Wastewater Treatment

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CE404 Environmental Engineering

Activity

What's the problem with direct discharge of untreated wastewater?

Treatment Processes

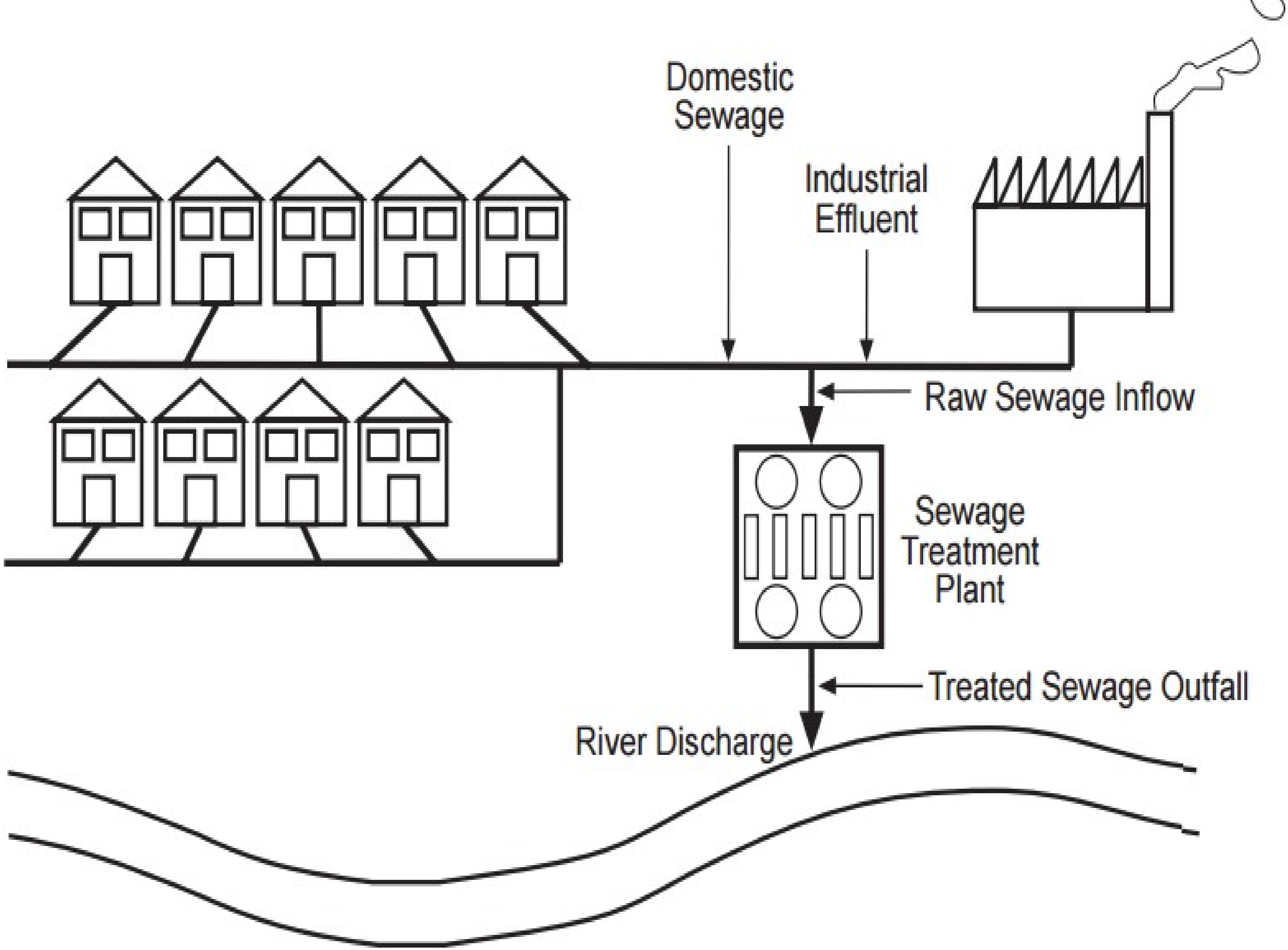
Centralized vs. onsite

Attached growth, suspended growth, wetlands Vs. Anaerobic, aerobic digestion

Treatment process = f(amount, type/source)

Discharge limits = f(type/source, discharge location, time of year)

CENTRALIZED TREATMENT

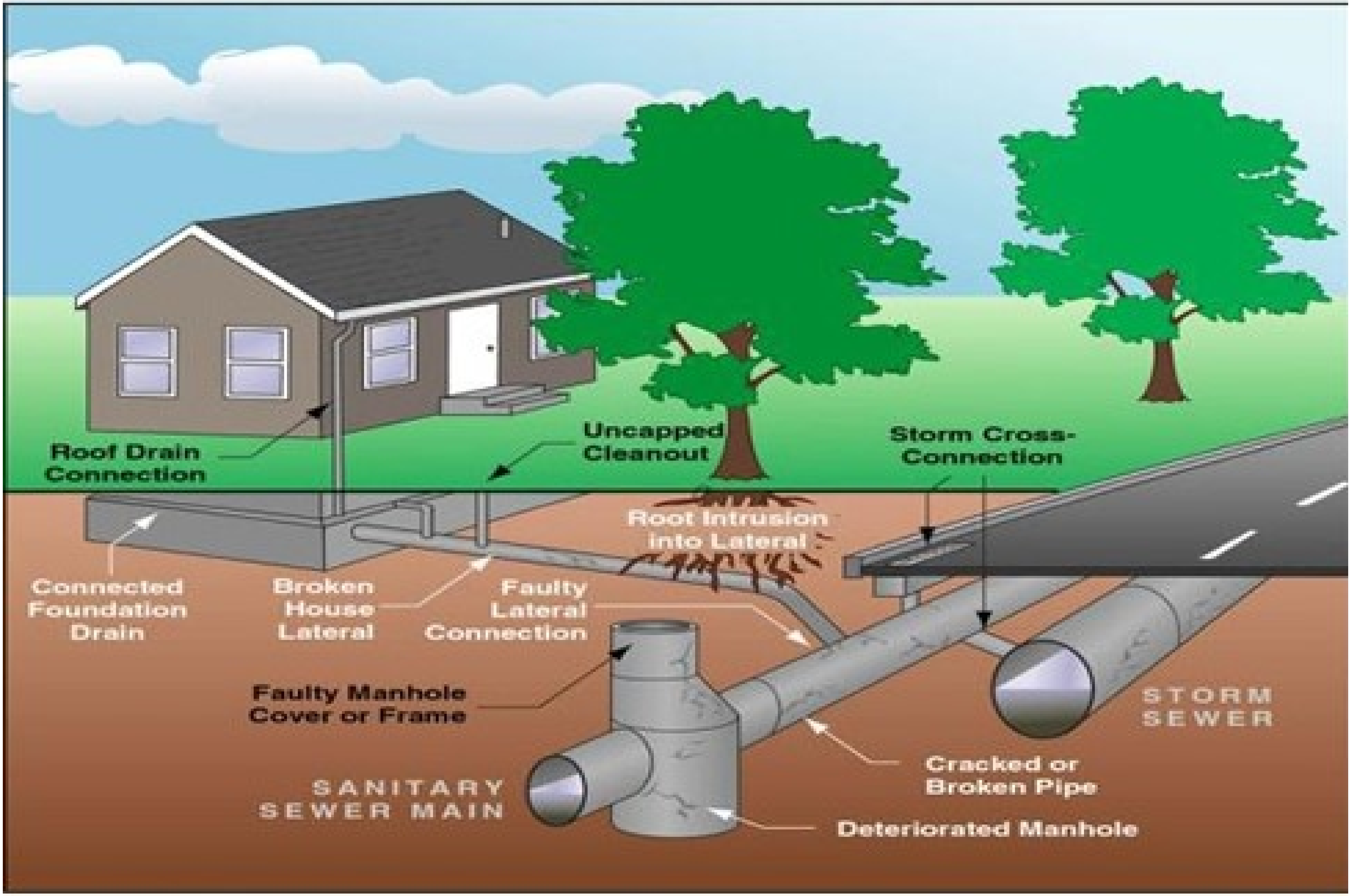

Domestic Sewage
Industrial Effluent
Raw Sewage Inflow
Sewage Treatment Plant
Treated Sewage Outfall
River Discharge

Types of Wastewater

From where does it all come?

Sewers

- **Types**
  - **Sanitary**
  - **Stormwater**
  - **Combined**
- **Collecting sewers to trunk sewers**
- **Gravity preferred**
- **Vacuum**
  - Vacuum pump at a central collection tank creates a negative pressure in the system
  - Sewage is pumped from the central collection tank to the treatment system
  - Require high O&M

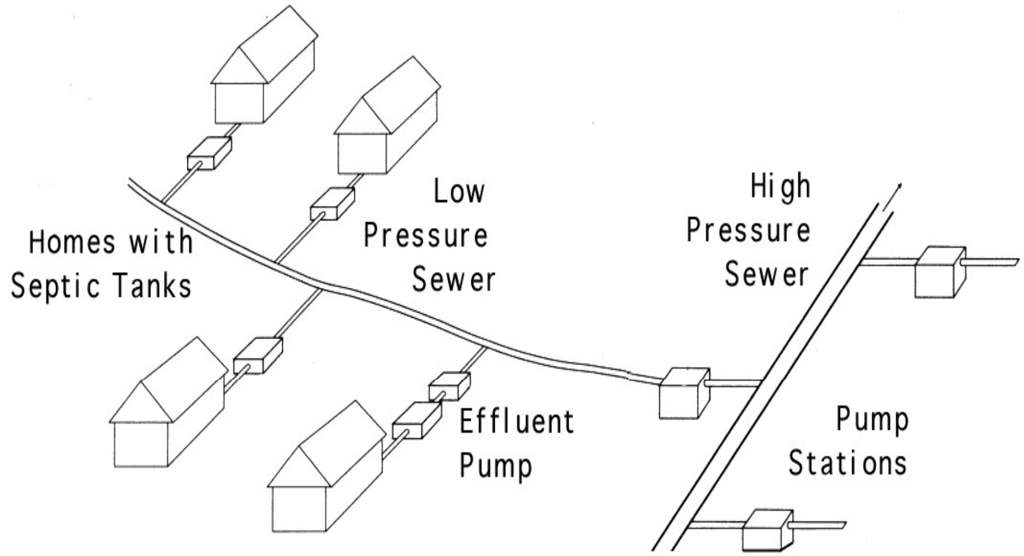


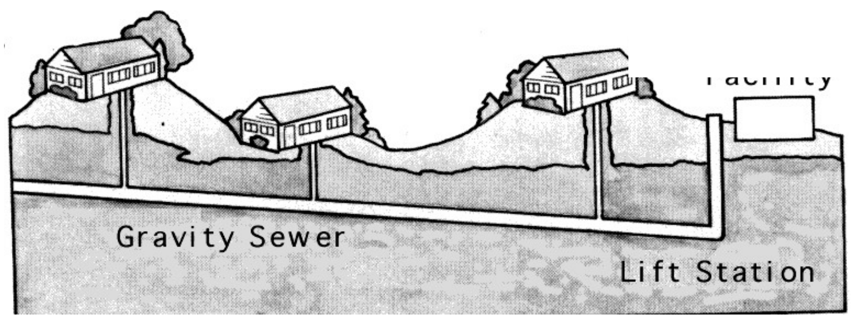
Key:

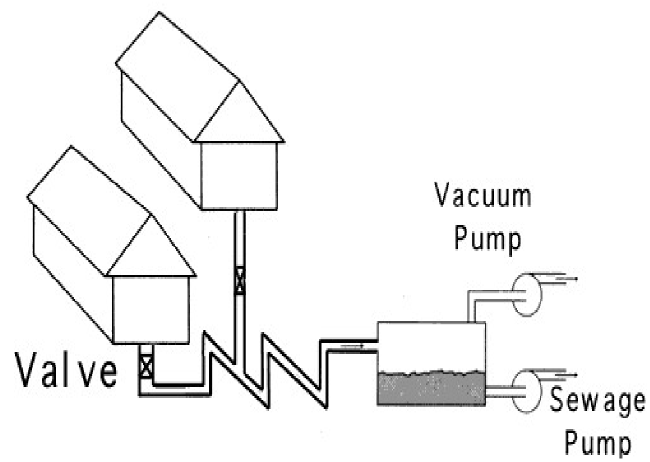
Inflow Source

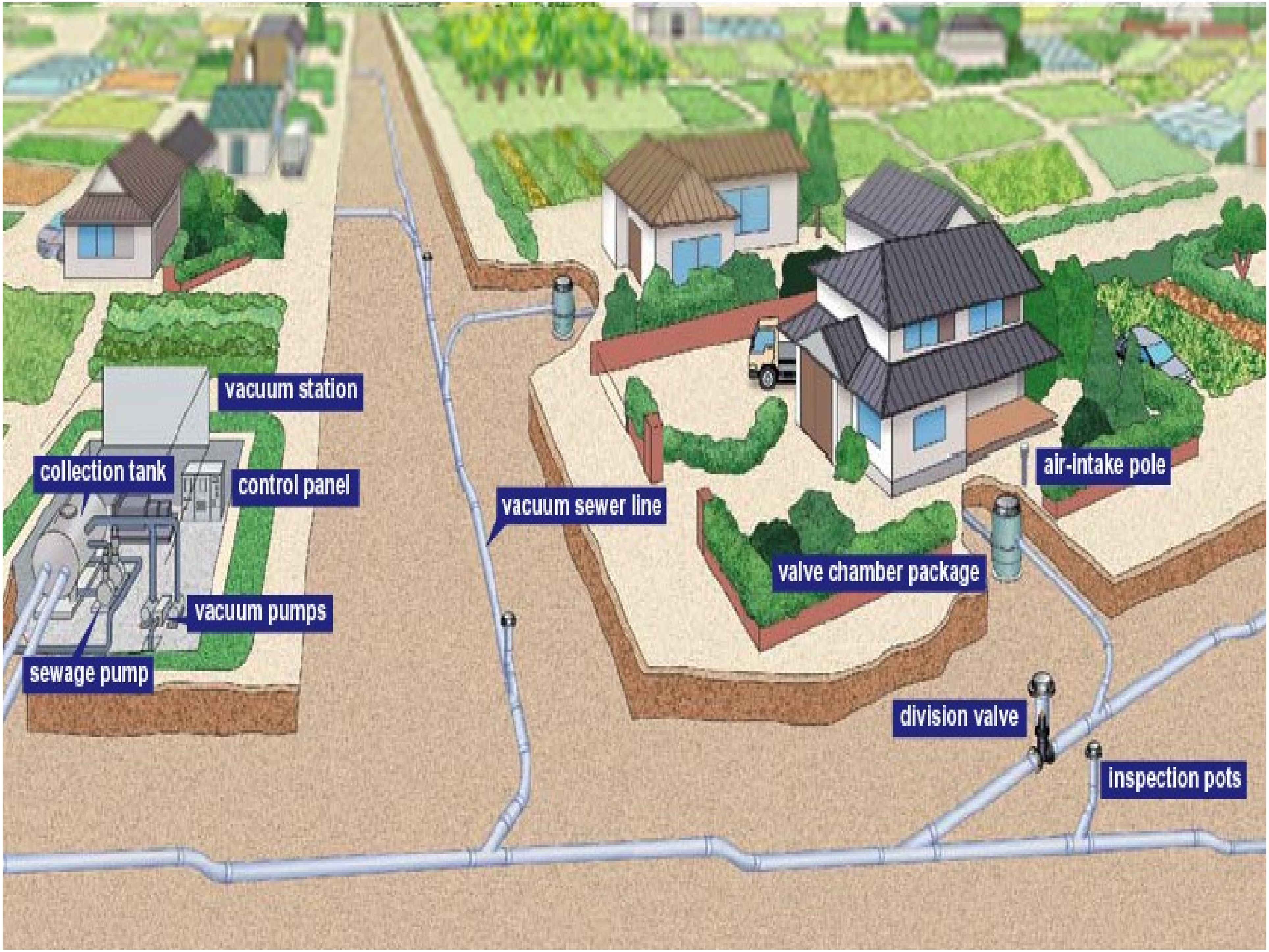
Infiltration Source

Transport of WW








vacuum station
collection tank
control panel
vacuum sewer line
air-intake pole
valve chamber package
vacuum pumps
sewage pump
division valve
inspection pots

CE 404 Current Event Assignment (Individual)

- The “environment” of environmental engineering is constantly changing. There are new data and/or theories, new devices and/or design techniques, new and/or anticipated regulations, etc. There are also too many aspects of the environment and environmental engineering to cover in a two-semester 6-credit-hour course. Therefore, to broaden you and your classmates’ perspectives, you need to bring to class to share two current events applicable to environmental engineering. For this current event, bring to class a report from a current source (e.g., an article from a newspaper, magazine (popular, trade, or professional), or newsletter (print or electronic)) or a brief written summary of a visual and/or audio presentation. Then provide a couple minute oral synopsis of the main point(s) to the class. Each article/printout/etc. must be unique. The topics covered in the class will be included in the class materials.

CE 404 Current Event Assignment (Individual)

- **Scoring Guide Rubric for Current Event Assignment (5 pts. for each one)**

Dimension	Description of highest level of performance
Currency (1 pt)	The topic is current; i.e., from the last 6 months.
Relevancy (1 pt)	The topic is relevant to environmental engineering.
Uniqueness *	The article/printout/etc. has not been used by anyone else.

*If the article/printout/etc. is not unique, then no credit is given. Note that the topic does not have to be unique.

Characteristics of WW

Parameter	Typical Concentration (mg/L)
BOD_5	250
SS	250
COD	500
Total-N	40
NH_3-N	30
Organic-N	10
NO_3-	0
P-Total	10
Ortho-P	6
Organic-P	4

Activity

Typical data: 0.17 lb/capita/d, 100 gpcd

Affects design and operation – effectiveness

Proportion of industrial to domestic

Types of industry (meat packing vs. plating)

Amount of I/I and stormwater

Why is it important to obtain local data on wastewater composition and flow rates rather than using typical data when designing a new or an expansion to a treatment plant?

Regulations

What's some examples of primary law for WWT?

What is the TMDL?

NPDES

- National Pollution Discharge Elimination System
- Example of NPDES

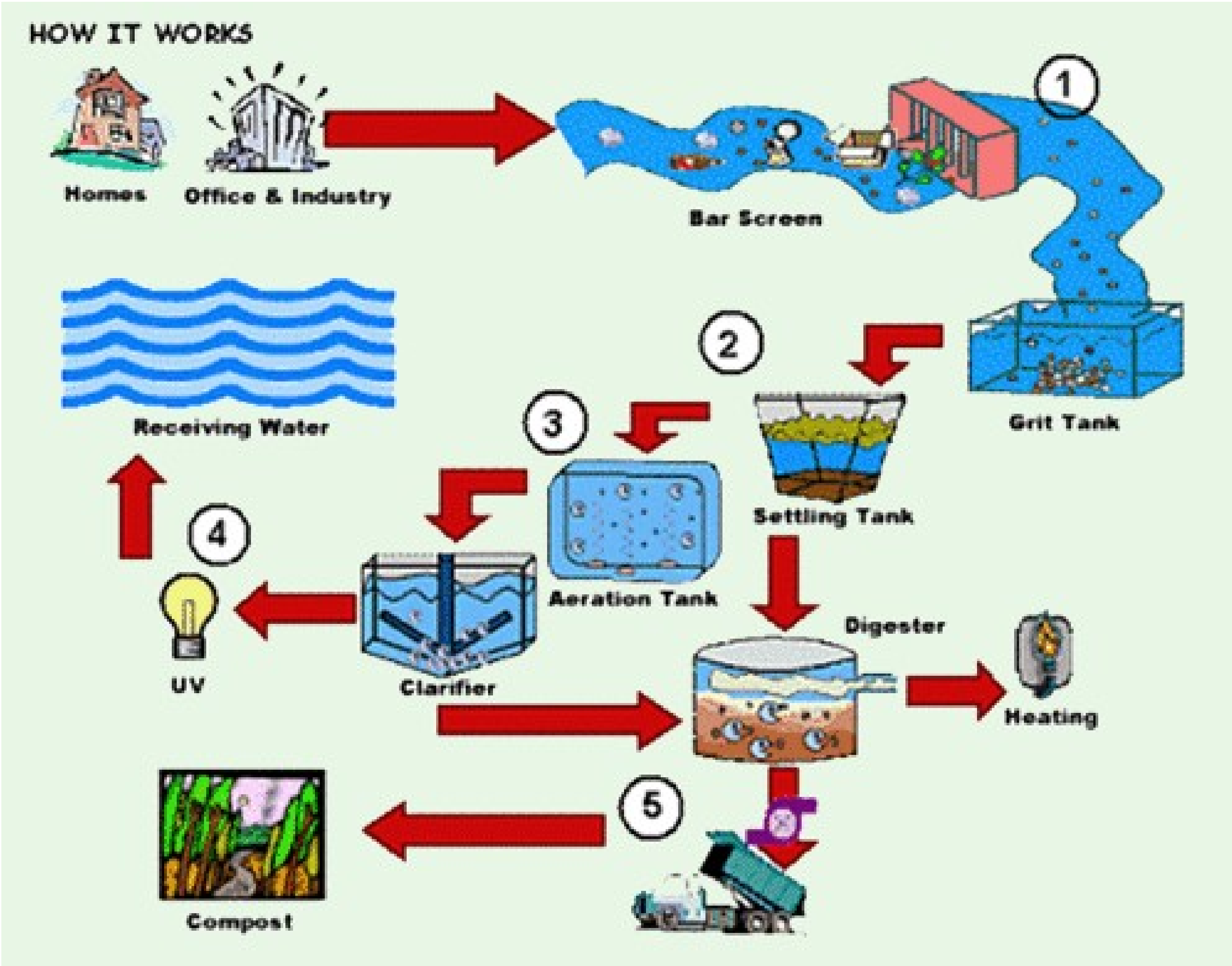
http://www.epa.state.il.us/public-notices/npdes-notices.html

Activity

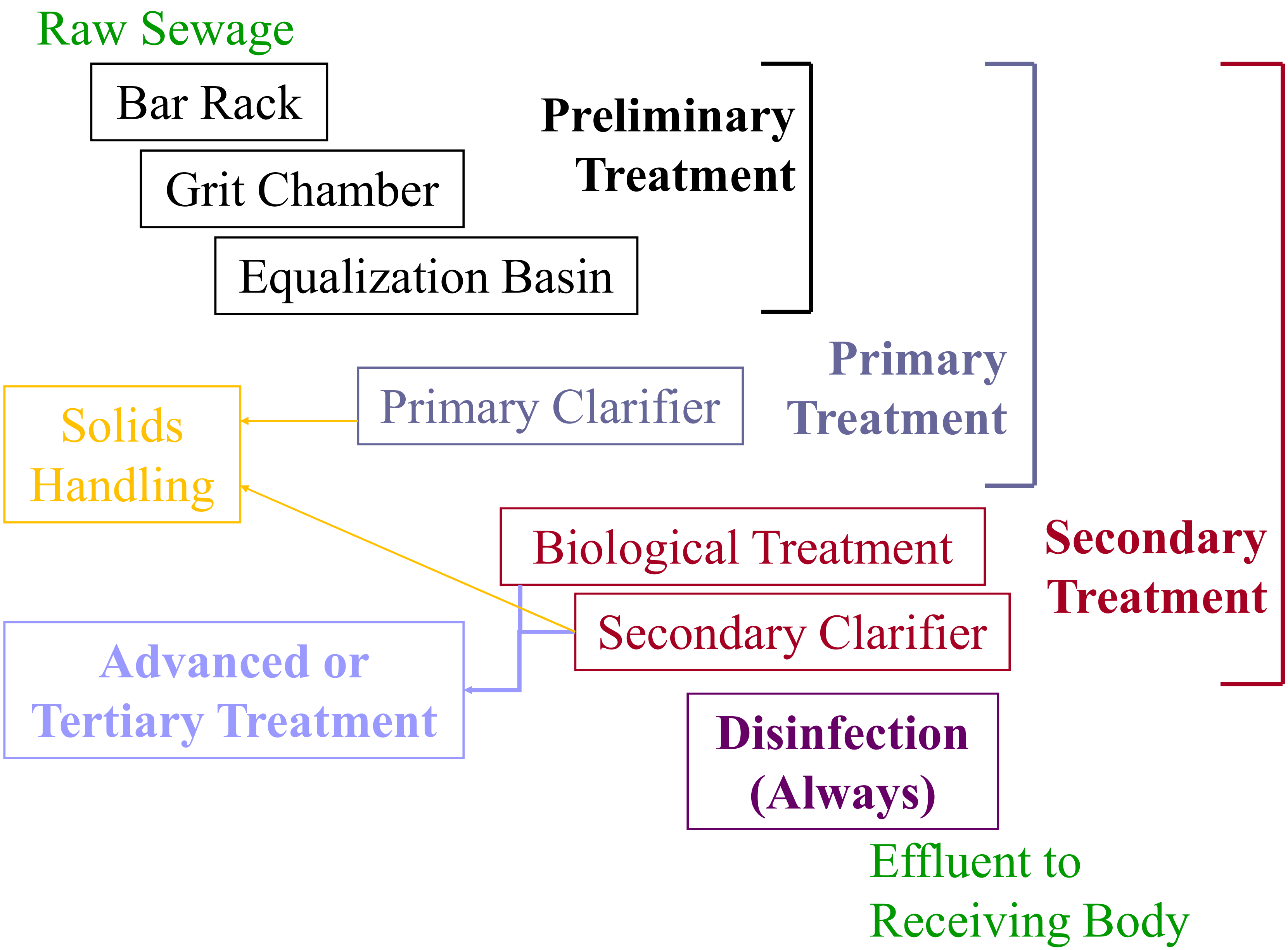
Who must obtain permit?

