Biological Nutrient Removal Challenges at Small WWTPs – Ellsworth, WI

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Outline

- Existing Conditions
- Project Goals
- WWTP Upgrades
- Performance and Optimization
- Conclusions

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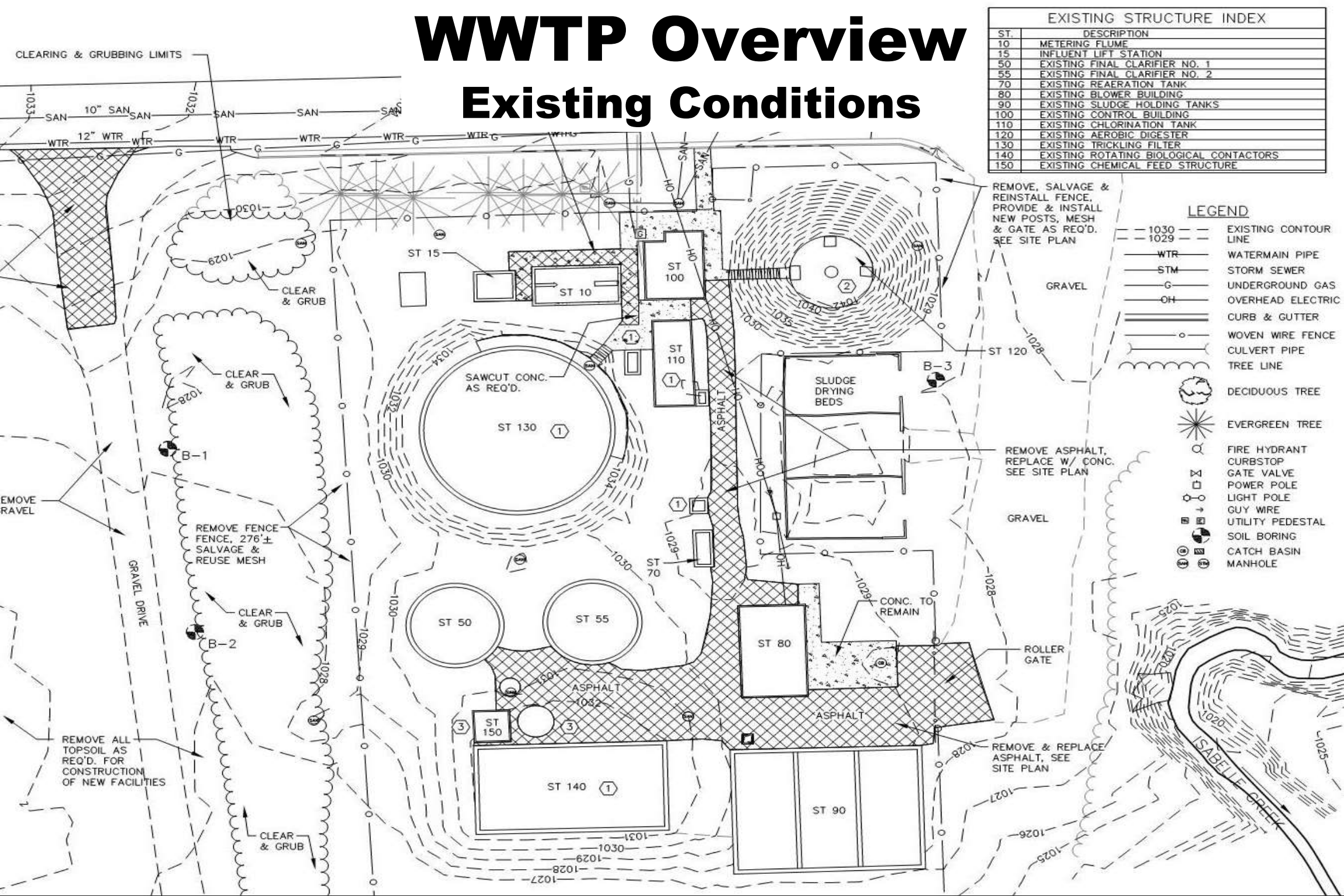
Existing Conditions

- WWTP overview
- Biological treatment process
- Other treatment processes
- Design capacity
- Effluent quality
- Reasons for upgrades

WWTP Overview

Existing Conditions



WWTP Overview

Existing Conditions

Biological Treatment Process
Existing Conditions

- RBCs (4)
- Trickling filter
- Secondary Clarifiers (2)
- Waste sludge pumps (3)

Other Treatment Processes

Existing Conditions

- Mechanical screens (2)
- Influent pumps (5)
- Effluent re-aeration
- Ferric chloride feed system
- Aerobic digestion

