Guideline 3: Wastewater Discharge to Land

This section provides guidelines to evaluate wastewater discharge alternatives that can be appropriate for specific winery site and operating conditions. To begin the evaluation, wastewater characterization information must be obtained or estimated, as recommended in Step 2 of the Winery Evaluation Process and Guideline 1 for Data Collection. In particular, both the total wastewater flow and the water quality must be known or estimated for the range of typical operating conditions (e.g, crush, non-crush, etc.) and associated seasonal variations. Once the characterization process is complete or at least underway, various discharge options can be evaluated as detailed below to design an appropriate system for managing the discharge, given the specific conditions and constraints at the winery and the owner's objectives.

3.1 Overview of Land Application Methods

The most common methods of wastewater discharge to land are:

1. **Discharge through a Septic Tank and Drainfield System.** This is a common solution for wineries with small wastewater flows in regions where site conditions are appropriate and regulations are not prohibitive. The discharge occurs beneath the ground surface and is typically located close to the facility.

2. **Irrigation of Wastewater on Agricultural Crops.** This is another common method, especially for wineries with adjacent agricultural or vineyard acreage. It is also referred to as slow-rate application (Crites et al., 2000).

3. **Land Application via Spreading Basins.** This technique, also known as rapid infiltration or high-rate application, makes use of permeable basins where wastewater can be discharged in larger volumes than a discharge for irrigation.

4. **Constructed Wetlands.** Discharge to a constructed wetland is most effective as a polishing treatment step before final discharge or irrigation reuse.

The general procedure for designing a system using any of these methods involves the same series of evaluation steps, as summarized in Guideline Table 3-1 and described in greater detail below.

3.1.1 Site Selection

A suitable site for wastewater land application has appropriate soil characteristics and subsurface properties that can sustain crop growth. As with agricultural land uses, medium-textured soils that are at least 5 feet deep with little slope are preferred. In practice, however, the location of an available parcel with respect to the winery is critical, and a wide variety of soil and site conditions can be adequate if proper management practices are used. Key factors that need to be evaluated when considering a prospective site include: soil properties, depth to groundwater, slope and topography, and neighboring land uses. Some of the required information is available from published soil surveys (www.websoilsurvey.nrcs.usda.gov), but for best results, a field evaluation of any prospective site is recommended.

3.1.2 Wastewater Characterization

As noted above, wastewater characterization is a critical precursor for design of any system for land application. In addition to the initial wastewater characterization, land application systems require ongoing monitoring because both wastewater quality and site characteristics change seasonally over the course of a year. Summer growing season conditions are well suited for wastewater discharge to land, while non-growing season (winter) conditions are less well suited. The primary reason for this is that biological processes that accomplish treatment of wastewater in soils and wetlands are much less active during cold weather.

3.1.3 Determining Acreage and Wastewater Storage Needs

The acreage of a land application system and wastewater storage requirements are closely related and commonly determined at the same time to find a balance that works for a given system. With more storage, less acreage is needed for irrigation, spreading basins, or wetlands treatment systems. But the exact

Table 3-1: Overview of Land Application Alternatives and Selection Criteria

Criteria	Land Application Methods: Septic Tank – Drainfield	Irrigation	Spreading Basins	Constructed Wetland
Site Selection	All methods require evaluation of soil properties, depth to groundwater, slope and topography, and neighboring land uses			
Wastewater Characterization	All methods require characterization of wastewater flow and chemistry (refer to Step 2 of the Guide). Wastewater quality (including pH, nitrogen, BOD_5, and salinity) is a critical component of design for irrigation, spreading basins and constructed wetlands			
Acreage Requirements	Requires only small areas because it is generally used for small flows.	Acreage depends on crop, irrigation water requirement, winter precipitation, and wastewater storage capacity available	A complex analysis is required, but acreage may be half of that required for irrigation	Size and specific components are specified after a detailed analysis. Acreage required can overlap both irrigation and spreading basins.
Wastewater Storage Requirements	The septic tank itself provides storage; often sized to hold two days of wastewater generation	Determined based on the same factors used to calculate required acreage for crops/spreading basins, plus the need for storage capacity to provide wastewater mixing.		Wetland design incorporates storage; additional storage is required for mixing.
Management Requirements	No significant day-to-day management necessary.	Skilled management of both the winery and fields/crops is necessary.	Skilled management of the winery is necessary, as well as system monitoring and analysis at least weekly.	Skilled management of the winery is necessary, along with ongoing monitoring and analysis by a trained operator.
Typical Regulatory Requirements*	Permit may be issued by a county agency for small systems, but larger systems sometimes require a state-level permit.	Refer to state-specific and Federal agency requirements. A state or Federal discharge permit is generally needed, depending on the location and proposed activity. In most cases the permit will include monitoring and reporting requirements.		

*Wineries are strongly encouraged to contact their state and local agencies to determine applicable requirements.

relationship between storage volume and land application acreage will be different for every winery due to the variability of site and winery conditions.

