Guidance for the Design of Land Treatment Systems Utilized at Wineries

This guidance document was developed by the Michigan Department of Environmental Quality (DEQ) to provide those within the Michigan winery industry that generate wastewater, which is not treated through a municipal wastewater treatment system, with general information regarding the design of suitable and appropriate land treatment systems to meet their individual needs in relation to protecting the natural resources of the State of Michigan. Discussion of pre-treatment technologies suitable for winery wastewater prior to land application is not included in this guidesheet. The intent of the recommendations made in this document is to ensure the discharge of winery wastewater is conducted in a manner which:

a) will not cause contamination of the water resources of the State of Michigan;
b) will be protective of the environment and public health;
c) will not cause the development of nuisance conditions due to odors or unsightly appearances.

Wineries that discharge their wastewater to the groundwaters of the State of Michigan are required to develop and implement wastewater management strategies which meet the requirements of the Part 22, Groundwater Quality Administrative Rules (Part 22 Rules) promulgated under the authority of Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA).

All wineries discharging their wastewater to the groundwater through land application should apply for a groundwater discharge authorization. *If an authorization is required, the type of authorization will be based upon the information provided on the permit application and the requirements of the Part 22 Rules.* The DEQ is available to discuss any particular questions or concerns an applicant may have regarding wastewater management strategies and the permit process. The applicant can contact the DEQ to arrange a pre-application meeting to discuss the application process.

Overview of Land Treatment of Winery Wastewater

Wastewater generated by wineries typically receives minimal treatment prior to being discharged to the groundwater. As such, these facilities must rely on land treatment of the wastewater to meet groundwater quality standards established in the Part 22 Rules. The choice of what type or method of land treatment system to use (slow rate, overland flow, rapid infiltration, or subsurface soil absorption) as well as the method of wastewater distribution (spray irrigation, vented pipe, subsurface tile, truck mounted applicator, drip irrigation, etc.) is left to the facility.

Some of the factors affecting these choices include: financial resources; staff time and level of expertise required to operate the system; proximity of suitable and available land to the facility; density and proximity of residential dwellings, schools, and/or commercial operations (restaurants, childcare, eldercare); topography and soil characteristics of the site; ownership of the site; current and future volume(s) of wastewater generated (daily and annually); characteristics of the wastewater; and potential odor issues. Land treatment systems are expected to be designed, constructed, and operated with the intent to protect the water resources of the State of Michigan and the public health.

Also, while the choice of land treatment system and means of wastewater distribution are up to the facility, the DEQ reserves its authority under Part 31 of the NREPA to evaluate proposed and existing systems and require any and all changes and or additions the DEQ deems necessary and appropriate to ensure the protection of the waters of the State of Michigan and the public health.

Methods of Land Treatment

The following are brief descriptions of the most commonly used methods used for land treatment of wastewater:

Slow Rate: This method involves application of wastewater to a vegetated land surface with the applied wastewater being treated as it flows through the plant and soil matrix. A portion of the treated wastewater is expected to percolate to the groundwater while the remainder is utilized by plants or lost through evaporation. The distribution of the wastewater typically occurs through spray or drip irrigation technology; however, other technologies or approaches such as distribution from a vehicle mounted apparatus may be acceptable.

Overland Flow: This method involves the application of wastewater to the upper reaches of vegetated slopes with excess wastewater collected at the end of the slopes for reapplication. While capable of providing treatment similar to Slow Rate, in order to function properly, overland flow systems require slowly permeable soils to facilitate the distribution of the wastewater.

Rapid Infiltration: This method involves the discharge of wastewater to basins constructed in areas with highly permeable soils. The applied wastewater receives minimal treatment as it percolates through the soil matrix to the groundwater. The use of this method will require site specific pretreatment of the wastewater prior to discharge.

Subsurface Soil Absorption (Drain field): This method involves the discharge of wastewater through a distribution system placed below ground level. The suitability of this method is largely a function of the soil properties of the site and the extent to which the winery utilizes materials such as bentonite and diatomaceous earth in their processes and, more importantly, their ability to prevent such substances and others (such as lees) from entering the waste stream and eventually clogging the subsurface distribution system. The use of this method may require site specific pretreatment of the wastewater prior to discharge.

