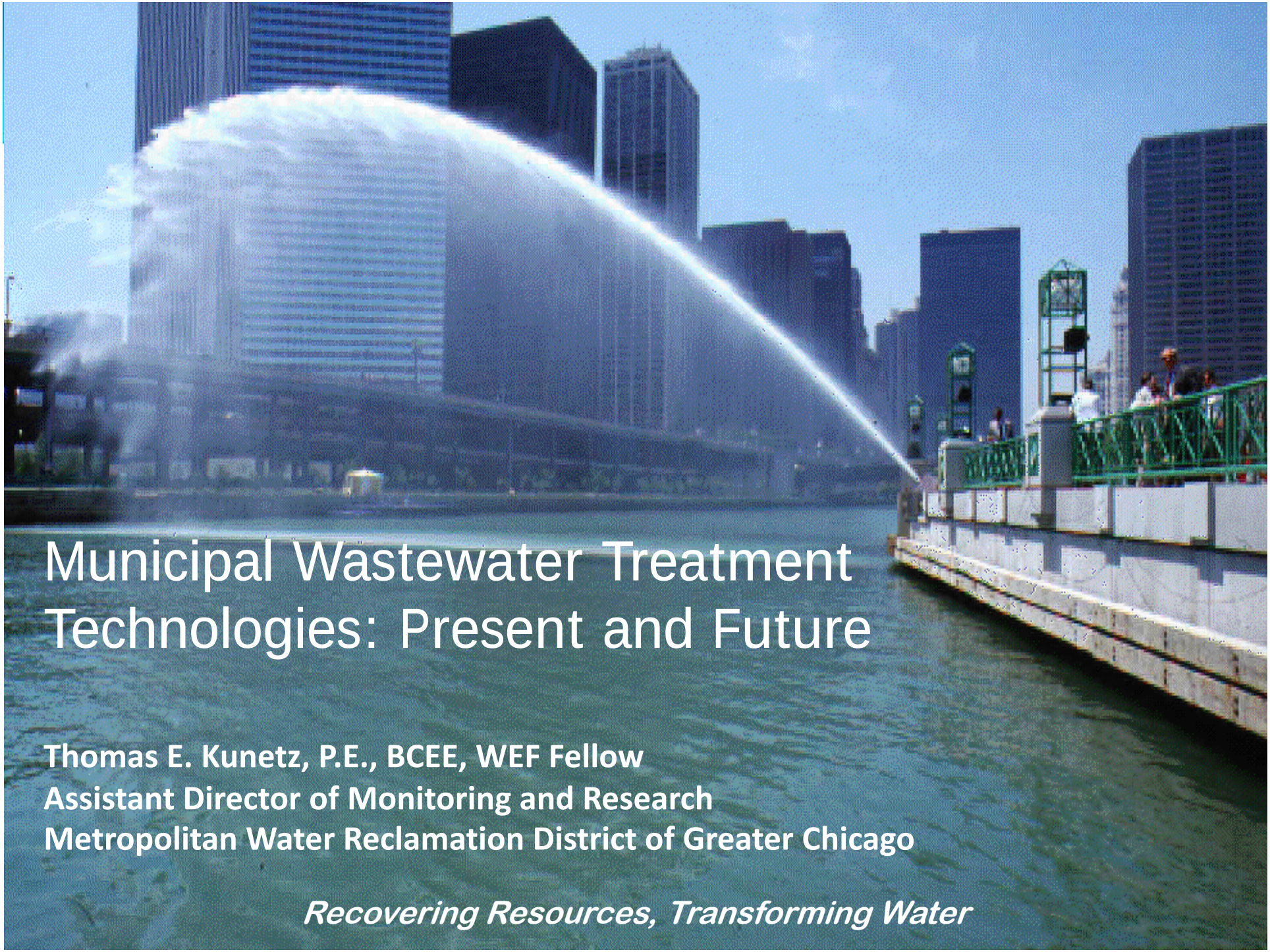


# Municipal Wastewater Treatment Technologies: Present and Future

**Thomas E. Kunetz, P.E., BCEE, WEF Fellow**
**Assistant Director of Monitoring and Research**
**Metropolitan Water Reclamation District of Greater Chicago**

