REINHOLD ENVIRONMENTAL Ltd.

2017 APC & Wastewater Round Table & Expo Presentation

July 17 & 18, 2017 in Charlotte, NC / Hosted by Duke Energy

Basin Design for Treatment of Suspended Solids

Reinhold Environmental 2017 APC & Wastewater Round Table

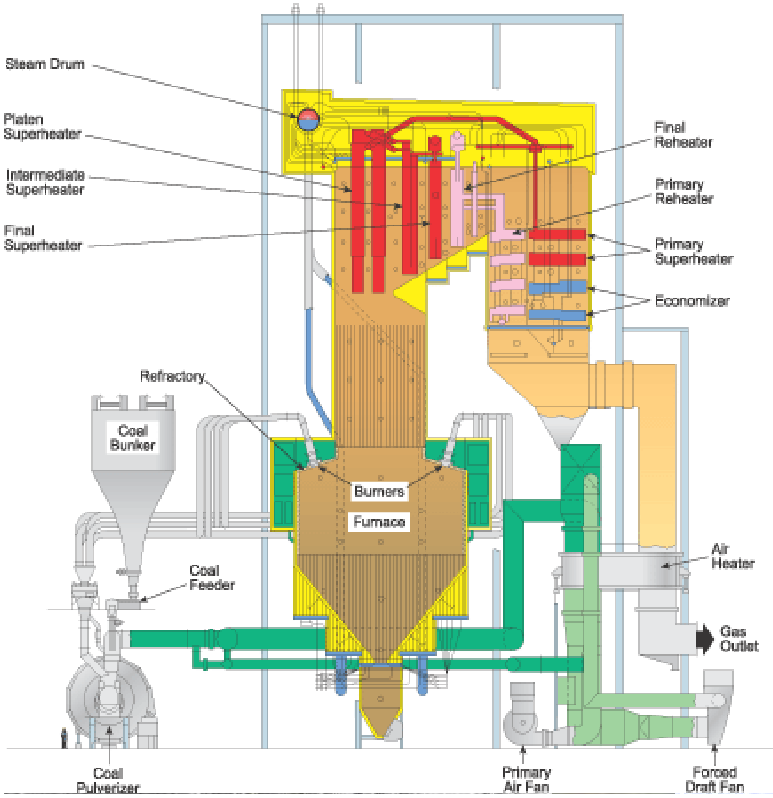
Parker Carpenter, Southern Company
Tuesday, July 18, 2017

Wastewater Primer

The Wastewater Spectrum

There are an assortment of wastewater types that can produced at a coal-powered generating plant:

- Low Volume Waste:
  - o Demineralizer regeneration waste
  - o Boiler blowdown
  - o Water plant waste
  - o Etc.
- Cooling Tower Blowdown
- Once-Through Noncontact cooling water
- WFGD Wastewater
- Coal Pile Runoff
- Stormwater
- Ash Transport Water
- Non-Chemical Metal Cleaning Waste
- Chemical Cleaning Waste



Pollutants with Potential Discharge Limits

National Pollutant Discharge Elimination System (NPDES) permits place site-specific discharge limits on various pollutants commonly found in power plant wastewater. Pollutant discharge limits are typically set on a concentration basis.

Permitted Pollutants Include:

- Total Suspended Solids (TSS)
- Oil and Grease
- Metals (Iron, Mercury, Selenium, Arsenic, Copper, etc.)
- pH

Discharge limits vary depending on plant location, wastewater type, and discharge point location.

Low Volume Waste Discharge Limits

Low volume waste is given baseline discharge limits in 40 CFR Part 423 – Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, also know affectionately as the ELG rule.

Low volume waste limits given in ELG

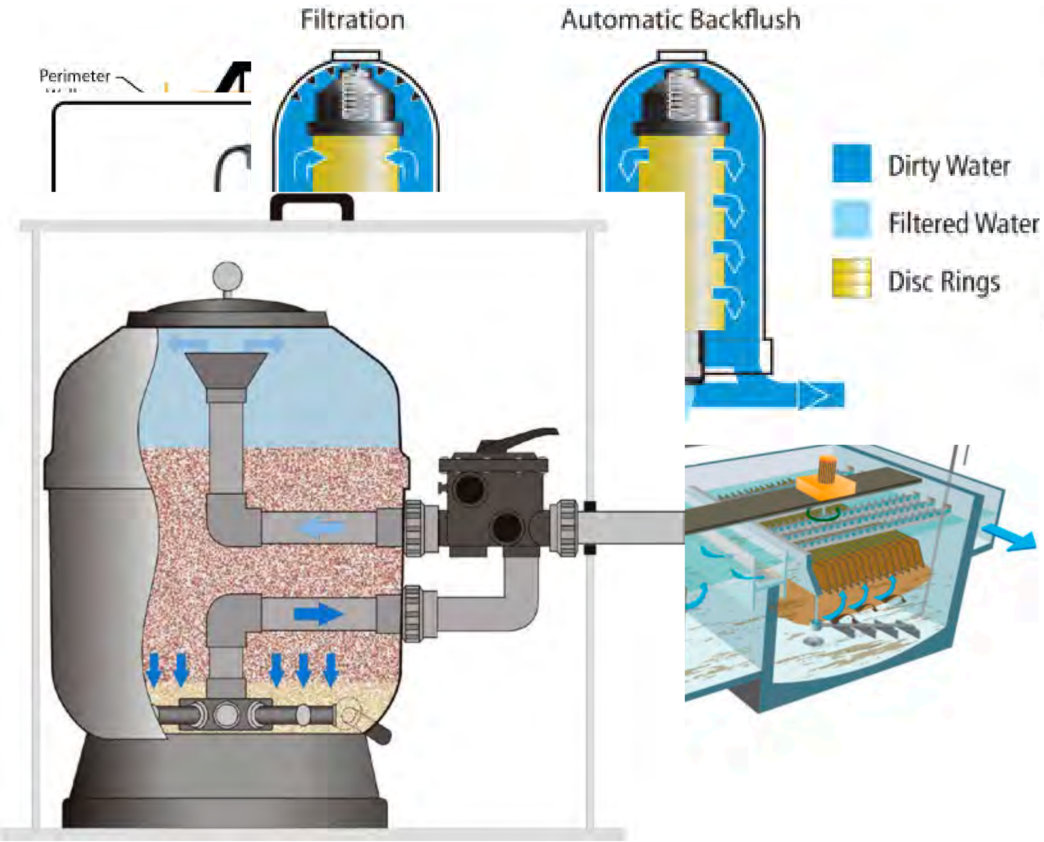
- TSS
  - o Daily Maximum = 100 mg/L (ppm)
  - o Monthly Average = 30 mg/L
- Oil and Grease
  - o Daily Maximum = 20 mg/L
  - o Monthly Average = 15 mg/L

Treatment Options

Low Volume Waste Treatment Options

Oil and Grease
Oil and grease float.
- Oil/water separator
- Underflow baffle

Total Suspended Solids
TSS sink (hopefully).
- Clarifier
  - o Contact clarifier
  - o Ballasted clarifier
- Filter
  - o Wedge wire
  - o Disk
  - o Media
- Sedimentation pond



Clarifier v Pond

Clarifiers		Ponds
✓	**Real Estate**	
	Flowrate Swings	✓
	Oil and Grease	✓
✓	**Treatment Specificity**	
	Solids Handling	✓
	pH Swings	✓
✓	**Capital Cost**	✓

Treatment Pond Operation

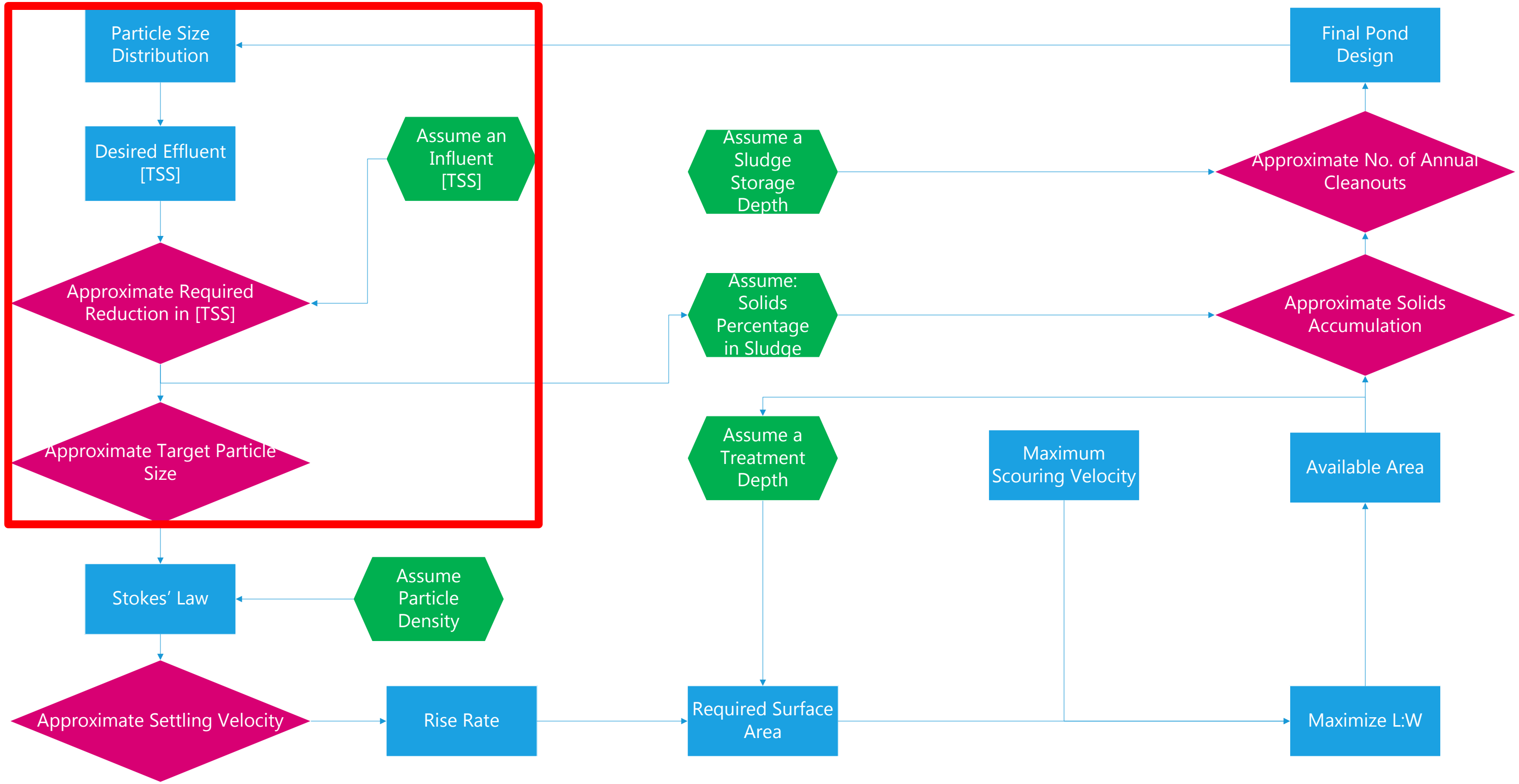
- Operate on the same principles as a clarifier:
  - o Rise rate (surface overflow rate) = flowrate divided by the surface area of the pond (has units of velocity)
  - o Scouring velocity = flowrate divided by the cross-sectional area
  - o Solids accumulation rate
  - o Gravitational settling
  - o Chemically assisted settling

