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## Introduction

Our topics for today

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## "Sedimentation"

The settling of heavier particles in the wastewater

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## "Flocculation"

Gathering fine particles together after coagulation to form larger particles by a process of mixing

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## "Floatation"

Floating lighter materials like grease to the top for removal

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The Sedimentation Principle is used throughout the treatment train.

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## Gravity Separation Theory

| Type | Description | Application |
|---|---|---|
| Discrete Particle Settling | Low solids concentration, particles settle by gravity, particles settle individually w/out significant interaction with other particles | Grit & sand removal from wastewater |
| Flocculant Settling | Dilute suspensions of particles that coalesce (flocculate) during the settling process, increase in mass and settle at a faster rate | TSS removal in primary settling facilities & upper portions of secondary settling facilities; also removes chemical floc in settling tanks |
| Ballasted Flocculant Settling | Addition of inert ballasting agent and polymer to partially flocculated suspension to promote rapid settling and improved solids reduction (some ballasting agent recycled typically) | TSS removal in primary settling facilities; combined system influent; industrial wastewater (also reduces BOD and phosphorus) |
| Hindered Settling (aka "Zone Settling") | Intermediate concentration suspensions where interparticle forces hinder settling, and the mass settles as a unit with a solids-liquid interface at the top | In secondary settling facilities used in conjunction with biological treatment facilities |
| Compression Settling | Where particles are so concentrated that further settling results from compression due to weight of solids being added by sedimentation | Occurs in lower levels of a deep solids or biosolids mass, such as deep secondary facilities or biosolids thickening facility |
| Accelerated Gravity Settling | Removal of particles in suspension by gravity settling in acceleration field | Removal of grit and particles |
| Floatation | Removal of particles in suspension that are lighter than water by air or gas floatation | Removal of greases and oils, light material that floats, thickening of solids suspensions |

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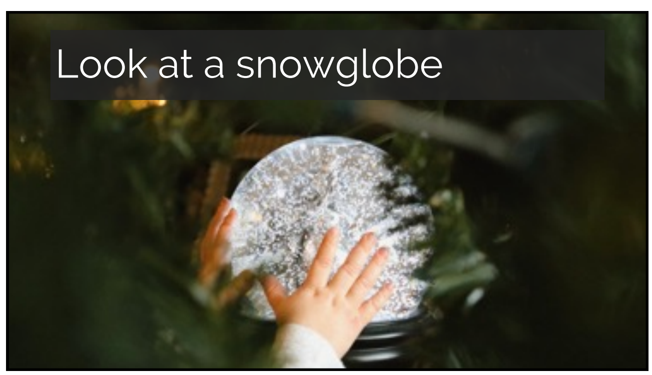


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## Grit removal works via sedimentation

**What's grit?** **Heavy particulate matter** like sand, eggshells, coffee grounds, bone fragments, seeds, etc.

**How is it removed?** **Water velocity is reduced** so that the **heavier** grit **particles** can **settle** to the bottom of the basin for mechanical removal, while lighter organic particles move to the next treatment unit

**What's the ideal water velocity for grit removal?** **1 ft/sec** is the ideal velocity though a range of 0.8 to 1.3 ft/sec is typically acceptable.

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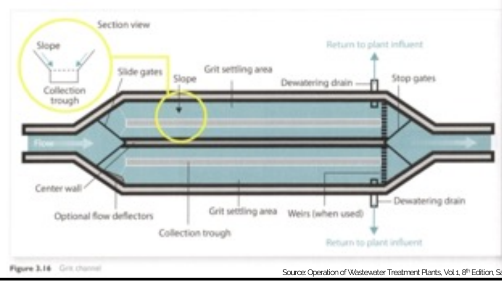
## A little review: Grit Channels




Source: Operation of Wastewater Treatment Plants, Vol 1, 8th Edition, Sacramento State, 2019

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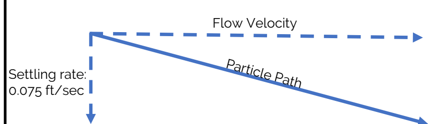
## Grit removal via sedimentation