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Design Capacity
Existing Conditions

- Design flow: 0.340 MGD
- Peak day flow: 0.905 MGD
- Design BOD_5 load: 834 lb/d
- Design TSS load: 834 lb/d
- Capacities based on 2007 re-rating

Effluent Quality
Existing Conditions

- Average annual data from 2007 – 09
  - 5 mg/L $cBOD_5$
  - 12 mg/L TSS
  - 15 mg/L NH_3
  - 0.6 mg/L TP
  - 387 mg/L chlorides

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Reasons for Upgrades
Existing Conditions

- Existing design was incapable of meeting new permit limits
- Needed to replace equipment and processes reaching the end of their design life
- Projected to exceed design flows and loads in near future

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Project Goals

- Meet new permit limits
- Upgrade existing processes
- Increase design capacity

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Meet New Permit Limits
Project Goals

- Discharge to Isabelle Creek
  - Disappearing stream (up to 0.223 MGD loss)
  - Classifications vary from Lower Aquatic Life to Cold Water Community
  - Also receives flow from Ellsworth Co-Op Creamery
    - 0.200 MGD process water
    - 0.100 MGD non-contact cooling water

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Meet New Permit Limits
Project Goals

- Discharge Option 1 – New Outfall 410th St
  - Surface water limits:
    - 1 mg/L TP
    - Seasonal disinfection to 200 c.f.u.
  - Potential to create sinkhole downstream
    - Public disapproval
  - Future reclassification as Cold Water
    - Would require tertiary filtration

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Meet New Permit Limits
Project Goals

- Discharge Option 2 – Existing Outfall
  - Surface water limits:
    - 1 mg/L TP
  - Creek disappears downstream of outfall
  - Groundwater limits:
    - 10 mg/L TN
    - 325 mg/L chlorides
    - Year-round disinfection to 400 c.f.u.

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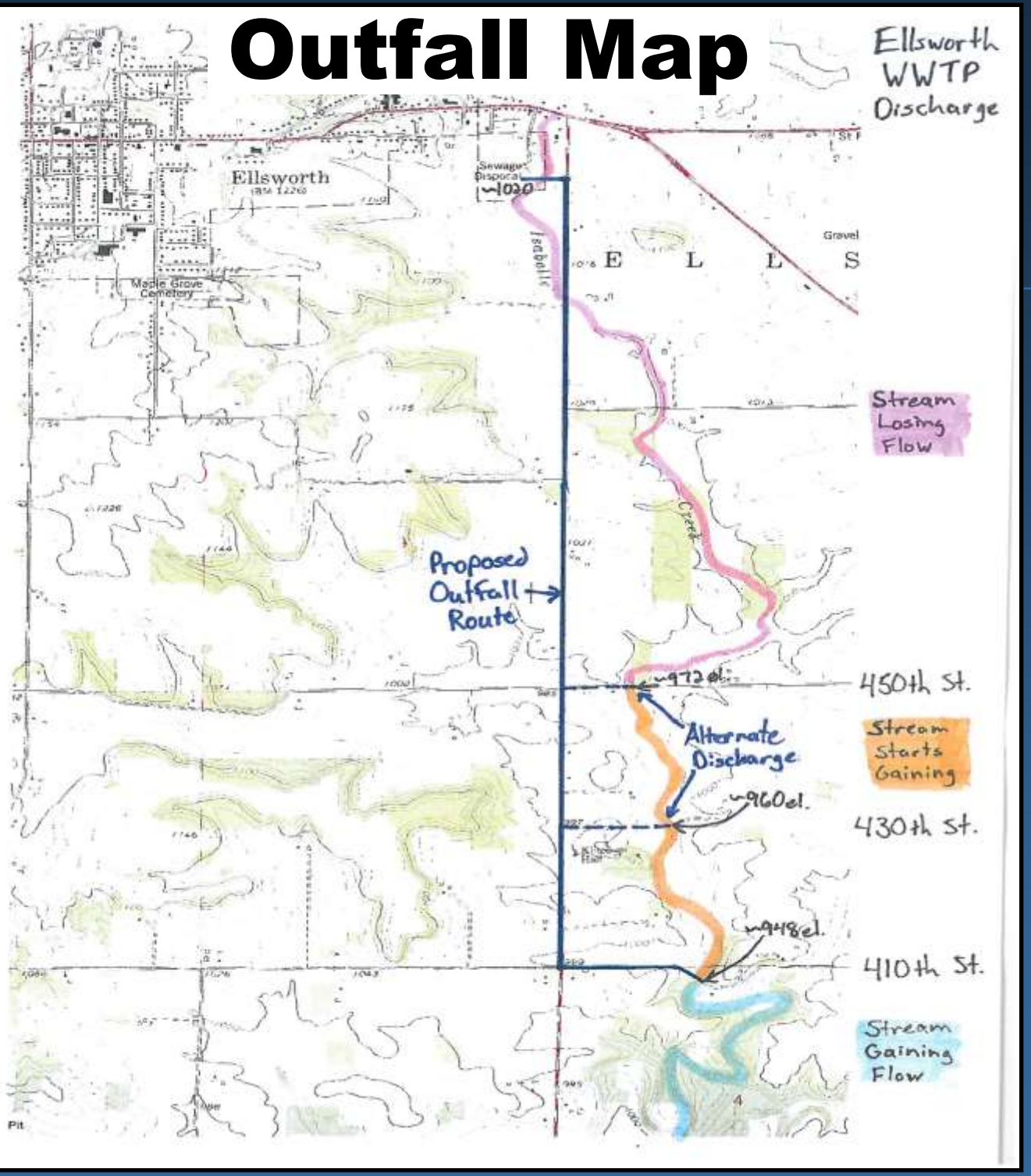
Outfall Map



