University Curriculum Development for Decentralized Wastewater Management

Hydraulics

Suggested Course Materials

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Citation of Materials

The educational materials included in this module should be cited as follows:

Trotta, P.D., and J.O. Ramsey. 2005. Hydraulics I: Basics Text. *in* (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Trotta, P.D., and J.O. Ramsey. 2005. Hydraulics I: Basics - PowerPoint Presentation. *in* (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Trotta, P.D., and J.O. Ramsey. 2005. Hydraulics II: Energy Text. *in* (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Trotta, P.D., and J.O. Ramsey. 2005. Hydraulics II: Energy - PowerPoint Presentation. *in* (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Trotta, P.D., and J.O. Ramsey. 2005. Hydraulics III: Pumps Text. *in* (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Trotta, P.D., and J.O. Ramsey. 2005. Hydraulics III: Pumps - PowerPoint Presentation. *in* (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Trotta, P.D., and J.O. Ramsey. 2005. Hydraulics IV: Groundwater and Onsite Text. *in* (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Trotta, P.D., and J.O. Ramsey. 2005. Hydraulics IV: Groundwater and Onsite - PowerPoint Presentation. *in* (M.A. Gross and N.E. Deal, eds.) University Curriculum Development for Decentralized Wastewater Management. National Decentralized Water Resources Capacity Development Project. University of Arkansas, Fayetteville, AR.

Hydraulics
Suggested Course Materials

TABLE OF CONTENTS

Hydraulics
Overview

This module presents concepts that are required for full understanding of hydraulic principles common to decentralized wastewater treatment. This module contains four chapters or sub-modules: Hydraulic Fundamentals I; Hydraulic Energy II; Pumps III; and Groundwater Movement IV.

This Hydraulic Fundamentals is aimed at students from non-engineering backgrounds or with limited prior exposure to hydraulic methodologies. Suggested prerequisite courses for this module include college algebra and Soils. Students who have previously had Fluid Mechanics and Engineering Hydraulics should be able to skip the Hydraulic Fundamentals chapter, simply review the Hydraulic Energy and Pump chapters, and then quickly advance into the Gravity and Pressure Distribution Modules. Most students should complete the Groundwater Movement chapter.

Knowledge of concepts covered in this module will be required to successfully complete other curriculum modules where the concepts are covered in greater detail and depth. Where greater coverage of topics is desired, instructors are encouraged to identify related modules for additional study.

Module materials include a text for student use, slide presentations, lecture notes, and various problem sets for use in and out of the classroom. The Hydraulics Fundamentals will require approximately 4 to 6 hours of classroom time. The Hydraulic Energy chapter will take an additional 2 to 4 hours of classroom instruction, the pumps will require approximately 1 to 3 hours of instruction and the Groundwater Movement chapter will require approximately 5 to 8 hours of instruction. Instructors are encouraged to use only chapters and topics that serve the needs of their student body.

Hydraulics

Class Agenda

The class agenda is based on a Monday, Wednesday, Friday schedule with 90 minute classes. This schedule is intended as an outline for a possible class agenda.

Week 1

Hydraulics I Fundamentals - This section is for students who have not completed Hydraulics related courses. This section and related questions will be completed in three class periods.

Week 2

Hydraulics II Energy - Students with previous Hydraulic courses will begin here. This section and related questions will be covered in two class periods.

Hydraulics III Pumps - This section and related questions will be completed in one class period.

Week 3

Hydraulics IV Groundwater and Onsite - This section and related questions will be completed in three class periods.

Week 4

Review and Test on Hydraulics Module - One or two class periods can be used to review and test on presented material.

Hydraulics
Module Outline

I. Hydraulics Fundamentals
- A. Fundamental Properties of Water
  1. Density:
  2. Viscosity
  3. Surface Tension
  4. Compressibility
  5. Vapor Pressure
- B. Useful Units and Equivalences
- C. Fluid Statics: Pressure and its Measurement
  1. Pressure – Definition
  2. Absolute Pressure
  3. Gauge Pressure
  4. Pressure "Head"
  5. The Manometer
  6. Buoyancy
  7. Buoyancy Analysis
- D. Continuity
  1. Continuity In Closed Systems
  2. Continuity In Open Systems
  3. Continuity for Water in Motion

II. Hydraulic Energy
- A. The Hydraulic Energy of Water
  1. Elevation Head
  2. Pressure Head
  3. Velocity Head
  4. Conservation of Hydraulic Energy
  5. Orifice Flow
  6. Friction Losses
- B. Water Hammer

III. Pumps
- A. The Use of Pumps In Onsite Systems

LEARNING OBJECTIVE: Understand how pumps are used in onsite systems.
- B. Classification of Pumps

LEARNING OBJECTIVE: Understand the differences in pumps.
  1. Centrifugal Pumps
  2. Rotary Pumps
  3. Rotary Vain Type Pump

4. Screw-Type Pump
5. Reciprocating
6. Lift Pump
7. Grinder Pumps

C. Pump Design Issues
1. Efficiency
2. Steep versus Shallow Performance Characteristics
3. Pump Horsepower
4. Affinity Laws
5. Multiple Pumps
6. Characteristics of pumps generally used in onsite
7. Low Head for systems discharging to pipes

IV. Groundwater and Onsite

A. Overview

B. Principles of soil water flow (Dave Gustofson)
1. Darcy's law
2. Water flow through soils

1. Know various zones in the soil water profile during/after infiltration
2. Know the impacts of initial soil water content on the initial infiltration rate
3. Know the impacts of final infiltration rate on runoff
4. Know some examples of various types of water flow

C. Application of Groundwater Movement to Onsite Systems

D. Linear Loading Rate Analysis
1. Linear Loading Rate Definition
2. Application of Tyler's Method For Linear Loading Rate Analysis

E. Isitu Measurement of Saturated Hydraulic Conductivity.

F. Constant-head Well Permeameter Method: In-Depth Background (Aziz Amoozegar)

G. Percolation Test

Hydraulics

Goals

The goal of this course module is to teach students the necessary applied hydraulics for the design and design review of gravity flow and pressure flow decentralized wastewater systems.