**Designed to remove 0.2mm sized sand and heavier particles**

**They typically settle downward at about 0.075ft/sec**

**Imagine a 5 ft deep basin with 4 ft of water in it**




$$settling\ time = \frac{depth}{settling\ rate}$$

$$settling\ time = \frac{4\ ft}{0.075\ ft/sec}$$

$$settling\ time = 53.3\ seconds$$

$$velocity = \frac{length}{time}$$

$$velocity \times time = length$$

$$1\frac{ft}{sec} \times 53.3 sec = 53.3\ ft$$

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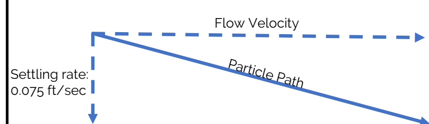
## Grit removal via sedimentation

**The flow has to be slow enough to let those particles settle to the bottom of the channel before it ends.**

**Of course, you're stuck with the channel length you have.**
**Let's say it's 50 feet long. What's the maximum velocity for removal?**

$$settling\ time = 53.3\ seconds$$




$$velocity = \frac{length}{time}$$

$$velocity = \frac{50\ ft}{53.3\ seconds}$$

$$velocity = 0.94\ ft/sec$$

**The maximum velocity of your flow in the channel is 0.94 ft/sec**

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## Grit removal via sedimentation

**The next question is: Will that velocity of 0.94 ft/sec be effective?**

| Item | Range Metric | Typical Metric |
|---|---|---|
| Detention Time | 45 - 90 seconds | 60 seconds |
| Horizontal Velocity | 0.8 – 1.3 ft/s | 1 ft/s |
| Settling Velocity (50 mesh) | 9.2 – 10.2 ft/min | 9.6 ft/min |
| Settling Velocity (100 mesh) | 2 - 3 ft/min | 2.5 ft/min |
| Headloss (% of channel depth) | 30 – 40% | 36% |

**It's in the right range**

Source: Operation of Wastewater Treatment Plants, Vol 1, 8th Edition, Sacramento State, 2019

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## Grit removal via sedimentation

**What other options are there for us to get to the ideal 1 ft/sec if that were determined to be necessary?**

- **Adjust the inflow?**
- **Lower the water depth in the channel by opening the other one?**
- **Alter flow equalization practices**
- **Other options?**

- **What could work?**
- **What would be practical?**

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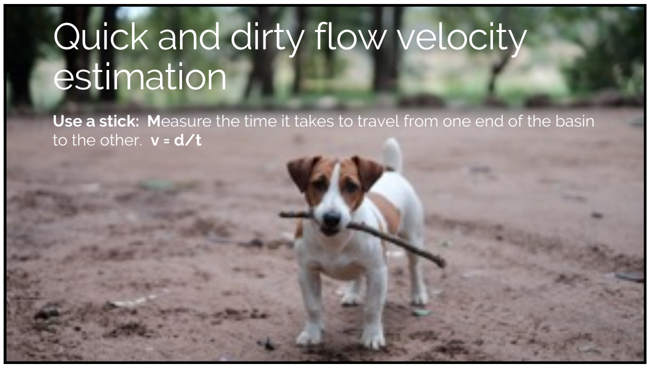


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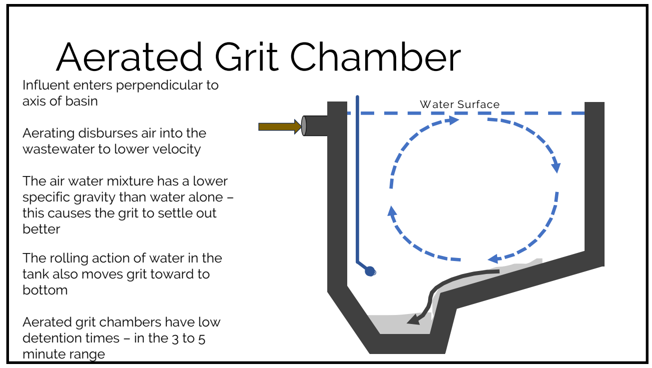