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Meet New Permit Limits
Project Goals

- Discharge Option 2 selected
  - Treat for TN and work on chlorides
  - No effluent lift station and force main
  - No tertiary filtration
  - Lower in total present worth
  - No potential for sinkhole creation
- Result: need biological TN and P removal

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Meet New Permit Limits
Project Goals

- Effluent Limits (biological)
  - 20 mg/L BOD_5 and TSS (monthly avg.)
  - 10 mg/L TN (monthly avg.)
  - Seasonal NH_3 limits
    - Daily max. as low as 7.8 mg/L
    - Monthly avg. as low as 3.6 mg/L
  - 1 mg/L TP (monthly avg.)

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Meet New Permit Limits
Project Goals

- Effluent Limits (other)
  - 4 mg/L DO (daily min.)
  - 400 c.f.u./100 mL (monthly geo. mean)
  - 325 mg/L chlorides (weekly avg.)

Meet New Permit Limits
Project Goals

- Biological processes evaluated:
  - Activated sludge system
    - Oxidation ditch
    - Anaerobic selector
  - Trickling filter upgrade
    - Add plastic media
    - Additional RBCs
  - RBC expansion
    - Additional RBCs
  - IFAS system
    - Convert sludge tanks
    - Add media
    - Add RAS pumping

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Meet New Permit Limits
Project Goals

- Selected activated sludge system
  - Lowest total present worth
  - Highly flexible system
    - Adjust biology (ML concentration)
    - Vary aeration rate
    - Add or remove cells from service
  - Capable of BioP
  - Capable of total nitrogen removal

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Upgrade Existing Processes
Project Goals

- Processes replaced:
  - Mechanical screening
  - Influent pumping
  - Final clarifiers
  - Chemical feed
  - Solids handling

Upgrade Existing Processes
Project Goals

- New processes:
  - Biological treatment
    - RBCs to oxidation ditch
  - Disinfection
    - New UV system
  - Re-aeration
    - Weir to diffused air

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Increase Design Capacity

Project Goals

- Peak Hour Flow: 2.160 MGD
- Peak Month BOD_5 Load: 1,019 lb/d
- Peak Month TSS Load: 1,253 lb/d
- Peak Month TKN Load: 140 lb/d
- Peak Month TP Load: 31 lb/d
- Design Year: 2030