Some storage is always valuable for land application systems because storage capacity provides an opportunity for additional mixing of the wastewater coming from various unit processes within a winery, if that was not fully accomplished in an upstream sump or other storage. For example, the acidic wastewater stream from a certain winery process may be offset by mixing it with a higher pH wastewater stream from another process, such as clean-up and sanitation. As a result, the wastewater applied to land is more likely to have a pH close to neutral. Mixing can also be valuable to manage weekly or seasonal variability in wastewater quality associated with different aspects of winery operations. In determining storage needs, it is important to account for the fact that treatment efficiency in soil or wetlands varies seasonally, and is typically not as effective during the cool winter season as it is during dry summer growing months. This means that the winery will rely on greater winter storage capacity.

3.1.4 Managing Daily Operations and the Ongoing Program

Land application procedures range from simply sending wastewater from the facility through storage to discharge at a constant flow rate, to more elaborate procedures that synchronize application to water needs for vegetation growth in an irrigation area. In general, water delivery is simplest for septic tank-drainfield systems because these can be operated with constant flow and without frequent management. Wetlands may also be simple because, during most of the year, steady flows through the wetland are desirable. Spreading basin and irrigation systems are more complex because there are limitations on the duration, volume and quality of wastewater that can be applied in a sustainable manner.

Managing an ongoing land application program is simplest for the septic tank - drainfield method. For the other three methods, management is more complex, requiring initial planning, day to day management, and routine monitoring to provide data for decision-making. In addition, these methods often require a state-level permit for the discharge.

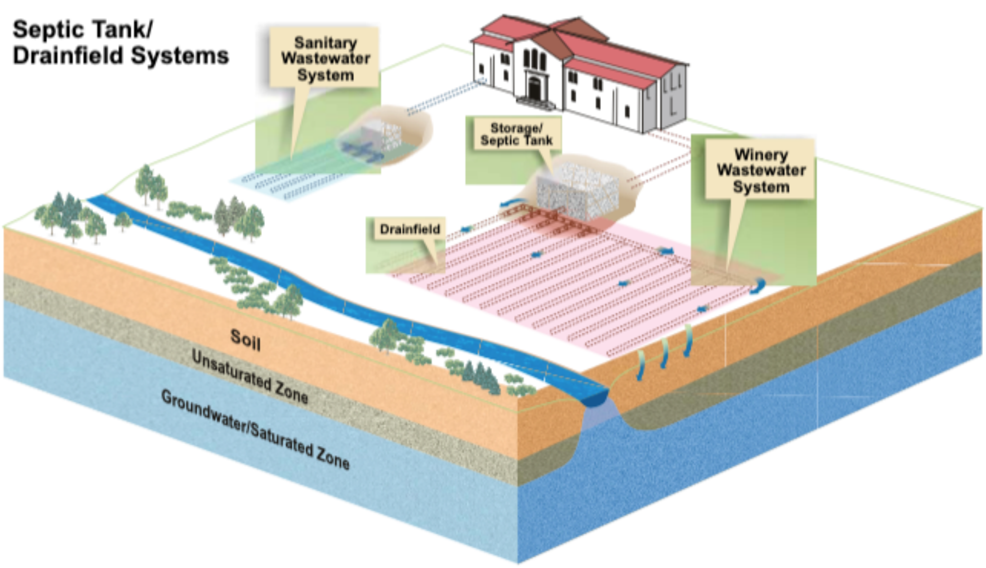
3.2 Septic Tank – Drainfield Systems

For small wineries with low production and wastewater flows, installation of a relatively simple wastewater treatment system consisting of a settling tank (a septic tank) and with a subsurface drainage discharge area (a drainfield) may meet their needs. In these systems, solids are allowed to settle in the septic tank, and the effluent is discharged to an adjacent draining field. The septic tank provides an anaerobic environment where some nitrogen transformations occur and microbes assimilate and decompose organic material. When the effluent is discharged to the soil, aerobic processes consume remaining BOD_5 and convert much of the wastewater nitrogen to nitrate-N.

Figure 3-1 shows the general layout of a septic tank – drainfield system. The figure shows two systems because domestic wastewater from the winery should be kept separate from the winery process water system. Although it isn't mandatory, a septic tank - drainfield system should be laid out to allow gravity flow from the winery through the septic tank to the discharge area, if possible.

Although extensive wastewater characterization data is not needed for initial design of the wastewater system, it is important to obtain wastewater quality measurements on an ongoing basis for analysis of system operations and potential impacts to groundwater. For small systems (less than 2,500 to 5,000 gallons per day, depending on the regulating entity), the owner is generally not required to calculate constituent loadings from the discharge. In some parts of California, however, periodic measurements of wastewater chemistry are required.

Figure 3-1: Septic Tank – Drainfield System Schematic



3.2.1 Site Selection

The suitability of a potential site for a septic system will be contingent on site and local area conditions, soil properties, groundwater elevations, and wastewater characteristics. These factors are summarized in Guideline Table 3-2 and should be addressed when evaluating any land application system.

Soil properties in particular are a primary factor in determining the suitability of a site for a septic system. The physical conditions of the soil that are relevant include soil texture, soil depth, depth to groundwater, and soil layers that may restrict water flow. It is common practice for regulatory agencies to require that soil pits be excavated at the proposed discharge location for their inspection.

Depth to groundwater should be assessed at the site if it is likely to be within 10 feet of the ground surface during any portion of the year. Drainfields are generally required to have at least 3 feet of unsaturated soil beneath the bottom of the discharge trench for proper functioning.

