CHAPTER 15

Small Alternative Wastewater Systems

15.1 Preface

This chapter presents the method to determine the proper design for decentralized wastewater treatment systems (DWWTS). DWWTS are systems that are not the traditional, centralized/regionalized wastewater treatment systems. DWWTS treat domestic, commercial and industrial wastewater using water tight collection, biological treatment, filtration and disinfection. These systems typically will utilize land application with either surface or subsurface effluent dispersal.

15.2 General Considerations

15.2.1 Ownership

Plans for sewer systems including domestic wastewater treatment systems will not be approved unless ownership and responsibility for operation are by a municipality, publicly owned utility, or a privately owned public utility regulated by the Tennessee Regulatory Authority (TRA). The owner is defined as the entity responsible for the operation of the system. The property being served is defined as the user.

Legal title to tanks, pumps, or other components should be vested with the owner. The objective of having title invested to the owner rather than the user is to avoid potential for cost disputes over equipment selection and repair methods. Regardless of where title is vested, the owner should completely control all tanks, pumps, service lines and other components of the system on private property. This requirement is essential to assure operable hydraulics and overall system reliability.

The owner shall possess a recorded general easement or deed restriction to enter the private property being served, and to access the system and its components. Access must be guaranteed to operate, maintain, repair, restore service and remove sludge.

Owners should operate and maintain facilities without interruption, sewage spills on the grounds, sewage backup into buildings, or other unhealthy conditions.

15.2.2 Planning

The applicant should contact the Division of Water Pollution Control as early as possible in the planning process. If a discharge to surface waters is proposed, the treatment works will be designated an appropriate Reliability Classification as detailed in Chapter 1 of this design criteria. Also for proposed surface water discharges, the designer should refer to the Wastewater Discharge Checklist, Appendix 15-A.

15.3 Design Basis

Small systems are more sensitive to influent problems due to a reduction in hydraulic or organic buffering capacity. Small systems are much more susceptible to flow variations due to daily, weekend or seasonal fluctuations. An accurate characterization of the waste and flow conditions should be projected for the site and should include flow, BOD_5, TSS, ammonia and, oil and grease.

15.3.1 Hydraulic Loading

For residential developments, the flows given below are generally considered appropriate for design purposes. For developments that include a preponderance of larger homes, higher flows should be considered. For non-residential flows, the engineer should use the tables given in Appendix 15-A. If the engineer determines that it is necessary to deviate from those values, then he/she must submit the basis for design flow, both average and peak. The type of collection system should be given serious consideration when determining total flow to the wastewater treatment plant.

For systems using water tight collection, the recommended design flow should be 300 gallons per day per unit. For projects dealing with commercial or very large residential developments, design flows should reflect expected variations from conventional systems and be evaluated and approved by the Division of Water Pollution Control based upon site-specific evaluation.

15.3.2 Engineering Report

An engineering report is required for all wastewater treatment projects. Small treatment plants require different design considerations than larger plants. During the design of a small treatment facility, the design engineer should evaluate the feasibility of various process alternatives. Except for systems proposed to serve single residential units, all other small flow systems or systems proposing to use land application for effluent dispersal should also submit an application for an NPDES permit or a State Operation Permit (SOP) to the Division of Water Pollution Control (Note: Exceptions may be contained in Memorandum of Agreement between the Divisions of Water Pollution Control and Ground Water Protection). The SOP application should include an engineering report, Water Pollution Control soils map, soil profile descriptions derived from soil borings and pit evaluations to determine soil type, texture and structure for all areas proposed for drip dispersal or spray irrigation as described in Chapters 17 and 16 of this criteria.

15.3.3 Pollutant Loading

While best engineering judgments for waste characterizations are sometimes necessary, an attempt should be made to project this character from similar facilities, instead of the absolute use of flow tables. For example, excess ammonia should be considered during design of a treatment system for a rest stop, truck stop or recreational vehicle park.

These types of facilities can have a significantly higher influent ammonia concentration than typical domestic systems

15.4 Preliminary Treatment

Preliminary treatment involves the removal of large solids that could damage pumps and equipment in the downstream treatment process. Such treatment may include properly designed and water tight septic tanks, or filters.

