3.3 Irrigation of Crops and Other Vegetation

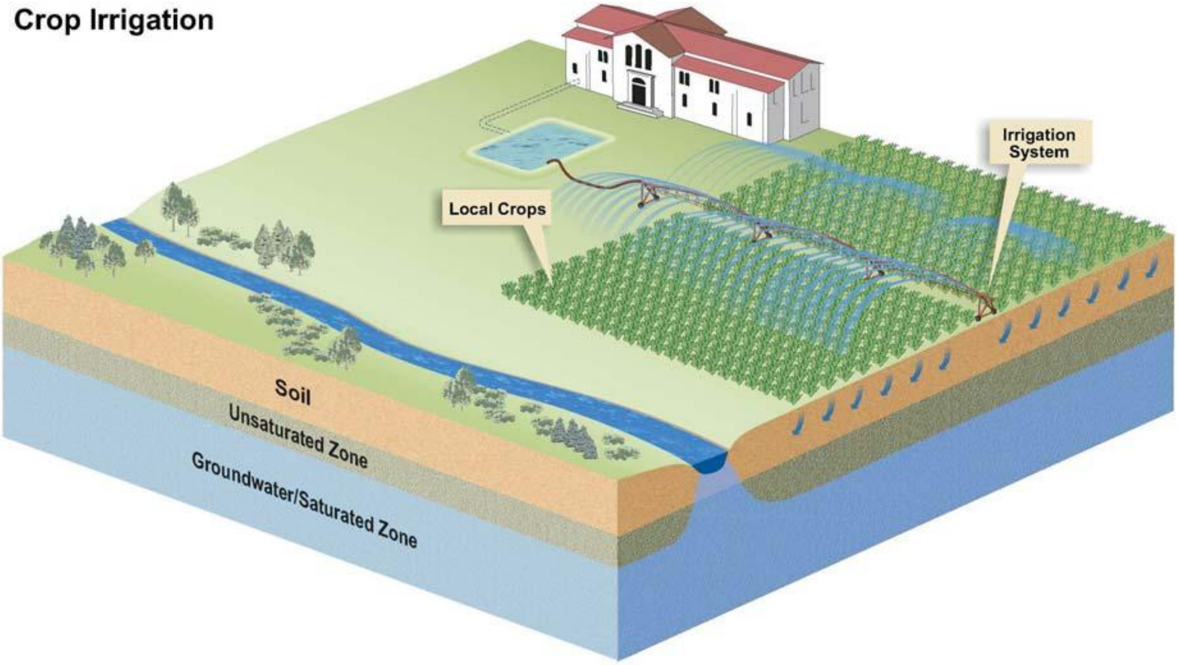
The site selection process requires deeper soil investigation than is commonly prescribed for agricultural purposes.

Some wineries and many food processors treat and discharge process wastewater by using it as an irrigation supply (refer to Guideline Figure 3-3). Irrigation involves slow-rate application to optimize crop growth and uptake of water, nutrients, and salts. Additional manuals that address wastewater irrigation programs: *Manual of Good Practice for Land Application of Food Processing/Rinse Water*, issued by California League of Food Processors (CLFP) in 2007 (CLFP, Brown & Caldwell and Kennedy/Jenks, 2007) and *Land Treatment Systems for Municipal and Industrial Wastes* (Crites et al., 2000).

Irrigation is an excellent method of wastewater reuse that puts both water and nutrients to a beneficial purpose: crop production. Because crops remove nutrients and salts from the wastewater and soil, this method can also be a positive factor in groundwater protection. Most wineries and vineyards have staff with the necessary background and management skills to effectively operate a wastewater irrigation system.

The key challenges for operating a wastewater irrigation program are matching the timing and volume of wastewater generation with crop needs for irrigation (through use of storage capacity, in some instances), and securing sufficient nearby acreage to accommodate the winery's wastewater flows. Some pre-treatment of wastewater may be required depending on the crops to be grown. Figure 3-3 shows, in schematic form, how the soil water supply must be controlled to provide sufficient water for crops, while avoiding percolation below the bottom of the root zone, and still maintaining some capacity in the soil to absorb precipitation.

Figure 3-3: Irrigation Management Schematic



3.3.1 Site Selection

The initial step in site selection for irrigation is to compile the wastewater and site characterization information identified in Table 3-2. Typically, the availability of land and the distance from the facility are key considerations. The site configuration and local area conditions are secondary, but should also be evaluated. These may pose limitations on use of a site and will likely affect the acreage available for irrigation.

For crop production, soil properties are a primary factor in determining the suitability of a site. Soil characteristics that affect water movement and crop growth, and therefore site suitability, include:

- **Depth to groundwater.** Groundwater should be at least 8-feet deep to provide an adequate soil depth to store irrigation and precipitation, as well as additional storage capacity below the root zone to hold any percolation above the level of groundwater. More precise management will be required if groundwater is shallower.