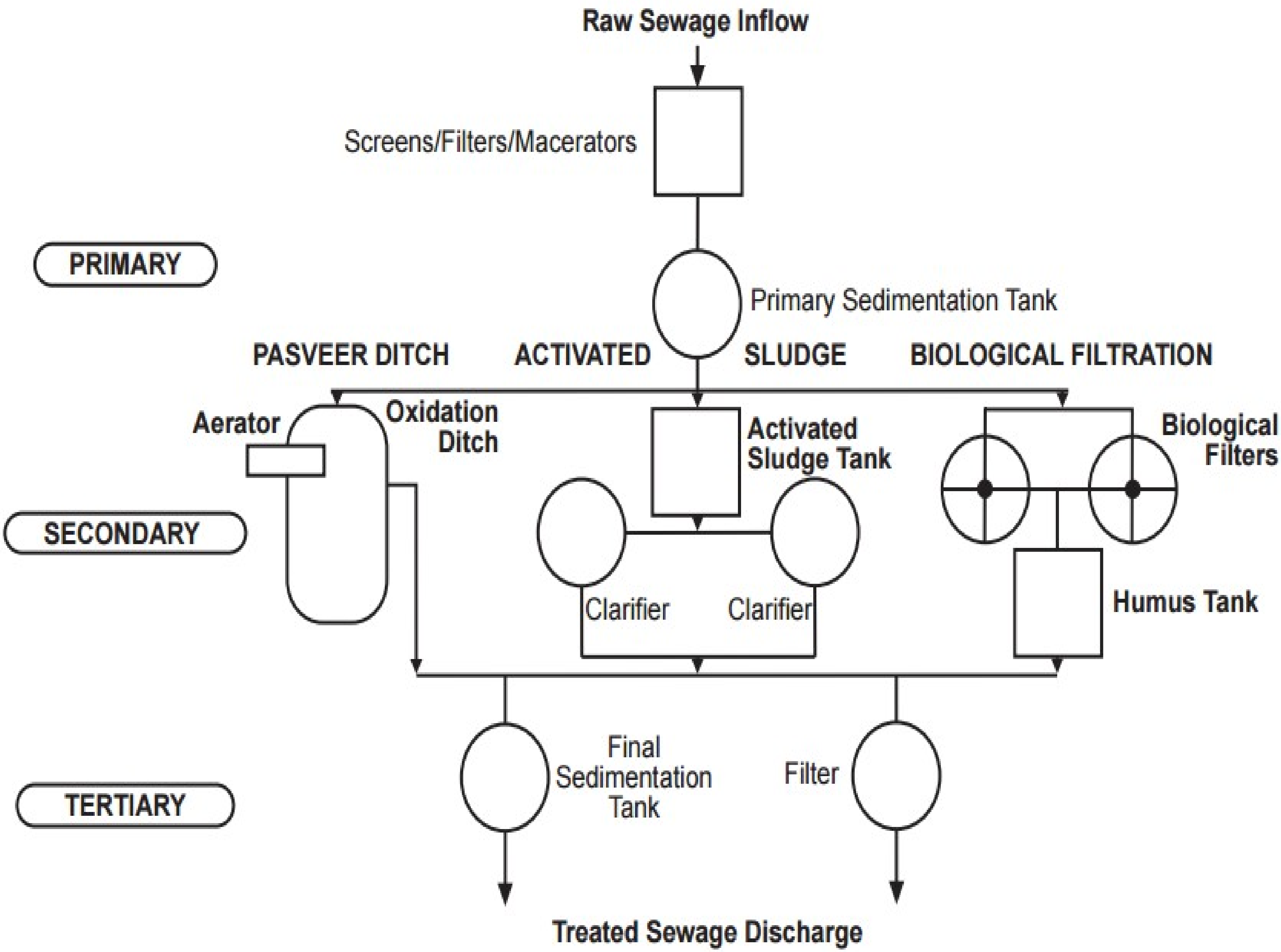
A. Manufacturers
B. Point source dischargers
C. Farmers
D. Septic tank owners
E. Municipalities

Typical Municipal WWTP

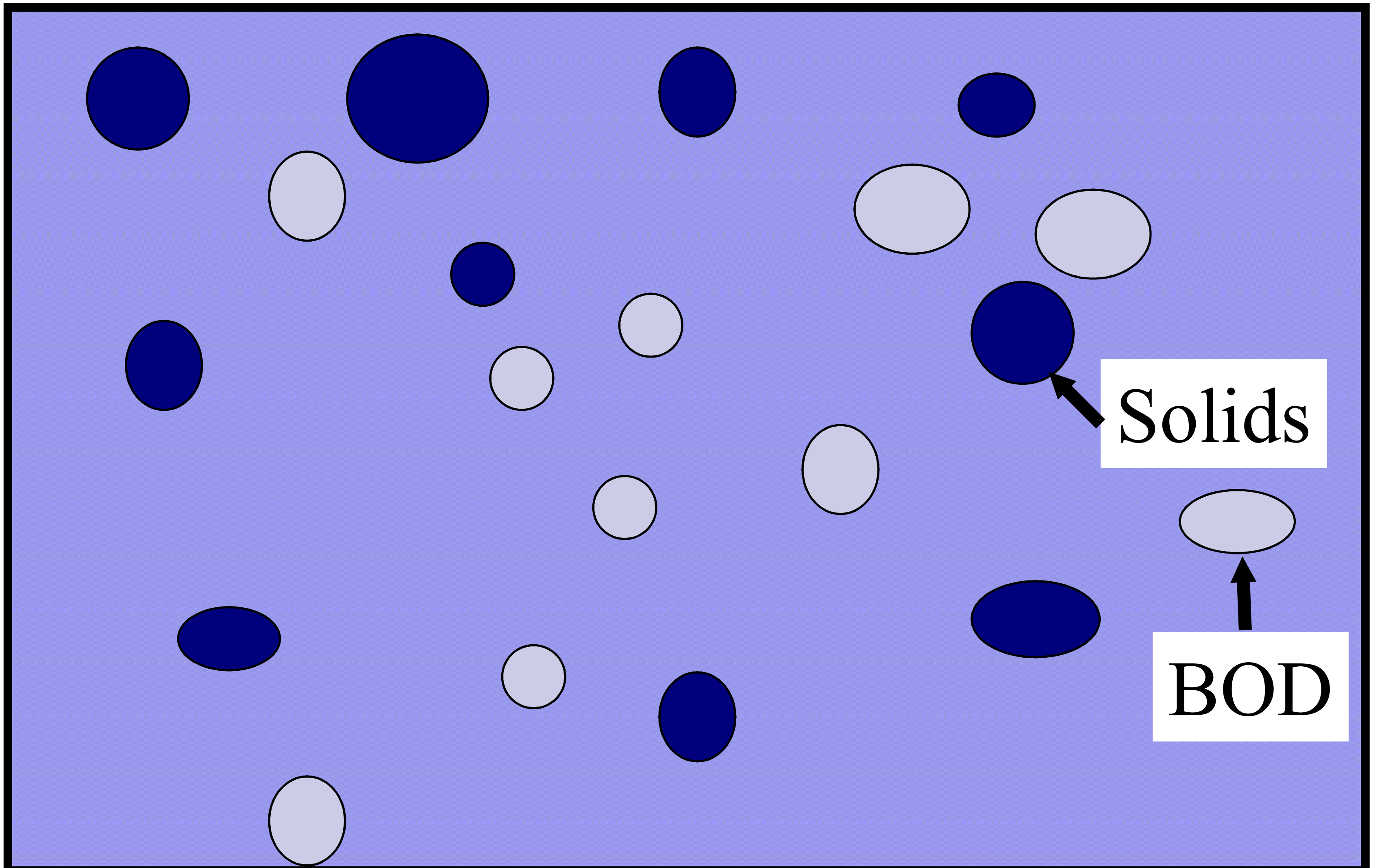


Degrees of Treatment - Example

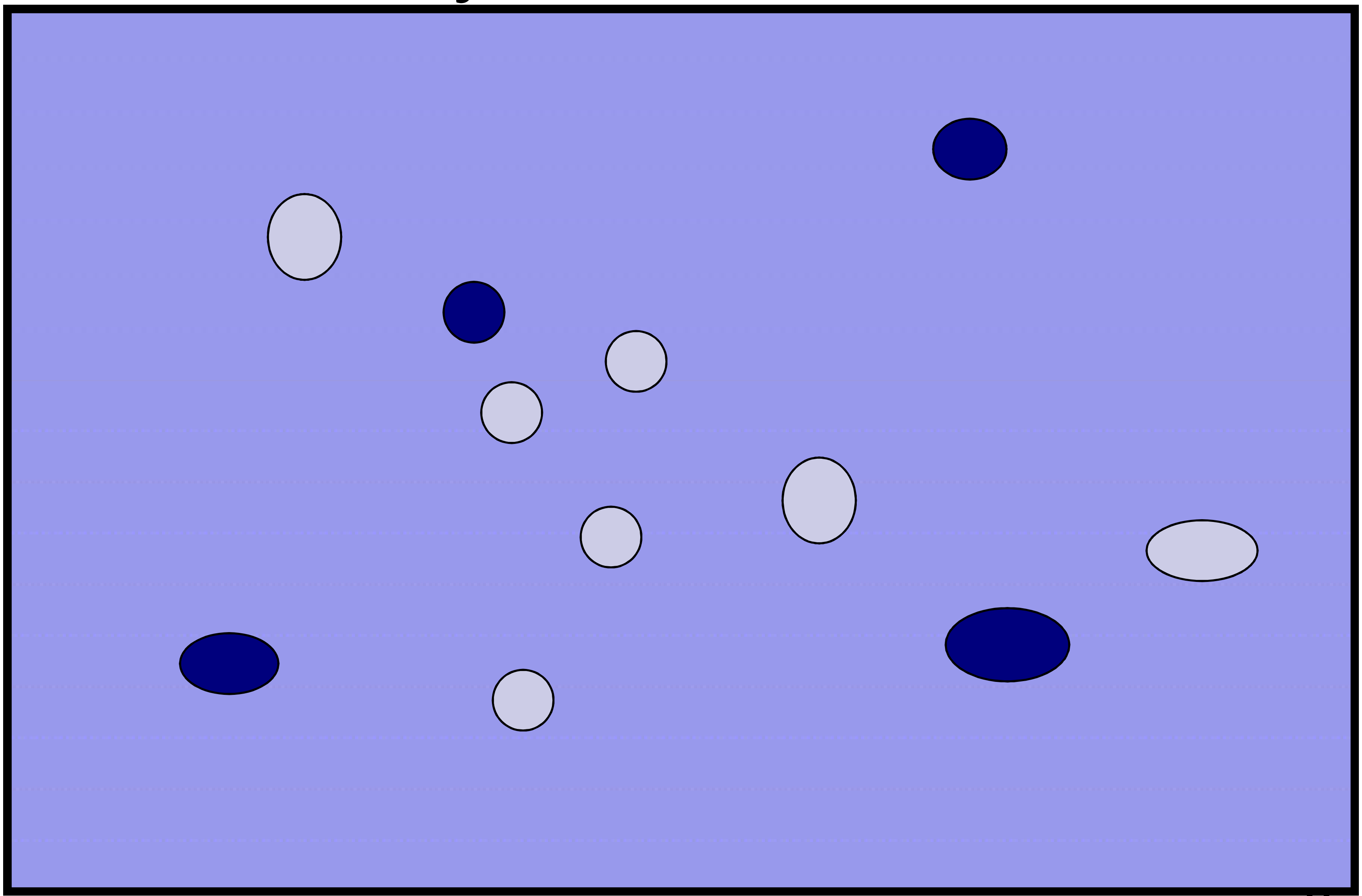



Raw Sewage Inflow
Screens/Filters/Macerators
PRIMARY
Primary Sedimentation Tank
PASVEER DITCH
ACTIVATED
SLUDGE
BIOLOGICAL FILTRATION
Aerator
Oxidation Ditch
Activated Sludge Tank
Biological Filters
SECONDARY
Clarifier
Clarifier
Humus Tank
TERTIARY
Final Sedimentation Tank
Filter
Treated Sewage Discharge

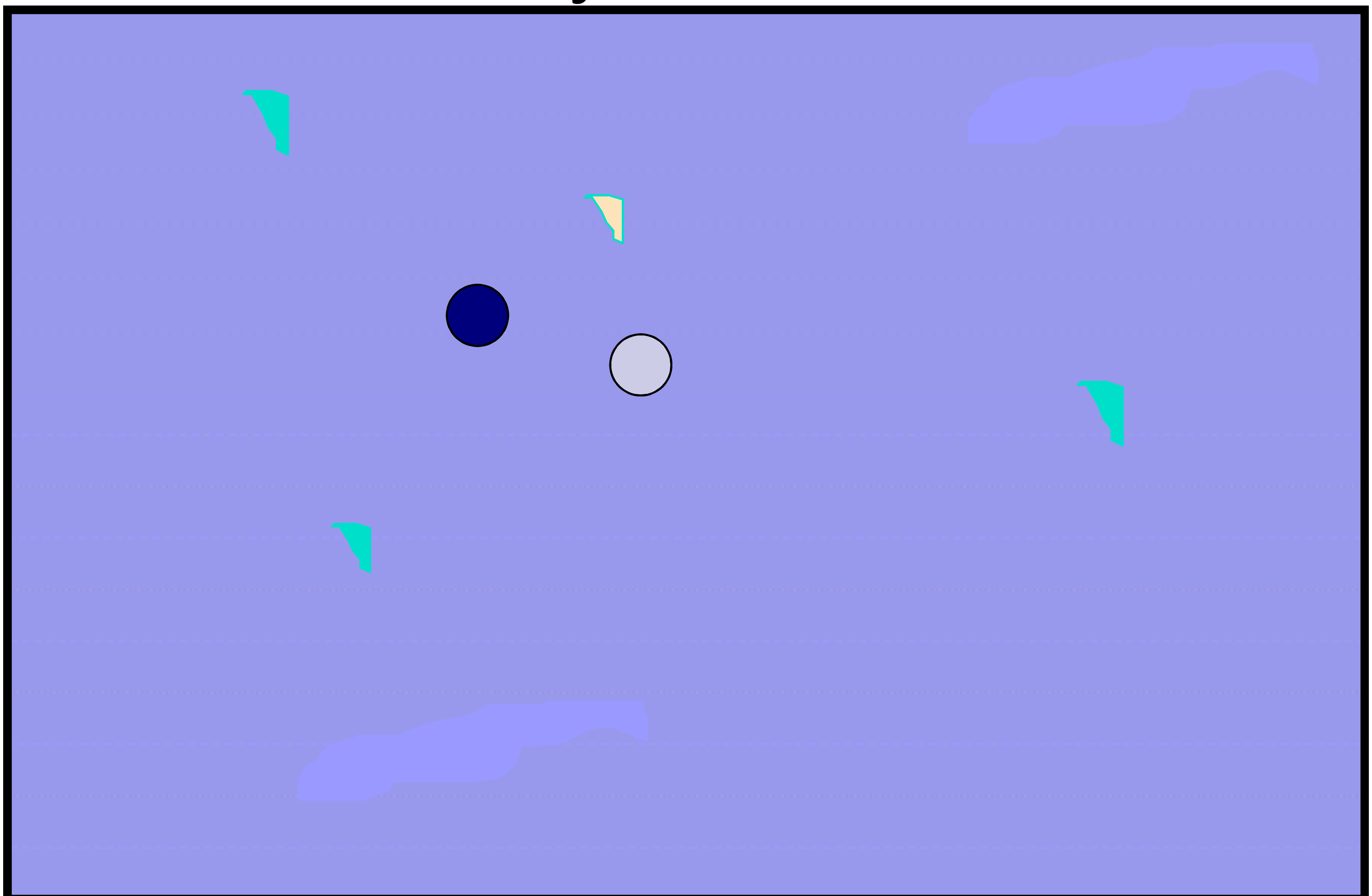
Influent – How much is removed?



After Primary Treatment

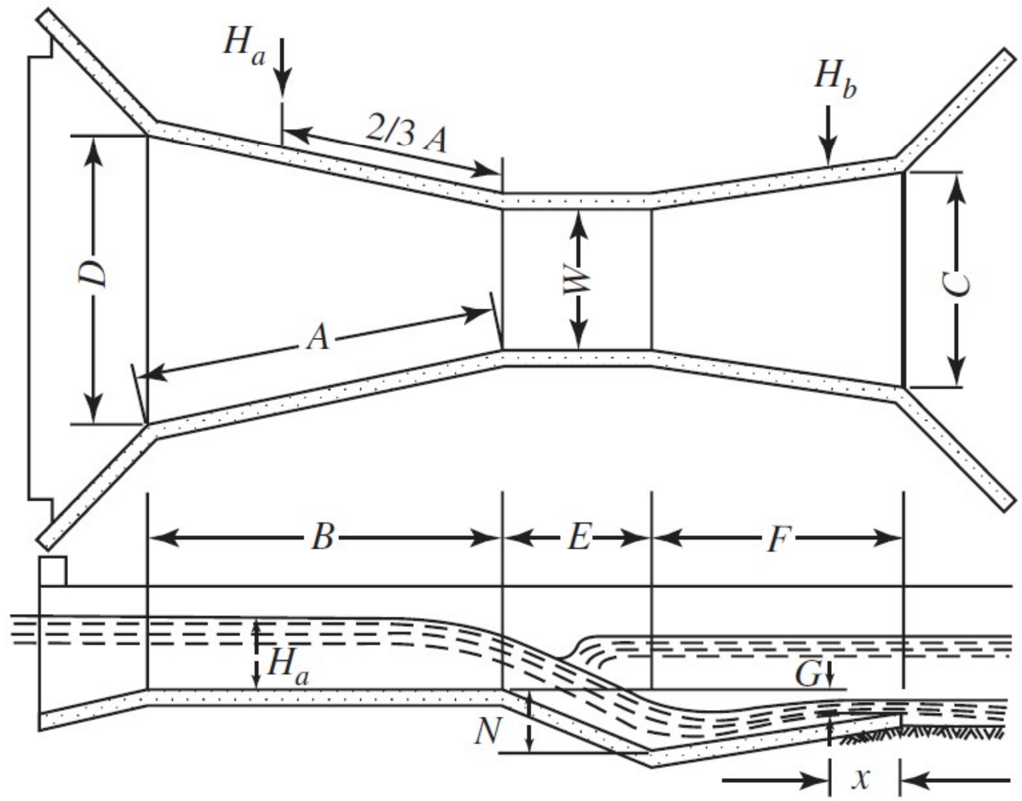


After Secondary Treatment



Flow Measurement

- Parshall flume
- Magnetic flow meter

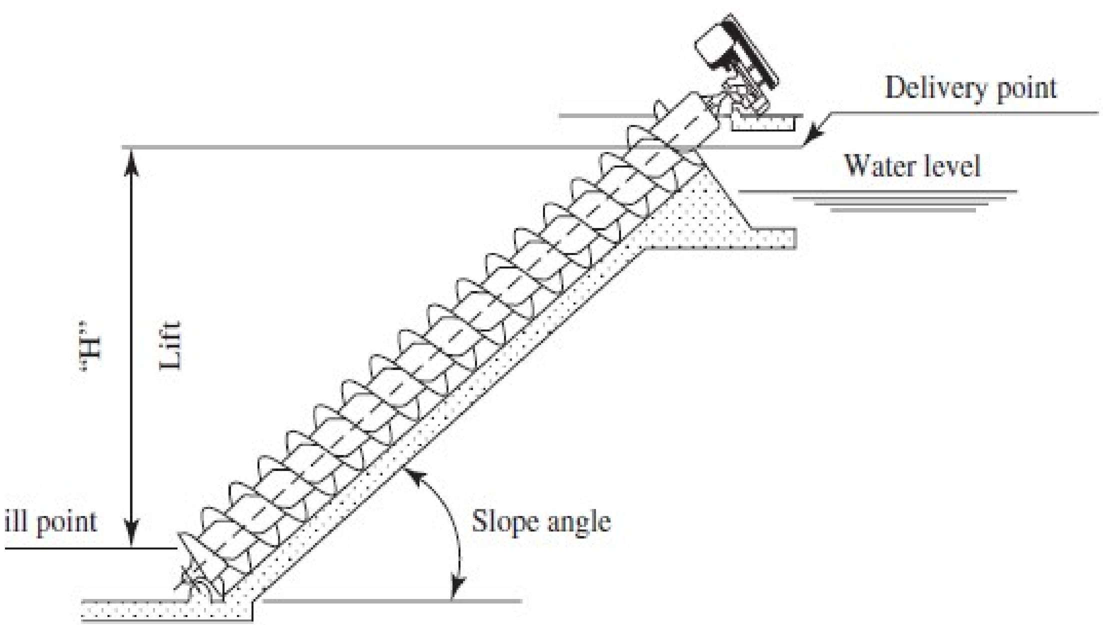


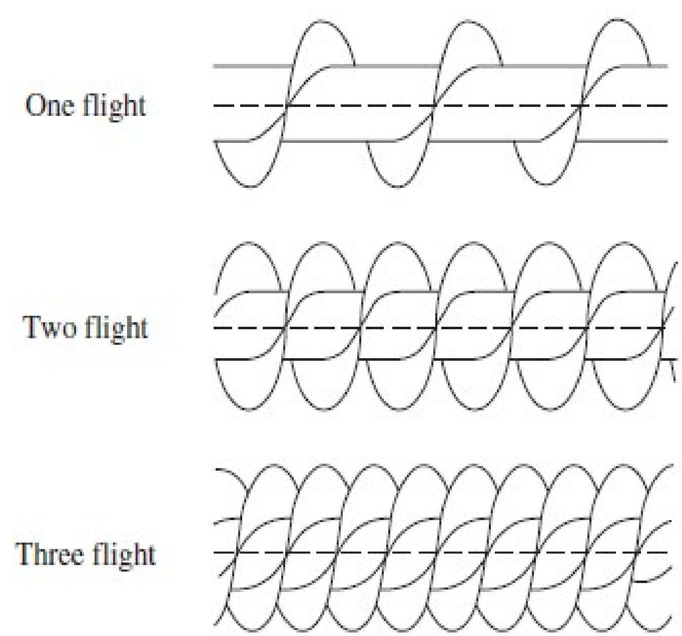
Pump Station

- Adequate capacity to handle the peak hydraulic flow rate.
  - Centrifugal pump
  - Screw pump
  - Static lift

Screw Pump or *Archimedes screw*

- High volume, non-clog, atmospheric head devices
- Open vs. enclosed
- Pros: provide good aeration and no clog
- Cons: requires large area, high maintenance, high slippage if open, and give low head





Preliminary Treatment in Al-Samawa WWTP

Preliminary Treatment

Screens

Grit Chamber

Comminutors
(Grinders)

Bar
Racks

Preliminary Treatment in Al-Samawa WWTP

Bar Racks and Screens

- Cleaned manually and mechanically
- Located ahead of the grit chambers to prevent fouling of the grit chamber equipment.

Nomenclature of racks and screens

Type	Typical opening	Typical use
Trash racks	40–150 mm	To prevent logs, stumps, and large heavy debris from entering treatment processes. Principally used in combined sewers ahead of pumping units. In WWTPs, frequently followed by coarse screens.
Bar racks or coarse screens	6–75 mm	To remove large solids, rags, and debris. Typically used in WWTP.
Fine screens	1.5–6 mm	To remove small solids. Typically follows a coarse screen.
Very fine screens	0.25–1.5 mm	To reduce suspended solids to near primary treatment level. Typically follow a coarse screen and/or fine screen. May be used when downstream processes do not include primary treatment.
Microscreens	1 μm–0.3 mm	Used in conjunction with very fine screens for effluent polishing.

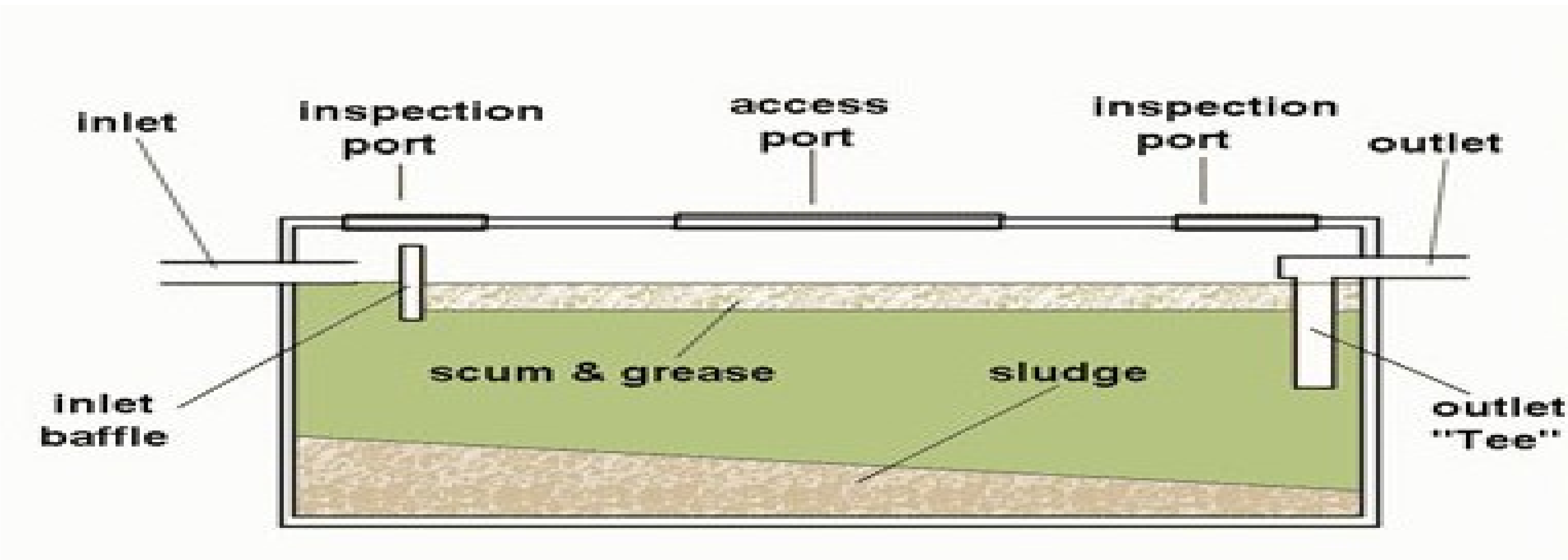
Sources: Daukss, 2006, WEF, 1998.