Treatment Pond Design

Treatment Pond Design Considerations

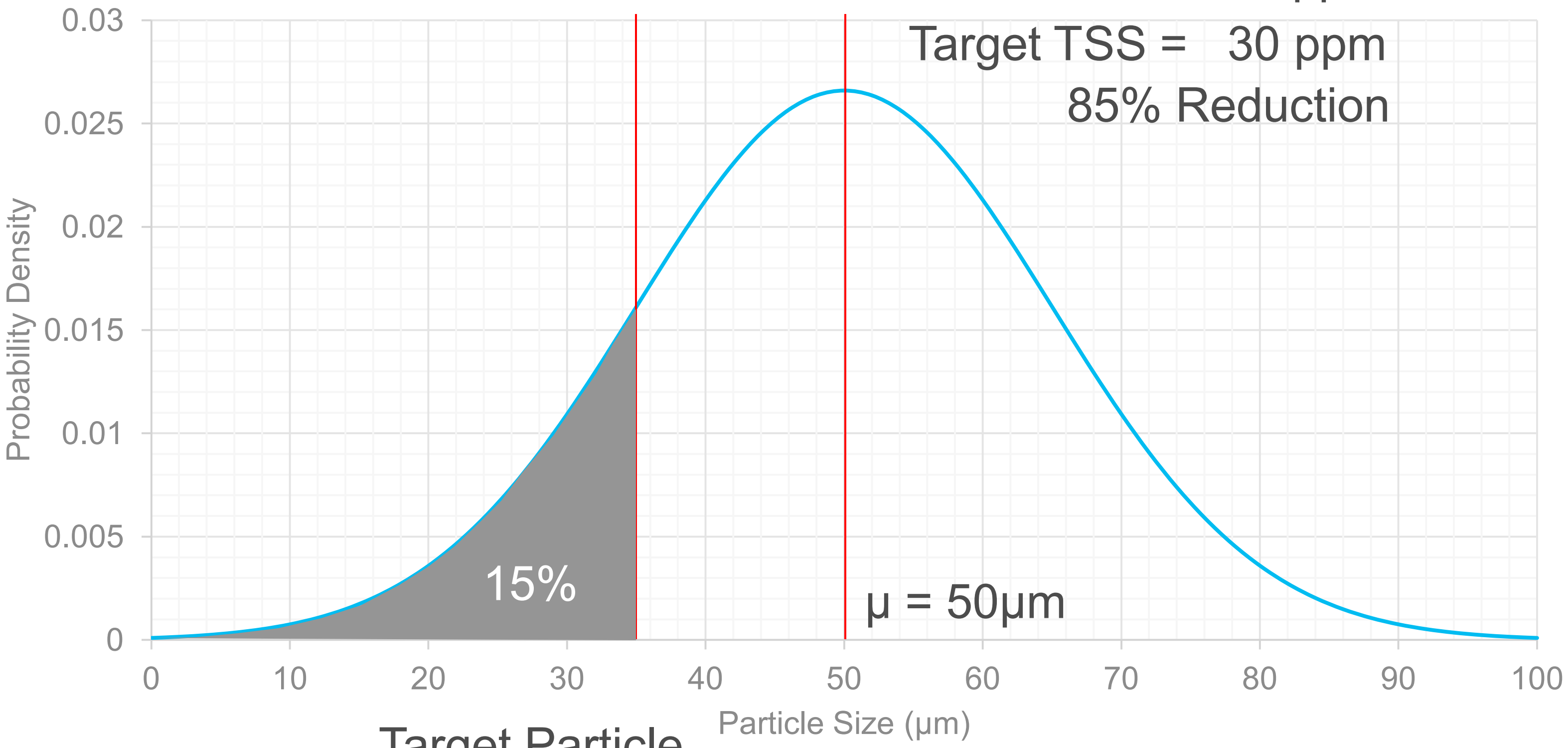
- **Wastewater Characteristics**
  - Flowrate (average, maximum)
  - pH
  - Oil and grease
  - Constituents to be removed
- **Required discharge limits**
- **Discharge structure**
- **Real estate**
- **Solids Loading**
- **Chemistry (coagulant, flocculant, pH)**

Step One – Target Particle Size



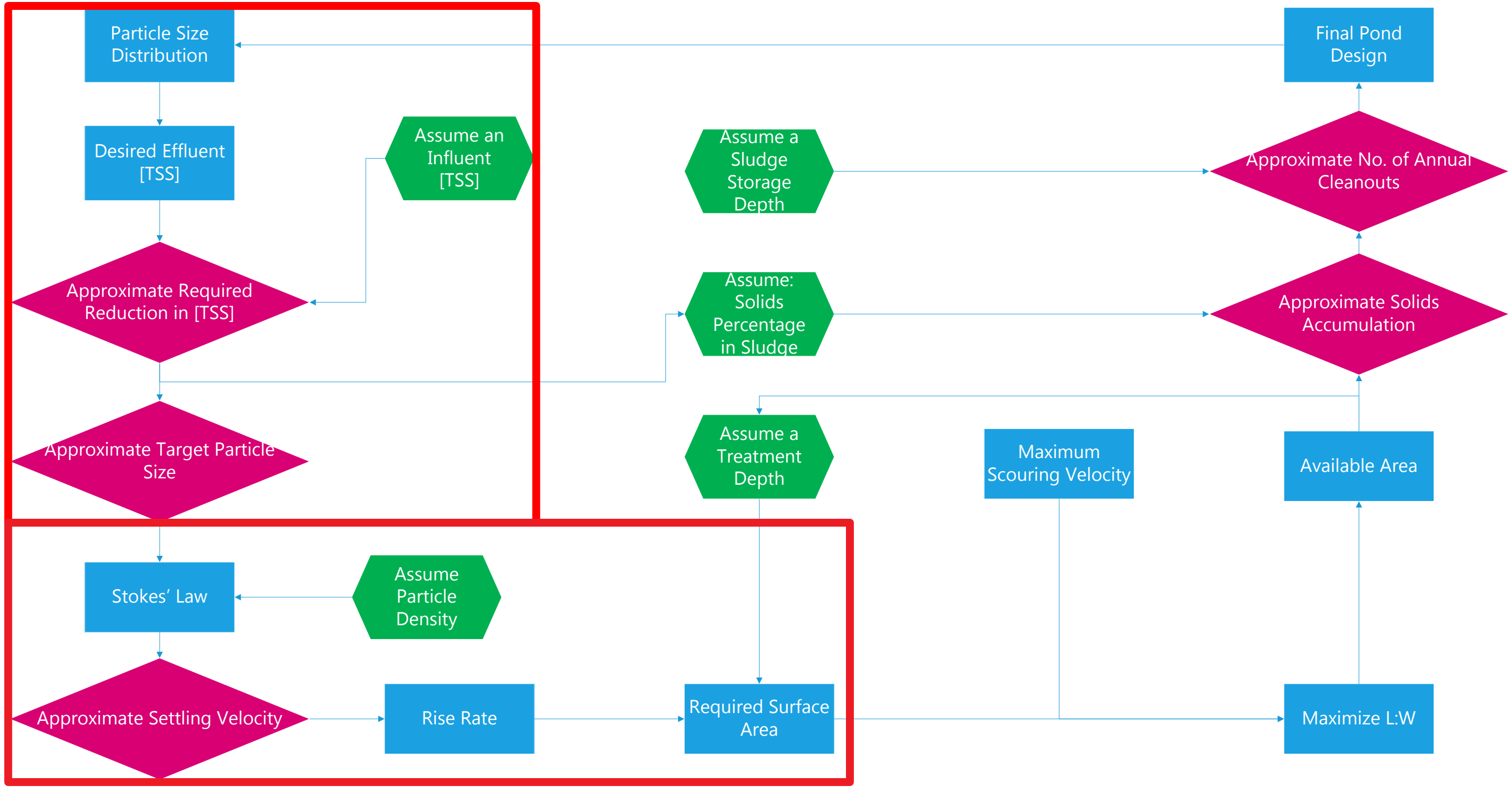
Step 1 – Sample, Sample, Sample

TSS = 200 ppm
Target TSS = 30 ppm
85% Reduction



Target Particle
Size = 35μm

Step Two – Settling Velocity



Stokes' Law

- Used to *approximate* settling velocities
- Relates a particles settling velocity to the particle's diameter and density and the fluid's density and viscosity

$$v_s = \frac{g D_p^2 \left(\rho_p - \rho_f\right)}{18\mu_f}$$

- Balances buoyant force, drag force, and force of gravity
- Assumes spherical particles
- Column settling tests should be used to confirm calculated settling velocity
- Must assume an average particle density (let's use a specific gravity of 2)
- Use this settling velocity (characteristic of the "target" particle) to determine the rise rate/overflow rate (characteristic of the pond) required

$$v_s = rise\ rate$$

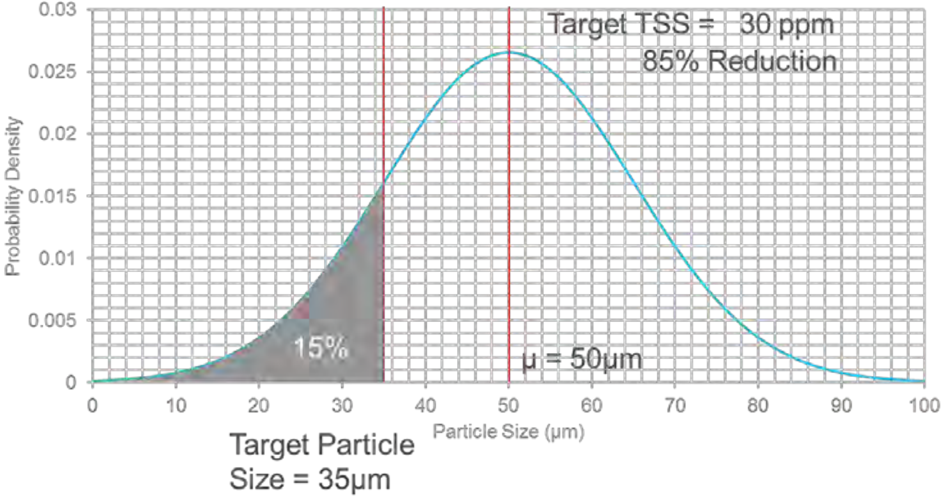
- Rise rate typically has units of GPM/ft^2

Design Case and Optimization

- Design Normal Operation Flow = 10,000 GPM
- Design Maximum Flow = 20,000 GPM
- Design Influent TSS Concentration = 200 mg/L
- Design Influent pH = 8
- Design Effluent TSS Concentration = 30 mg/L (monthly average)
- Design Effluent pH range = 6-9

- $\rho_p = 2.0$

Textural classes	Particle density (g/ cm3)
Coarse sand	2.655
Fine sand	2.659
Silt	2.798
Clay	2.837



Settling Velocity, Rise Rate, and Required Surface Area

$$v_s = \frac{gD_p^2\,(\rho_p - \rho_f)}{18\mu_f}$$

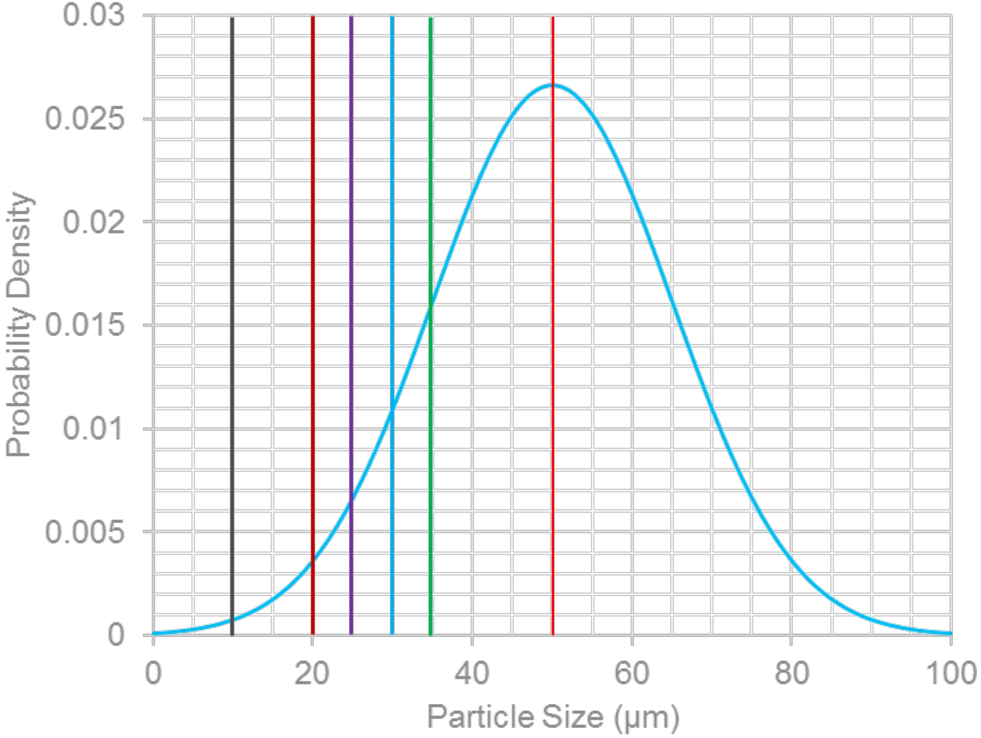
- **v_s = 0.0022 ft/s**

- **Rise Rate = 1.0 GPM/ft^2**

$$A_{surface} = \frac{Flowrate}{Rise\ Rate}$$

- **Required Surface Area = 20,000 ft^2**
  - o Use maximum expected flow for treatment calculations