Following are the individual section goals:

- Recognize how the fundamental properties of water affect on onsite wastewater system
- See the relationship between the various measurements units which are commonly used in onsite wastewater analysis and design
- Understand pressure considerations and measurements
- Understand the use of continuity to solve/analyze onsite problems
- Understand hydraulic energy concepts
- Understand possible effects of momentum and decentralized wastewater
- Understand how pumps are used in onsite systems
- Understand the differences in pumps
- Understand basic concepts of pump design and applications
- Understand differences between Effluent and Grinder pumps
- Know the factors that directly impact soil water movement
- Know Darcy's law and its components
- Know various zones in the soil water profile during/after infiltration
- Know the impacts of initial soil water content on the initial infiltration rate
- Know the impacts of final infiltration rate on runoff
- Know some examples of various types of water flow
- Know hydraulics of distribution systems in soil-based treatment systems and in media filter systems
- Understand the concept and application of Linear Loading Rate analysis
- Apply Tyler's method for Linear Loading Rate Analysis

Hydraulics
Learning Objectives

After the successful completion of this module, the students will be able to size the hydraulic features (pipes, tanks, pumps) required for an onsite wastewater system.

I. Hydraulics Fundamentals

- *Recognize how the fundamental properties of water affect onsite wastewater system.*
- *See the relationship between the various measurements units which are commonly used in onsite wastewater analysis and design.*
- *Understand pressure considerations.*
- *Understand the use of continuity to solve/analyze onsite problems .*

II. Hydraulic Energy

- *Understand hydraulic energy concepts.*
- *Understand possible effects of momentum.*

III. Pumps

- *Understand how pumps are used in onsite systems.*
- *Understand the differences in pumps.*
- *Understand basic concepts of pump design and applications.*

IV. Groundwater and Onsite

- *Know the factors that directly impact soil water movement.*
- *Know Darcy's law and its components*
- *Know various zones in the soil water profile during/after infiltration*
- *Know the impacts of initial soil water content on the initial infiltration rate*
- *Know the impacts of final infiltration rate on runoff*
- *Know some examples of various types of water flow*
- *understand the concept and application of Linear Loading Rate analysis.*
- *Apply Tyler's method for Linear Loading Rate Analysis*

Hydraulics
Pre-Requisites

Suggested prerequisite courses for this module include:

- College algebra
- Soils
- Fluid Mechanics
- Engineering Hydraulics

This Hydraulic Fundamentals is aimed at students from non-engineering backgrounds or with limited prior exposure to hydraulic methodologies. Students who have previously had Fluid Mechanics and Engineering Hydraulics should be able to skip the Hydraulic Fundamentals chapter, simply review the Hydraulic Energy and Pump chapters, and then quickly advance into the Gravity and Pressure Distribution Modules.

Hydraulics
Fundamentals

Evaluation Form

Reviewer: ______________________________

We are requesting your assistance in reviewing the modules developed through the On-Site Consortium curriculum project. Please complete the following form while reviewing the materials

With a rating scale of 1 (Disagree) to 5 (Agree), please respond to the following questions

Review of printed materials:

	Disagree Agree
The text completely covers the topic area.	1 2 3 4 5
The visuals completely cover the topic area.	1 2 3 4 5
The discussion notes completely cover the topic area.	1 2 3 4 5

Review of learning objectives:

I gained a better understanding of basic water fundamentals.	1 2 3 4 5
I gained a better understanding of hydraulic principles.	1 2 3 4 5
I have a better understanding of units and equivalences.	1 2 3 4 5

What specific recommendations would you provide for the text.

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What specific recommendations would you provide for the visuals.

____

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What specific recommendations would you provide for the notes.

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Please give specific positive comments on the topic/module.

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Hydraulics

Energy Considerations

Evaluation Form

Reviewer: ______________________________

We are requesting your assistance in reviewing the modules developed through the On-Site Consortium curriculum project. Please complete the following form while reviewing the materials

With a rating scale of 1 (Disagree) to 5 (Agree), please respond to the following questions

Review of printed materials:

	Disagree -Agree
The text completely covers the topic area.	1 2 3 4 5
The visuals completely cover the topic area.	1 2 3 4 5
The discussion notes completely cover the topic area.	1 2 3 4 5

Review of learning objectives:

I gained a better understanding of hydraulic energy of water.	1 2 3 4 5
I gained a better understanding the differences in hydraulic energy.	1 2 3 4 5
I have a better understanding of friction losses.	1 2 3 4 5
I gained a better understanding of pressure discharge equations.	1 2 3 4 5
I gained a better understanding of pressure wastewater distribution systems.	1 2 3 4 5
I gained a better understanding of hydraulic machines (pumps).	1 2 3 4 5

What specific recommendations would you provide for the text.

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What specific recommendations would you provide for the visuals.

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What specific recommendations would you provide for the notes.