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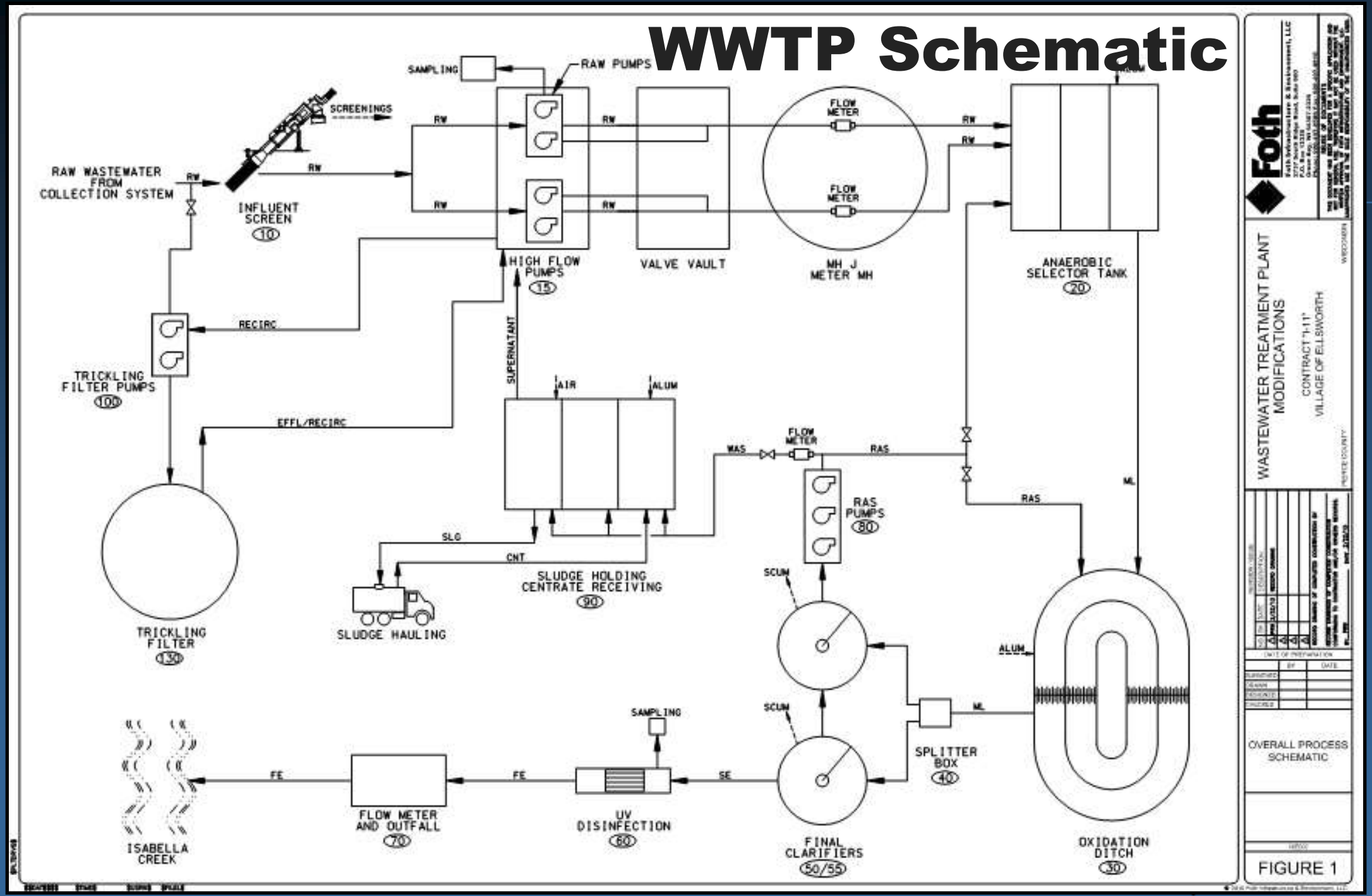
WWTP Upgrades

