Wastewater Treatment Technologies for Nutrients

Point Source Workgroup Meeting

Presented by

Scott Schaefer, PE - AE2S

October 14, 2014

OUTLINE

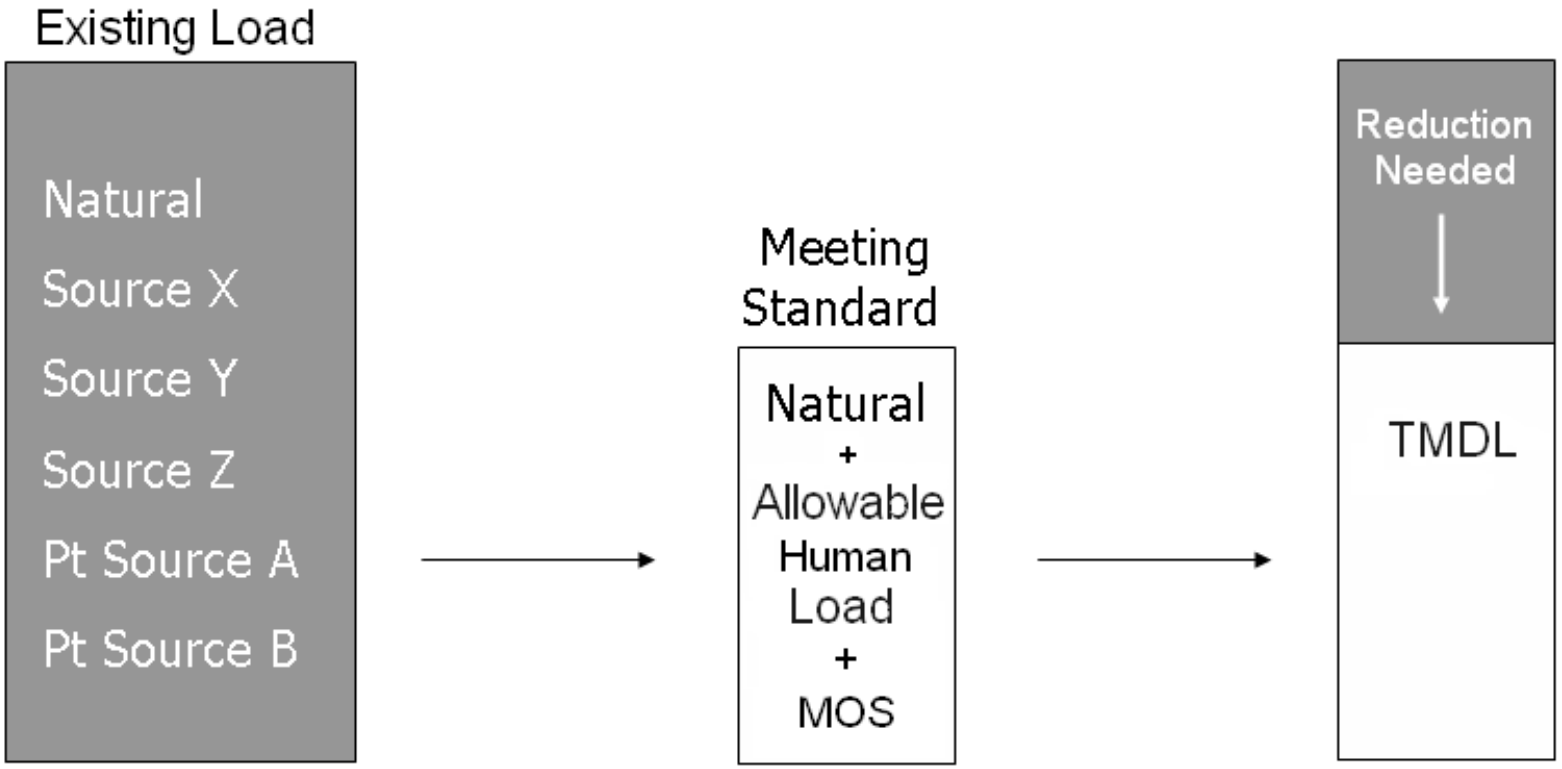
- Discharge Limits Basics
- Neighbor's Nutrient Limits
- Nutrient Removal Fundamentals
- Nutrient Removal Technologies
- Wrap Up

TYPES OF DISCHARGE LIMITS

- ✓ Technology Based Effluent Limits (TBELs)
- ✓ **Water Quality Based Effluent Limits (WQBELs)**
- ✓ Total Maximum Daily Load (TMDL)
- ✓ Antidegradation

TMDL BASICS

What is a TMDL? | What a TMDL Does & Does Not Do



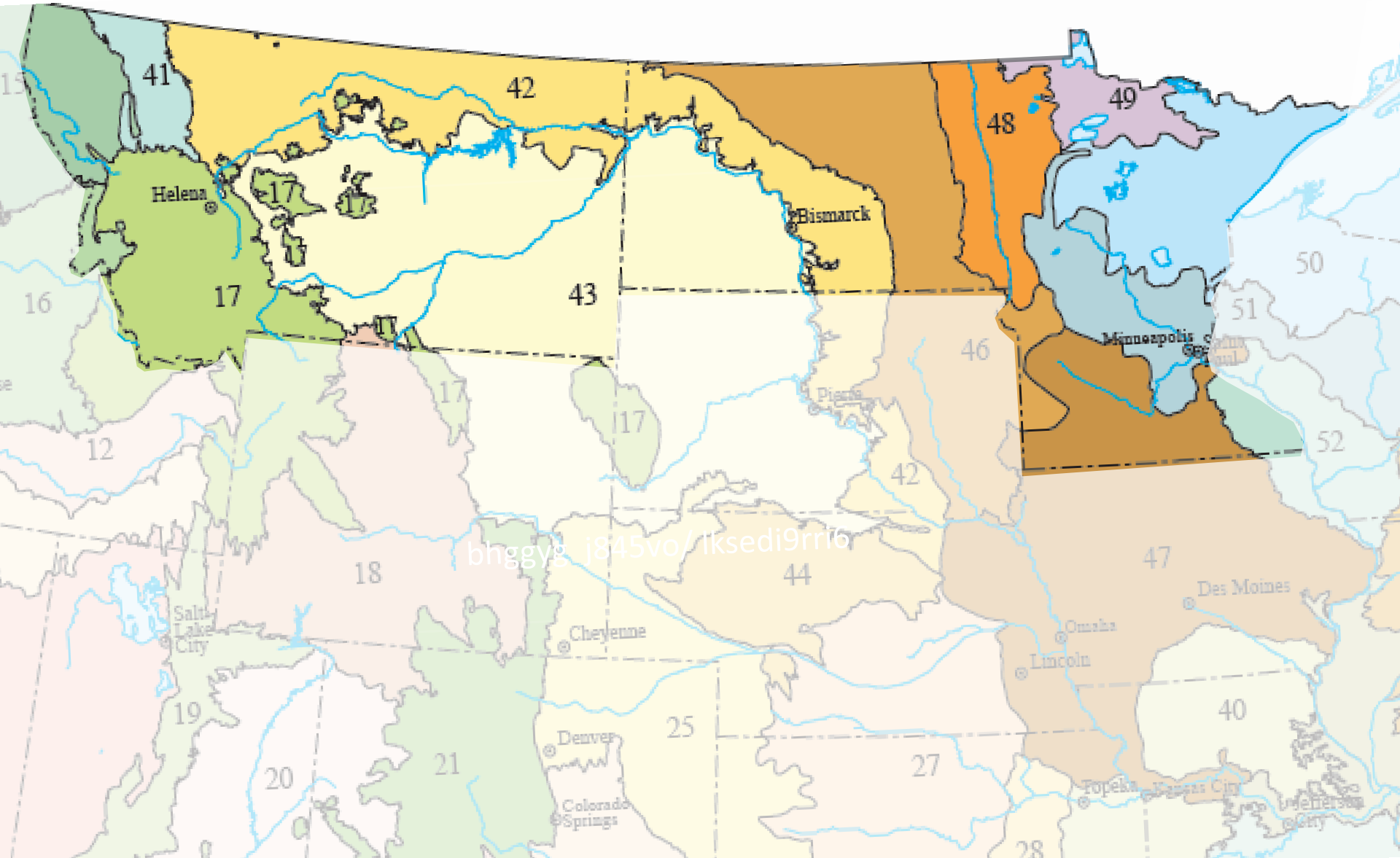
MOS = Margin of Safety

Water Quality Based EFFLUENT LIMITS

Water Quality Based Effluent Limits (WQBELs)

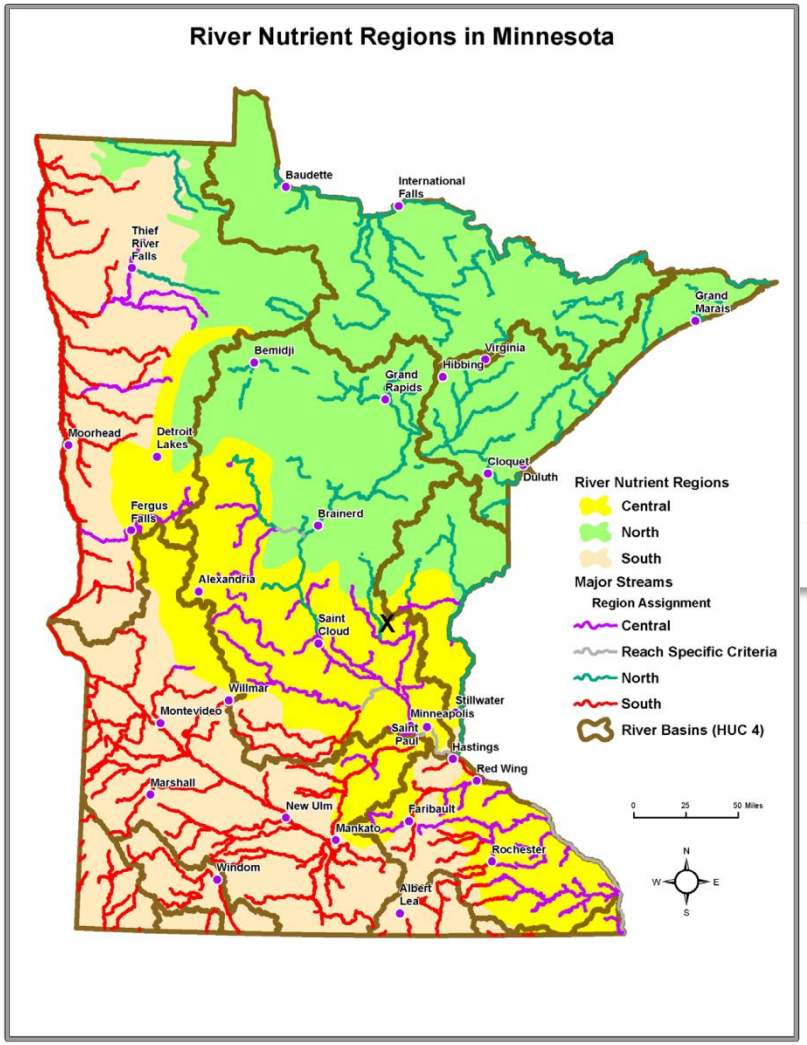
- Examples: Ammonia, metals, pesticides
- Based on In-Stream Standards
  - Can be very low