The infiltration capacity and permeability of site soils should be sufficiently high to allow penetration of wastewater. State regulations generally specify the amount of wastewater discharge per unit area based on soil texture. If soils with some limitations occur at an otherwise well-suited site, locate the drainfield system elsewhere.

Soil chemical constituents should be evaluated to provide general information about soil productivity of the proposed location and to document background site conditions. But in practice, this information is not used for design of the septic system.

Table 3-2: General Site and Wastewater Characterization Needs

Wastewater	
Water Quality	See Guideline 1 for additional information about sampling and analysis. Obtain monthly (or at a minimum seasonal) data for: pH, BOD_5, Total N, Ammonia-N, Nitrate-N, TDS, FDS, EC Obtain one-time characterization data for: Na, Ca, K, Mg, Cl, SO4, HCO_3, SAR, P, soluble BOD_5
Water Flow	Irrigation and spreading basin systems: determine average monthly flow and days of operation in order to define acreage and storage needs Septic tank - drainfield systems: determine average daily flow for the peak month of wastewater production
Site	
Site soils	Develop general soil description including soil depth, texture, layering, depth to groundwater, and variability. If possible, determine the depth to groundwater with an on-site boring that provides a log of soil and subsurface conditions. Measure soil properties at representative locations, including: • Chemical properties: pH, salinity, nitrogen, phosphorus, potassium, calcium, sodium, magnesium, chloride, sulfate, cation exchange capacity, soil organic matter percentage • Physical properties: texture, permeability and available water storage capacity Each distinct soil layer from the surface to 5 feet depth should be characterized.
Site layout	Consider shape and size of parcel in the system design and layout. Slope and topography should be gentle.
Local area	Consider distance from the facility, neighboring land uses, available buffers, distance to surface water, distance to nearby drinking water wells.

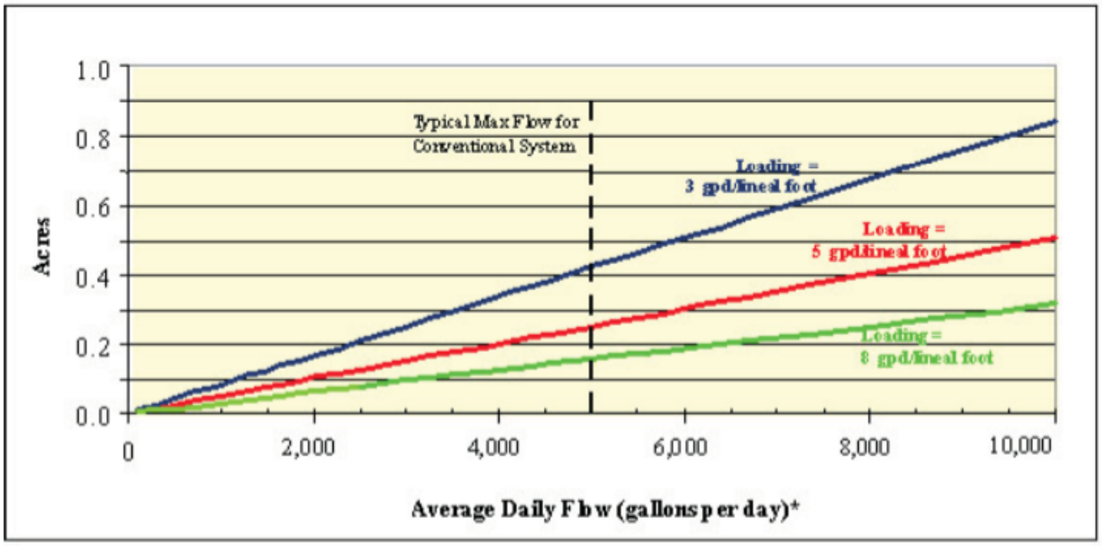
3.2.2 Determining Acreage and Wastewater Storage Needs

Guidelines for determining the drainfield acreage and wastewater storage needs for a septic system are presented in Figure 3-2.

3.2.2.1 Acreage

The most common method for estimating the drainfield size needed for a given discharge rate is to rely on standard handbook values for the acceptable discharge rate per unit area or per lineal foot of discharge trench. These are summarized on Figure 3-2 for three loading scenarios: 3, 5, and 8 gallons per day per lineal foot. The figure can be used to determine the required acreage for a given wastewater discharge rate, assuming a particular soil loading rate. For the wastewater discharge, use the average daily flow during peak flow conditions (typically crush) to ensure adequate capacity. Estimate the loading rate to be used for the system based on soil texture, depth to groundwater, and/or plans to use improved system design features.

Figure 3-2: Drainfield Acreage for Selected Loading Rates



*Average peak season flow.

The dashed vertical line on Figure 3-2 indicates a general upper limit of flow for systems that are permitted using standard design criteria. In most states, to develop a system for greater daily flows the owner will be required to apply for a permit that imposes additional design and monitoring requirements. For this reason, septic tank – drainfield systems are generally used in low wastewater flow situations. It should also be noted that most regulatory agencies require plans for septic systems to identify a second, backup drainfield area to be reserved for use in case the primary drainage area fails. In practice, this doubles the required acreage for a system.