- **Soil profile depth.** If a soil is shallow, it can still be used for irrigation, but the site capacity will be less and more precise irrigation management will be required. In some cases, soil layers that impede root growth and water movement, such as compacted layers, can be corrected with tillage. Other layers will become limitations to the capacity of the site's crops to take up water and nutrients.

- **Infiltration capacity and permeability of site soils.** The soil should have sufficiently high infiltration capacity and permeability to allow irrigation to penetrate with little or no runoff. This can also be addressed by designing the irrigation system to match the soil conditions.

- **Soil available water capacity.** This is the amount of water that can be stored in the root zone, which is important because it is the water available for plant growth. A soil with low storage capacity requires frequent irrigation and careful management to prevent over-irrigation and percolation of water below the root zone.

Although the evaluation procedure is oriented toward identifying sites that are clearly suitable for reuse of wastewater for irrigation, if a site does not meet these standards, it may still be suitable, but additional evaluation or management constraints may be needed.

Table 3-3: Characteristics of a Suitable Wastewater Irrigation Site

CRITERIA	IRRIGATION SITE CHARACTERISTICS[1]
Depth to Groundwater	Greater than 8 feet
Soil profile layering	If layers that could impede water flow or root penetration are present, determine whether these limitations can be corrected.
Infiltration and permeability	Soil profile should have a permeability of 0.2 inches/hour to a depth of 5 feet below ground surface.
Soil chemical/physical properties	• Soil pH should be between 5.5 and 8.5 in all layers • Salinity should be less than 3 dS/m • Exchangeable sodium should be less than 10% • Clay content should be less than 40%
Available water storage capacity (AWC)	AWC should be greater than 4 inches in the top 5 feet of soil
Site layout and local area conditions	Ideally, the site can be divided into fields while maintaining setbacks from property boundaries, surface water and water supply wells. Where possible, buffer strips between the site and neighboring houses or other non-agricultural uses are recommended.

[1] The characteristics presented in this table are to readily identify suitable sites. If a site does not meet these requirements, it may still be suitable, but may require more careful management practices to be successful.

- **Soil chemical properties.** At sites with soil chemical properties that are not optimal, fertilizer and soil amendments can sometimes be added to overcome limitations. However, under some conditions, soil chemistry may still cause a site to be unsuitable. Specifically:
    - Soil pH can be adjusted to fall within the acceptable range of 5.5 to 8.5, but it should be noted that the common effect of winery wastewater irrigation is a lowering of surface soil pH.
    - Excessive salinity and/or sodium will likely result in poor crop growth and a low site capacity for wastewater irrigation.
    - High clay percentage is an indirect limitation on crop growth, such that these soils should be avoided, if possible.

If soils with some limitations occur at an otherwise well-suited site, these areas should either be excluded from the irrigation program or separated into a field that is managed appropriately.

After compiling necessary information per Table 3-2, refer to Table 3-3 for site screening. Note that the site selection process requires deeper soil investigation than is commonly prescribed for agricultural purposes. This is necessary because irrigation sites often receive discharges during both the growing and non-growing season and have deeper penetration of water than sites irrigated only during the summer. Although the evaluation procedure is oriented toward identifying sites that are clearly suitable for reuse of wastewater for irrigation. If a site does not meet these standards, it may still be suitable, but additional evaluation or management constraints may be needed.

3.3.2 Determining Acreage and Wastewater Storage Needs

To determine acreage and storage needs, the first step is to calculate constituent loadings to the irrigated area. Guidance and examples for this calculation are presented below, followed by instructions for determining acreage and storage needs.

3.3.2.1 Calculating Constituent Loadings

After winery wastewater has been fully characterized (see Step 2, Guideline 1 and Guideline Table 3-2), the dataset can be used to calculate total loadings of wastewater constituents to the land application area. This procedure is shown by example on Worksheet G3-1. The first of the two examples is based on annual wastewater production of 70 MG, assuming average annual concentrations for BOD_5 of 2,000 mg/l; total nitrogen of 30 mg/l; and salinity of 750 mg inorganic dissolved solids (IDS). This approach is suitable for a first assessment of loading, but the same calculations should be made using monthly or seasonal data to determine the acreage requirement for the facility.