*Recovering Resources, Transforming Water*

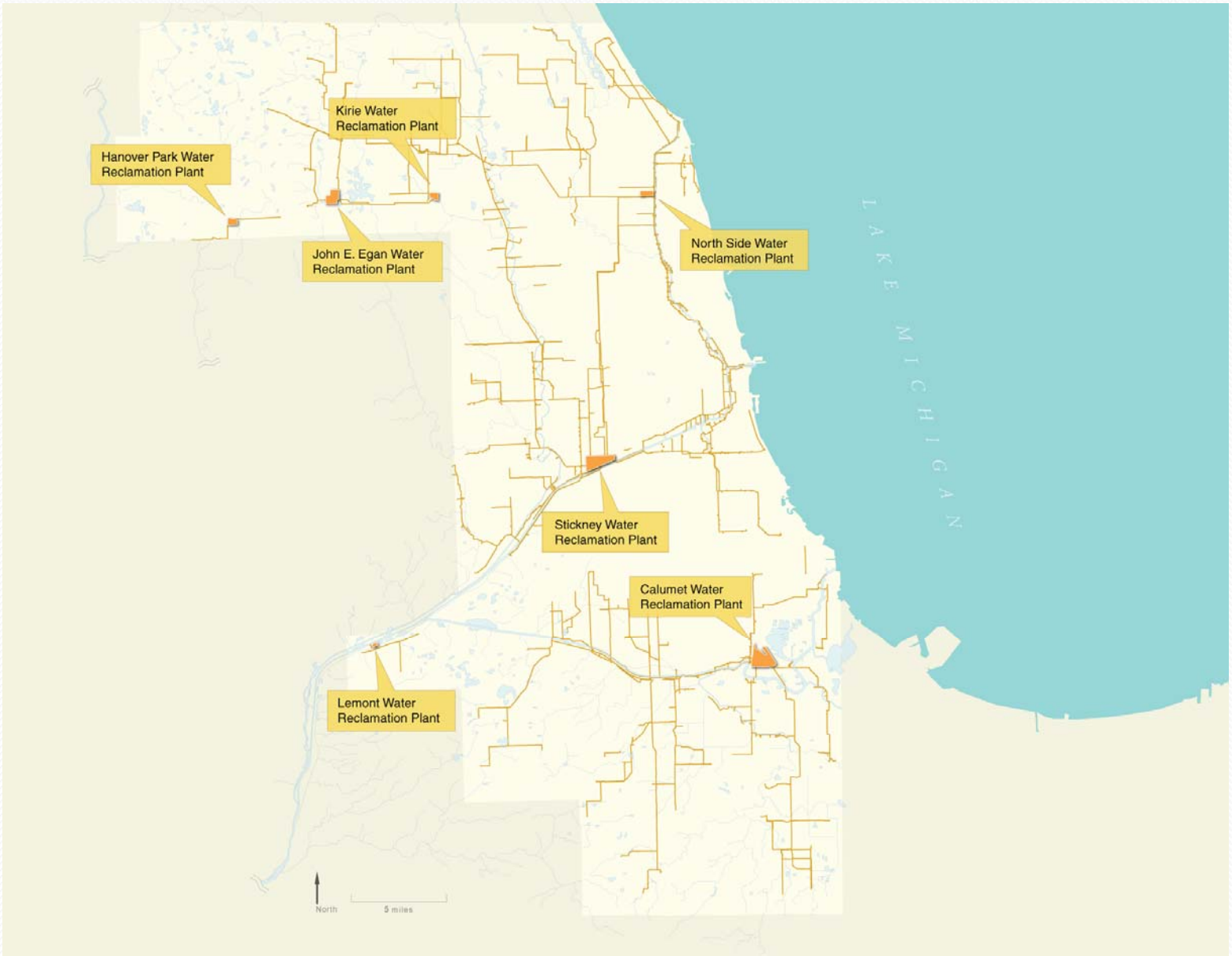
# Metropolitan Water Reclamation District of Greater Chicago

- Independent government and taxing body
- Treatment of wastewater from 125 municipalities plus city of Chicago
- Collection is done by local municipalities
- Stormwater management for Cook County
- TARP system for pollution and flood control

# Metropolitan Water Reclamation District of Greater Chicago

| | |
|---|---|
| Real population served | 5.25 million |
| Equivalent Commercial and Industrial population served | 4.5 million |
| Combined Sewer Overflow Equivalent Population | 0.6 million |

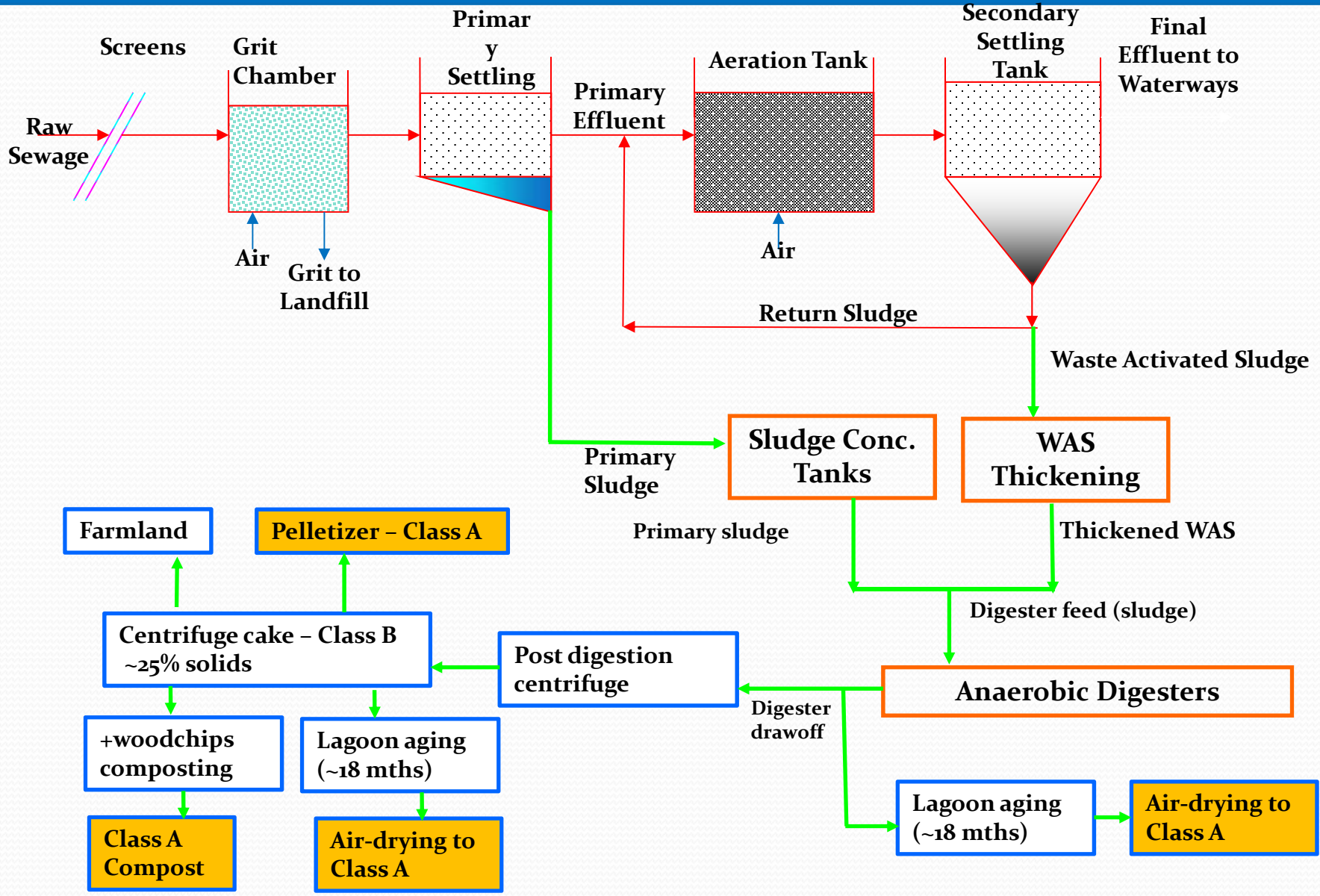
# MWRD Intercepting Sewers and Water Reclamation Plants

