OPERATOR MATH

NMWWA Short School
OHKAY/Casino Conference Center
Monday 13 May 2024; 2.30-5p
Wednesday 15 May 2024; 2.30-5p

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OPERATOR MATH

Monday 13 May 2024; 2.30-3.40p

References, Problem Solving

Data Management

Fractions, Percent

Fundamental Units, Conversions

Area and Volume Geometry

References

❖ Basic Math Concepts for Water and Wastewater Plant Operators, Joanne Kirkpatrick Price, Technomic Publishing Co., Inc., 1991.

❖ Applied Math for Water/Wastewater Plant Operators & Workbook, Texts and Workbooks, Joanne Kirkpatrick Price, Technomic Publishing Co., Inc., 1991.

❖ Wastewater Math The Basics, Skeet Arasmith, ACR Publications, Inc., 1995.

❖ The Math Text for Water and Wastewater Technology, 2nd ed., Grover Wright, Wright's Training, 1994.

❖ Simplified Math for Waterworks Operators, George Mason, ACR Publications, Inc., 1992.

Words and Symbols

Hierarchy of Operations

MATH OPERATION	SYMBOL	EXAMPLE
Multiplication	x	Q = V x A
Multiplication	.	$Q = V \cdot A$
Multiplication	No space	Q = VA
Multiplication	( ) ( )	Q = (V) (A)
Division	÷	r = D ÷ 2
Division	—	$r = \frac{D}{2}$
Division	/	r = D/2

Word Problems

- Word problems are a series of expressions that fits into an equation. An equation is a combination of math expressions. Suggestions:

- **Read the problem entirely**
  Get a feel for the whole problem
- **Draw a diagram to describe the problem statement**
- **List information** and the **variables** you identify
  Attach units of measure to the variables (gallons, miles, inches, etc.)
- **Define what answer you need**,
  as well as its units of measure
- **Set up equation(s), solve for variable, populate with data**
- **Work in an organized manner**
  Working clearly will help you think clearly
  - Draw and label all graphs and pictures clearly
  - Note or explain each step of your process;
    this will help you track variables and remember their meanings
- **Look for the "key" words (**above**)**
  Certain words indicate certain mathematical operations.

Data Management - Averaging

The Concept

- Used to analyze plant performance
  - day-to-day
  - unit process or entire plant
- Difficult to recognize trends in performance due to the variation in the data
- Averaging can frequently sort out that variation by applying some basic statistical concepts to the data

Data Management - Averaging

Definition of Terms

- Average: one number that may be considered typical of a group of data
  - mean, or arithmetic mean
  - median, and
  - mode
- Mean, or arithmetic mean: sum of all measurements/# of measurements
- Median: the middle value of a data group that has been arranged according to value, usually in ascending order (low to high)
  - for an even # of measurements the median would be halfway between the 2 middle values
- Mode: the value that occurs most frequently in a data group
  - there may be no mode, 1 mode, 2 modes (bimodal), or more
- Mean vs median: if the data set contains extreme values (unusually high or low) than the mean will be "pulled" in that direction
  - in such cases the median may be more representative of the data set than the mean

Data Management - Averaging

More Terms

- Moving average: the calculation of an arithmetic mean that drops the oldest value and adds the newest value
  - moving averages are good indications of system operation trends since they "smooth out" data fluctuations

- Weighted average: used to determine the average of a large data set
  - Arrange the data into groups with 5-, 10-, ect. point spans depending on the point span of the original data set
  - Tabulate the "frequency" – the number of data points in each grouping
  - Calculate the average of each group based on the point span
  - Multiply the frequency by the average for each group
  - Sum those products & divide this sum by the total frequency (total number of data points in data set)

Data Management - Averaging

Determine the arithmetic mean, median and mode for the following data sets:

MPN/100 ml: 260, 220, 240, 290, 360, 3310, 415, 280, 240

mg/L influent BOD: 170, 190, 180, 240, 190, 160, 175

mg/L MLSS: 2450, 2610, 2290, 2540, 2650, 1820, 2210, 2290

Calculate the first five 7-day moving averages for the following data:

day 1 SVI=110	day 4 SVI=123	day 7 SVI=133	day 10 SVI=122
day 2 SVI=105	day 5 SVI=140	day 8 SVI=126	day 11 SVI=124
day 3 SVI=113	day 6 SVI=117	day 9 SVI=131	

Compare the weighted average and arithmetic mean for the following data:

170	126	182	146	168	145	115	108
115	147	141	159	174	151	136	110
122	164	136	129	192	137	144	121
105	137	107	118	181	123	153	143
118	153	124	120	164	117	140	181

Fractions

- Anatomy: top # or unit = numerator

  bottom # or unit = denominator

- Addition and subtraction: only add or subtract numerators and only when denominator is the same; if denominators are different then must convert 1 or both fractions to same denominator

Fractions

- Multiplication: multiply numerators, multiply denominators, then reduce to lowest common factors
- Division: invert 2nd fraction (flip numerator & denominator) and follow steps for multiplication
- Convert integer to fraction by putting a “1” in denominator
- Convert fraction to number by dividing numerator by denomination and express as whole # or decimal

Percent, %

- Specific application of fractions
- Percent means parts per 100
  - 26% = 26 parts out of 100 or 26/100
  - Can also be expressed as a decimal 0.26
- % may not always be parts per 100
  - What is the absentee rate for a class of 26 students with 6 absent?
- Converting % to decimal and decimal to % means simply moving decimal 2 places right or left (ahhh, the metric system…!)

Application of Percent

- Removal efficiencies
  - Clarifier influent 150 mg/L; effluent 12 mg/L
  - $\% \text{ rem} = \frac{(150-12)\text{ mg/L}}{150\text{ mg/L}} \times 100\% = 92\%$
- Pump or motor efficiencies
  - P_{eff} or $M_{eff} = HP_{out}/HP_{in} \times 100\%$
  - Can also calculate HP data if you know efficiency and 1 of the HPs

Mg/L to Percent

- Dilute concentrations in water can be expressed as mg/L or ppm, and can also be expressed as a %.
- Mg/L x L/1000-mL x mL/g x g/1000-mg = ppm = 1 part per 1,000,000 parts
- % = parts per hundred = 1 part per 100 parts
- 10,000 ppm = 1%; Proof:

$$\frac{10{,}000 \text{ parts}}{1{,}000{,}000 \text{ parts}}$$; canceling zeros = 1/100 = 1%

Mg/L to Percent Examples

- A chemical is to be dosed at 25 mg/L. Express the dosage as %.

  ANS = 0.0025%

- Express 120 ppm as %.

  ANS = 0.012%

- HTH used for disinfection has concentration of 65%. Express the concentration as mg/L.

  ANS = 650,000 mg/L

Percent Strength

The strength of a solution can be expressed as a percent by weight:

$$\% \text{ strength} = \frac{\text{wt of solute}}{\text{wt of solution}} \times 100\text{, where}$$

solute = weight of chemical being added

solution = the combined weight of solute plus liquid (or solvent)

Percent Strength Examples

What is the percent strength of a solution that contains 25 # of chemical and 400 # of water?

ANS = 5.9 %

What is the percent strength of a solution if 40 pounds of chemical is added to 120 gallons of water?

ANS = 3.8 %

Units – The Fundamentals

- Expressing 1 dimension
- Expressing 2 dimensions
- Expressing 3 dimensions
- What is the fourth dimension?
  - Stand-alone
  - As denominator

Common Equivalents (Handout Reference)

1. **Linear Measurements**
- 1 inch = 2.54 cm
- 1 foot = 30.5 cm
- 1 meter = 100 cm = 3.281 ft = 39.4 inches
- 1 acre = 43,560 ft^2
- 1 yard = 3 feet

2. **Volume**
- 1 gal. = 3.78 liters
- 1 ft^3 = 7.48 gals.
- 1 liter = 1000 mL
- 1 acre foot = 43,560 ft^3

3. **Weight**
- 1 ft^3 of water = 62.4 lbs
- 1 gal = 8.34 lbs
- 1 lb = 453.6 grams
- 1 kg = 1000 g = 2,2 lbs
- 1 % = 10,000 mg/L
- 1 lb = 16 oz dry wt.

4. **Pressure**
- 1 ft of head = 0.433 psi
- 1 psi = 2.31 ft of head

5. **Flow**
- 1 cfs = 448 gpm
- 1 gpm = 1440 gpd

Example

Question: How many feet are in 18 inches

Known: 1 foot = 12 inches

ANS = 1.5 ft

Example

Question: How many gallons are in 3291 ft^3?

Known: 1 ft^3 = 7.48 gallons

ANS = 24,617 gal

Example

Question: how many feet are in ¼ mile?

Known: 1 mile = 5280 ft

ANS = 1320 ft

Example

Question: convert 3,920 ft^3 to yd^3

Known: 1 yd^3 = 27 ft^3

ANS = 145 yd^3

Example

Question: convert 3,211,000 GPD to MGD

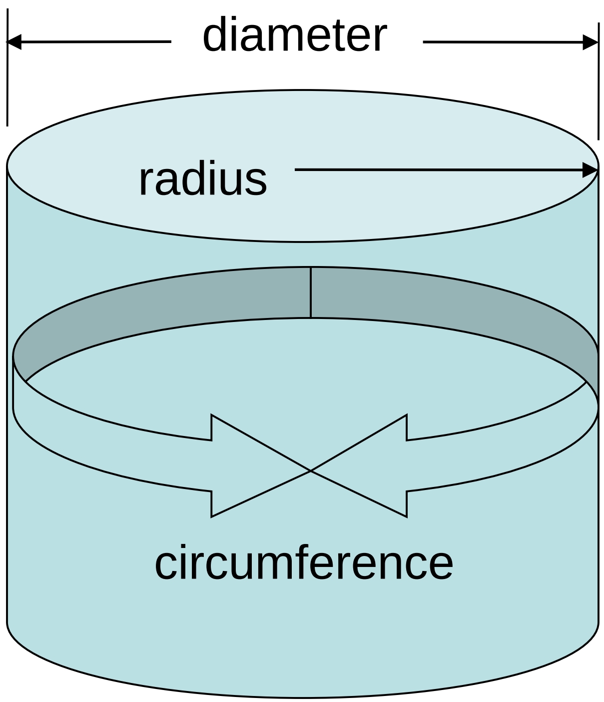
Known: 1 MGD = 1,000,000 GPD

ANS = 3.211 MGD

Circumference of a Circle (1-dim)

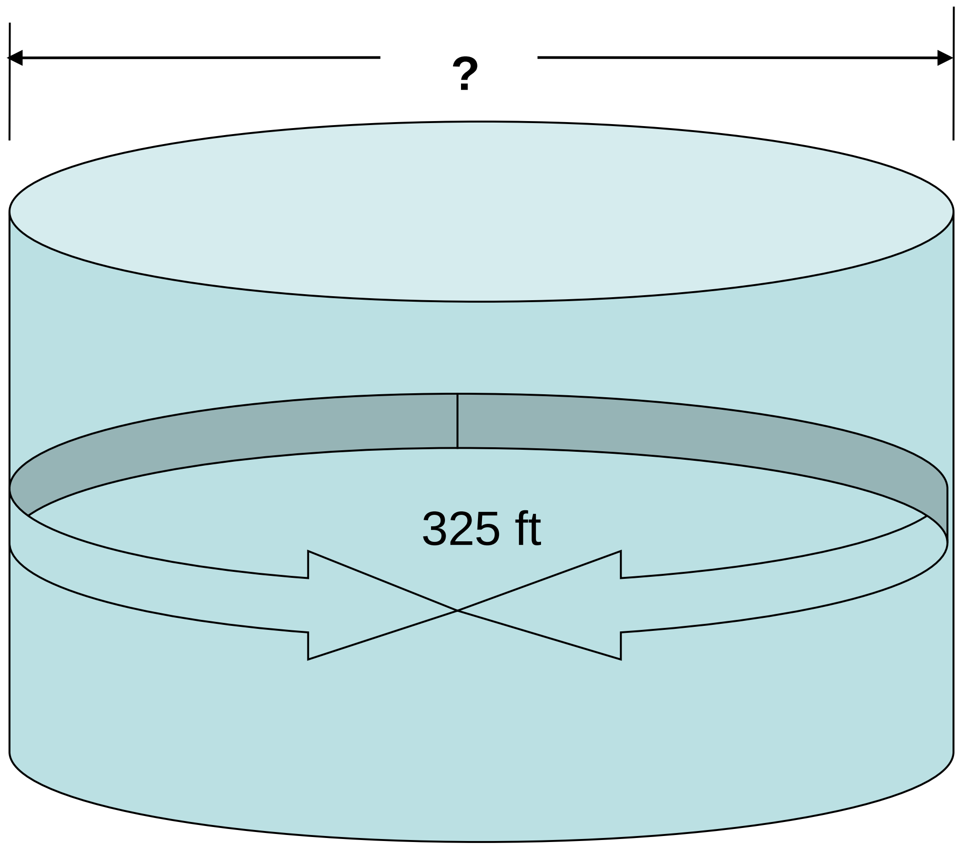
The circumference, C of a circle is the length or distance around the edge of the circle.

C = π x diameter, or C = π x 2r (r = ½ diameter)



The circumference of a tank is 325 ft. What is the diameter of the tank?

ANS = 103 ft



Area Calculation

- Area measurements defines the size or surface of an object. Sometimes an area is described as the X-section (cross section) of an object.
- U.S. units of area:

1. Square inches = in^2
2. Square feet = ft^2
3. Square yards = yd^2
4. Square mile = mi^2

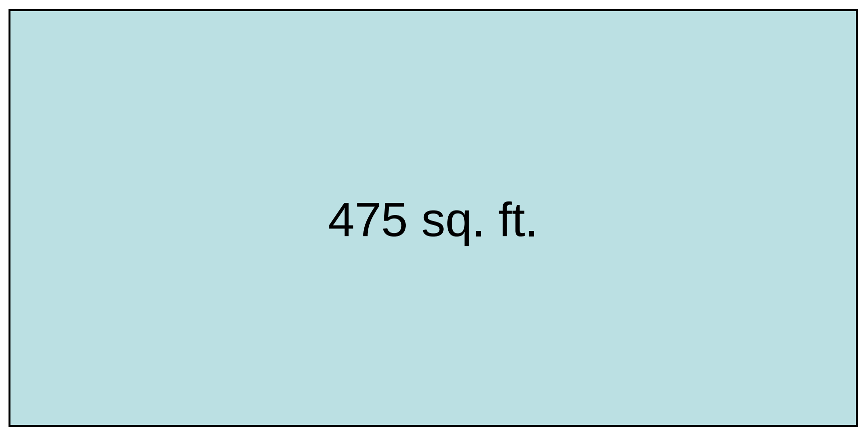
Rectangular Area

A room needs carpeting. If the room measures 25 ft by 19 ft how much carpet is needed to cover the floor?

ANS = 475 ft^2

- If one roll of carpet covers 80 ft^2, how many rolls of carpet are needed?

ANS = 6 rolls



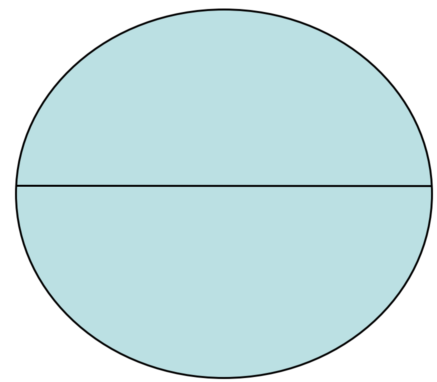
A sedimentation tank is 75 ft long and 35 ft wide. What is the surface area of the water tank?