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Hydraulics

Pumps

Evaluation Form

Reviewer: ______________________________

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With a rating scale of 1 (Disagree) to 5 (Agree), please respond to the following questions

Review of printed materials:

	Disagree - Agree
The text completely covers the topic area.	1 2 3 4 5
The visuals completely cover the topic area.	1 2 3 4 5
The discussion notes completely cover the topic area.	1 2 3 4 5

Review of learning objectives:

I gained a better understanding of pump types.	1 2 3 4 5
I gained a better understanding of hydraulic horsepower.	1 2 3 4 5
I have a better understanding of pumps in series and parallel.	1 2 3 4 5
I gained a better understanding pump operations in onsite and decentralized wastewater applications.	1 2 3 4 5

What specific recommendations would you provide for the text.

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What specific recommendations would you provide for the visuals.

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What specific recommendations would you provide for the notes.

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Hydraulics
Groundwater

Evaluation Form

Reviewer: ______________________________

We are requesting your assistance in reviewing the modules developed through the On-Site Consortium curriculum project. Please complete the following form while reviewing the materials

With a rating scale of 1 (Disagree) to 5 (Agree), please respond to the following questions

Review of printed materials:

	Disagree - Agree
The text completely covers the topic area.	1 2 3 4 5
The visuals completely cover the topic area.	1 2 3 4 5
The discussion notes completely cover the topic area.	1 2 3 4 5

Review of learning objectives:

I gained a better understanding of Groundwater Movement.	1 2 3 4 5
I gained a better understanding of Groundwater principles in Onsite and decentralized wastewater.	1 2 3 4 5
I have a better understanding of Groundwater Applications.	1 2 3 4 5

What specific recommendations would you provide for the text.

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What specific recommendations would you provide for the visuals.

____

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What specific recommendations would you provide for the notes.

____

____

Please give specific positive comments on the topic/module.

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Hydraulics

Sets of Questions

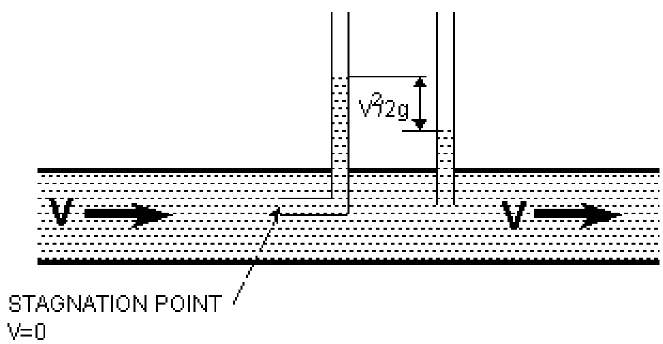
Gage vs Absolute Pressure Problem

Given:
A pump is located under 20 feet {6.1 m} of water.

Find:
What would be the absolute and gage pressures at the pump's location?

USE OF PITOT TUBE PROBLEM

Given:
A set of tubes is placed in a wastewater disposal line in efforts to assure that the minimum velocity is at least 5 ft/sec {1.5 m/s}.



Find:
What is the minimum difference in the water levels in the manometer tube that would justify the assumption that the velocity is adequate?

Bouyancy Problem

Given:
A 1700 gallon {6736 L} septic tank weighs 19,000 lbs {8626 kg} and has outside dimensions of:

12 ft {3.66 m} (length) by
6 ft {1.82 m} (width) by
5.66 ft {1.73 m} (height)

It has 3-inch {7.62 cm} thick concrete sides. It is to be buried with ½ ft {0.15 m} of soil cover. The minimum depth of water expected in the tank is 20 inches {50.8 cm}
Additional Useful Data:

Specific Gravity of Concrete = 2.4
Specific Gravity of Soil = 2.0

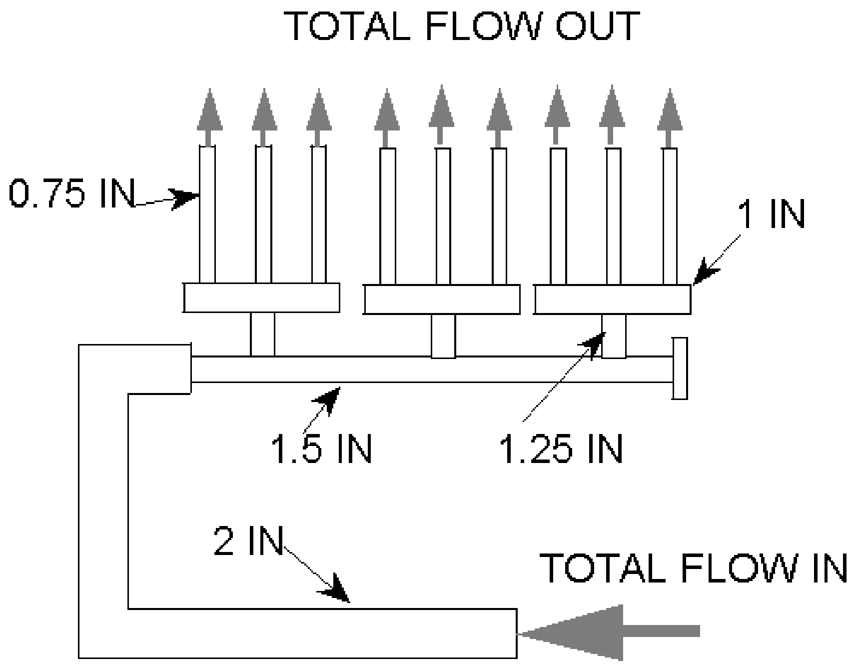
The tank has a totally full capacity of 2156 gallons {8163 L}.

Ignore the inside baffles for now.
Assume that the water level will come up to the original grade.

Find:
Will the tank need additional ballast to avoid flotation?