LEVEL III ECO-REGION MAP



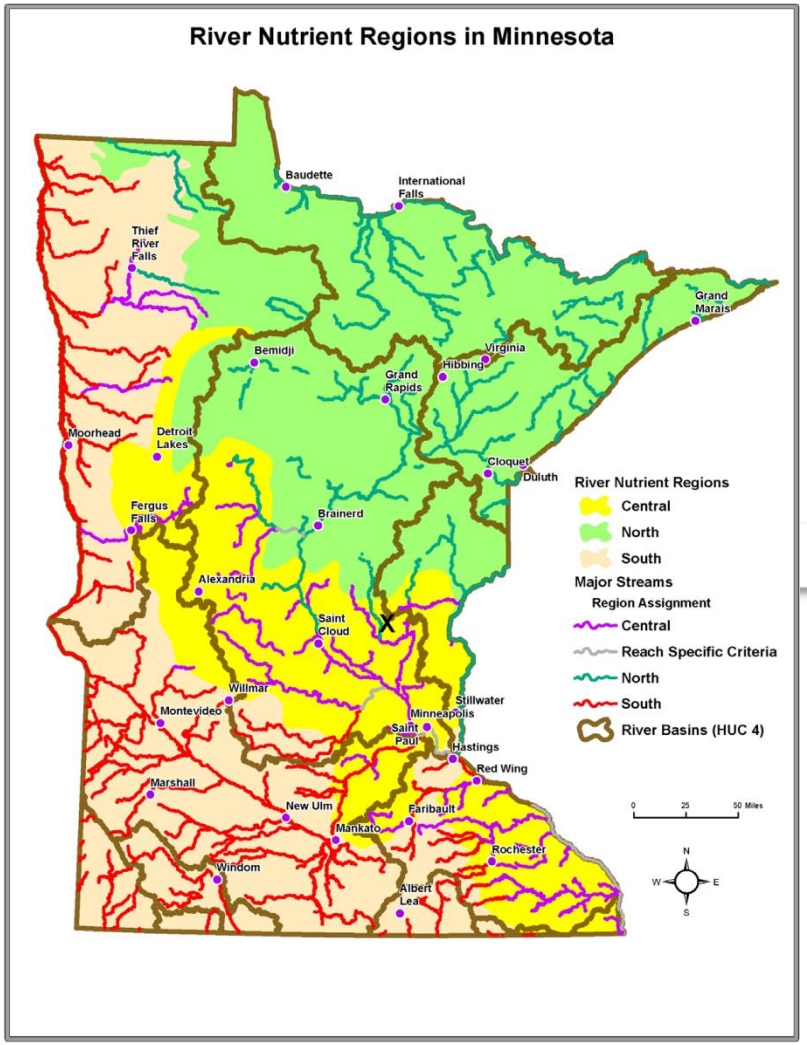
MINNESOTA

- "Eutrophication Standard"
- Phosphorus (for now) plus
  - Chlorophyll-a
  - DO flux
  - BOD
- Seasonal
  - June – September (implicit)



MINNESOTA

- **Three River Nutrient Regions**
  - North – 50 µgTP/L
  - Central – 100 µgTP/L
  - South – 150 µgTP/L
- **Chl-a <150 mg/m²**
- **Reach specific criteria:**
  - Lower Mississippi Pools
  - Crow River
- **MESERB**



MONTANA
Adopted Standards: DEQ-12A

Ecoregion (III) Based Nutrient Criteria

In-Stream Concentration Based Standards for Wadeable Streams and Rivers

Level III Ecoregion	Period When Criteria Apply	Nutrient Criteria	
		Total P (µg/L)	Total N (µg/L)
Northern Rockies	July 1 – Sept. 30	25	275
Canadian Rockies	July 1 – Sept. 30	25	325
Middle Rockies	July 1 – Sept. 30	30	300
Idaho Batholith	July 1 – Sept. 30	25	275
Northwestern Glaciated Plains	June 16 – Sept. 30	110	1,300
Northwestern Great Plains, WY Basin	July 1 – Sept. 30	150	1,300

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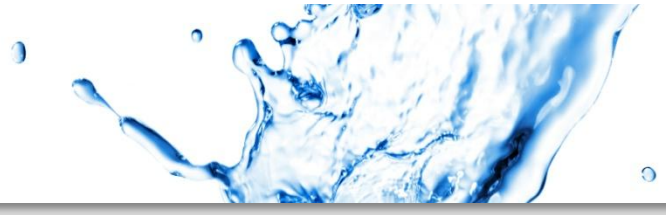
DEQ-12A; Ecoregion Level iV not shown.

MONTANA
Adopted Standards: DEQ-12A

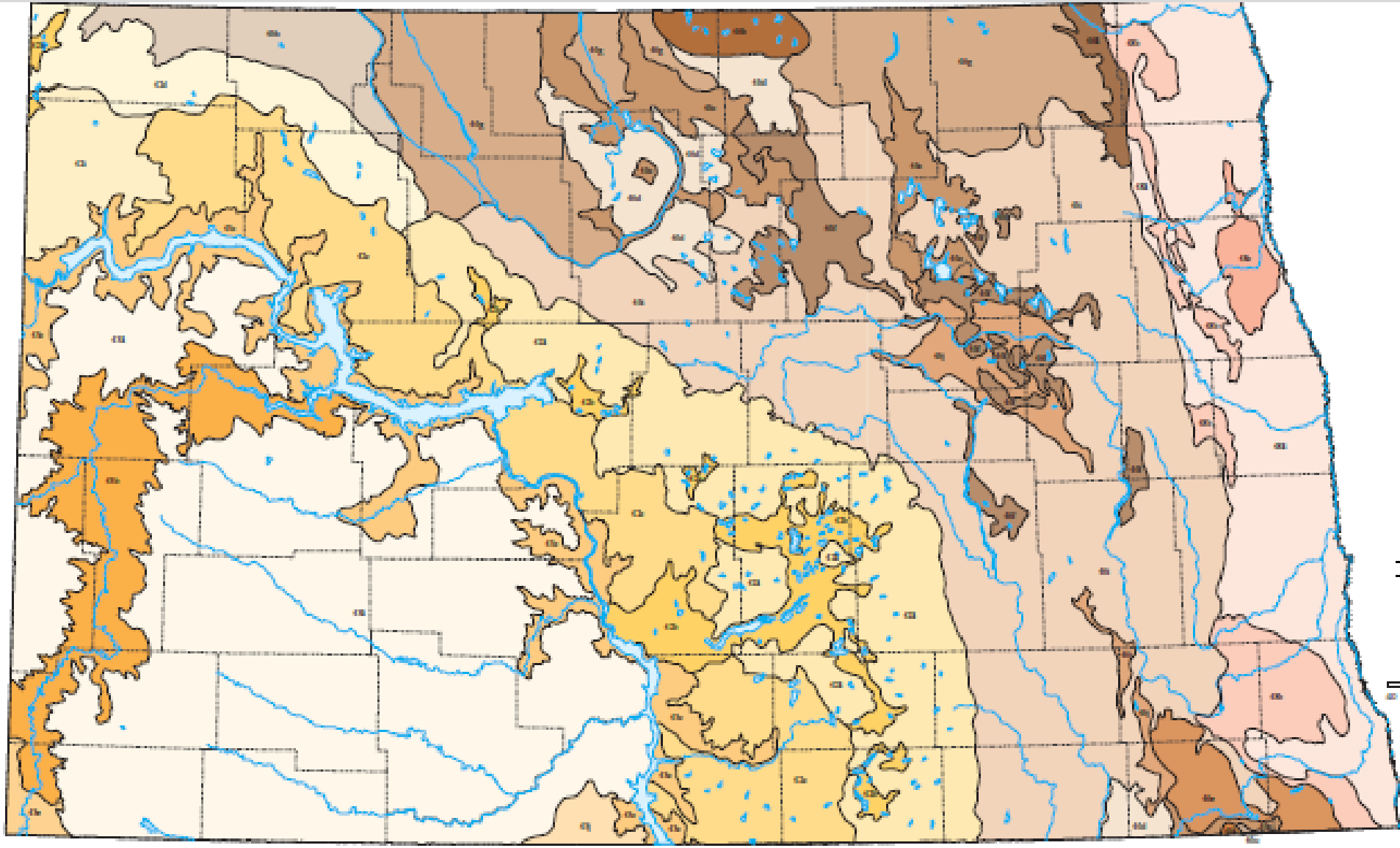
- Large Rivers
- Individual Streams
- Eco-Region Level IV (fine detail) and Level III
  - *Background Concentration statistics*
    - *Permit writer discretion*

Flow: Seasonal 14Q5 with 100-percent mixing

Annual 7Q10 with 10-percent mixing



LEVEL IV ECO-REGION MAP



STANDARDS IN PERSPECTIVE

	Phosphorus	Nitrogen
In-Stream Standard, ug/L	25 to 150	275 to 1,300
Limits of Technology, ug/L	<70	<4,000
BNR effluent, ug/L	200 to 800	5,000 to 8,000
"Normal" effluent, ug/L	2,000 to 4,000	20,000 to 30,000
Raw wastewater, ug/L	5,000 to 8,000	30,000 to 45,000
Raw wastewater, mg/L	5 to 8	30 to 45

CAN'T MEET THE LIMIT?