3.2.2.2 Wastewater Storage Requirements

Storage requirements for septic tank – drainfield systems are not based on detailed engineering design considerations but do have good support based on operational experience. In some areas of California, septic tank size requirements are based on the design wastewater flow. It is common to specify a tank sufficient to hold two days of wastewater flow during the peak month of wastewater production. This allows sufficient time for solids settling as well as time for partial treatment of the wastewater through anaerobic processes. During seasons with lower flows, residence time in the tank will be longer.

3.2.3 Other System Design Considerations

Detailed engineering design information is available for septic systems for on-site sewage disposal systems (Salvato, 1995), and much of this information is useful for designing winery wastewater systems as well. Advances in system design that are pertinent to winery wastewater discharge systems include:

Improved drainfield distribution. Drain lines that rely on gravity for distribution often do not achieve uniform application rates throughout the drainfield. There are several methods to improve distribution:

- Periodically discharge wastewater in larger volumes, providing sufficient flow to reach a larger area of the drainfield. This can be done with a water level float or a dosing siphon with no power requirements.

- Install a low pressure distribution system. A system with small-diameter distribution piping and small discharge orifices can achieve very uniform distribution under low pressure.

- Divide the drainfield into smaller zones for more uniform distribution. This method allows for alternating wet and dry cycles, which further improves wastewater treatment.

Shallow discharge for irrigation. Conventional drainfields are installed at depths of 30 inches or deeper below ground surface. A number of shallow discharge designs have been developed to allow beneficial use of wastewater for irrigation water supply. This is particularly appropriate for winery wastewater, which does not have the public health issues associated with sewage (e.g., pathogens).

Solids separation to prevent clogging. Lees, bentonite and diatomaceous earth should be excluded from septic tank – drainfield systems to avoid clogging of the drainfield. Although the septic tank partially protects the drainfield, a separate system for these larger solid waste streams should be planned.

3.2.3.1 Daily Operations and Program Management

Septic tank – drainfield systems do not require extensive day-to-day management, but ongoing monitoring will improve operations. A program of wastewater flow measurement should be implemented and periodic wastewater sampling and analysis is recommended. These datasets will provide the winery manager with a record of discharges to evaluate ongoing water conservation and pollutant reduction activities at the winery, as discussed in the implementation section of the guide (Step 5). The data may also be useful if questions arise regarding potential environmental impacts.

Specifically, a monthly monitoring and inspection procedure should be established for the wastewater system. Inspection of the various system components can be conducted and recorded in a log book. This will help identify any slowly occurring changes in the system and will also allow identification of operations and maintenance needs (such as periodic septic tank pumping).

3.2.3.2 Regulatory Considerations

Typically a permit is issued by a county agency, but a state-level permit may be required for larger systems. Consult the local agencies in your area for specific requirements. In some areas, regulatory agencies do not allow use of these systems for winery wastewater applications due to the potential for system overloading and clogging. An example of regulatory agency wastewater discharge requirements that includes design criteria for septic systems is provided in Appendix G.

3.3 Irrigation of Crops and Other Vegetation

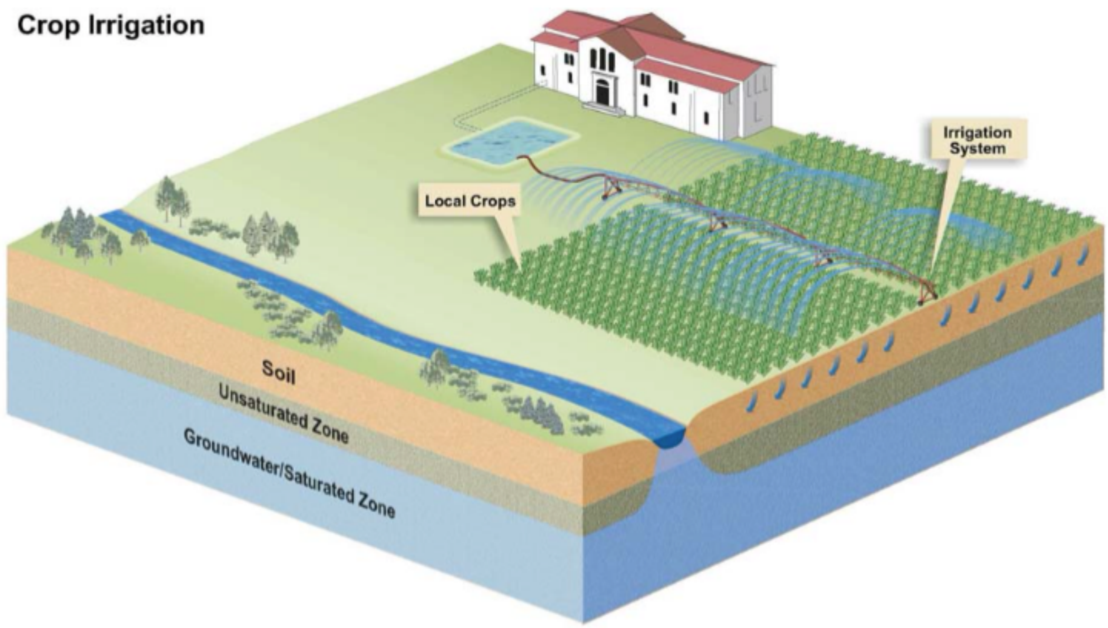
The site selection process requires deeper soil investigation than is commonly prescribed for agricultural purposes.