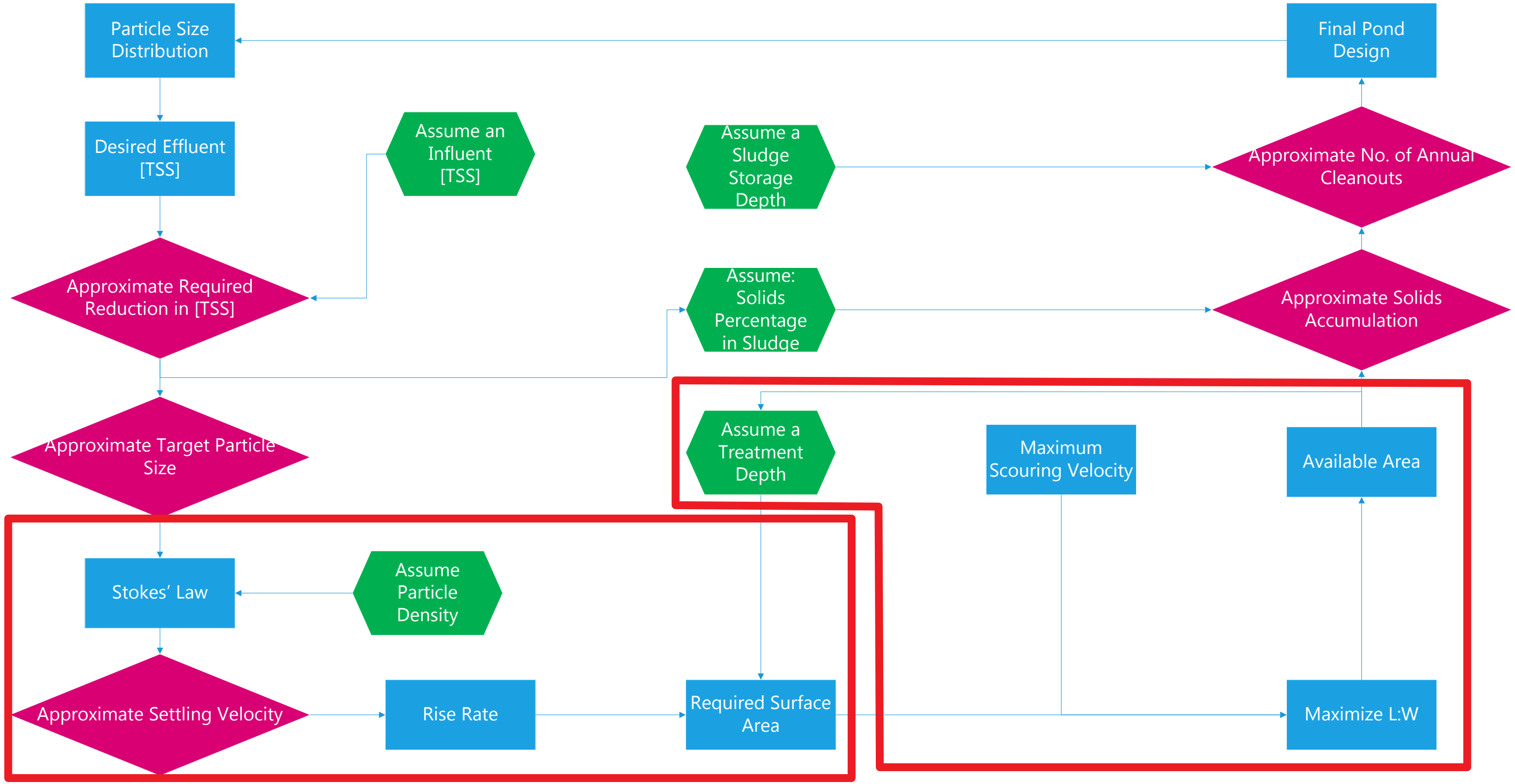
PAUSE - Treatment Comparison



TSS = 200 ppm

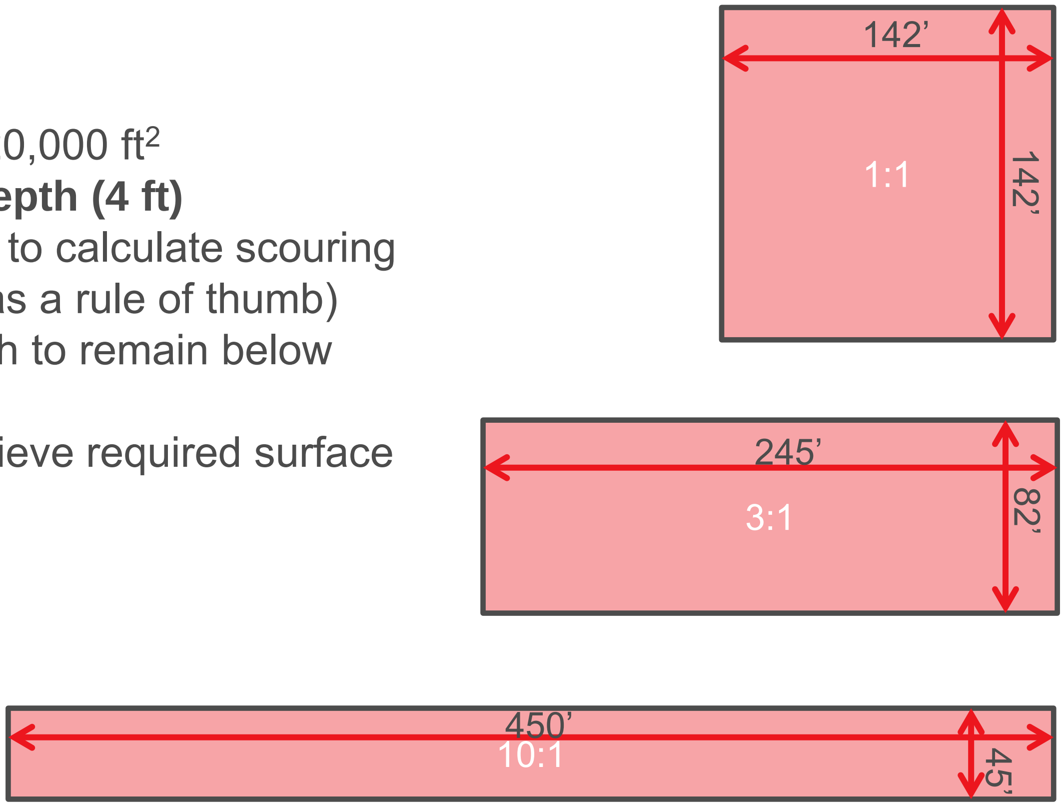
Target TSS (ppm)	Reduction	Diameter (μm)	Required Area (acre)
30	85%	35	0.46
20	90%	30	0.62
10	95%	25	0.89
5	97.5%	20	1.4
1	99.5%	10	5.6

Step 3 – Pond Dimensions

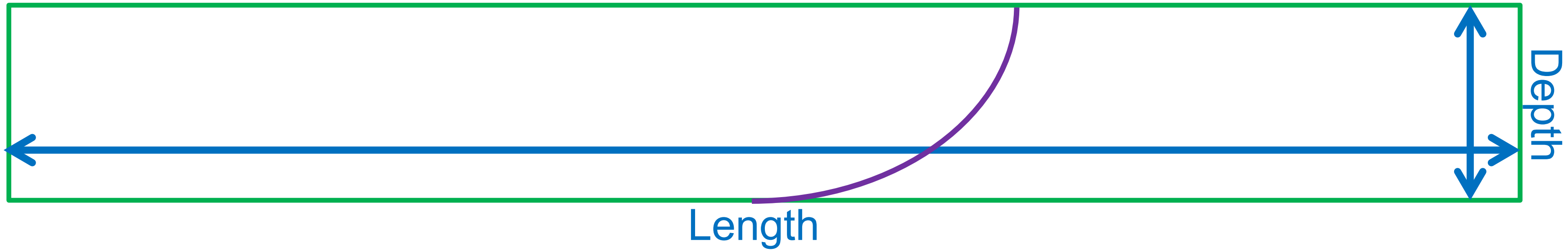


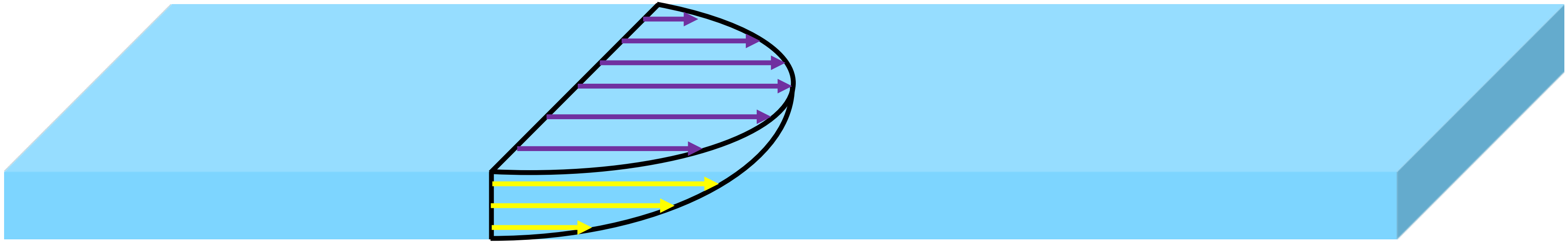
Pond Surface Area

- Rise Rate = 1.0 GPM/ft^2
- Required surface area = 20,000 ft^2
  - **Assume a treatment depth (4 ft)**
  - Use the Camp Equation to calculate scouring velocity (or use 0.2 fps as a rule of thumb)
  - Determine required width to remain below scouring velocity
  - Determine length to achieve required surface area