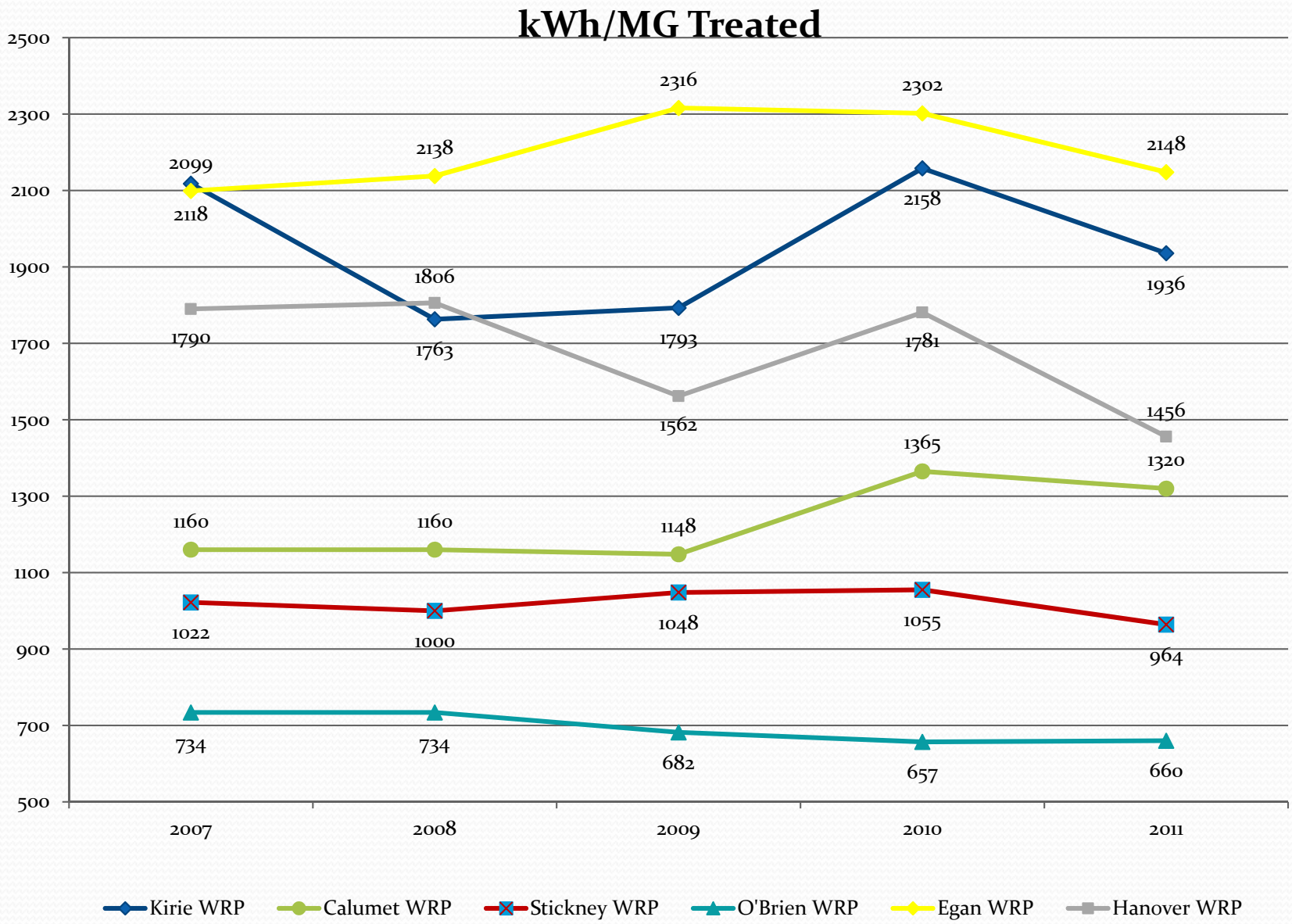


# MWRD Water Reclamation Plants

| Water Reclamation Plant | Design Capacity (MGD) | Design Capacity ($M^3$/day) |
|---|---|---|
| Stickney | 1,200 | 4,542,000 |
| Calumet | 354 | 1,340,000 |
| O'Brien | 333 | 1,260,000 |
| Kirie | 52 | 196,000 |
| Egan | 30 | 113,000 |
| Hanover Park | 12 | 45,000 |
| Lemont | 2.3 | 8,700 |

