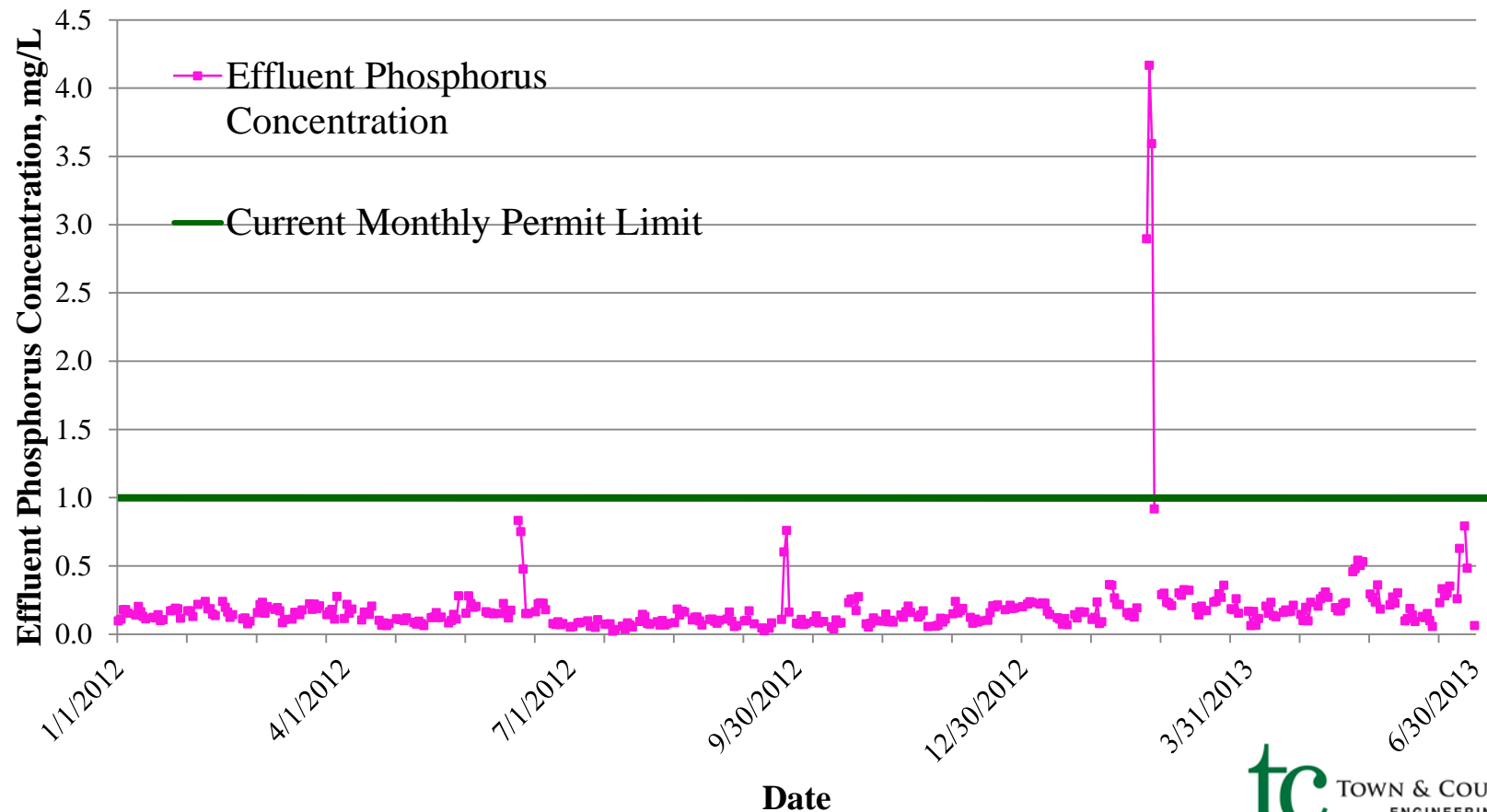


# Tomah June – July 2000 Results



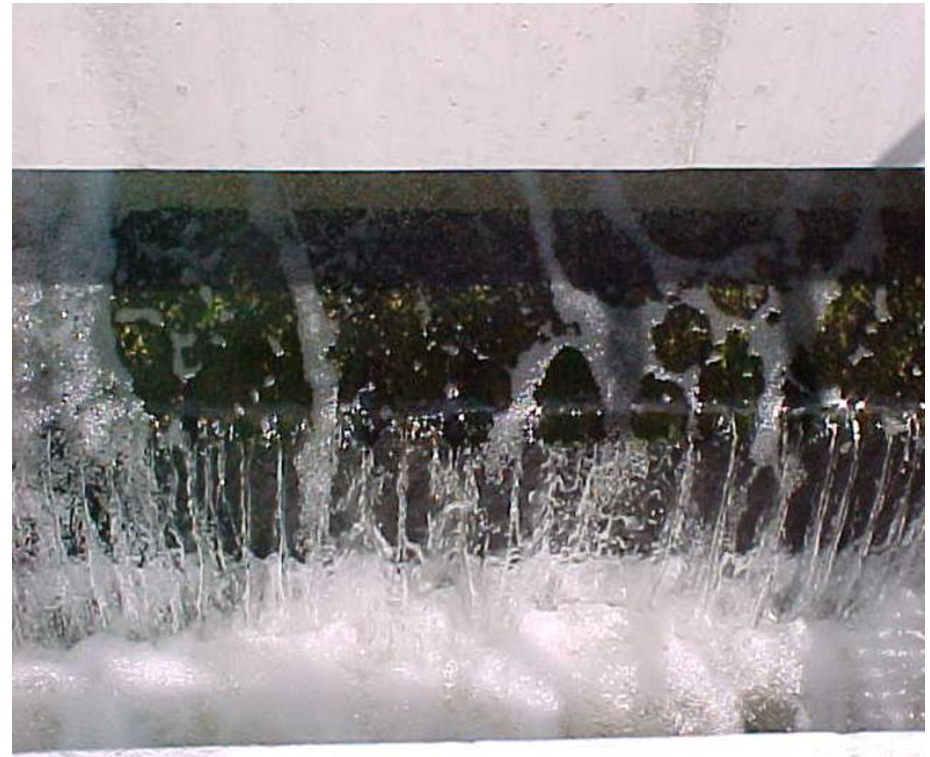
# Tomah Operation (2012 - 2013)