Preliminary Treatment: grit chamber

- Sandy material, mostly inorganic, is grit
- Mostly between 0.05 and 1 mm in diameter
- Considered to be “non-sticky” particles, but are mostly “sticky” particles. Coated with fats, oils and grease in the sewers, increasing buoyancy (upward force)
- If not removed in grit tanks, ends up in digesters

Preliminary Treatment: grit chamber

- Reduce the velocity
- Grit settled to the bottom
- Typical ϴ= 45-90 sec.
- Designed based on settling rate. (typically 0.075 ft/sec)



Problem:

- A plant is currently using two grit channels. Each channel is 3 ft wide and has a water depth of 1.3 ft. What is the velocity when the influent flow rate is 4.0 MGD?

Solution:

$$\text{Velocity} = \frac{4.0 \text{ MGD} \times 1.55 \text{ cfs/MGD}}{2 \text{ channels} \times 3 \text{ ft} \times 1.3 \text{ ft}}$$

$$= \frac{6.2 \text{ cfs}}{7.8 \text{ ft}^2} = 0.79 \text{ fps}$$

Note: Because 0.79 is within the range of 0.7 to 1.4, the operator of this unit would not make any adjustments.

Grit Chamber in Al-Samawa WWTP

Grit Chamber in Al-Samawa WWTP

HW

- Al-Samawa WWTP has a design capacity to treat 37000 cubic meter/day. For unknown reason the 2 grit chambers in the plant were built with no front and rear walls as shown in pervious pictures. If you asked to install these walls, with dimensions of 4x4 meters for each chamber, what would you suggest the height of these walls?

Primary Treatment
(Section 11.2.2)

Primary Treatment

- Primary settling tank, may also called Primary Clarifier
- Remove organic particles by gravity instead of costly biological treatment
- Typical operating value:

Primary clarifier 1000 gpd/ft2 average

Secondary clarifier 600 gpd/ft2 average

- May add chemicals or a coagulant (like metal salts) to enhance treatment

Problem

- A circular clarifier has a diameter of 50 ft. If the primary effluent flow is 2,150,000 gpd, what is the surface overflow rate in gpd/ft2?

Solution:

$$\text{Area} = 0.785 \times 50\ \text{ft} \times 50\ \text{ft}$$

$$\text{Surface overflow rate} = \frac{\text{Flow (gpd)}}{\text{Area (ft}^2)}$$

$$= \frac{2{,}150{,}000}{0.785 \times 50\ \text{ft} \times 50\ \text{ft}} = 1096\ \text{gpd/ft}^2$$

Primary Treatment

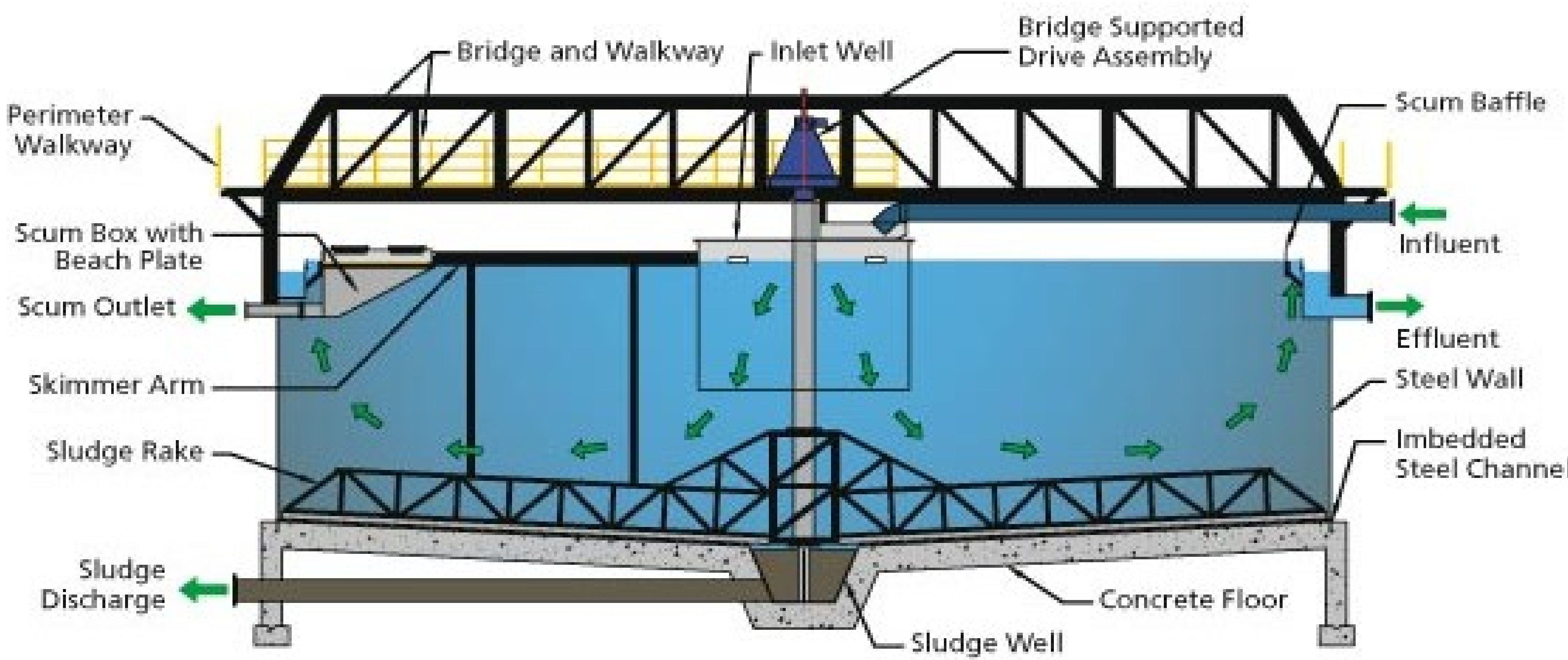
- Normally, each primary clarification unit can be expected to remove 90 to 95% settleable solids, 40 to 60% total suspended solids, and 25 to 35% BOD5.
- Velocity is reduced to approximately 1 to 2 fpm.
- Remove floated grease and scum, as well as the settled sludge solids.

Factors affecting primary clarifier performance

- Rate of flow through the clarifier
- Wastewater characteristics (strength, temperature, amount and type of industrial waste, and the density, size, and shapes of particles)
- Performance of pretreatment processes
- Nature and amount of any wastes recycled to the primary clarifier

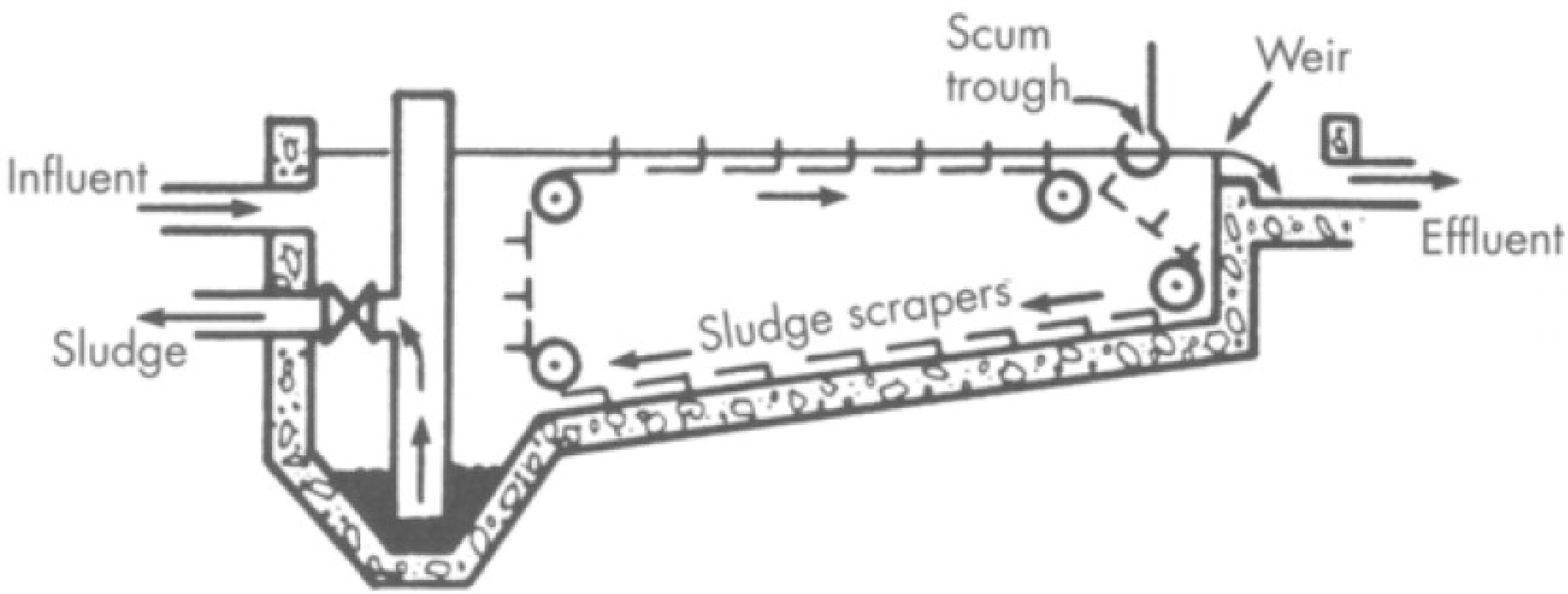
Clarifiers

- Suspended solids removal (50-65%)
- Circular or rectangular
- Typical dimensions (40-150 ft Diameter and 10-16 ft depth)



Source: http://www.monroeenvironmental.com/water-and-wastewater-treatment/circular-clarifiers/circular-clarifiers-primary

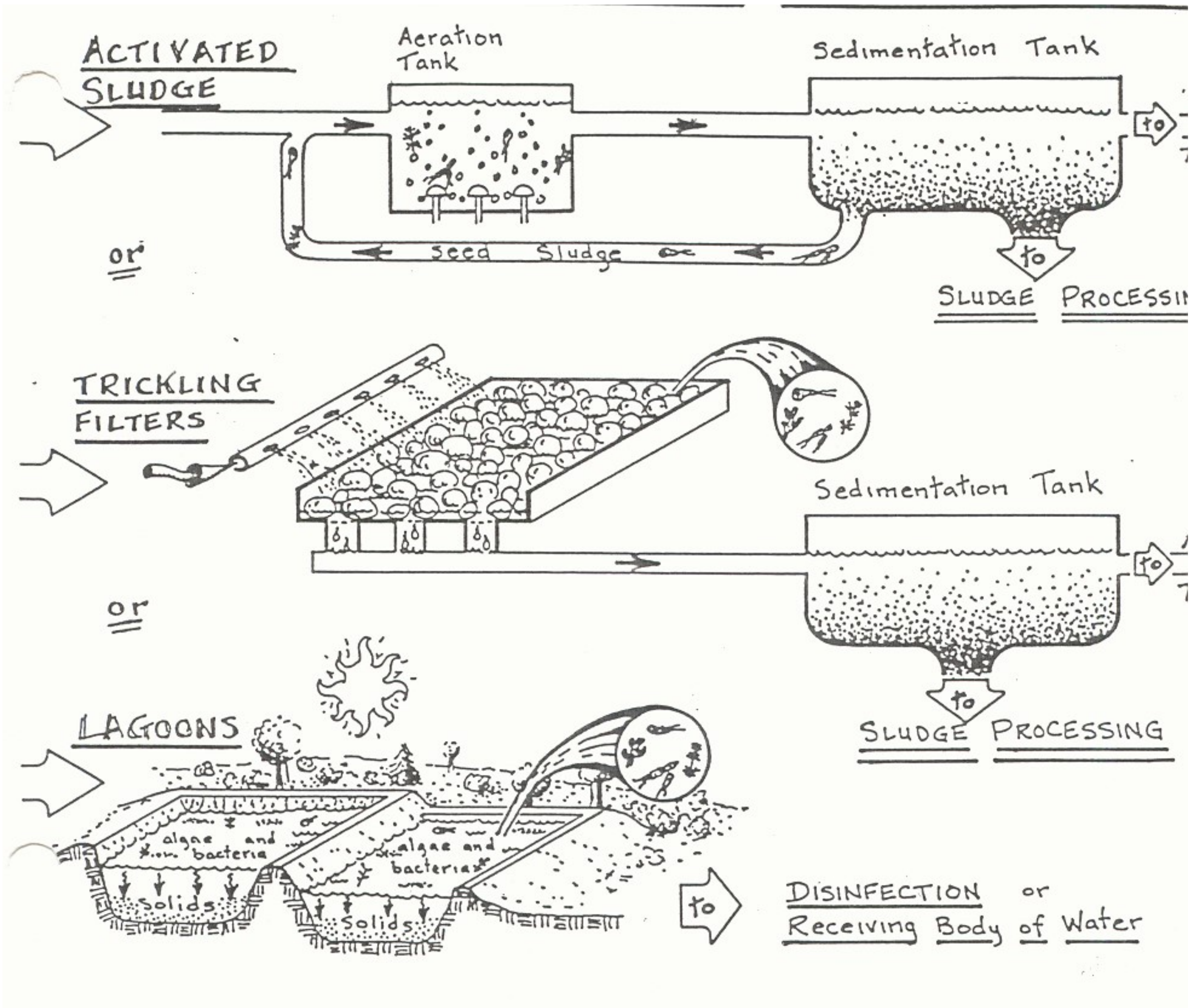
Rectangular Settling Tank



Secondary Treatment

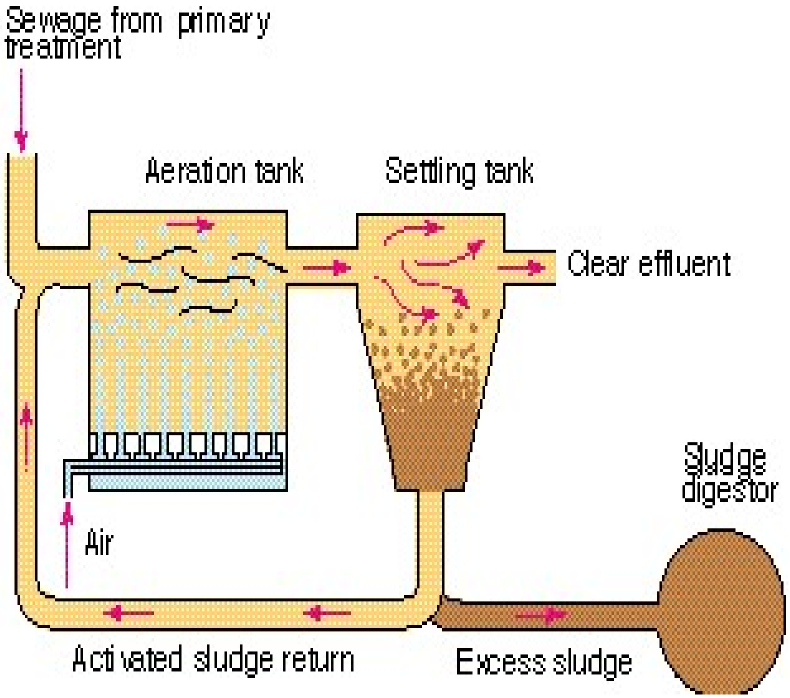
- To convert most of BOD into settleable solids
- Types:
  - Activated sludge AS
  - Trickling filter TF
  - Rotating biological contactor RBC
  - Stabilization pond
  - Oxidation ditches
  - Sequencing batch reactor SBR
  - Lagoons

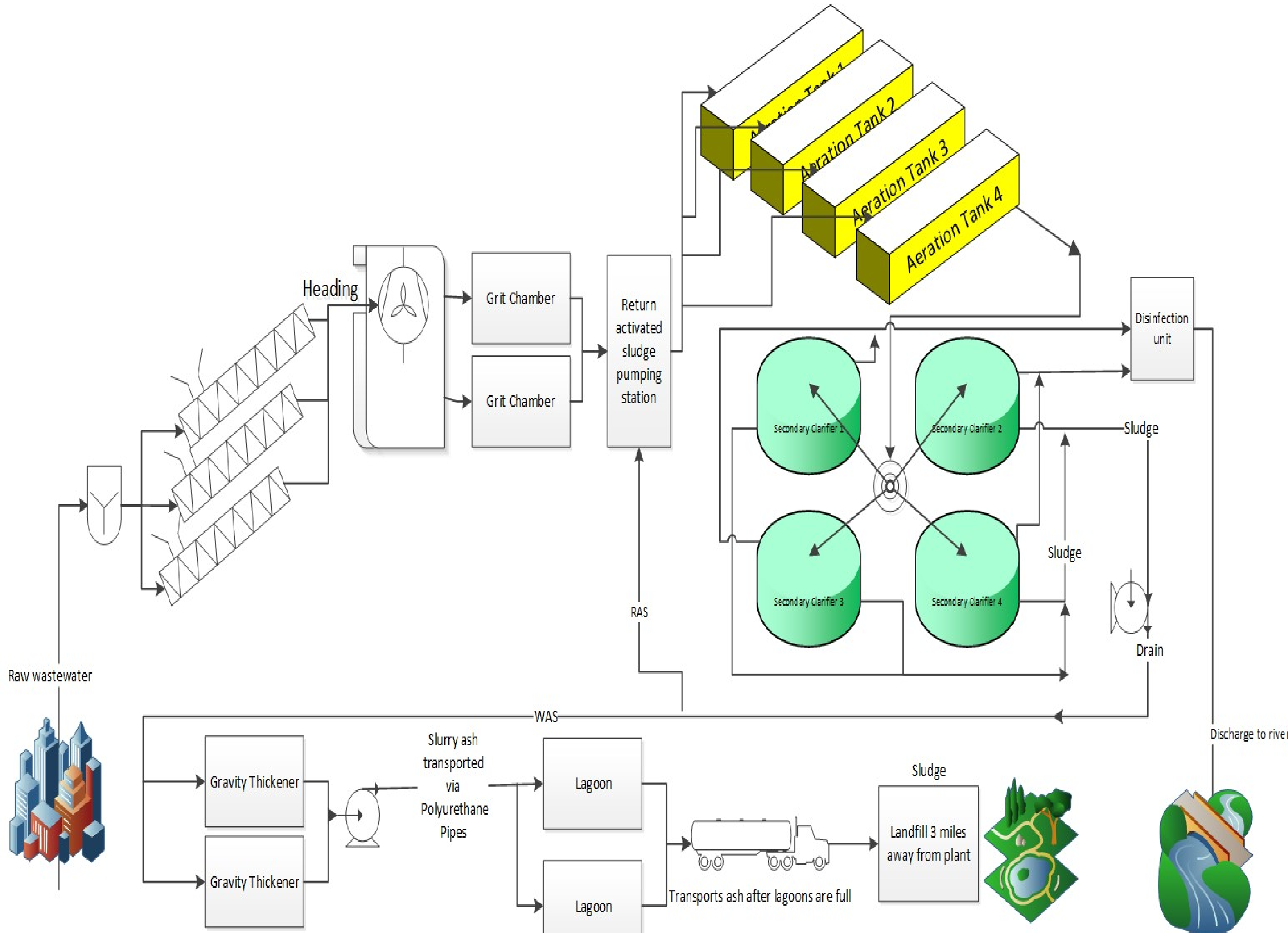
Secondary Treatment
(Section 11.3)



Secondary Treatment

- Activated Sludge (AS)
  - Suspended growth system
  - Production of an activated mass of microorganisms capable of aerobically stabilizing the organic content of a waste.





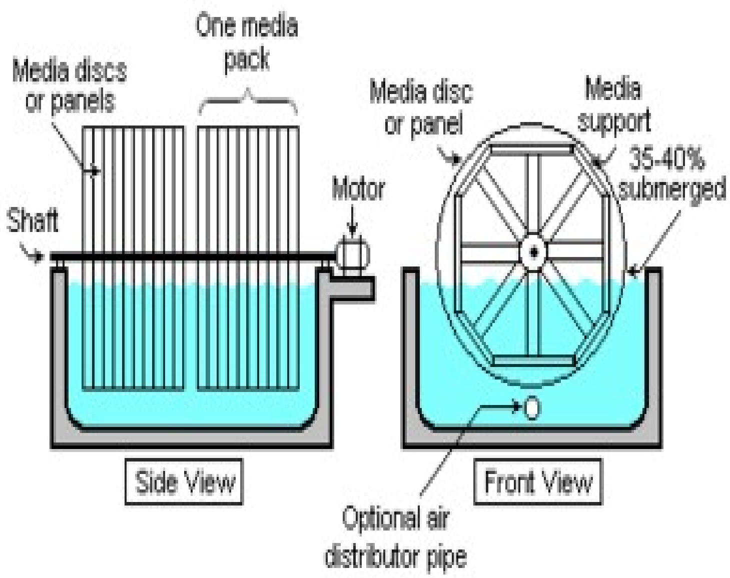
Aeration Tank 1
Aeration Tank 2
Aeration Tank 3
Aeration Tank 4
Heading
Grit Chamber
Grit Chamber
Return activated sludge pumping station
Disinfection unit
Secondary Clarifier 1
Secondary Clarifier 2
Secondary Clarifier 3
Secondary Clarifier 4
Sludge
Sludge
Drain
RAS
Raw wastewater
WAS
Discharge to river
Gravity Thickener
Gravity Thickener
Slurry ash transported via Polyurethane Pipes
Lagoon
Lagoon
Transports ash after lagoons are full
Sludge
Landfill 3 miles away from plant

Secondary Treatment

- Trickling Filter
  - Attached growth system
  - A bed of highly permeable media on whose surface a mixed population of microorganisms is developed as a slime layer

Secondary Treatment

- Rotating Biological Contactor (RBC)
  - Attached growth system
  - The process operates as a fixed-film biological reactor. A biological film or bio-mass grows on the surface of a series of discs mounted on a shaft and placed in a tank conforming to the general shape of the discs.



Secondary Treatment

- Oxidation Pond
- Lagoons
- Sequencing Batch Reactors (SBR)

OXYGEN DEMAND

Oxygen Demand

- Amount of oxygen required to oxidize a waste
- Indirect measure of the amount of organic impurities in water
- Methods
  - Theoretical oxygen demand (ThOD)
  - Biochemical oxygen demand (BOD)
  - Chemical oxygen demand (COD)

Theoretical Oxygen Demand

Total ThOD = C-ThOD + N-ThOD

- C-ThOD = stoichiometric amount of O_2 required to convert an organic substance to CO_2, H_2O, and NH_3
- N-ThOD = stoichiometric amount of O_2 required to convert NH_3 and organic N to NO_3^-

Example 1

What is the total ThOD to oxidize completely 25 mg/L of ethanol (CH_3CH_2OH)?

$CH_3CH_2OH + a\ O_2 \leftrightarrow b\ CO_2 + c\ H_2O$

Determine Volume of O_2 or Air

Example 2

What is the ThOD to oxidize completely 25 mg/L of serine ($CH_2OHCHNH_2COOH$)?

$CH_2OHCHNH_2COOH + a\ O_2 \leftrightarrow b\ CO_2 + c\ H_2O + d\ NH_3$

$NH_3 + a\ O_2 \leftrightarrow b\ HNO_3 + c\ H_2O$

Biochemical Oxygen Demand (BOD)

Lab: Unseeded BOD

$$BOD_t = \frac{DO_i - DO_f}{V_s / V_b} = \left(DO_i - DO_f\right)DF$$

- BOD_t = BOD at t days (mg/L)
- DO_i = initial dissolved oxygen (mg/L)
- DO_f = final dissolved oxygen (mg/L)
- V_s= sample volume (mL)
- V_b = bottle volume (mL) = 300 mL
- DF = dilution factor = V_b/V_s

Lab: Seeded BOD

$$BOD_t = \frac{\left(DO_i - DO_f\right) - \left(B_i - B_f\right)\left(1 - \frac{V_s}{V_b}\right)}{\frac{V_s}{V_b}}$$

- B_i = initial DO of blank (mg/L)
- B_f = final DO of blank (mg/L)

In-Class Activity

- 10 mL of a wastewater sample are placed in a 300-mL BOD bottle with unseeded nutrient broth. The initial DO of the sample is 8.5 mg/L. The DO is 3 mg/L after 5 days. What is the 5-day BOD?
- A 17^{o}C sample is initially saturated with oxygen. Saturated seeded dilution water is used to obtain a 1:25 dilution. The final DO of the seeded dilution water is 8.2 mg/L while the final DO of the diluted sample is 2.8 mg/L. What is the 5-day BOD?

In-Class Activity

You received the results of a BOD test of the influent to a municipal WWTP run with 300-mL bottles. The initial DOs of the samples and seeded dilution water were at saturation (9.07 mg/L). All samples were run at a dilution factor of 40:1. The 5-day DOs are shown in the table below. The client is on the phone with your boss wanting to know why he hasn't gotten a report yet. Justify why you threw out this data and made the lab redo the test.