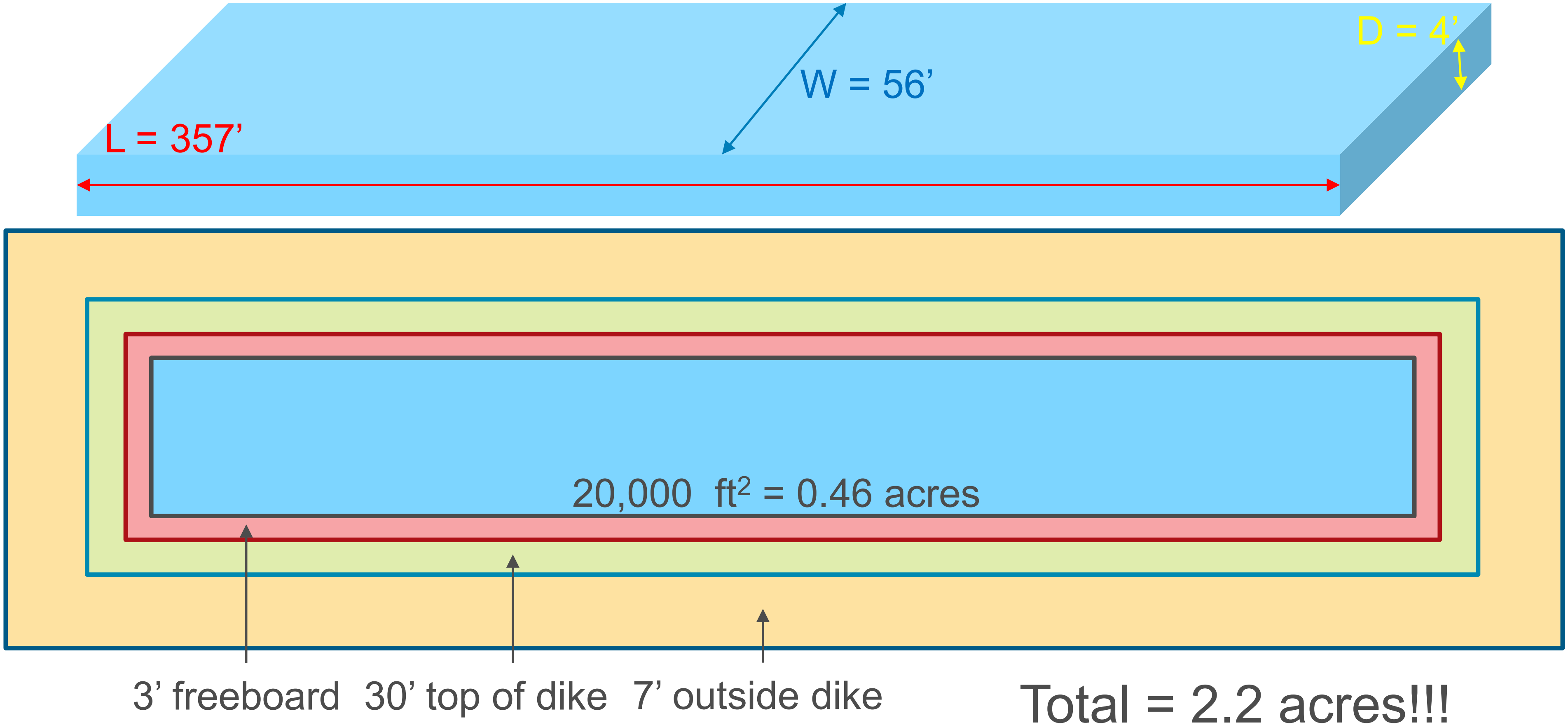


Sweeping Velocity





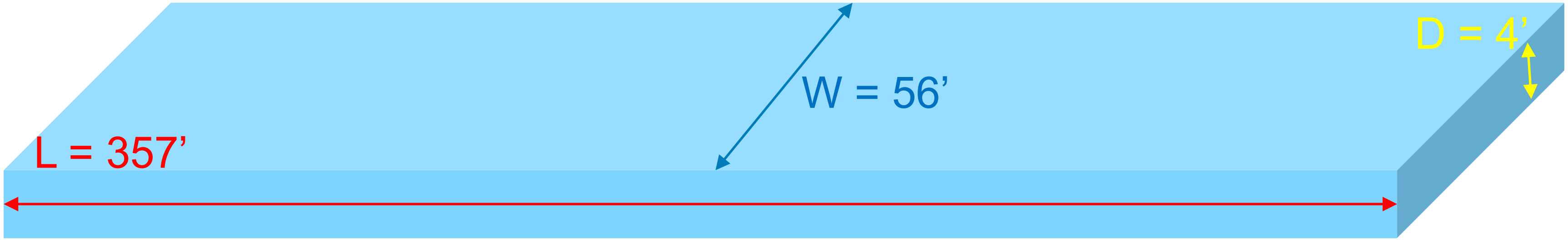
Is There Enough Real Estate?



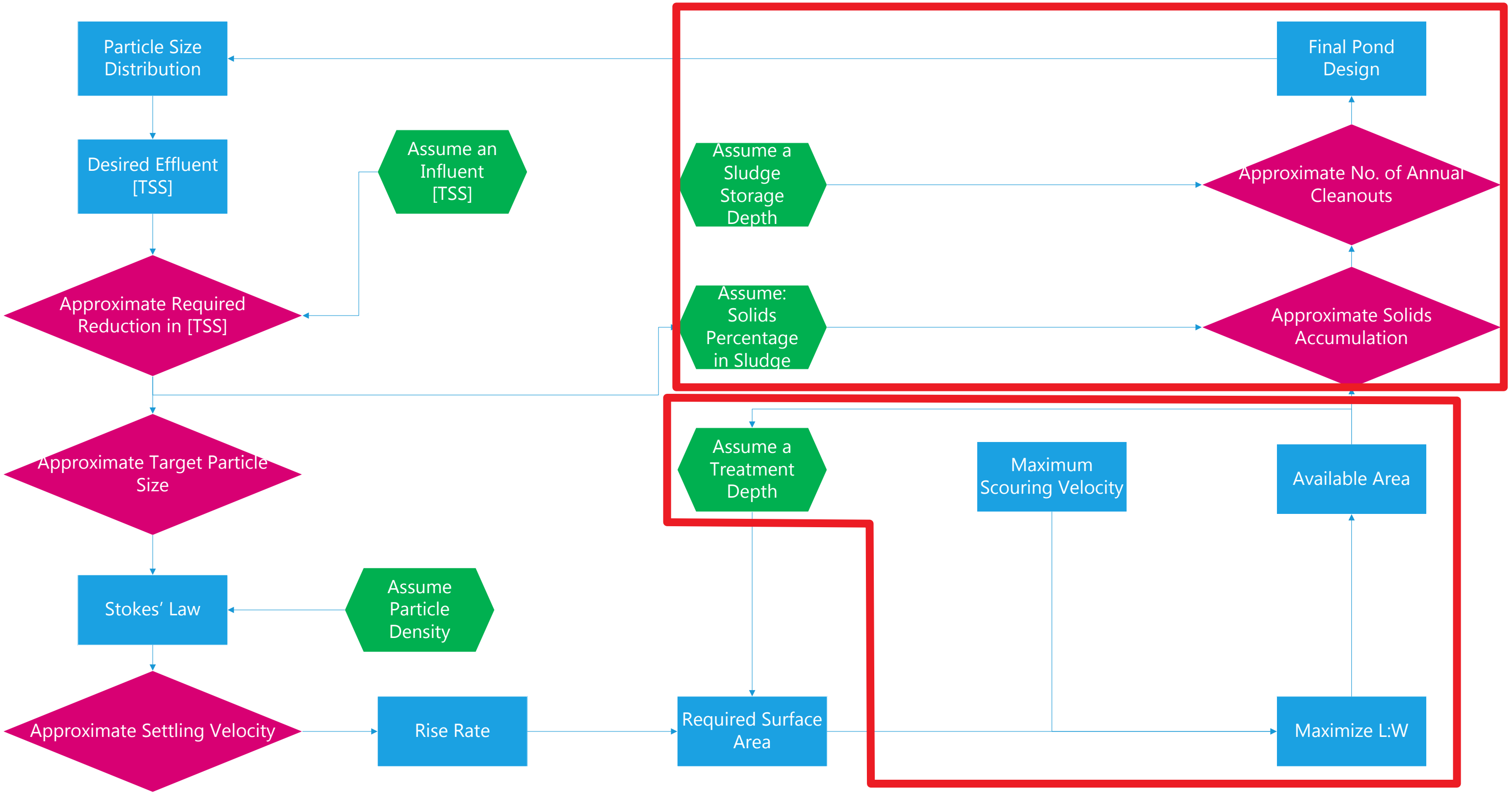
Total = 2.2 acres!!!

Final Pond Design (?)

- Design Surface Area = 0.46 acre
- Design Flow = 20,000 GPM (use design maximum flowrate for treatment calculations)
- Design Treatment Depth = 4 ft
- Design Effluent [TSS] = 30 ppm



Step Four


Particle Size Distribution
Desired Effluent [TSS]
Assume an Influent [TSS]
Approximate Required Reduction in [TSS]
Approximate Target Particle Size
Stokes' Law
Assume Particle Density
Approximate Settling Velocity
Rise Rate
Required Surface Area
Assume a Sludge Storage Depth
Assume: Solids Percentage in Sludge
Final Pond Design
Approximate No. of Annual Cleanouts
Approximate Solids Accumulation
Assume a Treatment Depth
Maximum Scouring Velocity
Available Area
Maximize L:W

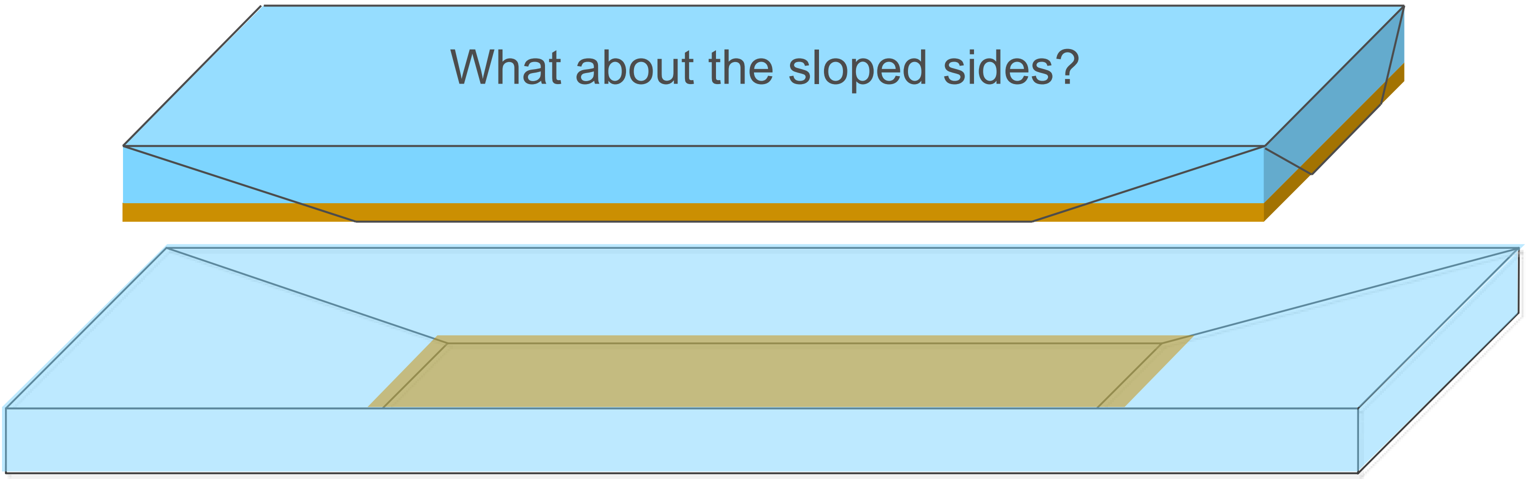
Sludge Accumulation, Storage, and Removal

How Much Storage Do You Need?

- Reuse some previous assumptions:
  - Influent TSS concentration = 200 mg/L
  - Effluent TSS concentration = 30 mg/L
  - Design influent flowrate = 10,000 GPM (**use the design average flow for solids accumulation calculations**)
  - Average specific gravity of solids = 2.0
- Solids Accumulation = 20,000 lb/day (= 70 ton/week = 3,640 ton/year)
- We need to assume a % solids in the sludge to determine a required storage volume
- Clarifier sludge can range from 2-3% solids to 15% solids. Given that there will be some compression of the lower layers, let's go with 5% solids for the bulk average.
- Solids Accumulation = 3,290 ft^3 sludge/day (>44,000 yd^3 sludge/year!)

