GRAYWATER CURRICULUM

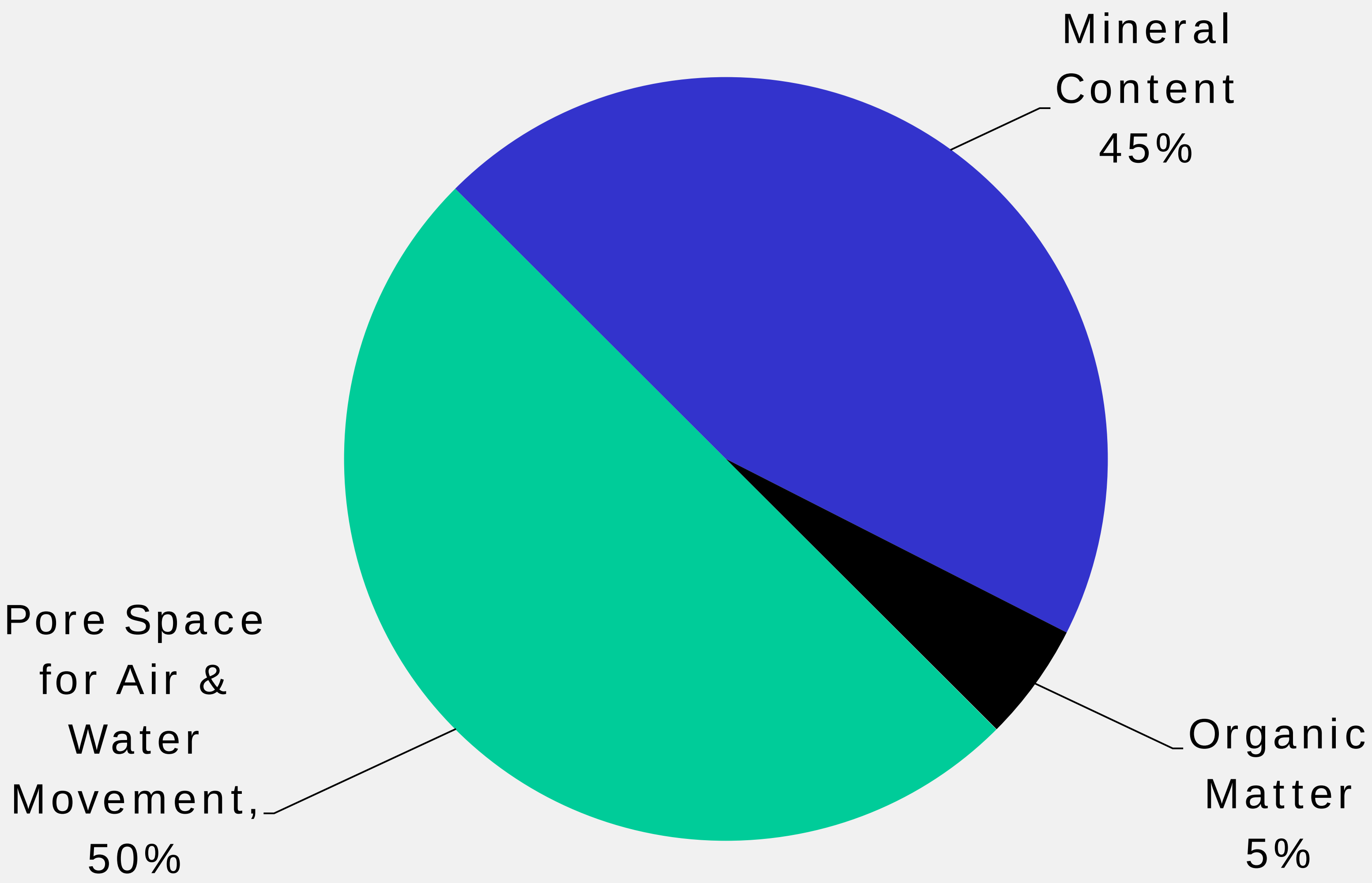
CLASS THREE

Sizing Irrigation Fields

Class 3 Objectives

1. **Soil composition**
2. **Evapotranspiration**
3. **Determine Graywater Irrigation Fields**
   - Graywater production
   - Determine water budget
   - Calculating Minimum Irrigation Field Area
   - Conform to code setbacks

What is Soil Made of?