Get a Variance (MT)

Montana Nutrient Standards
VARIANCES

The Details

Recognition that limits are unattainable

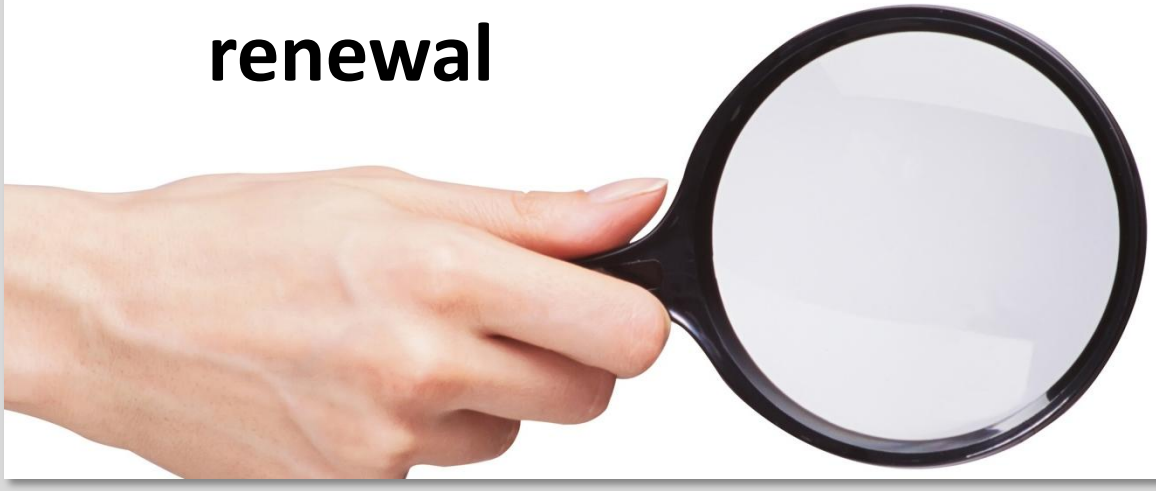
MT-DEQ 12B

General and Individual Variances

Montana Nutrient Standards
VARIANCES

The Details – General Variance

- Up to 20 years (plus compliance schedules)
- Reviewed every three years
- Changes at permit renewal



Montana Nutrient Standards
VARIANCES

The Details – General Variance

- End-of-Pipe "TBEL"
- Set through May 2016
- May preclude TMDLs
- Optimization study required

	Monthly Average	
Discharger Category	TP, ug/L	TN, ug/L
≥ 1.0 MGD	1,000	10,000
< 1.0 MGD	2,000	15,000
Lagoons not designed to actively remove nutrients	Maintain Current Performance	

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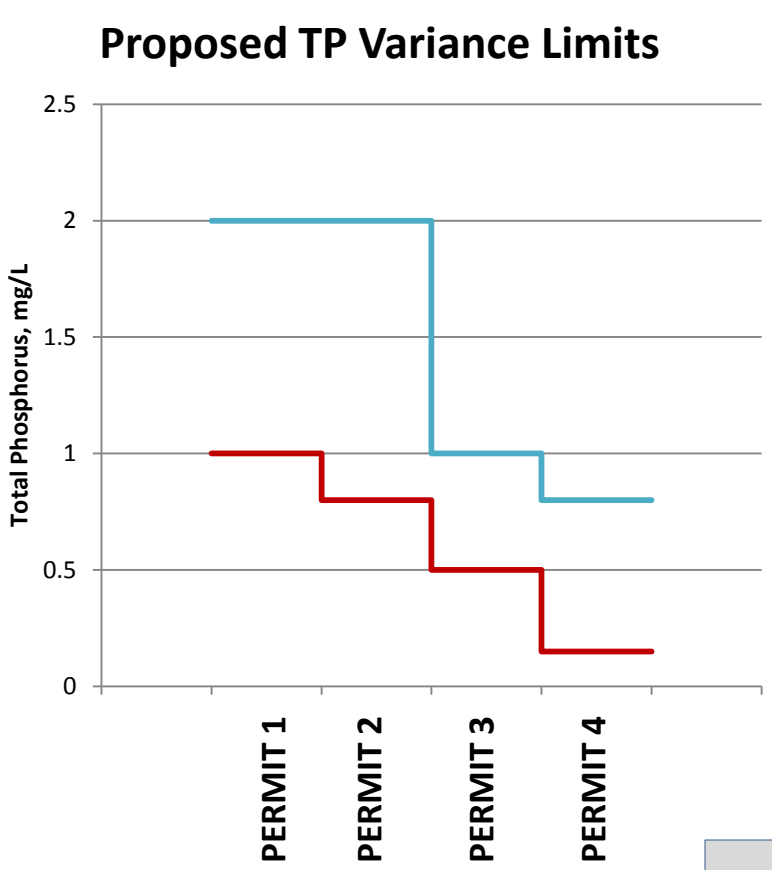
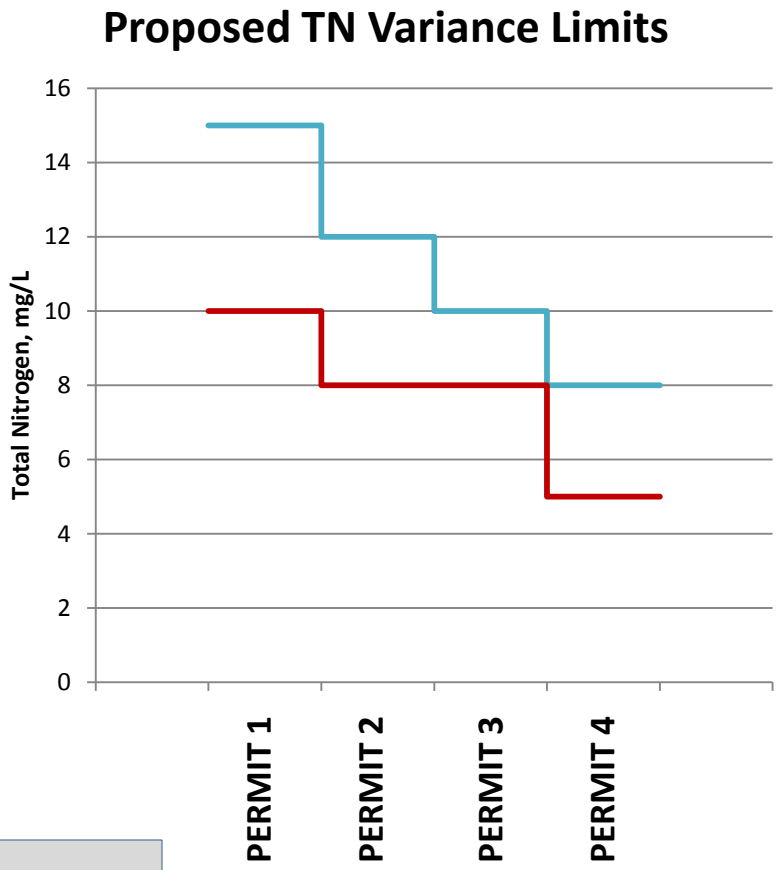
TREATMENT CONSIDERATION SUMMARY FOR NUTRIENT LIMITS





Small Facility
Large Facility

WHAT DOES IT ALL MEAN?

LAGOONS

- Restore & Maintain Performance
- Avoid July-September discharges?
- Stream data
- Start thinking about trading
- Optimization Study
- Next Permit: Implement BMPs from Optimization Study

MECHANICAL SYSTEMS

- Optimization
- Stream data
- Move discharge?
- Start thinking about trading
- Get ready for changes

TN AND TP TRANSFORMATIONS

Atmosphere

Organic Nitrogen → Ammonia → Nitrate → Nitrogen Gas

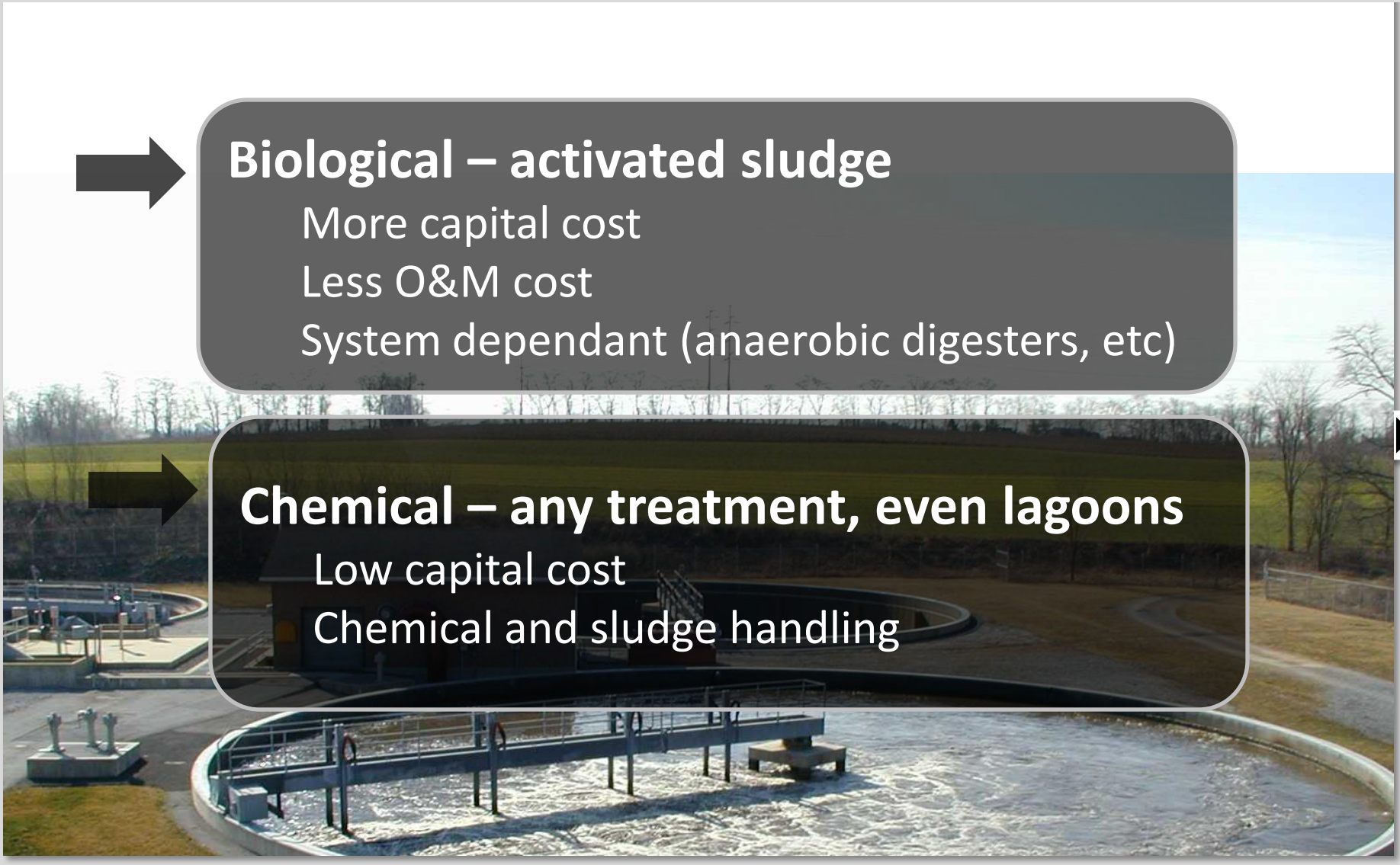
Input: Oxygen

Input: Carbon Source

Particulate and Dissolved Phosphorus → Particulate Phosphorus → **Solids Removal = TP Removal**