15.4.1 Septic Tank Effluent Pumping (**STEP**) and Septic Tank Effluent Gravity (**STEG**) Systems

An effluent sewer is a wastewater collection and treatment system shared by multiple users, consisting of multiple watertight septic tanks (to capture and remove gross solids, oil and grease), and small diameter watertight piping to convey wastewater from the tanks to a treatment facility and common dispersal area. Treated "clear" effluent from the mid-depth of the septic tank is filtered (through an effluent filter or screened pump vault) and transported under pressure via the pressurized collection system. An effluent sewer may include septic tank effluent pumping (STEP) systems, or septic tank effluent gravity (STEG) systems, or both. In a STEP system, the effluent is pumped from the septic tank under pressure while in a STEG system, pressurization is achieved using hydrostatic pressure (gravity).

Septic tanks should be sized to accommodate a minimum of two and one-half (2.5) times the design daily sewage flow anticipated to flow through the tank. Additionally, septic tanks may be either compartmentalized or not, since un-baffled tanks allow the tank to be pumped from either end. **All tanks regardless of size must be water-tight as evidenced by post installation testing and structurally sound by design as certified by a Licensed Professional Engineer stamp on tank plans and structural analysis**. Tanks may be made of concrete or other structurally sound materials such as fiberglass Water testing is preferred with the water level being a minimum of 3-inches above the top of the cover for the tank. If vacuum testing, it is preferred that the tank be capable of maintaining 4-inches of mercury (HG) without loss for five (5) minutes. However, at minimum the tank must meet the water pressure testing and vacuum testing in accordance with ASTM C1227. Structural soundness will usually require reinforcing bars incorporated into the tank walls, sides, top, and bottom. Acceptable burial depths and loading conditions should be explicitly noted on the drawings and made available to installers.

All tanks should be equipped with rubber inlet and outlet boots installed through the tank wall and sealed to the piping with stainless steel band clamps. All tanks should be equipped with water-tight risers over the inlet and outlet of the tank. The riser should have a water tight seal to the top of the tank. Access risers should extend to grade and be equipped with a water-tight lid bolted or locked to the riser.

15.4.1.1 STEP Tanks

In a typical septic tank system, household sewage is pretreated in a watertight septic tank where gross solids and grease are held back. A “clear” effluent from the mid-depth of the tank is transported to a common or lateral sewer. In a septic tank effluent pump (STEP) system, the effluent is pumped from the septic tank under pressure to a small-diameter, pressurized collector sewer.

In most cases, a single phase, ½ HP effluent pump is adequate for septic tank effluent. However, if a working head over 150 feet is expected, a higher horsepower pump may be required.

The effluent pump should be located within a screened pump vault. The vault, at a minimum, should be fitted with 1/8-inch mesh polyethylene screen and a 4-inch diameter PVC (or equivalent) flow inducer for a high head pump.

The pump chamber should also include float switches that turn the pump on and off and activate high and low level alarms.

15.4.1.2 STEG Tanks

Effluent may also flow by gravity, where available hydraulic gradient allows, to small-diameter gravity collector lines. Gravity system tanks should be equipped with an effluent filter that at a minimum consists of a 1/8-inch mesh polyethylene screen housed within a PVC (or equivalent) vault. The lateral from the tank to the collection line should be laid at a uniform grade with no high points.

15.4.2 Grinder Pumps

For systems served by grinder pumps, all raw wastewater should be collected from individual buildings/dwellings and transported to the pressure or gravity system by appropriately sized pumps. For restaurants or facilities with commercial-grade kitchen facilities, grease and oil interceptors (as described in 15.4.4) should be installed prior to the grinder pump.

All pumps must have adequate operating curves that allow for pumping into the pressurized common line under maximum head conditions. Additionally, each pump must be equipped with properly installed and approved backflow prevention assembly. Furthermore, tanks must be watertight and located above the seasonal groundwater table where possible. Where it is not possible to locate tanks above the seasonal groundwater table, the design engineer must provide anti-buoyancy calculations and specify appropriate anti-flotation devices. Installations should ensure that odors are minimized.

15.4.3 Grease and Oil

Facilities with commercial-grade kitchen facilities should be equipped with an effective grease and oil interceptor. Other potential sites of grease/oil production should be investigated by the design engineer.

One or more interceptors in series are required where grease or oil waste is produced that could hinder sewage disposal or treatment, and/or create line stoppages. Interceptors must be located so as to provide easy access for inspection, cleaning and maintenance. In commercial-grade kitchen facilities, the dishwasher(s) must not be connected to the primary grease trap and/or separator. A separate device may be required to allow for cooling of the dishwasher discharge prior to primary treatment.