The overall procedure for designing a land treatment system using any of the methods described above involves the same step-wise process described at the end of this document.

Dry-wells: The DEQ does not recommend the use of dry-wells as a means of wastewater disposal. The DEQ's extensive experience with food processor wastewater, which is similar in character to that produced by wineries, indicates dry-wells are generally not suitable for wastewater discharge. This is due to concerns with the elevated Biochemical Oxygen Demand (BOD) of the wastewater and the potential to solubilize naturally occurring heavy metals within the soil column. This issue is discussed in more detail later in this document. Those facilities currently using dry-wells are encouraged to begin exploring alternative methods for managing their wastewater**. The DEQ intends to phase out the use of dry-wells by wineries and will be working with facilities through the permit application process to accomplish this goal.**

Land Treatment Design

In order to properly design a land treatment system for a given winery facility, a number of parameters are required to be determined and/or evaluated. Such parameters include the maximum daily discharge volume (MDDV) for both crush and non-crush operations, the maximum annual discharge volume (MADV), wastewater characteristics, soil characteristics of the land treatment site, hydraulic and constituent loading rates, and proper sizing of the land treatment system.

The following provides information regarding these parameters and how they relate to the design of a suitable and appropriate land treatment system. Once these issues have been addressed, the facility can begin considering which method of land treatment and wastewater distribution technology is most appropriate for their situation.

Maximum Daily Discharge Volume (MDDV)

Accurate information regarding discharge volumes is often unavailable. This is due, for the most part; to the lack of discharge flow monitors at existing winery operations. In addition, the nature of how winery wastewater is produced and collected can make measurement of wastewater volume generated prior to discharge difficult. Nevertheless, determining the MDDV is critical to decisions regarding regulatory categorization of the discharge as well as selection and design of land treatment system options.

There are a number of methods for determining the MDDV for a given facility. The most accurate of these is the use of a flow meter specifically installed to measure the volume of wastewater discharged on a daily basis. A second, nearly as accurate method is the use of flow meters and/or run-time meters installed on pumps used to bring water into the facility. The assumption being that the volume of water coming into the facility is equal to the volume being discharged. **The DEQ recommends the use of reliable, properly installed and calibrated flow meters for measuring and monitoring wastewater flows.**

Estimated MDDV

In the absence of actual flow data, it is theoretically possible to estimate the MDDV. The DEQ does not recommend using estimates of MDDV for the purposes of designing land treatment systems. An inaccurate estimate of the MDDV used as part of the basis of design of a land treatment system could lead to miscalculations of a number of critical elements of the system. Nevertheless, if actual flow data cannot be obtained, it is theoretically possible to estimate the MDDV. The following provides two methods for estimating MDDV. The first is the “Napa Valley” formula:

MDDV = (Annual Production $_{(gallons)}$ X 1.5)/Number of Crush Days

The concerns with the use of this approach are that the formula appears to only calculate the average volume of wastewater generated over the duration of the “crush season” and not an estimation of the maximum daily volume of wastewater. The approach also appears to be based on the assumption that all fruit is processed at the winery which may or may not be true. Nevertheless, some facilities have indicated the Napa Valley formula appears to provide a fairly accurate estimate based on their historical data.

An alternative approach to the calculation of MDDV was suggested by an expert from the Michigan wine making industry. For the purposes of this guidance, this alternative approach will be referred to as the “Fenn Valley Method.” This approach considers wastewater generated during the “crush” period as well as those situations where a facility receives pressed juice or just racks the wines (“non-crush”). The greater of the two estimated volumes calculated (crush v non-crush) is to be considered the MDDV to be used in the basis of design of the land treatment system and indicated on the facility's permit application.