Determining Velocities Problem

Figure 1 Pipe Systems with both Diameter Changes and Flow Division Changes



Given: Figure 1 shows a branching pipe system with pipe diameters labeled. A flow of 30 gpm {114 L/min} enters the system through the 2-inch {5.08 cm} supply line. You may assume that the diameters given are the inside diameters of the pipes.

Find:
What is the velocity of flow in each of the pipes shown?

Hydraulics

Groundwater Questions

Linear Loading Rate Problem

Given:
Consider a disposal field with overall dimensions of: width = 50 ft {15.24 m} and trench length = 100 ft {30.48 m}.

Find:
What is the Linear Loading Rate for a flat site?

Silt Loam Site Design Problem

Given:
Consider a proposed disposal field in silt loam with overall dimensions of: width = 50 ft {15.24 m} and trench length = 100 ft {30.48 m}. There are 5 parallel trenches each with a bottom width of 3 ft {0.9144 m}. The effective depth of the conducting soil band is 1.5 ft {0.4572 m}. The slope of ground in the area is 0.01 ft/ft {0.01 m/m}.

Find:
According to Tyler's method will the proposed design work? What configuration would work for the given site?

Clay Loam Site Design Problem

Given:
Consider a proposed disposal field in clay loam soil with overall dimensions of: width = 50 ft {15.24 m} and trench length = 100 ft {30.48 m}. There are 5 parallel trenches each with a bottom width of 3 ft {0.9144 m}. The effective depth of the conducting soil band is 1.5 ft {0.4572 m}. The slope of ground in the area is 0.01 ft/ft {0.01 m/m}.

Find:
According to Tyler's method will the proposed design work? What configuration would work for the given site?

Hydraulics

Questions w/ Answers

Head Measurements Problem

Given:
An inspector reports that the residual pressure "head" found at the end of a pressure dosed disposal field is 1.5 inches of mercury.

Find:
What would be the equivalent head expressed in inches of water?

Solution:
The specific gravity of mercury is 13.6 so each inch of mercury would have the same mass or weight as 13.6 inches of water. Therefore 1.5 inches of mercury x 13.6 = 20.4 inches {51.8 cm} of water

Specific Gravity Problem

Given:
An onsite wastewater system is being planned for a space station that has an artificial gravitational acceleration of 10 ft/sec^2 {3.05 m/s^2}

Find:
What would be the weight of 1 cubic foot of water {0.0283 m^3}?

Solution:
The mass of 1 cubic foot of water is 1.94 slugs {28.3 kg}. The acceleration of gravity on the space station is 10 ft/sec^2 {3.05 m/s^2}. Therefore the force necessary to lift the cubic foot of water would be 1.94 slugs/ft^3 * 10 ft/sec^2 = 19.4 lbs/ft^3 {311 kg/m^3}.

Or, seen another way the weight of one cubic foot of water at the space station equals the weight of water on earth multiplied by the ratio of the gravitational forces (acceleration of gravity on space station / acceleration of gravity on earth)

62.4 lbs/ft^3 x (10 ft/sec^2 /32.2 ft/sec^2) = 19.4 lbs/ft^3

Specific Gravity In A Septic Tank Problem

Given:
Assume the following. The SG of an influent wastewater has been measured with a hydrometer and found to be 1.01. A 500 ml sample of this wastewater was allowed to settle for 2 days and a sample of the sludge, which accumulated on the bottom, was extracted for testing. The sludge material occupied 150 ml of the bottom of the settling column and was found to have a SG of 1.07 and the scum layer occupied the top 75 ml of the settling column.

Find:
a) What would be the expected SG of the scum material?
b) If 1000 gallons {3786 L} of this material is added to a septic tank with inside dimensions of 6 ft (long) by 5 ft (wide) by 5 ft (deep) {1.8m by 1.5m by 1.5m} what would be the top and bottom elevation of the clarified water zone (SG = 1) and what would be the upper elevation of the scum. (Measurements will be made relative to the bottom of the tank.)

Solution:
a) The SG of the clarified water is known to be 1.0 and the SG of the sludge was determined to be 1.07 from the laboratory analysis. Mass balance allows the derivation of the SG of the Scum:

Mass balance for the total contents of water results in the volume of clarified effluent:

500 ml = 150 ml (sludge) + 75 ml (scum) + X ml of clarified effluent

X = 500 – 150 – 75 = 275 ml

275 ml of clarified effluent was produced.

Mass balance for the three components (clarified effluent, sludge and scum) by volume results in the SG of the scum:

500 ml * 1.01 = 275 ml * 1.00 + 150 ml * 1.07 + 75 ml * Y

Solving for Y results in:

Y = (500 ml * 1.01 – 275 ml * 1.0 – 150 ml * 1.07)/ 75 ml = 0.875

The SG of the scum is therefore 0.93

b) With 1000 gallons {3786 L} of sewage entering the tank the same ratio of sludge and scum to the original volume would be expected. Therefore:
150 ml/500ml = 30 % of the total volume would be sludge

75 ml/500ml = 15% of the total volume would be scum

275 ml/500ml = 55% of the total volume would be sludge
These percentages will apply as well to the elevation of each fluid in the vertical walled tank.
1000 gallons / 7.48 gallons/ft3 = 66.84 ft3 {1.89 m^3}
66.84 ft3 / 6 ft x 5 ft = 4.46 ft {1.4 m}

Therefore:
a. The sludge blanket on the bottom would be expected to be
4.46 ft x 30% = 1.34 ft or 16 inches {0.41 m), and
b. The scum blanket on the top would be
4.46 ft x 15% = 0.67 ft or 8 inches {0.20 m}, and
c. The clarified effluent in the middle clear zone would be
4.46 ft x 55% = 2.45 ft or 29 inches {0.75 m}.