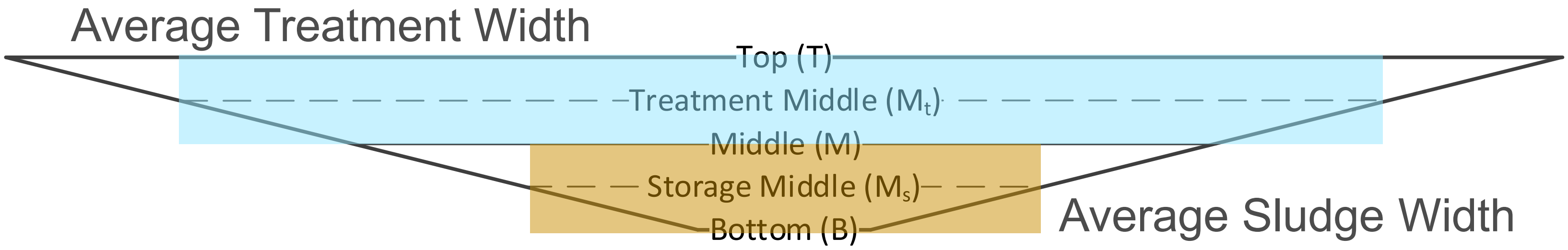
Cleanout Frequency

- Minimize O&M costs by constricting the required cleanout (C/O) frequency
- Assume 1 cleanout per quarter
- 14 foot of sludge depth – assumes width of 56’ and length of 357’



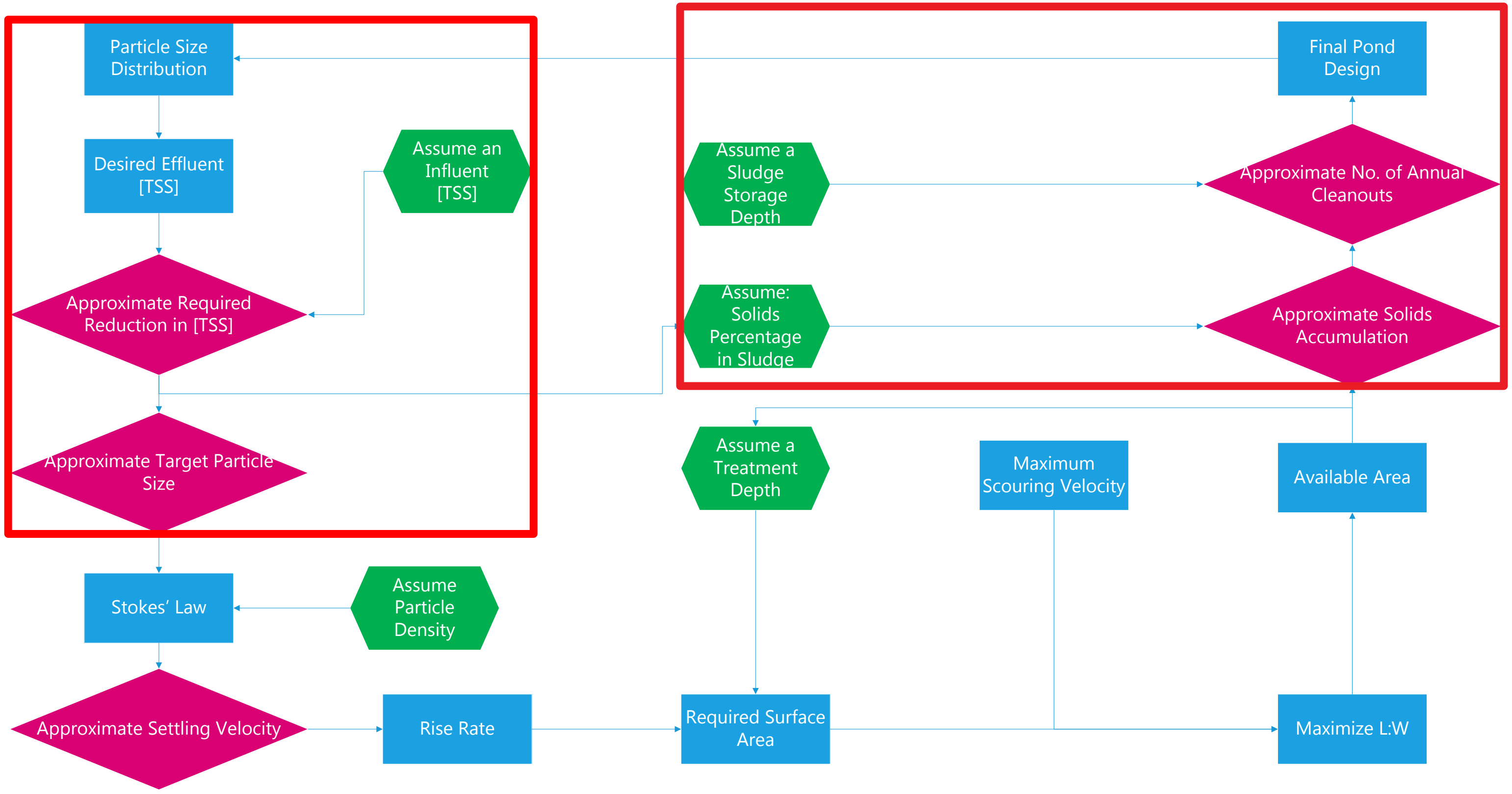
Approximating Volumes in an Earthen Pond

- Typical earthen slopes are 4:1 (they can be 3:1 in some applications)
- These broad slopes make the previously assumed constant surface area a very bad assumption
- Due to the sloped sides, the maximum sludge depth possible is 5 feet, which equates to over 37 cleanouts per year.



Start Over

Step 5 – See Step 1



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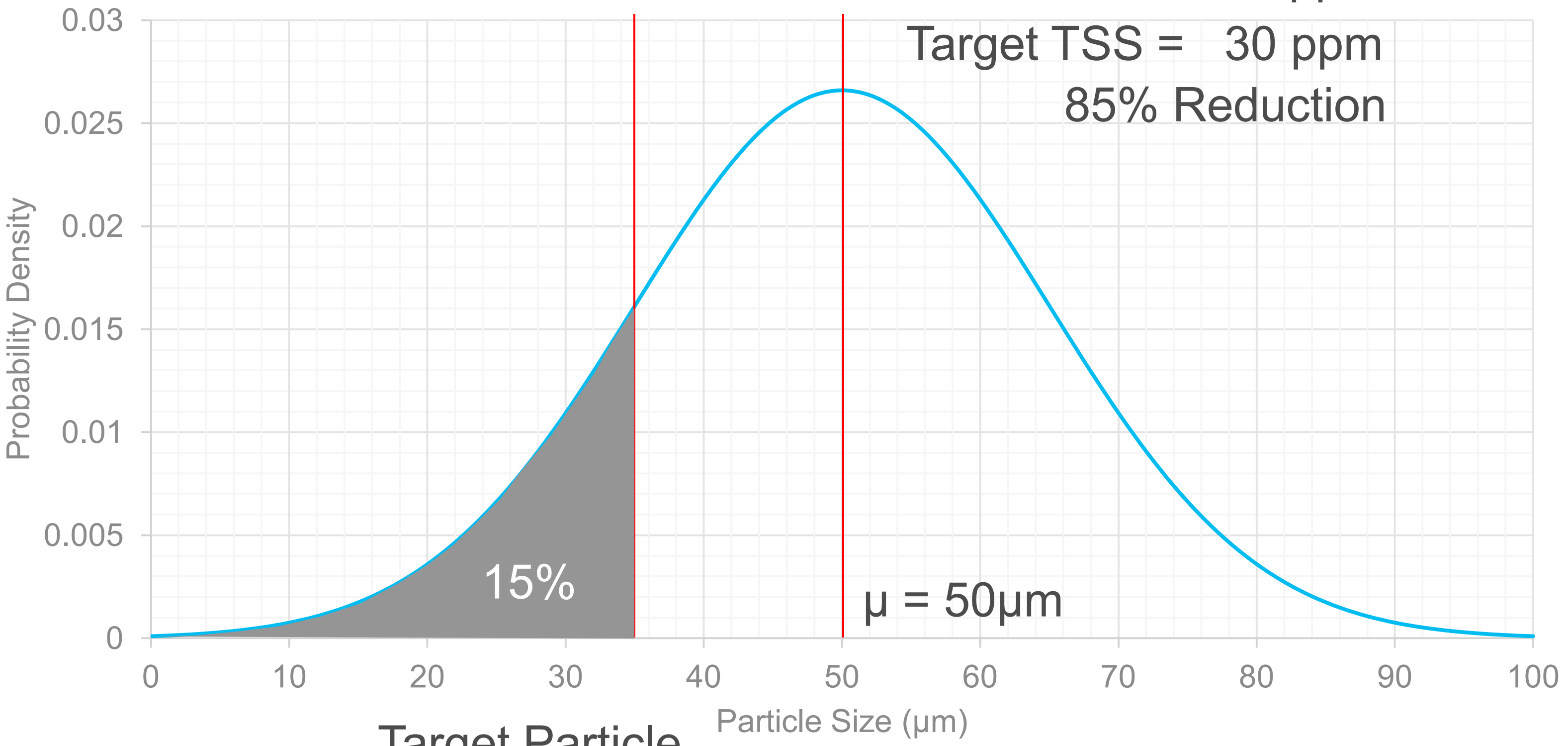


Target Particle Size = 35μm

Settling Velocity, Rise Rate, and Required Surface Area

$$v_s = \frac{gD_p^2\,(\rho_p - \rho_f)}{18\mu_f}$$

- **v_s = 0.0022 ft/s**

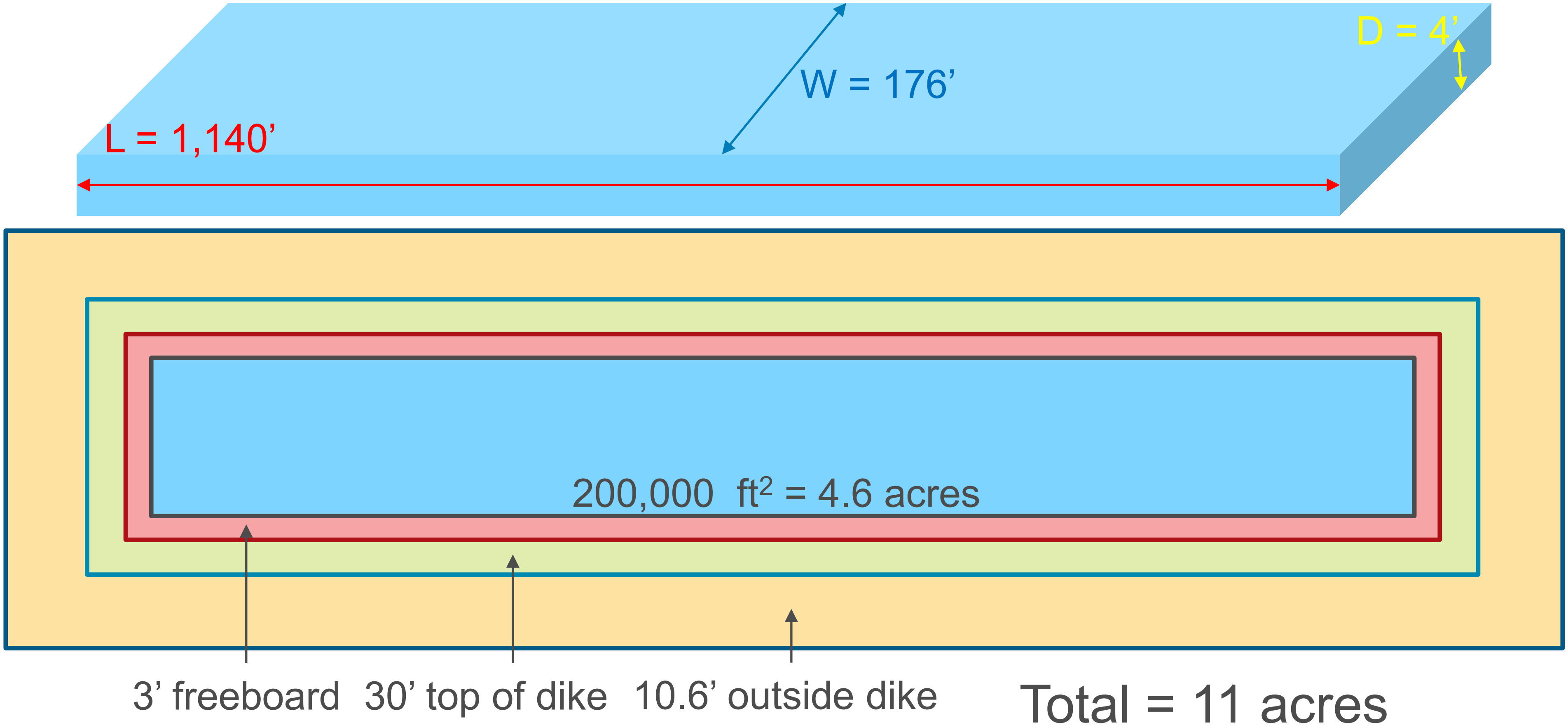
- **Rise Rate = 1.0 GPM/ft^2**

$$A_{surface} = \frac{Flowrate}{Rise\ Rate}$$

- **Required Surface Area = 20,000 ft^2**
  - Use maximum expected flow for treatment calculations