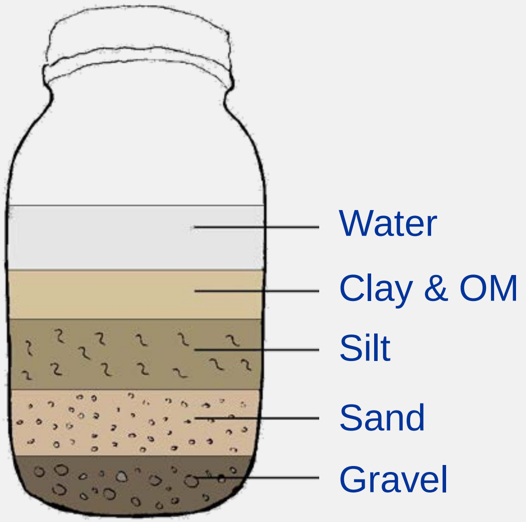
Physical Properties of Soil: Texture

Texture = how it feels

3 textural classes: Sand, Silt, and Clay

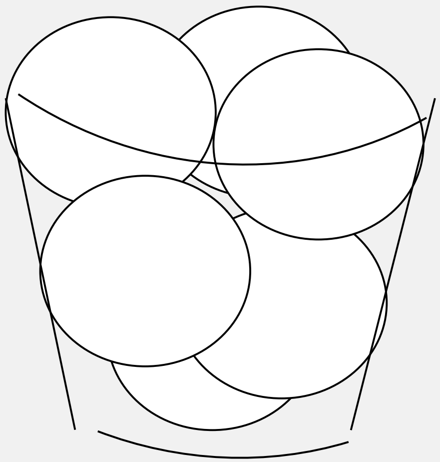
Conducting a soil sample will help you determine how water will be absorbed in the irrigation field

This can easily be done in a few simple steps with a jar of water, a handful of soil, and a tablespoon of salt