The Fenn Valley Method for determining MDDV during the "crush" period is centered on the daily grape processing capacity or the maximum number of tons the facility can physically handle per day. It is assumed that this is essentially a fixed characteristic for a facility which cannot change without structural modifications, additional equipment, increases in staffing, and significant capital expenditure. It is also assumed that one ton of grapes will yield approximately 150 gallons of juice and that 1.4 gallons of water is used for cleaning and rinsing purposes per gallon of grape juice produced during the "crush" period.

The following equation is suggested for use when calculating the MDDV during the "crush" period:

$MDDV_{(crush)}$ (gallons) =
Processing Capacity (tons)/day X 150 gallons juice/ton X 1.4 gallons water used/gallon of juice

While this equation actually calculates the volume of wastewater generated, since winery operations in Michigan do not typically include significant amounts of wastewater storage in their treatment systems, the volume of wastewater generated on a given day is assumed to be the volume discharged to the land treatment system.

The Fenn Valley Method for determining the MDDV for "non-crush" related operations is somewhat different. This calculation is centered on the number of fermentation tanks and their volume(s) that can be emptied and cleaned on a given day. As with "grape processing capacity," it is assumed the maximum number and volume(s) of fermentation tanks that can be emptied and cleaned on a given day at a facility are essentially fixed characteristics for similar reasons. The calculation also assumes that approximately 0.15 gallons of water is used per gallon of fermenter capacity for activities such as pre-rinse, washing, and final rinse. The following equation is suggested for use when calculating the maximum daily discharge volume of wastewater generated from fermentation and racking operations ($MDDV_{(non\text{-}crush)}$):

$MDDV_{(non\text{-}crush)}$ (gallons) = (Volume "$A_{(t)}$" + Volume "$B_{(t)}$" + Volume "$C_{(t)}$" + ……) X 0.15

Where;

Volume "$A_{(t)}$" = Number of volume "A" fermenters X volume "A" (gallons)
Volume "$B_{(t)}$" = Number of volume "B" fermenters X volume "B" (gallons)
Volume "$C_{(t)}$" = Number of volume "C" fermenters X volume "C" (gallons)

Note: The number of fermenters refers to how many fermenters of that volume that can be emptied and cleaned in a given day. Facilities with several fermenters of various volumes should consider all of the possible combinations to ensure the value for $MDDV_{(non\text{-}crush)}$ used for design purposes is representative of the maximum volume of fermentation tanks which can be emptied and cleaned within a given day.

Again, it is important to recognize that estimating MDDV for both crush and non-crush operations are based on assumptions which will not hold true for all facilities. There are some operational scenarios where the actual volume of wastewater generated could be significantly different from the estimates calculated using this approach. The design and construction of a land treatment system represents a significant investment for most winery operations. As such, all facilities are urged to use caution when using estimated MDDV calculated from any method for use in the basis of design of their individual land treatment systems.

Maximum Annual Discharge Volume (MADV)

The MADV is the total volume of wastewater discharged by a facility within a given calendar year. As with the MDDV, the DEQ recommends the use of flow meters for determining MADV. As an alternative, information from other states with significant wine industries, primarily California and Oregon, indicate the unit volume ratio of wastewater generated to wine produced appears to range from 2.9:1 to 8:1. Based on conversations with several Michigan wine producers, this range appears to be fairly reliable in terms of estimating a given facility's annual wastewater volume. The ratio within this range that would apply to a particular facility is largely determined by the water use practices implemented by the wine maker. Thus, a facility that produces 50,000 gallons of wine/year and incorporates no water conservation practices could be expected to generate approximately 400,000 gallons of wastewater/year based upon a wastewater ratio of 8:1. The same facility implementing stringent water use practices could, on the other hand, be expected to generate approximately 145,000 gallons of wastewater/year based upon a wastewater ratio of 2.9:1.