Input: Chemical (or PAO)

TOTAL PHOSPHORUS REMOVAL



Biological – activated sludge

- More capital cost
- Less O&M cost
- System dependant (anaerobic digesters, etc)

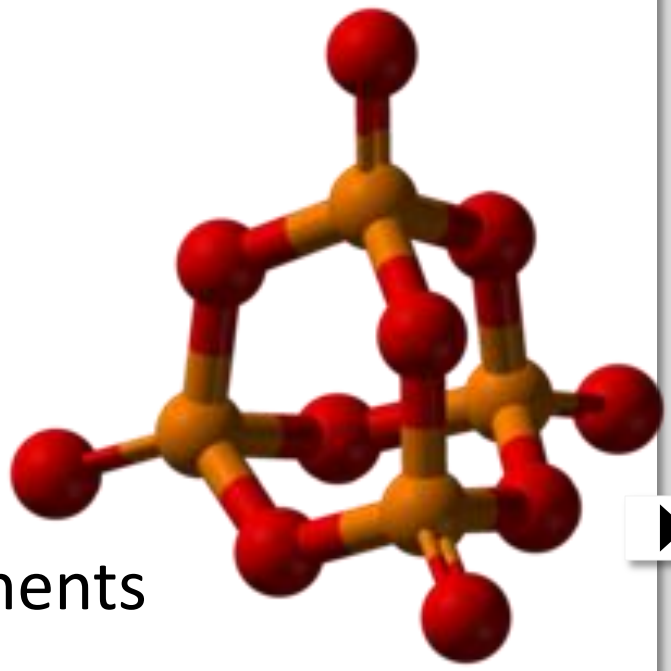
Chemical – any treatment, even lagoons

- Low capital cost
- Chemical and sludge handling

TOTAL PHOSPHORUS REMOVAL

1 mg/L

➡ Bio-P or Chem-P



<1 mg/L

➡ Bio-P or Chem-P with improvements

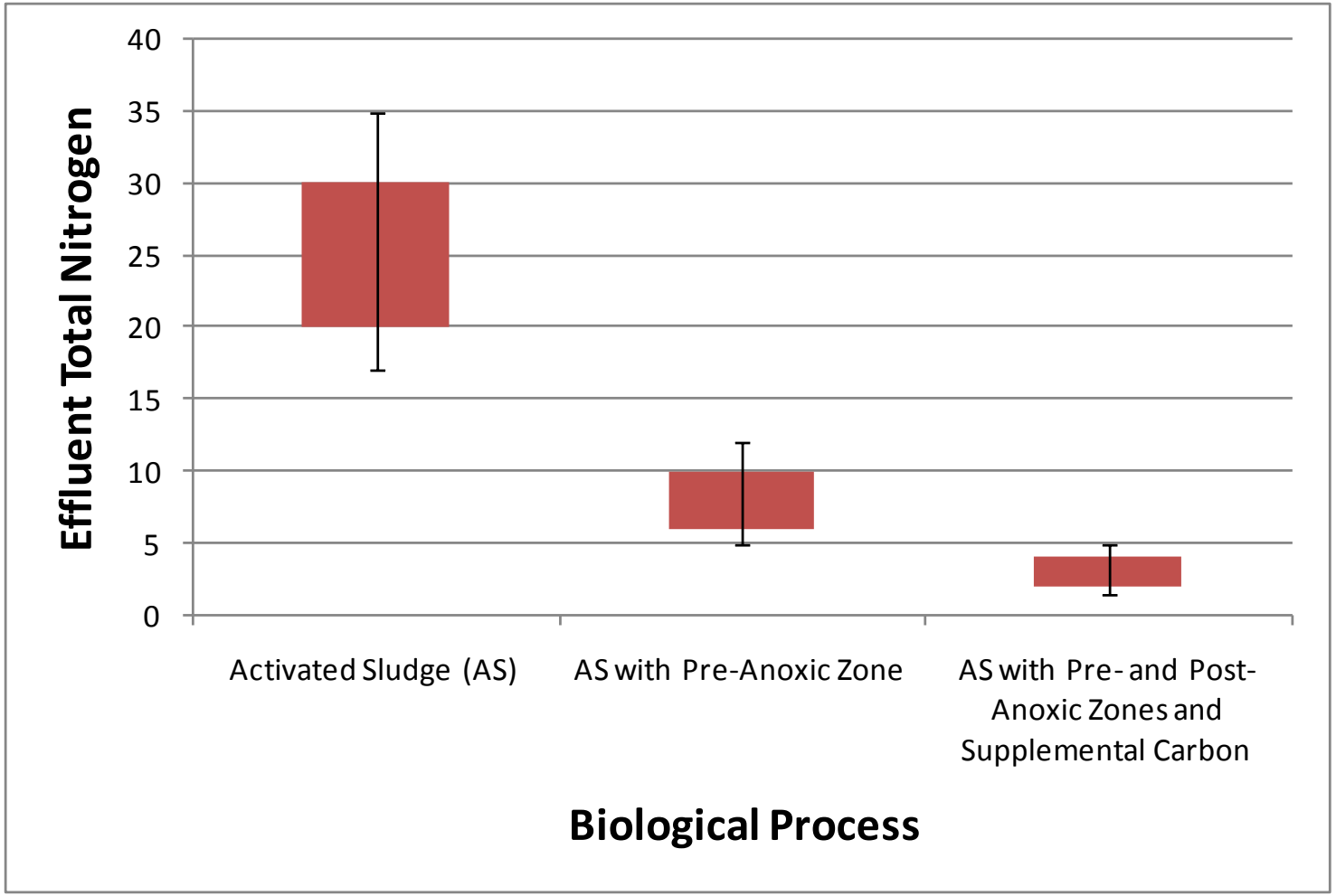
<0.1 mg/L

➡ Add a water treatment plant on the back end!

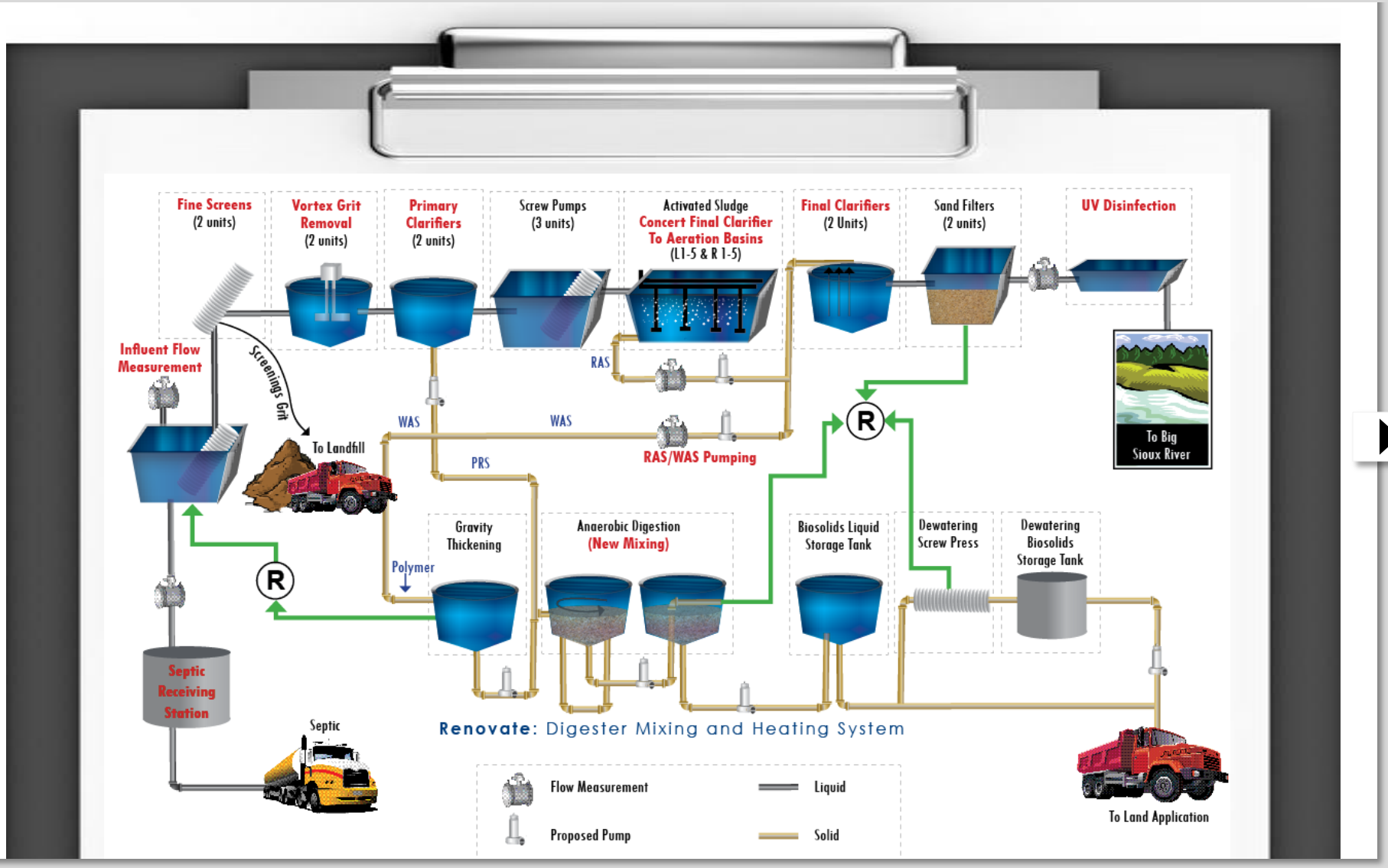
TOTAL NITROGEN REMOVAL

- **Air stripping with pH adjustment – not used**
- **Ion Exchange – not used**
- **Biological**
  - Mechanical plant or “special” ponds
  - Nitrification/denitrification
  - Activated sludge
  - Denitrification filters