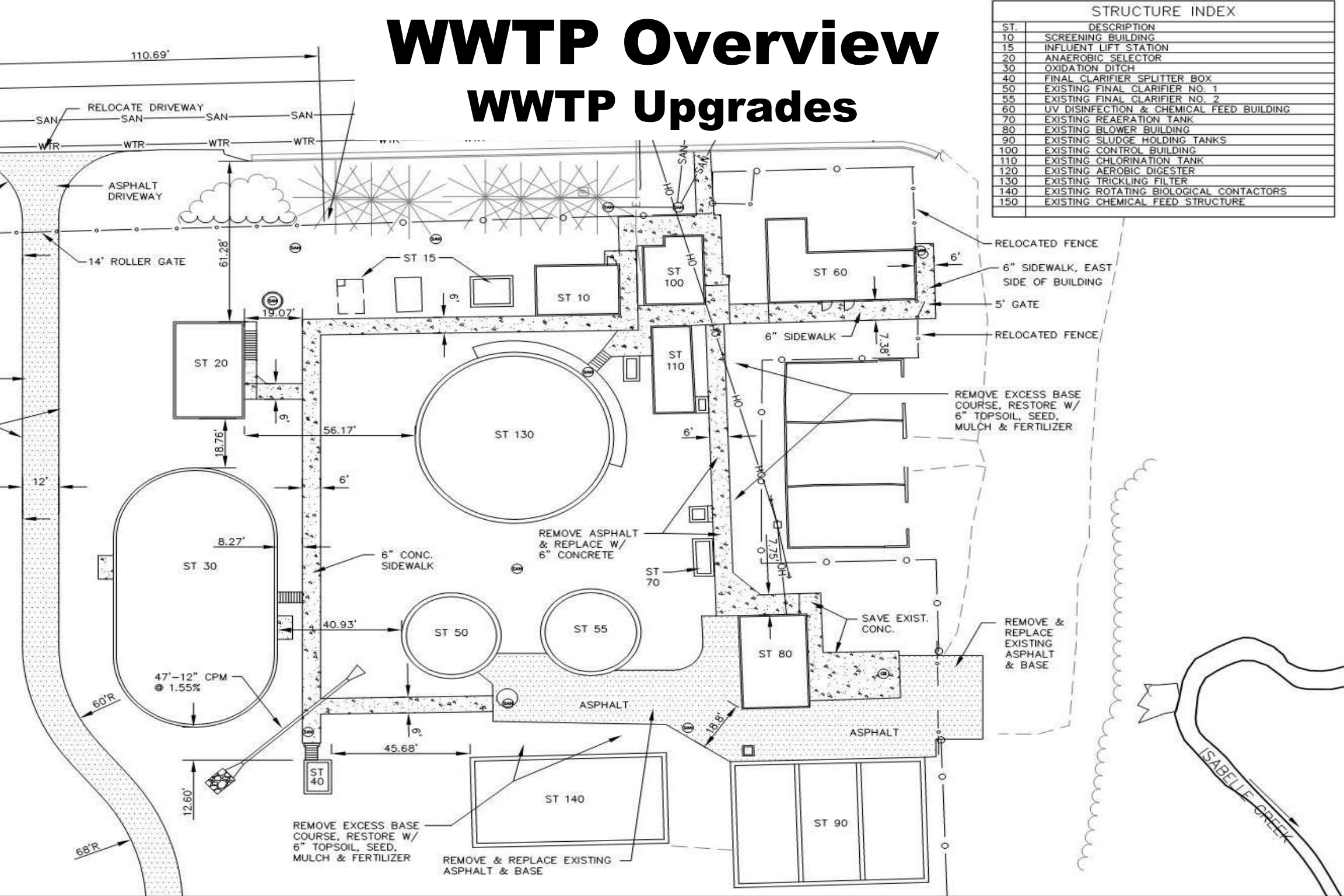
- WWTP overview
- Biological treatment upgrades
- Biological nutrient removal (BNR) design
- Other upgrades
- Bidding and construction

WWTP Schematic



WWTP Overview

WWTP Upgrades



Biological Treatment Upgrades
WWTP Upgrades

- Type: extended aeration AS with biological nitrogen and phosphorus removal
  - Three cell anaerobic selector
  - Two channel oxidation ditch with simultaneous nitrification/denitrification (SND)
  - Two final clarifiers
  - RAS pumping system
  - Internal mixed liquor recycle

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Biological Process Parameters
WWTP Upgrades

- Anaerobic selector volume: 35,000 gal
- Oxidation ditch volume: 280,000 gal
- Maximum MLSS: 5,000 mg/L
- Peak month volumetric BOD_5 loading: 24.2 lb/d
- Peak month F:M: 0.103
- Design average SRT: 15 days
- RAS rate: 50 – 200% design average flow