Wastewater Characteristics

Information regarding the characteristics of wastewater from Michigan wineries is somewhat limited. However, as part of a study commissioned by the Michigan Department of Agriculture and Rural Development, wastewater samples from five unidentified Michigan wineries were collected and analyzed for a number of constituents of environmental concern. Wastewater samples were collected over the course of one year on nine separate occasions for each facility. The information provided in Table 1 is the average concentration of the specified constituent for each winery which participated in the study as reported in "A Study in the Effectiveness of Onsite Wastewater Treatment Systems for Michigan Wineries," Final Performance Report to Michigan Department of Agriculture and Rural Development, May 22, 2015 (Study).

Table 1. Average concentrations of selected parameters in wastewater from five Michigan wineries.

		Wineries				
Parameter	Units	A	B	C	D	E
Total Phosphorus (TP)	mg/L	8.62	1.29	5.82	9.19	1.72
Total Inorganic Nitrogen (TIN)	mg/L	4.44	3.64	18.5	8.77	2.63
Sodium	mg/L	396	792	53	124	28
Chloride	mg/L	673	1,500	10.8	53	7.2
pH	S.U.	5.8	6.7	5.5	6	6.8
BOD5	mg/L	2,249	336	3,578	3,111	957

To help ensure appropriate wastewater management and protection of the water resources of the State, the DEQ encourages all Michigan wineries to characterize the wastewaters generated at their facilities. Furthermore, it is in a facility's best interest to conduct such a characterization in order to be confident the land treatment system of choice has been designed appropriately. The DEQ recommends that winery wastewater be analyzed for the following parameters:

BOD_5
Ammonia Nitrogen (NH_3 – N)
Nitrate Nitrogen (NO_3^- - N)
Nitrite Nitrogen (NO_2^- - N)
pH
Total Kjeldahl Nitrogen
Total Phosphorus
Sodium
Chloride

Available information suggests that wastewater exhibiting the highest strength is generated during crush operations. As such, the DEQ recommends collecting wastewater samples during this period for analysis of the parameters listed above. The DEQ is available to provide assistance in developing an appropriate wastewater characterization.

Recognizing that some facilities may find such analyses to be cost prohibitive, in the absence of facility specific wastewater quality data, the DEQ recommends using the default values listed in Table 2 when considering the design and management of land treatment systems used for winery wastewater. The default values in Table 2 were calculated using the average concentration of a given parameter from all five wineries (n=45) plus one Standard Deviation for that parameter as reported in the Study.

Table 2. Default wastewater characteristics

Parameter	Units	Average Concentration	Standard Deviation	Default Value
Total Phosphorus (TP)	mg/L	5.26	4.61	9.87
Total Inorganic Nitrogen (TIN)	mg/L	7.6	9.5	17.1
Sodium	mg/L	279	300	579
Chloride	mg/L	459	612	1071
pH	S.U.	6.13	0.9	7.03
BOD5	mg/L	2,046	1,768	3,814

Biochemical Oxygen Demand and Constituent Loading Rates

Available information indicates winery wastewater, like other food processing wastewater, can and will contain very high concentrations of BOD. Groundwater monitoring data from several sites utilized by food processors around the State indicate impacts from wastewater discharges resulting in high BOD loading rates. The specific impacts are heavy metals such as iron, manganese, arsenic, and lead detected at levels in the groundwater above those allowable under the Part 22 Rules and Part 201, Environmental Remediation, of the NREPA. The mechanism by which this takes place is complex. In brief, the presence of the heavy metals in the groundwater at these locations is caused by the development of anaerobic conditions within the soil. These conditions develop as a result of oxygen being consumed by aerobic organisms metabolizing organic substrates, such as carbohydrates, which comprise the BOD in wastewater. Once oxygen is no longer available, organic substrates in the wastewater are metabolized by anaerobic organisms. The metabolic activity of these organisms and the environmental conditions produced by their activity results in the chemical reduction of naturally occurring heavy metals in the soil by a variety of direct and indirect pathways. Once reduced, the metals become water soluble, thus mobile and eventually leach into the groundwater.