As vegetable oil usage has become more common, it should be understood that oils will not solidify until approximately 70^{o} F. or less. Therefore, the minimum interceptor design should be a baffled, three-compartment, elongated chamber to allow for cooling with a capacity of at least 1,500 gallons. The design should be in accordance with accepted engineering practice. Tanks must also be sized in accordance with local requirements. The tank should be buried, with manhole accesses to all compartments. Tanks should be manufactured and furnished with access openings having a minimum diameter of twenty-one (21) inches. The tank top should be able to support a minimum of 2500 lb. wheel load. Inlet plumbing should be designed to penetrate 18 inches or more below the discharge invert elevation. In order to demonstrate water-tightness, tanks (including all risers and lids) must be tested prior to acceptance by filling with either air or water in accordance with ASTM standard C1227-05.

15.5 Secondary Treatment Design

The following secondary systems should be evaluated for small flow designs.

15.5.1 Fixed Media Biological Reactors

A fixed media biological reactor (FMBR) is an aerobic, fixed film process that uses sand, gravel or other media to provide secondary treatment of septic tank effluent. The FMBR typically consists of a septic tank and recirculating tank, media bed with a special distribution system installed within a structure or excavation lined with impervious synthetic liner and a flow splitter device.

Design considerations include the media size, type and surface area, the required bed area and depth, dose volumes and dosing frequency.

All sites for fixed media reactors should be properly prepared before installation. For reactors that are installed directly on soil with a synthetic liner (as opposed to package units with rigid bottoms), the liner may lie directly on the graded soil if it is free from material that might puncture the liner. Otherwise, a layer of sand or other suitable material should be placed below the liner to protect it from puncturing.

15.5.1.1 Granular Media Reactor

The media bed should be sized by comparing the organic and hydraulic loads and then using the more restrictive of the two. Table 15-1 gives suggested design parameters for the reactor, support bedding and underdrain media. All media should be washed and screened to limit fines to less than 1% by weight passing a 100 screen (0.15 mm).

Table 15-1 Suggested Design Parameters for Granular Media Reactors

Design Parameter	**Effective Size (D_{10})**	**Depth**	**Design Value**
Reactor Media:			
Sand or other, similar granular media	1.5-2.5 mm (Uniformity Coefficient = 1-3)	24 to 30 inches	3-5 gpd/ft^2 (hydraulic loading – forward flow) ≤ 6.2 lb BOD_5 /1000 ft^2/day (organic loading)
Gravel or other, similar granular media	0.6 - 1 cm diameter	24 – 30 inches	10 - 15 gpd/ft^2 (hydraulic loading – forward flow) ≤ 10 lb BOD_5 /1000 ft^2/day (organic loading)
Underdrain Media	#57 inch stone	12-18 inches	

A synthetic media may also be used as long as it meets the above criteria.

A minimum of 30 mil impermeable synthetic liner is required for the bottom and sides of the filter.

15.5.1.2 Other Fixed Media Reactors

These systems will be approved on a case-by-case basis. The design engineer must provide adequate rationale that such systems are preferable to more traditional granular media reactors.

15.5.1.3 Distribution and Underdrain System

15.5.1.3.1 Spacing

Distribution mechanisms should ensure uniform application of the applied flow to the surface of the media. These mechanisms may involve spray nozzles in synthetic media reactors or drilled or perforated pipe in sand filter or other fixed media reactors.

For sand filters, the distribution pipes should be spaced on 18-inch centers or less. Underdrain lines, where used, should be spaced no farther than 8-feet on center.

15.5.1.3.2 Sizing of Lines

Distribution pipes should be no smaller than 1-inch. Clean-out caps should be provided on the ends of the distribution pipes. In the underdrain system, pipes should have a minimum inside diameter of 4 inches. As an alternative, collection vaults may also be employed.

15.5.1.4 Recirculation Tank and Pump System

Where a separate recirculation tank is used, the tank may serve as a wet well for the septic tank effluent and treated, recirculated effluent to be pumped to the media bed. The minimum tank volume should equal the design daily flow.

The tank should be equivalent in strength and materials to the septic tank as described in 15.4.1. No internal baffles are necessary. An access manhole is necessary for replacement of submersible dosing pumps if such are used.

A minimum of two alternating recirculation pumps are required for commercial multiuser FMBRs. Recirculating pump operation should be time-controlled. Float switches are required and should be wired in parallel with the timer to control the pumps during periods of either low or high wastewater flows, and as a back-up in case of timer malfunction.