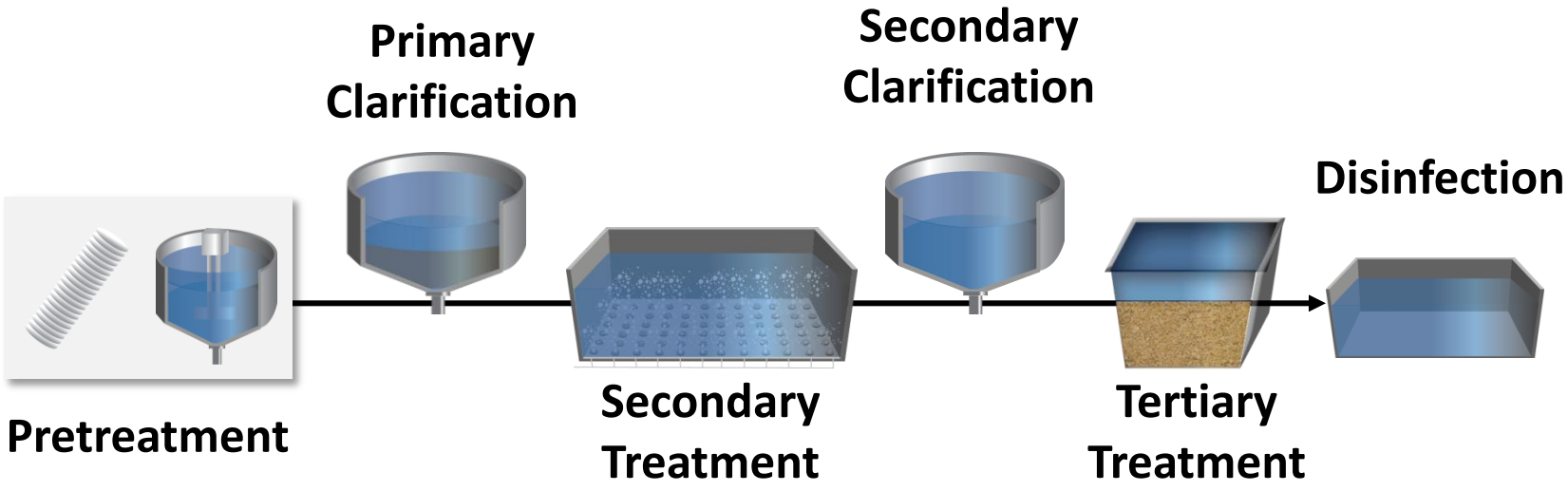
TOTAL NITROGEN REMOVAL

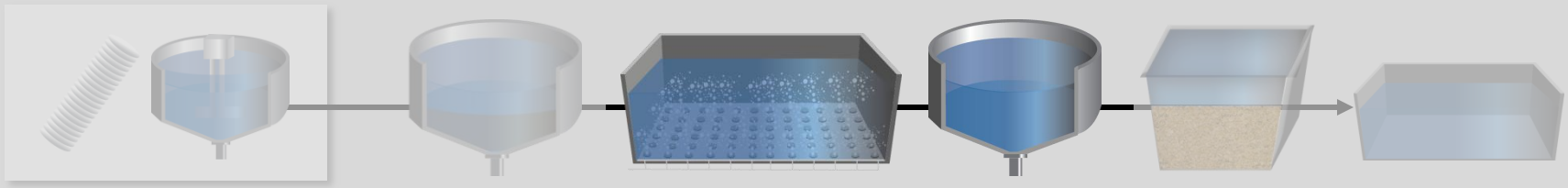


COMPLEX SYSTEMS!



SIMPLIFIED PROCESS FLOW





SECONDARY TREATMENT

Secondary Treatment is Biological

Water + Oxygen + Bugs = Secondary Treatment

Suspended Growth (Activated Sludge)

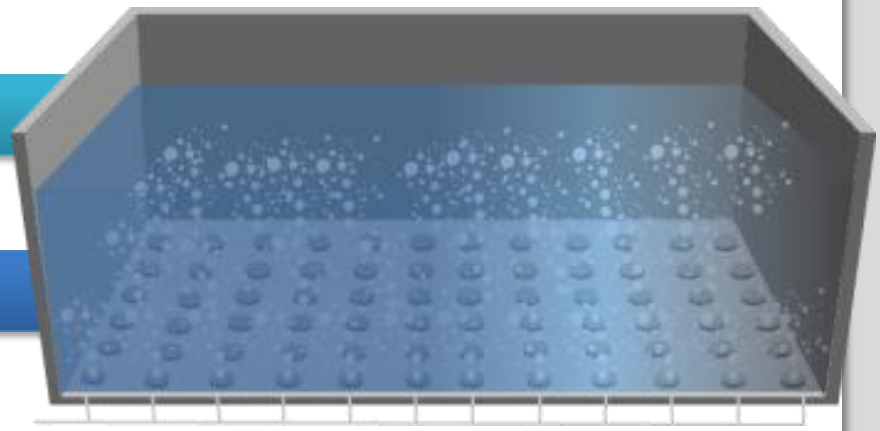
- Aeration Basin with Final Clarifiers
- SBR
- MBR

Attached Growth (Fixed Film)

- Tricking Filters, RBC, MBBR

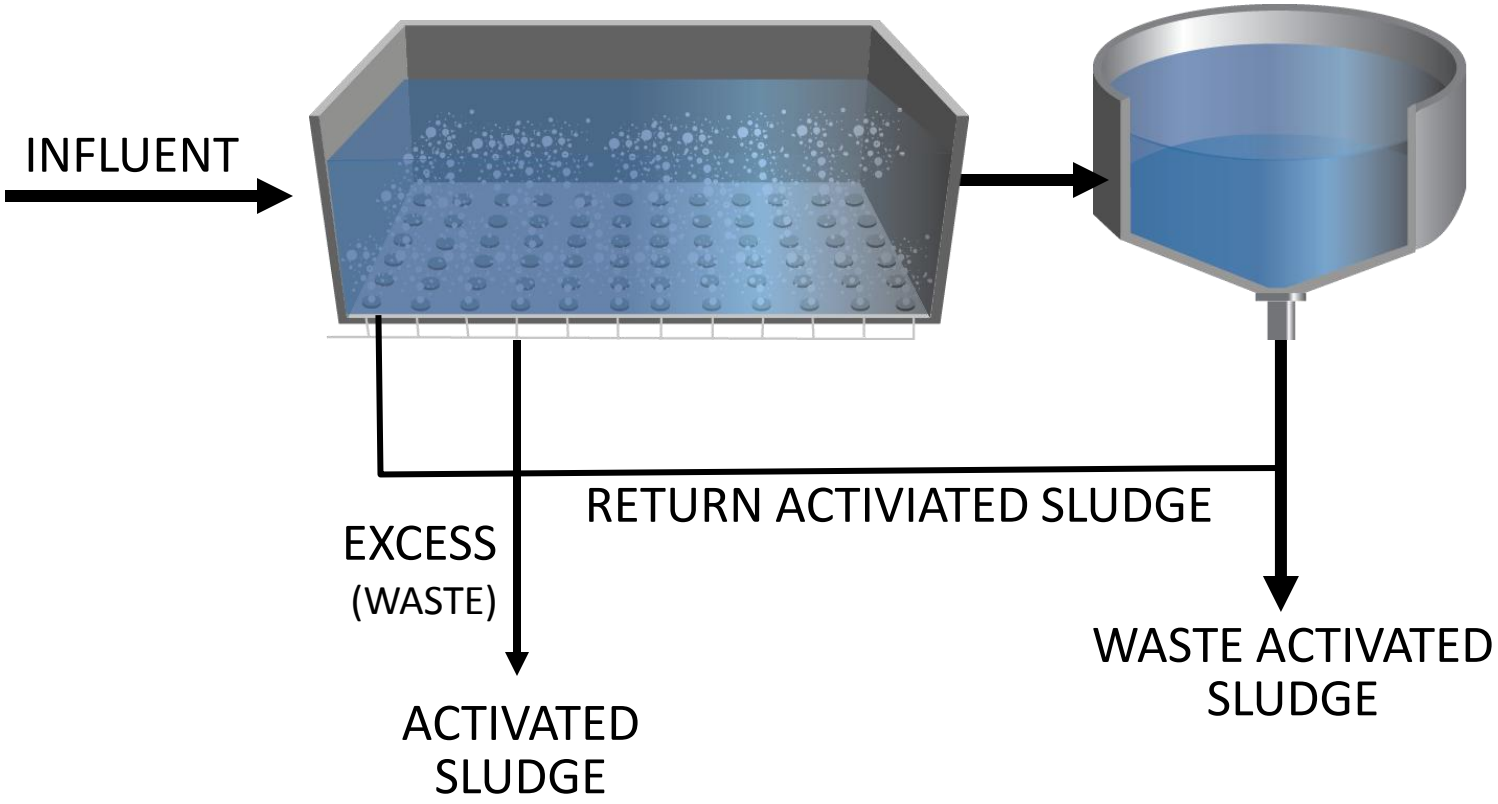
Hybrids

- IFAS

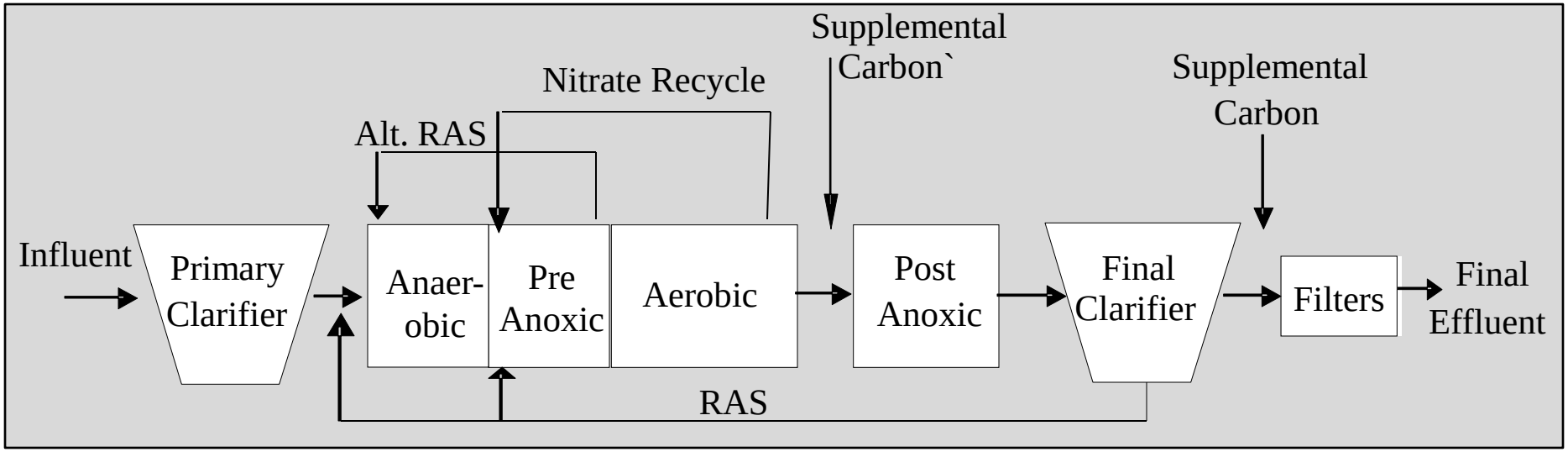


ACTIVATED SLUDGE

Conventional Activated Sludge



BNR IN MANY FLAVORS



Variations

- 4- or 5-Stage Bardenpho
- Modified Ludzack-Ettinger
- University of Cape Town
- A^2/O
- Johannesburg
- Virginia Institute Plant
- Sidestream treatments
- Others