## Tomah WWTF



# Tomah Plant Operating Results

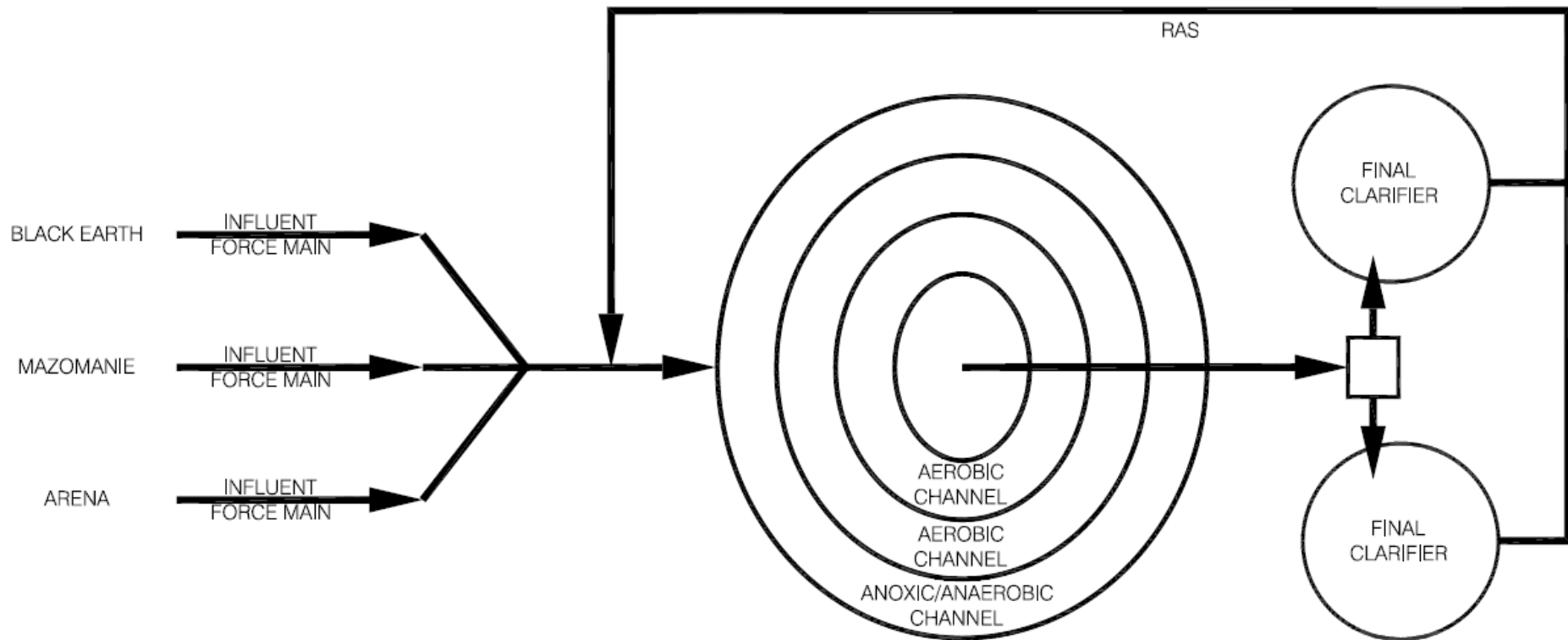
- Effluent Results 2012
  - BOD/SS < 5 mg/L
  - Ammonia < 0.5 mg/L
  - Phosphorus < 0.3 mg/L
- No chemical usage for “P” removal
- No control on recycle streaming