A quick disconnect coupler and hanger pipe are recommended for pump removal and convenience. Additionally, panels for operation of FMBRs should also feature programmable digital timers and multiple settings for optimizing dosing during normal and peak flow conditions.

15.5.1.5 Flow Splitter

The system should be equipped with a device or computerized process control that allows for reactor effluent to be split between the recycle stream and discharge to either the disinfection system and/or drip disposal area. It is recommended that the designer choose a device that provides flexibility in setting the recycle ratio.

15.5.1.6 Dosing Chamber

Where the treated effluent is intended to be distributed through a drain field, drip dispersal system or other land application mechanisms, a dosing chamber should be employed, sized and equipped to provide timed-dosing of the daily wastewater flow with adequate reserve storage capacity for system malfunctions.

The dosing chamber should be equipped with an audible visual or other approved high-water alarm set to provide notification to the owner/operator of a malfunction when the design high water level is exceeded and the emergency reserve capacity is being used. A low-water cutoff device must be provided to prevent damage to the pump during low-water conditions.

A programmable timer and control panel should be employed to regulate the dosing frequency and volume, and to record wastewater flow, the number of doses and other pertinent dosing data.

Time dosing should be utilized to dose the absorption field or zones. The frequency of dosing must be based upon the soil's hydraulic loading rate and the design flow. Fields or zones should be time dosed to ensure the total twenty-four (24) hour wastewater effluent flow is applied in a 24-hour period.

15.6 Disinfection and Fencing

Disinfection of effluent is required prior to spray irrigation. Disinfection of effluent will be required for drip dispersal of unfenced drip irrigation if the drip field access is classified as either "Open Access" (where drip areas are used for ball fields, playgrounds, picnic areas, golf courses, etc.) or "Attractive Access" (where open spaces are maintained similar to residential lawns with easy access and with grass maintained at short heights, but with the area undeveloped for recreational purposes). In these cases, if the entire drip dispersal area is properly fenced, disinfection of the effluent is not required.

Disinfection of effluent may not be required for drip dispersal of unfenced drip irrigation if the drip field access is classified as either "Inhibited Access" (where drip areas are allowed to return to natural vegetation and are used for wildlife food plots or other similar uses and where routine access by humans is discouraged by growth of vegetation) or "Difficult Access" (where drip areas are located on generally steep, greater than 10% slopes, on heavily wooded slopes, and access by humans will be rare due to terrain, location, or vegetation).

In the design of UV disinfection units there are three basic areas that should be considered:

a. Reactor hydraulics – adequate residence time.

b. Factors affecting transmission of UV light to the microorganisms.

c. Properties of the wastewater being disinfected.

In addition, an automatic self-cleaning mechanism is recommended to ensure proper performance of the UV system.

As an alternative to disinfection, the drip field may be fenced with a 4-foot chain link, woven wire fence, wooden, four-strand barbed wire, or other as approved by the Department of Environment and Conservation.

15.7 Oxidation Ponds and Artificial Wetlands

15.7.1 Oxidation Ponds

1. The maximum design loading on the primary cell(s) should be 30 lbs BOD_5 per acre per day.
2. The design average flow rate should be used to determine the volume required to provide a minimum combined storage capacity of 90 days in the stabilization ponds. The minimum recommended operating depth is 3 feet for facultative ponds and 10 feet for aerated ponds.
3. The minimum number of cells should be three when the system is designed to discharge to surface waters.
4. The shape of the cells should be such that there are no narrow, L-shaped or elongated portions. Round or rectangular ponds are most desirable. Rectangular ponds should generally have a length not exceeding three times the width. Dikes should be rounded at the corners to minimize accumulation of floating material.

15.7.2 Basis of Wetland Design

The artificial wetland treatment system has been around since the 1980's. Like other land application systems, artificial wetlands are site specific. Consequently, all proposals will be reviewed on a site-by-site basis. This section is limited to subsurface flow wetlands utilizing gravel or other granular media. Free-water surface wetlands can also be used, but their design follows different parameters and approval will be on case-by-case basis.