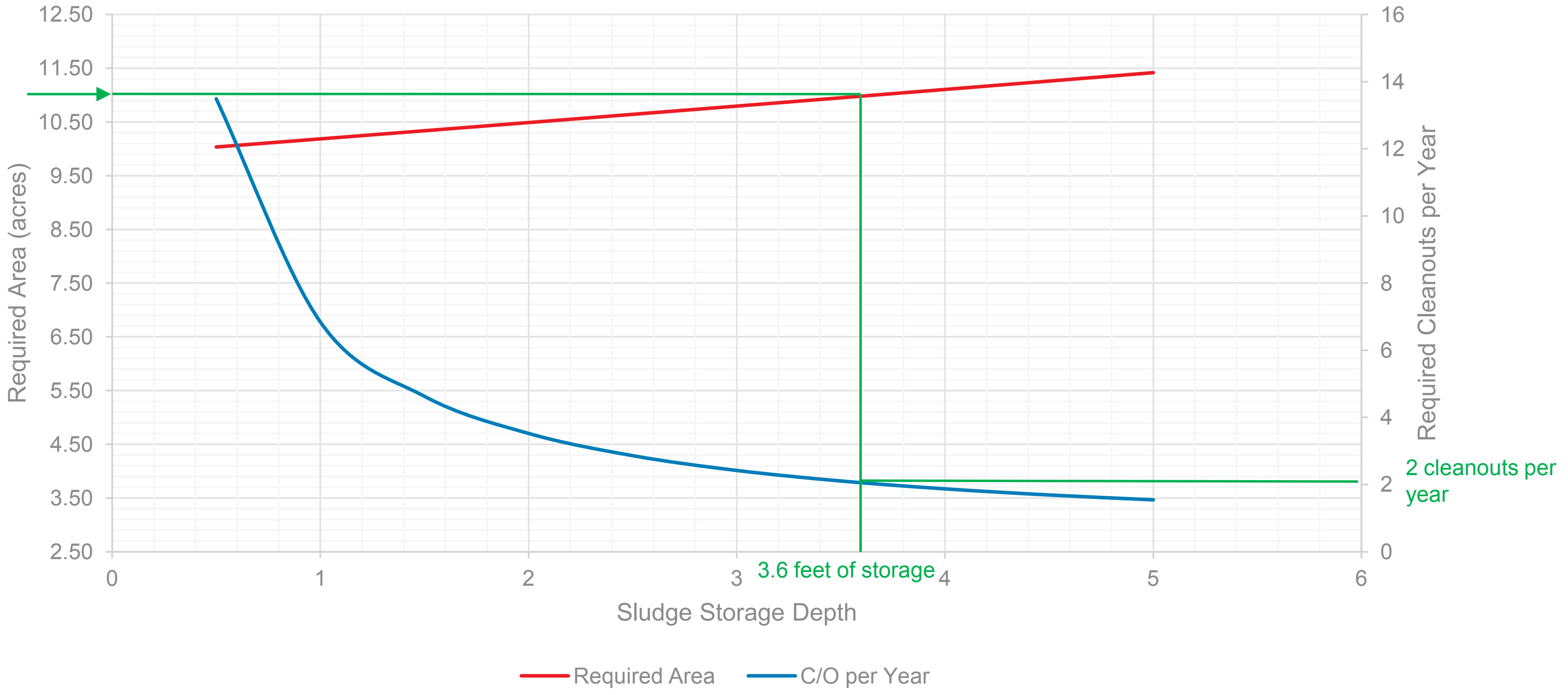
- **Specified Surface Area = 200,000 ft^2**

Is There Enough Real Estate?



Total = 11 acres

Determining Required Sludge Storage Volume



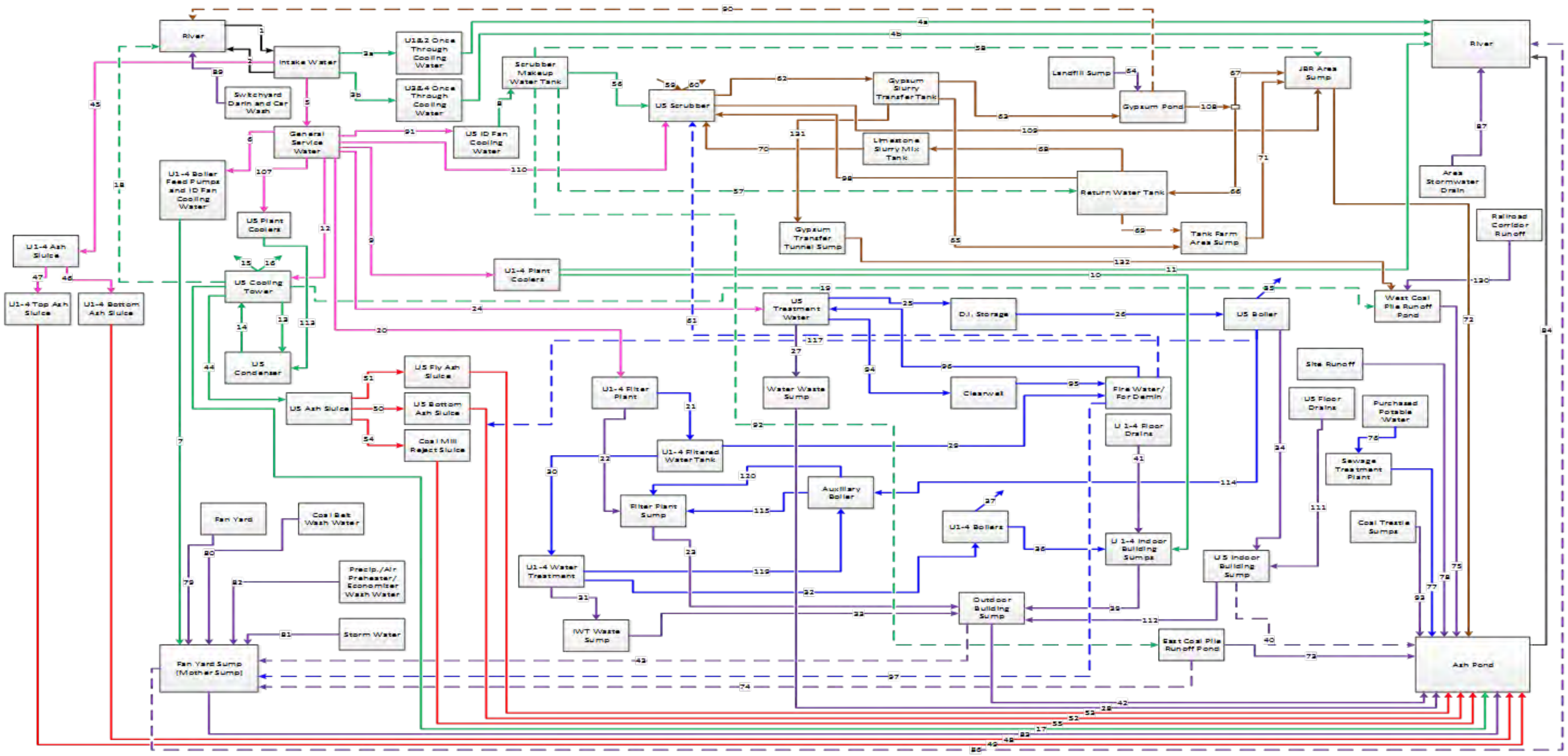
Diminishing return with increased sludge depth

Final Pond Design(!)

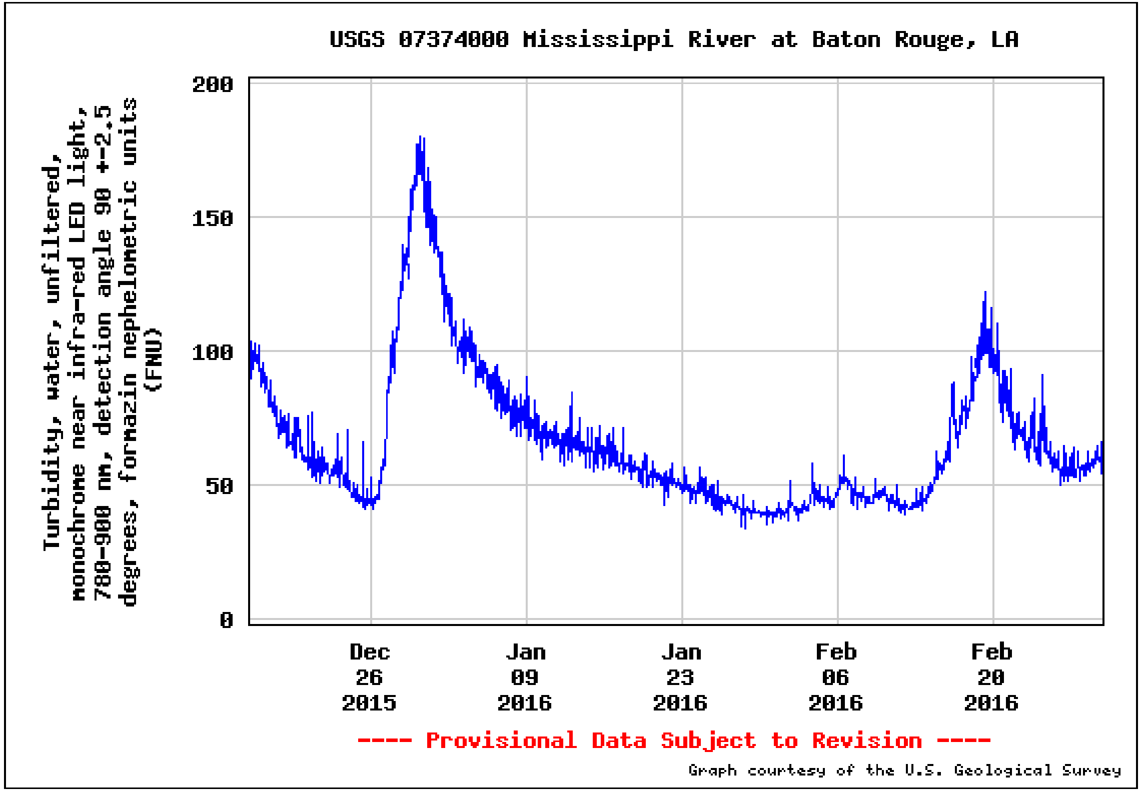
Parameter	Value	Units
Maximum Flow / Average Flow	20,000 / 10,000	GPM
Influent [TSS] / Effluent [TSS]	200 / 30	mg/L
Minimum Particle Diameter	35	µm
Settling Velocity	0.0022	ft/s
Rise Rate	1.0	GPM/ft^2
Average Treatment Width x Length	176 x 1140	ft x ft
Average L:W	6.5	-
Sweeping Velocity	0.06	ft/s
Annual Solids Accumulation	3,730	ton/year
Cleanout Frequency	2.0	Cleanouts/year