Bottle Number	Type[1]	DO (mg/L)
10	B	8.91
14	B	8.89
18	S	7.85
22	S	8.15
28	S	8.52

[1]B = blank (seeded dilution water), S = sample with seeded dilution water

Rate of BOD Removal

- Relate BOD exerted (BOD_t or L_t) to total, or ultimate, BOD (BOD_u or L)
- Assume that the BOD reduction rate (dC/dt) is proportional to the BOD remaining (C):

$$dC/dt = -k_1 C$$

Rate of BOD Removal cont.

Integration yields (Eq. 9.5, p. 257):

$$y = L\left(1 - e^{-k_1 t}\right)$$

$$BOD_t = BOD_u\left(1 - e^{-k_1 t}\right)$$

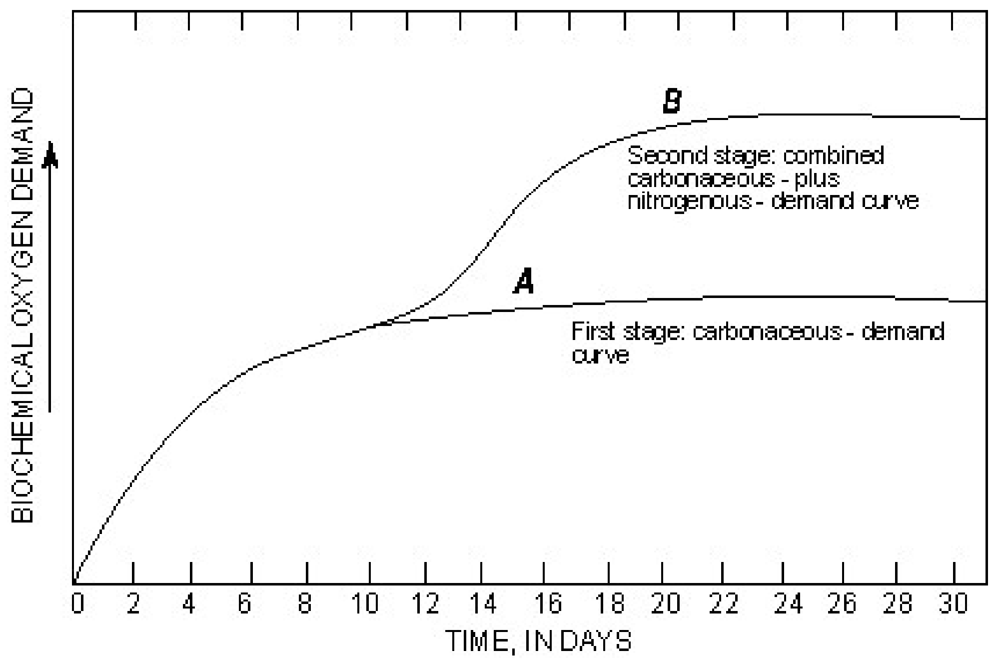
- y = BOD exerted in t days = BOD_t
- L = ultimate BOD = BOD_u
- k_1 = BOD degradation rate constant = deoxygenation constant

In-Class Activity continued

10 mL of a wastewater sample are placed in a 300-mL BOD bottle. The initial DO of the sample is 8.5 mg/L. The DO is 3 mg/L after 5 days. What is the 5-day BOD? 165 mg/L

What is the 3-day BOD if the reaction rate constant is 0.23/d?

Ultimate BOD



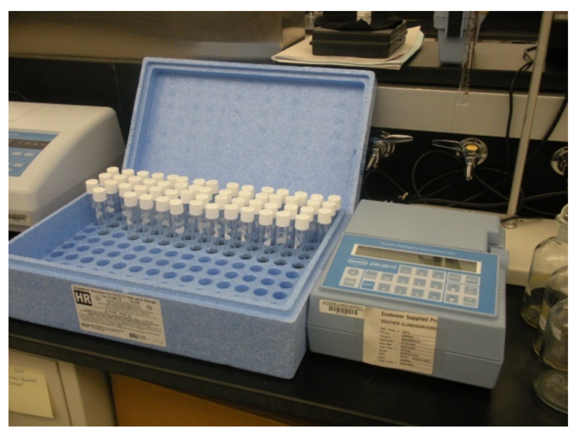
CBOD

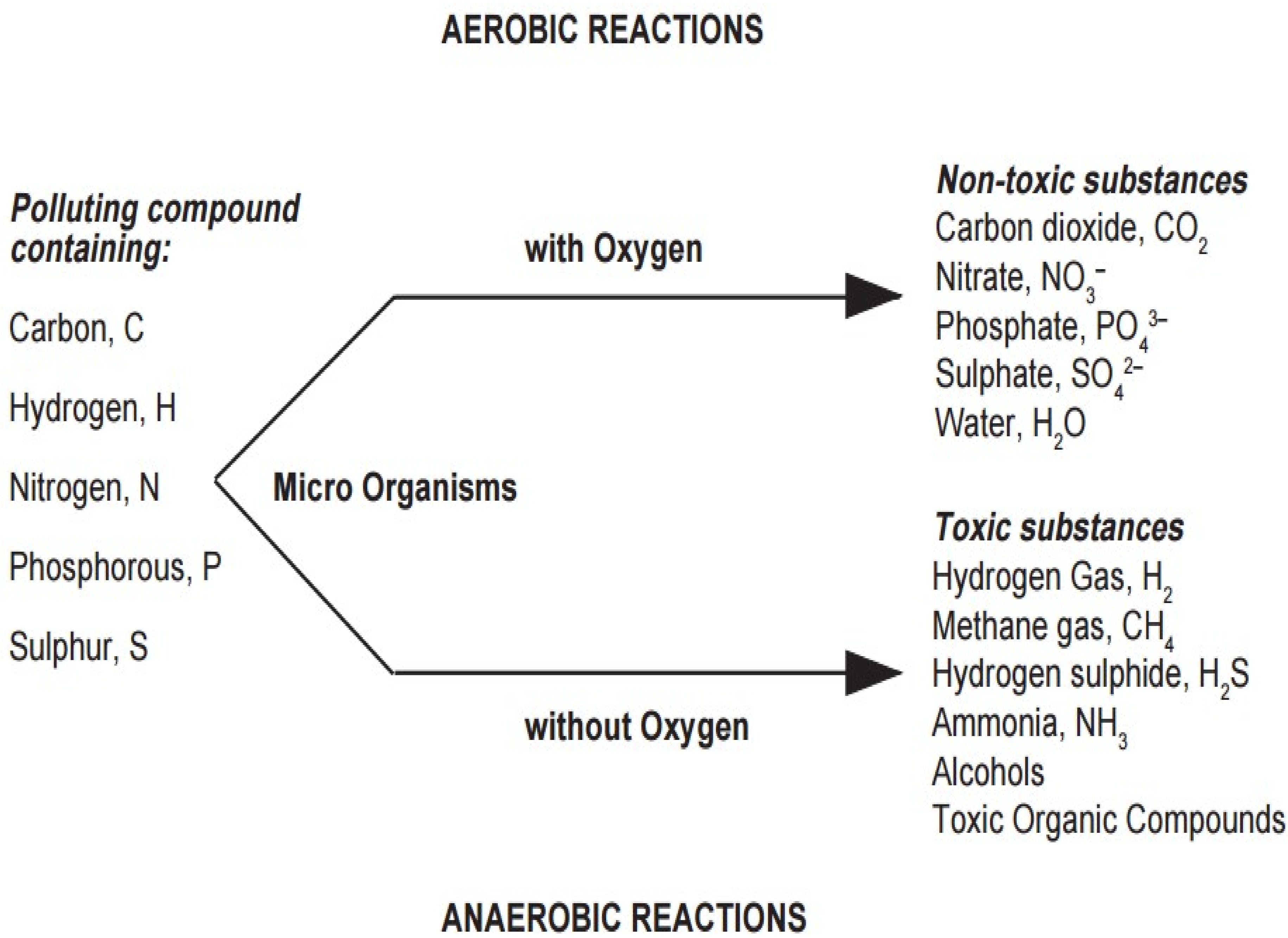
- What is CBOD?
- How nitrogen and carbon compounds assimilated?
- Jump in the curve after 5 to 8 days
- Start of nitrification processes
- BOD=CBOD +NBOD
- Why?

Chemical Oxygen Demand (COD)

Reactor Digestion Method

- Strong chemical oxidizing agent (potassium dichromate, $K_2Cr_2O_7$) plus a strong acid (H_2SO_4).
- Mix with sample and heat for 2 hours in a reactor (150ºC)
- Measure consumption of , $K_2Cr_2O_7$ and use a colorimetric or a titrimetric method to convert to oxygen equivalent.



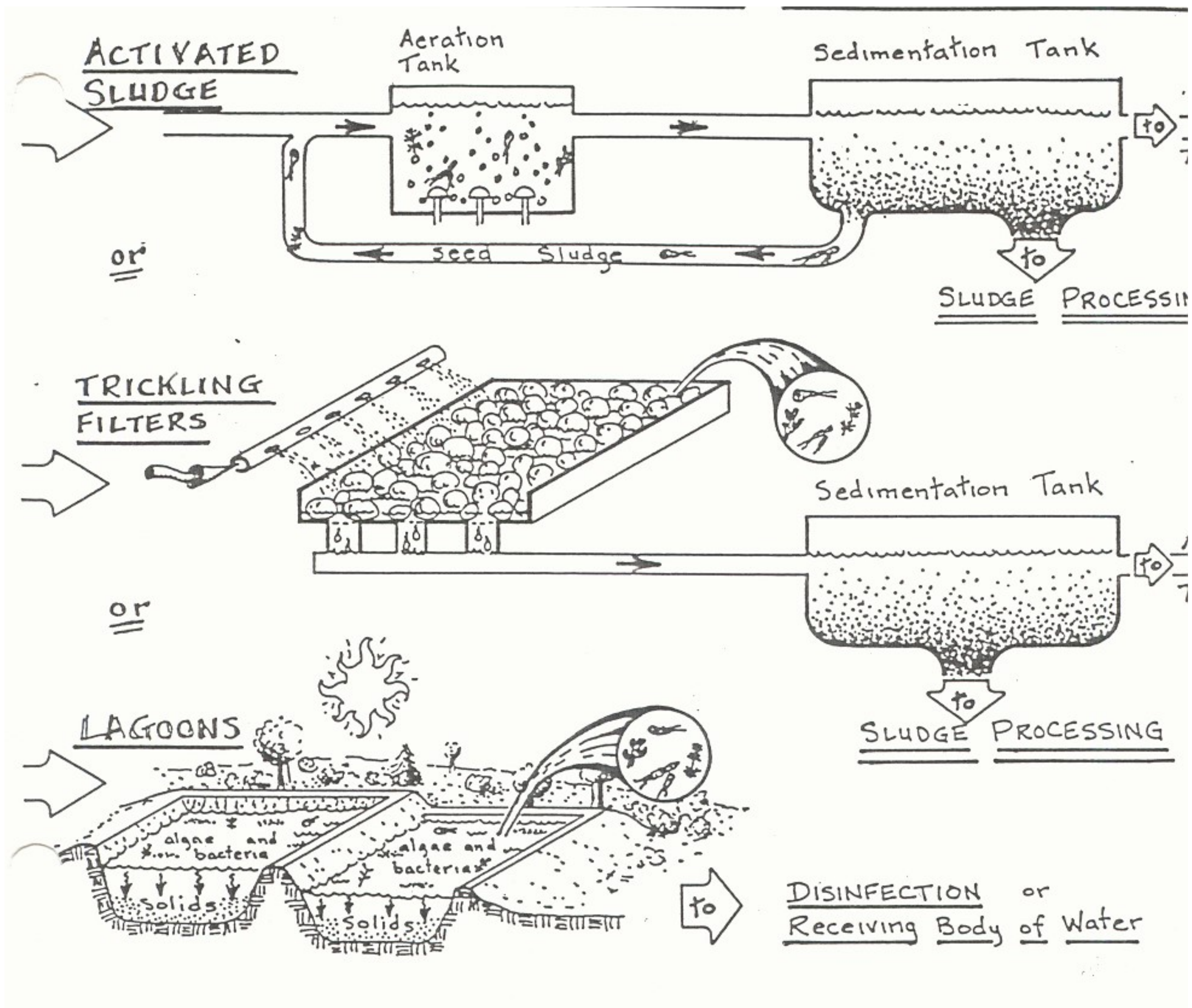


AEROBIC REACTIONS
Polluting compound containing:
Carbon, C
Hydrogen, H
Nitrogen, N
Phosphorous, P
Sulphur, S
Micro Organisms
with Oxygen
without Oxygen
Non-toxic substances
Carbon dioxide, CO_2
Nitrate, NO_3^-
Phosphate, PO_4^{3-}
Sulphate, SO_4^{2-}
Water, H_2O
Toxic substances
Hydrogen Gas, H_2
Methane gas, CH_4
Hydrogen sulphide, H_2S
Ammonia, NH_3
Alcohols
Toxic Organic Compounds
ANAEROBIC REACTIONS

HW

- group assignment (no more than 5/group)
- Due date: ?????????
- Use your computer and your notes to type in a collection of all equations and conversion factors we presented during the entire class. This will prepare you for the final exam.
- You need to email your answer-file to ialyase@gmail.com

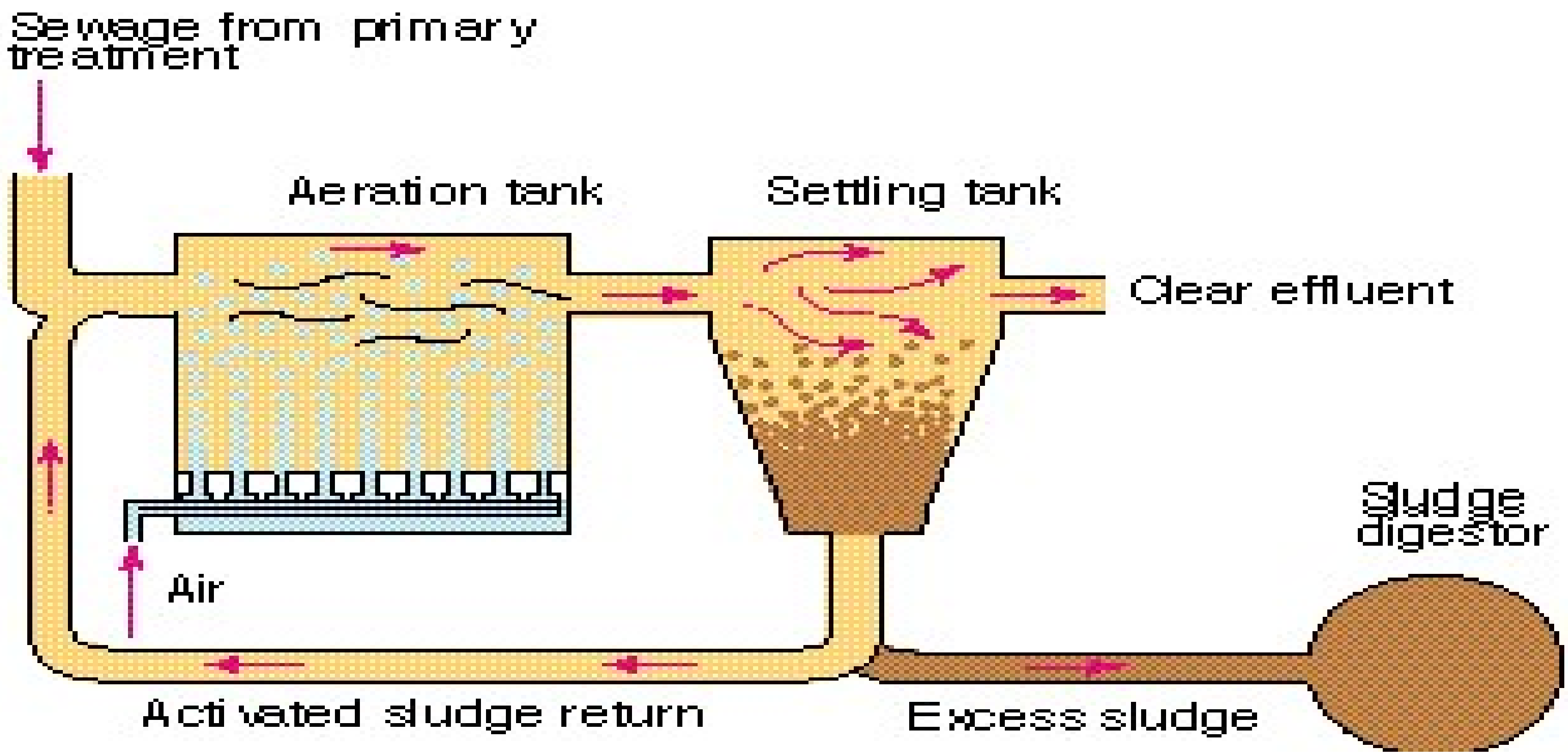
Secondary Treatment



Activated Sludge: Aeration Basin

Activated Sludge (AS)

- Production of an activated mass of microorganisms capable of aerobically stabilizing the organic content of a waste.



Activated Sludge (AS)

- MLSS?
- WAS?
- RAS?
- Substrate?
- Microbial growth?
- F/M ratio?

$$\frac{\text{Food}}{\text{Microorganism}} = \frac{\text{BOD (lb/day)}}{\text{MLVSS (lb)}}$$

$$= \frac{\text{Flow (MGD)} \times \text{BOD (mg/L)} \times 8.34\ \text{lb/gal}}{\text{Vol. (MG)} \times \text{MLVSS (mg/L)} \times 8.34\ \text{lb/gal}}$$

Activated Sludge Terminology

- *Activated sludge*—A floc or solid formed by the microorganisms. It includes organisms, accumulated food materials, and waste products from the aerobic decomposition process.
- *Activated sludge process*—A biological wastewater treatment process in which a mixture or influent and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated mixed liquor by sedimentation and is returned to the process as needed. The treated wastewater overflows the weir of the settling tank in which separation from the sludge takes place.

Activated Sludge Terminology

- *Bulking*—A problem in activated sludge plants that results in poor settleability of sludge particles.
- *Coning*—A condition that may be established in a sludge hopper during sludge withdrawal when part of the sludge moves toward the outlet while the remainder tends to stay in place; development of a cone or channel of moving liquids surrounded by relatively stationary sludge.

Activated Sludge Terminology

- *Dissolved oxygen*—Atmospheric oxygen dissolved in water or wastewater; usually abbreviated as DO.

Note: The typical required DO for a well-operated activated sludge plant is between 2.0 and 2.5 mg/L.

- *Facultative bacteria*—Bacteria that can use molecular (dissolved) oxygen or oxygen obtained from food materials. In other words, facultative bacteria can live under aerobic or anaerobic conditions.
- *Filamentous bacteria*—Organisms that grow in thread or filamentous form.
- *Food-to-microorganism ratio*—A process control calculation used to evaluate the amount of food (BOD or COD) available per pound of mixed liquor volatile suspended solids

Activated Sludge Terminology

- *Mixed liquor*—The contribution of return activated sludge and wastewater (either influent or primary effluent) that flows into the aeration tank.
- *Mixed liquor suspended solids (MLSS)*—The suspended solids concentration of the mixed liquor. Many references use this concentration to represent the amount of organisms in the activated sludge process.
- *Mixed liquor volatile suspended solids (MLVSS)*—The organic matter in the mixed liquor suspended solids; can also be used to represent the amount of organisms in the process.

Activated Sludge Terminology

- *Settleability*—A process control test used to evaluate the settling characteristics of the activated sludge. Readings taken at 30 to 60 min are used to calculate the settled sludge volume (SSV) and the sludge volume index (SVI).
- *Settled sludge volume (SSV)*—The volume (mL/L or percent) occupied by an activated sludge sample after 30 or 60 min of settling. Normally written as SSV with a subscript to indicate the time of the reading used for calculation (e.g., SSV30 or SSV60).
- *Sludge volume index (SVI)*—A process control calculation used to evaluate the settling quality of the activated sludge. Requires the SSV30 and mixed liquor suspended solids test results to calculate:

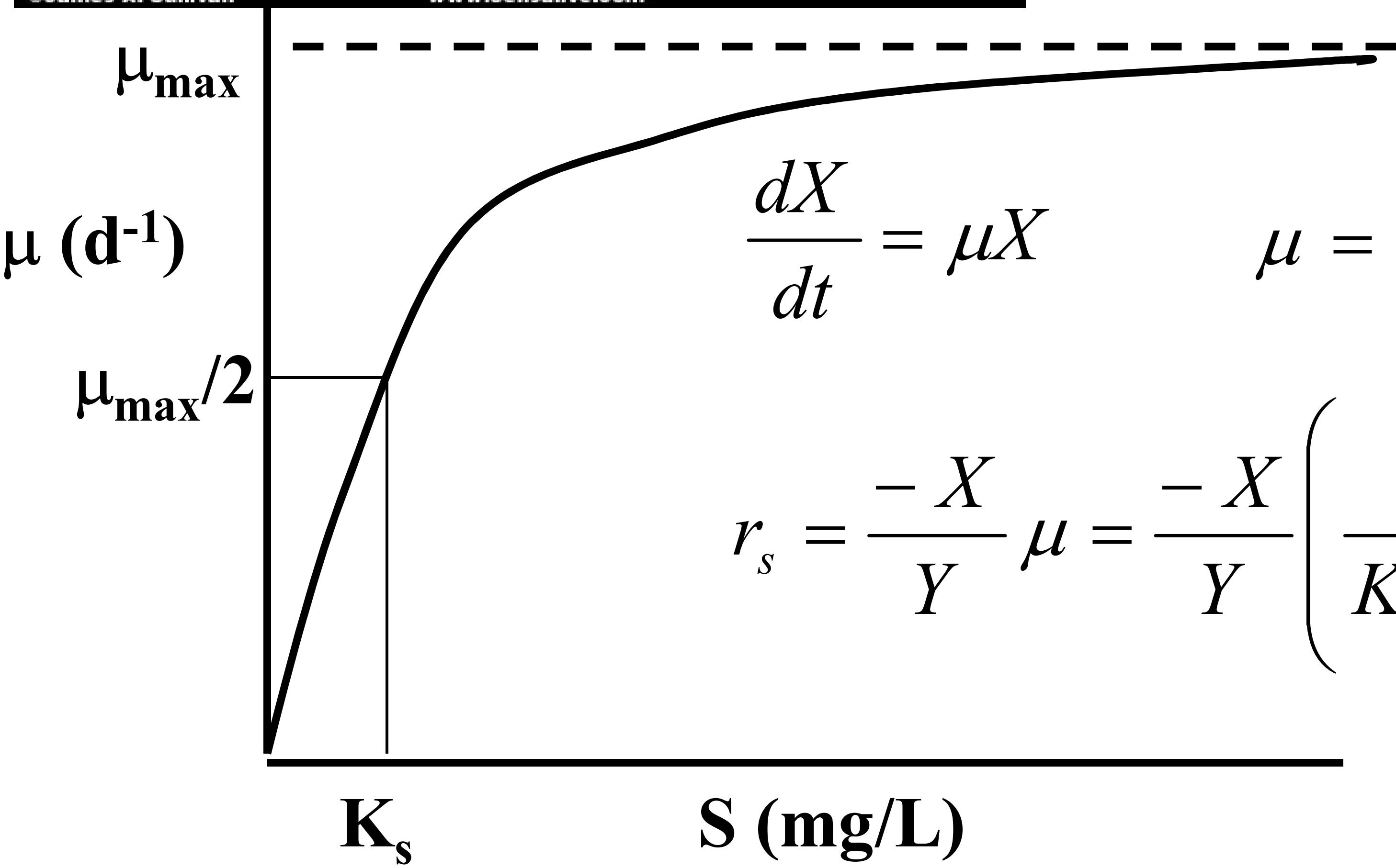
Activated Sludge Terminology

- *Mean cell residence time (MCRT)*—The average length of time particles of mixed liquor suspended solids remain in the activated sludge process; may also be referred to as the *sludge retention rate* (STR)