ANS = 2625 ft^2

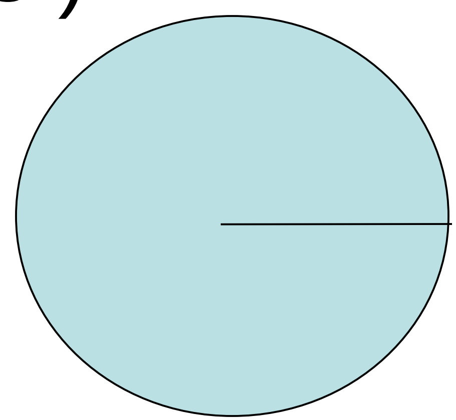
Circular Area Formulae

- Circle:

Area = (0.7854) x ($diameter^2$)

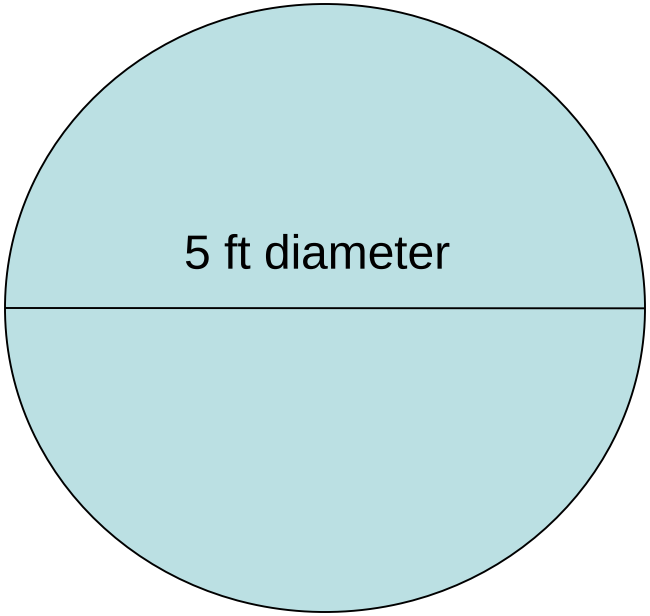


Area = π or (3.1416) x ($radius^2$)



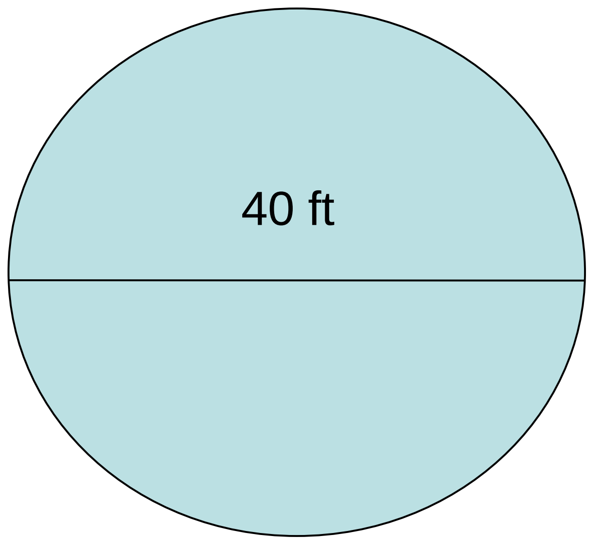
Calculate the area of the circle shown.

ANS = 19.6 ft^2



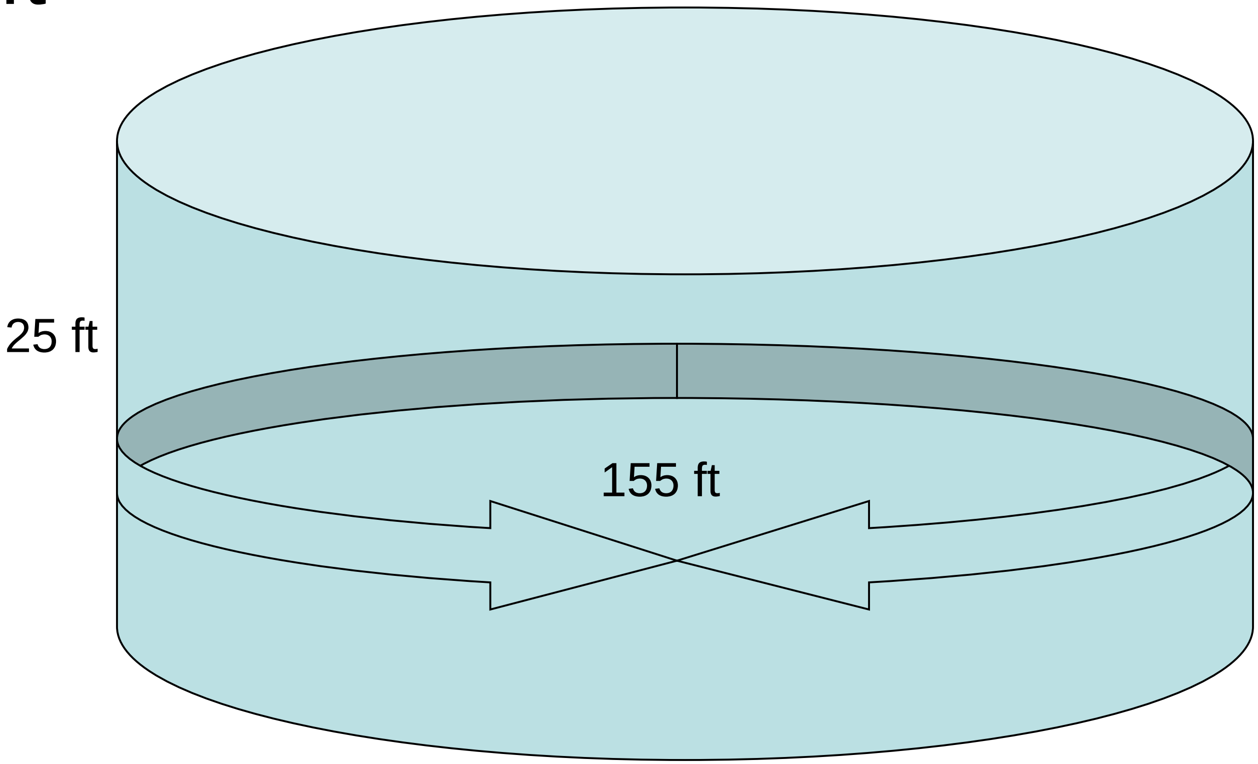
A circular clarifier has a diameter of 40 ft. What is the surface area of the clarifier?

ANS = 1256 ft^2



What is the total surface area (top + side) of a tank with a circumference of 155 ft and a sidewall depth of 25 ft?

ANS = 5787 ft^2



Volume Calculation

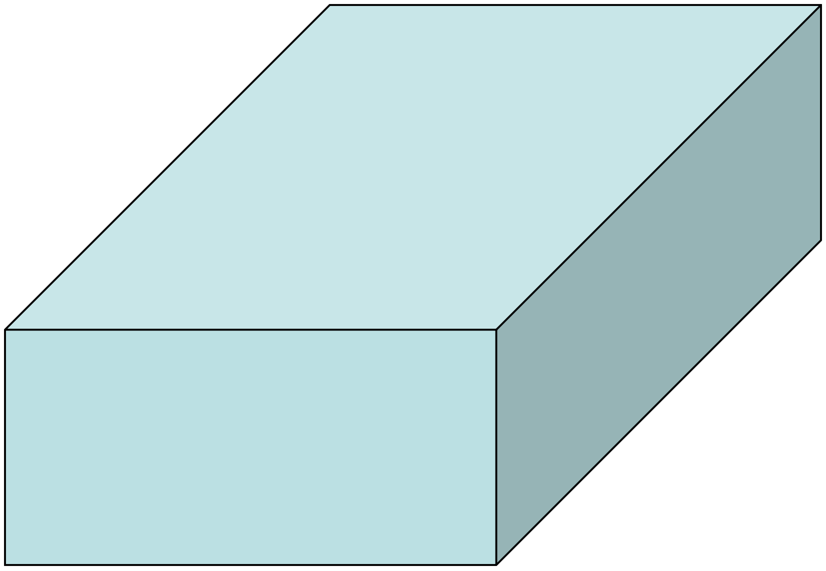
- Volume measurements define the amount of space that an object occupies.
- Some U.S. units of Volume:

1. Cubic inches = in^3
2. Cubic feet = ft^3
3. Cubic yards = yds^3
4. Gallons per cu.ft. = 7.48 gals
5. Cylinder = 0.7854 x (d^2) x (3^{rd} dimension)
6. Cylinder = 3.14 x (r^2) x (3^{rd} dimension)

Rectangular Volume

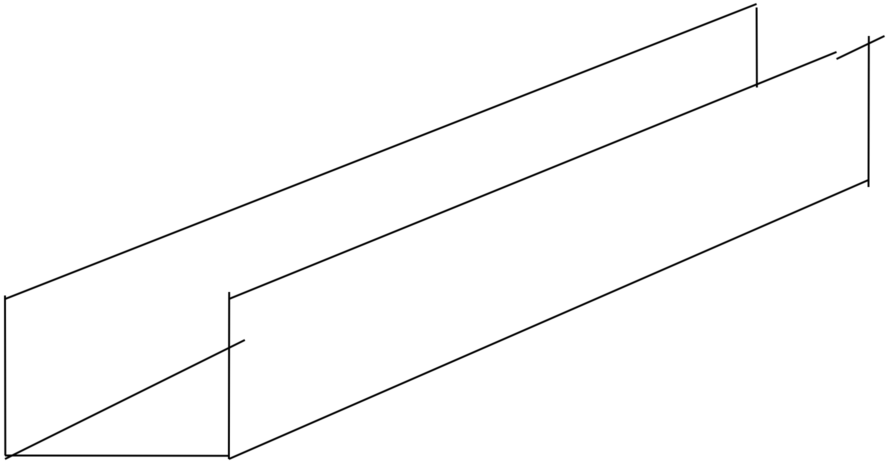
Calculate the volume of a tank that is 35 ft long, 22 ft wide and 11 ft deep.

ANS = 8470 ft^3



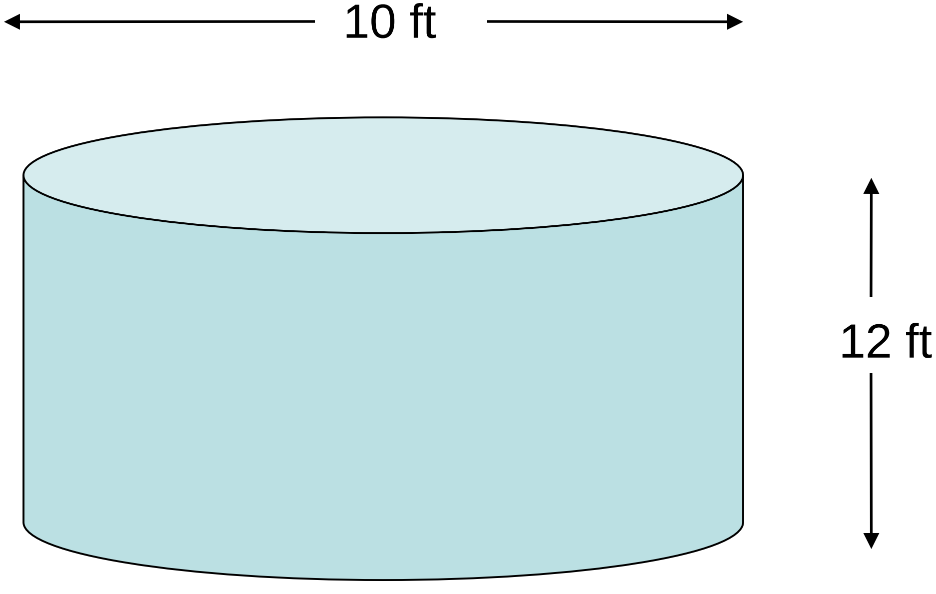
- How many cubic yards of backfill would be required fill a 3,500 ft trench, which is 4.5 ft wide and 6 ft deep?
- (Hint) 27ft³ per 1cu.yd.

ANS = 3500 yd^3



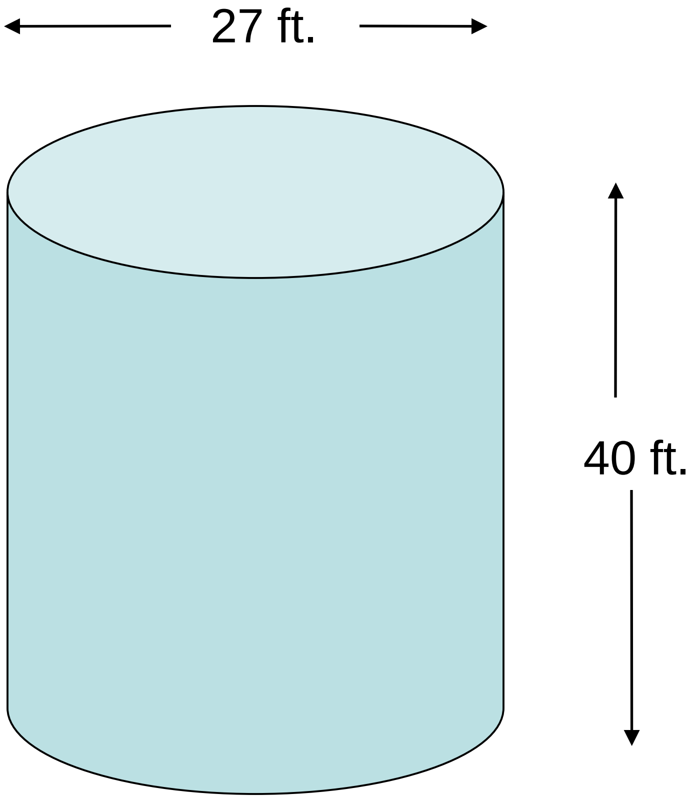
- What is the volume of a tank which has a diameter of 10 ft and a height of 12 ft?
- Hint: the 3rd dimension is the height of the tank

ANS = 942 ft^3



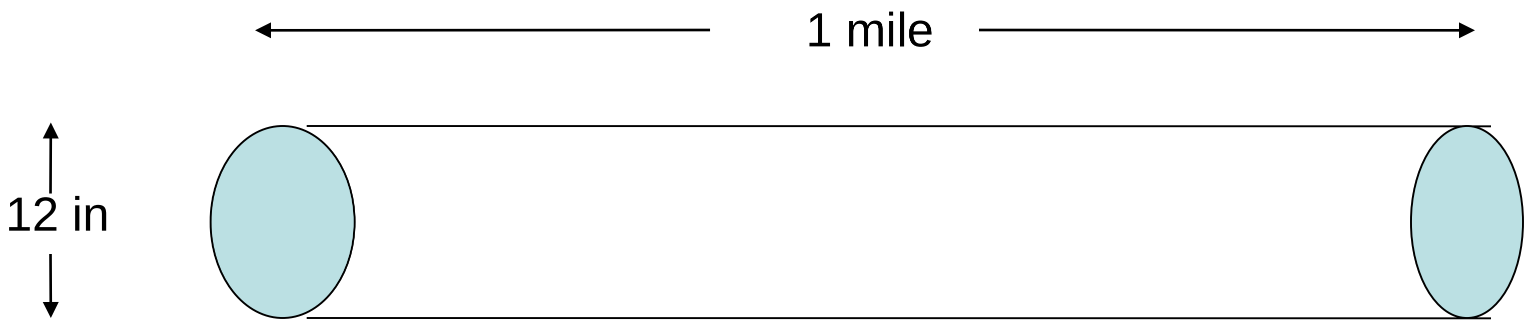
How many gallons of water will a storage tank hold if it has a 27 ft diameter and 40 ft height?

ANS = 171,222 gal



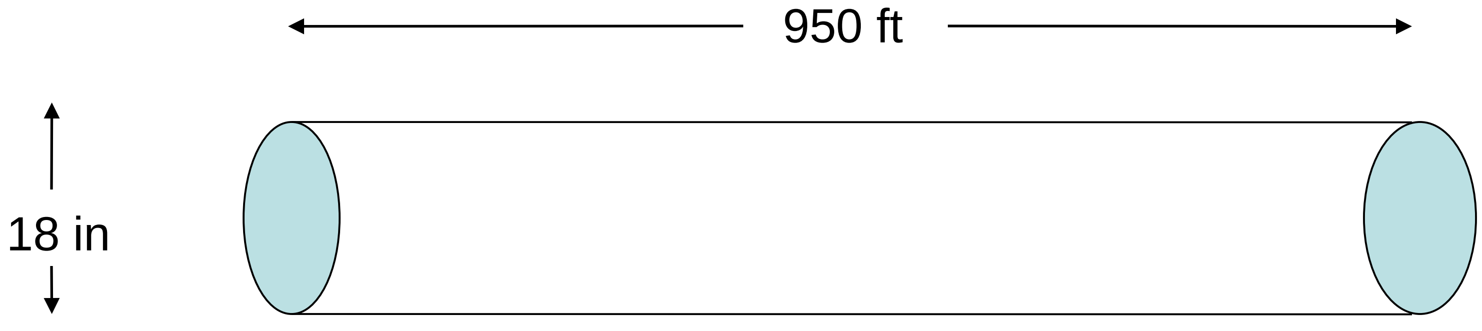
What is the volume of a 1 mile long 12 inch diameter pipe?