# Dane-Iowa WWTP

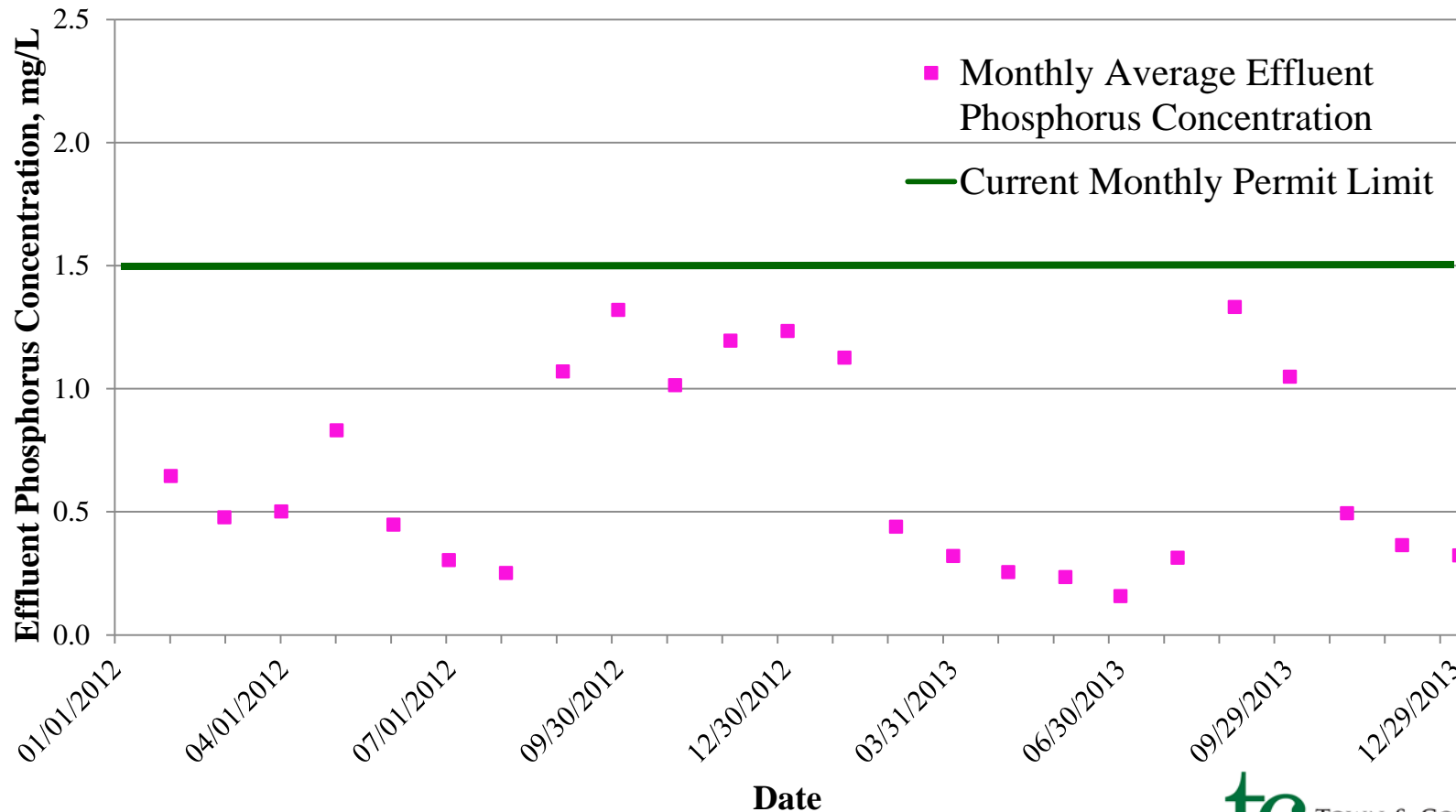
- Design Flow 0.693 MGD
- Peak Hourly 1.981 MGD
- BOD 1,369 lbs/day
- TSS 1,501 lbs/day
- TKN 230 lbs/day
- Phosphorus 37 lbs/day