Computations like this can be used to determine the internal configuration of a septic tank to allow the discharge of only the clarified effluent from the middle zone.

Evapotranspiration Bed Problem

Given:
An evapotranspiration bed is 50 ft wide {15.24 m} and 100 ft long {30.48 m}. The climate can support an average year round design evaporation rate of 0.12 gallons/ft^2/day {4.89 L/m^3}. The sand media has been evaluated in the laboratory and found to have a capillary rise of 16 inches {40.64 cm} and a porosity of 35%

Find:
What is the average daily flow that can be evaporated and transpired from this ET bed under average conditions?

During wet overcast weather conditions no evapotranspiration can be expected. Determine the number of days of storage available between the limit of capillary rise and the surface.

Solution:
The surface of the ET bed is 50 ft x 100 ft or 5000 sq. ft {464.5 m^2}. With an average evaporation of 0.12 gal/ft^2/day a total of 5000 sq ft X 0.12 ft/day = 600 gal/day {2271 L} can be evaporated under normal conditions.

With 16 inches {40.64 cm} of capillary rise and 35% porosity a total depth of 5.6 inches {14.2 cm} of water can be stored in the bed above the lower limit of percolation.

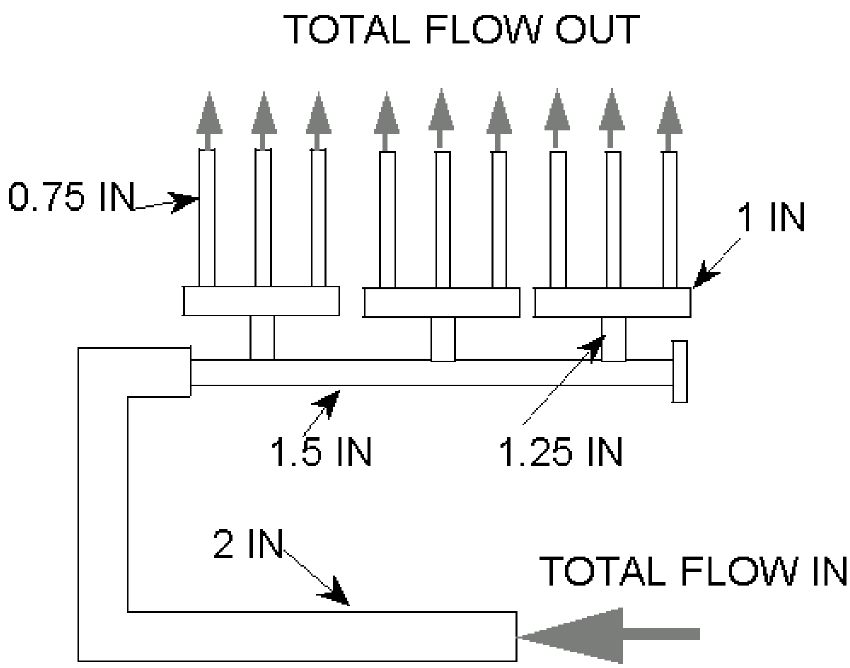
16 inches {40.64 cm} x 0.35 = 5.6 inches {14.2 cm}

With 5000 square feet {464.5 m^2} of surface this results in a potential storage of 5000 x 5.6inches/12 = 2333 cubic feet {66 m^3} of water. With 7.48 gallons per cubic foot {1000 L/m^3} of water this translates into 17,450 gallons (66,066 L}. Considering the estimated average design flow rate of 600 gallons per day {2272 L/day} it is evident that the ET bed can store 29 days of flow assuming no evaporation (and no rain!).

Note: Evapotranspiration may continue to a lesser degree once the saturated level descends below 16 inches {40.64 cm} but the evapotranspiration will be significantly reduced since the water will not be carried to the surface (or root zone) by capillarity. Evaporation may continue at much lower rates below the surface due to the lower temperatures below the surface and high vapor pressure in the soil pores just above the saturated level (see following discussion about vapor pressure). However, this evaporation will depend upon water vapor moving up through the dry sand from the upper limits of the capillary fringe. Transpiration from plants may also continue if the plant roots extend deep enough to intersect the saturated layer and/or capillary fringe where they can extract soil moisture from the saturated or unsaturated soils.

Continuity In Pipe Systems Problem

Figure 2 Branching Pipe System



Given:
Consider the pipe system in **Figure 2** in which a total flow of 30 gallons per minute {113.6 L/min} is supplied to the laterals.

Find:
Determine the flow in the individual laterals

Solution:
The flow in the individual laterals would therefore be the total flow divided by 6 resulting in 5 gallons per minute {18.9 L/min} for each lateral.

Continuity in a Septic Tank Problem

Given:
Consider a 2000-gallon {7572 L} septic tank that initially holds 1500 gallons {5679 L}. 400 gallons {1514 L} are added and 250 gallons {947 L} are removed.

Find:
How much water sewage remains in the tank?