ACTIVATED SLUDGE

High Purity Oxygen

- Oxygen concentrator
- Mixers in aeration basin

Image courtesy of PCI

ACTIVATED SLUDGE

Oxidation Ditches

- **Similar to conventional AS but different aeration**
  - Brush Aerators
  - Turbine Aerators

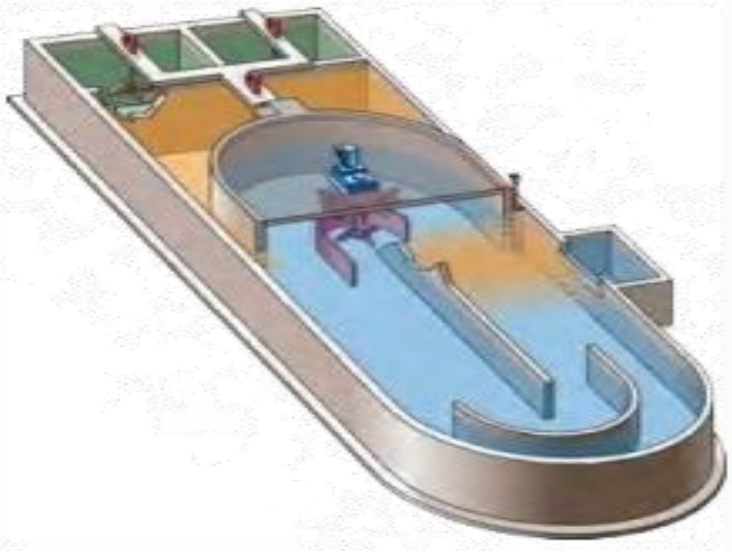
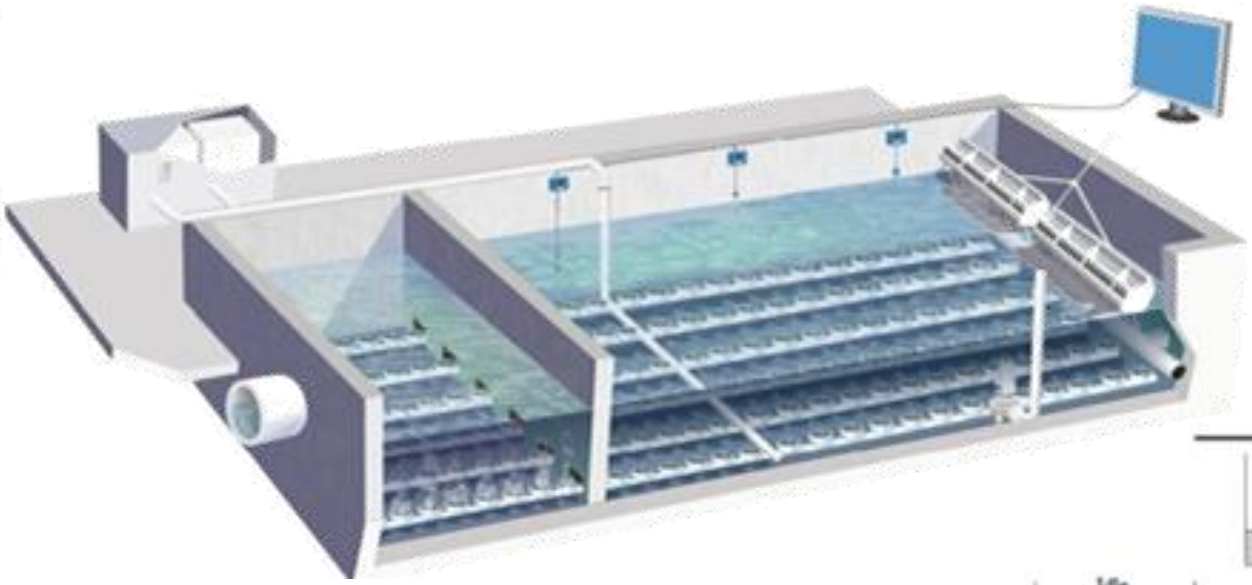


Image courtesy of Smith and Loveless; and Ovivo

ACTIVATED SLUDGE

Sequencing Batch Reactor (SBR)



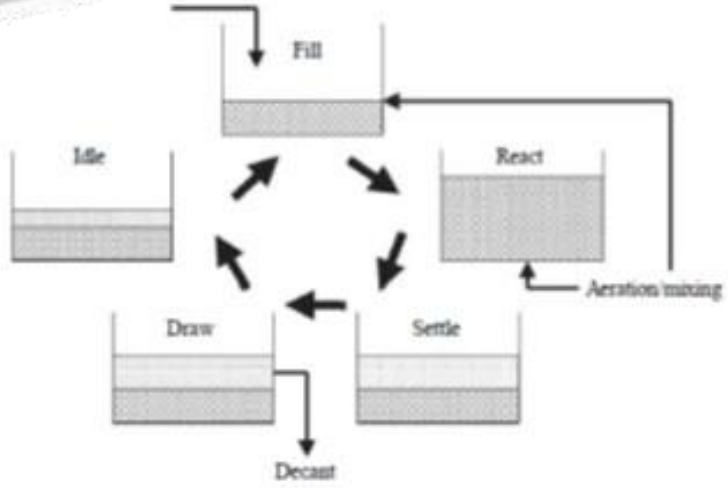


Image courtesy of Sanitaire

ACTIVATED SLUDGE

Membrane Bioreactor (MBR)

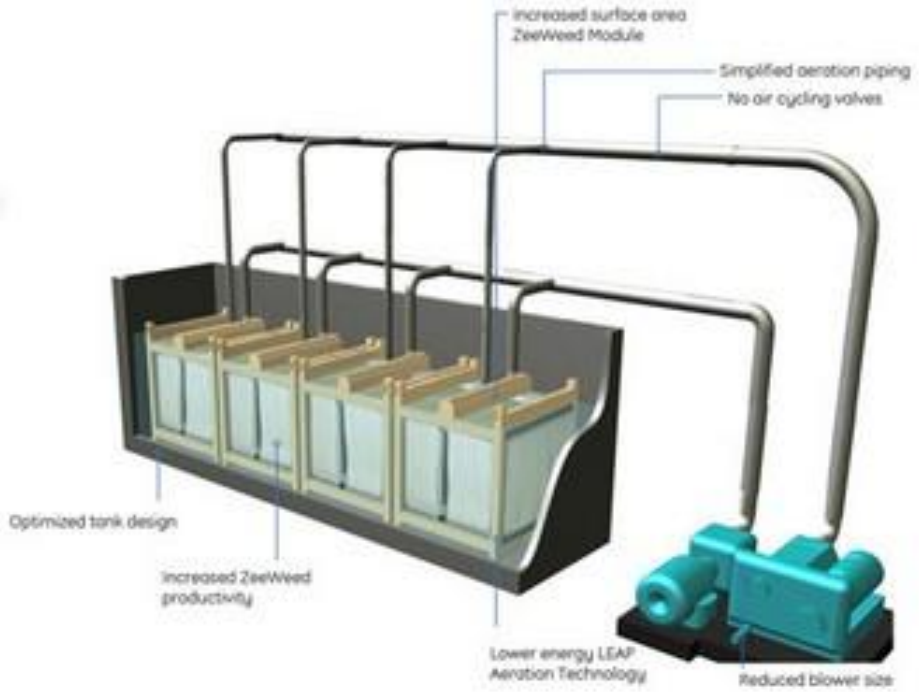
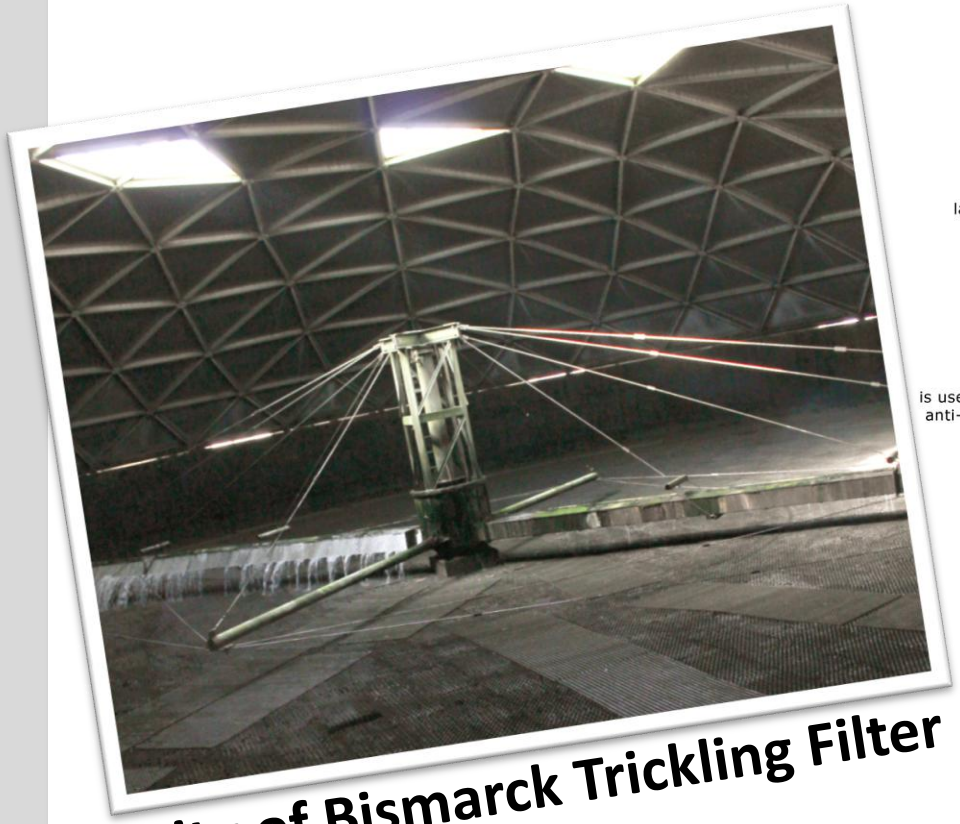