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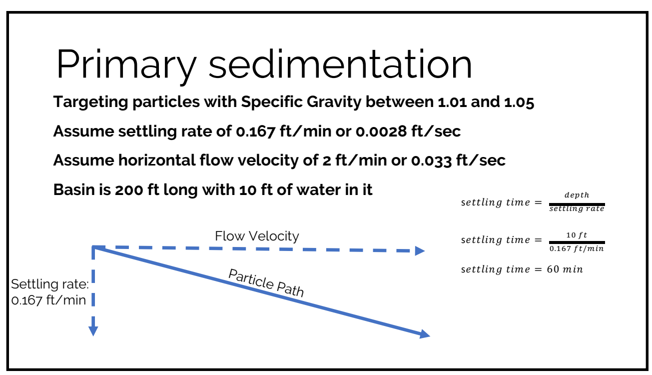


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## Primary sedimentation

**Targeting particles with Specific Gravity between 1.01 and 1.05**

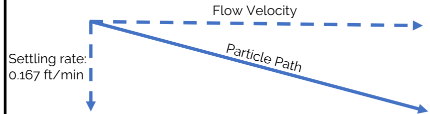
**Assume settling rate of 0.167 ft/min or 0.0028 ft/sec**

**Assume horizontal flow velocity of 2 ft/min or 0.033 ft/sec**

**Basin is 200 ft long with 10 ft of water in it**

$settling\ time = 60\ min$

**What's the horizontal distance traveled?**




$horizontal\ velocity = 2\ ft/min$

$velocity = \frac{length}{time}$

$velocity \times time = length$

$2\ \frac{ft}{min} \times 60\ min = 120\ ft$

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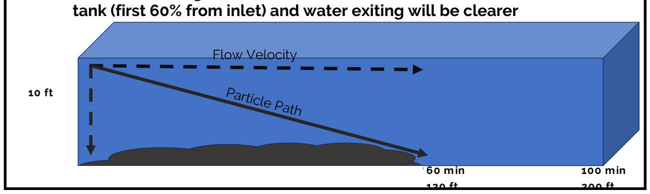
## Primary sedimentation

So, what does that mean?

**Particles settling at this rate will settle within first 120 ft of 200 foot tank (first 60% from inlet) and water exiting will be clearer**

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## Sedimentation Tanks Expected Removal Efficiency – 2 hr DT

**BOD and TSS removal:**

- **50 to 70% of TSS**
- **25-40% of BOD**

$$R = \frac{t}{a + bt}$$

$R$ = expected removal efficiency
$t$ = nominal detention time (hrs)
$a$, $b$ = empirical constants

| Item | b | a |
|---|---|---|
| BOD | 0.020 | 0.018 |
| TSS | 0.014 | 0.0075 |

$$R_{TSS} = \frac{2}{0.0075 + 0.014(2)} = 56.3\% \qquad R_{BOD} = \frac{2}{0.018 + 0.020(2)} = 35.5\%$$

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## Detention Time

Settling tanks are typically designed for 2 to 3-hour detention times (though designs may vary)

Operator experience comes into play when actually running the plant because flows can increase or decrease suddenly, and organic loads can vary as well

Can calculate theoretical detention time using tank volume and flow rate

Can verify using dyes, tracers or floats

Actual detention times are often shorter than the calculated theoretical time

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## Detention Time

If you have a detention time of less than 2 hours and lab tests are showing poor solids removal, you may need to add tanks, or restrict flow to solve the detention time/solids removal problem

Detention times are going to vary considerably between day and night

This is one reason some systems use flow equalization techniques in preliminary treatment

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## Horizontal Flow Design Criteria for Sedimentation

| Item | Typical Horizontal Grit Channel | Typical Primary Settling Tank |
|---|---|---|
| Detention Time | 1 to 3 min | 2 to 3 hours |
| Horizontal Flow Velocity | 0.8 to 1.3 ft/s | 1 to 2 ft/min |
| Specific Gravity of Particles | ~ 2.5 to 2.6 | <1 to 1.25 |

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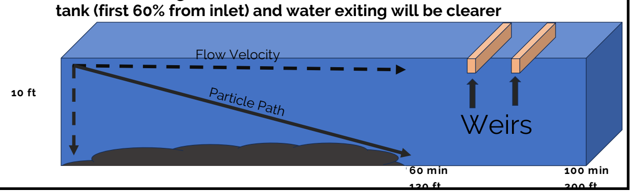
# Primary sedimentation

**Particles settling at this rate will settle within first 120 ft of 200 foot tank (first 60% from inlet) and water exiting will be clearer**