Aeration Basin Design

Mean cell residence time & hydraulic retention time

Kinetics: Logistic Growth

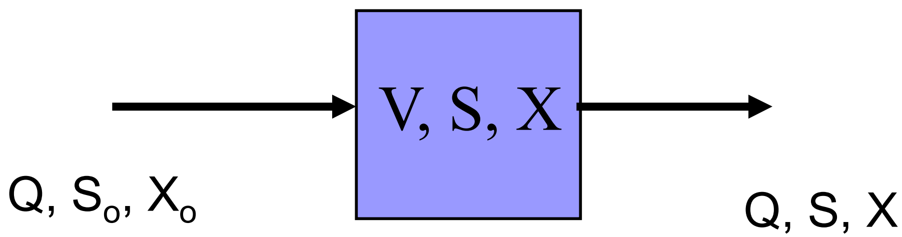


$$\frac{dX}{dt} = \mu X$$

$$\mu = \frac{\hat{\mu}\, S}{K_s + S}$$

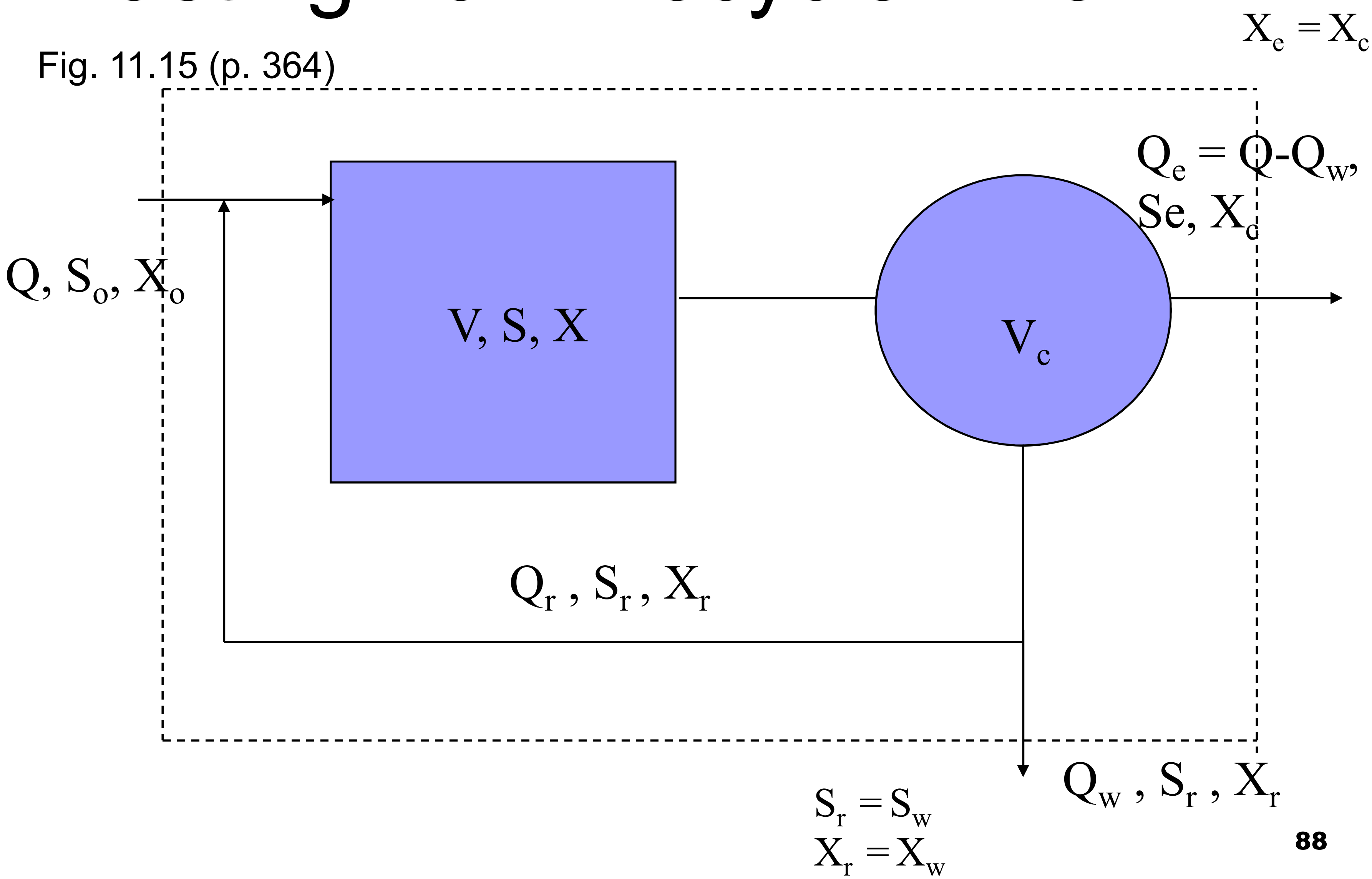
$$r_s = \frac{-X}{Y}\mu = \frac{-X}{Y}\left(\frac{\hat{\mu}\, S}{K_s + S}\right)$$

MCRT from a Reactor without Recycle



Wasting from Recycle Line

Fig. 11.15 (p. 364)



General Equation for Mean Cell Residence Time

Eq. 11.9 (p. 364)

$$\theta_c = \frac{VX}{Q_w X_w + Q_e X_c} \cong \frac{VX}{Q_w X_w}$$

Example

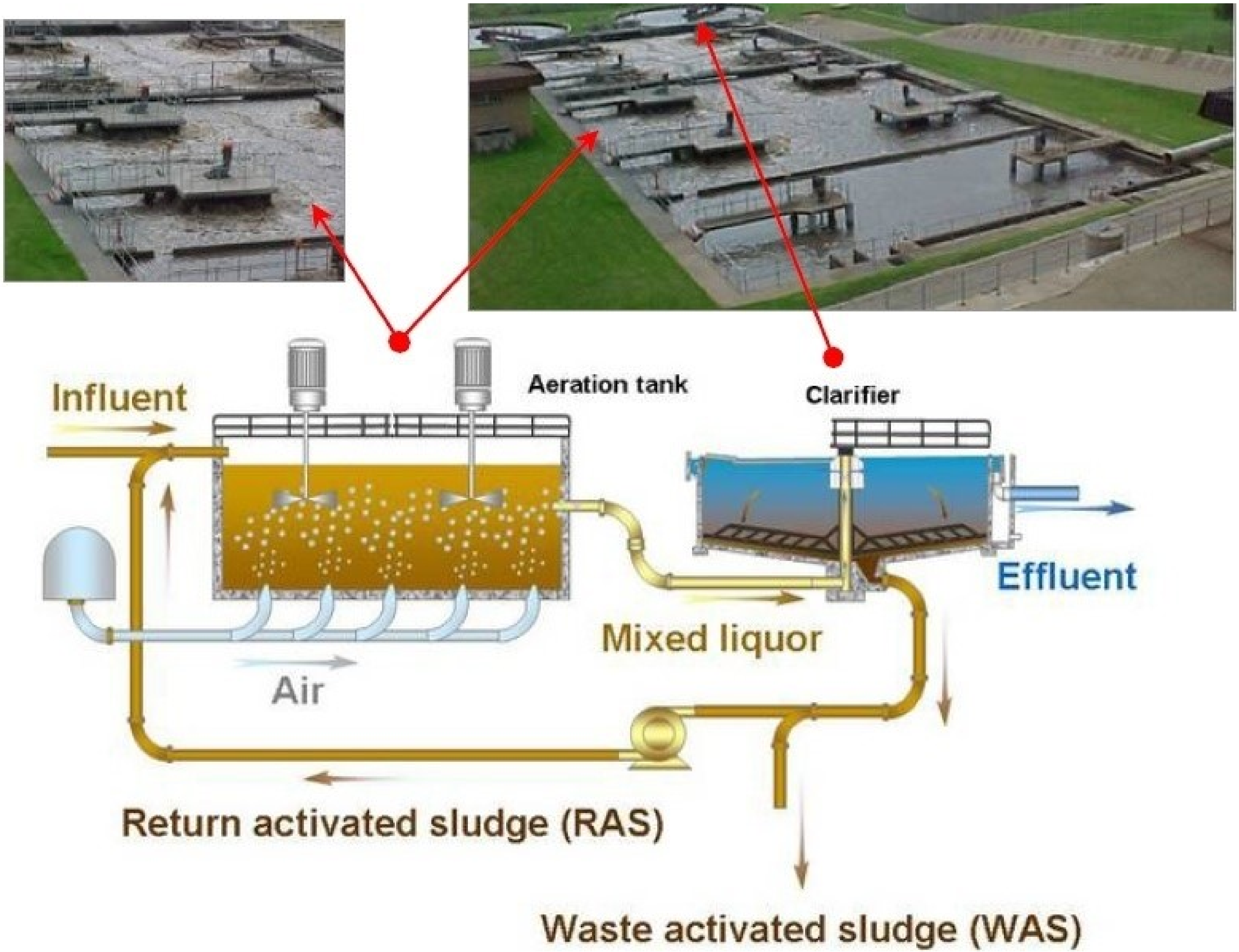
A conventional WWTP receives 2 MGD with an average BOD of 165 mg/L to the aeration basin. The aeration basin is 100,000 ft^3. The MLSS is 2,800 mg/L and the effluent SS is 25 mg/L. The WAS is 38,000 gpd from the recycle line. The SS of the recycle flow is 9,000 mg/L. What is the mean cell residence time?

ACTIVATED SLUDGE FORMATION

- ***Transfer*—**Organic matter (food) is transferred from the water to the organisms. Soluble material is absorbed directly through the cell wall. Particulate and colloidal matter is adsorbed to the cell wall, where it is broken down into simpler soluble forms, then absorbed through the cell wall.
- ***Conversion*—**Food matter is converted to cell matter by synthesis and oxidation into end products such as CO2, H2O, NH3, stable organic waste, and new cells.
- ***Flocculation*—**Flocculation is the gathering of fine particles into larger particles. This process begins in the aeration tank and is the basic mechanism for removal of suspended matter in the final clarifier. The concentrated *biofloc* that settles and forms the sludge blanket in the secondary clarifier is known as activated sludge.

Efficient System

- Proper balance must be maintained among the amounts of food (organic matter), organisms (activated sludge), and oxygen (dissolved oxygen)
- Process requires sufficient alkalinity to ensure that the pH remains in the acceptable range of 6.5 to 9.0
- If organic nitrogen and ammonia are being converted to nitrate (nitrification), sufficient alkalinity must be available to support this process



Aeration tank
Clarifier
Influent
Effluent
Mixed liquor
Air
Return activated sludge (RAS)
Waste activated sludge (WAS)

Secondary Clarifier

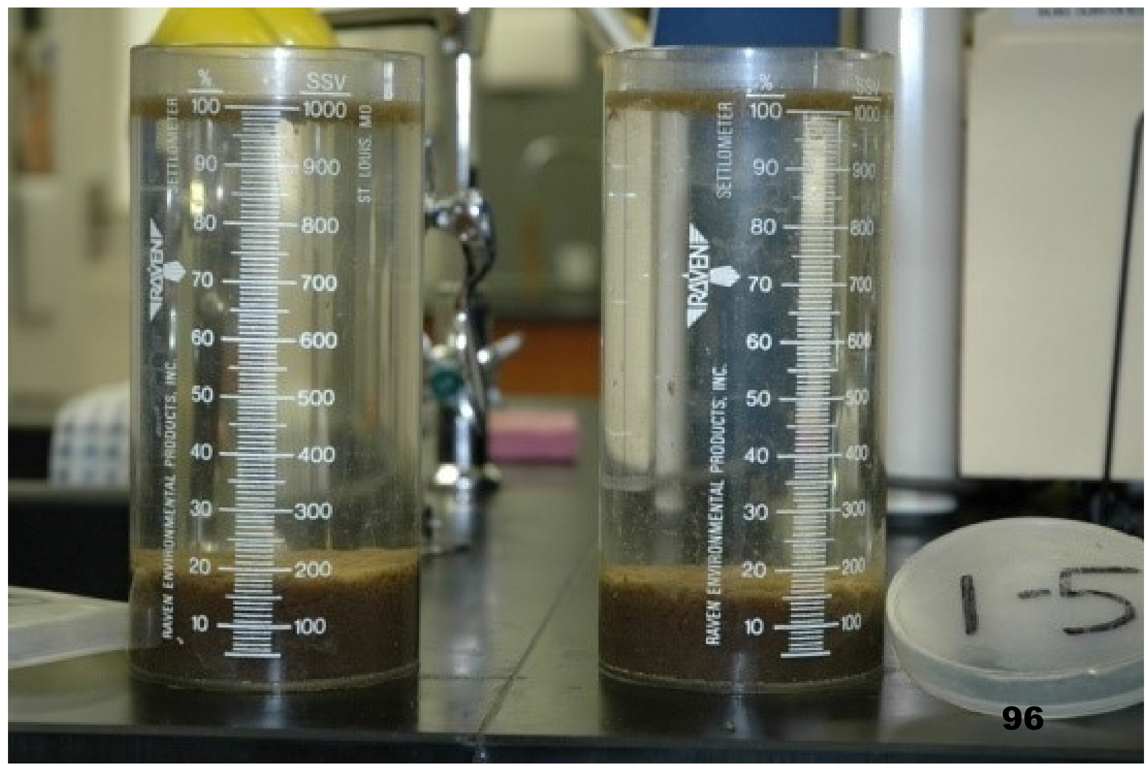
Secondary Clarifier

- A WWTP is to treat 2 MGD of wastewater using activated sludge. Five sets of aeration tank followed be secondary clarifier to be used of which four of them to be working at any time. The MLSS is 2500 mg/L. The solids loading rate to each clarifier is 40 $lb/d.ft^2$. and the cross section area is 280 ft^2. what is the flow rate of activated sludge need to be returned from the recycling line?

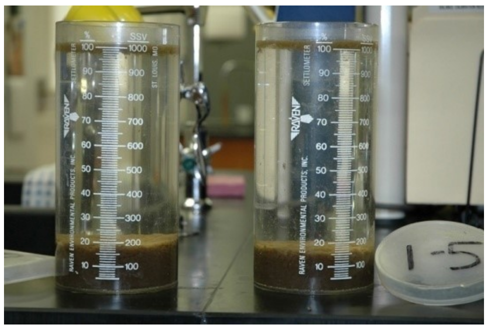
Sludge Volume Index (SVI)

$$SVI = \frac{volume - of - sludge - settled, (mL/L)}{MLSS(mg/L) * (g/1000mg)}$$

- Settling test



Sludge Volume Index (SVI)



- Estimated using settling test
- SVI of 60 to 120 mL/g is desired
- SVI < 100 mL/g ok.
- SVI > 150 mL/g → bulking and difficult to settle due to the presence of filamentous organisms that form lattice structure

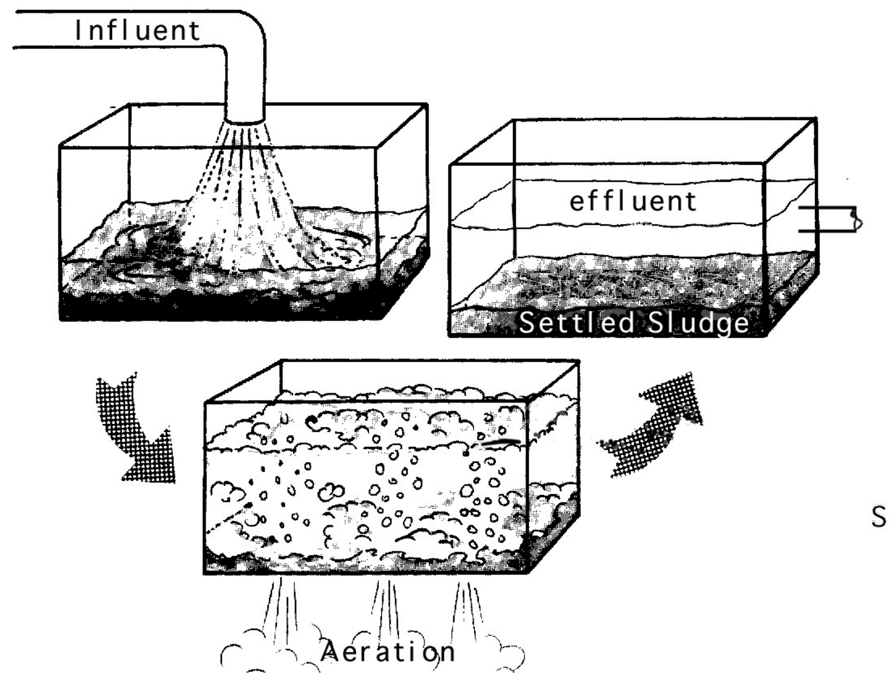
Temperature Effect

- As temperature decreases, activity of the organisms will also decrease.
- Cold temperatures also require longer recovery times for systems that have been upset.
- Warm temperatures tend to favor denitrification and filamentous growth.

Other Secondary Treatment Options

Sequencing Batch Reactor (SBR)

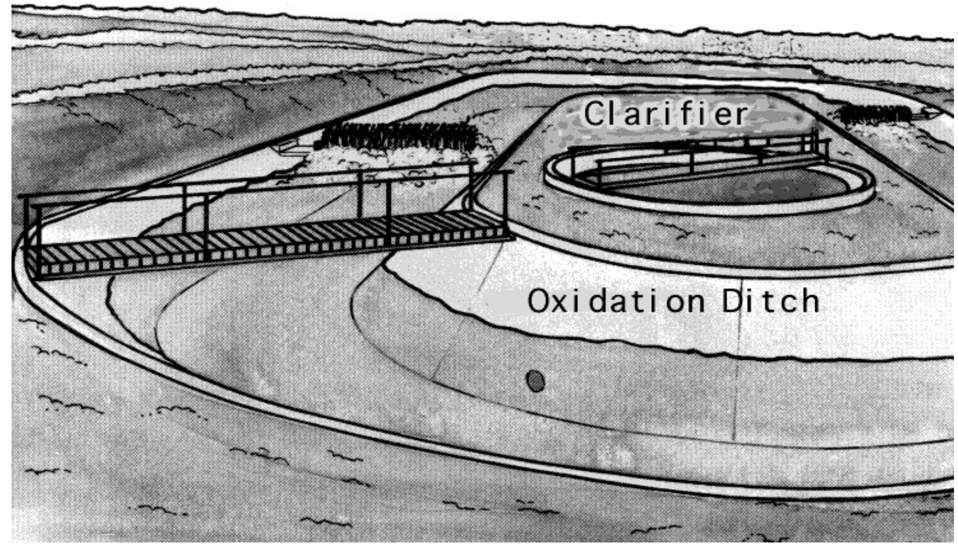
- Fill and draw reactor with complete mixing
- Aeration and clarification in the same tank
- 5 steps
- No RAS system
- Low capitol cost
- Moderate O&M requirment



Aerated Lagoons

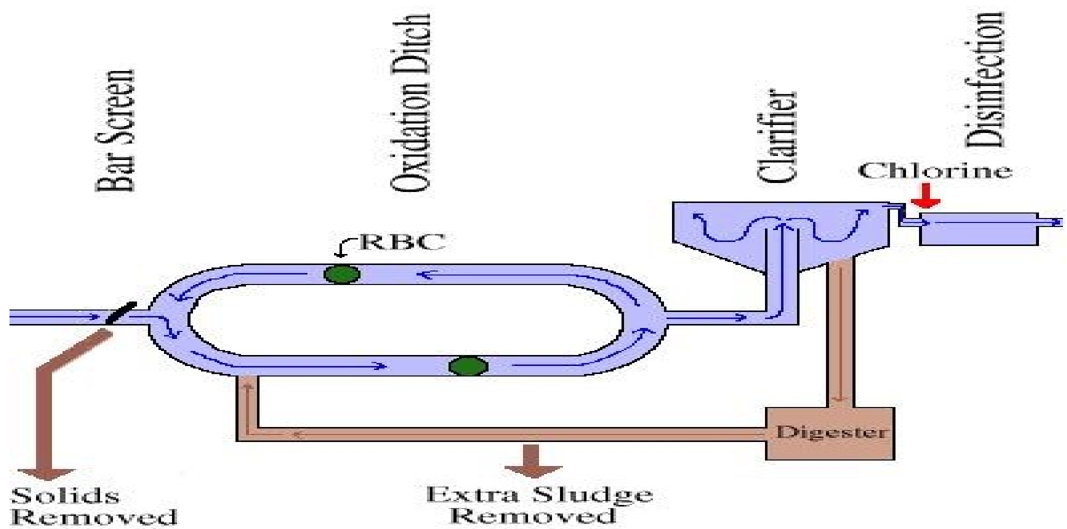
- Shallow earthen basin (2-5 meter depth)
- Mechanical aerators to provide oxygen for bio-treatment
- Types:
- ➢ Facultative partially mixed lagoon
- ➢ Aerobic lagoon with solids recycle

Oxidation Ditch



- Mechanical, activated sludge process
- Circular ditch through which wastewater flows
- No aeration basin
- Typically used for flows greater than 50,000 gpd
- Requires skilled operator
- Higher energy costs
- High maintenance

Oxidation Ditch

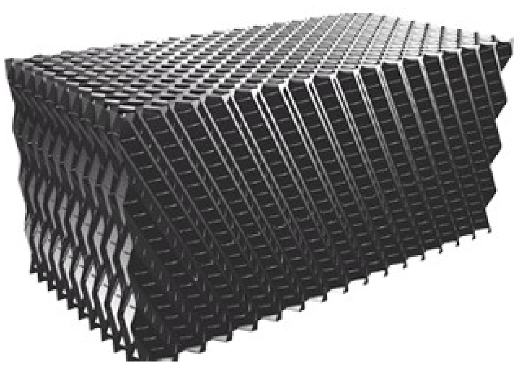


Source: http://water.me.vccs.edu/concepts/oxidation.html

Source: http://www.mgconsulting.me/

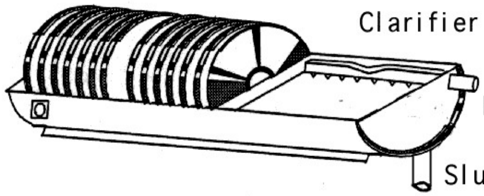
Trickling

- Tricking wastewater over a media
- Microorganisms on media obtain food from waste dripping over by rotating arm
- Generally, aerobic with nitrification
- No sludge recycling
- Problems: ponding, odor, and flies

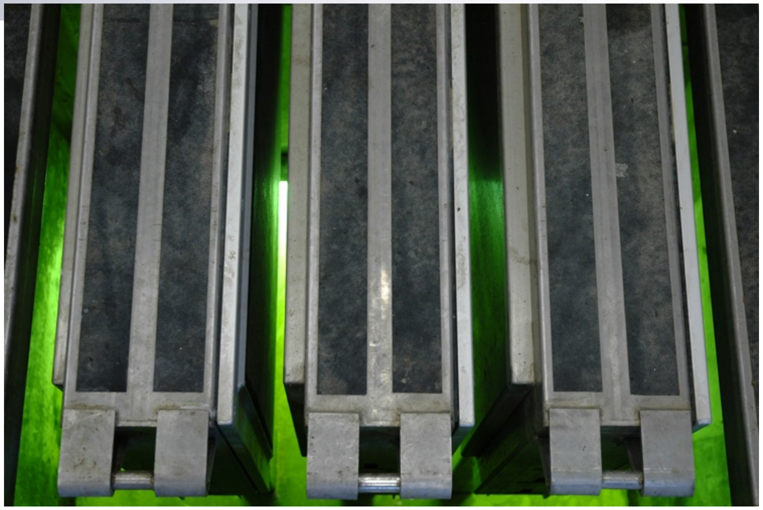


Rotating Biological Contactors

- Partially submerged disks (40%)
- Design based on pilot studies to determine the removal rates and oxygen requirements
- Typical
  - Diameter 10-12 ft
  - Rotational speed around 1.5 rpm
- advantage over TF: no hydraulic head loss
- multiple identical units in stages
- enclosed to prevent freezing



DISINFECTION
Section 11.3.6



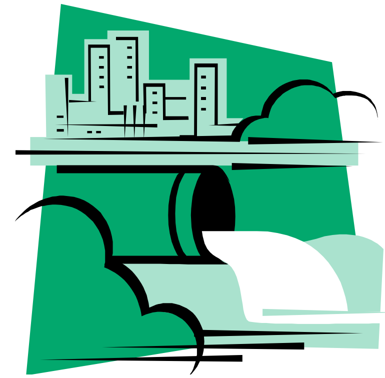
UV Generator and Lamps

- Chlorine, ozone or UV
- For chlorine:
  - Same way to decide the concentration but no residual
  - Plug-flow-reactor
  - May use Na sulfite for de-chlorination

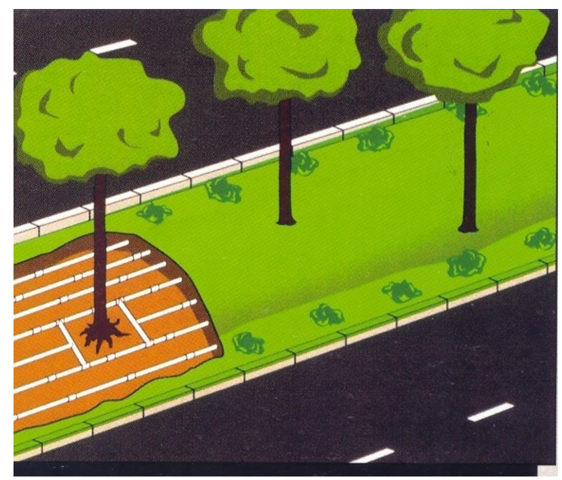
Chlorine Contact Basin

Section 11.4

TERTIARY TREATMENT



- N removal
- P removal
- Filtration
- oxidation ponds



Wetlands


Chisholm Street
Eylandt Street
Forebay
Micropool
Zone A — El. 15.0'–15.5'
Shallow marsh
Zone B — El. 15.0'–16.0'
Wet meadow
Zone C — El. 16.0'–18.0' (Extended detention)
Shrubs/herbaceous wetland
Zone D — El. 16.0'–18.0' (Extended detention)
Shrubs/herbaceous wetland at forebay
Zone E — El. 18.0'– 21.0' and above
Wetland forest
Zone F — El. 21.0' and above
Protected upland forest
Zone G — El. 21.0' and above
Upland forest
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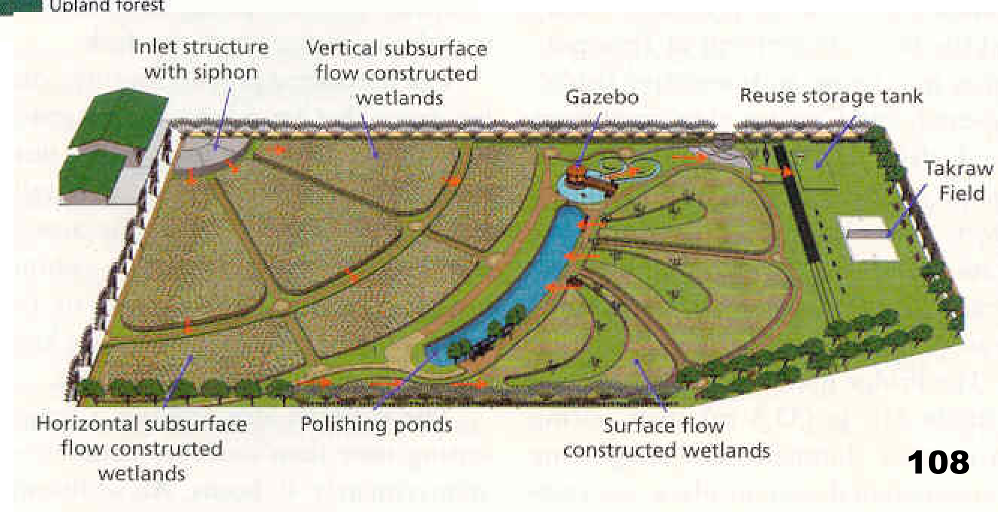
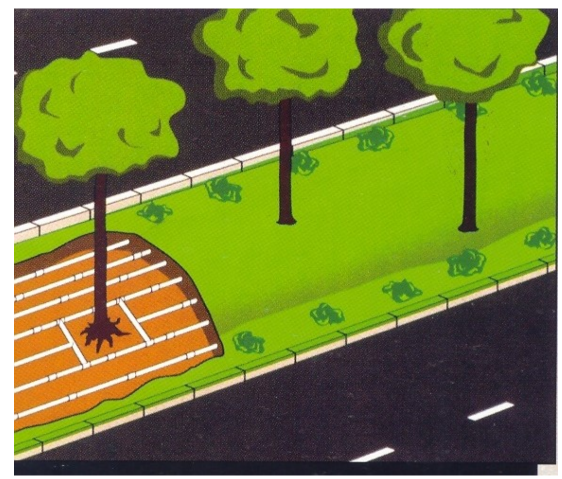
Civil Engineering FEBRUARY 2003