Image courtesy of Ovivo; GE

ATTACHED GROWTH

Trickling Filter



City of Bismarck Trickling Filter

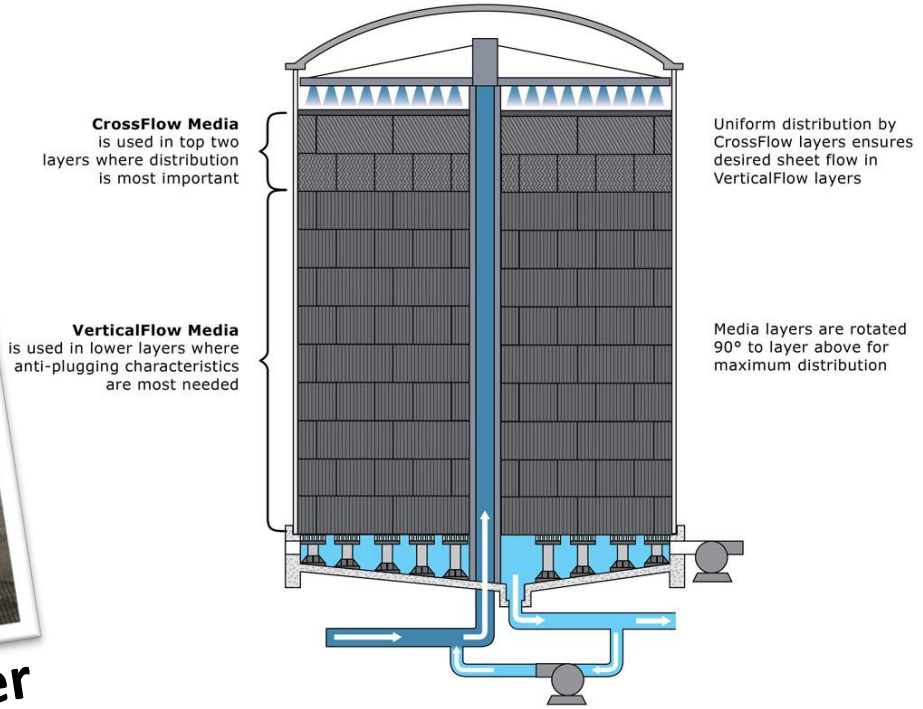


Image courtesy of Brentwood Industries

ATTACHED GROWTH

Rotating Biological Contactors (RBC)

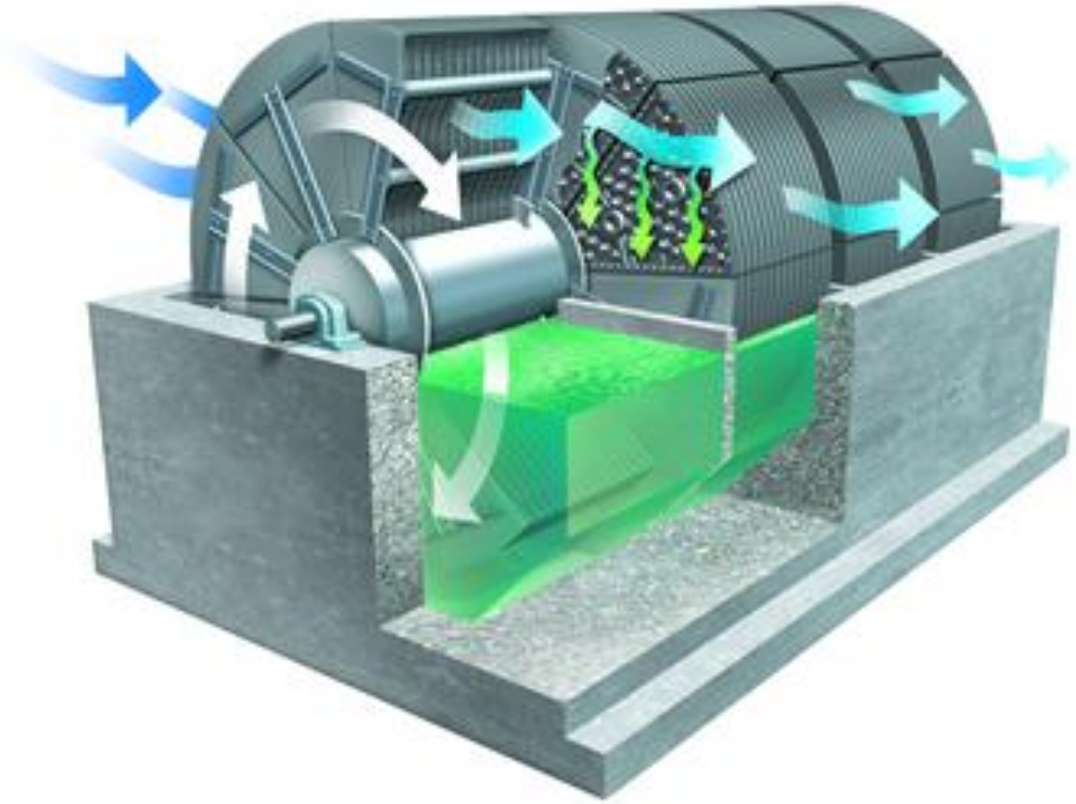


Image courtesy of Walker Process Equipment

ATTACHED GROWTH

Moving Bed BioReactor (MBBR)

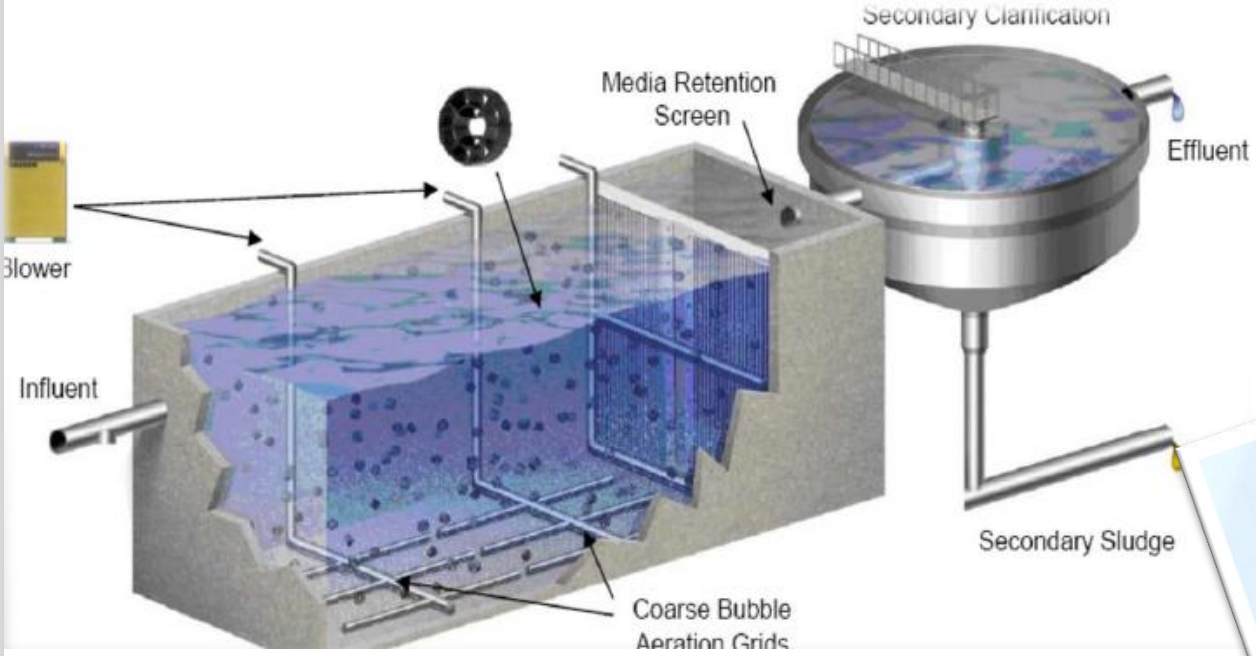
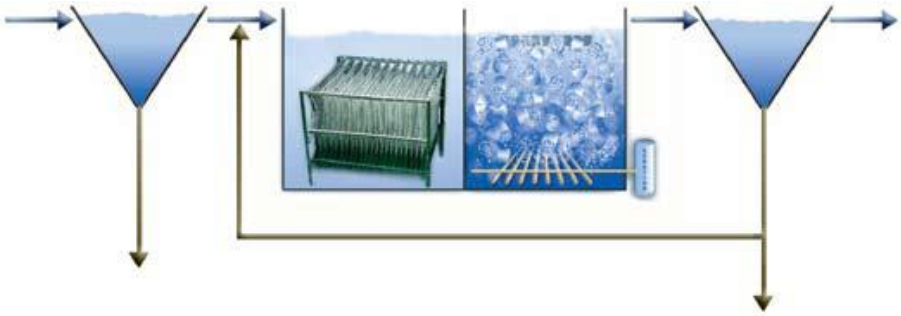


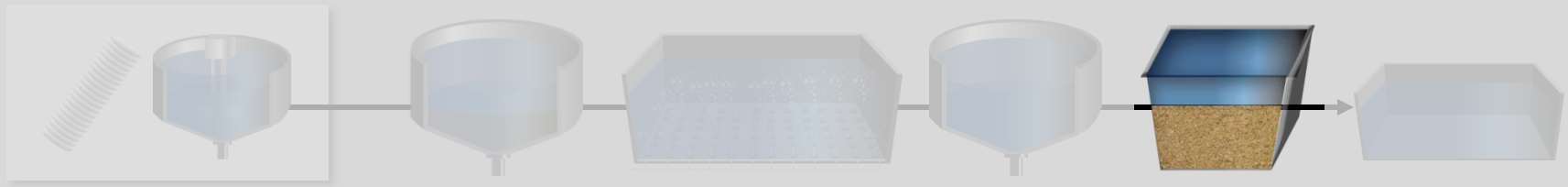
Image courtesy of World Water Works

HYBRIDS

Integrated Fixed-Film Activated Sludge (IFAS)