A loading is calculated by multiplying the total flow by concentration, and applying appropriate conversion factors. For example:

Loading (lb/Ac) = Flow (Ac-in//Ac/yr) x Concentration (mg/l) x 0.23

or

Loading (lb/Ac) = Flow (MG/Ac/yr) x Concentration (mg/l) x 8.3

3.3.2.2 Determining Acreage Requirements

Once individual constituent loadings are determined, they can be compared to per-acre loading limits. Loadings for irrigation rate and key constituents are established as follows:

- **Irrigation Rate.** This is based on the irrigation requirement for specific crops plus some amount of water that may be applied before or after a crop to prepare the site for the following crop. The irrigation requirement incorporates local climate (precipitation and evaporation rate) as well as specific crop requirements. In the example shown, crop irrigation requirements for grass hay are used: 48 inches per year. This allows an application of 1.3 MG per acre per year. In Table 3-4, irrigation amounts are shown for a variety of climatic regimes, primarily in California and the Pacific Northwest. The common range for hydraulic loading for winery wastewater ranges from 0.5 to 1.5 MG per acre.

- **BOD_5.** Loading rate recommendations for BOD_5 were established many years ago when the initial studies of wastewater effects on land application were conducted (EPA 1977). The rule of thumb from these studies was that 300 pounds per acre per day would result in applications that would not result in nuisance odors and other impacts. It has been observed in ongoing wastewater management programs that this value is quite conservative for land application, especially in the growing season when biological processes are active. BOD_5 concentration does impact the potential to recycle wastewater within facilities and may also affect the reliability of some irrigation systems.

- **Total Nitrogen.** The nitrogen application limit is generally termed the "agronomic rate", or the amount of nitrogen addition required to produce a standard crop yield. It is often equated to the amount of nitrogen a crop takes up before harvest which must be replaced for the next crop season. When applied to total nitrogen, this limit is generally conservative because not all the nitrogen applied is available to crops (Crites et al., 2000).

- **Salt Loading.** In arid regions, accumulation of salts has an important impact on soil quality, groundwater quality, and crop growth. In these areas, salt loading limits, expressed as fixed dissolved solids (FDS) or electrical conductance (EC), have been set based on the amount of salt taken up by a crop. Values range from 500 pounds per acre per year for biomass crops to over 2,000 pounds per acre per year for double crop or perennial crop farming practices.

The applied loads and loading limits for various constituents are used to determine the acreage requirements for a land application system. Specifically, the total number of acres needed is found by dividing the total load for each constituent by the loading limit per acre for that constituent. The highest acreage requirement among these results is the acreage that must be available each year for the system. The constituent that required the largest acreage is thus termed the limiting constituent. If the applied irrigation volume dictated by the limiting constituent is less than crop's irrigation needs, then wastewater irrigation will need to be supplemented with an additional irrigation supply to provide sufficient water for crop growth.

As a practical matter, the maximum acreage calculated for each wastewater constituent is increased by 25 percent during system planning and design so that there is extra acreage available. This acreage will be needed when additional wastewater is generated in some years. In addition, the extra acreage allows the manager of the land application area to rest some areas or temporarily remove some acreage from production in order to perform occasional maintenance or soil improvement tasks.

3.3.2.3 Determining Storage Needs

Acreage requirements should be determined in conjunction with storage plans. Temporary wastewater storage is beneficial because it allows mixing of wastewater, contributing to more consistent wastewater characteristics. A minimum storage volume for mixing can be estimated as the volume of the maximum monthly average daily flow. This can be determined by dividing the total flow for each month by the days of operation during that month, and selecting the maximum value, which usually occurs during crush.

Storage is commonly used as an opportunity to perform some pretreatment of wastewater; the most common treatment is aeration to decrease BOD_5 and total nitrogen. Minimum storage required to accomplish these objectives may be roughly the volume of total flow during one week of operation.

Larger storage volumes are valuable because they give the land application manager the flexibility to operate the system for best results, such as defering irrigation during poor weather conditions. Further, water produced by the winery during the winter can be held until the summer, when evaporative demand is higher and additional water supply is beneficial. If sufficient storage is available to avoid irrigation during months when precipitation exceeds evapotranspiration, the irrigated acreage requirements can be reduced substantially. These calculations are complex because they incorporate trade-offs in a number of variables that are specific to the site and wastewater characteristics.

3.3.3 Other System Design Considerations

Development of an irrigation system includes engineering design for water delivery mainlines, pump stations, and in-field irrigation systems. It is likely that there will be two sources of water to be delivered to the irrigation fields: wastewater and a supplemental water supply. It is becoming increasingly common to equip wastewater irrigation systems with automated controls, computerized data collection, display of real time monitoring information, and soil moisture monitoring in irrigation areas to provide detailed information for scheduling irrigation and other crop management activities.