Review of Assumptions

Maximum / Average Flowrate

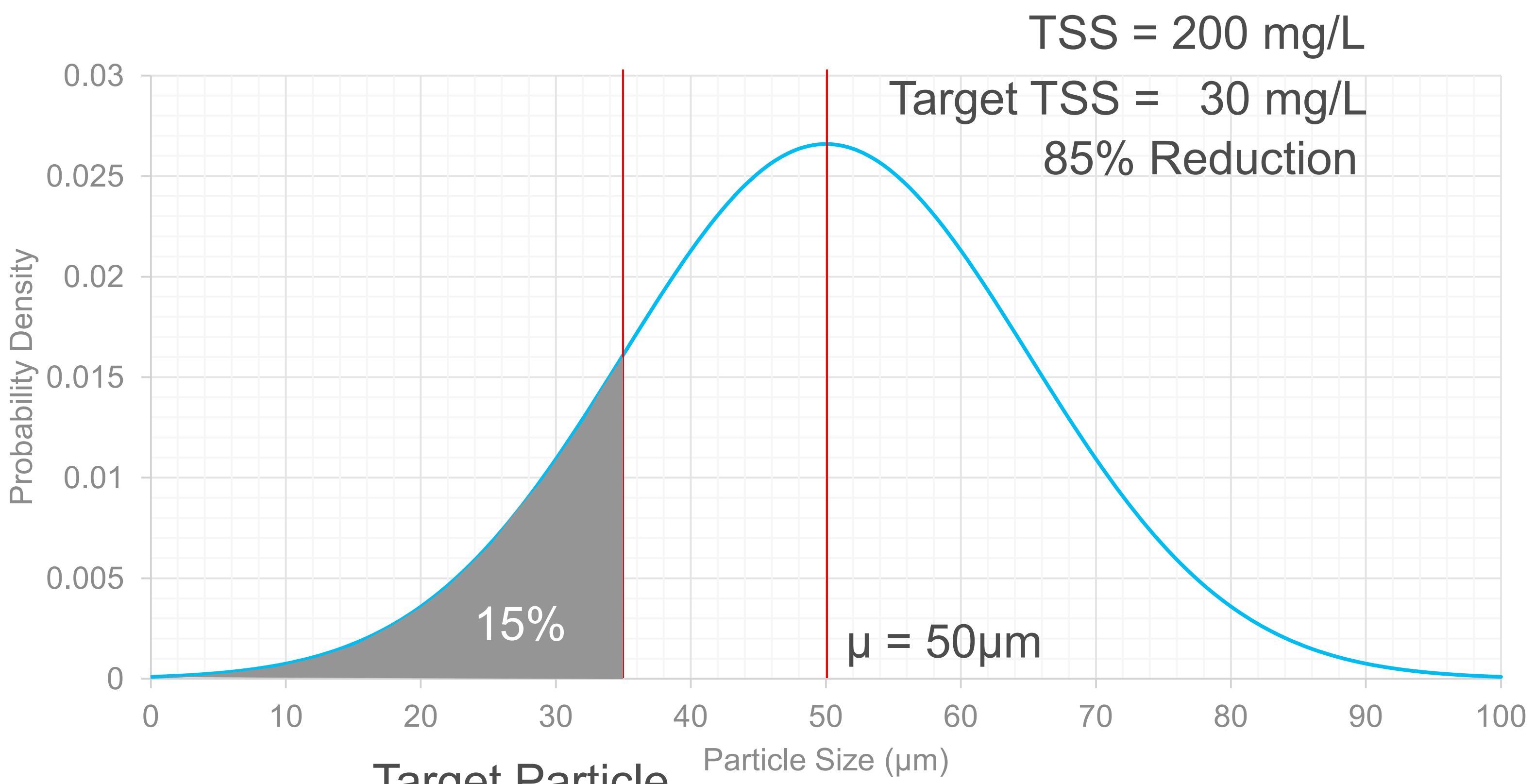


Influent TSS



River Variability ~ Pond Variability

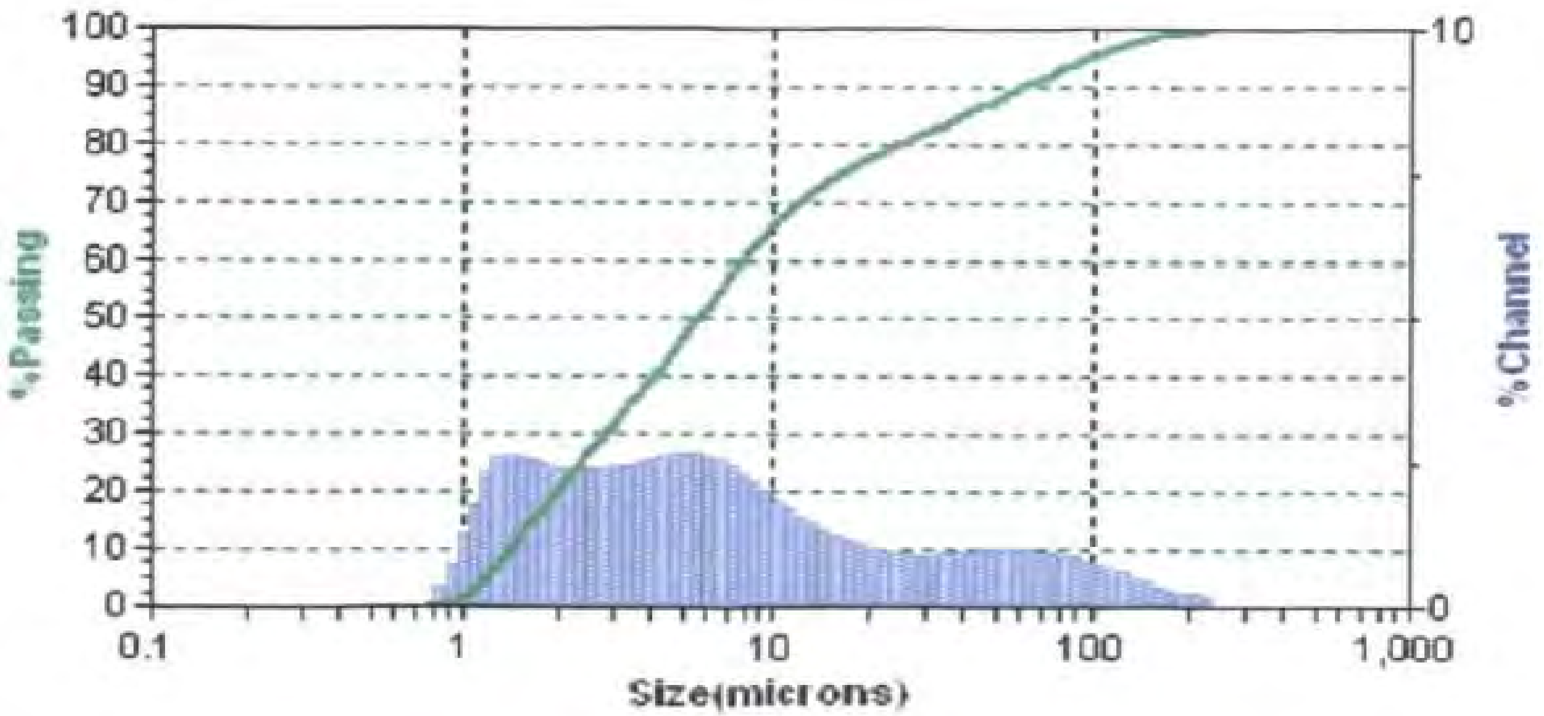
Minimum Particle Diameter



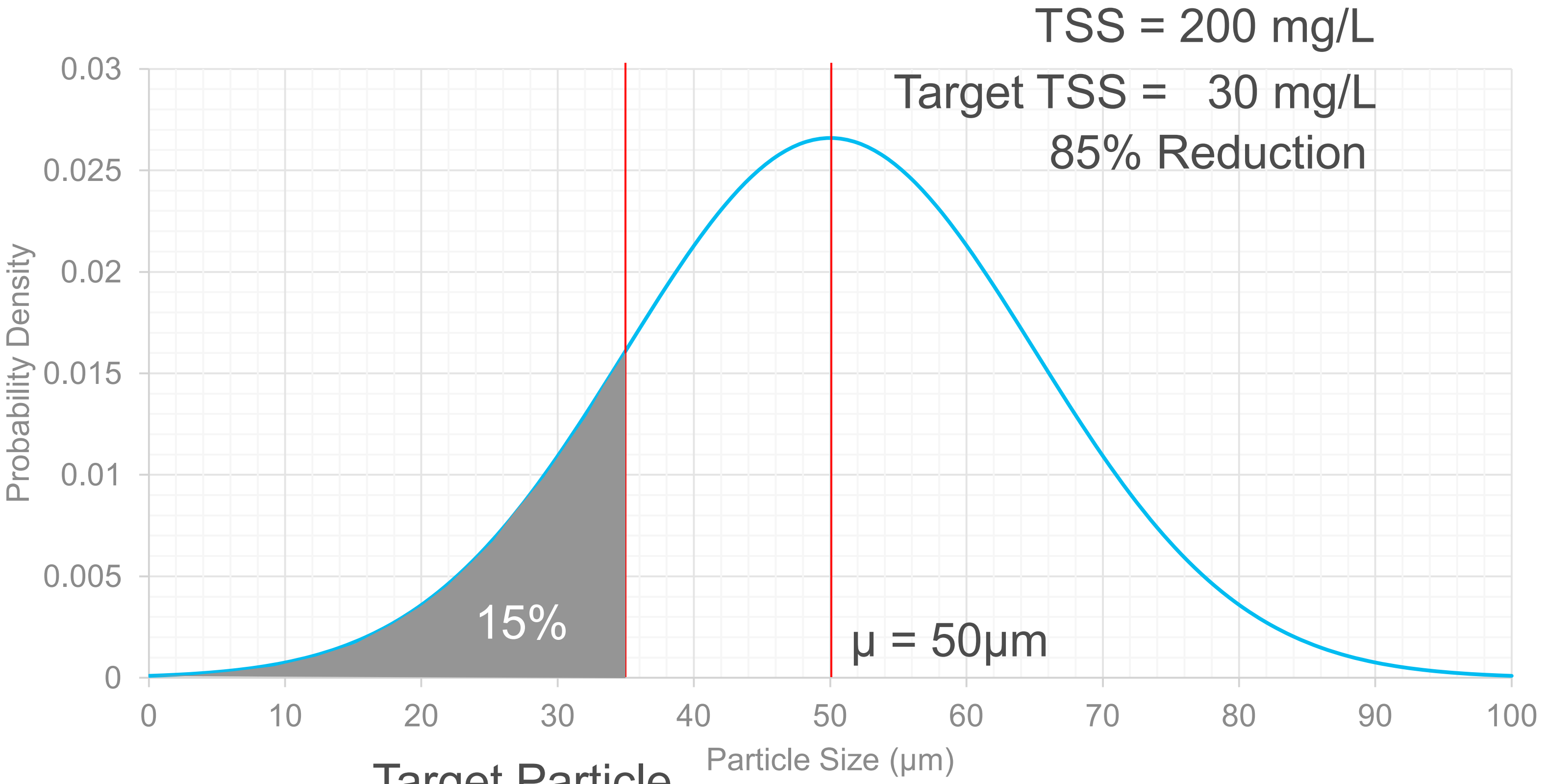
Target Particle Size = 35μm

SG = 2.0

Minimum Particle Diameter



Mass Basis vs Count Basis



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Settling Velocity and Rise Rate