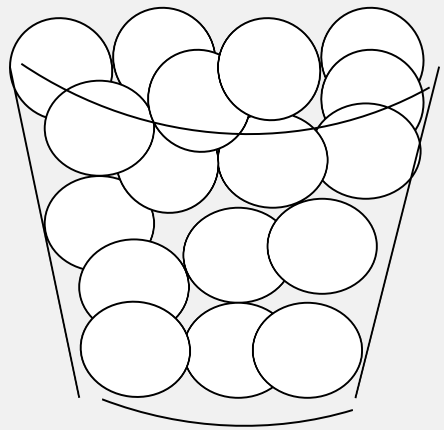
Soil Particle Size

Sand: Basketballs Watermelon



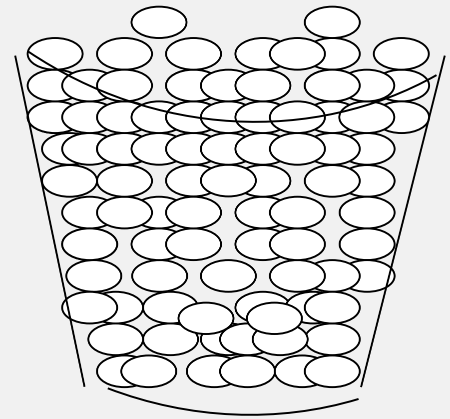
0.05 mm to 2 mm

Silt: Softballs Grapefruit



0.002 mm to 0.05 mm

Clay: Golf balls Eggs



less than 0.002 mm

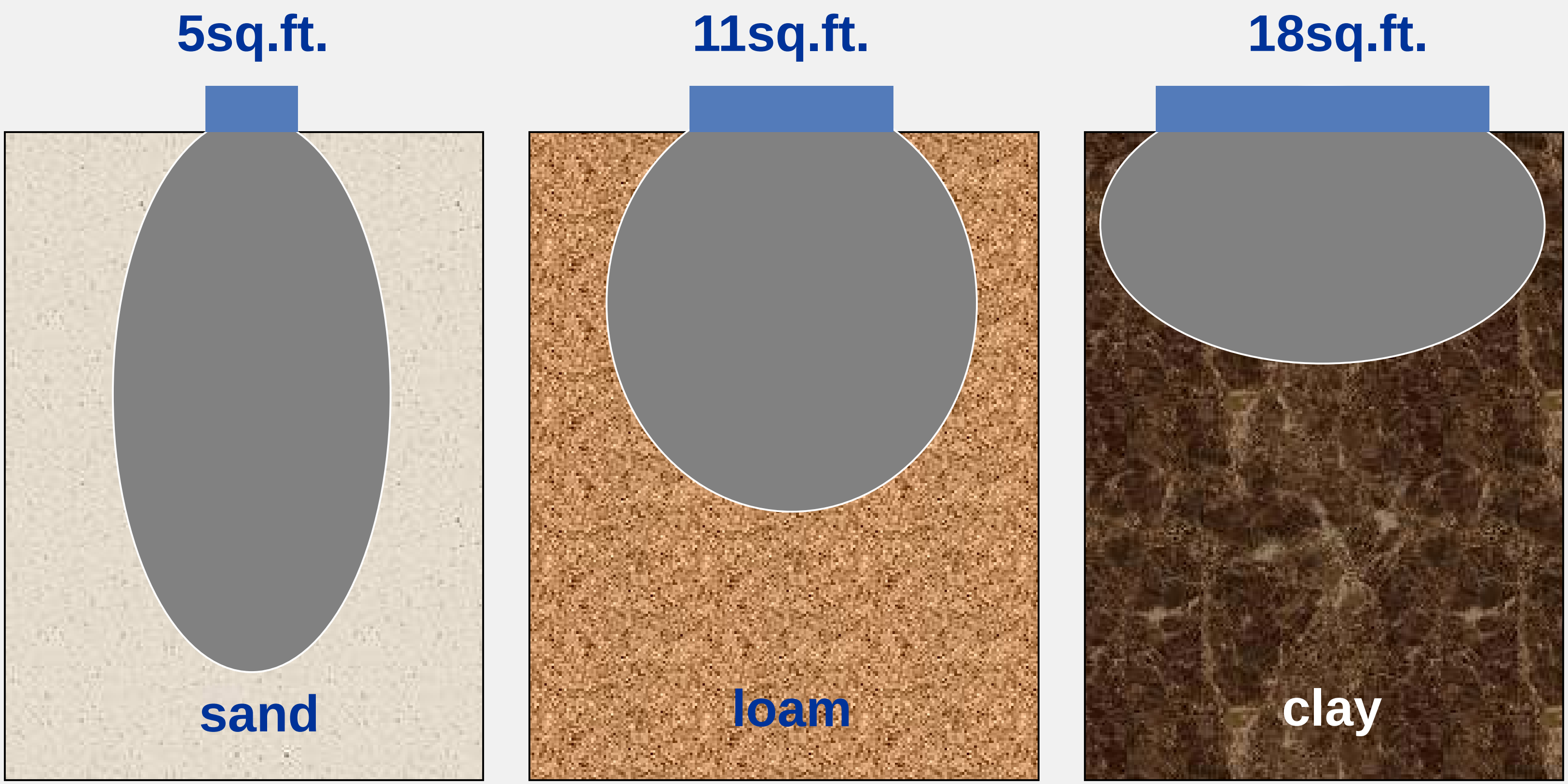
Which one holds more water?

Which one has more air space?

How Water Travels in Soil

When water is applied at a single point

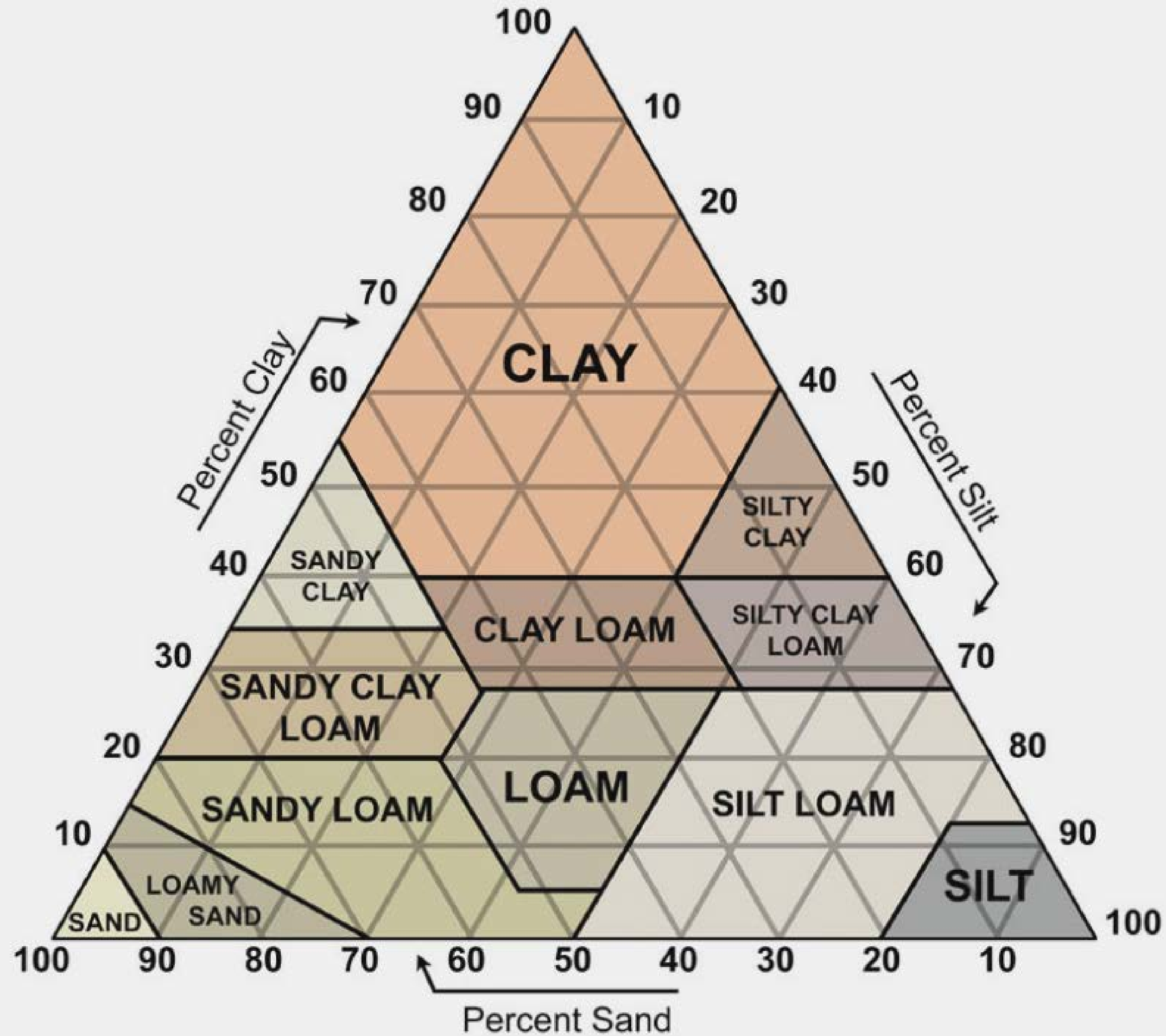
1 gallon per hour emitter will cover:



How Water Travels in Soil

- The forces that allow water to move through soil are gravitational forces and capillary forces
- Capillary action involves adhesion (attraction of water molecules to solid surfaces) and cohesion (attraction of water molecules to each other)
- Graywater is typically discharged on a daily basis in relatively small amounts creating a ‘moisture blanket’ in the top few inches of soil
- Moist (not saturated) soil promotes capillary action and means that irrigation discharge points can be spaced farther apart and some distance from the plant root crown
- Gravitational forces take over when soil is saturated and pull water down below the root zone
- Soil pore size and other factors such as organic matter and compaction greatly impact the manner in which water moves through soil

Soil Textural Triangle



Activity 1: Soil Triangle

In small groups, use the percentages from the chart in your activities handout determine soil texture using the soil texture triangle

	Example 1	Example 2
Percent Sand	40	10
Percent Silt	40	45
Percent Clay	20	45
Soil Type		

Soil Structure/Soil Life and Graywater

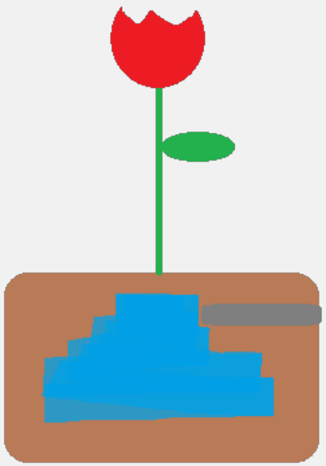
What do soil organisms do for graywater absorption?

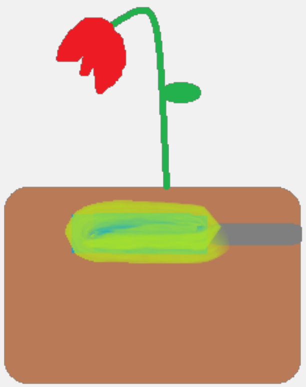
1. Microorganisms in mulch basins and irrigation field decompose organic debris in graywater

What do soil organisms do to improve the soil for plants?

1. Break down raw organic material and mineral soil
2. Improve the soil by building ‘humus’ and releases nutrients
3. Improve soil aggregation and infiltration rates

Healthy soil with organisms = happy plants and filtered water





Soil without organisms = dead plants and standing water

Determine the Maximum Absorption Capacity

Maximum Absorption Capacity is how much water can be infiltrated in the soil (measured in gallons/sq^2)

- Use Table 1602.10 for common soil types
- For other soil types use percolation test

If percolation test shows soil will not absorb the graywater system can't be built!

Table 1602.10 Design of Six Typical Soils

Type of Soil	Minimum sqft of irrigation area per 100 gallons of graywater/day	Max absorption capacity (gallon/sqft/ day)
Coarse sand or gravel	20	5.0
Fine Sand	25	4.0
Sandy Loam	40	2.5
Sandy Clay	60	1.7
Clay w/ considerable sand or gravel	90	1.1
Clay w/small amounts of sand or gravel	120	0.8

Use this table to calculate the square feet of irrigation area needed for a system

Example:
80 gpd in sandy clay = 80/1.7 = 47 ft²

Types of Irrigation Fields

Mulch Basin

A subsurface type of irrigation or disposal field filled with mulch or other permeable materials sized to prevent ponding /runoff