Images courtesy of Entex

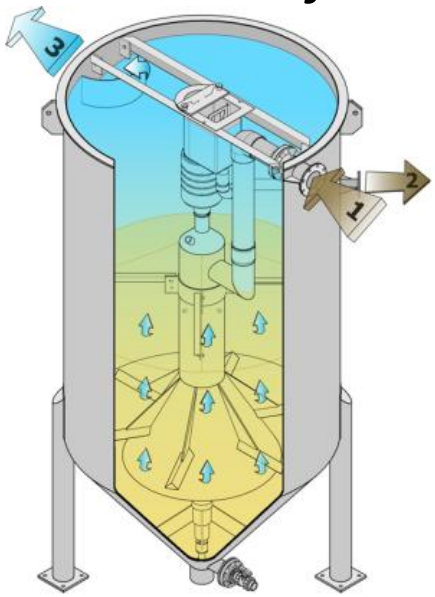


TERTIARY TREATMENT

(Advanced Treatment)

Upflow Sand Filter

Optional Denitrification



Cloth Media Filter

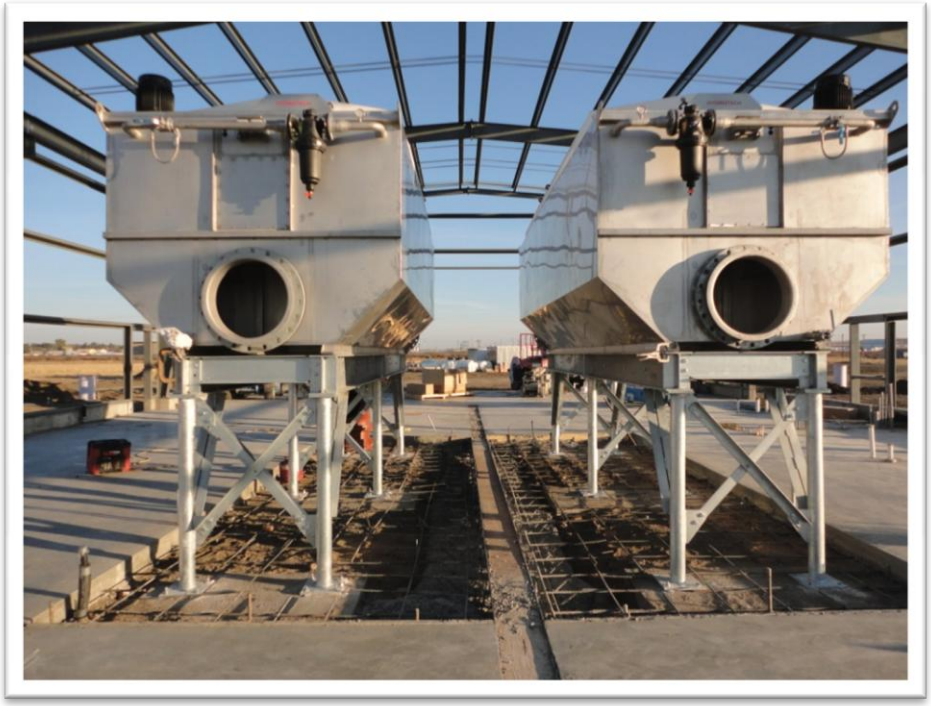


Image Courtesy of Bluewater Technologies

RECYCLE STREAMS

- **Backwash**
- **Solids Thickening**
- **Digester Decant**
  - Aerobic vs Anaerobic
- **Dewatering Supernatant**
- **Issues**
  - Alkalinity
  - BOD:TP ratios

RECYCLE STREAMS

TREATMENT

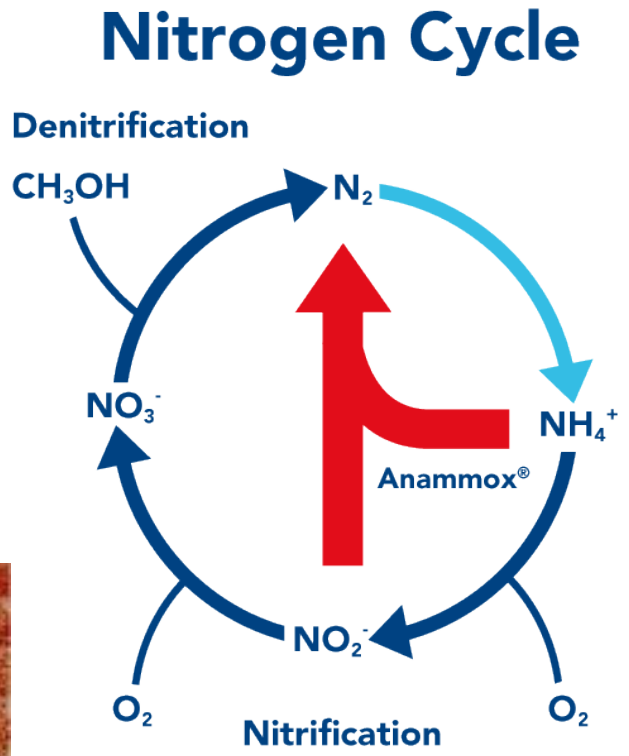
Struvite Harvesting

- Ammonia, Phosphate, Magnesium

RECYCLE STREAMS

TREATMENT

- **Short-Cut Nitrogen**
- **Anammox**
  - Temperature
  - Concentrations
  - Controls



Images Courtesy of World Water Works and Paques

RELATIVE COSTS

Level	Total Project Costs ($/gpd)	Operations Cost ($/MG Treated) *
1 (No N/P Removal)	7.9	190
2 (8 mg/L N; 1 mg/L P)	13.5	340
3 (4-8 mg/L N; 0.1-0.3 mg/L P)	14.4	510
4 (3 mg/L N; <0.1 mg/L P)	16.9	690
5 (2 mg/L N; <0.05 mg/L P)	21.6	1,180

Notes:

- *WERF, A. Pramanik*
- Based on 10 MGD
- Total project costs are equipment, construction, and “soft” costs
- Operations cost = energy and chemical cost; labor and maintenance are excluded

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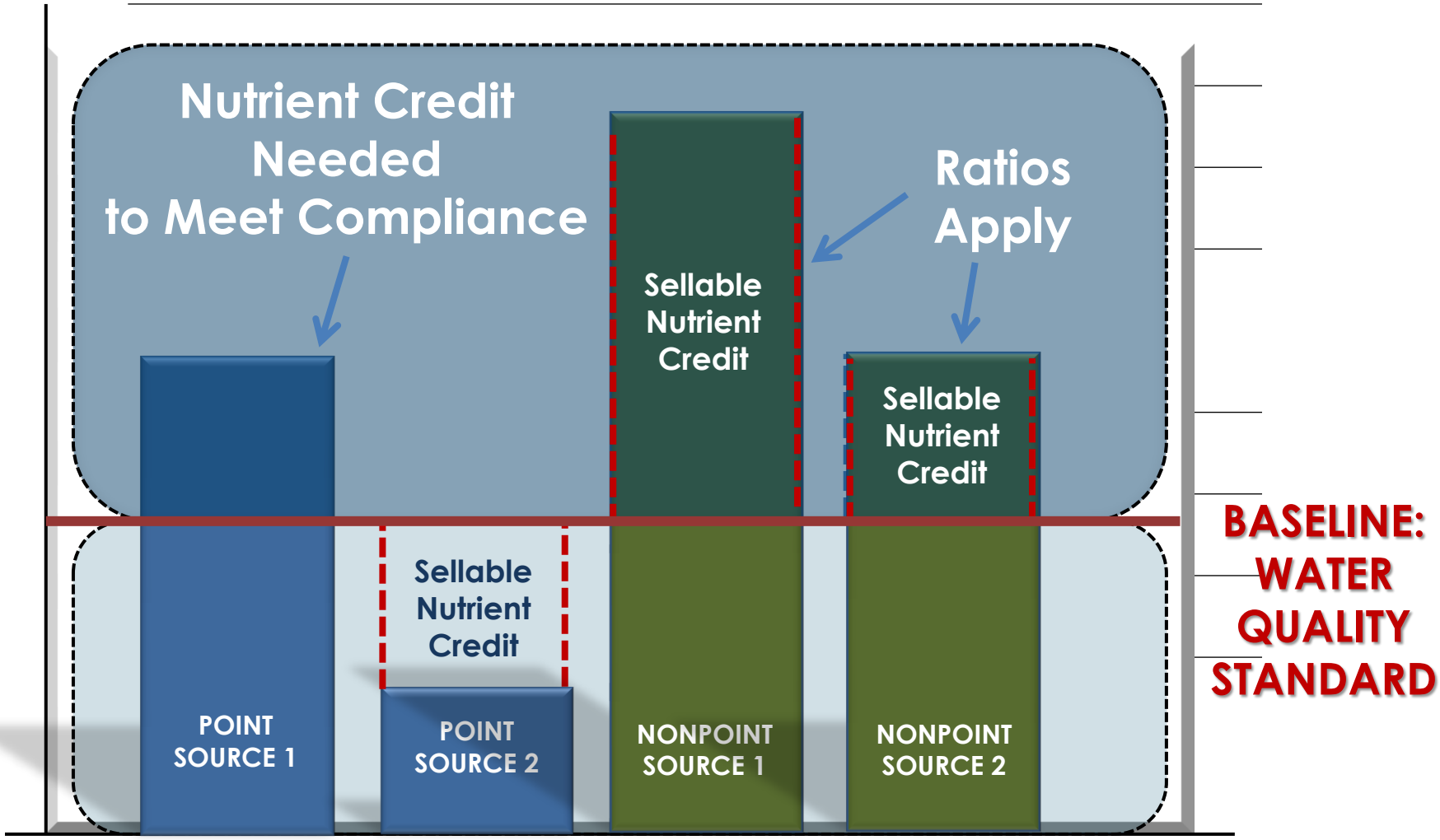
NUTRIENT TRADING BASICS



CONCLUSIONS

Nutrient Standards adopted in MN/MT

Variances will soften the impact

Options for ponds

More mechanical systems

Financial impacts

Trading will help

QUESTIONS