ANS = 4145 ft^3 or 31,003 gal



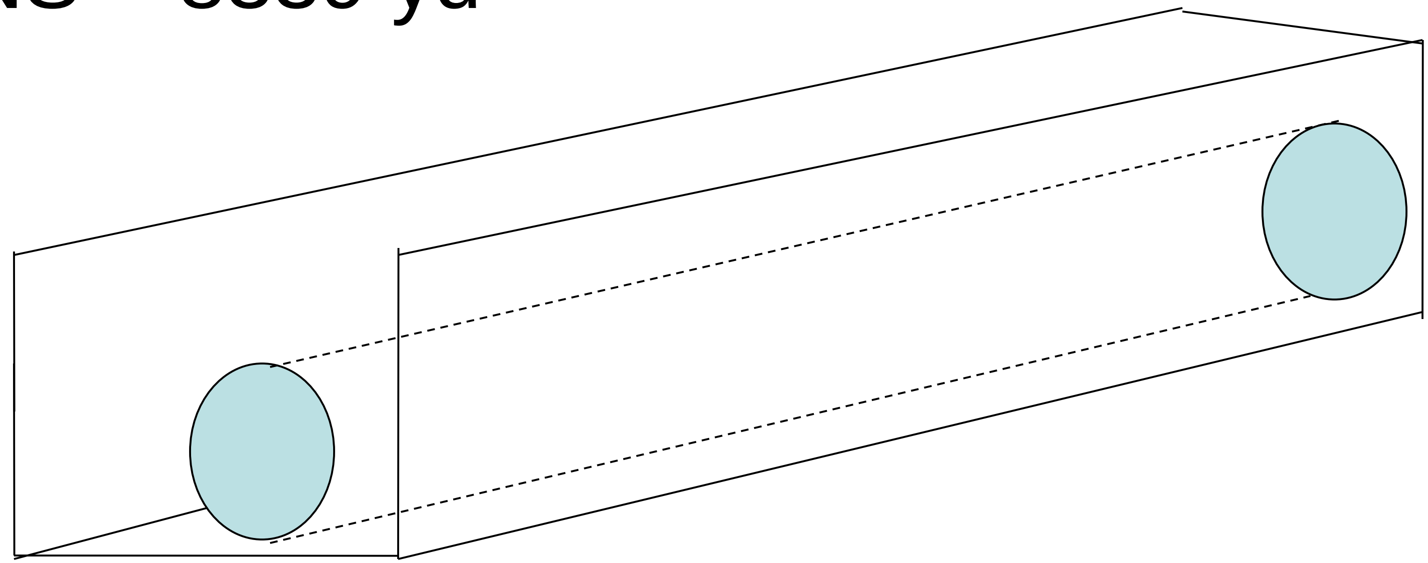
- How many gallons water will be required to fill a 950 ft long pipe and 18 in diameter?

ANS = 12,551 gal



- How many cubic yards of backfill would be required to fill a 5,500 ft trench that is 6 ft wide and 8 ft in depth after a 36 inch diameter water main pipe has been laid in the trench?

ANS = 8339 yd^3



Cones

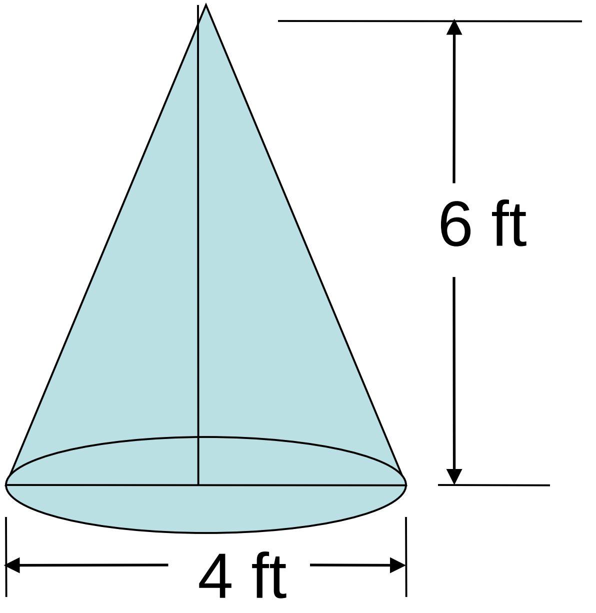
Calculate the volume of the cone, where

V = ⅓ (volume of a cylinder), then

$$V = \frac{(0.7854)\ (D^2)\ (\text{Third dimension})}{3}, \text{ and}$$

$$V = \frac{(0.7854)\ (4\ ft)^2\ (6\ ft)}{3}$$

ANS = 25 ft^3

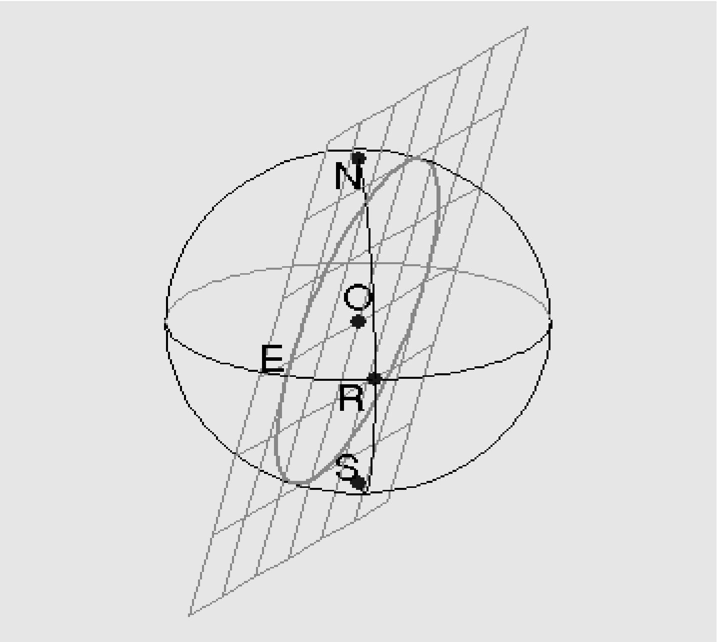


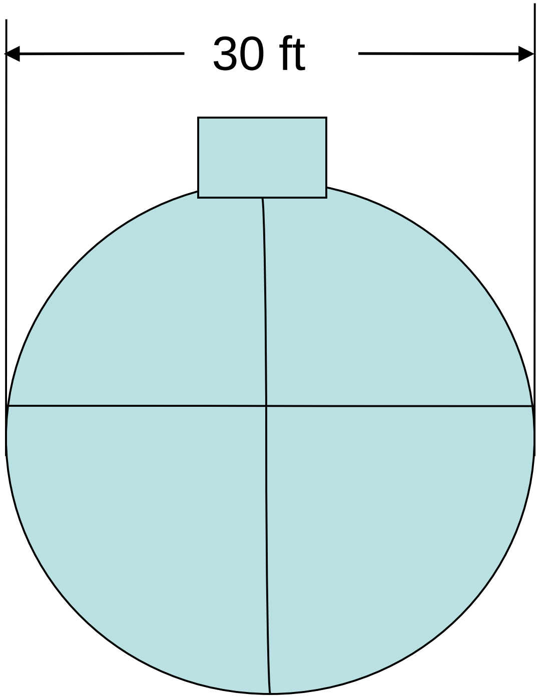
Spheres

Find the volume of the sphere, where

$V = \pi/6 \times \text{Diameter}^3$

ANS = 14,137 ft^3 or 105,746 gal





OPERATOR MATH

<u>Monday 13 May 2024; 3.50-5p</u>

Electricity, Temperature

Wastewater Characteristics: mg/L and %

Preliminary Treatment Grit Removal Flow and Velocity

Clarifier Detention Time, Surface Loading Rate, Weir Overflow Rate & Removal Efficiencies

The Ohm's Law Pie Chart

P = Watts

Watts = $\frac{\text{Volts}^2}{\text{Ohms}}$

Watts = $\text{Amperes}^2 \text{ X Ohms}$

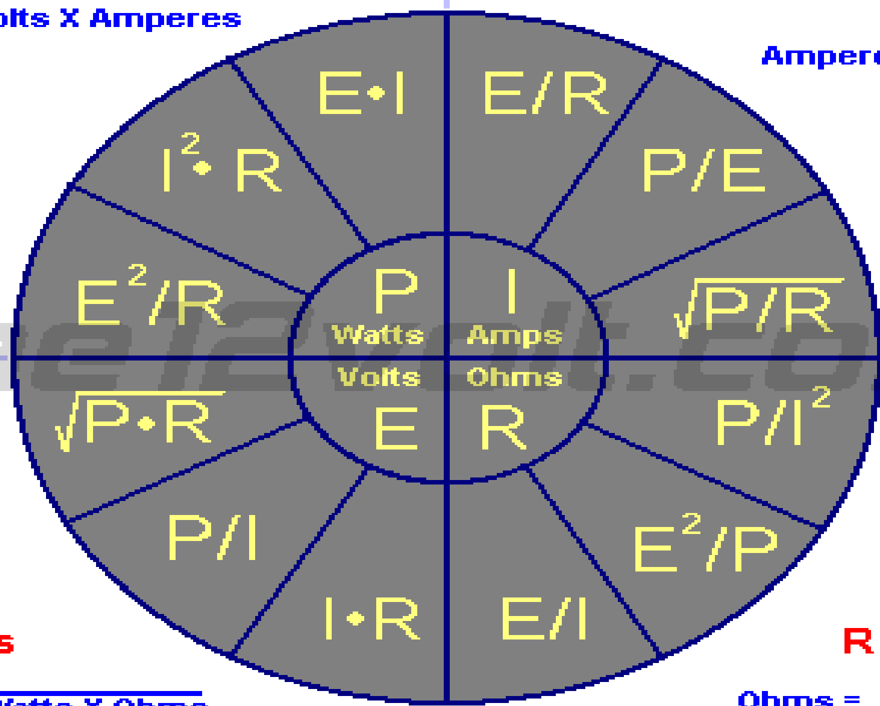
Watts = Volts X Amperes

I = Amperes

Amperes = $\frac{\text{Volts}}{\text{Ohms}}$

Amperes = $\frac{\text{Watts}}{\text{Volts}}$

Amperes = $\sqrt{\frac{\text{Watts}}{\text{Ohms}}}$



E = Volts

Volts = $\sqrt{\text{Watts X Ohms}}$

Volts = $\frac{\text{Watts}}{\text{Amperes}}$

Volts = Amperes X Ohms

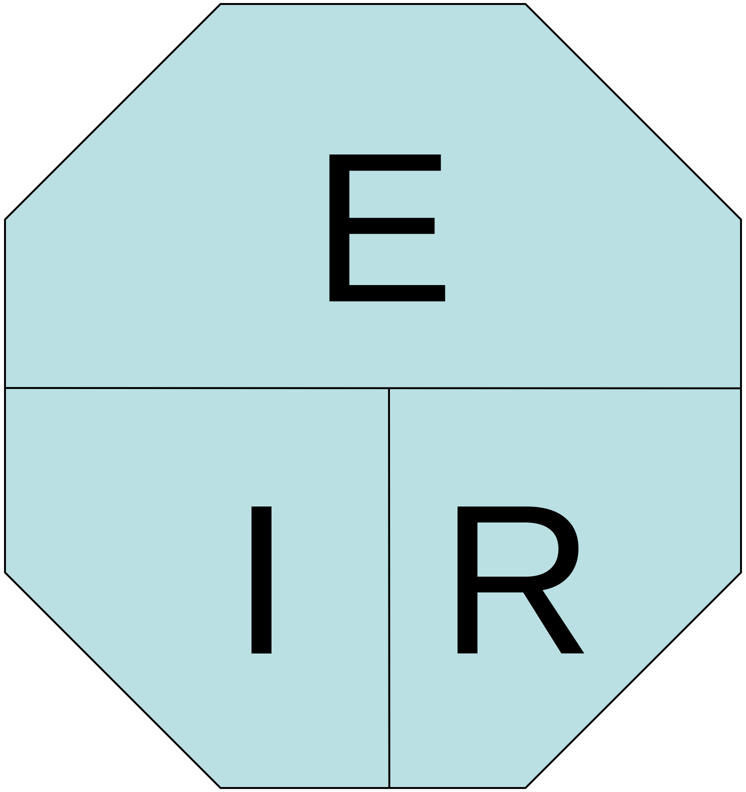
R = Ohms

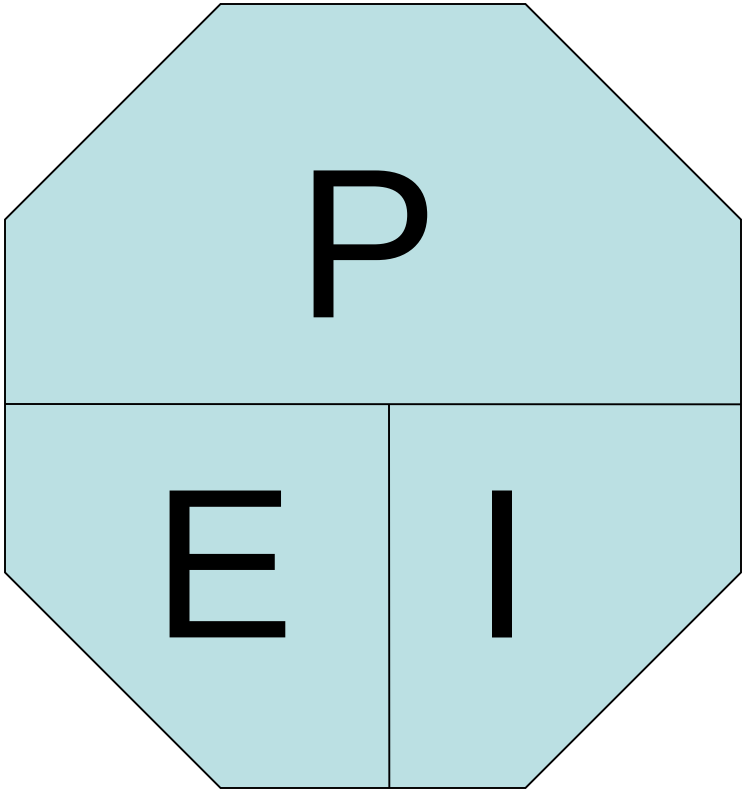
Ohms = $\frac{\text{Volts}}{\text{Amperes}}$

Ohms = $\frac{\text{Volts}^2}{\text{Watts}}$

Ohms = $\frac{\text{Watts}}{\text{Amperes}^2}$

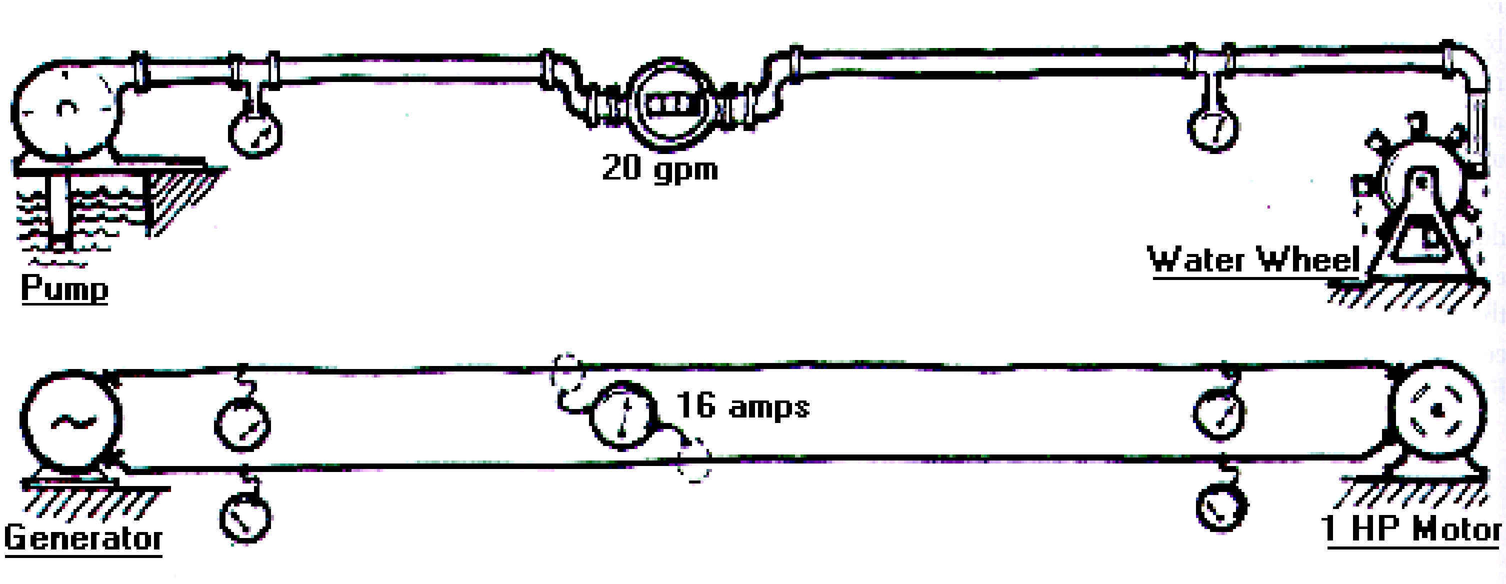
The Ohm's Law Pie Chart Shortcut Calculations





Current, I (Amps)