Table 3-4: Irrigation Requirements for Selected Crops and Climates

	Average Annual Precipitation[1]		Irrigation water requirement for grass hay			Irrigation water requirement for winter wheat		
Location	Winter (inches)	Summer (inches)	in/yr	MG/Ac/yr	Irrigation Period	in/yr	MG/Ac/yr	Irrigation Period
Lodi CA	15.7	1.9	33.3	0.9	Apr - Oct	18.7	0.5	Mar - Oct
Fresno CA	9.7	1.2	34.5	0.9	Mar - Oct	20.4	0.6	Mar - Oct
Napa CA	20.4	2.6	25.6	0.7	Apr - Oct	13.4	0.4	Apr - Sep
Salinas CA	13.3	1.3	25.8	0.7	Apr - Oct	15.7	0.4	Mar - Oct
Santa Barbara CA	16.6	1.1	26.4	0.7	Apr - Oct	15.1	0.4	Mar - Oct
Temecula CA[2]	10.2	1.1	30.6	0.8	Mar - Nov	18.9	0.5	Mar - Nov
Mendocino CA[3]	33.1	5.0	15.4	0.4	May - Sep	6.9	0.2	Apr - Sep
Auburn CA	30.5	4.0	31.5	0.9	Apr - Oct	15.7	0.4	Apr - Sep
Richland WA	4.8	2.3	41.5	1.1	Mar - Oct	24.0	0.7	Feb - Oct
Aurora OR	30.5	10.7	18.4	0.5	May - Sep	6.4	0.2	Apr - Aug
Rochester NY	15.3	18.7	13.2	0.4	Apr - Oct	7.1	0.2	Apr - Oct

Notes:

[1] Winter duration: November – April; Summer duration: May - October

[2] Precipitation data from Elsinore, CA

[3] Precipitation data from Fort Bragg, CA

3.3.4 Daily Operations and Program Management

The basic operations of land application of wastewater are similar to conventional agricultural irrigation but are more complex due to the need to account for the application rate of constituents in the water. This is commonly done by determining the amount of wastewater that can be applied to each crop and field under irrigation. This planning step establishes how much wastewater can be applied; simple daily or weekly accounting of application amounts provide the information needed to determine when to switch from wastewater application to irrigation with supplemental water.

The decision about when to irrigate fields is made based on two factors: the soil moisture status of the fields (the need to irrigate for crop water use) and the available capacity of storage. When the facility's storage is nearly full, irrigation must be scheduled to avoid overfilling the storage. In practice, irrigation is scheduled on the driest fields during periods of clear weather during the winter to maintain some storage capacity.

3.3.4.1 Regulatory Considerations

Land application systems that discharge using irrigation commonly have wastewater discharge permits that are issued by a State agency. In Oregon, California, and Washington, state agencies have a responsibility to protect groundwater. In some cases, usually operations that only discharge during certain seasons, general permits for discharge may be available. It is more common for a winery to have an individual permit with conditions and requirements specifically tailored to the operations of the facility. The permittee is required to follow prescribed operating guidelines, perform routine monitoring, and report results to the agency.

3.4 Spreading Basins for Rapid Infiltration

Many wineries treat and discharge process wastewater by flood application to uncropped, bermed areas referred to as spreading basins (refer to Guideline Figure 3-4). This method involves periodic application of wastewater using a technique called rapid infiltration (Crites et al., 2000). When wastewater is applied to a spreading basin, it displaces the water in the soil profile by pushing it downward under the force of gravity. The applied wastewater is then allowed to remain in the soil to be treated by natural soil processes. The basic steps in spreading basin treatment of wastewater are shown in the first three panels of Figure 3-5, shown on the following page and as summarized below:

- Rapid infiltration begins with a wastewater application to initiate a period of wet soil conditions. Much of the applied BOD_5 is oxidized very rapidly upon application.

- The remaining BOD_5 establishes an anaerobic treatment zone. Refer to the Application (Cycle 1) frame in Figure 3-5. Most of the organic nitrogen applied is converted to ammonia-nitrogen.

- The next period of time, known as a resting cycle or drying cycle. Refer to the Resting frame of Figure 3-5. This allows time for air to re-enter the profile either due to evaporative water loss or soil drainage. During this time, remaining organics are oxidized and ammonia-N is converted to nitrate-N.

- The second application cycle to the spreading basin again establishes an anaerobic treatment zone. Refer to the Re-Application frame in Figure 3-5. A significant fraction of nitrate-N (up to 95% removal has been documented in recent studies (Wine Institute, 2004)) is reduced to gaseous nitrogen and lost to the atmosphere, and BOD_5 is oxidized as before.

This treatment method is effective because the wastewater applied to land first consumes oxygen, and then oxygen is re-introduced during the drying cycle. By managing the application cycles to achieve alternating anaerobic and aerobic conditions, treatment and removal occur in the upper layers of the soil. Residual solids in the wastewater are filtered out and dry on the surface of the checks during the drying cycle. After drying, the soil may be scarified or disked before the next application of wastewater. Some wineries plant cover crops in a spreading basin during spring or summer, when wastewater flows are low