The Part 22 Rules do not specify a limit for BOD in wastewater or groundwater; however, to address the observed impacts, the DEQ recommends limiting the concentration of BOD in effluents to 30 mg/l prior to discharge. For facilities discharging wastewaters with BOD concentrations above 30 mg/l, the DEQ recommends limiting daily BOD loading rates to land treatment systems to 50 LBs/acre. This recommendation is based on the results of a study conducted at Michigan State University. Facilities proposing discharge strategies with BOD loading rates above 50 LBs/acre/day will be required to demonstrate to the DEQ's satisfaction, that the approach does not result in contamination of the groundwater resource.

The following equation may be used to calculate the estimated maximum daily quantity (in pounds) of a constituent, such as BOD discharged based on a known or assumed maximum concentration of the constituent and the MDDV:

$(MDDV_{gallons}/1,000,000) \times Constituent_{mg/L} \times 8.34 = LBs\ constituent$

Example:
The quantity of BOD discharged from a facility with a MDDV of 700 gallons with a BOD concentration of 12,000 mg/L is:

(700 gallons/1,000,000) X 12,000 mg/L X 8.34 = 70 LBs BOD

For design purposes, this calculation should be performed for each constituent of concern in the facility's wastewater. This equation may also be used to calculate annual loading rates if necessary. Simply use the MADV in place of the value for MDDV.

Site Soil Characteristics

The DEQ anticipates most wineries will want to use soil information published by the USDA, Natural Resources Conservation Service (NRCS) in their design calculations. This information may be accessed through the "Web Soil Survey" which is owned and maintained by the NRCS at:
http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx or found in hard copy Soil Surveys published by the NRCS for individual Michigan Counties. The soils information provided by the NRCS includes detailed descriptions of soil profiles, seasonal high water table depth, limitations for specific uses, soil permeability, and more.

The Part 22 Rules allow for the use of published NRCS soils data which are often used for the purposes of design and evaluation of land treatment systems in Michigan. However, if the soil beneath the point of discharge has been excavated, replaced, or modified, published information may no longer apply and on-site testing may be necessary.

When published information regarding soil permeability is utilized for calculating hydraulic loading rates, and it is given as a range of expected values, use seven percent of the minimum value given the most restrictive soil layer within the solum (0 - 60 inches typically) as required by Part 22 Rules [R 323.2233(4)(a)(v)].

Example:

Published data for a proposed site indicates the most restrictive soil layer occurs at a depth between 12 and 18 inches and has a permeability that ranges from 1.0 – 4.0 inches/hour (in/hr). The maximum daily hydraulic loading rate for this site would be:

1.0 X .07 X 24 = 1.68 acre-inches/day (in/d)

0ne acre-inch equates to 27,150 gallons distributed over one acre or approximately 0.6 gallon/square-foot (one acre = ~43,560 square feet). Thus, the soil at this site is hydraulically suited to receive up to 45,612 gallons per acre per day (~1.0 gallon per square foot per day)

Sizing of Land Treatment Systems

The size of a facility's land treatment system is a function of the information and calculations discussed earlier. It is important that maximum daily values rather than averages be used in the basis of design of the land treatment system. Using average values for the purposes of designing a land treatment system will likely result in the system frequently being overloaded and thus unable to provide adequate treatment of the wastewater. This in turn will result in negative impacts to the groundwater and potential downgradient users of the resource.

Discharge Management

The soil environment provides a variety of mechanisms by which winery wastewater may be treated. However, in order for these mechanisms to function as needed, the wastewater must be applied in a controlled manner. Loading rates as well as the frequency of application should be adjusted to the physical, chemical, and biological characteristics of the soil to which the wastewater is applied in order to achieve the level of treatment required.

Land treatment systems are expected to be managed to maintain aerobic conditions within the soil and allow time between applications for soil organisms to aerobically metabolize organic constituents in the wastewater. In general, the lower the loading rate and longer the period between applications, the better.

Nutrient loading, principally nitrogen and phosphorus, resulting from the land application of winery wastewater limited by the BOD loading rate of 50 LB/acre/day is not expected to exceed loading rates associated with typical residential on-site wastewater treatment systems. As such, nutrient loading under these conditions is not expected to require additional consideration in relation to discharge management.