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.

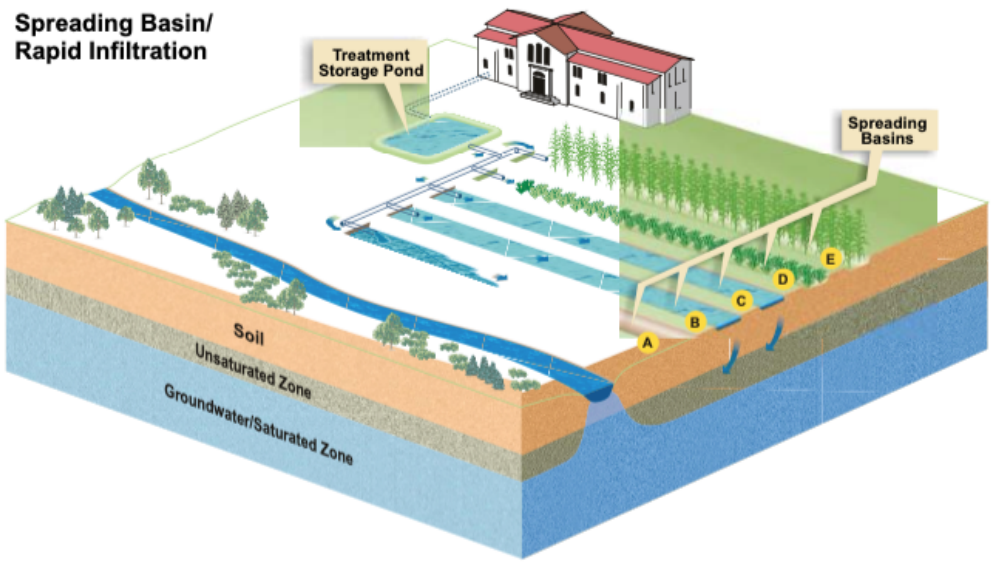
- The remaining BOD_5 establishes an anaerobic treatment zone. Refer to the Application (Cycle 1) frame in Figure 3-5. Most of the organic nitrogen applied is converted to ammonia-nitrogen.

- 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

Figure 3-4: Spreading Basin Schematic



and evapotranspiration is high enough to allow wastewater application to be confined to a smaller area. Crops take up residual nutrients (e.g., nitrogen) and some salts, and those constituents are removed from the spreading basin when the crops are harvested. This helps prepare the spreading basin for reuse.

Rapid infiltration requires careful monitoring and management.

The rapid infiltration method of wastewater treatment is often used by larger wineries because it can be accomplished on a smaller acreage than other methods of treatment and discharge. However, it does require extensive monitoring and management. The Wine Institute conducted a series of field trials on this method to identify best practices (Wine Institute and Kennedy/Jenks, 2004). Findings from the study have been incorporated in this section.

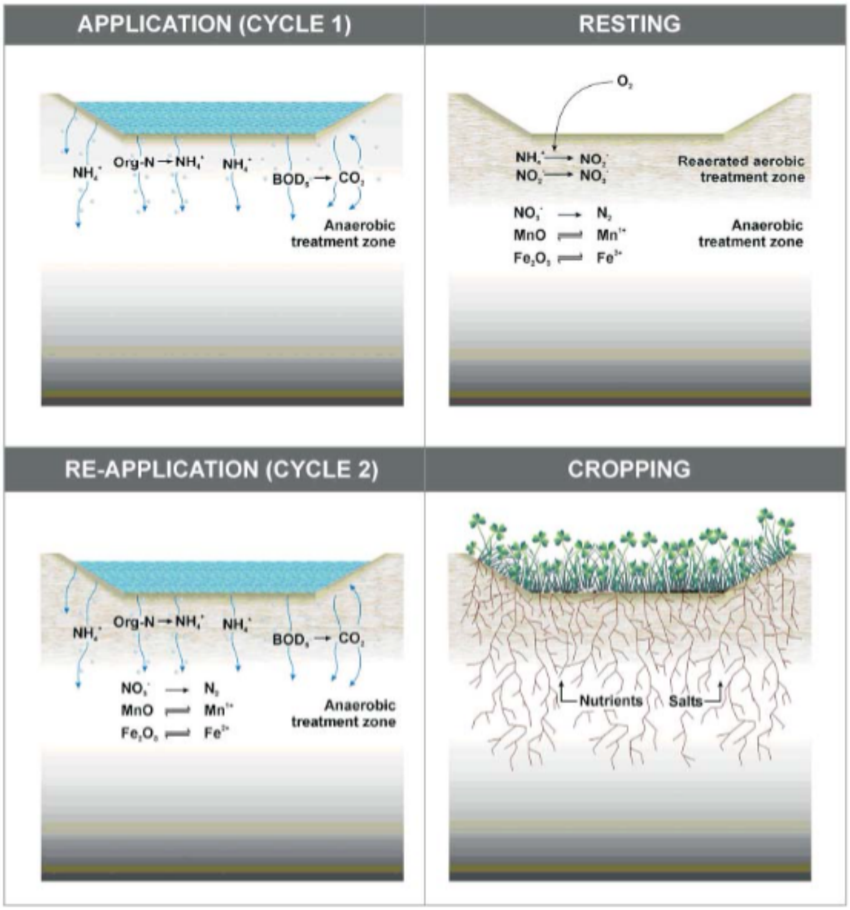
3.4.1 Site Selection

The first step in the site selection process for spreading basins is to compile the general site characterization information specified in Guideline Table 3-2. This information will provide an indication of the general suitability of a site for flood irrigation. 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 that can be used to establish spreading basins.