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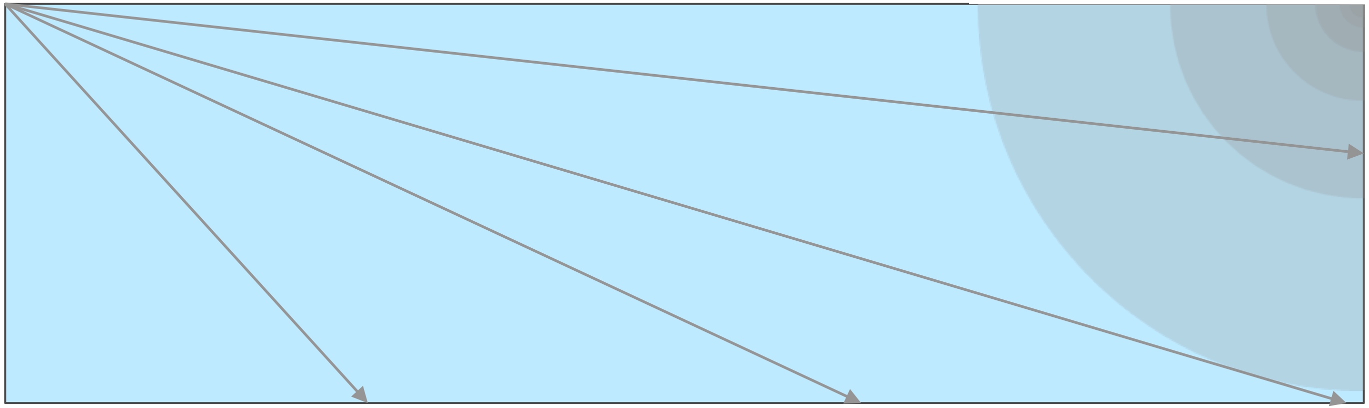
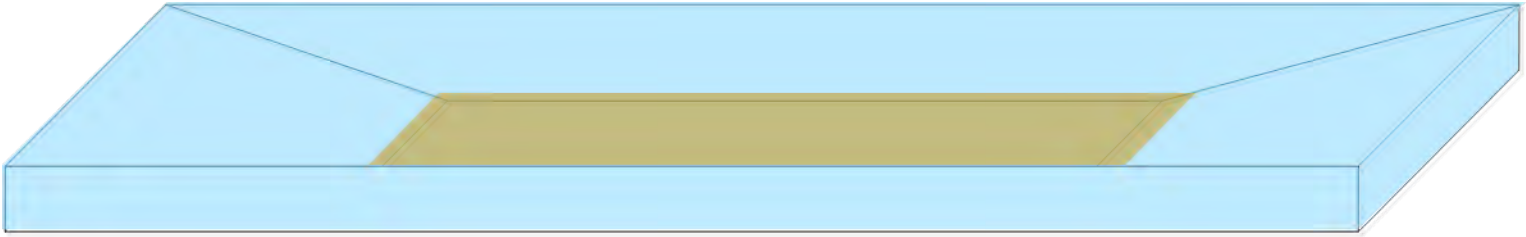
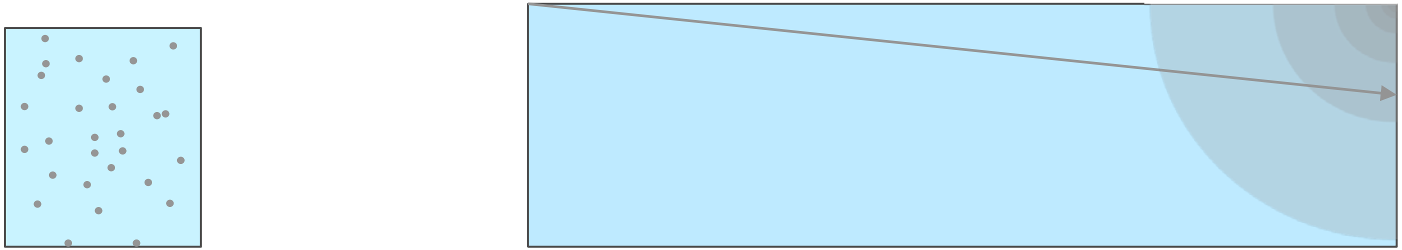


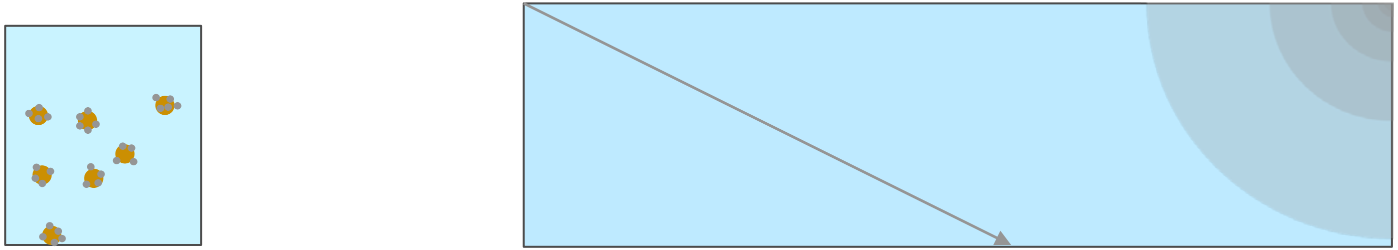


Chemistry – The Great Equalizer

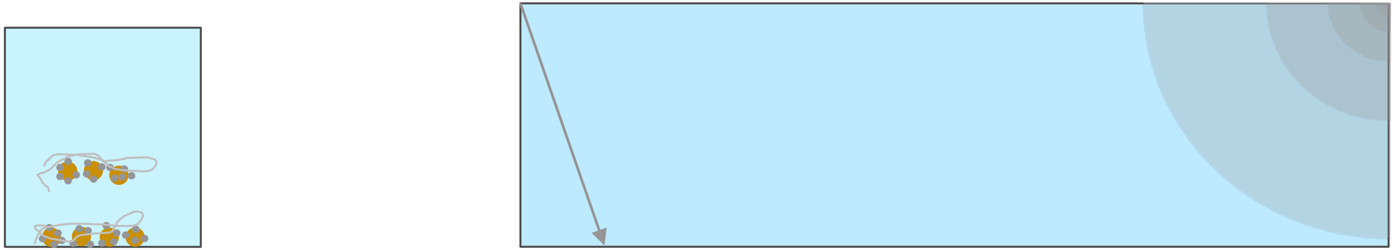
Coagulants and Flocculants



+ Coagulant (Ferric Chloride)



+ Flocculant (Anionic Polymer)




A
B
C
D

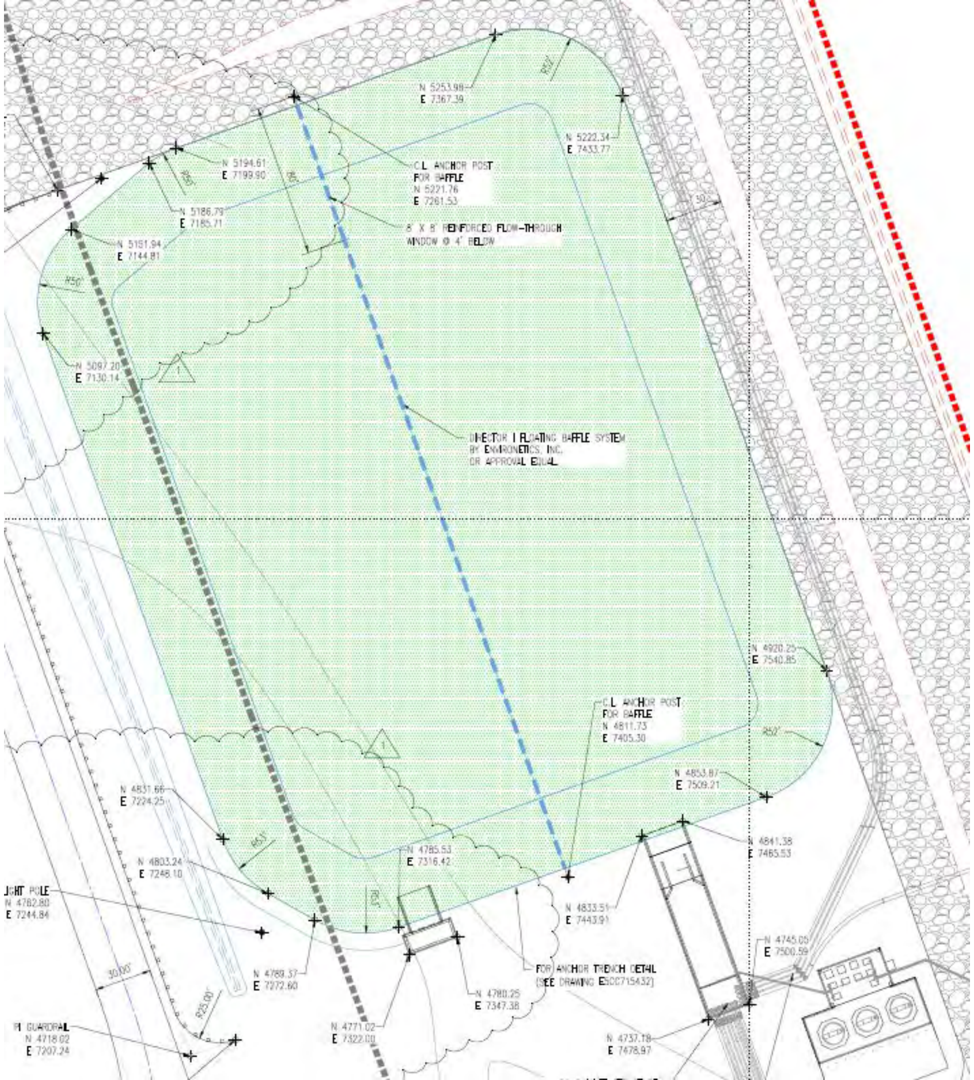
Wrapping it Up

- Data, data, data
  - *The more data, the better*

- The line between a conservative design and over designing is not so clear
  - *Be conservatively conservative*

- Get out ahead of possible hang-ups and resolve these issues during the preliminary design
  - Example: Annual cleanouts

- Know the trade-offs of assumptions and their effect on treatment


N 5253.98
E 7367.39
N 5222.34
E 7433.77
N 5194.61
E 7199.90
C.L. ANCHOR POST
FOR BAFFLE
N 5221.76
E 7261.53
N 5186.79
E 7185.71
8' X 8' REINFORCED FLOW-THROUGH
WINDOW @ 4' BELOW
N 5151.94
E 7144.81
N 5097.20
E 7130.14
DIRECTOR I FLOATING BAFFLE SYSTEM
BY ENVIRONETICS, INC.
OR APPROVAL EQUAL
N 4920.25
E 7540.85
C.L. ANCHOR POST
FOR BAFFLE
N 4811.73
E 7405.30
N 4853.87
E 7509.21
N 4831.66
E 7224.25
N 4841.38
E 7465.53
N 4785.53
E 7316.42
N 4803.24
E 7248.10
LIGHT POLE
N 4782.80
E 7244.84
N 4833.51
E 7443.91
N 4745.05
E 7500.59
FOR ANCHOR TRENCH DETAIL
(SEE DRAWING E5CC715432)
N 4789.37
E 7272.60
N 4780.25
E 7347.38
GUARDRAIL
N 4718.02
E 7207.24
N 4771.02
E 7322.00
N 4737.18
E 7478.97

Southern Company