Solution:
1500-gallons (initial) + 400 gallons (added) – 250 gallons (removed) = 1650 gallons {6247 L} (remaining)

Continuity with Flows in a Septic Tank Problem

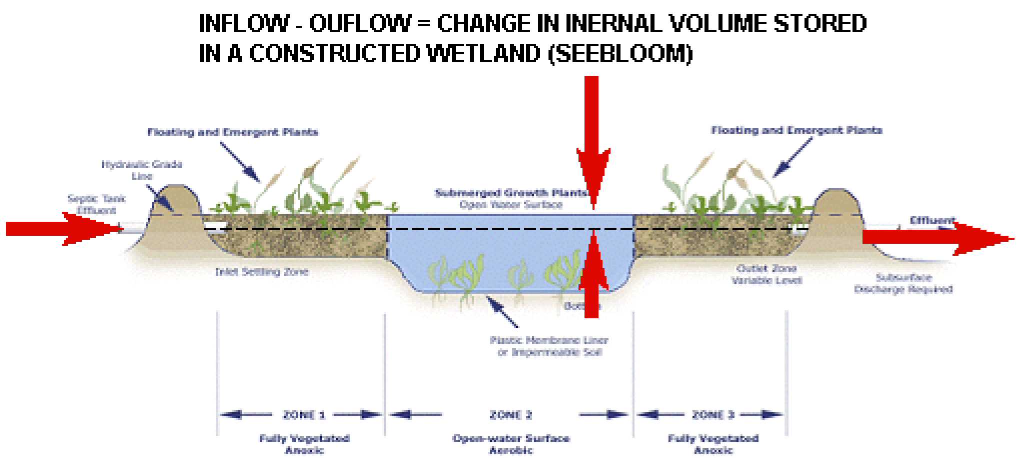
Given:
A 200-gallon {757 L} pump tank initially holds 100 gallons {379 L} of liquid. 10 gallons/minute {37.9 L/min} are added for 10 minutes and 25 gallons/minute {94.7 L/min} are removed for 2 minutes.

Find:
Find the final volume.

Solution
Final Volume = 100 gallons + 10 gallons/minute x 10 minutes - 25 gallons/minute x 2 minutes
Final Volume = 150 gallons {568 L}

Continuity in a Constructed Wetland Problem

Figure 3 Constructed Wetland



Given:

A 0.5-acre {2023 m^2} constructed wetland has a 0.2-acre {809 m^2} open water surface. Near the surface the edge of the constructed wetland is near vertical as shown in Figure 3.

The overall porosity (or void %) of the media surrounding the open surface area is 0.4 (40%).

Find:

How much flow (total volume) would have to enter the wetland to increase the water surface by 0.5 inches {1.27 cm}? (Assume no outflow during this period.)

Solution:

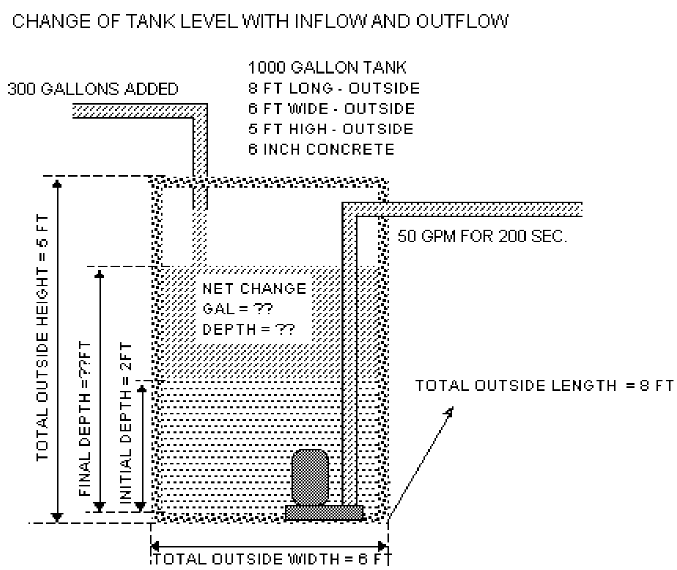
If the net overall Evapo-Transpiration from the entire wetland surface averaged 0.05 gallon/day/sq.ft. {2.04 L/day/m^2} and the downstream soil absorption field can accept of 1000 gallons {3786 L} per day what could the average daily inflow be for a peak period of two weeks if the water surface elevation is to rise no more than 0.25 inches {0.625 cm} over that two week period?

Continuity with Flows Problem

Given:
A 1000-gallon {3786 L} pump tank has outside dimensions of 8 feet {2.44 M} long x 6 feet {1.83 m} wide x 5 feet {1.52 m} deep. The concrete used is 0.5 feet {0.15 m} thick (all around). (Concrete tanks are usually less than 0.5 feet {0.15 m} thick) Initially there is 2 feet {0.61 m} of water in the tank. 300 gallons {1136 L} are added from household use and the pump goes on for 200 seconds, pumping 50 gallons per minute {189 L/min}.

Find:
What is the final water surface elevation in the tank?

Figure 4 Continuity with Flows



Solution
First compute the outflow in gallons:
50 gpm x 200 seconds/ 60 seconds/min = 166.7 gal {631 L}

Next compute the total change in volume:
300 gal (inflow) - 166.6 gal (outflow) = 133.4 gal {505 L}(increase)

Next convert gallons to cubic feet.
133.4 gal/7.48 gal/ ft^3 = 17.83 ft^3 {0.5 m^3}

The inside dimensions of the tank are obtained by subtracting the wall thickness (twice – once for each side)
8 ft – 0.5 ft – 0.5 ft = 7 ft {2.13 m}
And

6 ft – 0.5 ft –0.5 ft = 5 ft {1.52 m}

Now divide the change in volume by the inside area.
17.83 ft^3 / (7 ft x 5 ft) = 0.51 ft {0.155 m}

Finally, convert the change in elevation to inches.
0.51 ft x 12 in/ft = 6.11 in {15.5 cm}(which is the change in tank depth)
Since more came in than went out the final tank elevation is
2.51 ft or 2 ft + 6.11 in (or 30.11 in){76.5 cm}

Determining Velocities Problem

Given:
D1 = 1 inches {2.54 cm} D2 = 2 inches {5.08 cm} and Q = 50 gallons per minute {1893 L/min}.