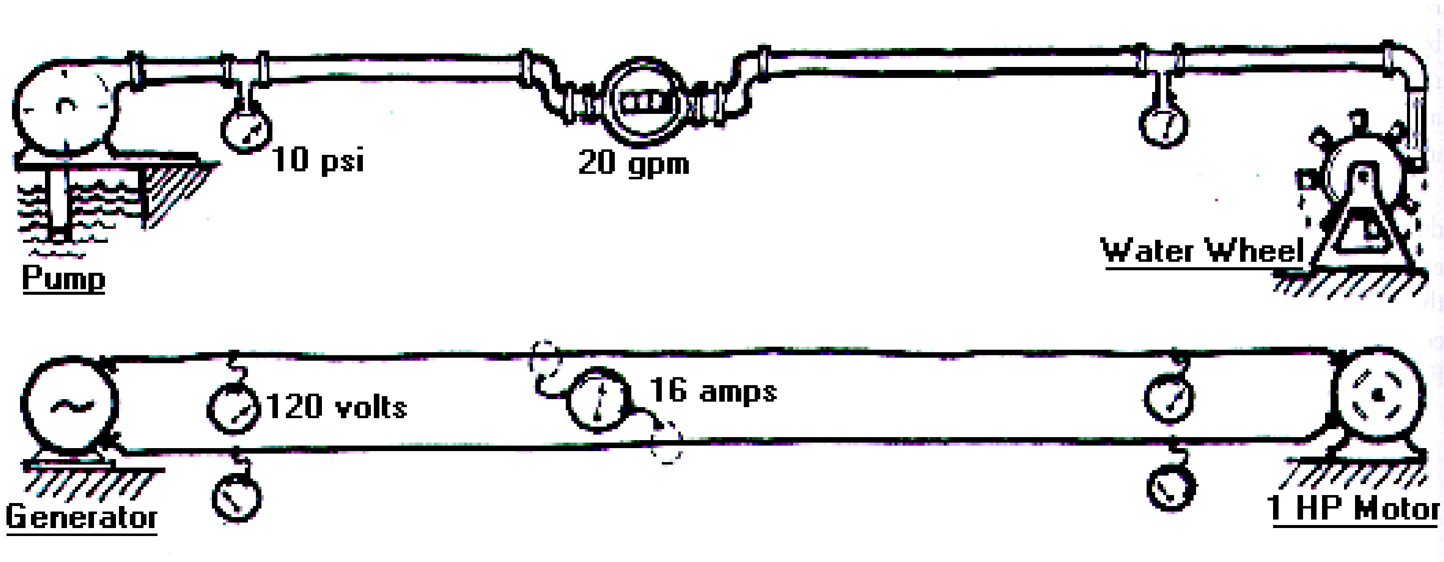
"Flow" of electricity defined as one Coulomb per second ($6.24(10)^{19}$ electrons)



Voltage, V (Volts)

- ❖ Defined as Electromotive Force, or EMF

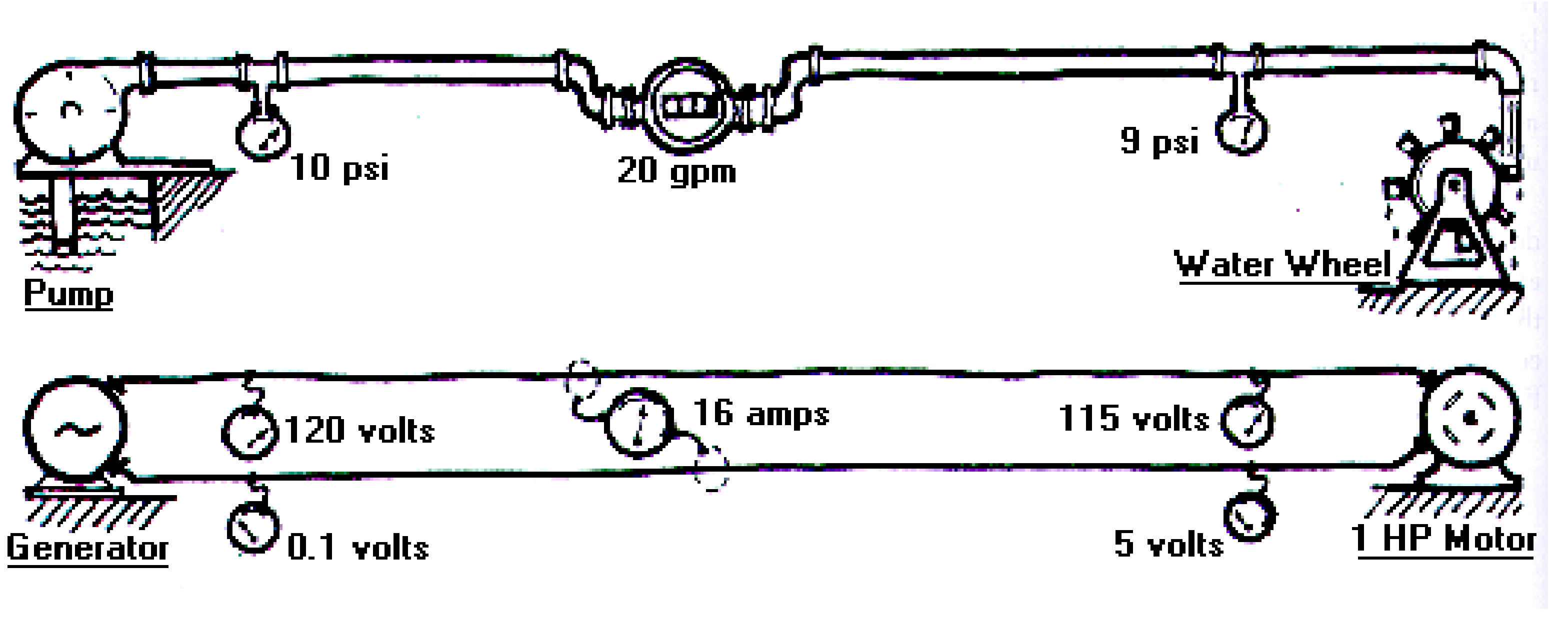
- ❖ Similar to pressure in a water system



Resistance, R (Ohms)

- The unit of resistance to current flow – similar to headloss in a water system

- An ohm is the amount of resistance that allows 1 amp of current to flow when the applied voltage is 1 volt



Power, P (Watts or HP)

- A function of both voltage and amps:
  - Volts X Amps = Watts
- Wattage is a measure of work
- 1000 watts = 1 KW = 1.34 HP, or
- 1 HP = 746 watts = 0.746 KW
- (FYI) RPM = (2 x Freq, Hz x 60)/# of poles

Temperature Conversion

- two scales used to report temperature:
  - Fahrenheit (F°) = English scale
  - Celsius (C°) = metric scale

- C° = 5/9 (F°- 32) or
- C° = 0.55 (F°- 32°) or
- C° = (F°- 32°) ÷ 1.8

- F° = (9/5 x C°) + 32° or
- F° = (1.8 x C°) + 32°

Temperature Scales

Fahrenheit	Celsius	Kelvin	
212	100	373	Boiling point of water at sea-level
194	90	363	
176	80	353	
158	70	343	
140	60	333	
122	50	323	
104	40	313	
86	30	303	
68	20	293	Average room temperature
50	10	283	
32	0	273	Melting (freezing) point of ice (water) at sea-level
14	-10	263	
-4	-20	253	
-22	-30	243	
-40	-40	233	
-58	-50	223	
-76	-60	213	
-94	-70	203	
-112	-80	193	
-130	-90	183	-89°C (-129 °F) Lowest recorded temperature. Vostok, Antarctica July, 1983
-148	-100	173	

Reference : Ahrens (1994)

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WHAT "UNITS" ARE USED IN WASTEWATER MEASUREMENTS?

- **THE BRITISH (or <u>ENGLISH</u>) SYSTEM**

  (FEET, GALLONS, POUNDS)

- **THE SYSTEM INTERNATIONAL (SI) or <u>METRIC</u> SYSTEM**

  (METERS, LITERS, GRAMS)

UNITS

CHEMICAL "INGREDIENTS":
WEIGHT per *VOLUME*

such as milligrams per liter
(abbreviated as mg/L)

EXAMPLE: The dissolved oxygen content of the wastewater was 5 mg/L (meaning there was five (5) milligrams of oxygen for each liter of wastewater)

UNITS

BIOLOGICAL "INGREDIENTS":
NUMBER per *VOLUME*

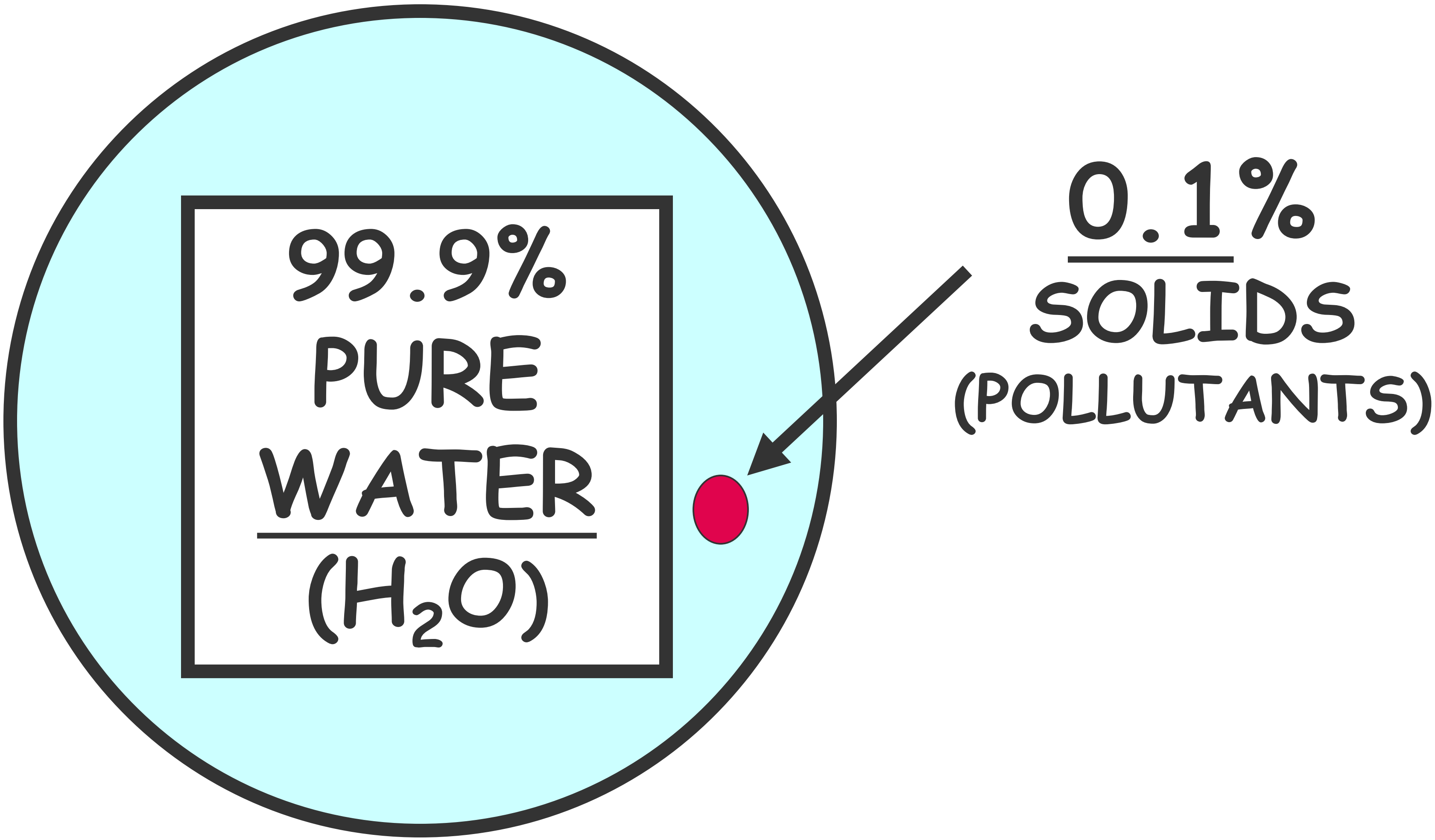
such as Colony Forming Units per milliliter (abbreviated as cfu/mL)

EXAMPLE: The bacteria concentration in the wastewater was 25 cfu/ 100 mL (meaning there were twenty five (25) colonies of bacteria in each 100 milliliters of wastewater)

MILLIGRAMS PER LITER or <u>PARTS</u> PER MILLION ???

ONE LITER OF WATER WEIGHS <u>1000</u> GRAMS (or ONE MILLION MILLIGRAMS). THEREFORE, ONE MILLIGRAM OF A CONTAMINANT, IN ONE LITER OF WATER WOULD BE "*<u>ONE</u> PART PER MILLION*" (ppm).

WHAT'S IN WASTEWATER?



0.1% = ? ppm

100% = 1,000,000 ppm

10% = 100,000 ppm

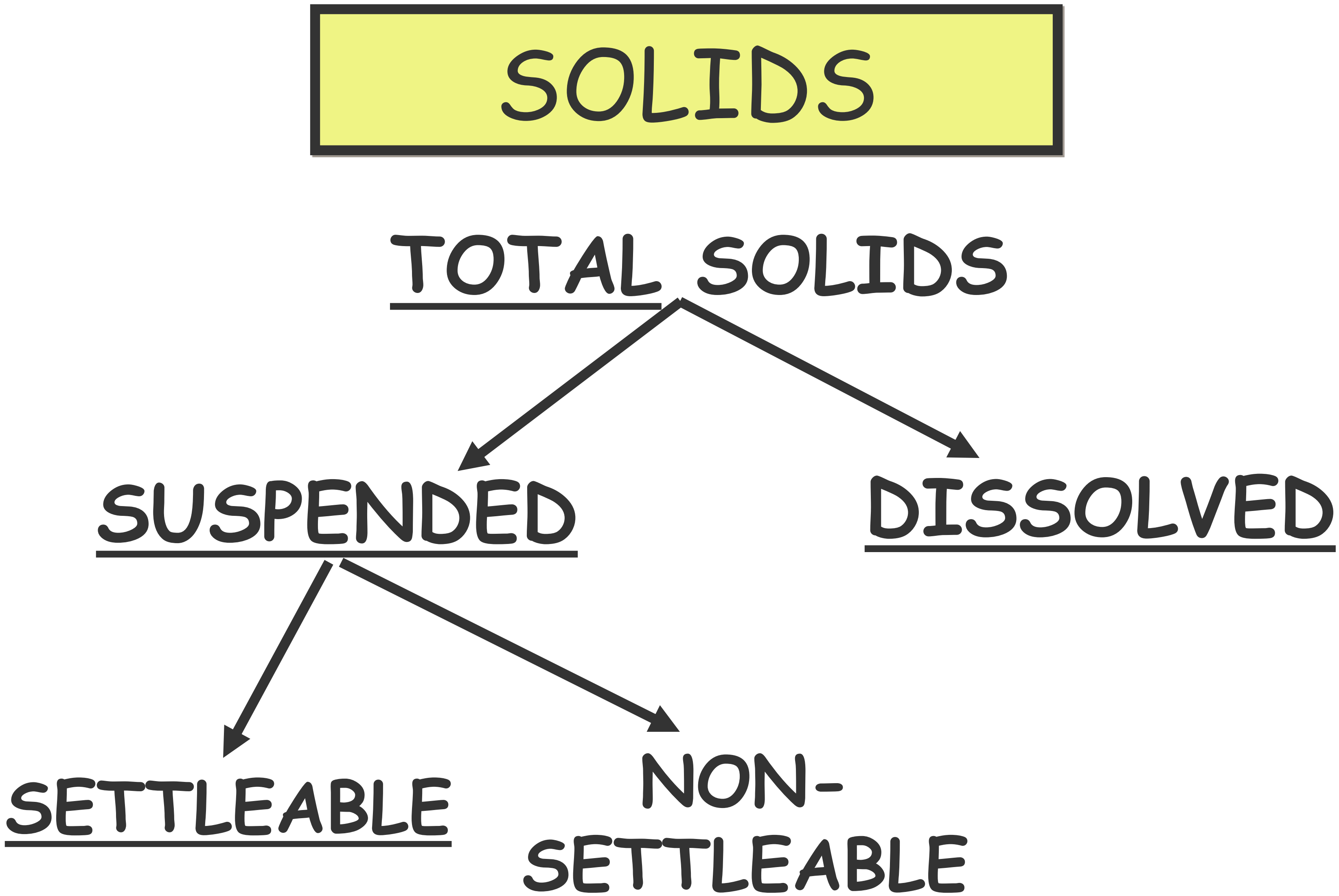
1% = 10,000 ppm

0.1% = 1,000 ppm or 1,000 mg/L

1000 mg/L of SOLIDS MEANS:

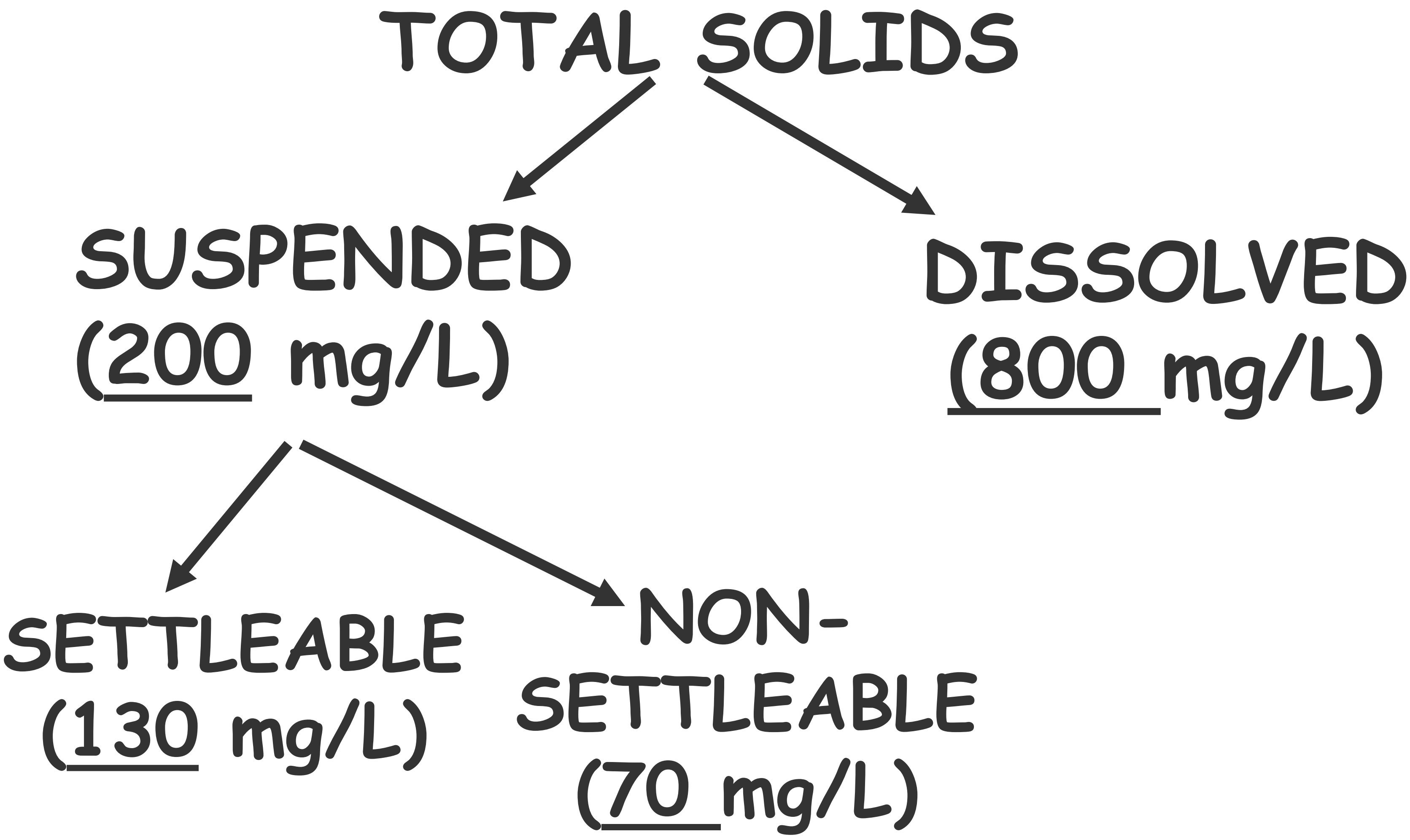
AN AVERAGE DOMESTIC WASTEWATER (SEWAGE) CONTAINS:

ONE THOUSAND (1,000) MILLIGRAMS OF SOLIDS IN EACH LITER OF WASTEWATER



SOLIDS
TOTAL SOLIDS
SUSPENDED
DISSOLVED
SETTLEABLE
NON-SETTLEABLE

SOLIDS



TOTAL SOLIDS
SUSPENDED (200 mg/L)
DISSOLVED (800 mg/L)
SETTLEABLE (130 mg/L)
NON-SETTLEABLE (70 mg/L)

HORIZONTAL GRIT CHAMBER

EXPERIENCE HAS SHOWN A VELOCITY AROUND 1 ft/sec IS BEST FOR GRIT REMOVAL

MAINTAIN A CONSTANT FLOW THROUGH THE CHAMBER

BECAUSE INFLUENT QUANTITIES VARY, YOU MUST:

VARY THE NUMBER OF CHAMBERS ON LINE

USE A PROPORTIONAL (aka SUTRO) WEIR AT THE OUTLET OF THE CHAMBER

WHAT'S A PROPORTIONAL WEIR?

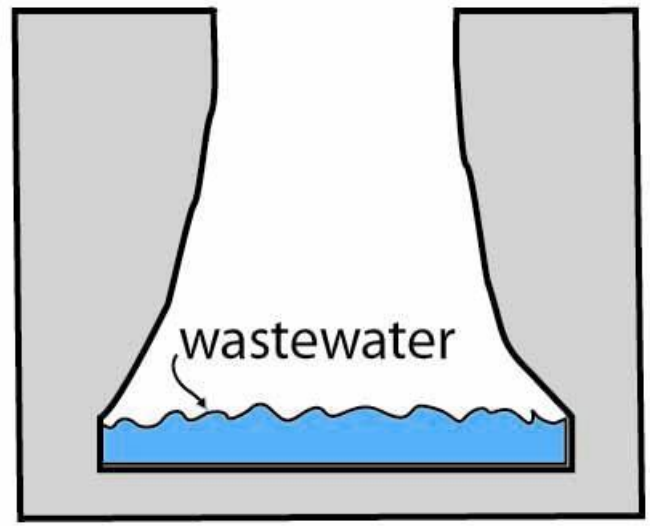
A SPECIALLY DESIGNED CONSTRICTION TO GO IN THE EFFLUENT END OF A GRIT CHAMBER

FLOW THROUGH THE WEIR IS PROPORTIONAL TO THE HEIGHT OF THE WATER IN THE CHANNEL

HOW A PROPORTIONAL WEIR WORKS:

$Q = \underline{V} \times \underline{A}$

WHERE: **Q** IS THE FLOW; **V** IS THE VELOCITY, AND **A** IS THE CROSS-SECTIONAL AREA



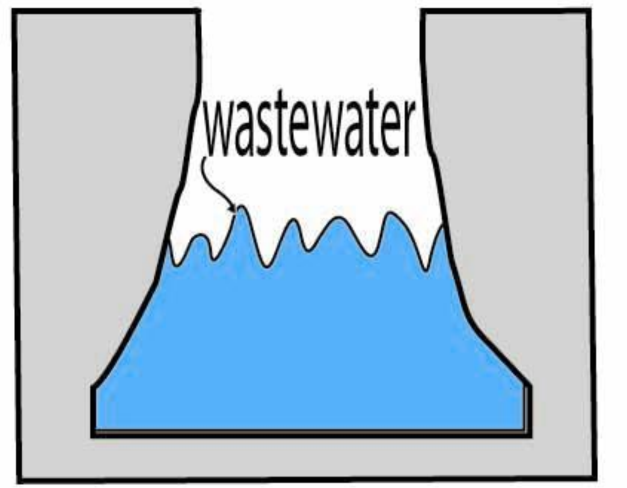
SUTRO (PROPORTIONAL) WEIR (AT LOW FLOWS)

VELOCITY = 1 FPS

HOW A PROPORTIONAL WEIR WORKS

V=Q/A

AS *Q* <u>INCREASES</u>, *A* MUST DECREASE FOR *V* TO REMAIN AT 1 FPS.

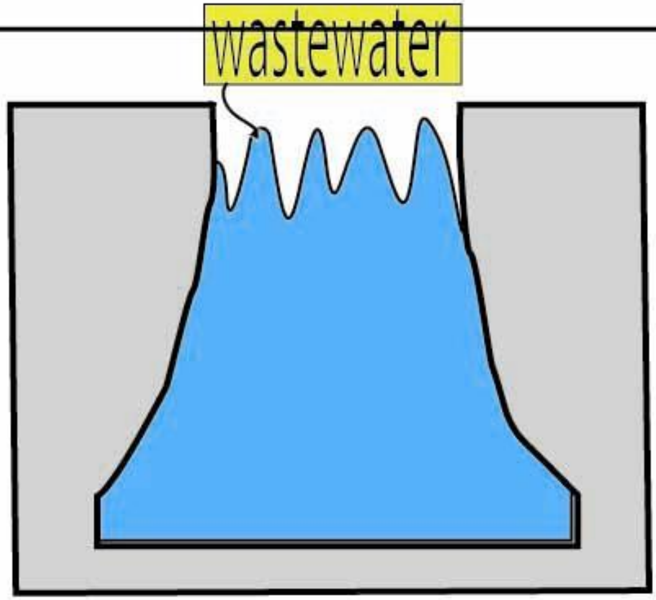


SUTRO (PROPORTIONAL) WEIR

(AT HIGHER FLOWS)

VELOCITY = 1 FPS

HOW A PROPORTIONAL WEIR WORKS



SUTRO (PROPORTIONAL) WEIR
(AT HIGHEST FLOWS)

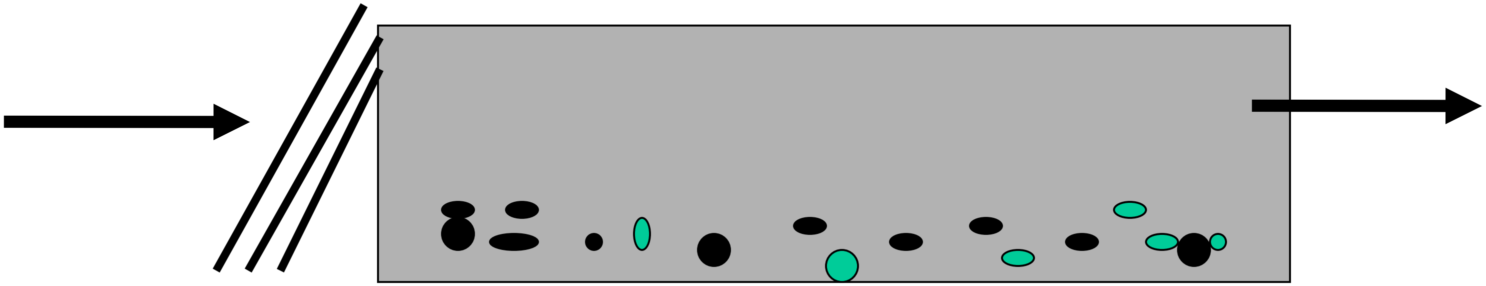
VELOCITY remains = 1 FPS

HOW TO MEASURE VELOCITY IN A GRIT CHAMBER

ONE EASY WAY IS TO DROP IN SOMETHING THAT FLOATS AND TIME IT OVER A MEASURED DISTANCE

EXAMPLE: YOU DROP IN A STICK AND IT TAKES 20 SECONDS TO FLOAT 25 FEET.

REMEMBER…



HEAVY, INORGANIC MATERIAL REMOVED IN GRIT CHAMBER (BY REDUCING THE VELOCITY)

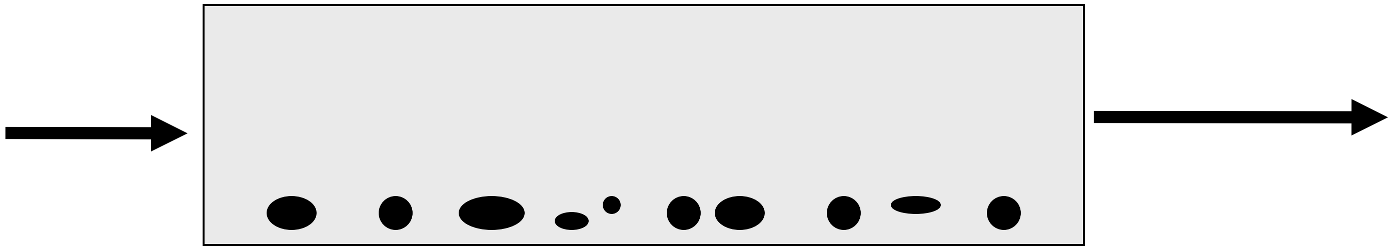
IF THE VELOCITY IS FURTHER REDUCED…

- ORGANIC SOLIDS WILL SETTLE OUT
- THE VELOCITY OF FLOW IN A SETTLING BASIN = 2 ft/min

RECALL...

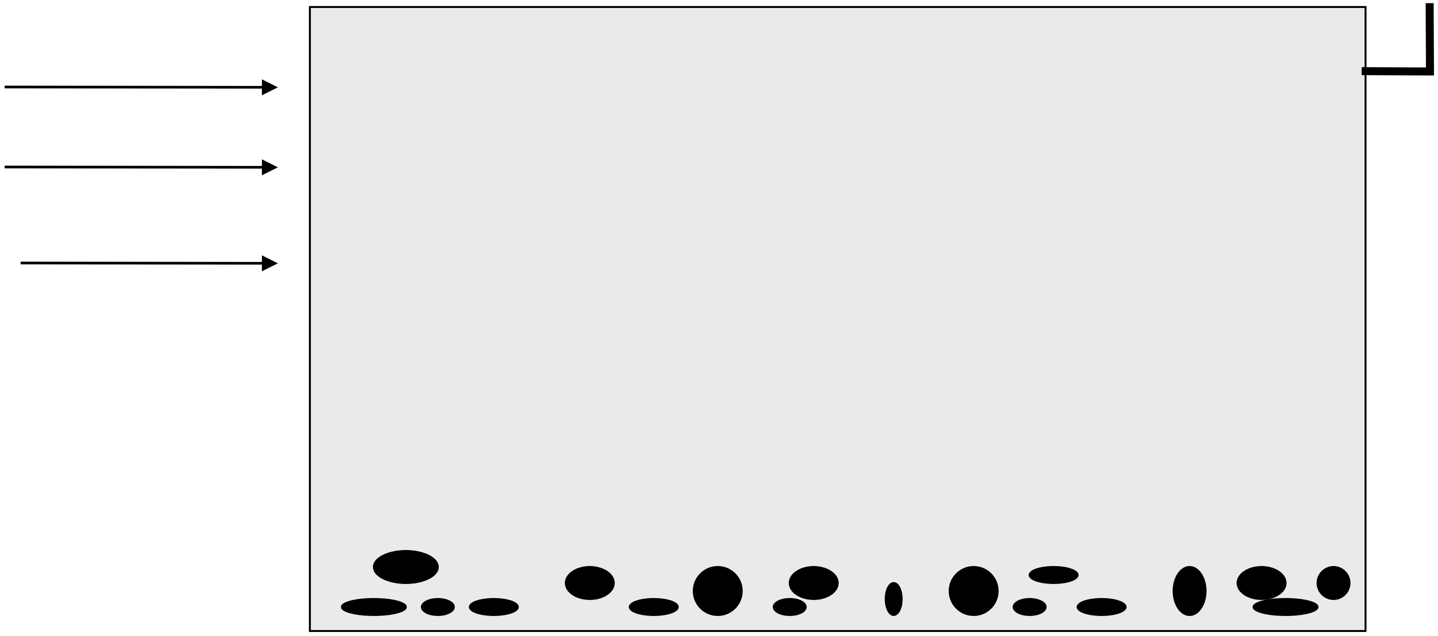
SEWER: 2 fps = 120 ft/min

(NO SETTLING)



GRIT CHAMBER: 1 fps = 60 ft/min

(HEAVY INORGANICS SETTLE OUT)



SETTLING BASIN

VELOCITY = 2 ft/min

(REMOVES SETTLEABLE SOLIDS)

CLARIFIER OPERATION

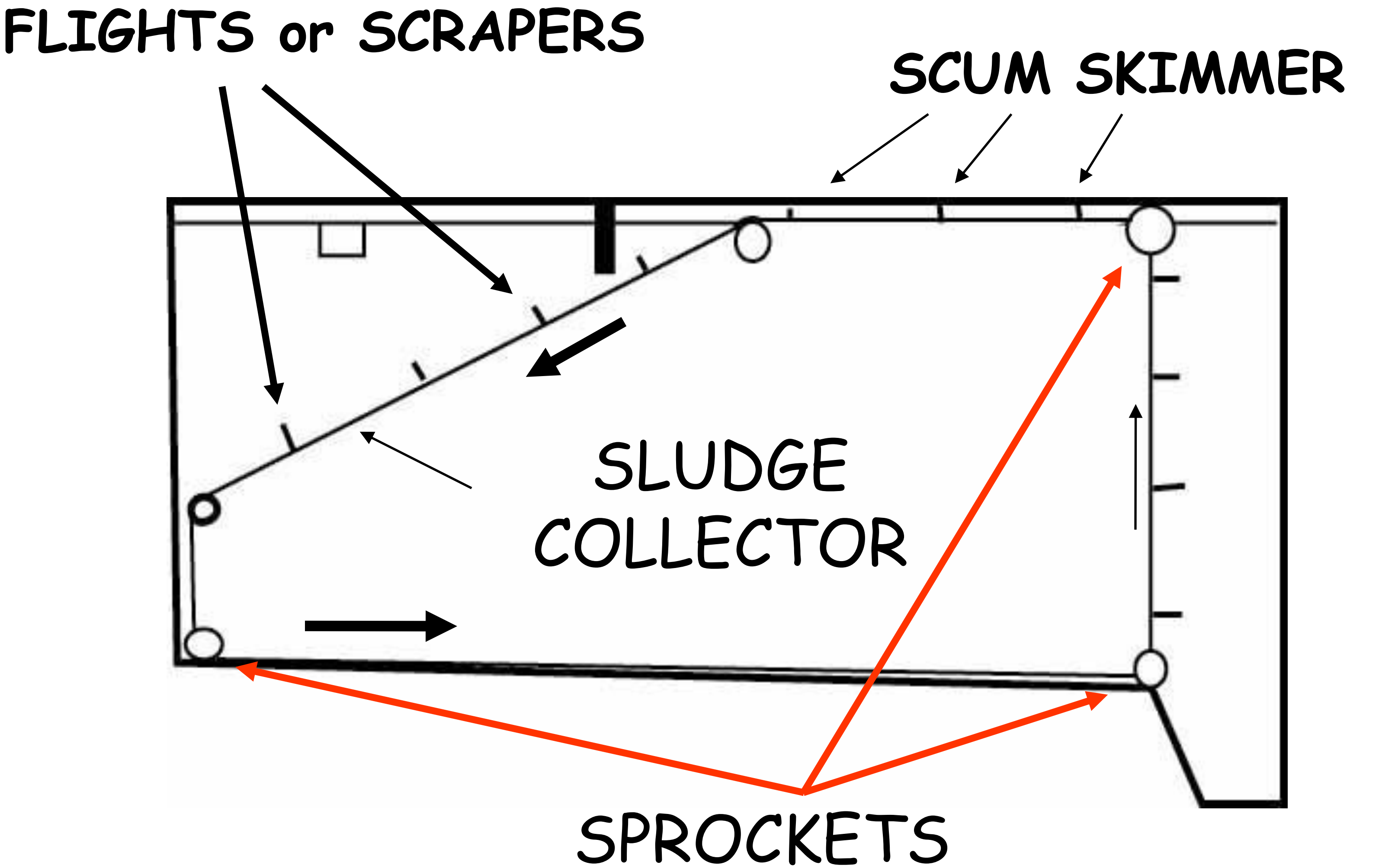
THREE IMPORTANT FACTORS:

1. DETENTION TIME = TANK VOL / FLOW

2. SURFACE LOADING = FLOW, gpd / SURFACE AREA, sq ft

3. WEIR OVERFLOW RATE = FLOW, gpd / WEIR LENGTH, ft

HORIZONTAL CLARIFIER



CLARIFIER OPERATION

THREE IMPORTANT FACTORS:

1.DETENTION TIME

The time it takes for water to flow through the tank

DT = TANK VOL/ FLOW

DETENTION TIME

EXAMPLE: VOLUME = 65,000 gal; FLOW = 550 gal/min then; DT=65,000/550 =118 min (1.9 hr)

D.T.= 317,925 gal/2,500,000 gal/day = 0.13 day x 24 hrs/day = 3.1 hours

2. SURFACE LOADING

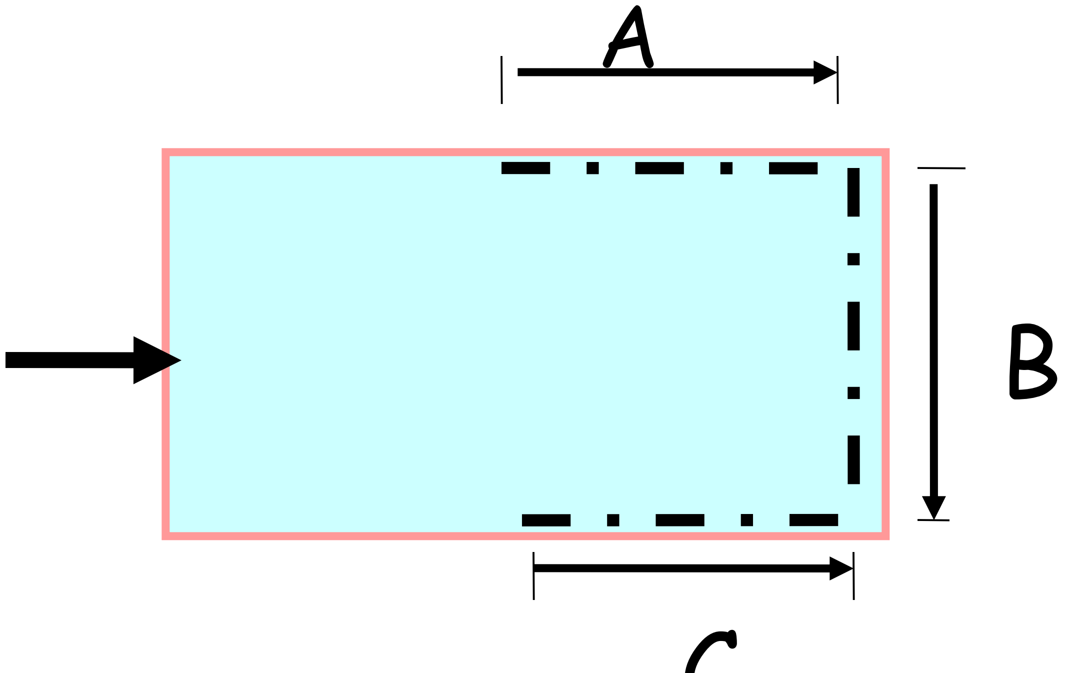
SURFACE LOADING = FLOW, gal/day DIVIDED BY THE SURFACE AREA, sq ft

EXAMPLE: Flow = 790,000 gal/day; 20'x60' clarifier; surface area of clarifier = 1200 sq ft; SURFACE LOADING =

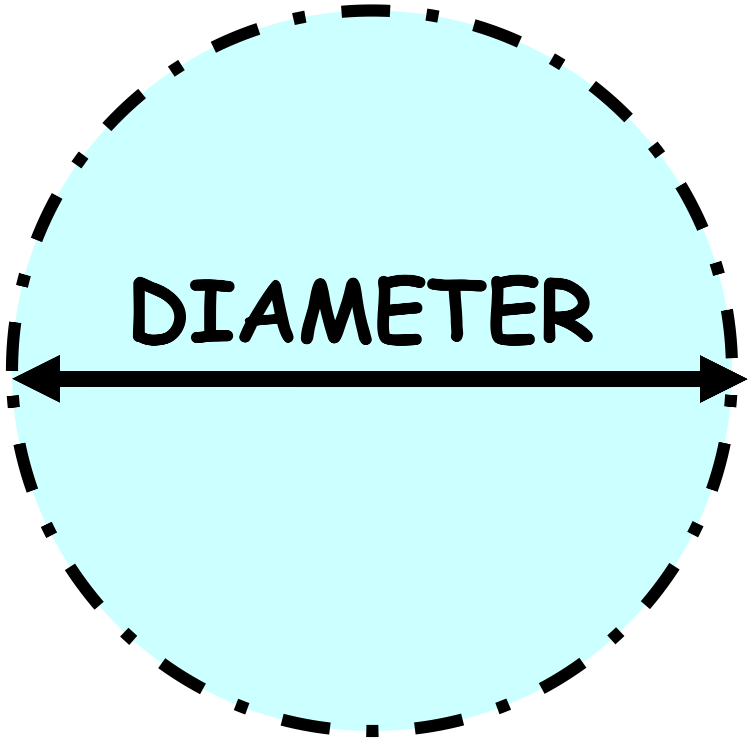
790,000 gpd / 1200 sq-ft = 658 gpd/sq-ft

EFFLUENT WEIR

WEIR LENGTHS



Weir Length=<u>A</u>+<u>B</u>+<u>C</u>



WEIR LENGTH on a CIRCULAR BASIN

$= \underline{\pi D}$

3. WEIR OVERFLOW RATE

WOR = **FLOW**, gal/day/ **weir length**, ft

EXAMPLE: WHAT IS THE WEIR OVERFLOW RATE IN A TANK HAVING **80'_OF WEIR LENGTH** THAT **RECEIVES 790,000_GPD?**

WOR = 790,000 gpd/80 ft = 9875 gpd/ft

WEIR OVERFLOW RATE

GIVEN: A 60' DIAMETER CIRCULAR CLARIFIER, 15' DEEP, RECEIVES 2.5 MGD. WHAT IS THE DETENTION TIME AND THE WEIR OVERFLOW RATE?

VOL=[0.7854 (60 ft)^2 x 15 ft] x 7.48 gal/ft^3 = **317,925 gallons**

WEIR LENGTH=ΠD=3.14 x 60'

=188'

WHAT IS THE SURFACE LOADING FOR THE SAME CLARIFIER?

SURFACE LOADING = FLOW/SURFACE AREA

$= 2{,}500{,}000 \text{ gal/day} \;/\; 0.7854 \times (60 \text{ ft})^2 = 653 \text{ gpd/ft}^2$

(WITHIN THE RANGE OF 300 to 1200 gpd/ft^2)

CLARIFIER OPERATING RANGES

	PRIMARY	SECONDARY
DETENTION TIME, hr	2-3	2-3
Weir overflow rate, gpd/ft	10,000-20,000	5,000-15,000
Surface loading, gpd/ft^2	300-1,200	300-1,200

DETERMINING EFFICIENCIES

$$\% \text{ EFFICIENCY} = \frac{(\text{IN} - \text{OUT})}{\text{IN}} \times 100\%$$

EXAMPLE: Given an influent conc. of suspended solids = 220 mg/L, and an effluent conc. of suspended solids = 8 mg/L, what is the efficiency of the clarifier?

$$\% \text{ Efficiency} = (220 - 8) / 220 \times 100\%$$

$$= 96\%$$

TYPICAL CLARIFIER EFFICIENCIES

PARAMETER	% EFF	Avg
Settleable Solids	90-99	97
Suspended Solids	40-60	50
Total Solids	10-15	10
BOD	20-50	35
Bacteria	25-75	50
pH	no change	

OPERATOR MATH

<u>Wednesday 15 May 2024; 2.30-3.40p</u>

Ponds Detention Time and Loading

Trickling Filter Geometry and Loading

Rotating Biological Contactor Loading

Secondary Clarifiers

PONDS DESIGN CRITERIA

DETENTION TIME:

$$\frac{\text{POND VOLUME, acre-ft}}{\text{INFLUENT RATE, acre-ft/day}}$$

- **HYDRAULIC LOADING:**

  INCHES/DAY

- **POPULATION LOADING:**

  PERSON/ACRE

PONDS DESIGN CRITERIA (cont'd)

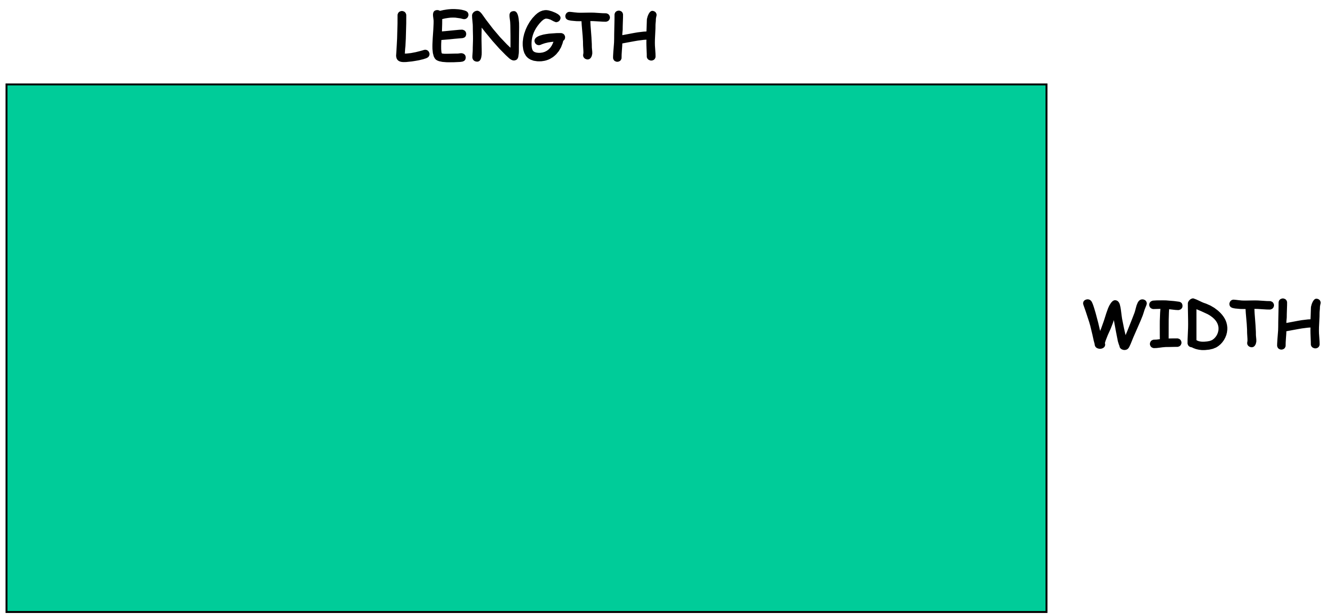
- ORGANIC LOADING:

  LBS BOD/DAY/ACRE

ORGANIC LOADING:

$$\frac{(\text{BOD mg/L})\ (\text{FLOW, MGD})\ (8.34\ \#/\text{gal})}{\text{POND AREA, acres}}$$

ARITHMETIC REVIEW



SURFACE AREA = L x W

1 ACRE = <u>43,560</u> SQ-FT

EACH PERSON DISCHARGES 75-100 GALLONS of WASTEWATER PER DAY

0.2 POUNDS BOD/PERSON

CALCULATING BOD LOADING

CONCENTRATION,ppm X FLOW,MGD X 8.34 lbs/gal = POUNDS/DAY

What is the daily BOD loading given the following: FLOW=300,000 gal/day; BOD = 225 mg/L?

BOD LOADING =

225 ppm X 0.3 MGD X 8.34 lbs/gal

= 563 lbs/day

AT AN ALLOWABLE LOADING OF

35 lbs BOD per day/acre, how large of a pond is necessary?

$$\frac{563 \text{ \#/day}}{35 \text{ \#/day/acre}} = 16 \text{ acres}$$

SOLIDS LOADING RATE

SLR=lbs of SOLIDS/day / ft^2

lbs/day=$C \times Q \times 8.34$

Where: C = Suspended Solids concentration in ppm; Q = flow in millions of gallons/day, and 8.34 is lbs/gallon

HOW MANY ACRES OF PONDS (WITH ZERO DISCHARGE) WOULD BE NEEDED TO SERVE 650 PEOPLE IN So. NEW MEXICO?

<u>ASSUME NO PERC & 60” per year EVAP</u>

(650 cap x 100 gpd/cap)/7.48 gal/ft^3 = 8690 ft^3/day

8690 ft3/day x 365 day/yr x yr/60 in x 12 in/ft

= 634,370 ft^2

634,370 ft^2/43,560 ft^2/acre = 14.6 acres

(plus allowances for rain)

POND PERFORMANCE

REMOVAL EFFICIENCIES

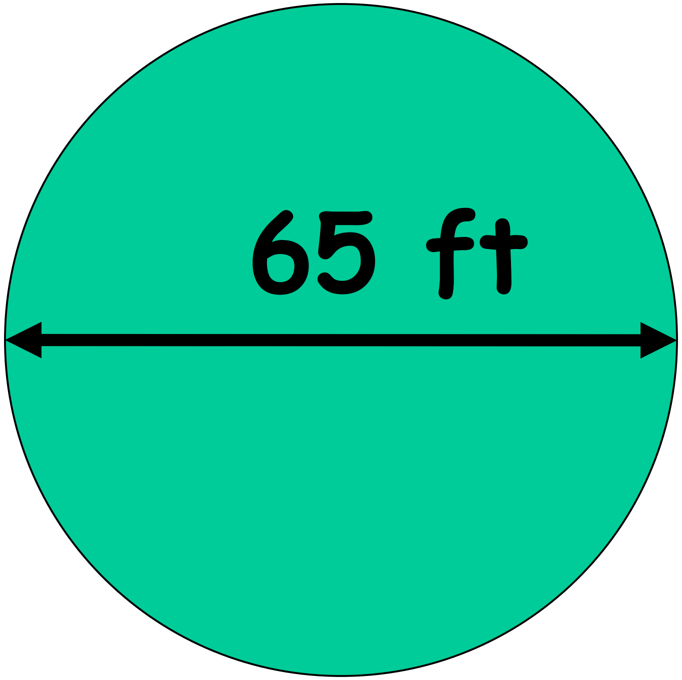
BOD/SS 90 - 95%

FECAL COLIFORM 99%

SURFACE LOADING RATES

TYPE	lbs BOD/acre/day
AEROBIC	60 - 200
ANAEROBIC	200 - 1000
FACULTATIVE	15 - 30
TERTIARY	5 - 15
MECH AERATED	20 - 400

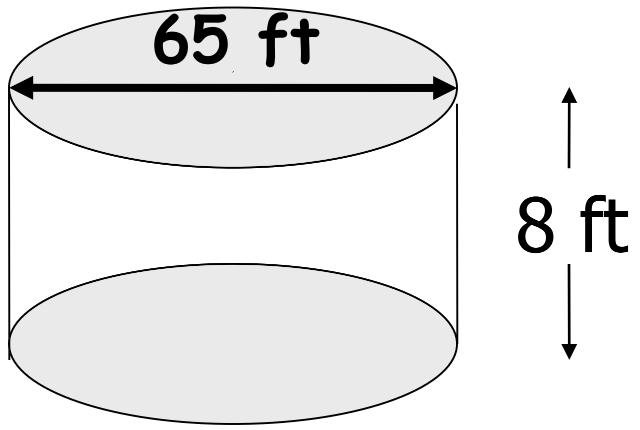
REVIEW OF ARITHMETIC



Example: What is the surface area of a trickling filter that is 65′ in diameter:

SA =0.785 x 65 ft x 65 ft = 3317 sq-ft

REVIEW OF ARITHMETIC

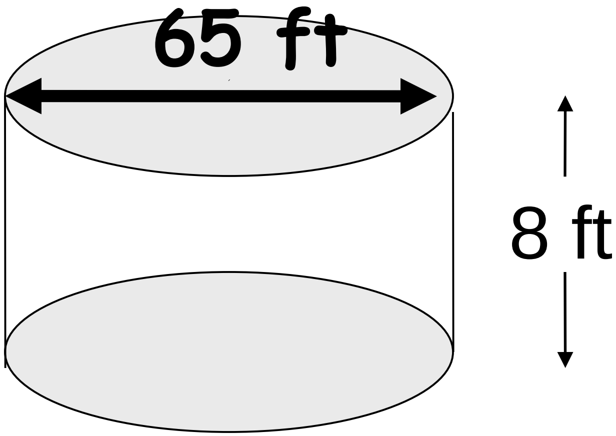


EXAMPLE: WHAT IS THE VOLUME of a 65′ diameter trickling filter with 8 ft of media?