# Dane-Iowa WWTP



# Dane-Iowa Performance

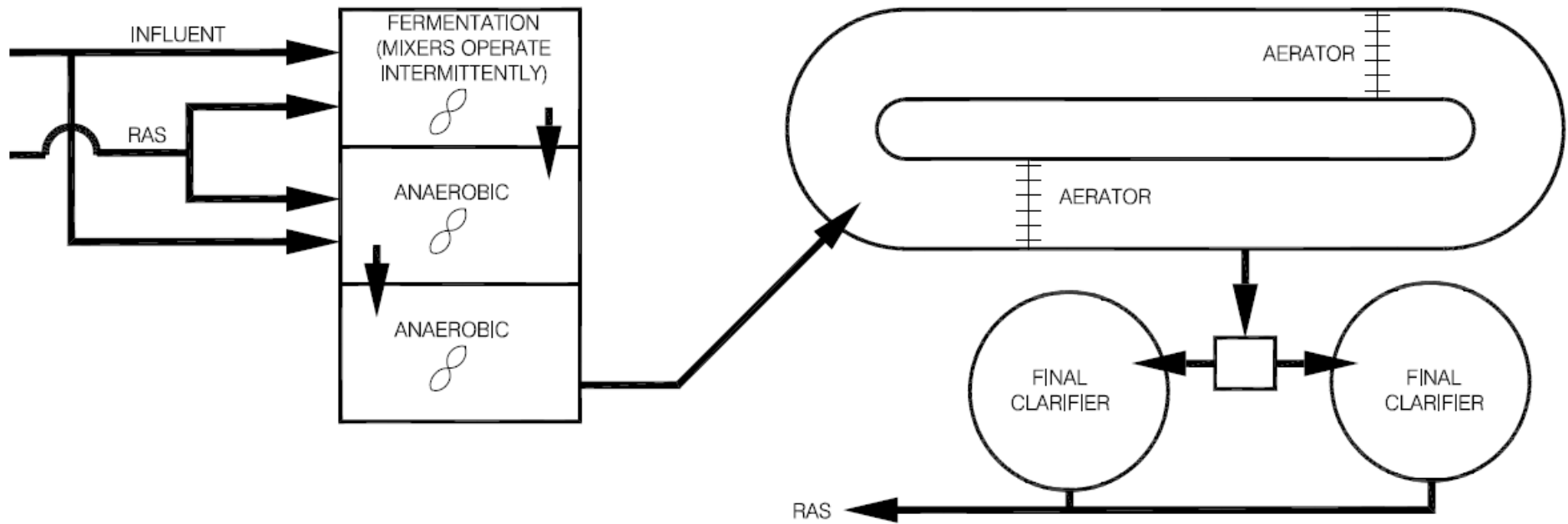
## Dane-Iowa WWTF



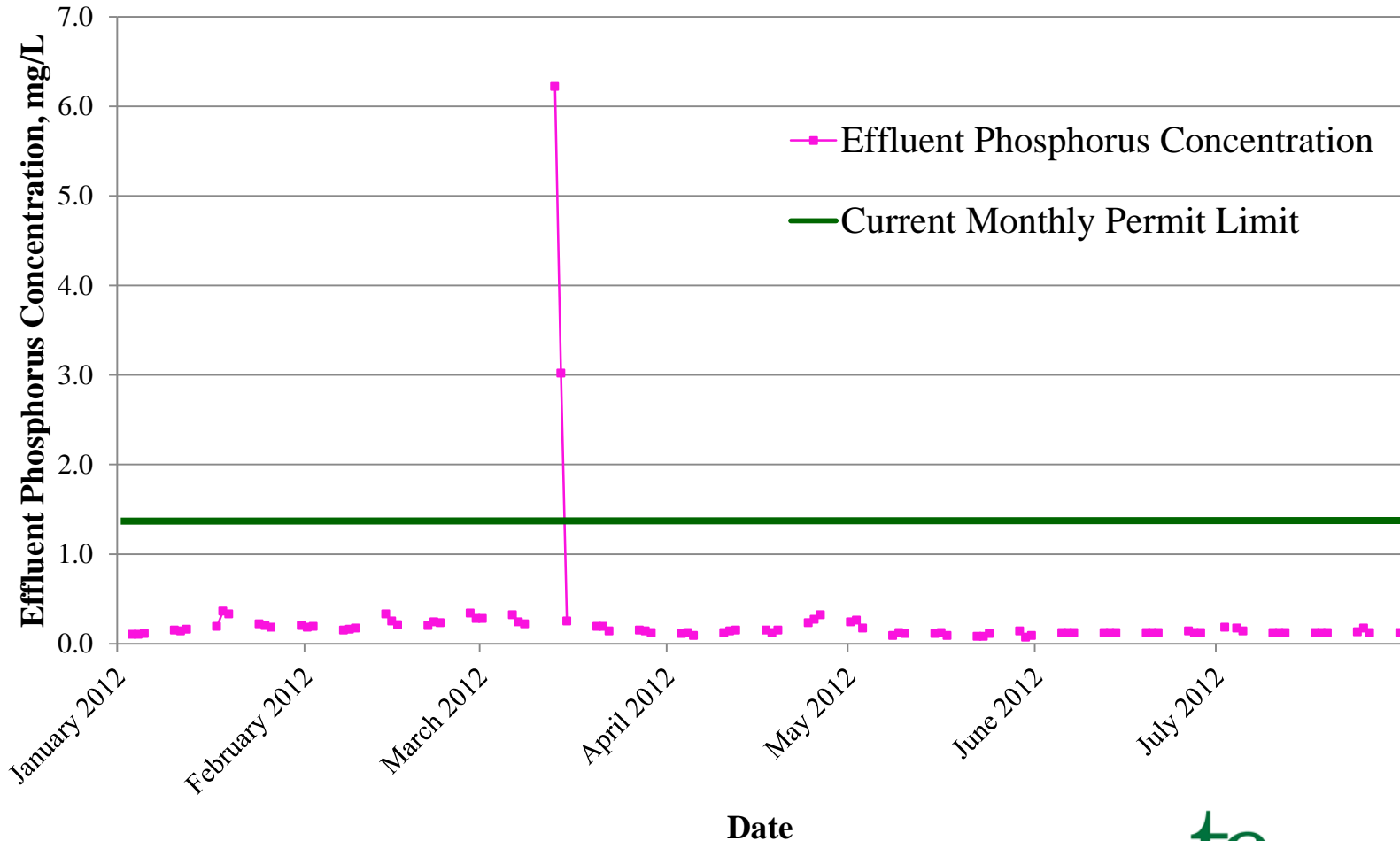
# Cross Plains, WI WWTP

- Design Flow 0.593 mgd
- Peak Hourly 2.27 mgd
- BOD 1,376 lbs/day
- TSS 1,493 lbs/day
- TKN 155 lbs/day
- Phosphorus 44 lbs/day