# Schematic of MWRD Stickney WRP Treatment Process




kWh/MG Treated
2500
2300
2100
1900
1700
1500
1300
1100
900
700
500
2007
2008
2009
2010
2011
2099
2118
2138
2316
2302
2148
2158
1936
1806
1790
1763
1793
1781
1562
1456
1320
1365
1160
1160
1148
1022
1000
1048
1055
964
734
734
682
657
660
Kirie WRP
Calumet WRP
Stickney WRP
O'Brien WRP
Egan WRP
Hanover WRP

# Current Regulatory, Operational and Public Relations Challenges

## Regulatory Requirements

- Disinfection
  - WRP effluents - Fecal coliforms – monthly geometric mean 200 CFU/mL
  - Combined sewer overflows
- Biosolids pathogen reduction – Class A standards for beneficial reuse
  - Fecal coliform <1,000 MPN/g,
  - Helminth ova <1/4g,
  - Enteric virus <1 PFU/4g
- Nutrient removal & recovery– Effluent P discharge limits
  - Current – 1 mg/L total P
  - Future – 0.5 mg/L total P

# Current Regulatory, Operational and Public Challenges

**Public Concerns**

- Emerging Contaminants (EC) – pharmaceutical and personal care products (PPCPs), endocrine disrupting compounds (EDCs) etc.
- Odor emissions – within and outside of treatment plants

**Operations**

- Energy Neutrality
  -- Decrease energy consumption
  – Increase biogas utilization
  -- Increase biogas production
  -- Biosolids to fuel

# Conventional and Current Technologies
## Phosphorus Recovery

| Sludge Liquor | Pre or Post Digested Sludge |
|---|---|
| Pearl® | AirPrex® |
| Crystalactor® | NuReSys® |
| Multiform Harvest (MFH) | CalPrex™ |
| Phospaq™ | Quick Wash™ |
| Phosnix® | ANPHOS® |
| Quick Wash™ | Phosnix® |
| Struvia™ | |
| NuReSys® | |

# Phosphorus Recovery

- Produce Struvite (Magnesium ammonium phosphate)
- Process removes 80-85% of the Phosphorus that enters the treatment plant
- Can generate up to 9,000 metric tons per year of product

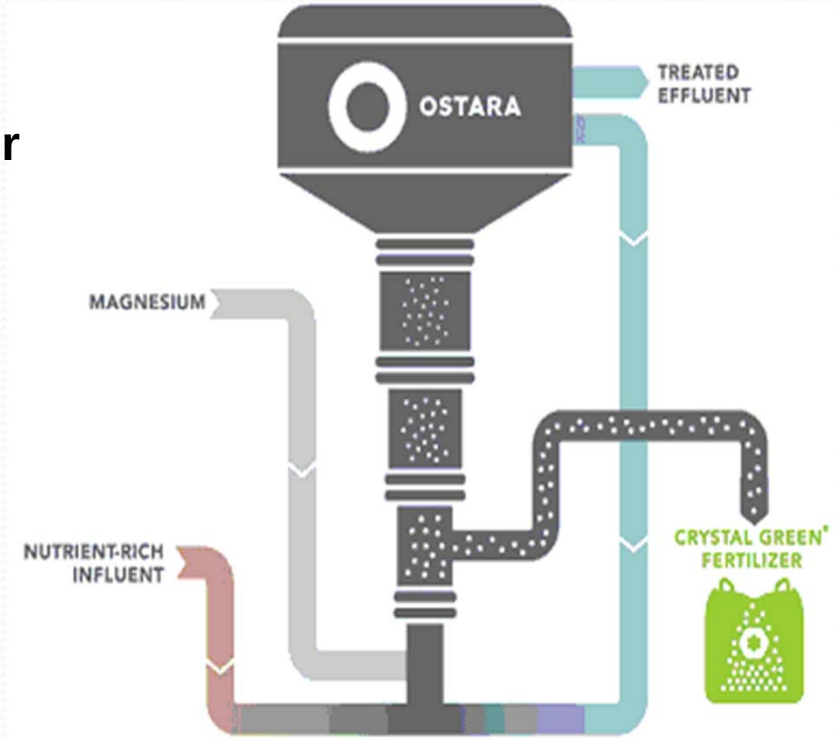
OSTARA
Creating Value from Waste

# Conventional and Current Technologies
## Phosphorus Recovery

## Pearl®

- **Input Stream:** Sludge Liquor
- **Type of Reactor:** Fluidized Bed Reactor
- **Reagents:** $MgCl_2$, NaOH
- **Influent Quality:** >75 mg/L ortho-P
  <1,000 mg/L SS
- **Product:** Struvite Pellets
- **Recovered**
- **Removal Efficiency :** 80-90 % P