VOLUME = 0.785 x 65 ft x 65 ft x 8 ft =

26,533 cu-ft

REVIEW OF ARITHMETIC



HOW MANY 1000 cu ft ARE THERE IN THIS FILTER?

26,533 cu-ft / 1000 = 26.533

A TRICKLING FILTER PLANT RECEIVES 300,000 gal/day, with a BOD = 230 mg/L

The trickling filter is 65 ft in diameter with 8 ft of rock media. Is this plant a standard rate or high rate trickling filter?

Hydraulic loading = gpd/sq-ft

= 300,000 gal/day/0.785 x (65 ft)^2

= 90.4 gpd/sq-ft

Organic Loading = lbs BOD/1000 cu-ft

= 230 mg/L x 0.3 MGD x 8.34 #/gal

= 576 #/day/26.5 1000 cu-ft

= 22 lbs BOD per day/1000 cu-ft

CLASSIFICATIONS OF TRICKLING FILTERS

BASED ON HYDRAULIC AND BOD LOADING…

HYDRAULIC LOADING:

GPD/SQ-FT

BOD LOADING:

Lbs BOD per day / 1000 cu-ft

CLASSIFICATIONS OF TRICKLING FILTERS

BASED ON HYDRAULIC AND BOD LOADING…

- STANDARD-RATE
- HIGH-RATE
- ROUGHING FILTERS

ROUGHING FILTER PRECEEDS SOME OTHER FORM OF SECONDARY TREATMENT (SUCH AS ACTIVATED SLUDGE)

STANDARD-RATE

PARAMETER	VALUE
• FLOW	25-100 gpd/sq-ft
• BOD	5-25 lbs BOD per day/ 1000 cu-ft
• % BOD removal	90-95 %

HIGH-RATE TRICKLING FILTER

PARAMETER	VALUE
• FLOW (ROCK)	100-1000 gpd/sq-ft
• FLOW (SYNTHETIC)	350-2100 "

HIGH-RATE TRICKLING FILTER

PARAMETER	VALUE
• BOD (rock)	25-100 lbs BOD per day/1000 cu-ft
• BOD (synthetic)	50-300 "
• BOD removal	90 - 95 %

ROUGHING FILTER

PARAMETER	VALUE
• FLOW	(same as high-rate)
• BOD	100–300 lbs BOD per day/1000 cu-ft
• BOD removal	80 – 85 %

COMPARISON OF HYDRAULIC LOADINGS—gpd/sq-ft

Standard Rate	25 to 100
High Rate (rock)	100 to 1000
(synthetic media)	350 to 2100
Roughing	100 to 2100

COMPARISON OF ORGANIC LOADING: lbs BOD per day/1000 cu-ft

Standard Rate 5 to 25

High Rate (rock) 25 to 100
(synthetic) 50 to 300

Roughing 100 to
300

ROTATING BIOLOGICAL CONTACTORS

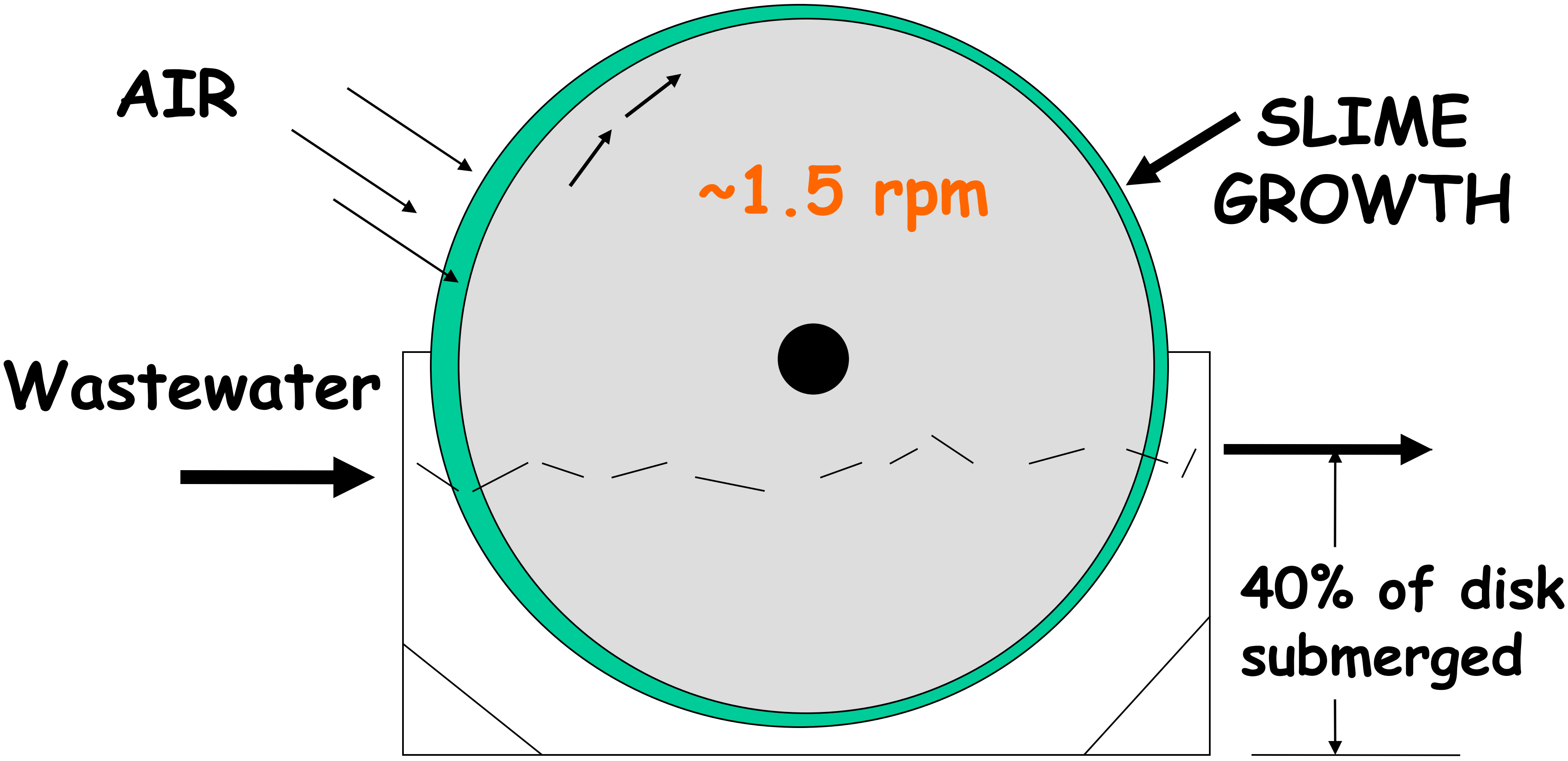
DESCRIPTION OF AN RBC

- ROTATING SHAFT (UP TO 25 ft LONG)
- ROUND PLASTIC DISKS (USUALLY 12 ft DIAMETER

MEDIA IS AVAILABLE AS STANDARD, MEDIUM OR HIGH DENSITY

A CONVENTIONAL RBC WITH STANDARD MEDIA, 25 ft LONG by 12 ft DIAMETER = >110,000 ft^2 of media surface area!

(high density >165,000 ft^2)



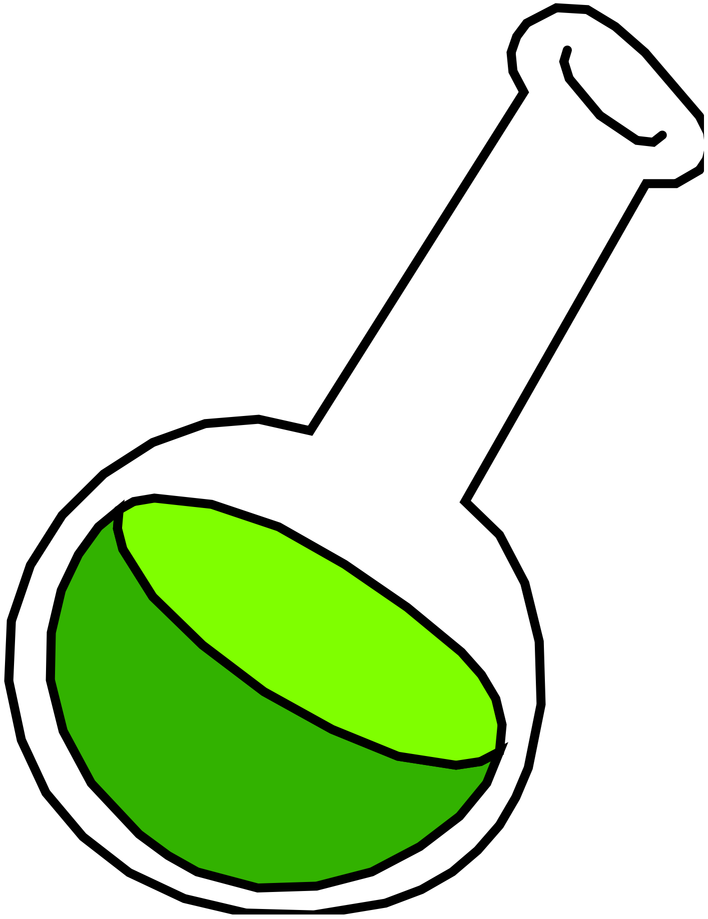
USUALLY A "ONCE THRU" OPERATION — NO RECIRCULATION

LOADING CALCULATIONS

ORGANIC LOADINGS ARE BASED ON SOLUBLE BOD

ORGANIC LOADING = lbs SOLUBLE BOD per day per 1000 ft^2 of MEDIA

SOLUBLE BOD IS MEASURED ON FILTERED WASTEWATER

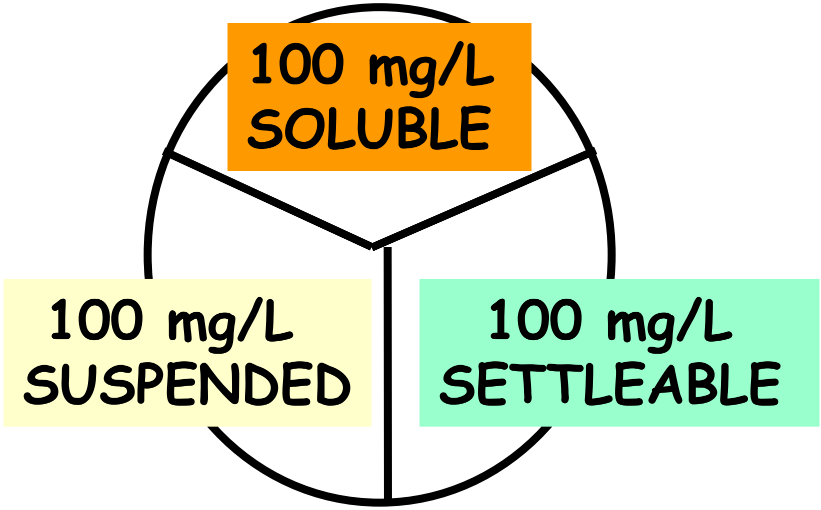


BOD REVIEW:

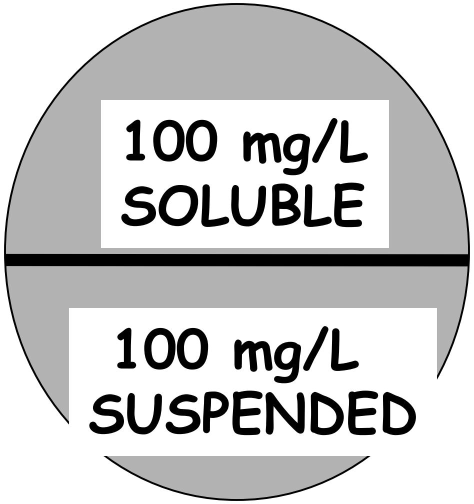
SAMPLE OF FILTERED WASTEWATER IS STORED IN BOD BOTTLES FOR 5 days at 20°C. DISSOLVED OXYGEN IS MEASURED AT THE BEGINNING AND THE END TO DETERMINE THE OXYGEN DEMAND

BOD REVIEW

EXAMPLE: BOD = 300 mg/L



RAW



AFTER PRIMARY SETTLING

ESTIMATING SOLUBLE BOD

SOLUBLE BOD CAN BE ESTIMATED ON THE BASIS OF TOTAL BOD AND SUSPENDED SOLIDS (TSS)

SOLUBLE BOD, mg/L =

TOTAL BOD, mg/L - (K x TSS, mg/L)

Where K = 0.5-0.7 (for sewage)

EXAMPLE:

AN RBC RECEIVES AN INFLUENT BOD of 220 mg/L and 230 mg/L SUSPENDED SOLIDS. WHAT IS THE ESTIMATED SOLUBLE BOD IN THIS WASTEWATER?

SOLUBLE BOD, mg/L =

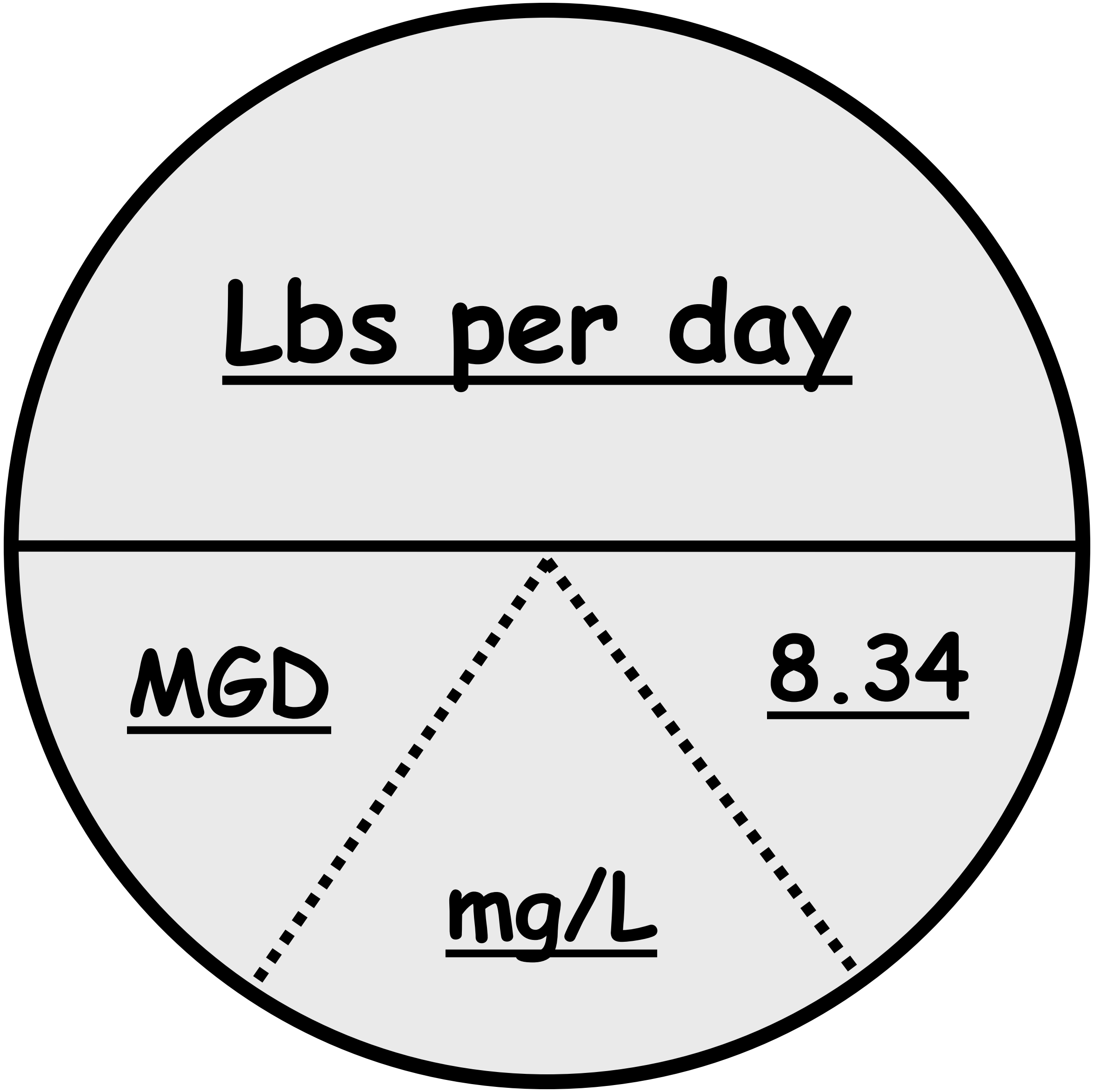
220 mg/L – (0.5 x 230 mg/L) =

220 mg/L – 115 mg/L = 105 mg/L

ORGANIC LOADING EXAMPLE (con't)

WHAT IS THE ORGANIC LOADING FOR THE FOLLOWING RBC?