Example Design Process

The following example provides a suggested step-by-step process for determining the required area of a land treatment system based on the MDDV as determined using the Fenn Valley Method and the default values for wastewater characterization from Table 2:

Example Facility Specifics:

Maximum annual volume of wine produced:	*20,000 gallons (~8,000 cases)*
Grape processing capacity:	*10 tons/day*
Fermentation tank configuration:	*12 @ 1,500 gallons*
	8 @ 1,200 gallons
Maximum daily tank processing capacity:	*2 @ 1,500 gallons + 1 @ 1,200 gallons*
Water conservation practices:	*Moderate*
Annual wastewater to wine ratio:	*5:1*
Wastewater Characterization:	*Table 2 default values*
Minimum reported soil permeability:	*0.5 inch/hr*

Step 1. Calculate the MDDV for crush and non-crush operations.

$MDDV_{(crush)} = 10 \times 150 \times 1.4 = 2,100$ *gallons/day*

$MDDV_{(non\text{-}crush)} = [(2 \times 1,500) + (1 \times 1,200)] \times 0.15 = 630$ *gallons/day*

Since $MDDV_{(crush)} > MDDV_{(non\text{-}crush)}$, $MDDV_{(crush)}$ *is used in the basis of design for the land treatment system.*

Step 2. Calculate the MADV

MADV = 20,000 gallons X 5 = 100,000 gallons/year

Step 3. Calculate the maximum daily quantity of BOD discharged based on MDDV determined in Step 1 and the concentration of BOD from Table 2.

(2,100 gallons/1,000,000) X 3,814 $mg/L_{(BOD)}$ *X 8.34 = ~67 LB BOD/day*

Step 4. Calculate the minimum area required to meet the DEQ's recommended maximum daily BOD loading rate (50 LB/acre/day) based on the quantity of BOD discharged determined in Step 3.

67 LB BOD / 50 LB BOD/acre/day = 1.3 acres

Step 5. Calculate annual nutrient loading rates based on the MADV determined in Step 2, concentrations of TIN and TP from Table 2 and the minimum area required determined in Step 4.

TIN: [(100,000/1,000,000) X 17.1 mg TIN/L X 8.34]/ 1.3 acres = ~11 LB TIN/acre/year

TP: [(100,000/1,000,000) X 9.87 mg TP/L X 8.34]/ 1.3 acres = 6.3 LB TP/acre/year

Step 6. Calculate maximum daily wastewater hydraulic loading rate **based on the minimum area required determined in Step 4.**

$(2{,}100_{\text{ gallons/day}} / 27{,}150_{\text{ gallons/acre-inch}}) / 1.3_{\text{ acres}} =\sim 0.06$ *inch/day*

Step 7. Calculate the allowable maximum daily hydraulic loading rate based on NRCS soils data.

$0.5_{\text{ in/hr}} \times .07 \times 24_{\text{ hr/day}} = 0.84$ *inch/day*

Since the calculated maximum daily wastewater hydraulic loading rate (0.06 inch/day) is less than the maximum rate allowed under Part 22 (0.84 inch/day), the wastewater loading rate is acceptable.

At this point the facility has determined that its MDDV is estimated to be 2,100 gallons and its MADV is estimated to be 100,000 gallons. Based on this information and the assumed default values from Table 2, the facility generates 67 LBs of BOD per day and will require at least 1.3 acres for its land treatment system to meet the recommended BOD loading rate of 50 LB BOD/acre/day. The maximum hydraulic loading rate to the 1.3 acre land treatment system is estimated to be 0.06 in/day which is less than what is allowed pursuant to the requirements of the Part 22 Rules according to information obtained from the NRCS. Nutrient loading is very low and not expected to require additional management.

From here, the facility can begin to consider the methods of land treatment and wastewater distribution options. The results of these calculations may also prompt the facility to evaluate its pre-treatment strategy.

For information or assistance on this publication, please contact the Water Resources Division, Groundwater Discharge Program through the DEQ Environmental Assistance Center at 800-662-9278. This publication is available in alternative formats upon request.