Subsurface Irrigation Field

Graywater irrigation field installed below the finished grade within topsoil

Subsoil Irrigation Field

Graywater irrigation field installed in a trench within the layer of soil below the topsoil. Generally for deep rooted plants

Mulch Basin

Mulch basins may be used as an irrigation or disposal field for graywater

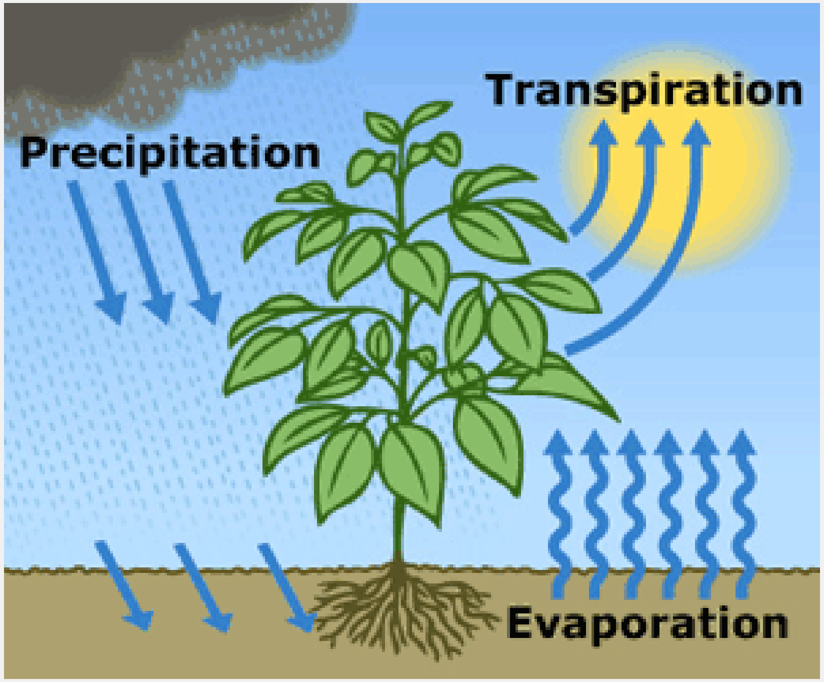
- Prevent runoff
- Prevent pooling (exposure)
- Provide surge capacity if sized correctly
- Discharge 2 in. under mulch shield for code compliance

EVAPOTRANSPIRATION (ET)

ET is a loss of water to the atmosphere by the combined processes of evaporation from soil and plant surfaces and transpiration from plants

How much water do plants need? = How Much Water Do I Need To Replace?