For spreading basins, soil properties are a primary factor in determining the suitability of a site. Characterization of the soil profile should address physical, chemical and site conditions that affect water flow. Soil chemical analysis is required to address potential groundwater impacts from rapid infiltration. As noted previously, some of this information is available from published soil surveys (http://www.websoilsurvey.nrcs.usda.gov) but, for best results, a field evaluation of any prospective site is recommended.

Note that the site selection process requires deeper soil investigation than is commonly prescribed for agricultural purposes. This is necessary because spreading basin 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 spreading basins, if a site does not meet these standards, it may still be suitable, but additional evaluation or management constraints may be needed.

Figure 3-5: Spreading Basin Treatment Process



Based on the collected data per Table 3-2, evaluation of specific site characteristics should include:

- **Depth to groundwater.** Groundwater should be at least 15 feet deep to provide an adequate unsaturated soil depth for implementing the wet and dry cycles described in detail later in this section. More precise management is required when groundwater is shallow.

- **Soil profile depth.** If a soil is shallow, it can still be used but the site capacity will be less and more precise 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 to transmit water.

- **Infiltration capacity and permeability of site soils.** The soil should have sufficiently high infiltration capacity and permeability to allow the applied water to penetrate. Accordingly, an upper limit for clay content at 20% is provided as a site selection criterion.

- **Soil available water capacity.** This is the amount of water that can be stored in the root zone, which is important because this is where wastewater treatment will occur in a spreading basin system. A soil with low storage capacity requires frequent, small wetting cycles.

- **Soil chemical properties.** The key soil chemical properties for rapid infiltration are those which affect soil microbial activity and soil permeability. Specifically:

Table 3-5: Characteristics of a Suitable Spreading Basin Site

Criteria	Spreading Basin Site Characteristics[1]
Depth to groundwater	Greater than 15 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 0.6 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 20%
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 should be divided into long, narrow spreading basins suitable for uniform surface water application. Setbacks should be maintained from property boundaries, surface water, and water supply wells. If possible, reserve buffer strips between the site and neighboring houses.

[1] The characteristics presented in this table are intended 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 pH. This can be adjusted to fall within the acceptable range of 5.5 to 8.5.
- Excessive sodium concentration would likely to result in lowered permeability; therefore the exchangeable sodium percentage for a soil should be measured.

If soils with some limitations occur at an otherwise well-suited site, these areas should be excluded from use for rapid infiltration. Refer to Guideline Table 3-5 for a full summary of site screening criteria.

3.4.2 Determining Acreage and Water Storage Needs

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

3.4.2.1 Calculating Constituent Loading to Spreading Basins

Land application using spreading basins is limited by the hydraulic capacity of the soil profile rather than wastewater concentrations because wastewater must he held in the soil for a period of time to allow treatment via the processes described above. There are, however, several operational limits based on wastewater characteristics that have been developed from past case studies of spreading basins (Wine Institute and Kennedy/Jenks, 2004):

- Wastewater should have pH values between 3 and 10
- The ratio of BOD_5 to total N concentration in wastewater should be greater than 20 to ensure that anaerobic conditions needed for denitrification will occur during rapid infiltration. If there is too much nitrogen present, spreading basin treatment may not be effective enough.
- Total BOD_5 loading per wetting cycle should not exceed 7,000 pounds per acre.

- The maximum amount of wastewater that can be applied during a wetting cycle is a function of the total BOD_5 load limitation (7,000 pounds per acre). It can be calculated as follows:

  Maximum application per cycle (in/Ac) = 7,000 (lb/Ac) / [BOD_5 concentration (mg/l) x 0.228]

3.4.2.2 Determination of Acreage

Acreage requirements for spreading basin land application can be determined using a rapid infiltration sizing calculation customized for winery wastewater. This is provided as Worksheet G3-2, which includes an example calculation. To complete the calculation, the winery will need to have the following information available:

- **Maximum monthly wastewater flow.** This is expressed in gallons per day. The maximum almost always occurs in the fall, during crush.

- **Maximum hydraulic loading rate.** Two values are needed to determine the maximum wastewater application rate per wetting cycle: (1) the BOD_5-limited application rate calculated in the previous section, and (2) the soil available water capacity for the surface 5 feet of soil, which will have been determined during initial site characterization (Tables 3-3 and 3-5). The lower of these two values is the design loading rate.

- **Soil infiltration rate.** Determined during site characterization.