Find:
Find the average velocity in the 1-inch {2.54 cm} pipe and the average velocity in the 2-inch {5.08 cm} pipe.

Solution:
The area of a circle is Π(Pi) x the radius squared or, $\Pi \times R^2$, this is the same as $\Pi \times D^2/4$.

A flow of 50 gallons per minute equals 50/(7.48 * 60) cubic feet per second or 0.11 cfs {0.003 m^3/s}.

The area of the 1 inch pipe is $\Pi \times (1/12)^2/4 =$ 0.0054 sq. ft. (or about 0.78 sq. in){5.03 cm^2}.
The area of the 2 inch pipe is $\Pi \times (2/12)^2/4 =$ 0.0216 sq. ft. (or about 3.11 sq. in){20.0 cm^2}.

Therefore, the average velocity in the 1-inch pipe must be:
0.11 cfs/.0054 sq. ft = 20.4 ft/sec {6.22 m/s} and

The average velocity in the 2-inch pipe must be:
0.11 cfs/.0216 sq. ft = 5.1 ft/sec {1.55 m/s} or ¼ of the velocity in the 1 inch pipe.

From this example we can see that the velocity was directly related to the area that was related to the radius or the diameter squared.

Determining Velocities Problem

Given:
D1 = 2 inches {5.08 cm}   D2 = 1.5 inches {3.81 cm}
The velocity of the flow in the 2-inch pipe is 10 ft/sec {3.04 m/s}

Find:
What is the velocity of flow in the 1.5-inch pipe if it is carrying the same flow?

Solution

$V1/V2 = (D2/D1)^2$

Therefore:

$V2 = V1/(D2/D1)^2$

$V2 = 10\ (2/1.5)^2 1 = 10 * 1.777 = 18$ ft /sec {5.2 m/s}

Hydraulics

Energy Questions

sprinkler system Problem

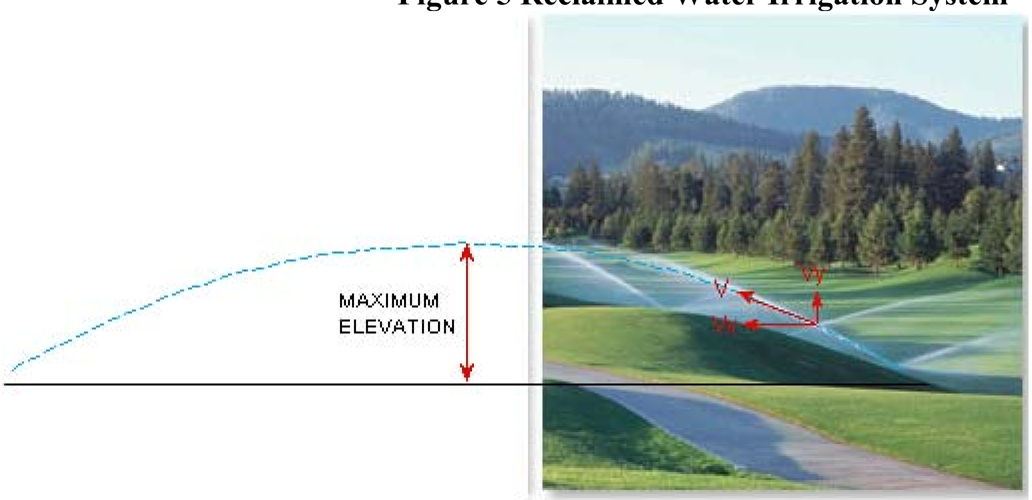
Given:
A sprinkler system discharges water as shown below in **Figure 5**, the maximum elevation attained by the spray is 20 ft above the elevation of the sprinkler head. The initial angle of the spray is 30 degrees above horizontal. The spray head has an opening that has a 0.5 inch diameter.

Find:
Estimate the flow rate coming out of the sprinkler head

Solution

Set maximum elevation equal to $(V_y)^2/2g$
Solve for Vy
Using sin 30 degrees solve for V (V= Vy/sin 30)
Multiply V by the area of the spray head opening.

Figure 5 Reclaimed Water Irrigation System



Hydraulics

Pump Questions

Pump Calculations Problem

Given:
A pump basin with a ¼ horsepower pump pumps septic tank effluent to a Wisconsin Mound. The pump delivers 13 gpm {49.2 L} at 24 ft {7.3 m} of dynamic head when run at 3600-rpm.

Find:
The change in operating characteristics if the pump's impeller is reduced from 6" to 4" {15.2 cm to 10.2 cm}.

Solution:

$$\frac{13}{Q_2} = \frac{6}{4}$$

$$Q_2 = 8.7\,gpm$$

$$\frac{24}{H_2} = \left(\frac{6}{4}\right)^2$$

$$H_2 = 10.7\,ft$$

Hydraulics

Groundwater questions

Using Ksat Values with Design problem

Given:
The table provided for a soil with a Ksat of 0.001 cm/sec. A daily effluent flow of 500 gallons per day {1893 L/day}. The slope of ground in the area is 0.01 ft/ft {0.01 m/m}. The depth of the soil horizon that is expected to carry effluent is 4 ft {1.23 m}, and the allowable percent of total saturated flow capacity is 30%.

Find:
Determine the length of trench along a slope that would be needed to dissipate the daily flow.

Solution:
It should also be noted at this time that the Ksat of the soils in immediate proximity to the trench wall might decrease through time as the soil pores become clogged with bio-solids. This clogging mat may turn out to be a greater limitation upon the design of onsite systems than the Ksat of the soils in the area.