ET = E + T

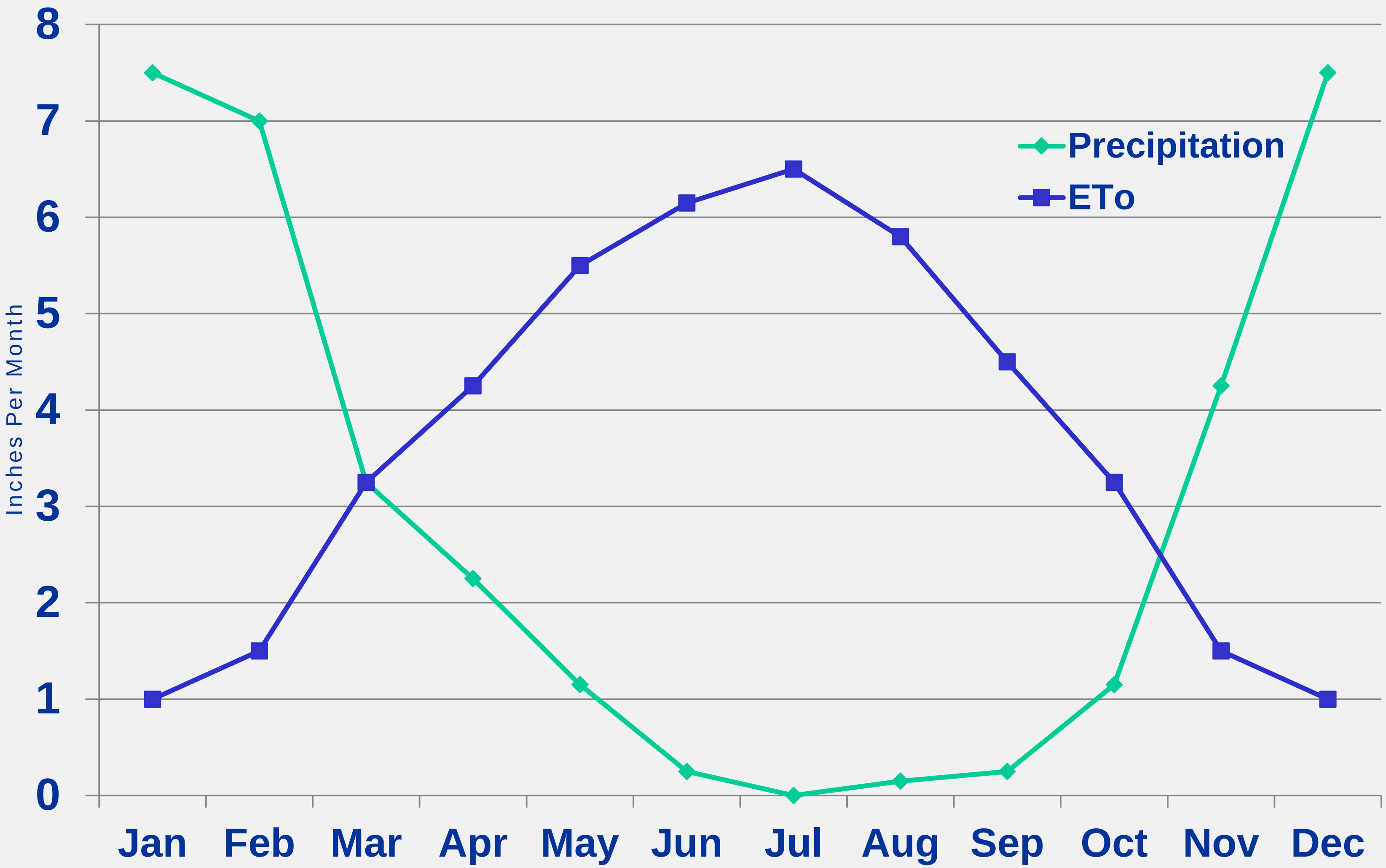


EVAPOTRANSPIRATION (ET)

Reference Evapotranspiration (ETo):

- Describes the amount of water that needs to be replaced for a crop
- Reference crop used is cool season grass or alfalfa
- Based on current weather conditions
- Measured in inches/unit time
- Influenced by wind, humidity, temperature, solar radiation

Evapotranspiration and Precipitation in Santa Rosa



Source: CIMIS Reference Evapotranspiration Zones

ETo & Local weather data: www.cimis.water.ca.gov

Santa Rosa (Laguna) Station #83

Date	CIMIS ETo (in)	Precip (in)	Sol Rad (Ly/day)	Avg Vap (mBars)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Max Rel Hum (%)	Min Rel Hum (%)	Avg Rel Hum (%)	Dew Pt (°F)	Avg wSpd (MPH)	Wnd Run (miles)	Avg Soil Temp (°F)
03/20/2014	0.14 R	0.00	463	9.3	70.5	37.2	50.9	96	43	73	42.7	3.0	72.8	55.3
03/21/2014	0.12	0.00	438	10.0	64.0	36.7	48.3	97	64	86	44.4	3.3	78.7	55.8
03/22/2014	0.13	0.00	449	9.4	64.9	33.2	47.8	97	54	83	42.8	3.3	78.7	55.4
03/23/2014	0.13	0.00	442	10.4	70.9	37.7	51.0	97	52	82	45.6	3.0	72.1	55.9
03/24/2014	0.14	0.00	481	9.3	72.6	33.8	48.8	98	44	79	42.7	2.8	67.4	55.7
03/25/2014	0.05	0.19	217	10.0	60.8	32.0	45.9	98	76	95	44.6	2.8	66.9	54.9
03/26/2014	0.09	0.52	342	11.1	60.6	44.5	51.3	96	68	86	47.3	4.5	107.5	55.0
Tots/Avgs	0.80	0.71	405	9.9	66.3	36.4	49.1	97	57	83	44.3	3.2	77.7	55.4

Six Active Stations in Sonoma and Marin County

1. Santa Rosa (Laguna) Station #83
2. Windsor Station #103
3. Petaluma Station #144
4. Point San Pedro (San Rafael) Station # 157
5. Santa Rosa (Bennett Valley) Station #158
6. Novato (Black Point) Station #187

How Much Water Do I Need To Replace During Peak Demand?

Historical ETo rate for Santa Rosa (zone 5) in July = 6.51 inches/month

- 6.51 inches of water would need to be replaced in the month of July

Adjustments?

- Landscape Coefficient = Plant Factor x micro-climate x density of plants

Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	32.9
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.3
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.1
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.4
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variability between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites wihtin a zone for all months is about 0.01 inches per day for the 200 sites used to develop the map.