# Cross Plains, WI WWTP



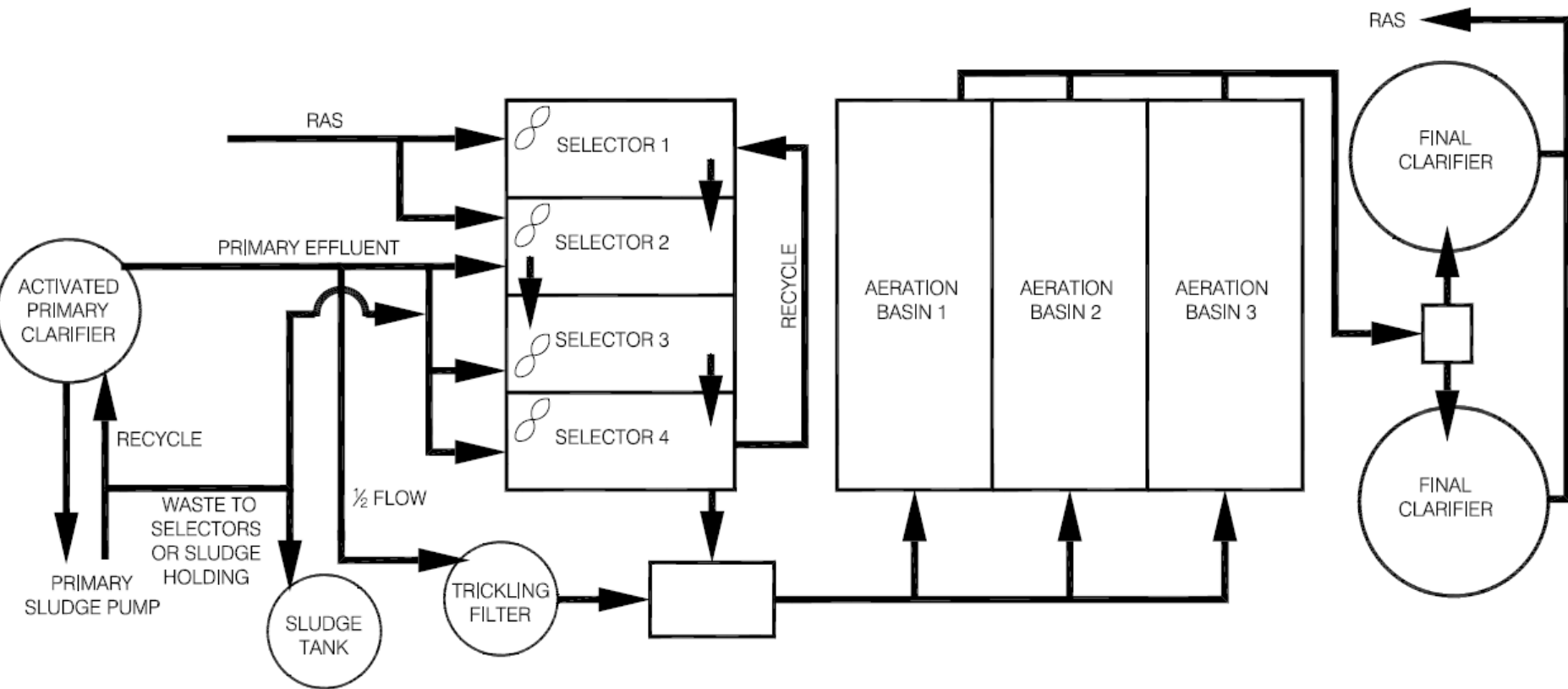
# Cross Plains Performance



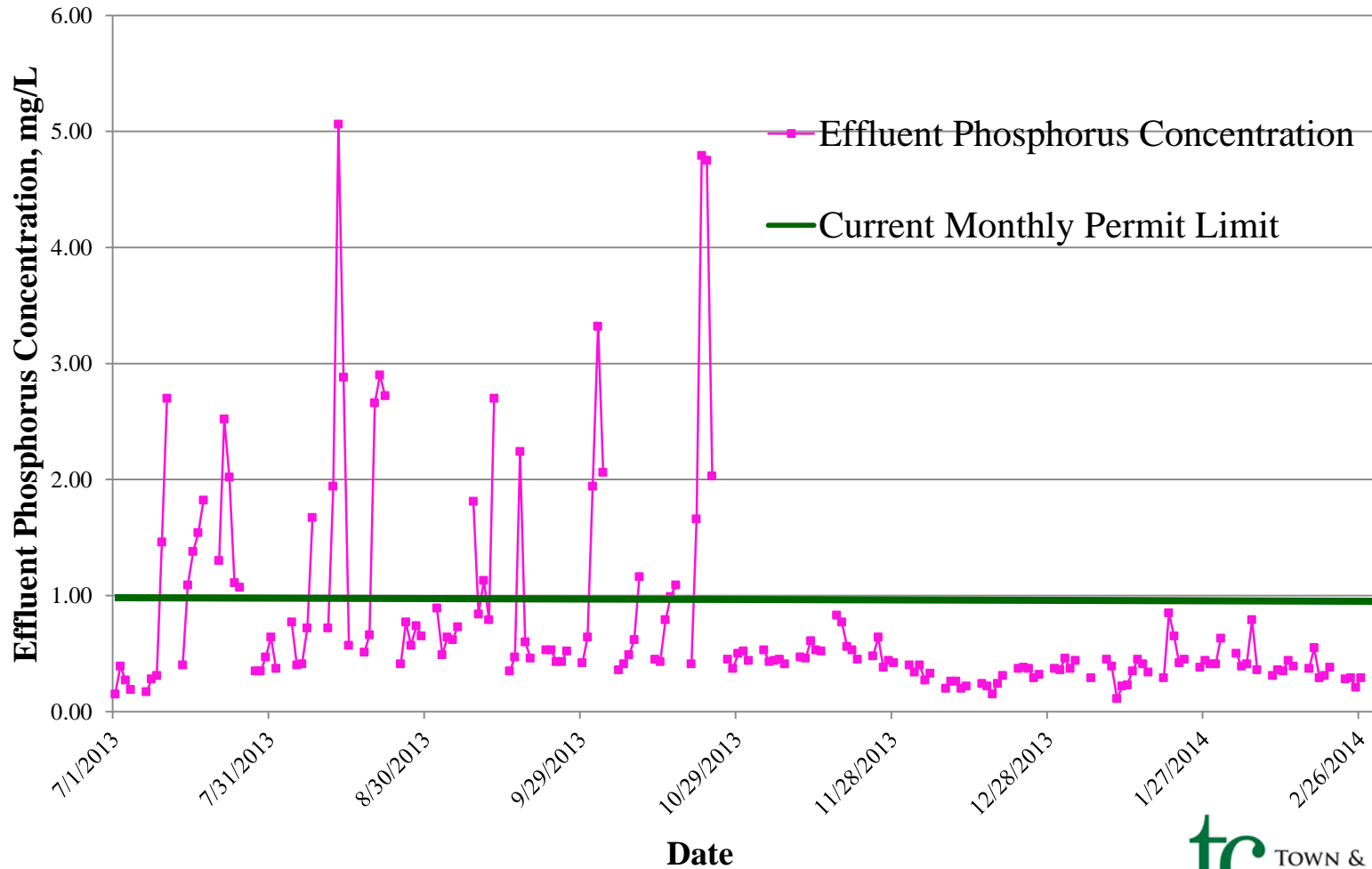
# Reedsburg, WI WWTP

- Design Flow 2.646 MGD
- Peak Flow 7.914 MGD
- BOD 6,331 lbs/day
- TSS 5,048 lbs/day
- TKN 687 lbs/day
- Phosphorus 205 lbs/day