- **Ostara installation at Stickney WRP**

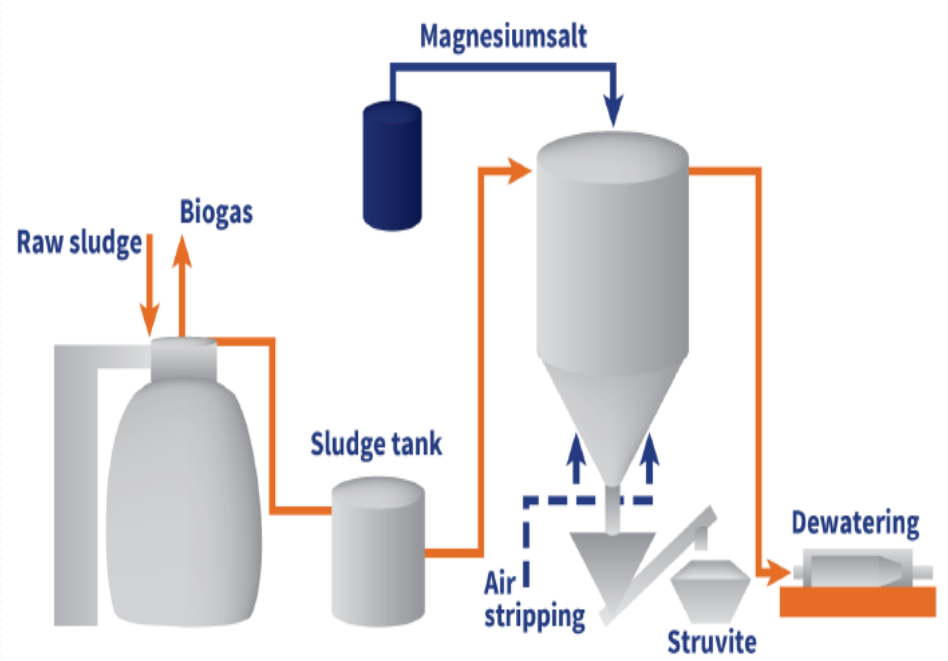



Pearl® Reactor

# Conventional and Current Technologies
## Phosphorus Recovery

## Airprex

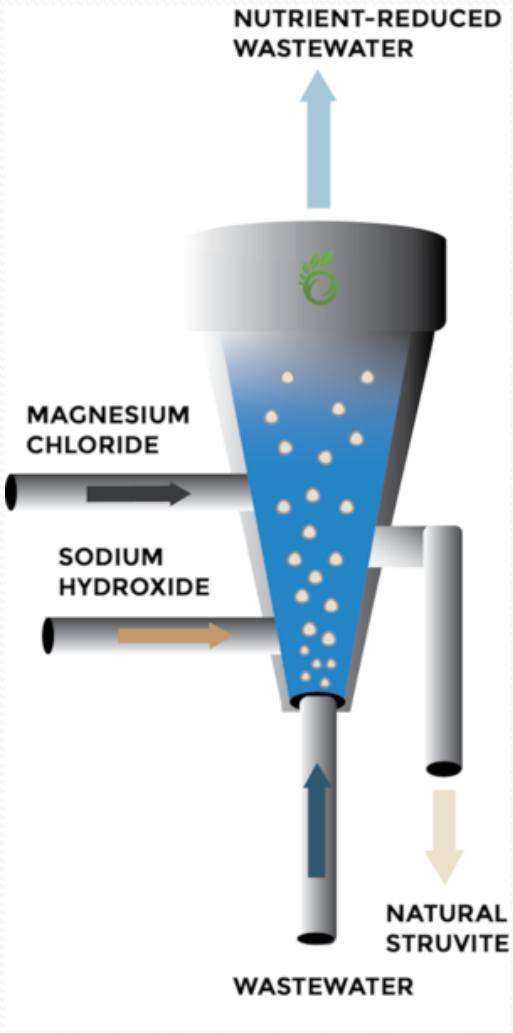
- **Input Stream: Digested Sludge**
- **Type of Reactor: Airlift Reactor**
- **Reagents: $MgCl_2$, Air**
- **Influent Quality: >50 mg/L ortho-P**
- **Product Recovered: Struvite**
- **Removal Efficiency : >90 % P**



# Conventional and Current Technologies
## Phosphorus Recovery

### Multiform™ Harvest

- **Input Stream: Digested Sludge**
- **Type of Reactor: Upflow Reactor**
- **Reagents: $MgCl_2$, NaOH**
- **Product Recovered: Struvite**
- **Removal Efficiency : 80-90 % P; 10- 40% $NH_3$-N**

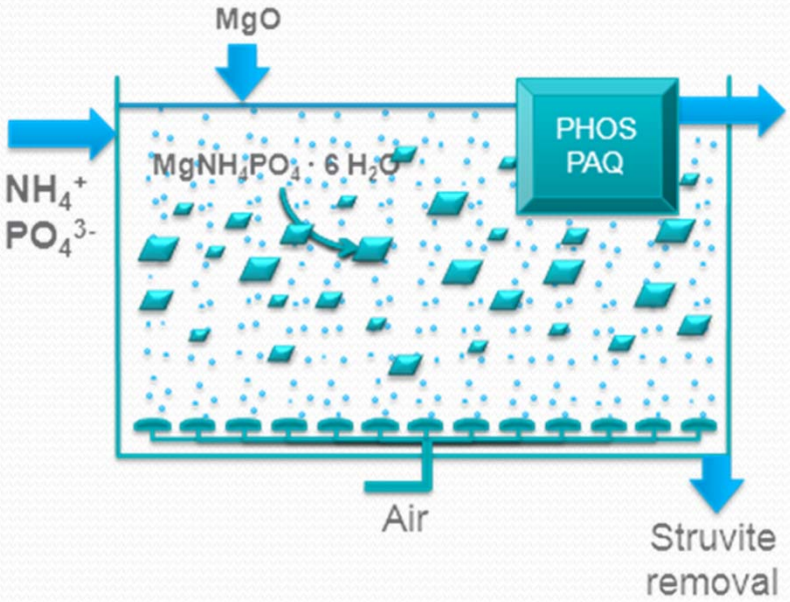



Multiform Harvest Reactor

# Conventional and Current Technologies
## Phosphorus Recovery

## Phospaq™

- **Input Stream: Sludge Liquor**
- **Type of Reactor: Continuous Stired Tank**
- **Reagents: MgO or $MgCl_2$, Air**
- **Product Recovered: Struvite**
- **Removal Efficiency : 80-90 % P; 10- 40% $NH_3$-N**