1. Design

a. Artificial wetlands designed to discharge to surface waters will have to meet NPDES permit limits at all times and must be designed accordingly.
b. Artificial wetlands are designed on the basis of a BOD removal rate which is assumed to follow the classic first order removal equation corrected for temperature.
c. The minimum recommended detention time for treatment of normal domestic waste in the artificial wetland system is 4 to 7 days.
d. The recommended depth of flow in the wetland system should be between 18 and 24 inches, with twenty-four (24) inches as the recommended optimum depth.
e. The aspect ratio of the wetland is determined by the design flow and substrate cross sectional area perpendicular to the flow. The aspect ratio should be such that one-third (⅓) of the available flow rate, as determined by Darcy' Law, is preserved and all flow remains subsurface. This will generally result in a rectangular configuration with a length to width ratio of between 1:1 and 1:3.
f. Seepage rates in the artificial wetland areas will be addressed on a site-by-site basis based upon in-situ material, groundwater depth and the groundwater use. Generally, no compaction will be required on wetland pond bottoms. The berms should be compacted to at least 90 percent of Standard Proctor Density.

g. The bottom of the artificial wetland treatment units should not have a slope greater than 0.2%.
h. Due consideration should be given to multiple wetland cells and to possible future expansion on suitable land when the original land acquisition is made for flexibility and for maximum operational capability.

2. Construction

a. The project site should be protected from surface inflow waters. The site should also be protected such that the top of the wetland surface is at least one foot above the 100 year flood elevation.
b. In order to prevent erosion and channelization at the inlet of the wetland, a discharge header should be utilized. The header should be equipped with removable end-plugs so the line may be drained to prevent freeze-up. Uniform distribution of wastewater to prevent short-circuiting through the wetland should be assured. It is recommended that the header outlet elevation be at or above the maximum design depth.
c. It is recommended that pipes and flumes located in or near inlet and discharge structures will not be in a completely submerged condition to maintain the integrity of the system and reduce freeze-up problems.
d. A suitable discharge structure from the wetland should be utilized. The structure should be adjustable so that the depth in the wetland may be modified as needed.
e. Care should be taken to establish the vegetation as soon as possible after construction. However, it is difficult to establish the vegetation in winter or mid to late summer. The emergent vegetation, once established, should prevent the erosion of the berms of the system. Riprap may be required around the inlet and outlet structures of the wetland. A cover crop may be planted on the interior slopes to prevent erosion prior to the establishment of the emergent vegetation. Consideration may be given to the use of excelsior blanket over seeding.
f. The exterior and interior slopes of the wetland berms surrounding the wetland basins should not be steeper than 3H:1V.
g. The top width of the berms should be a minimum of eight feet.
h. Following the final grade, the substrate should consist of a minimum of two feet of clean ¾-inch to 11/2-inch stone (#57).
i. The dike elevation should be a minimum of two feet above the high water level in the wetland.
j. If groundwater contamination is a potential problem, the bottom of the wetland may be sealed with a suitable material. However, generally no liner will be necessary in the artificial wetland.
k. Aluminum, concrete, or PVC pipe or other material generally accepted for sewers should be specified for the piping requirements in the wetland. Provisions may be required to prevent the settling of the piping structures under load. It is recommended where structures are partially or completely submerged in ice conditions that a flexible piece of pipe be installed to allow for some movement of structure.
l. The effluent discharge structure should be equipped with a suitable flow monitoring device, such as a flume or V-Notch weir, to monitor flows leaving the treatment site. Staff gages for measuring depths in structures should be provided where flow monitoring is required.

m. In order to accurately monitor influent flows to the artificial wetland system, an influent measurement structure should be included.
n. The entire wetland area must be enclosed with a suitable fence to provide public safety, exclude livestock and to discourage trespassing.
o. Warning signs must be provided along the fence around the treatment facility. There must be at least one sign on each side of the facility, with a minimum spacing of 500 feet.
p. Removable screens should be provided on pipe ends to prevent entrance of trash and wildlife.

3. Vegetation Establishment

a. Specifications for the seeding of the artificial wetland should as a minimum include:

1. Plant species
2. Plant distribution (vegetative zone)
3. Planting (including time restraints)
4. Fertilization
5. Water level control and site maintenance.

b. Placing top soil in the graded wetland area is generally not required. Substrate properties generally do not limit the establishment of a wetland.

c. Only indigenous plant species should be used; preferably collected within a 100 mile radius. Preferred species include, but are not limited to:

1. Typha Latifolia - Common cattail,
2. Typha Angustifolia - Narrow leaf cattail,
3. Scirpus spp. - Bullrush, and/or
4. Phragmites communis - Reed.