- **Infiltration rate correction factor.** This is a value used to correct infiltration measurements made at a single point in a field, in order to represent infiltration rates for larger areas (EPA 1981). Past work has shown that single point measurements overestimate infiltration for larger areas. Correction factors can range from 0.04 for measurements with considerable lateral flow, to 1 for measurements made using large basins that simulate spreading basins well.
- **Length of the drying cycle.** The duration required for spreading basin soils to drain or evaporate water to establish aerated conditions must be estimated. EPA guidance provides a range of values. The duration can also be estimated by determining the time required for soil drainage to remove water from the soil profile. During the summer, drying times are shorter than during the winter because the higher summer evaporation rates can remove more water. The climate information in Table 3-4 provides some basis for estimating drying times based on rainfall amounts for the winter season. When developing a design, it is important to review the impact of various estimates of drying cycle duration on the calculated acreage requirements.

Key outputs of the calculation procedure are used to complete next steps to ultimately determine the required acreage of spreading basins. These steps include:

- Calculate the duration of the loading/wetting cycle by comparing the design loading rate to the daily infiltration rate. This determines how long it will take for the design loading rate to infiltrate.

- Once the length of a complete wetting and drying cycle is known for typical winter and summer scenarios, calculate the number of basins required to allow adequate residence time for wetting and drying. Because the drying cycle is longer for winter conditions, the number of basins required is determined by winter conditions.

- Determine the total basin acreage that is needed based on the design facility flow and the number of basins required. The acreage of each single basin can then be calculated.

3.4.2.3 Wastewater Storage Requirements

As with other land application methods, temporary wastewater storage is beneficial for mixing of wastewater with different properties that result from the variety of winery processing and clean-up activities. A minimum storage volume for mixing can be estimated as the volume of the maximum monthly average daily flow (this is calculated by dividing each monthly total flow by the number of days of operation and selecting the maximum value, which usually occurs during crush).

Use of storage as a location for pretreatment of wastewater is generally not needed for spreading basin land application. Larger storage volumes do provide with the flexibility to implement best practices, such as deferring wastewater discharge during portions of the winter when large acreage would be required to long enough resting cycles. If wastewater is stored for any length of time, however, some aeration will be required for odor control.

Winter land application acreage needs are much larger than summer needs (see reference values on Worksheet G3-2). Adding storage capacity to the land application system may be the least expensive solution, with the added benefit of greater flexibility for managing the land application program. One method to determine the effect of storage on land application acreage is to determine acreage requirement for each month of the winter, thereby identifying critical times when additional wastewater storage could significantly reduce acreage needed.

3.4.3 Other System Design Considerations

Development of the spreading basin system should include engineering designs for water delivery mainlines, pump stations, and in-field wastewater spreading. The spreading basin distribution system is often less complex than that required for irrigation systems.

3.4.4 Daily Operations and Program Management

Management of a spreading basin land application system requires more daily oversight than other methods. Daily or at least weekly planning is done to determine which checks can receive water and, based on current wastewater quality measurements, the application amount may change. Another field variable is moisture status of the spreading basins themselves. Current management practices call for some form of soil moisture measurement to determine whether the soil has dried sufficiently to create aerobic conditions needed for complete wastewater treatment.

3.4.4.1 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. Wineries using spreading basins commonly have an individual permit with conditions and requirements specifically tailored to the operations of the facility. The winery is required to follow prescribed operating guidelines, perform routine monitoring, and report results to the agency.

3.5 Constructed Wetlands

Wetlands are an alternative for wastewater discharge that combines wastewater polishing and a biological habitat with aesthetic appeal (refer to Guideline Figure 3-6). These treatment systems are generally best suited for small wastewater flows. A natural wetland system is a biologically active zone that can oxidize BOD_5, reduce nitrates, provide settling for particulates, and remove some wastewater constituents by plant uptake. Constructed wetlands can improve upon the limited performance of natural wetlands by modifying the hydraulic flow patterns and retention time, creating sequential oxic and anoxic environments for wastewater treatment, and incorporating plant species best suited for removal of wastewater constituents. The weakest part of wetlands treatment is considered to be oxidation of BOD_5 and ammonia.

Treatment wetlands have been most successful when employed as a final polishing step following other treatment steps. Treatment accomplished by wetlands is usually not sufficient to serve as a primary biological treatment of wastewaters, with the possible exception of very small systems.