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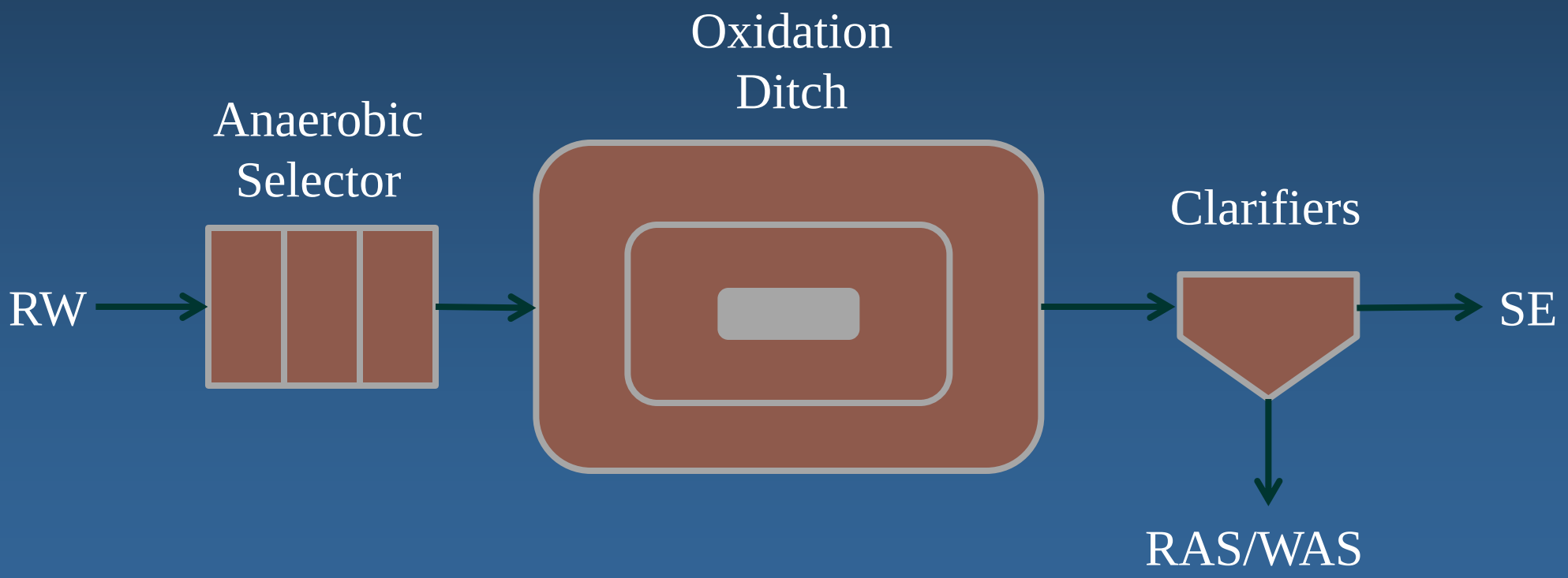
Biological Treatment Schematic

WWTP Upgrades



Biological Treatment System

WWTP Upgrades

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Anaerobic Selector Basins

WWTP Upgrades

Oxidation Ditch
WWTP Upgrades

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Oxidation Ditch
WWTP Upgrades

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BNR Design
WWTP Upgrades

- Key biological processes
  - BOD removal
  - Nitrification
  - Denitrification (ML and RAS)
  - BioP
  - Settling

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BNR Design
WWTP Upgrades

- Simultaneous Nitrification/Denitrification
  - $NH_3 \rightarrow NO_2 \rightarrow N_2\uparrow$
  - Nitrospirea – Ammonia Oxidizer
  - Nitrobacter – Nitrite Oxidizer
- Nitrospirea
  - Out competes Nitrosomonas in Aerated Anoxic Reactors
  - Can Go Dormant

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BNR Design
WWTP Upgrades

- Anaerobic selector basins
  - RAS denitrification
  - Readily biodegradable chemical oxygen demand (rbCOD) uptake
  - Soluble phosphorus release
  - Fermentation (?)

BNR Design
WWTP Upgrades

- Oxidation ditch (outer channel)
  - BOD removal
  - Simultaneous nitrification/denitrification
  - RAS denitrification
- Oxidation ditch (inner channel)
  - BOD removal
  - Nitrification
  - Soluble phosphorus uptake