Several authors have attempted to balance the long-term acceptance rate of the clogging mat, which lines the trenches with the hydraulic conductivity of the surrounding soils. The next section introduces several techniques for addressing these issues simultaneously.
Solution Table Illustrating Darcy Flow Through Homogeneous (Non Structured) Loam Soil with an assumed Ksat of 0.001 cm/sec

USE OF DARCY'S LAW FOR ANALYSIS OF LINEAR ABSORPTION RATE

(EXTREMELY CONSERVATIVE FOR STRUCTURE LESS SOILS)

Soil Type LOAM

Ksat 0.0010 cm/sec (log value
2.83 ft/day
21.20 gal/day/sq.ft.

Ground Slope(%)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Soil Depth (inch)		GALLONS PER FOOT PER DAY OF FLOW AT SATURATION										
6	0.05	0.11	0.16	0.21	0.27	0.32	0.37	0.42	0.48	0.53	0.58	0.64
9	0.08	0.16	0.24	0.32	0.40	0.48	0.56	0.64	0.72	0.80	0.87	0.95
12	0.11	0.21	0.32	0.42	0.53	0.64	0.74	0.85	0.95	1.06	1.17	1.27
15	0.13	0.27	0.40	0.53	0.66	0.80	0.93	1.06	1.19	1.33	1.46	1.59
18	0.16	0.32	0.48	0.64	0.80	0.95	1.11	1.27	1.43	1.59	1.75	1.91
21	0.19	0.37	0.56	0.74	0.93	1.11	1.30	1.48	1.67	1.86	2.04	2.23
24	0.21	0.42	0.64	0.85	1.06	1.27	1.48	1.70	1.91	2.12	2.33	2.54
27	0.24	0.48	0.72	0.95	1.19	1.43	1.67	1.91	2.15	2.39	2.62	2.86
30	0.27	0.53	0.80	1.06	1.33	1.59	1.86	2.12	2.39	2.65	2.92	3.18
33	0.29	0.58	0.87	1.17	1.46	1.75	2.04	2.33	2.62	2.92	3.21	3.50
36	0.32	0.64	0.95	1.27	1.59	1.91	2.23	2.54	2.86	3.18	3.50	3.82
39	0.34	0.69	1.03	1.38	1.72	2.07	2.41	2.76	3.10	3.45	3.79	4.13
42	0.37	0.74	1.11	1.48	1.86	2.23	2.60	2.97	3.34	3.71	4.08	4.45
45	0.40	0.80	1.19	1.59	1.99	2.39	2.78	3.18	3.58	3.98	4.37	4.77
48	0.42	0.85	1.27	1.70	2.12	2.54	2.97	3.39	3.82	4.24	4.66	5.09
51	0.45	0.90	1.35	1.80	2.25	2.70	3.15	3.60	4.06	4.51	4.96	5.41
54	0.48	0.95	1.43	1.91	2.39	2.86	3.34	3.82	4.29	4.77	5.25	5.72
57	0.50	1.01	1.51	2.01	2.52	3.02	3.53	4.03	4.53	5.04	5.54	6.04
60	0.53	1.06	1.59	2.12	2.65	3.18	3.71	4.24	4.77	5.30	5.83	6.36

Solution Table Illustrating Darcy Flow Through Homogeneous (Non Structured) Loam Soil with an assumed Ksat of 0.0001 cm/sec

USE OF DARCY'S LAW FOR ANALYSIS OF LINEAR ABSORPTION RATE
(EXTREMELY CONSERVATIVE FOR STRUCTURE LESS SOILS)

Soil Type LOAM

Ksat 0.0001 cm/sec (log value
0.28 ft/day
2.12 gal/day/sq.ft.

Ground Slope(%)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Soil Depth (inch)		GALLONS PER FOOT PER DAY OF FLOW AT SATURATION										
6	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06
9	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.10
12	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.12	0.13
15	0.01	0.03	0.04	0.05	0.07	0.08	0.09	0.11	0.12	0.13	0.15	0.16
18	0.02	0.03	0.05	0.06	0.08	0.10	0.11	0.13	0.14	0.16	0.17	0.19
21	0.02	0.04	0.06	0.07	0.09	0.11	0.13	0.15	0.17	0.19	0.20	0.22
24	0.02	0.04	0.06	0.08	0.11	0.13	0.15	0.17	0.19	0.21	0.23	0.25
27	0.02	0.05	0.07	0.10	0.12	0.14	0.17	0.19	0.21	0.24	0.26	0.29
30	0.03	0.05	0.08	0.11	0.13	0.16	0.19	0.21	0.24	0.27	0.29	0.32
33	0.03	0.06	0.09	0.12	0.15	0.17	0.20	0.23	0.26	0.29	0.32	0.35
36	0.03	0.06	0.10	0.13	0.16	0.19	0.22	0.25	0.29	0.32	0.35	0.38
39	0.03	0.07	0.10	0.14	0.17	0.21	0.24	0.28	0.31	0.34	0.38	0.41
42	0.04	0.07	0.11	0.15	0.19	0.22	0.26	0.30	0.33	0.37	0.41	0.45
45	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.32	0.36	0.40	0.44	0.48
48	0.04	0.08	0.13	0.17	0.21	0.25	0.30	0.34	0.38	0.42	0.47	0.51
51	0.05	0.09	0.14	0.18	0.23	0.27	0.32	0.36	0.41	0.45	0.50	0.54
54	0.05	0.10	0.14	0.19	0.24	0.29	0.33	0.38	0.43	0.48	0.52	0.57
57	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
60	0.05	0.11	0.16	0.21	0.27	0.32	0.37	0.42	0.48	0.53	0.58	0.64