Inlet structure
with siphon
Vertical subsurface
flow constructed
wetlands
Gazebo
Reuse storage tank
Takraw
Field
Horizontal subsurface
flow constructed
wetlands
Polishing ponds
Surface flow
constructed wetlands

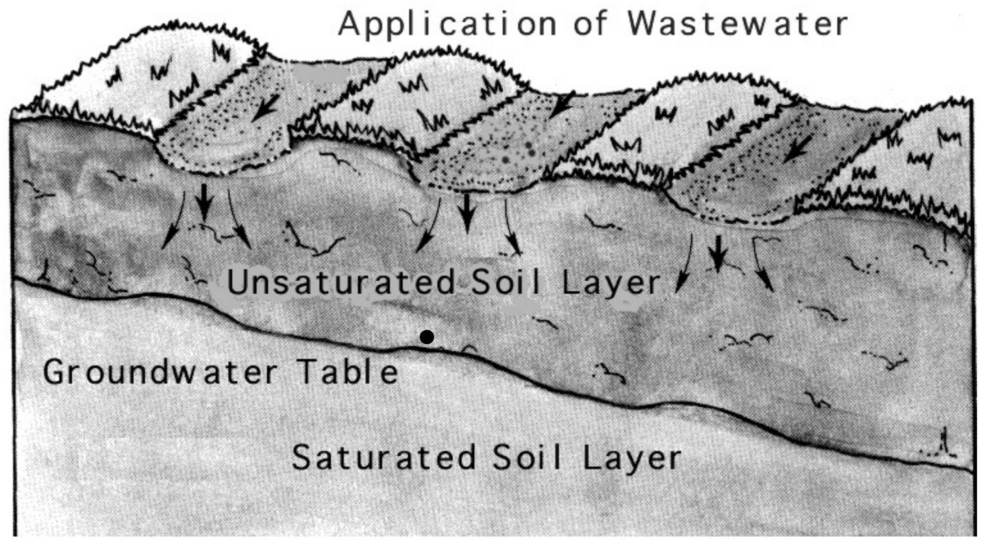
EFFLUENT DISCHARGE

- Reuse
  - Irrigation
  - Industry
  - Groundwater recharge
  - Non-potable urban use
- Disposal
  - Natural evaporation
  - Outfall to surface water



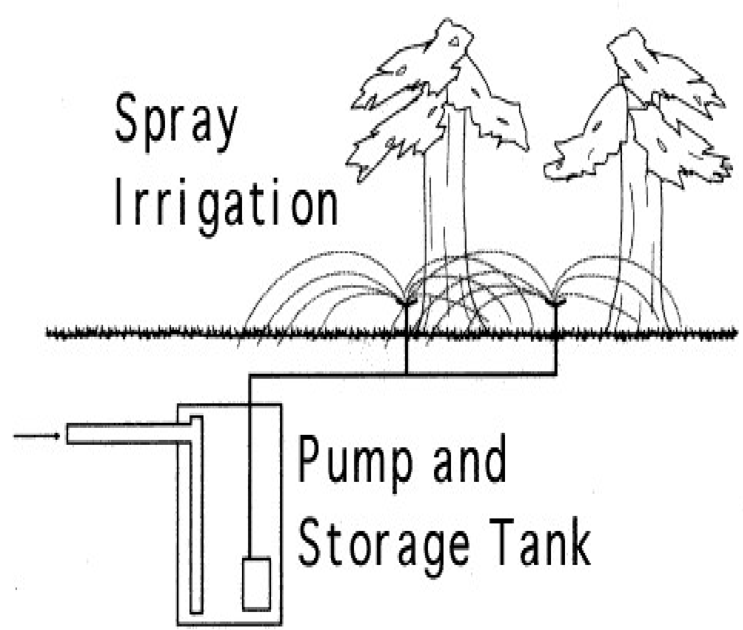
Rapid Infiltration

- Land-based treatment / disposal method
- Designed for a repetitive cycle of flooding, infiltration / percolation, and drying
- Recharges groundwater
- Recommended as a disposal method
- Use is limited to suitability of the site



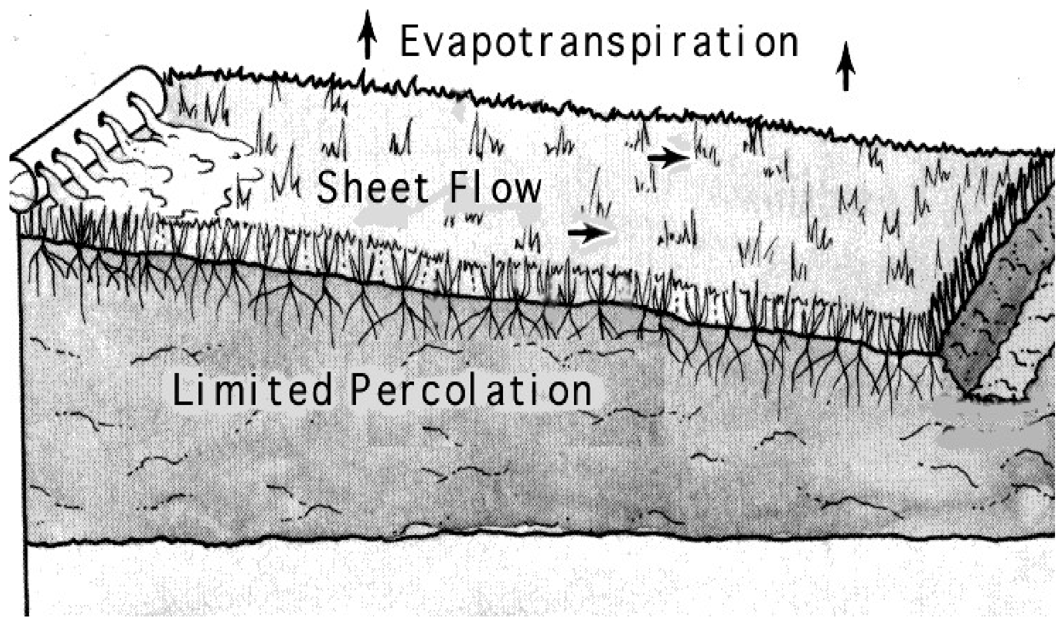
Slow-Rate Land Application

- Considered as a treatment and disposal method
- Wastewater must receive prior treatment
- Application is made at slow rates to prevent runoff
- Relies on percolation and evapotranspiration
- Proper siting is critical
- Low O&M
- Beneficial reuse



Overland Flow

- Effective land-based treatment process with a point-source discharge
- Primary treatment of wastewater is required
- Relatively low capital and O&M costs
- Requires attention to operation

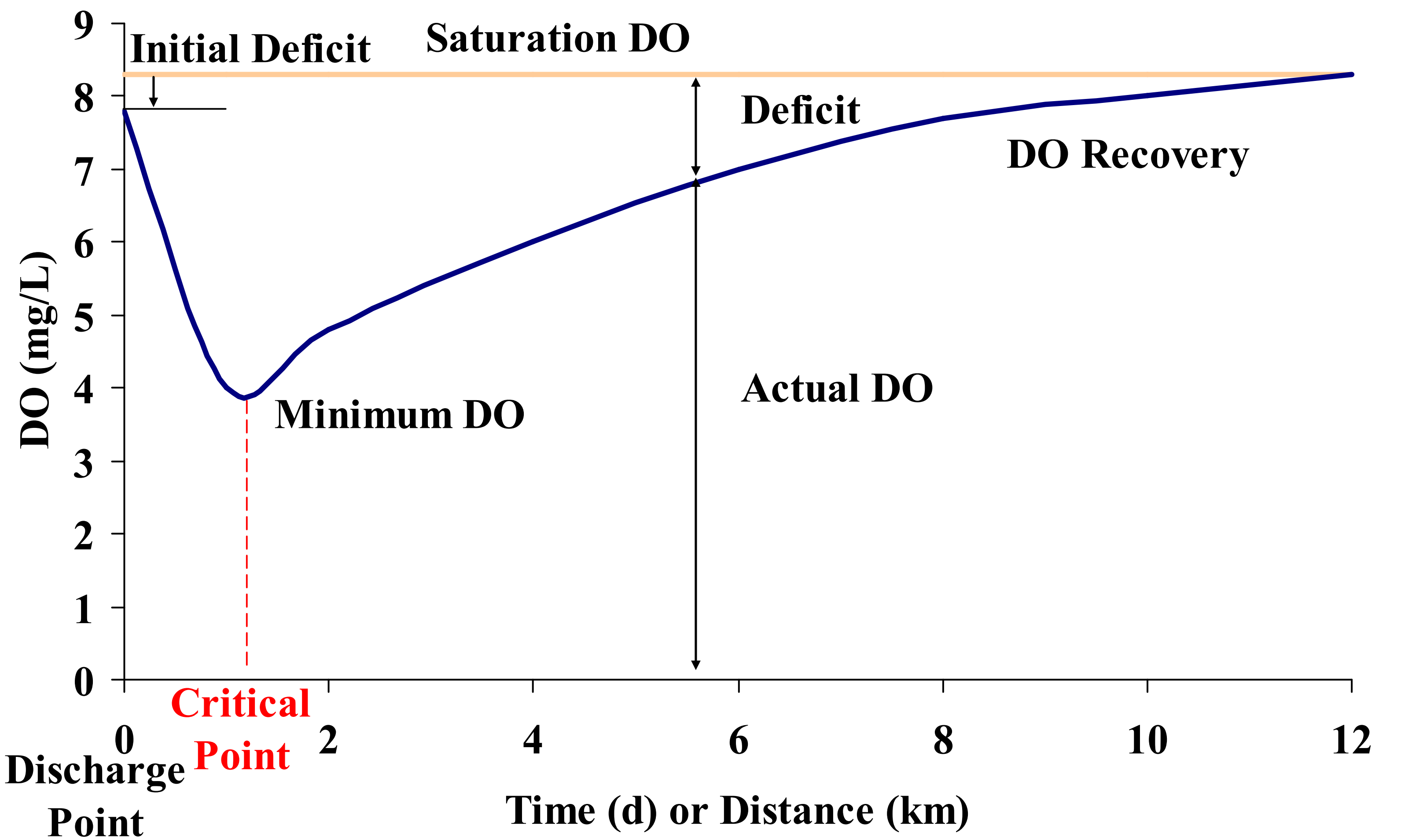


Discharge to a Stream

Effects:

- Nitrogen species
- Biodiversity
- DO

Discharge to a Stream: DO



Streeter-Phelps Model

Eq. 8.2 (p. 228)

$$D = \frac{k_1 L_o}{k_2 - k_1}\left(e^{-k_1 t} - e^{-k_2 t}\right) + D_o e^{-k_2 t}$$

- ***D***: *Deficit at any time t*
- ***Lo*: *Ultimate BOD at the mixing point***

D_o: *Initial deficit at the mixing point (immediately below the discharge location)*

where D = oxygen deficit

= DO_{sat} - DO_{actual}

Critical Point

Eq. 8.3 (p. 228)

Obtain from dD/dt = 0:

$$t_{crit} = \frac{1}{k_2 - k_1} ln\left[\frac{k_2}{k_1}\left(1 - \frac{D_o(k_2 - k_1)}{k_1 L_o}\right)\right]$$

$$x_{crit} = ut_{crit}$$

u : Stream velocity
$t_{critical}$: Time to critical point
$x_{critical}$: Distance to critical point

Example 1

- A stream with a velocity of 0.5 m/s, de-oxygenating rate of 0.2/day, and re-oxygenation rate of 0.3/day. The ultimate BOD in the discharge point is 30 mg/L. The stream is in a saturation level before outfall with a temperature of 20ºC. What is the dissolved oxygen 5 km downstream?

Example 2

- A waste stream has a flow rate of 0.5 m^3/s, dissolved oxygen of 2.5 mg/L, ultimate BOD of 48 mg/L and temperature of 20ºC is discharging to a water stream with a flow rate of 2 m^3/s, deoxygenating rate of 0.2/day and re-oxygenation rate of 0.3/day. The ultimate BOD in water steam is 15 mg/L. If the water stream was in saturation level before outfall with temperature of 10ºC, what is the concentration of dissolved oxygen one day downstream?
- If the stream has a velocity of 0.85 m/s, how far is the critical point from the discharge point? Is there any problem with dissolved oxygen at the critical point?

Evaluation of Model

- Very simple to use
- But not like nature
  - Assumes steady state
  - Assumes a single discharge
  - Assumes no upstream dispersion
  - Assumes complete mixing
  - Assumes all the BOD is soluble
  - Doesn’t include scouring
  - Doesn’t include DO from algae

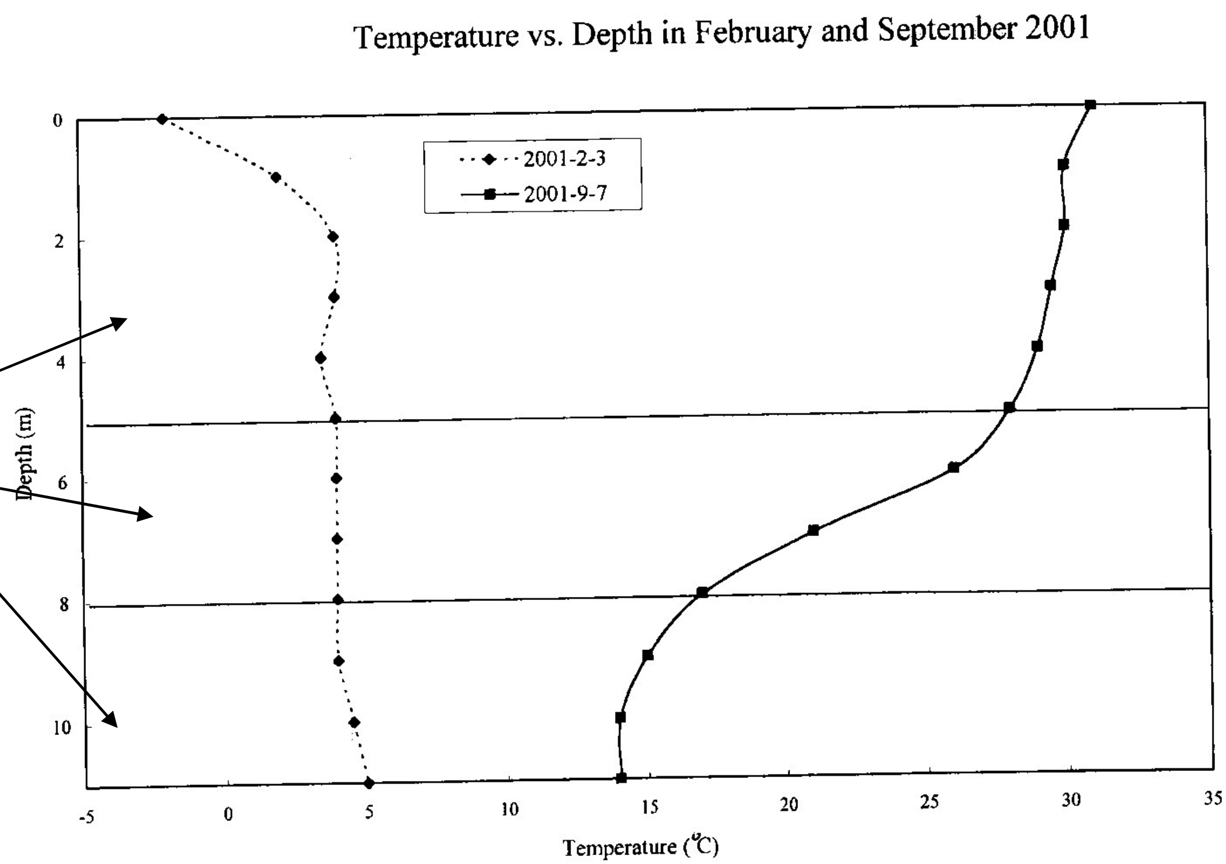
Discharge to a Lake

Fig. 8.8 (p. 223)

(Section 8.2.2)

Cougar Lake

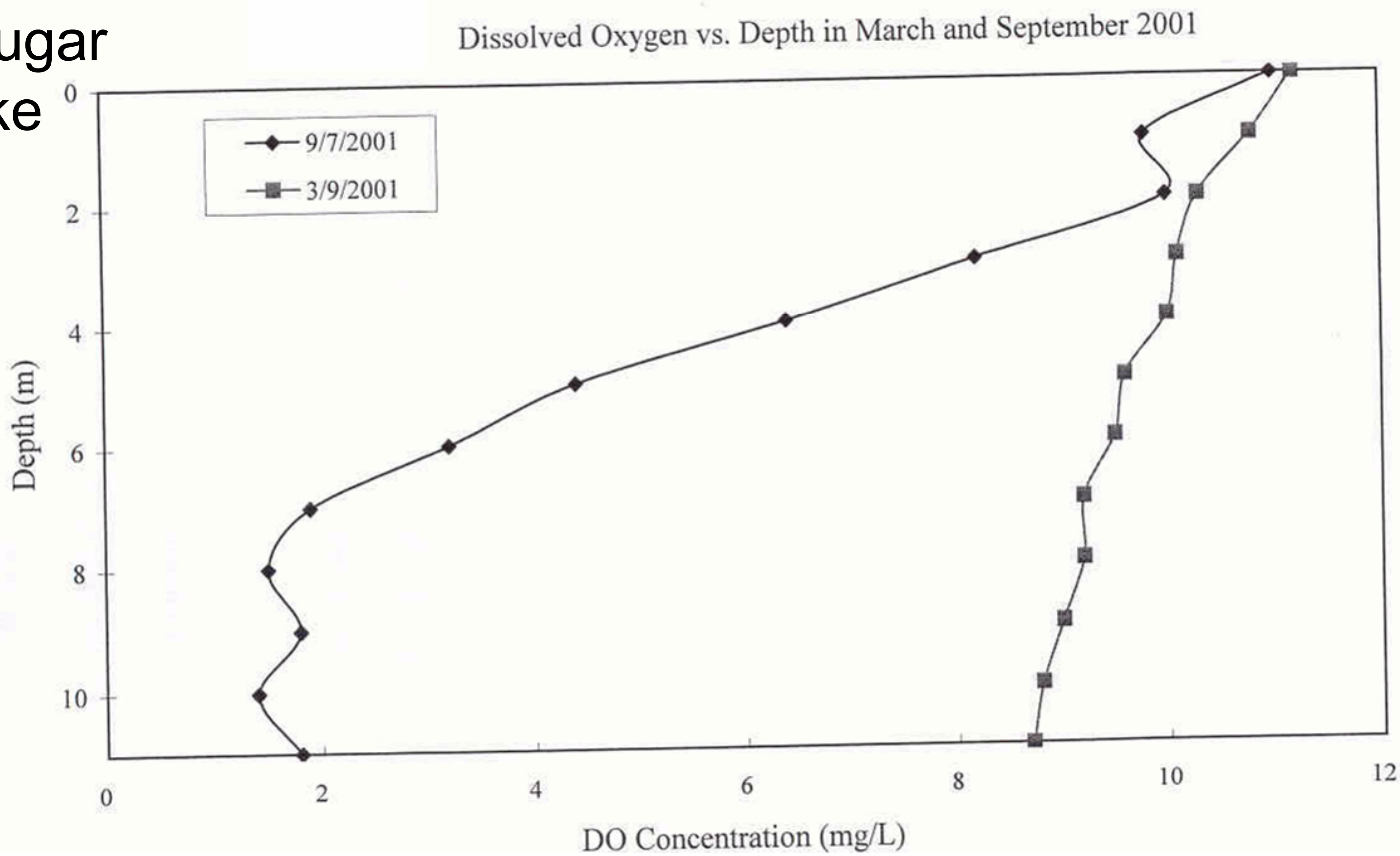
epilimnion
metalimnion
hypolimnion



Effect on a Lake

Fig. 8.7 (p. 221)

Cougar Lake



Section 11.5

SLUDGE MANAGEMENT

Purpose

- Reduce/inactivate pathogens
- Increase solids content
- Reduce odor & putrescence

Sludge Disposal

- How can we get rid of the sludge???
- How do we choose the best option?
- **Processes:**

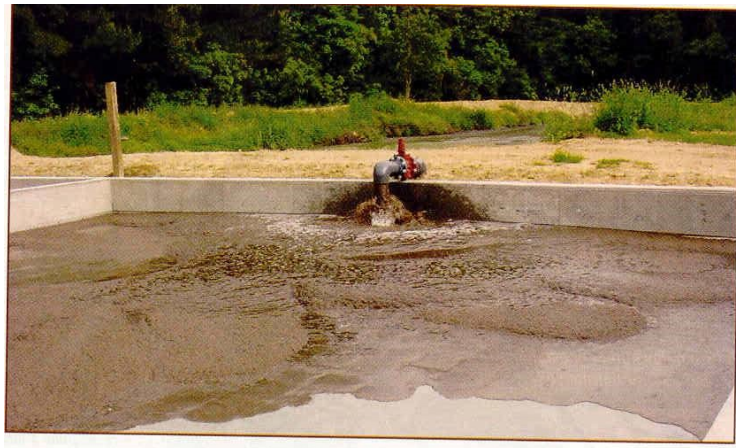
Physical
- Gravity thickening
- Mechanical dewatering
- Drying bed
- Centrifuge

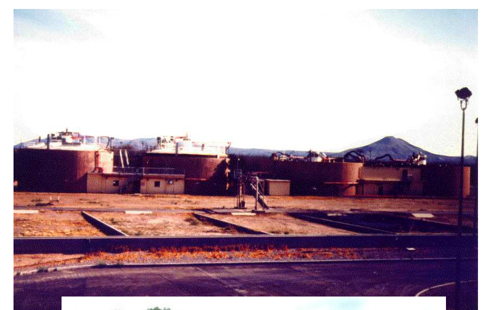
Biological
- Lagooning
- Composting
- digestion

Chemical
- Lime addition

Disposal
- Landfill
- Incineration
- Land application
- Fertilizer or soil amendment

Sludge Treatment





Treatment Train Options

Preliminary Operation

- Storage
- Grinding
- Blending

Thickening

- Gravity
- Flotation
- Centrifuge
- Gravity belt
- Rotary drum

Stabilization

- Lime stabilization
- Anaerobic digestion
- Aerobic digestion

Conditioning

- Chemical
- Other

Dewatering

- Centrifuge
- Belt-filter press
- Filter press
- Drying beds
- Lagoon

Heat drying and other processing

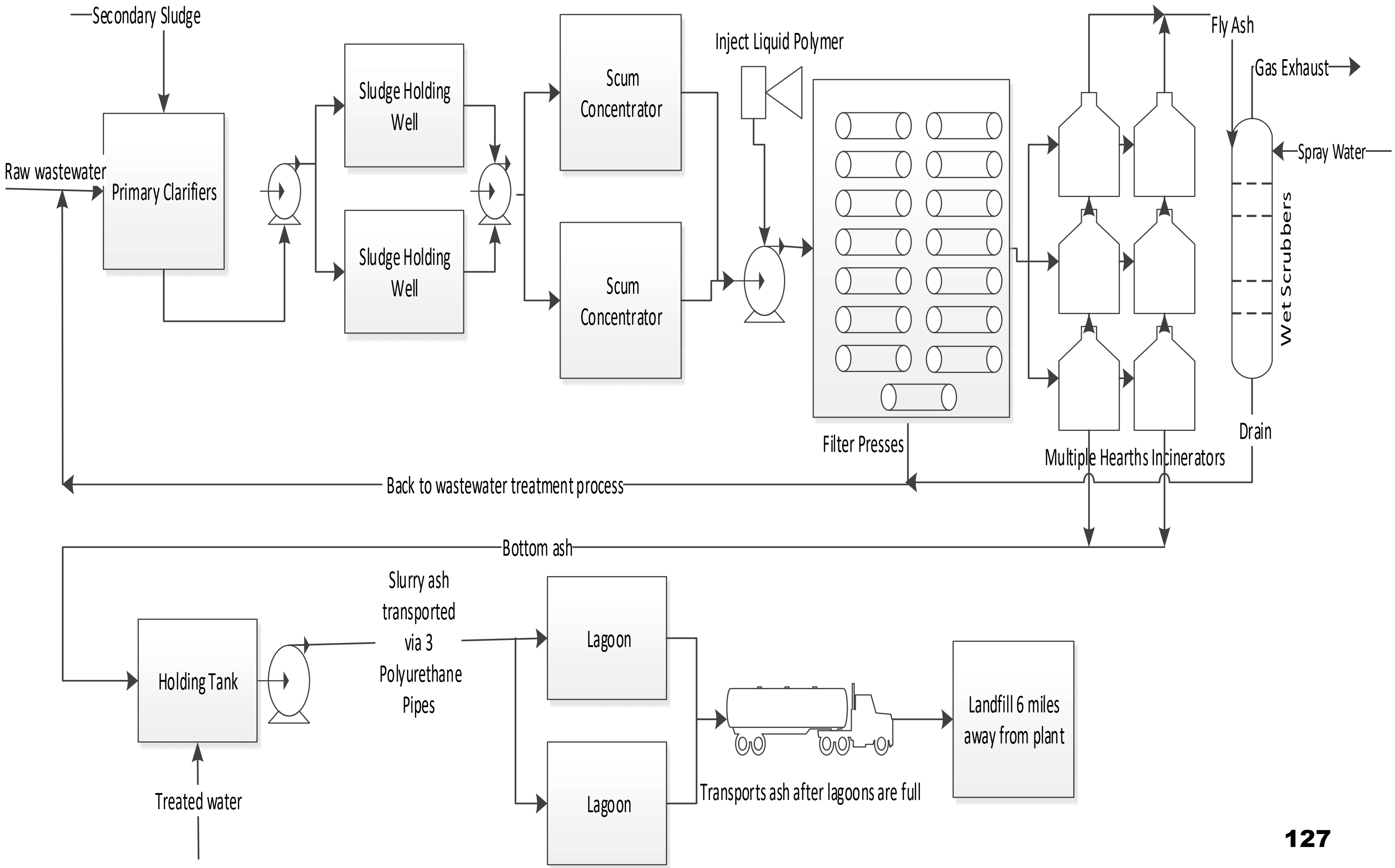
- Direct dryer
- Indirect dryer
- Composting
- Alkaline stabilization/pasteurization