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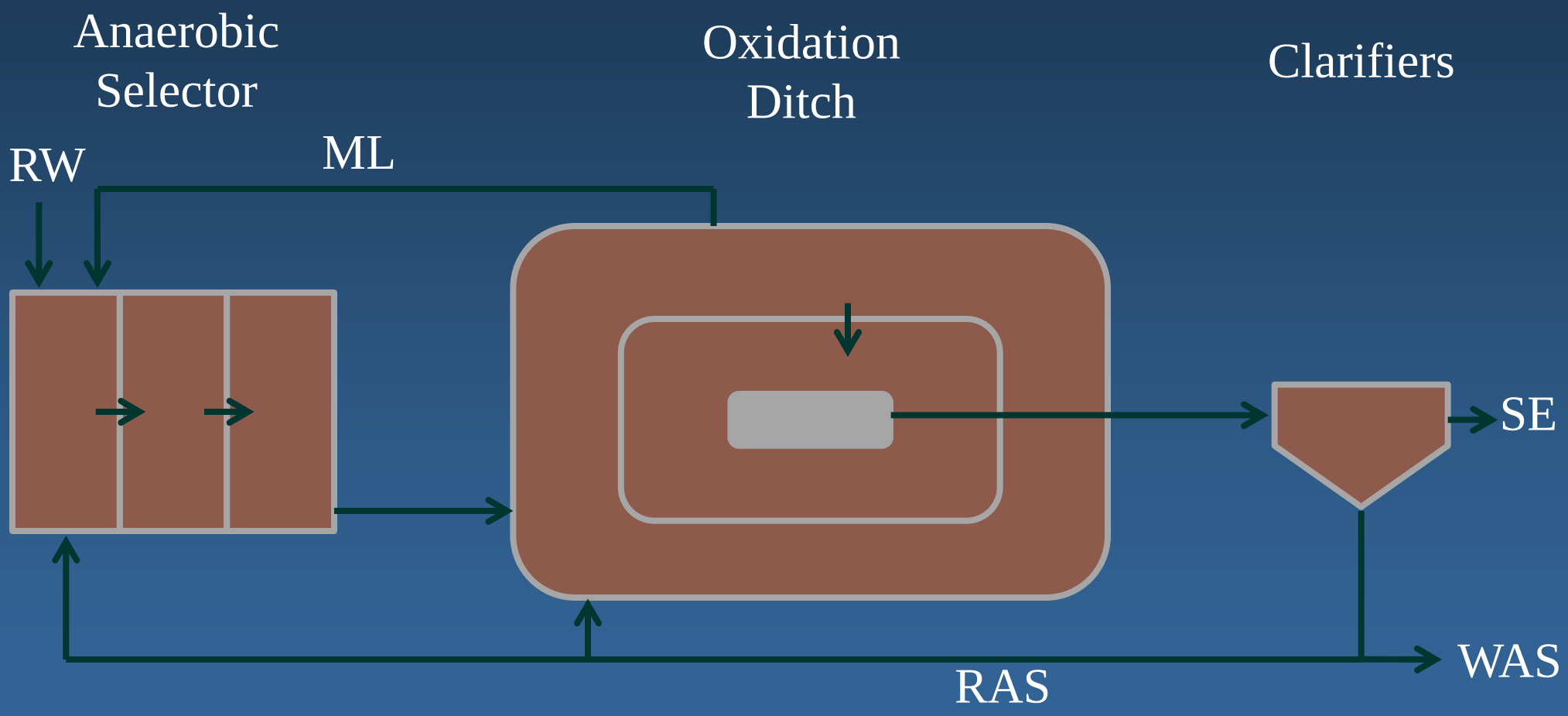
Biological Treatment Schematic

WWTP Upgrades



Design Flexibility
WWTP Upgrades

- Multiple process basins
- Multiple RAS addition points
- Multiple basin functions
  - RAS denitrification
  - Detention time
- Flow and load fluctuations

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Other Upgrades
WWTP Upgrades

- New mechanical fine screen
- Increased RW pumping capacity
- Replaced clarifier mechanisms
- New UV disinfection
- New diffused air re-aeration
- New chemical feed system
- Solids handling system modifications

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Bidding and Construction
WWTP Upgrades

- Bid Price: $3.34 million
- Funding: CWF loan and 30% grant
- General Contractor: Rice Lake Construction Group
- Mobilization: April 2011
- Substantial Completion: May 2012

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Performance and Optimization

- Initial performance
- Operational and process optimization
- Current performance

Initial Performance
Performance and Optimization

- Influent (July 2012 – April 2013):
  - Flow: 0.269 MGD
  - BOD: 401 lb/day
  - TSS: 399 lb/day

Initial Performance
Performance and Optimization

- MLSS: 2,500–4,000 mg/L
- F:M: 0.067
- SRT: 17 days
- Loading: 10.7 lb/d/kcf
- DO: 2.2 mg/L
- ORP: -150 – -250 mV
- RAS rate: 50%
- Alum rate: 10 gpd

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Initial Performance
Performance and Optimization

- Effluent quality (July 2012 – April 2013):
  - BOD_5: 21.6 mg/L
  - TSS: 7.6 mg/L
  - NH_3: 3.5 mg/L
  - TN: 12.4 mg/L (some months up to 20 mg/L)
  - TP: 0.84 mg/L

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System Optimization
Performance and Optimization

- Operational Changes (April – Nov 2013)
  - Established consistent nitrification (decreased ORP to -100 mV)
  - Added some WAS to centrate and aerated to promote nitrification
  - Attempted to increase denitrification by raising RAS rate
- Reduced TN to consistently 9 – 12 mg/L

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Nitrate Recycle
Performance and Optimization

- Nitrate recycle port installed
  - Opening cut in ditch wall between channels
  - Installed November 2013
  - Starting December 2013, NO_3 + NO_2 improved
  - Winter of 2013-14 cold, NH_3 increased
  - Nitrification rebounded in May and system began meeting TN limit