Phospaq Process

# Conventional and Current Technologies
## Disinfection

**Mature Technologies**

- Chlorination
- Chloramination
- Ozonation
- Ultraviolet Irradiation

**Practicable Tech.**

- Chlorine Dioxide
- Peracetic Acid

**Combination Tech.**

- Ultraviolet/Ozonation
- Ultraviolet/Peracetic
- Ultraviolet/Chlorination
- Ultraviolet/Peroxide
- Ozonation/Peroxide

**Emerging/Innovative Technologies**

- Bromine chemicals
- Ferrate
- Gamma/Electron Beam
- Membrane
- Microwave Irradiation
- Pasteurization
- Pulse Ultraviolet
- Quatanary Ammonium
- Tin Oxide Anodes
- TiO2/Photocatalysis
- Ultrasonic Caviation
- Zero Valent Iron

# Conventional and Current Technologies
# Disinfection

## Calumet WRP – Chlorination/Dechlorination

- DAF: 354 mgd
- Installed 2016
- Disinfection season: March – Nov.
- Chemical cost: ~$12/ mil gal.

# Conventional and Current Technologies
## Disinfection

### O'Brien WRP – UV Disinfection

- DAF: 333 mgd
- Installed 2016
- Disinfection season: March – Nov.
- Electricity: ~40 kwh/mil gal, ~ $3/mil gal.
- 900 bulbs replacement: every 3 yrs, ~$500,000/yr

# Conventional and Current Technologies
## Emerging Contaminants (EC)

- EC destruction processes
  - Ozone
  - Advanced oxidation processes (AOPs)
- EC removal (separation) processes
  - Membranes (e.g. RO, NF)
  - Activated carbon
- Advanced treatment can provide complete to near complete removal of most ECs, but at a high cost

# Conventional and Current Technologies
## Emerging Contaminants (EC)

### Cost ranking of options for reducing ECs in effluent

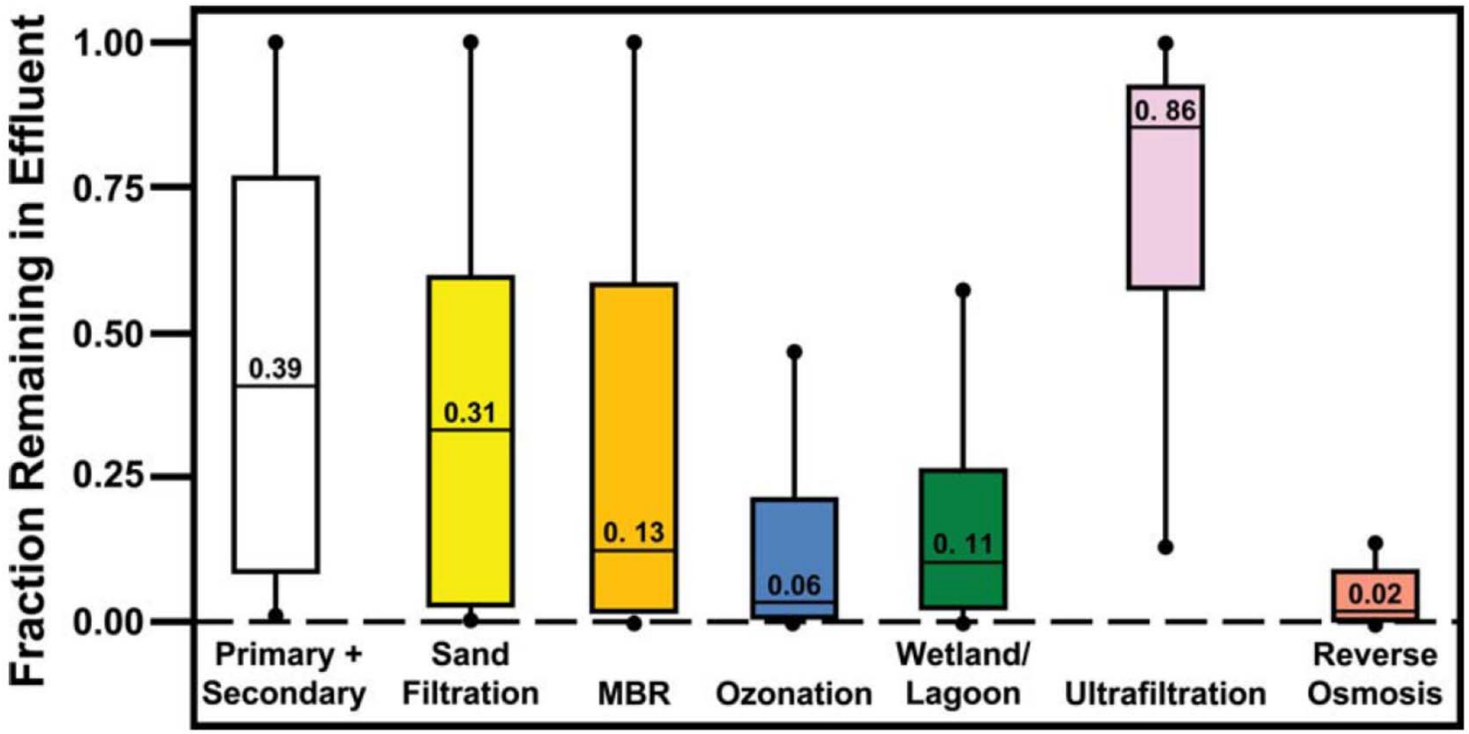
High cost

Low cost

1. Advanced treatment
   - Membranes, activated carbon
   - Ozone, advanced oxidation processes
2. Tertiary treatment
   - BNR
   - Sand filtration
3. Optimize conventional WWT
   - Increase SRT
4. Source control
   - (Effectiveness is uncertain)

# Conventional and Current Technologies
## Emerging Contaminants (EC)

### Comparison of PPCP Removal efficiencies by different WWTP technologies




Oulton et al. 2010. Pharmaceuticals and personal care products in effluent matrices: a survey of transformation and removal during wastewater treatment and implications for wastewater management. *Journal of Environmental Monitoring*. 12. 1956-1978.