# Reedsburg, WI WWTP



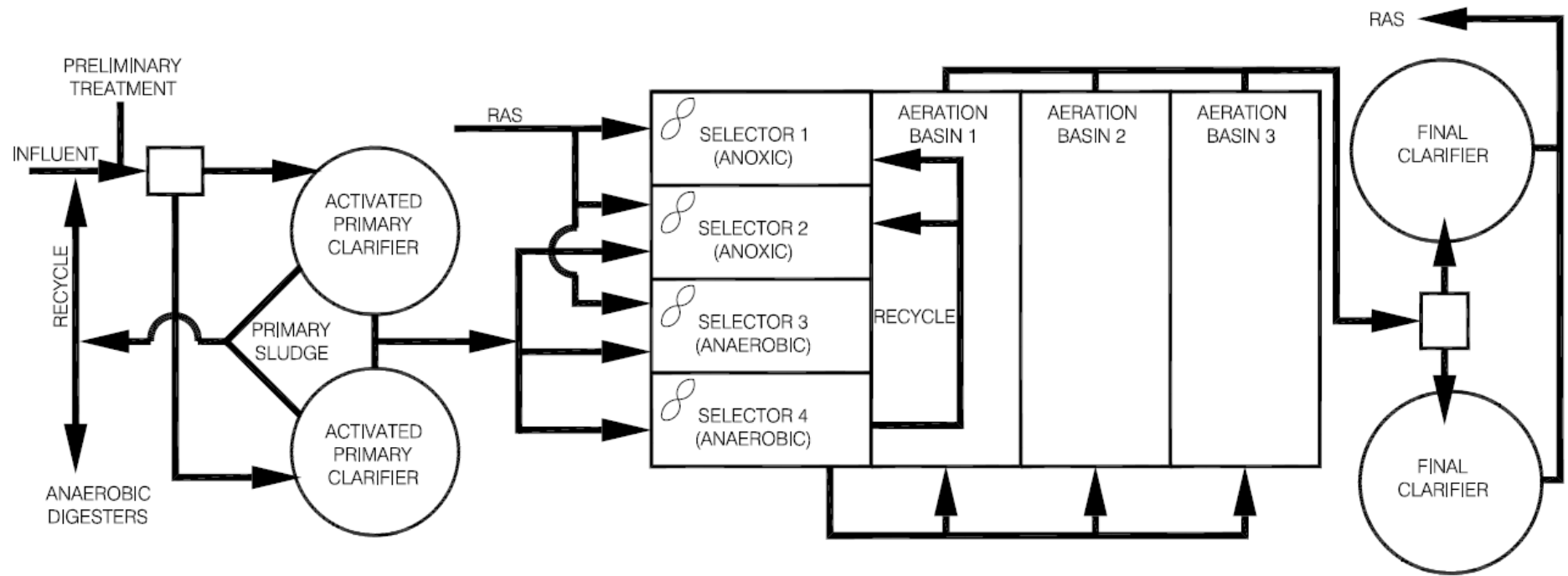
# Reedsburg Performance



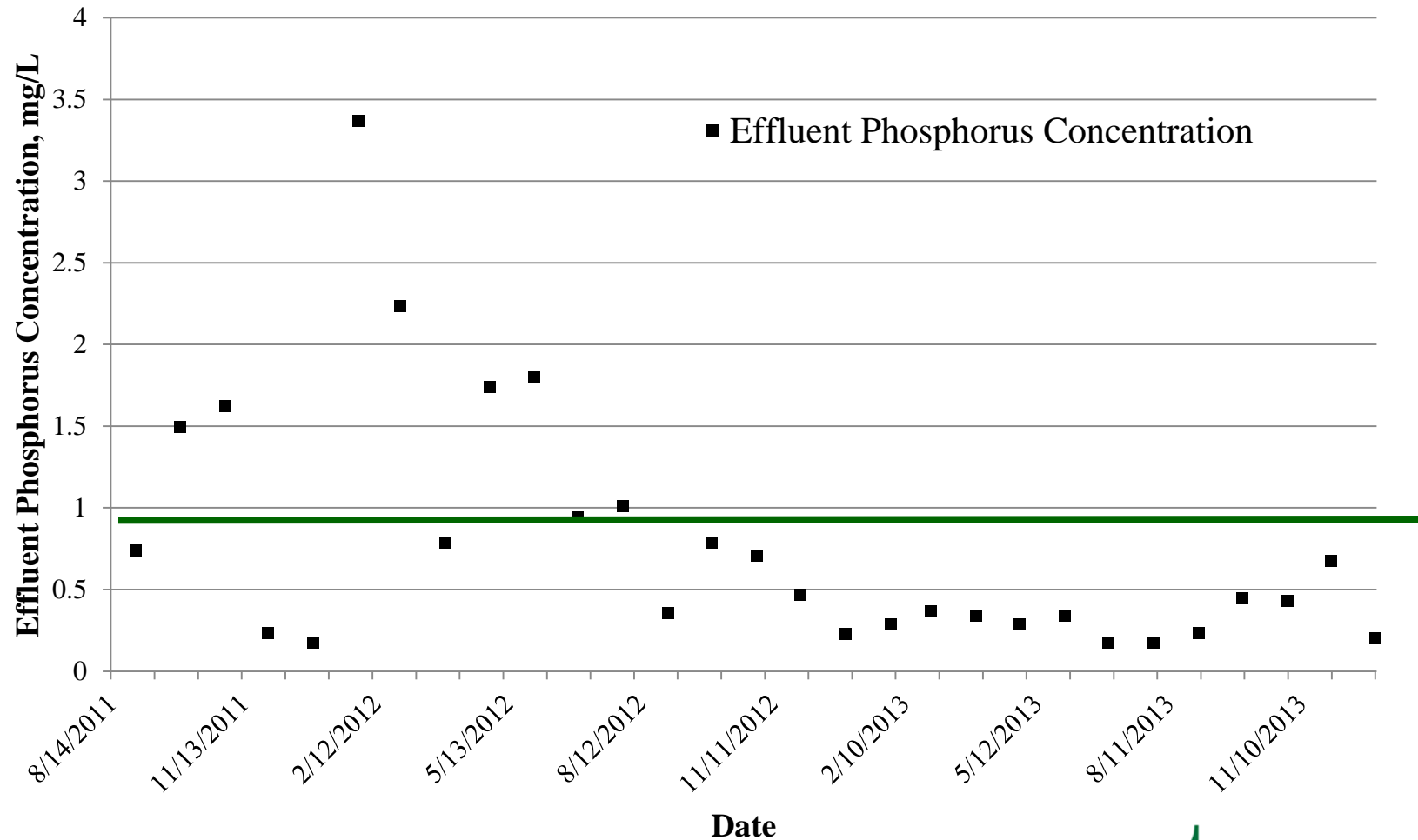
# Rhineland, WI WWTP

- Design Flow 2.153 mgd
- Peak Hourly Flow 7.894 mgd
- BOD 4,277 lbs/day
- TSS 4,349 lbs/day
- TKN 423 lbs/day