Thermal reduction

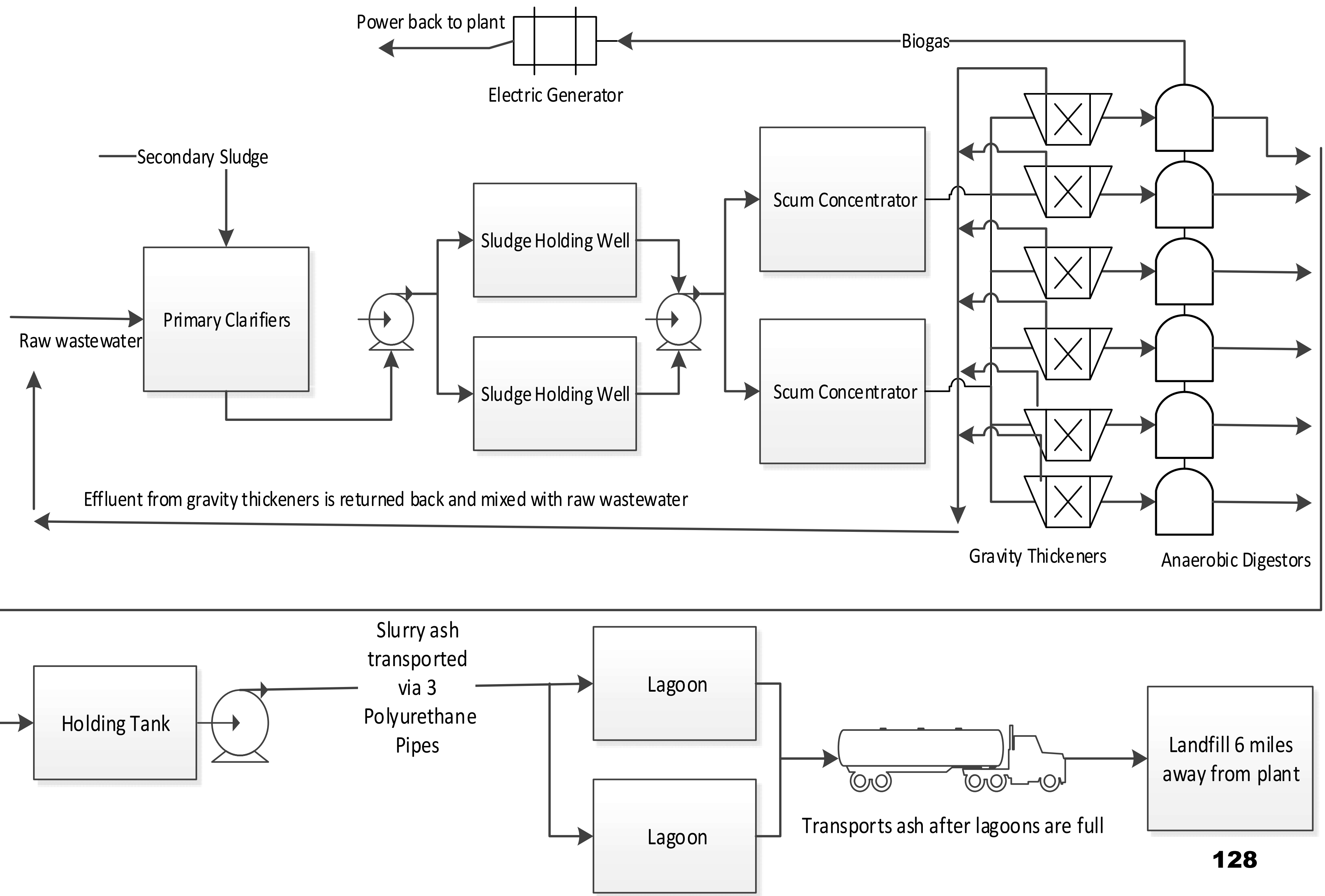
- Mono incineration
- Co-incinerator

Sludge stabilization train prior to reuse or disposal

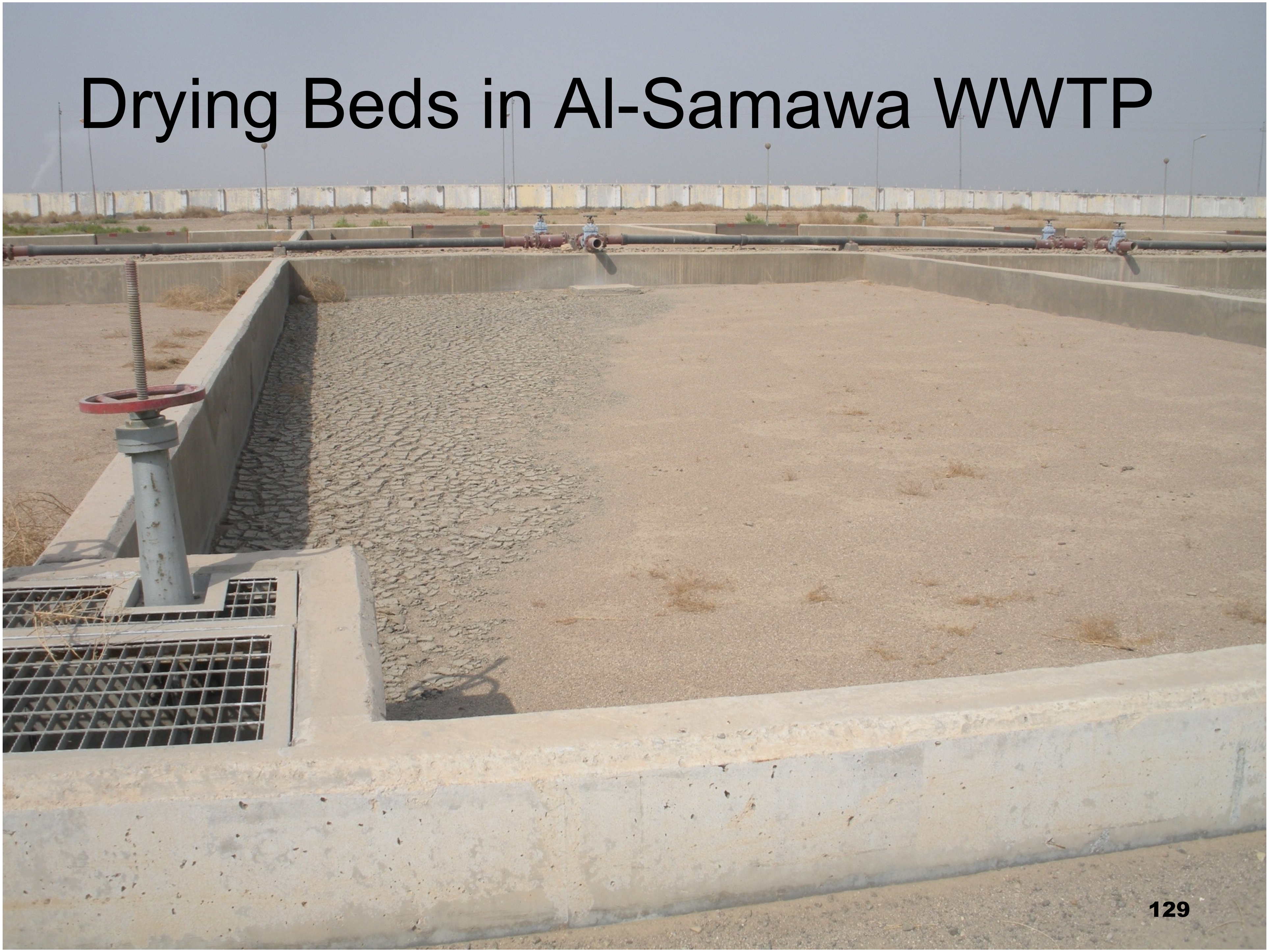
Existing sludge treatment train for Bissell Point WWTP



Proposed sludge treatment train for Bissell Point WWTP



Drying Beds in Al-Samawa WWTP



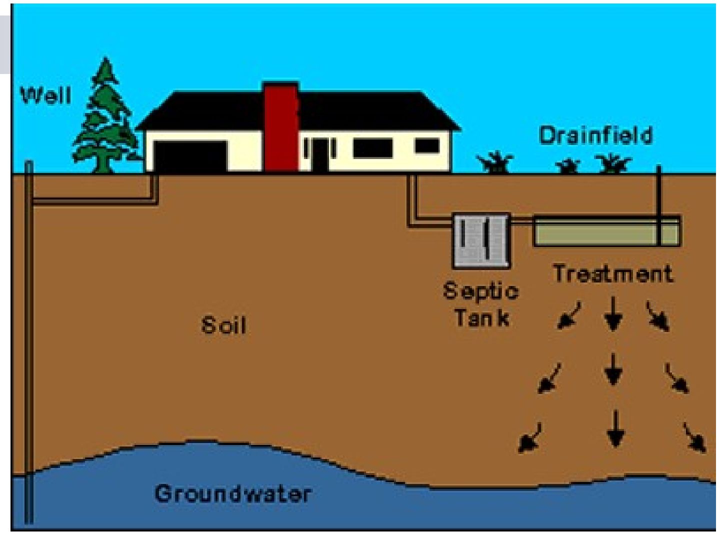
VOC Analyzer

- VOC emissions and odors
  - Health concerns
  - Air quality concerns
- Energy conservation
  - Power consumption
- Methane as fuel source

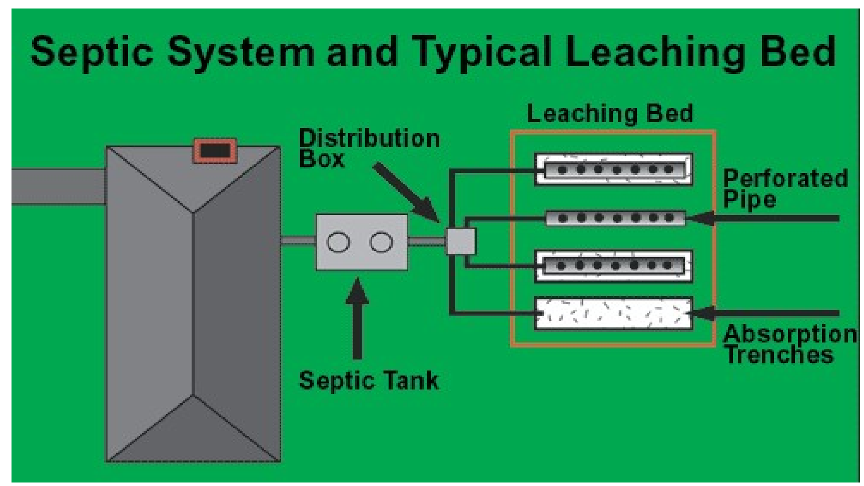
OTHER DESIGN ISSUES

ONSITE TREATMENT

Conventional Septic System

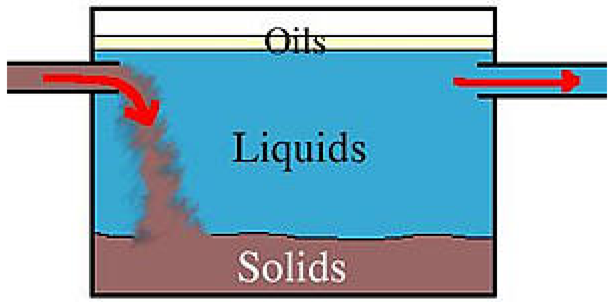


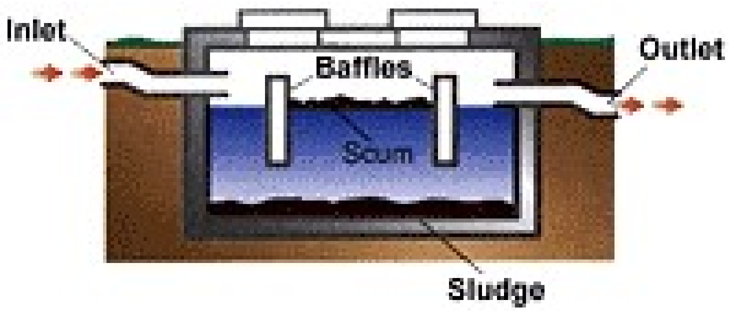
- Based on anaerobic digestion
- sized to retain the daily sewage flow for a minimum of two days.
- Pump every 3-5 years
- Disposal
  - Land application
  - Co-treatment at WWTP
  - Co-disposal with solid wastes (landfill or incineration)



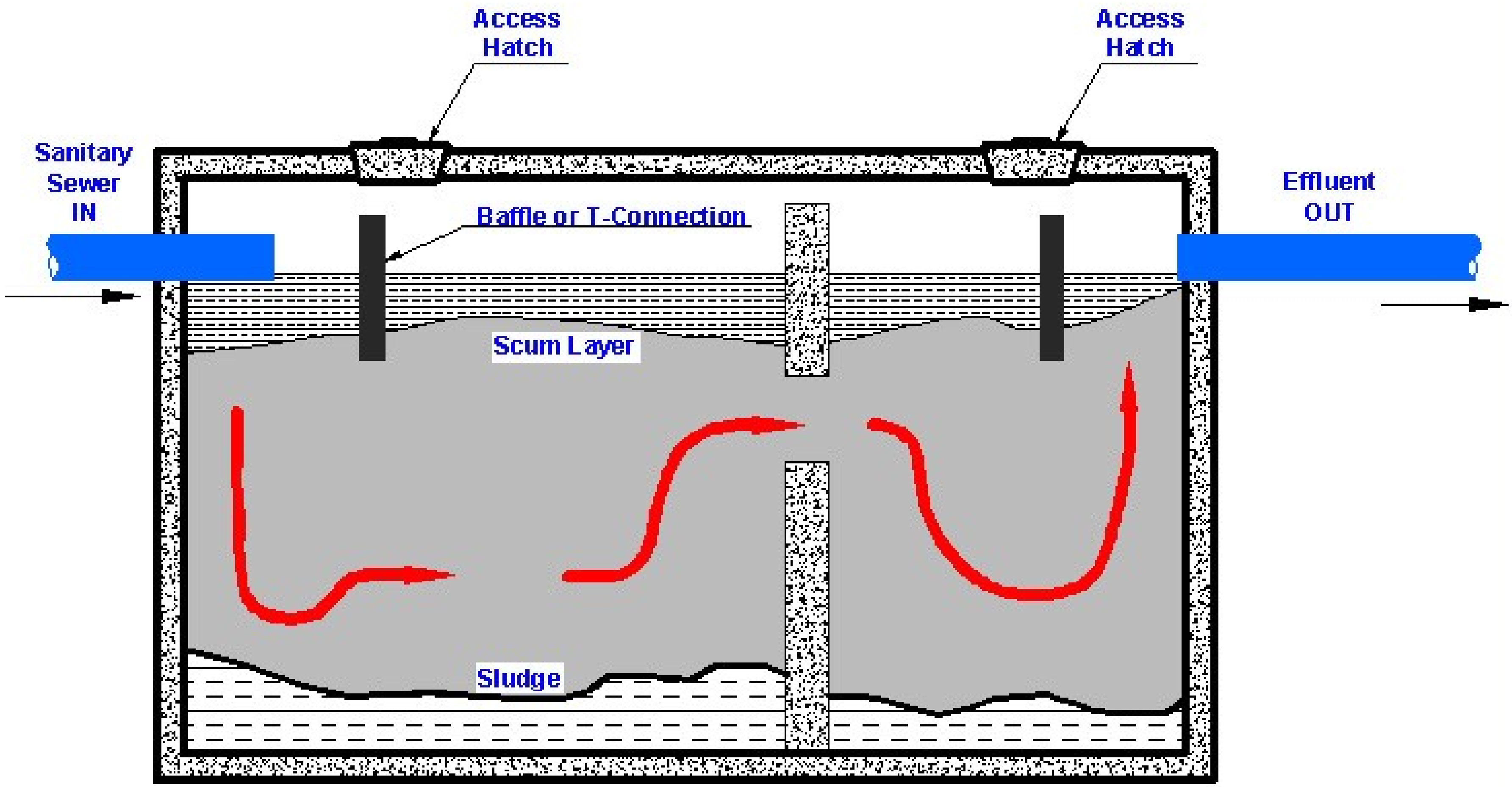
Anaerobic Septic Tank

- **Prefabricated tanks**
- **Combined settling, skimming, anaerobic digester, and sludge storage**

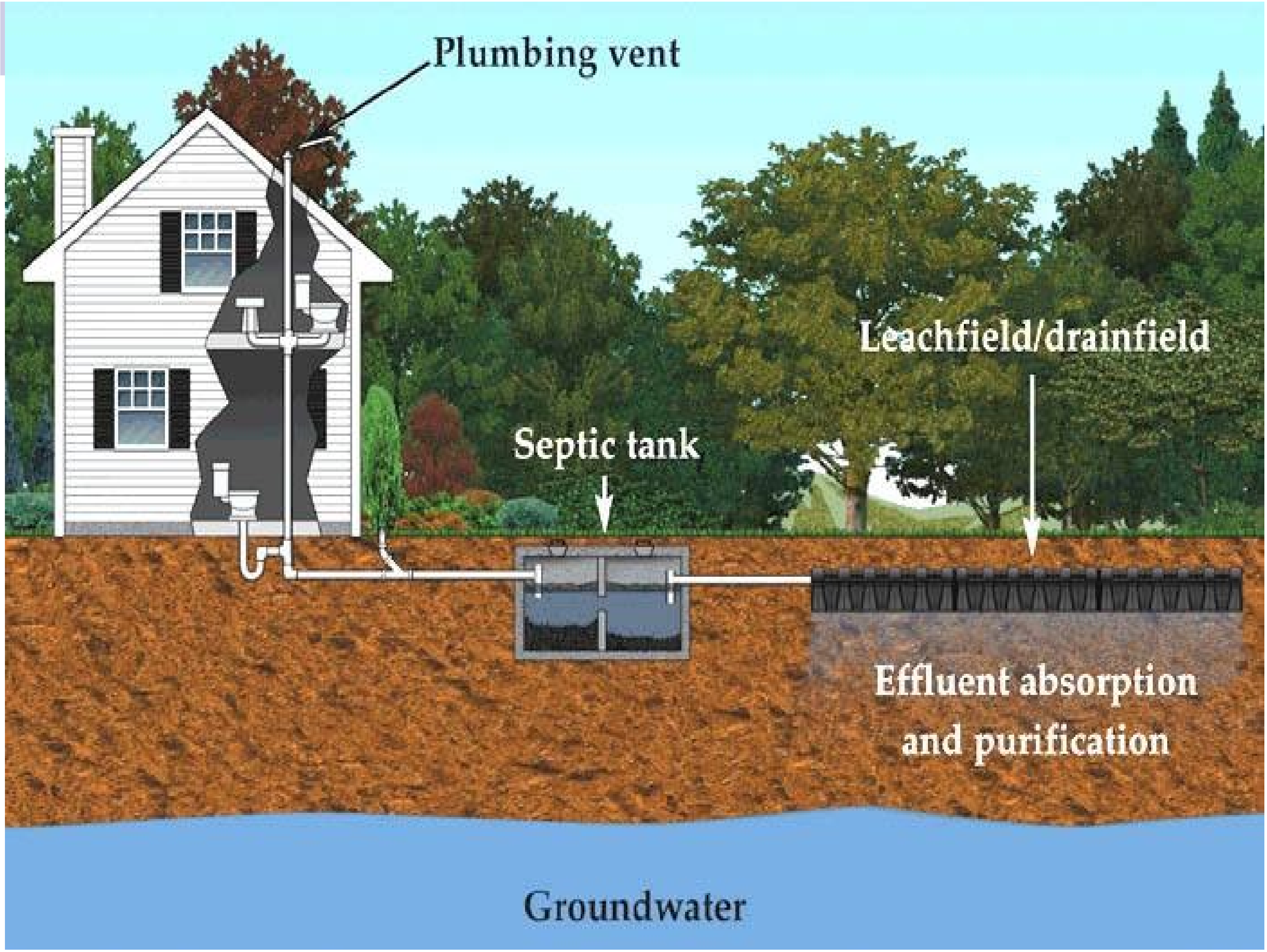


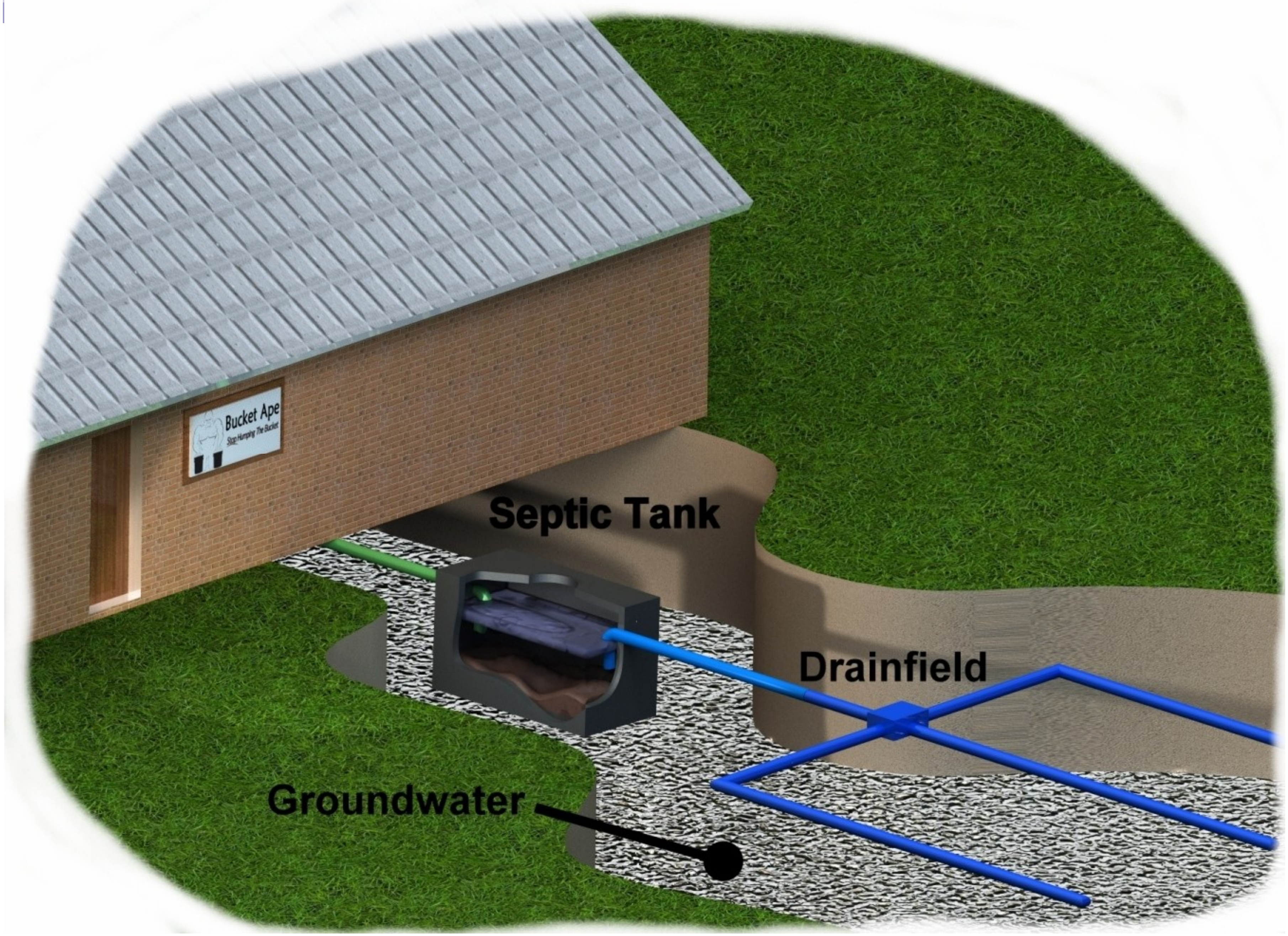


TYPICAL SEPTIC TANK



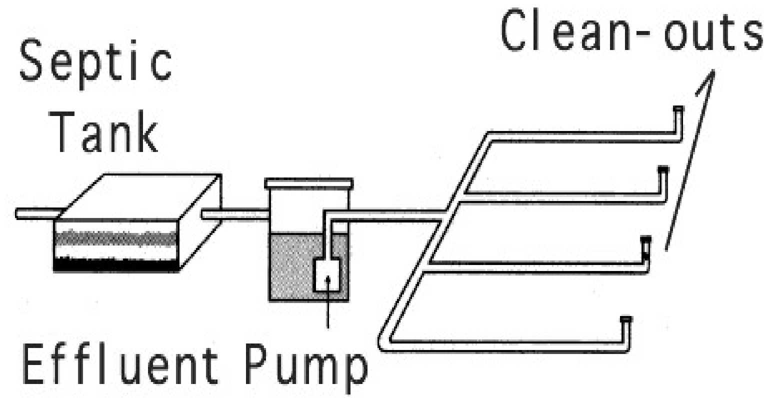
Gunnell Engineering


Plumbing vent
Leachfield/drainfield
Septic tank
Effluent absorption
and purification
Groundwater