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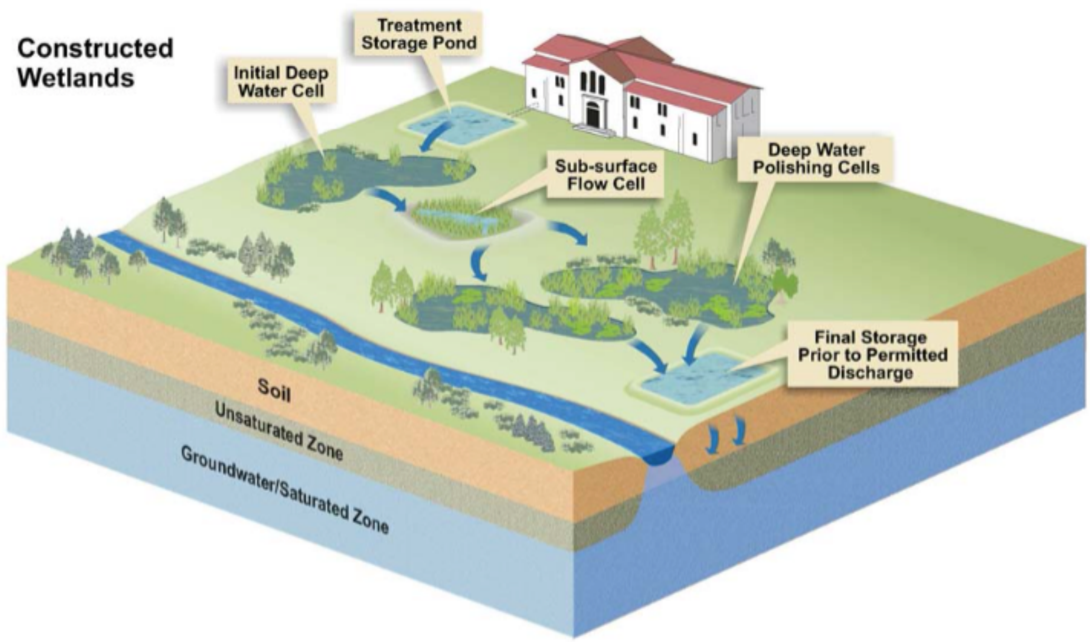
In this section, we provide an overview of design principles for wetlands treatment.

Figure 3-6: Constructed Wetlands Schematic



3.5.1 Site Selection

The suitability of a potential wetlands site will be contingent on site and local area conditions, soil properties, groundwater elevations, and wastewater characteristics. These factors are summarized in Table 3-2. Wastewater characterization or estimation is an important part of the evaluation, including data on seasonal variations. This information is used to determine the wastewater constituent that most limits discharge, usually nitrogen, organic constituents (BOD_5), total dissolved solids, or total volume of water.

Because design of constructed wetlands is highly site specific, guidance could not be provided at the same level of detail as other land application methods.

3.5.2 Acreage Requirements and Water Storage Needs

Wetland treatment systems are generally sized to provide a certain hydraulic retention time, rather than a specific loading capacity. Biological wastewater treatment methodologies that have been applied to wetlands treatment of municipal wastewater were previously summarized by Crites and Tschobangulous (1998).

Free-surface wetlands are sized to accommodate about 12 to 15 acres per MGD of inflow. For short periods of time during the crush season, the wetlands may be able to accommodate higher flows without harmful effects. Accordingly, the design for a new wetlands area should include a deeper section that could potentially provide temporary storage of larger flows. Often, this is accomplished by adding higher banks around a normally shallow wetlands cell so that it can be temporarily inundated for storage.

Detention time in the wetlands will depend on influent quality and effluent objectives, but is often on the order of a week. The wetlands design will need to incorporate sequential aerated and anoxic environments to provide treatment of BOD and nitrogen. In addition, zones with deeper water depths and some filtration through sand or gravel are recommended to provide settling of total suspended solids.

3.5.3 Other System Design Considerations

Long-term management of the wetlands should include periodic maintenance of the berms to address any degradation from animal burrowing and bulldozer work to maintain the desired plant types. In the first two years, non-suitable plants must be periodically weeded. If wetlands are constructed in a flood plain and flooding occurs, restoration may be required, such as reforming the berms and restoring the pipes between wetland cells.

Seepage of treated effluent from a newly constructed wetlands system will decline over time as the wetlands self-seal; algae and organics will sink into the mud, slowing permeability. Because the influent quality will be closely controlled to ensure tolerance of the wetlands, seepage from the system that does occur is unlikely to constitute a source of contamination to groundwater. However, regulatory agencies in some areas may require installation of a fabric or clay liner. Alternatively, if the effluent TDS concentrations are comparable to or below background groundwater concentrations, it may be possible to use the treatment wetlands as a means to recharge groundwater.

An example of a constructed free-surface wetlands system would consist of two or three parallel treatment trains, with three to five cells per train. The bottom surface would be compacted soil. The wetlands would be planted primarily with bulrush or cattails obtained from local sources. Three to five trenches about six-feet deep would be excavated to reduce short-circuiting. The polishing cells would be separated by berms that are wide enough for vehicle access. In between cells, pipes with weirs or other control structures would be constructed. Water in the wetlands would average about two-feet deep.

3.5.4 Daily Operations and Program Management

A wetlands treatment system is designed to accept continuous flow from the winery. For this reason, there are few day-to-day decisions to be made regarding water management. However, there is a need for more active field observations to assess the performance of the wetlands on a daily basis. Daily inspections should include observing the health of the vegetation, water levels in various cells of the wetlands, evidence of animal activity or damage to the system, patterns of flow through the wetlands (water must flow along a slow-moving, circuitous pathway to provide treatment), evidence of algal blooms and discharge water quality. Due to the variability of the biological ecosystem and wetlands conditions, an experienced operator is essential to the success of this treatment method.

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3.5.5 Regulatory Considerations

Wetlands may be subject to regulatory requirements in the design phase, with particular emphasis on plans for the final discharge. If the wetlands are designed to discharge to surface water, a permit will be required to address surface water quality requirements; this permitting process can be arduous. If wetlands are not designed to discharge to surface water, the regulatory agency focus will be on management and monitoring for groundwater protection.