Plant Factors

Plant Factors (also known as a Species Factor) - The amount of water a plant needs (Pf, Ks)

High - 70 to 100% ETo

- Up to 23 gallons per sq. ft.
- Up to 36 inches/year

Moderate - 40 to 60% ETo

- Up to 15 gallons per sq. ft.
- Up to 24 inches/year

Low - 10 to 30% ETo

- Up to 8 gallons per sq. ft.
- Up to 12 inches/year

Estimating Graywater Discharge 1602.8

Design system to distribute the <u>total amount</u> of estimated graywater on a <u>daily basis</u>

Options for determining occupancies discharge:

<u>Residential:</u>

1. Water use records
2. Formula in the Code 1602.8.1
3. Local daily per person interior water use

<u>Commercial, Industrial, & Institutional</u> (CII):

1. Water use records
2. Formula in the Code 1602.8.2
3. Other documentation accepted by the local authority

Daily Discharge (1602.8.3). *Gray water systems using tanks shall be designed to minimize the amount of time gray water is held in the tank and shall be sized to distribute the total amount of estimated gray water on a daily basis*

Exception: *Approved on-site treated nonpotable gray water systems*

Which procedure do you think is most accurate?

How would over or under estimating flow affect the system?

Steps to Determine Graywater Irrigation Fields

Four Step Process:

Step 1: Determine legal and actual daily output of graywater fixture(s)

Step 2: Determine required irrigation field size for legal daily output based on soil type

Step 3: Estimate the water budget (gallons/day) for peak ET month for each Hydrozone

Step 4: Cross check and adjust

Step 1: Estimating Residential Graywater Production

Graywater production based on actual water usage:

- Laundry only: (# loads/week) x (measured gallons/load) = gallons/week
- Showers, bathtubs, and wash basins: (water use per fixture/week) x (number of occupants) = gallons/week

Graywater production based on Code formula (1602.8.1):

1. Estimated graywater
   - Laundry = 15 GPD per person
   - Showers, bathtubs, and wash basins = 25 GPD per person
2. Number of occupants
   - 1st bedroom = 2 people
   - Additional bedrooms = 1 person
3. To estimate graywater multiply the number of people by estimated graywater production per-person

Activity 2: How much residential discharge is generated based on 1602.8.1?

Calculate how much graywater discharge is generated?

1. From the laundry of 2 people in a 3 bedroom house?

2. From the shower of 1 person living in a 4 bedroom house?

3. Total graywater from a 3 bedroom house?

Step 2: Sizing Irrigation Fields

Use the estimated gallons per day that will be emitted (gal/day) and the maximum absorption capacity of the soil type (gallon/ ft^2 /day) from Table 1602.10* to determine the minimum irrigation field size:

(___ gal/day / ___ gallon/ ft^2 /day) = ____ ft^2

*Table 1602.10 provides min. ft^2 of irrigation field per 100 gallons of estimated graywater discharge. Divide 100 by min. ft^2 to get gallon/ft^2/day.

Step 2: Sizing Irrigation Fields

Mulch basins should be sized to provide sufficient surge capacity for graywater

- Rule of thumb: size mulch basins in accordance with Table 1062.10 and 1 ft. deep
- Alternative method:
  - Approximately 20% of the volume in a mulch basin is occupied by mulch (depending on material used)
  - Surge capacity of mulch basin = (gallons of estimated graywater discharge per day / 7.48 gal/ft^3) / 0.80
  - (___ gal/day / 7.48 gal/ft^3) / 0.80 = ____ ft^3
- Ensure volume of mulch basin exceeds calculated surge capacity

Activity 3: Irrigation Field Sizing Examples

Using Table 1602.10 'Design of Six Typical Soils' calculate the minimum graywater irrigation field area.

Scenario	**Minimum Irrigation Area**
Example: 80 gpd in fine sand	80 gal/day / 4.0 gal/ft^2/day = <u>20 ft^2</u>
1. 100 gpd in sandy loam	
2. 40 gpd in sandy clay	
3. 40 gpd in clay with small amounts of sand or gravel	
4. 80 gpd in course sand	

Step 3: Estimate Water Budget

Water Budget = gallons of water required per day

Water Budget = 0.62 x Area x ETo x Pf

- 0.62 = constant that converts inches to gallons (0.62 gallon in 1” of water covering 1 ft^2)
- Area = Hydrozone* canopy area (ft^2)
- ETo = Peak reference evapotranspiration (use the month with the highest Eto) (inches)
- Pf = Plant factor for hydrozone

*Hydrozone: A grouping of plants with similar water requirements (low, medium, or high plant factor)

Step 3: Estimate Water Budget

Example: Determine the water budget for an apple tree with a five foot drip line radius in Santa Rosa

Water budget = 0.62 x Area x ETo x Pf

- Water budget = gallons of water required per month
- 0.62 = constant that converts inches to gallons
- Area of apple tree = 3.14 x 5^2 = 78.5 ft^2
- ETo (July) = 6.51” or 0.22”/day
- Pf = Plant Factor = 0.5 (medium water use tree)

Water Budget = 0.62 x 78.5 ft^2 x 6.51” x 0.5

= <u>158 gal/month</u> or <u>5.3 gal/day</u>

Step 3: Estimate Water Budget

Example: Determine the water budget for an almond tree with an 8 foot drip line radius in Healdsburg.