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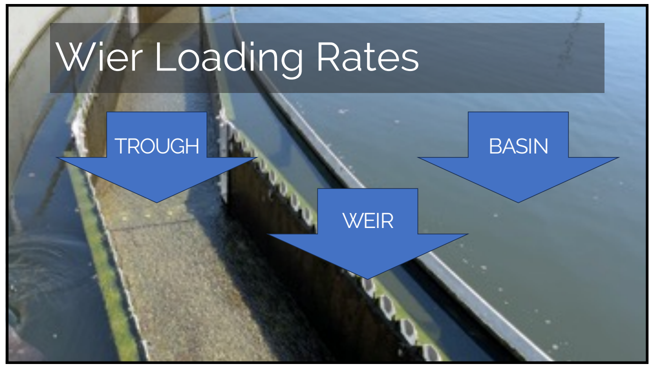
# Wier Loading Rates

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# Wier Loading Rates

Number of lineal feet of weir on the clarifier in relation to flow

Weir Loading Rate is what volume flows over **1 linear foot** of weir **per day**

Typical design parameters are **10,000 to 20,000 GPD** per foot of weir

Might be higher for fast settling solids or intermediate treatment

Secondary clarifiers and higher quality water will require lower WLRs that what's acceptable for primary clarifier

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# Wier Loading Rates

So how do we calculate it?

$$LR_{Weir} = \frac{Q}{L}$$

$Q = Flow\ rate\ per\ day$

$L = Length\ of\ weir$

Note that for a circular basin: $L_{circular\ weir} = \pi \times D$

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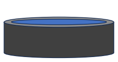
# Wier Loading Rates Example



$D_{weir} = 75\ ft \quad Q = 5{,}000{,}000\ gpd$

$L_{circular\ weir} = \pi \times D$

$L_{circular\ weir} = 3.149 \times 75ft$

$L_{circular\ weir} = 236.18ft$

$$LR_{Weir} = \frac{5{,}000{,}000\ gpd}{236.18\ ft}$$

$LR_{Weir} = 21{,}170\ gpd/ft$

Typical design parameters are 10,000 to 20,000 gpd/ft
This **might** be a problem.

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## Wier Loading Rates Example

$D_{weir1} = 75\,ft$ $D_{weir2} = 70\,ft$ $Q = 5{,}000{,}000\ gpd$

$L_{circular\ weir} = \pi \times (D_1 + D_2)$

$L_{circular\ weir} = 3.149 \times 145ft$

$L_{circular\ weir} = 456.61ft$

$$LR_{Weir} = \frac{5{,}000{,}000\ gpd}{456.61\ ft}$$

$LR_{Weir} = 10{,}950\ gpd/ft$

Typical design parameters are 10,000 to 20,000 gpd/ft
We're **are** within typical design parameters.

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## Surface Loading Rates aka "Overflow Rates"

GPD per ft² of clarifier surface area

Typical range is 300 to 1200 GPD/ft² depending on solids and treatment requirements

In cold regions low surface loading rates are common for small plants but in warm regions low SLRs can cause excessive detention time result in septicity

$$LR_{Surface} = \frac{Q_{GPD}}{A_{Surface}}$$

$A\ (circular\ clarifier) = \pi \times Radius^2$

Or

$A\ (circular\ clarifier) = \frac{\pi}{4} \times Diameter^2$

$A\ (rectanguar\ \ clarifier) = L \times W$

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# Things that impact sedimentation

A few examples

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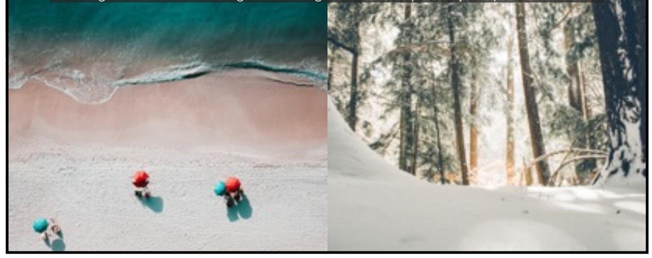
## Temperature

You might see seasonal changes in settling rates that are primarily temperature driven