# Conventional and Current Technologies
## Emerging Contaminants (EC)

## O'Brien WRP – UV disinfection: Pharmaceuticals Pre and Post-Disinfection 2016-2017

| Compound | Samples Detected[§] | Average Concentration (ng/L) Pre-disinfection | Post-disinfection | Percent Change |
|---|---|---|---|---|
| estrone (E1) | 1 | 9 ± 2 | 9 ± 2 | -6 |
| estradiol (E2) | 1 | 2 ± 3 | nd | - |
| bupropion | 15 | 120 ± 50 | 100 ± 40 | -1 |
| carbamezipine | 15 | 230 ± 150 | 170 ± 70 | -29 |
| citalopram | 15 | 130 ± 40 | 120 ± 40 | -7 |
| duloxetine | 10 | 12 ± 15 | 4 ± 3 | -65 |
| fluoxetine | 15 | 13 ± 17 | 20 ± 35 | 53 |
| norfluoxetine | 7 | 3 ± 4 | 4 ± 6 | 66 |
| norsertraline | 15 | 210 ± 140 | 180 ± 150 | -6 |
| paroxetine | 4 | 8 ± 1 | 2 ± 2 | -68 |
| sertraline | 16 | 60 ± 90 | 24 ± 16 | -62 |
| venlafaxine | 16 | 240± 440 | 160 ± 60 | -37 |

**Data from Heiko Schoenfuss: NSF Study**

# Conventional and Current Technologies
## Emerging Contaminants (EC)

## Calumet WRP – Hypochlorite disinfection: Pharmaceuticals Pre and Post-Disinfection

| Compound* | Samples Detected§ | Average Concentration (∝g/L) Pre-disinfection | Post-disinfection | Percent Change |
|---|---|---|---|---|
| estrone (E1) | 1 | 9 ± 1 | 8 ± 1 | -12 |
| estradiol (E2) | 0 | nd | nd | |
| bupropion | 16 | 90 ± 100 | 60 ± 40 | -30 |
| carbamazepine | 16 | 160 ± 50 | 150 ± 50 | -1 |
| citalopram | 16 | 82 ± 70 | 29 ± 20 | -64 |
| duloxetine | 16 | 3 ± 3 | 2 ± 2 | -53 |
| fluoxetine | 16 | 320 ± 550 | 130 ± 140 | -59 |
| norfluoxetine | 10 | 63 ± 68 | 18 ± 31 | -71 |
| norsertraline | 16 | 270 ± 240 | 220 ± 180 | -12 |
| paroxetine | 4 | 3 ± 1 | 2 ± 1 | -17 |
| sertraline | 16 | 39 ± 65 | 13 ± 6 | -66 |
| venlafaxine | 16 | 100 ± 40 | 67 ± 28 | -33 |

**Data from Heiko Schoenfuss: NSF Study**

# Conventional and Current Technologies
## Class A Biosolids

**Biosolids Class A pathogen reduction**

- USEPA – Processes to further reduce pathogens (PFRP)
- Includes composting, heat drying, irradiation, pasteurization

**MWRD** – Lagoon-aging and air-drying (USEPA approved site-specific PFRP)

# Conventional and Current Technologies
## Class A Biosolids

### Heat Drying

Biosolids Pelletizing Facility at Stickney WRP

# Conventional and Current Technologies
## Class A Biosolids

### Biosolids Composting at MWRD
**1 part biosolids:3 parts wood chips**
**~23 day active composting followed by ~ 16 weeks curing**