Water Budget = 0.62 x Area x ETo x Pf

- Area of almond tree = 3.14 x 8^2 = 201 ft^2
- ETo (July) = 7.44”/month or 0.23”/day
- Pf = Plant Factor = 0.5 (medium water use tree)

Water Budget = 0.62 x 201 ft^2 x 7.44” x 0.5

= <u>464 gal/month</u> or <u>15.5 gal/day</u>

Activity 4: Estimating Water Budgets

1. Estimate the water budget for a lemon tree (Pf of .5) with a 3 foot radius drip line in Monterey/Salinas/Santa Cruz (zone 2)

2. Estimate the water budget for a 50’x 30’, CA native, drought tolerant landscape (Pf of .3) in Santa Clara-San Jose (zone 8)

3. Estimate the water budget for a 100’ x 100’ home vineyard (Pf of .4) in Sacramento (zone 14)

Step 4: Cross Check and Adjust

Total area of hydrozones (=) or (>) minimum required irrigation field size (Table 1602.10)?

- If No, expand hydrozone/irrigation field area to meet code requirement

Does the total Water Budget for hydrozones match actual graywater output?

- Total Water Budget gal/day (=) (>) (<) graywater output gal/day
- If the Water Budget is more than 20% > graywater output, plants may experience drought stress and/or require supplemental irrigation

Design Strategies for Graywater Production

- Design system so graywater production meets <u>peak</u> irrigation requirement
  - No supplemental irrigation required
  - Excess graywater production wasted when irrigation demand is lower
- Design system so graywater production meets <u>average</u> irrigation requirement
  - More efficient use of available graywater
  - Supplemental irrigation required during driest months
- Design a system capable of distributing graywater according to varying plant type and seasonal demand
  - Efficient use of graywater
  - Complex and expensive to install

Water Conscious Household Example Scenario

- 4 bedroom house, 5 occupants
- Local weather data zone 5 (Santa Rosa, Eto = 6.51)
- Clay soil w/ small amount of sand
- 5 min shower/day average
- Shower only (flow-rate is 1.5 gpm)
- Client would like to irrigate a mature fruit tree orchard (Pf = .5) with 6’ radius drip lines around each tree
- Use the actual data from the house instead of the code estimates

Four Step Process – Example Scenario

Step 1: Determine the output of graywater fixtures (find code estimate and actual data)

- Code estimates: 5 occupants x 25 gal/day = 125 gal/day
- Actual data: 5 occupants x 1.5 gal/min x 5 min/day = 37.5 gal/day

Step 2: Determine required mimimum irrigation field size

- 37.5 gal/day / 0.8 gal/ft^2/day = 46.9 ft^2

Step 3: Estimate water budget (gal/month and gal/day) for 1 mature fruit tree

- Area = 3.14 x 6^2 ft^2; Eto = 6.51; Pf = .5
- Water Budget = 0.62 x 113 ft^2 x 6.51 x 0.5 = 228 gal/month or 7.4 gal/day

Step 4: Cross check and adjust

- 37.5 gal/day / 7.4 gal/day = 5.07
- The orchard will need about 5 trees to use all the graywater produced by the shower

Graywater Drip Irrigation Fields

- Filtered pumped systems provide the opportunity to irrigate with graywater using dripperline
- Care must be taken to align the drip system with the estimated graywater discharge volume and rate
- Typically, dripperline length should not exceed 450 ft. as the quantity of water required to pressurize the line would be excessive
- Length of dripperline should be sufficient to ensure that collection container is not at risk of overflowing into the sewer or septic
  - 150 ft. of dripperline will irrigate at 5 gallons per minute (assuming 2 gph emitters spaced 12 in. apart)
  - If graywater is generated at 10 gallons per minute it will build up in the collection container and could overflow into the sewer or septic

Graywater Drip Irrigation Fields

Table 1602.11 prescribes the minimum number of drip emitters to be used for a subsurface irrigation field and the maximum discharge per emitter each day

Type of Soil	Maximum emitter discharge (gpd)	Minimum # of emitters per gallon of estimated graywater discharge per day (gpd)
Sand	1.8	5.0
Sandy loam	1.4	4.0
Loam	1.2	2.5
Clay loam	0.9	1.7
Silty clay	0.6	1.1
Clay	0.5	0.8

Homework: Sizing Graywater Irrigation Fields Scenario

Complete the Sizing Graywater Irrigation Fields Scenario.