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Nitrate Recycle

Performance and Optimization

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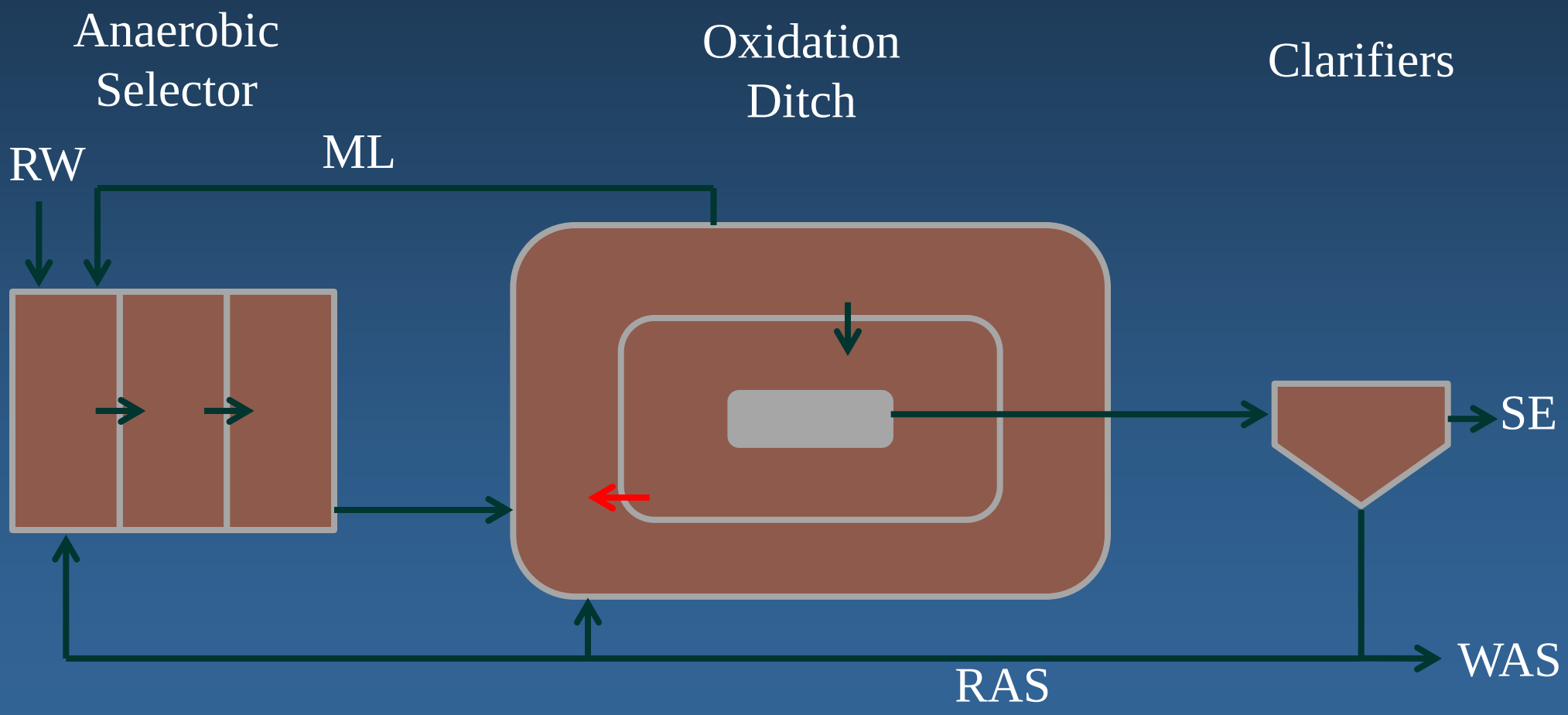
Nitrate Recycle
Performance and Optimization

Nitrate Recycle
WWTP Upgrades



Current Performance
Performance and Optimization

- Influent (May 2014 – July 2015):
  - Flow: 0.347 MGD
  - BOD: 381 lb/day
  - TSS: 464 lb/day

Current Performance

Performance and Optimization

- MLSS: 2,500–5,500 mg/L
- F:M: 0.052
- SRT: 18 days
- Loading: 10.1 lb/d/kcf
- DO: 3.0 mg/L
- ORP: -100 mV
- RAS rate: 50%
- Alum rate: 10 gpd

Current Performance
Performance and Optimization

- Effluent quality (May 2014 – July 2015):
  - BOD_5: 7.3 mg/L
  - TSS: 3.9 mg/L
  - NH_3: 0.4 mg/L
  - TN: 4.5 mg/L
  - TP: 0.43 mg/L

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Current Performance

Performance and Optimization

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Conclusions

- Biological process start-up is not automatic
- Flexibility in design benefits future operation
- Effective TN and BioP is possible at small WWTPs


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