# Opportunities for E-beam Treatment

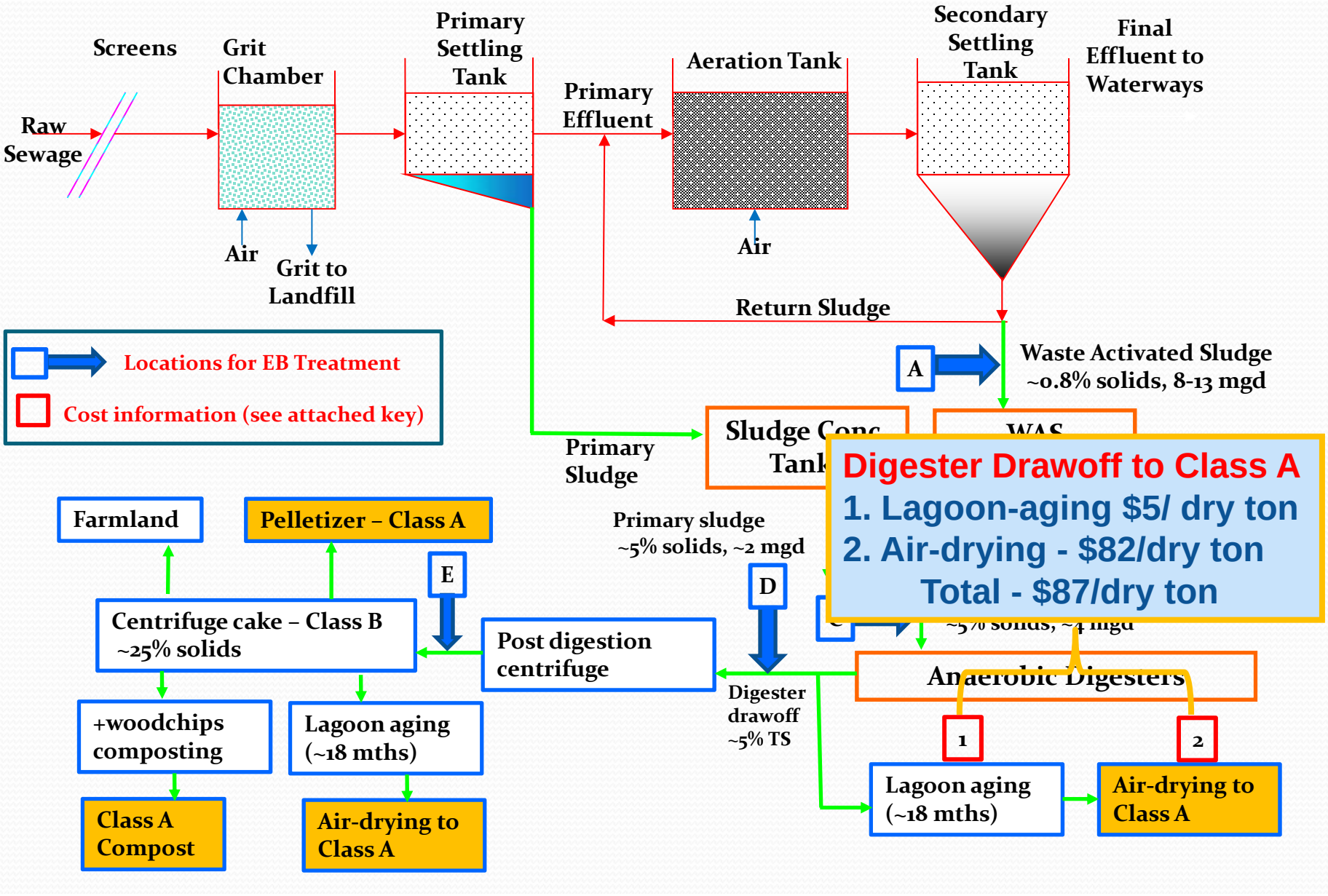
- **Sludge and biosolids - Cell lysing**
  - Energy recovery
  - Carbon for biological P removal
  - P release for recovery via Ostara
  - Pathogen reduction – Class A biosolids
- **Disinfection and**
  - WRP Effluent
  - Combined sewer overflows
  - Reduce EC
- **Odor Control**
  - Odor emissions from WRP

# Opportunities for E-beam Treatment
## Sludge and Biosolids

| Location | Description | Potential Benefits |
|---|---|---|
| A | Waste activated sludge (WAS) | • Improve dewatering of WAS<br>• Solubilize P for recovery in centrate |
| B | Thickened WAS | • Solubilize P for recovery in centrate via Ostara |
| C | Digester feed | • Pathogen reduction – USEPA Part 503 Class A standard<br>• Increase recovery of digester gas<br>• Solubilize P for recovery |
| D | Digester drawoff | • Pathogen reduction – USEPA Part 503 Class A standard |
| E | Centrifuge cake | • Pathogen reduction – USEPA Part 503 Class A standard |

# Opportunities for E-beam Treatment

## Sludge and Biosolids



# Opportunities for E-beam Treatment
## Sludge and Biosolids

### Centrifuges

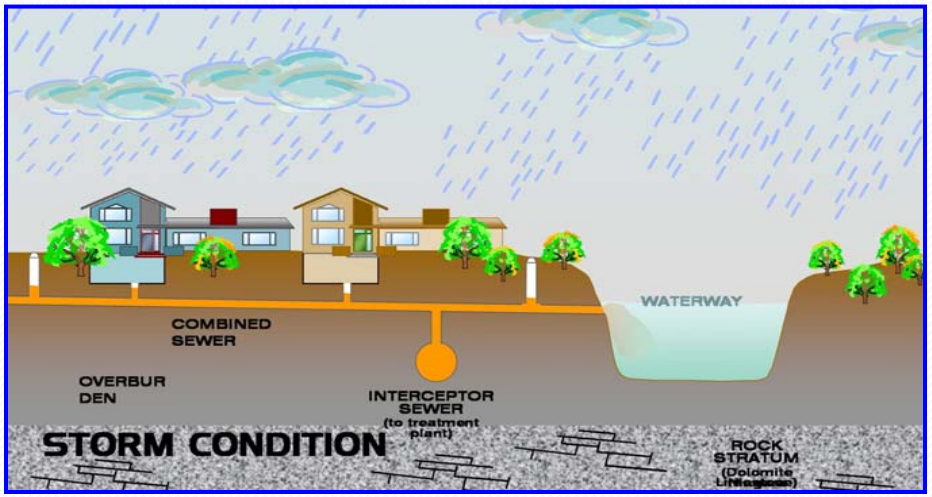
### Anaerobic digesters

# Opportunities for E-beam Treatment
## Disinfection of Effluents & CSOs

### Lemont Wet Weather Facility

### O'Brien WRP UV Disinfection Facility

# Opportunities for E-beam Treatment
## Disinfection of Effluents & CSOs




**Combined Sewer Overflows (CSO) during wet-weather conditions**
**Disinfection requirement**

# Opportunities for E-beam Treatment

## Odor Control

**Biofilter at Stickney WRP**