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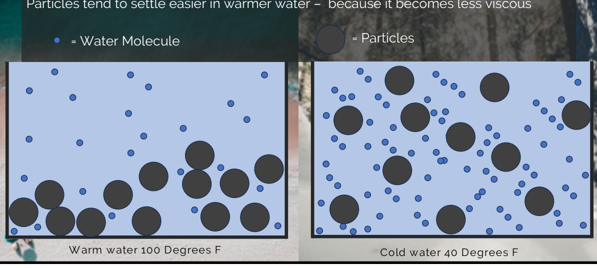
## Temperature

Particles tend to settle easier in warmer water – because it becomes less viscous

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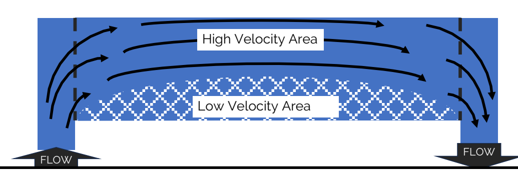
## Short Circuiting

When water isn't evenly disbursed across the tank area and velocity is much faster in some parts than others

In the high velocity area detention time is reduced and particles escape before settling; in the low velocity area septic conditions and odor can arise.

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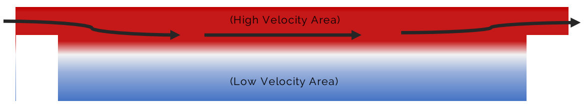
## Short Circuiting: Temperature

Temperature stratification can cause short circuiting too.

Cold water is denser, warmer water tends to float on top.

If the basin is cold and the influent is very warm, it may flow along the top and cause septic conditions at the bottom

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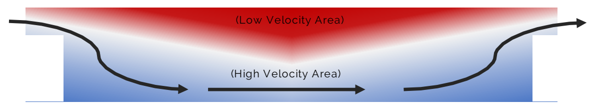
## Short Circuiting: Temperature

Temperature stratification can cause short circuiting too.

Cold water is denser, warmer water tends to float on top.

If the basin is warm and the influent is very cold, it may flow along the bottom, and cause septic conditions at the top

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## Scour Velocity (it's complicated)

$$v_H = \left[\frac{8k(s-1)gd}{f}\right]^{0.5}$$

| | Value |
|---|---|
| Particle cohesion constant (k) | 0.05 |
| Darcy-Weibach friction factor (*f*) | 0.025 |
| Specific Gravity (s) | 1.25 |
| Gravity | 9.81 m/s$^2$ |
| Particle diameter | 100 x 10$^{-6m}$ |

$$v_H = \left[\frac{8(0.05)(1.25-1)(\frac{9.81m}{s^2})(100x10-6)}{0.025}\right]^{0.5}$$

$$v_H = 0.063\frac{m}{s} = 0.21\frac{ft}{s} = 12.4\ ft/min$$

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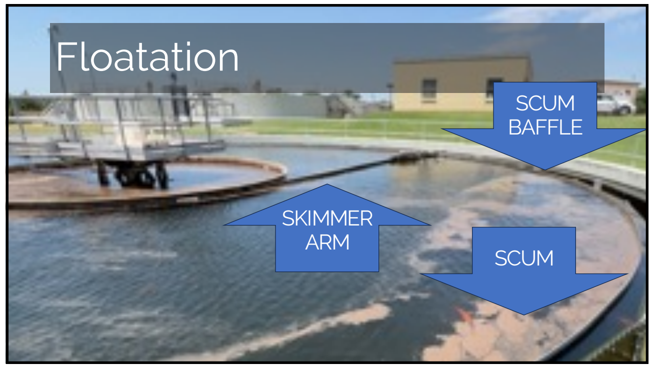


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## Checking Facility Performance

You can use SLR, WLR, Removal Efficiency and detention time formulas to compare facilities to common design values

Used in combination with lab tests, process control tests they can help to verify operational goals are being achieved

If lab tests showing poor performance these math tests can help identify operational problems

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## Office Hour Details

Time: Every Tuesday from: 9:00 AM to 10:00 AM PDT
10:00 AM to 11:00AM MDT
11:00 AM to Noon CDT
Noon to 1:00 PM EDT

Reach out via email: ajbarney1@unm.edu
jmarkham@unm.edu

We'll provide a Zoom link

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## CONTACT INFORMATION

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