Bucket Ape
Stop Humping The Bucket
Septic Tank
Drainfield
Groundwater

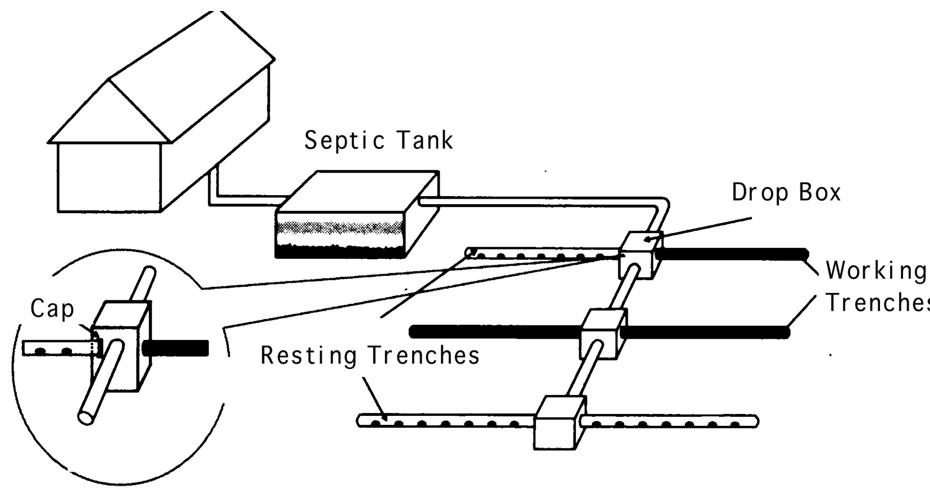
Absorption Fields

- Conventional – gravity flow
- Shallow trench – pump
  - Allow greater soil aeration
  - Used in areas with high groundwater, steep slopes, or shallow soils
  - Requires annual flushing



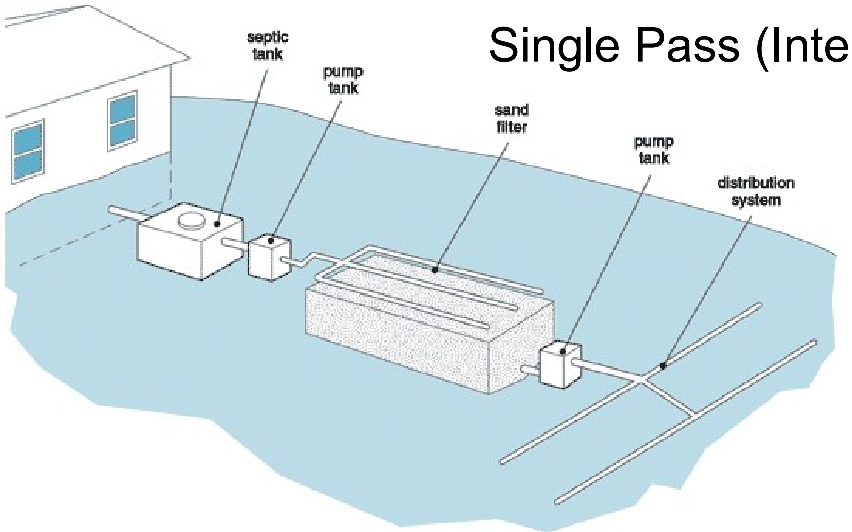
Shallow Trench

- Modified conventional field
- Allows placement on gentle to steeply sloped sites
- Drop boxes allow trenches to fill evenly
- Trenches can be capped to allow resting

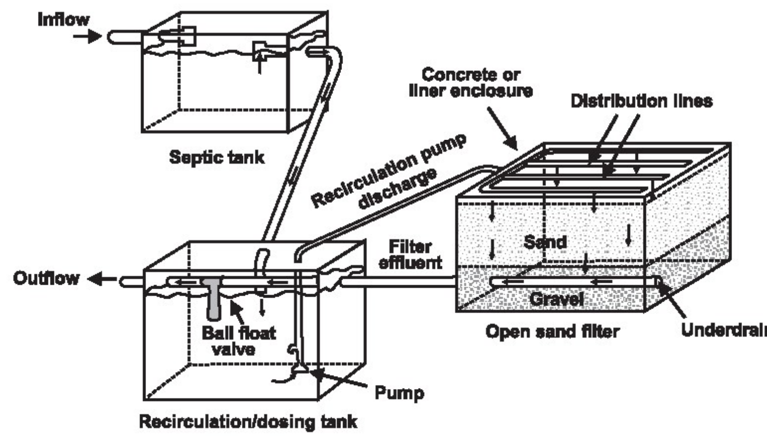


Drop Box

Septic Tank with Sand Filter



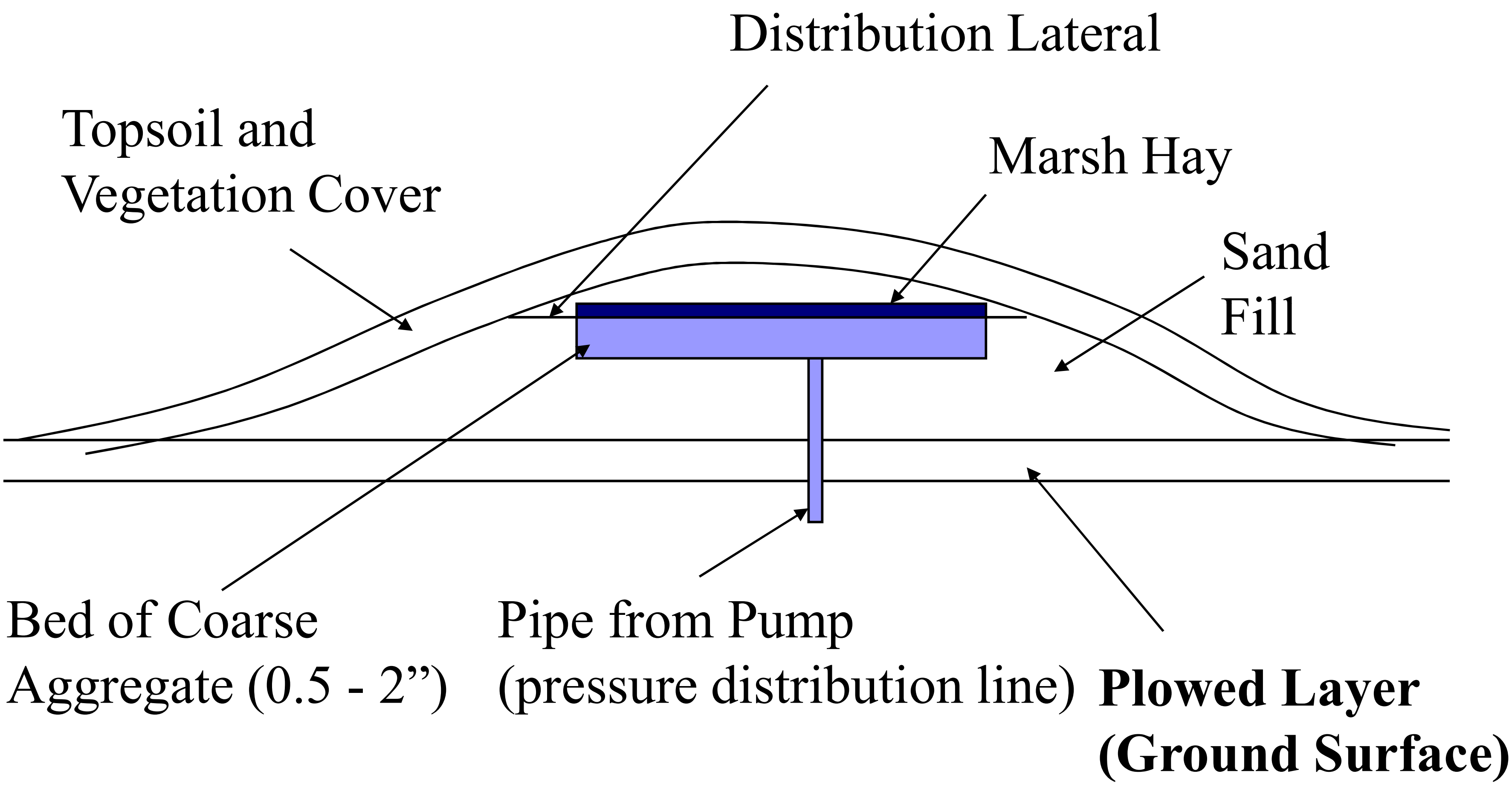
Single Pass (Intermittent)



Recirculating

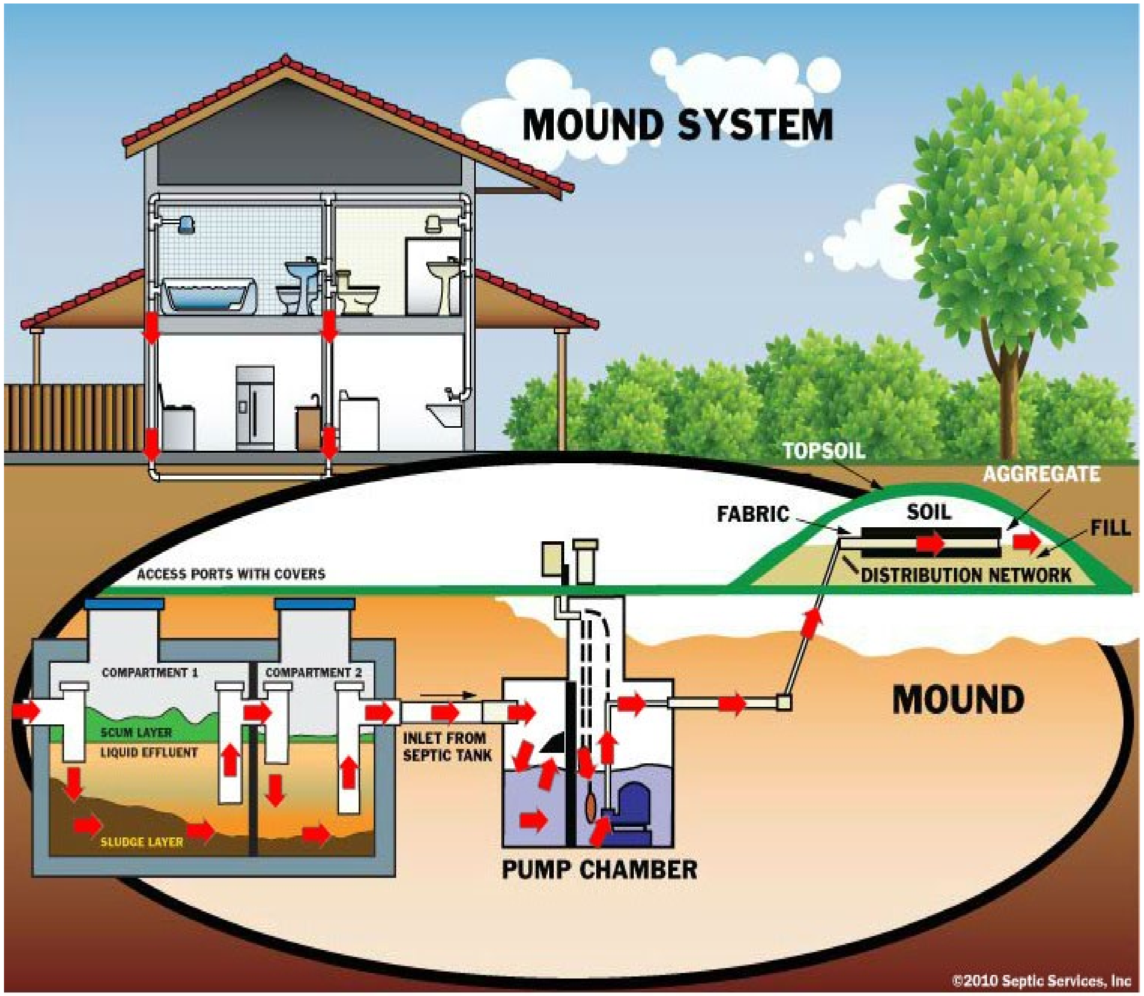
- Combined with septic tank treatment
- Produce high quality effluent
- Single pass, recirculating, others

Mound System

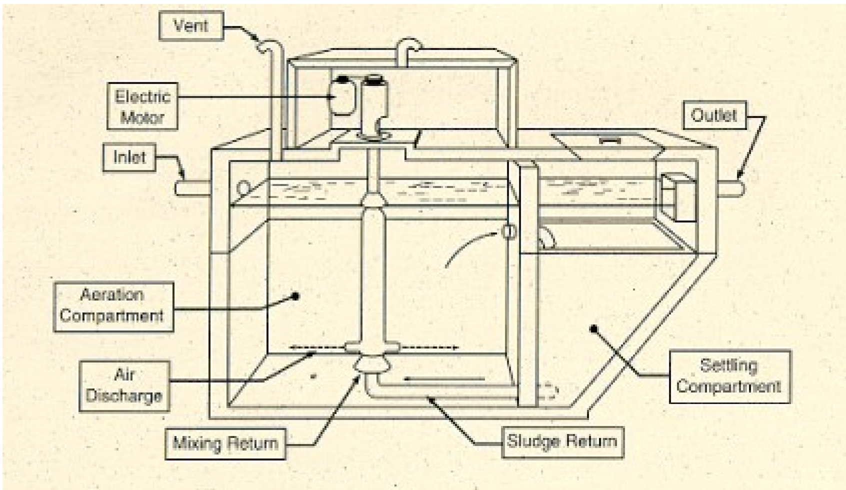


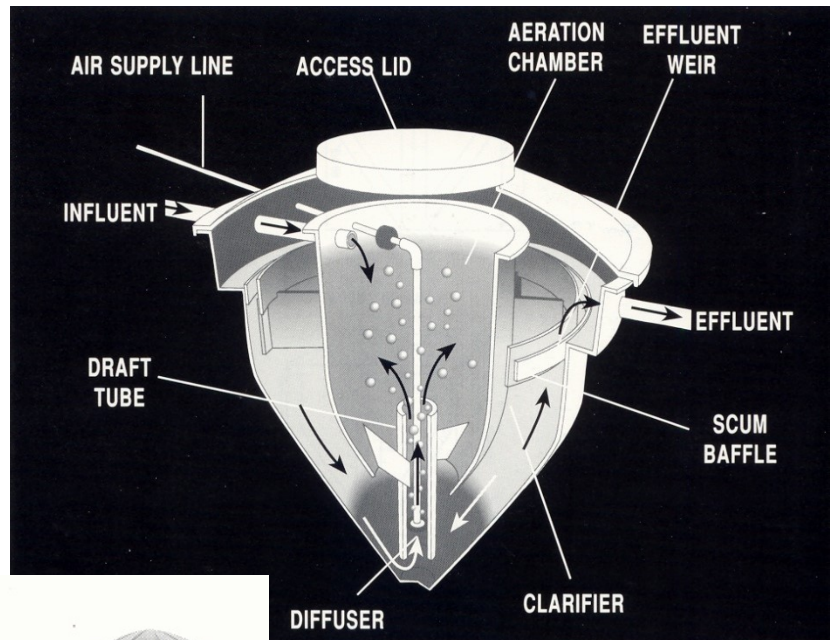
Mound System

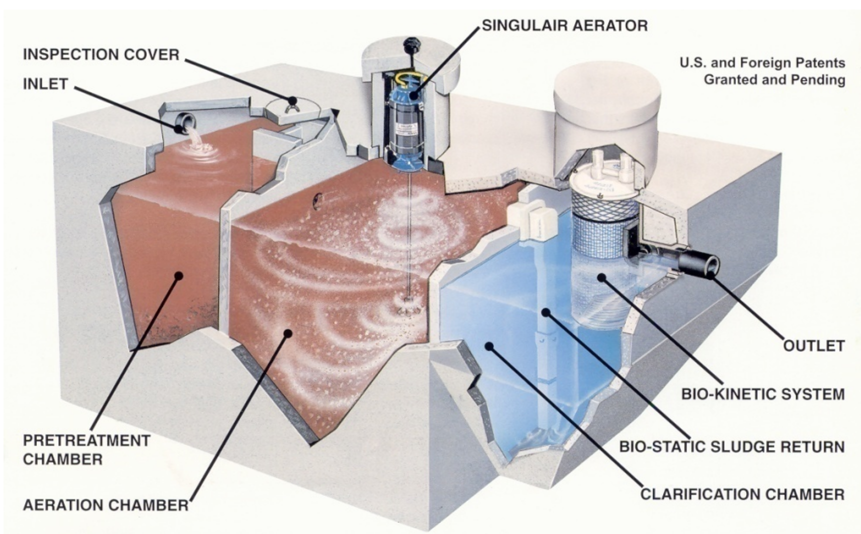
- Absorption portion elevated above ground surface
- Allows use of septic systems in areas with poor soils, shallow bedrock, or high water table
- Must have a minimum of 2 ft of unsaturated soil at the proposed site
- Operates in all climates
- Higher installation cost than conventional absorption fields & more space needed
- Typical slope is 1:3



Aerobic Treatment Units (ATU)



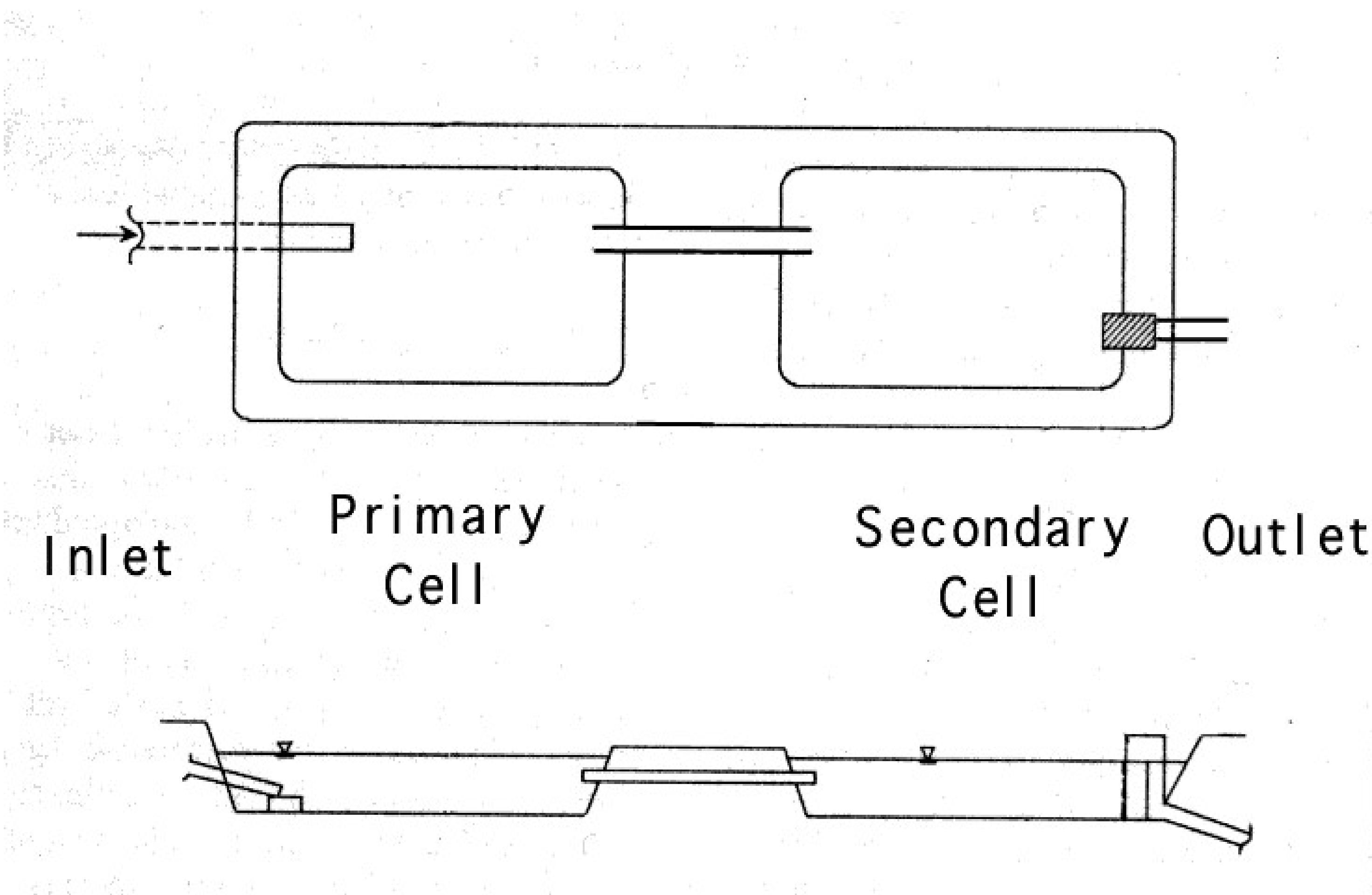




Aerobic Treatment Unit (ATU)

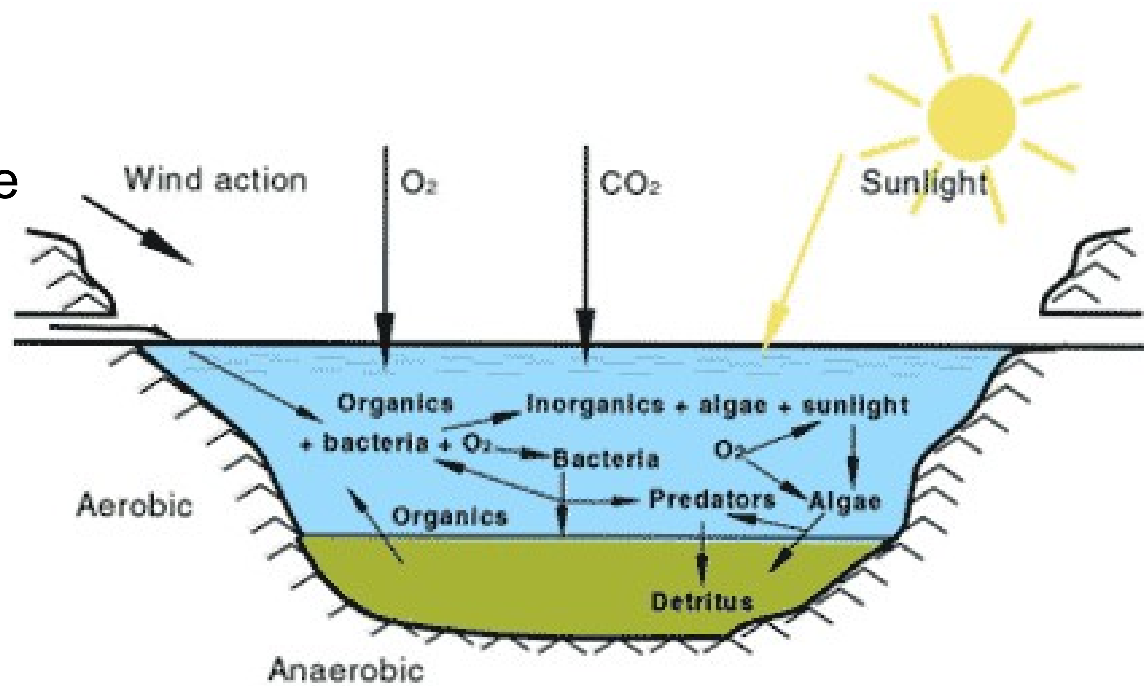
- Advantages
  - Cleaner effluent (remove BOD up to 90%)
  - Able to use on sites unsuitable for septic system
  - Potential for reduced sand filter area
  - Potential for direct discharge
- Disadvantages
  - More expensive to own and operate
  - Requires more operation costs and maintenance

Lagoon/Waste Stabilization Pond



Lagoon/Waste Stabilization Pond

- Variety of designs allow flexibility of treatment
- Alone or after septic tank
- Aeration by natural or mechanical processes
- May be used as pretreatment or storage for other processes
- Requires considerable space



Examples of Wastewater Treatment Processes

- http://www.youtube.com/watch?v=i9L45sC20qk
- https://www.youtube.com/watch?v=OocKzAowo_0
- https://www.youtube.com/watch?v=pRaptzcp9G4
- https://www.youtube.com/watch?v=vC42YTIjxpM