- Phosphorus 138 lbs/day

# Rhineland, WI WWTP



# Rhineland Performance



# Rhinelanders Challenges

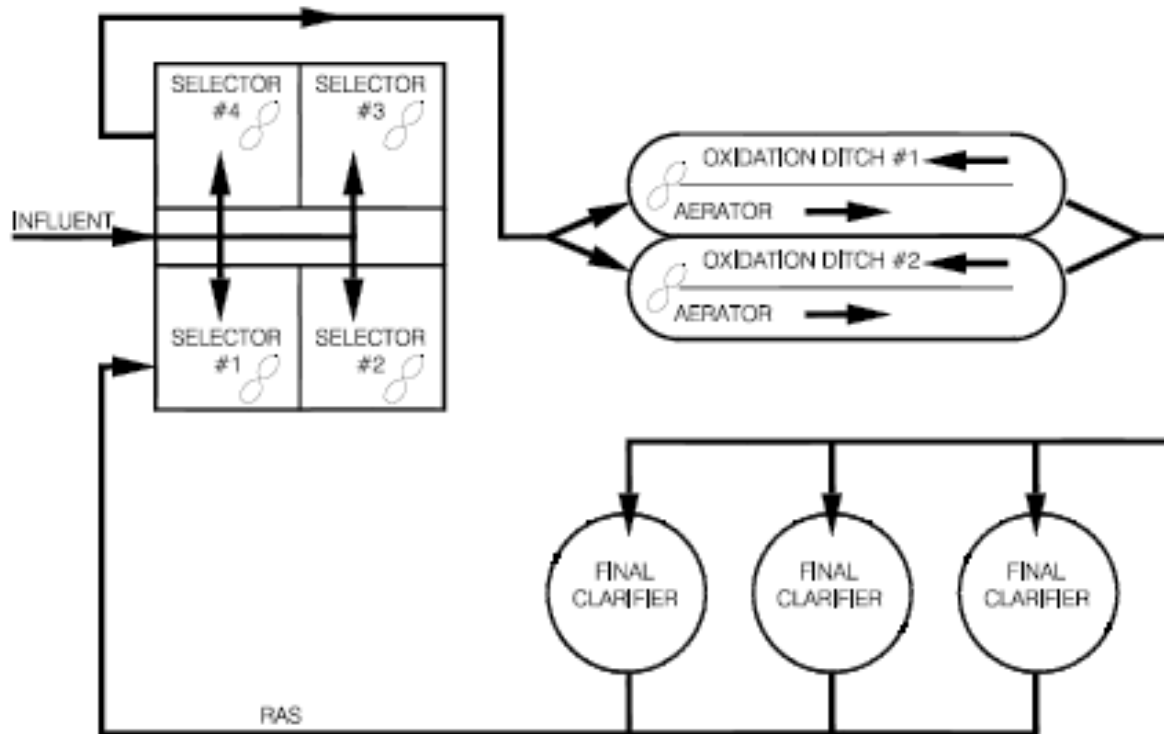
- Anaerobic digester recycle streams
- Carbon – need to feed Bio P and anaerobic digester
- Batching for digester
- More complex controls