- FLOW = 2.5 MGD
- SOLUBLE BOD = 105 mg/L
- MEDIA SURFACE AREA = 800,000 ft^2


Lbs per day
MGD
8.34
mg/L

ORGANIC LOADING =

$$\frac{105 \text{ mg/L} \times 2.5 \text{ MGD} \times 8.34 \text{ \#-L/mg-Mgal}}{800{,}000 \text{ ft}^2/1000}$$

= 2.7 lbs BOD per day/1000 ft^2

HYDRAULIC LOADING

HYDRAULIC LOADING IS:

GALLONS per DAY / FT^2 of MEDIA

WHAT IS THE HYDRAULIC LOADING FOR THE PREVIOUS EXAMPLE?

2,500,000 gpd/800,000 ft^2 = 3.1 gpd/ft^2

TYPICAL LOADING RATES

	RANGE
HYDRAULIC LOADING	
BOD REMOVAL	1.5 - 6 GPD/ft^2
NITROGEN REMOVAL	1.5 – 1.8 GPD/ft^2
ORGANIC LOADING	
SOLUBLE BOD	2.5 – 4 lbs BOD/day/1000 ft^2
TOTAL BOD	6 – 8 " " "

ACTIVATED SLUDGE CLARIFIERS ARE DESIGNED FOR…

- **DETENTION TIME: <u>2</u> – 3 hours**
- **SURFACE LOADING: <u>300</u>-1200 gpd/ft²**
- **WEIR OVERFLOW RATE: 5,000 – 15,000 GPD/FT**
- **SOLIDS LOADING: 24-30 lbs/day/ft²**

SOLIDS LOADING RATE

SLR=lbs of SOLIDS/day / ft^2

lbs/day=$C \times Q \times 8.34$

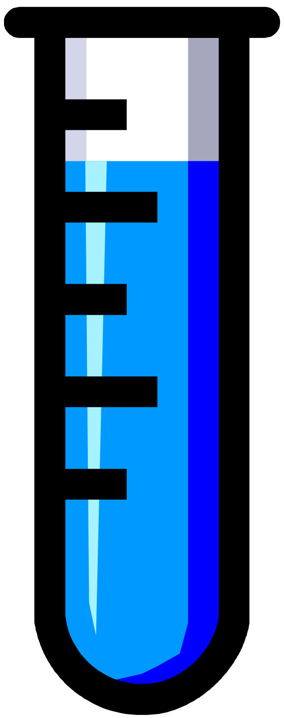
Where: C = Suspended Solids concentration in ppm; Q = flow in millions of gallons/day, and 8.34 is lbs/gallon

TYPICAL RANGE=12 -30 #/day/ft^2

SLUDGE VOLUME INDEX (SVI)

- A GOOD OPERATING TEST FOR SLUDGE CONSISTENCY
- RELATES THE SETTLEABLE SOLIDS TO THE SUSPENDED SOLIDS

SLUDGE VOLUME INDEX TEST



- 1 Liter of mixed liquor, settled for 30 minutes
- ON SAME BATCH, RUN SUSPENDED SOLIDS

SVI, mL/gm = volume in mL of 1 gram (weight) of MLSS after 30 minutes

SVI EXAMPLE

FROM A SAMPLE OF MIXED LIQUOR YOU DETERMINE:

SETTLEABLE SOLIDS = 610 mL/L
SUSPENDED SOLIDS = 5580 mg/L

SVI = 610 ml/L / 5580 mg/L x 1000 mg/gm = <u>109</u> mL/gm

OPERATOR MATH

<u>Wednesday 15 May 2024; 3.50-5p</u>

Pressure and Head

Static Head

Pump and Motor Efficiencies

Water to Wire Calculations

Pressure & Head Calculation

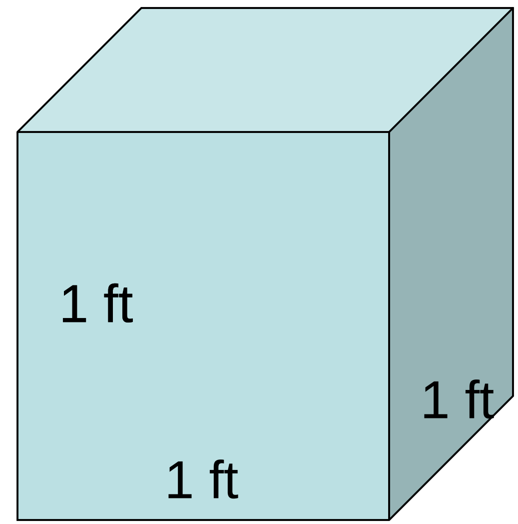
- Pressure is the weight per unit area
- Pounds per square inch, lbs/in^2
- Pounds per square foot, lbs/ft^2
- Pressure on the bottom of a container is not related to the volume of the container, nor the size of the bottom.
- Pressure is dependent on the height of the fluid in the container.
- The height of the fluid in a container is referred to as Head. Head is a direct measurement in feet & directly related to pressure.

Pressure and Head

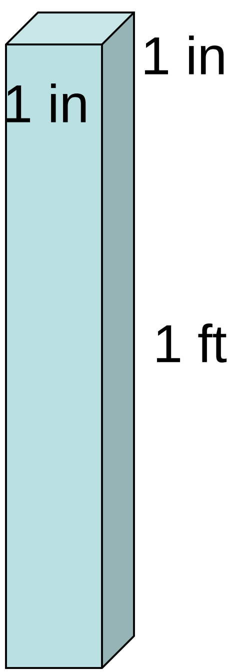
1 ft^3 of water weighs 62.4 #/ft^3

Based on: 7.48 gal/ft^3 x 8.34 #/gal = 62.4 #/ft^3

Now, the bottom of this cube measures 12-in x 12-in = 144-in^2



The cube will then contain 144 columns of water 1-ft tall & 1-in square



Weight of 1 column =
62.4 #/144 in^2 = 0.433 #/in^2 or 0.433 psi

Therefore, 1 Foot of water exerts a pressure of 0.433psi

How many feet to exert 1 psi?

Some Pressure-Head Examples

- Convert 40 psi to feet of head ANS = 92.4 ft

- What is the pressure in psi 112 feet below the top of a reservoir? ANS = 48.5 psi

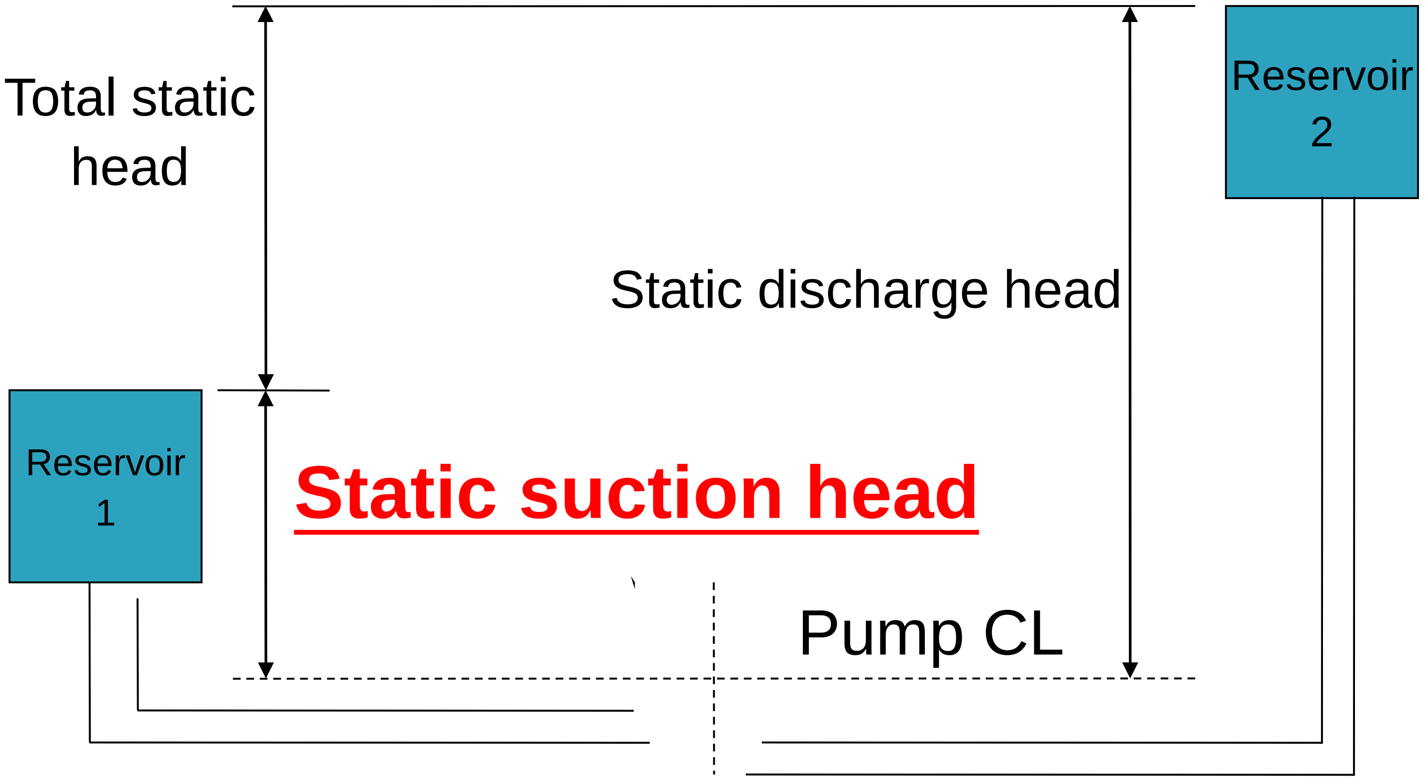
- What is the height of water in a storage tank on top of a 100-ft hill if the pressure at the bottom of the hill is 65 psi? ANS = 50 ft

Static Head

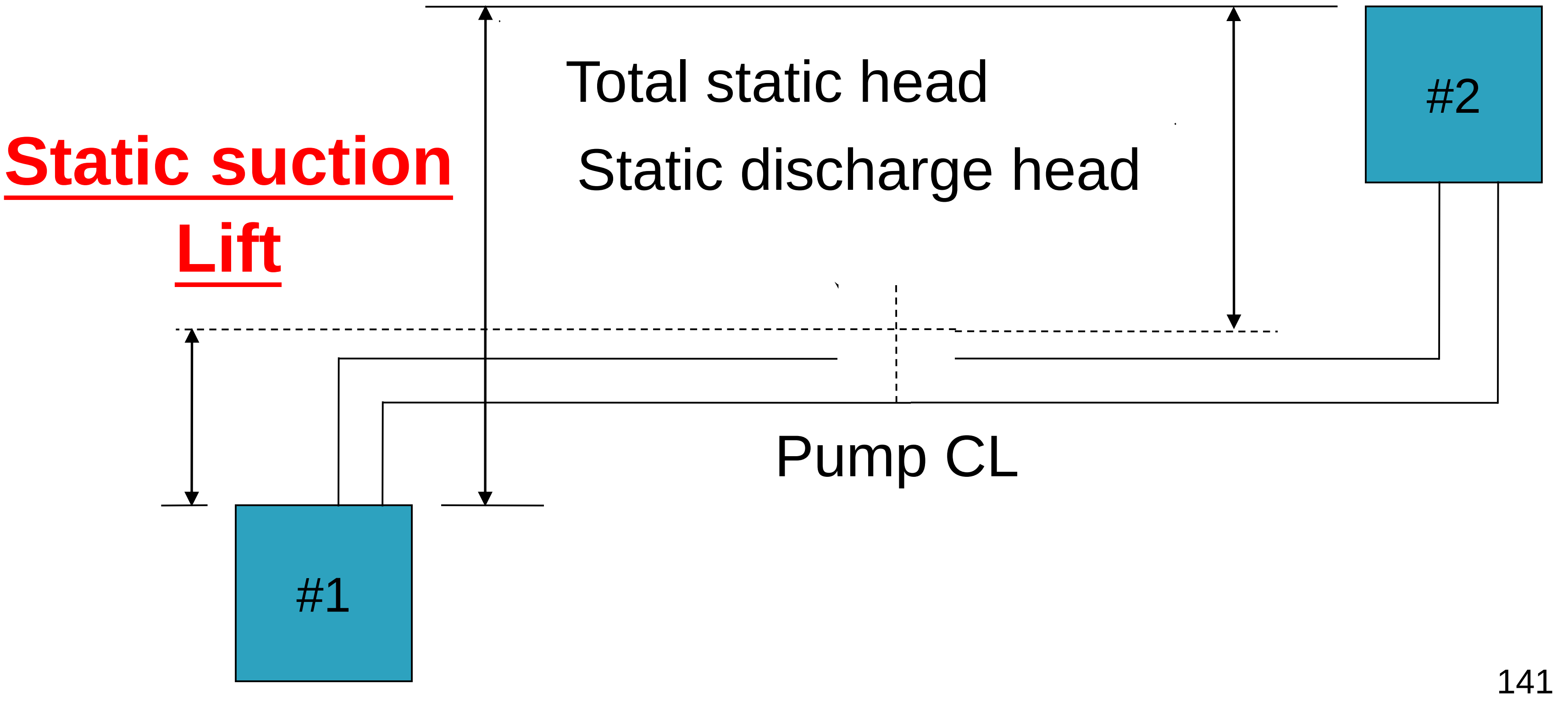
Static discharge head is defined as the difference in height between the pump’s horizontal center line and the maximum height of the free water surface on the discharge side of the pump.

Total static head is the total height that the pump must lift the water when moving it from one reservoir to another reservoir.

In a system where the reservoir feeding the pump is higher than the pump, the difference in elevation between the pump center line and the free water surface of the reservoir feeding the pump is…



In a system where the reservoir feeding the pump is lower than the pump, the difference in elevation between the center line of the pump and the free water surface of the reservoir feeding the pump is…

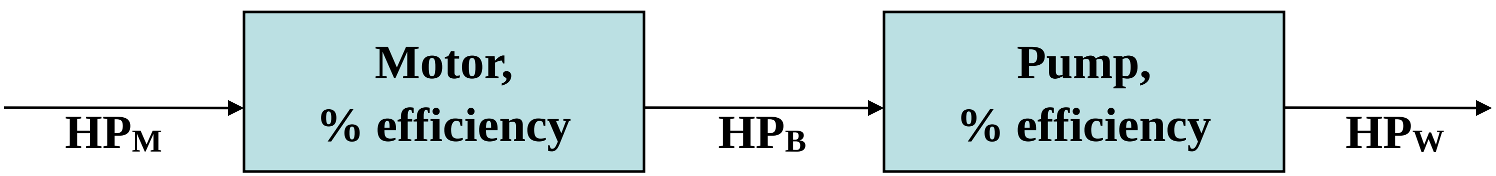


Pump and Motor Efficiencies

motor or wire HP, HP_M = electrical energy in HP supplied to motor; motor efficiency determines brake HP

brake HP, HP_B = mechanical energy in HP supplied to pump shaft from motor; pump efficiency determines water HP

water HP, HP_W = mechanical energy in HP transferred to water by pump



Water To Wire Calculations

Step 1: Calculate static head, H_s

Step 2: Calculate or determine friction losses, H_L

Step 3: Calculate TDH = $H_s + H_L$

Step 4: Calculate Water HP, where

1 HP = 33,000 ft-#/min; for the weight of water

$$1 \text{ HP} = \frac{33{,}000 \text{ ft-\#/min}}{8.34 \text{ \#/gal}} = 3957 \text{ gpm-ft, then}$$

$$HP_W = \frac{Q, \text{ gpm} \times TDH, \text{ ft}}{3960 \text{ gpm-ft/HP}}$$

Water To Wire Calculations

Step 5: Calculate HP_B based on pump efficiency:

$HP_B = HP_W/E_P$

Step 6: Calculate HP_M based on motor efficiency

$HP_M = HP_B/E_M$

Step 7: Calculate pumping costs based on HP_M, pump/motor assembly runtime and local power rate(s) for peak, off-peak, commercial, etc