d. Transplanting of live or dormant plant stock will achieve greater success than seed. However, the plants have to be set into the gravel with their roots near the water level in the wetland. Transplanting of reeds is by placing a section of rhizome containing the “eye” in the shallow surface of the gravel.

e. Seeding should generally be accomplished in the spring. Also, at least one fertilization should be required, preferably shortly after seed germination or at one month. The recommended fertilizer is the standard 10- 10-10 or 20-10-10 mixture at a rate of 600 lbs/ac or 300 lbs/ac, respectively. Where wastewater stabilization ponds exist, fertilization may not be necessary, as the nutrients in wastewater may suffice.

f. For seeding, the following is recommended:

The seed should be broadcast uniformly over the substrate at a rate of 10 viable seeds per square foot. The seeds should be cultivated to subsurface depths of 0 to 1 inch followed by lightly packing, rolling or dragging the tilled surface. Flood the site with 1-2 inches of water until the seeds germinate and become several inches tall. At this time, the area should be fertilized.

g. For transplanting (the recommended method of vegetation establishment) the propagule should be transplanted, as a minimum, on a two foot grid. The number of transplants required may be calculated from Equation 15-1:

$$N = (L/D + 1) \times (W/D + 1)$$ (**Equation 15-1**)

Where:

N = Number of transplants

D= Distance between transplants

L = Length of site (ft.)

W = Width of site (ft.)

Transplanting on a two foot grid should provide a uniform vegetative cover in one growing season. Transplants should be kept moist, but not flooded to submerged conditions. The transplants should also be fertilized, preferably with controlled release fertilizer such as Osmocote 18-5-11 for fall and winter planting, Osmocote 18-6-12 for spring planting, and Osmocote 19-6-12 for summer planting. Refer to suppliers instructions when transplanting.

15.8 Lagoons (Note: This chapter does not replace Chapter 9)

- The maximum allowable seepage is 0.0625 inches per day.
- A lagoon must be artificially lined with clay, bentonite, plastic, rubber, concrete, or other materials to prevent groundwater pollution.
- Lagoons can be round, square, or rectangular with rounded corners. Their length should not exceed three times their width, and their banks should have outside slopes of about three units horizontal to one unit vertical.
- A lagoon must be surrounded by a 4-foot high fence with a locking gate and sign.
- There should be a 2 x 2 ft concrete pad in the center of the lagoon directly below the opening of the outlet pipe to protect the integrity of the liner.
- There should be a minimum of 2 feet between the bottom of the lagoon and groundwater. The liquid depth of a lagoon should be maintained between 2 to 5 feet.
- There should be a depth marker near the center of the lagoon.
- A minimum of 1 foot of freeboard should be maintained.

15.9 Package Activated Sludge Plants

For any activated sludge or fixed film process, the criteria presented in Chapters 4, 5, 6, 7, 8, 10, 11, and 12 of these design criteria must be utilized for each unit process.

The design should include aerobic digestion or sludge holding for sludge wasting. A sludge wasting schedule should be included in the engineering report to better define operator time requirements. The disposal site or landfill should be given. Where tertiary filters are employed, the use of an equalization tank is mandatory. Also, based on the Reliability Classification as determined by the appropriate WPC field office, multiple units and standby power (or a generator) may be required. These costs should be included in the cost effective/reliability analysis.

APPENDIX 15

Recirculation Tank/Pump System Example Calculation

Given: 20,000 gpd (14 gpm) system a desired 4:1 recycle rate and numerous small doses.

1. Pumping volume = (1440 min/day / (On + Off time)) x On time x # of pumps x Pump Capacity
2. 80,000 gpd = (1440 min/day / (On Off Time) x On Time x 4 x 45 gpm
3. 80,000 gpd/(1440 min/day x 4 x 45 gpm) = On time/(On + Off time)
4. On time/(On + Off time) = 0.31
5. On time = 0.31 On + 0.31 Off
6. 0.69 On = 0.31 Off
7. Off = 2.22 On
8. Choose 2 minutes On: Off = 4.44 minutes
9. Total dosing cycle = 6.44 minutes.
10. Adjust dose cycle if calculated pumping volume is less than minimum recommended for selected recycle rate
11. Note: The above is an iterative process. The quickest solution is to pick a cycle time, divide it into 1440 min/day, multiply by the On time, multiply by the number of pumps, and multiply by the pump capacity. Compare this number to the desired total pumping volume including recycle. If too little increase On time. If too much decrease on time. .