# Dodgeville, WI WWTP

- Design Conditions

- Design Flow 1.350 MGD
- Peak Hourly Flow 3.600 MGD
- BOD 1,925 lbs/day
- TSS 1,650 lbs/day
- NH<sub>3</sub> 380 lbs/day
- Phosphorus 50 lbs/day
- Typical Discharge .5 mg/L to .7 mg/L with chemical

# Dodgeville, WI WWTP



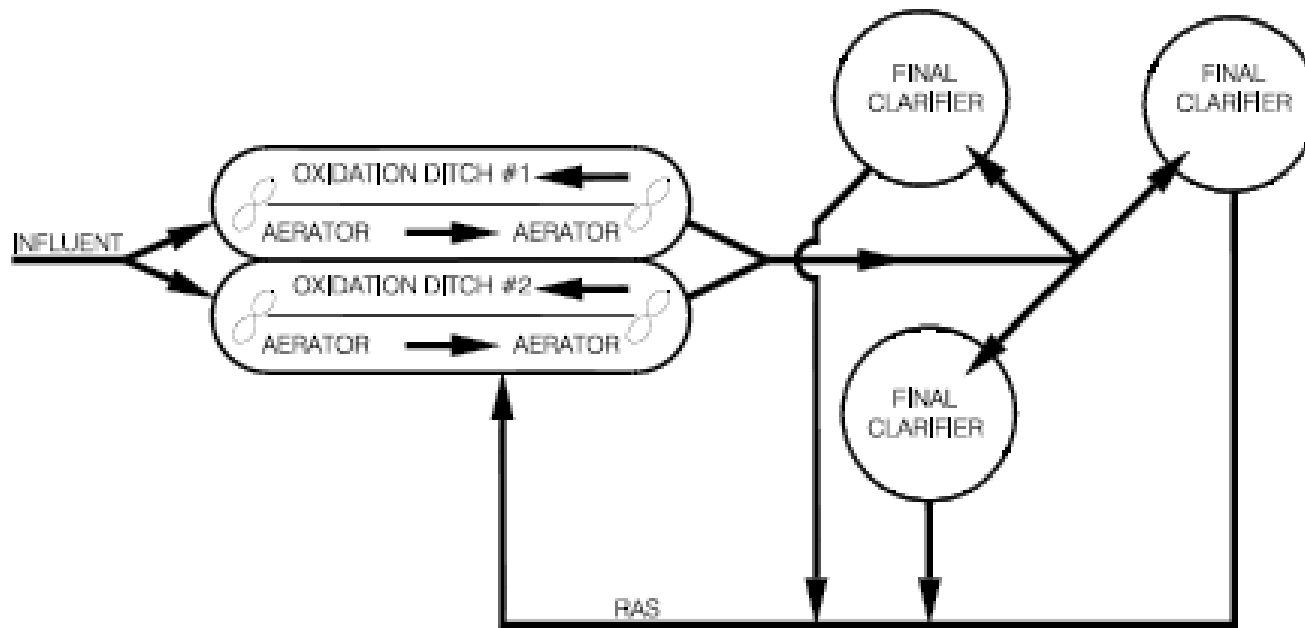
# Dodgeville, WI WWTP

- WWTP Operational Modifications
  - Revised Process Flow – Influent Flow Diverted to Tank #1
  - Timers Added to Mixers – Operated 20 Minutes/Hour
- WWTP Improvements
  - Effluent Improvements
    - Effluent P reduced to 0.30 PPM annual average
  - Chemical Addition Reduced
    - Previous Chemical Addition Seasonally
    - Reduced Chemical Consumption – Saving >\$35,000 per Year

# Marshfield, WI WWTP

- Design Conditions
  - Design Flow 7.91 MGD
  - Peak Hourly Flow 28.0 MGD
  - BOD 11,000 lbs/day
  - TSS 11,100 lbs/day
  - TKN 1,550 lbs/day
  - Phosphorus 350 lbs/day
- Unique features
  - High peak flow
  - Designed for only chemical phosphorus removal

# Marshfield, WI WWTP



# Marshfield, WI WWTP

- Plant Performance Prior to Changes in Operation
  - Generally BOD/SS Very Good
  - Required 200 gpd of Ferric Chloride
  - Effluent Phosphorus .7 mg/L to .9 mg/L
- WWTP Operational Modifications
  - Operate Two Ditches in Series
  - First Ditch Operated with Low DO/Anoxic

# Marshfield, WI WWTP

- WWTP Improvements
  - Effluent Improvements
    - Effluent P reduced from 0.90 mg/L to 0.1 – 0.2 mg/L
  - Chemical Addition Reduced
    - Chemical Addition Reduced to 25 gpd
    - Projected Annual Savings of \$95,000
  - Sludge Dewatering
    - Reduce Polymer Addition 40% to 50%
  - Potential Future Improvement
    - Update Controls
    - Replace Aerators to Lower Power and Improve Mixing

# Summary

- Biological phosphorus removal is a reliable alternative for phosphorus removal down 0.2mg/L to 0.5 mg/L or below
- Designs must incorporate flexibility to ensure systems can be optimized
- Treatment arrangements should be suited for the specific WWTP
- Process control allows ease of operation

# Questions / Comments