IN THE TENNESSEE REGULATORY AUTHORITY
AT NASHVILLE, TENNESSEE

IN RE:	)	
	)	
PETITION OF TENNESSEE	)	
WASTEWATER SYSTEMS, INC.	)	DOCKET NO. 14-00136
FOR APPROVAL OF CAPITAL	)	
IMPROVEMENT SURCHARGES	)	
AND FINANCING	)	
ARRANGEMENTS		

DIRECT TESTIMONY

OF

BRAD HARRIS

AT THE REQUEST OF THE

CONSUMER ADVOCATE AND PROTECTION DIVISION

OF THE

OFFICE OF ATTORNEY GENERAL

APRIL 30, 2015

IN THE TENNESSEE REGULATORY AUTHORITY
AT NASHVILLE, TENNESSEE

IN RE:	)	
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PETITION OF TENNESSEE	)	
WASTEWATER SYSTEMS, INC. FOR	)	**DOCKET NO. 14-00136**
APPROVAL OF CAPITAL	)	
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AND FINANCING ARRANGEMENTS	)	

AFFIDAVIT

I, Brad Harris, with the Tennessee Department of Environment and Conservation, on behalf of the Tennessee Department of Environment and Conservation, hereby certify that the attached Direct Testimony represents my opinion in the above-referenced case.

Brad Harris
BRAD HARRIS

EMILY KNIGHT STATE OF TENNESSEE NOTARY PUBLIC DAVIDSON COUNTY, TENN.
My Commission Expires JULY 6, 2015

Sworn to and subscribed before me
this 27th day of April, 2015.

Emily Knight
NOTARY PUBLIC

My commission expires: July 6, 2015

Q.1 STATE YOUR NAME, BUSINESS ADDRESS, AND OCCUPATION.

A.1 Brad C Harris, P.E., Land Based Unit Manager, Division of Water Resources, Tennessee Department of Environment and Conservation ("TDEC"), William R. Snodgrass – Tennessee Tower, 312 Rosa L. Parks Avenue, 11th Floor, Nashville, TN 37243-1102.

Q.2 PROVIDE A SUMMARY OF YOUR BACKGROUND AND PROFESSIONAL EXPERIENCE.

A.2 I am licensed as a professional engineer in the state of Tennessee, and I have worked for TDEC as an Environmental Program Manager and Environmental Protection Specialist since 2003. I received a Bachelor of Science degree in Civil Engineering from Tennessee Technological University in 1996. More detail about my educational, technical, and professional background is attached as Attachment 1.

Q.3 ON WHOSE BEHALF ARE YOU TESTIFYING?

A.3 The Consumer Advocate and Protection Division of the Attorney General's Office requested my testimony.

Q.4 HAVE YOU PROVIDED TESTIMONY BEFORE THE TRA IN ANY PREVIOUS CASES CONCERNING TENNESSEE WASTEWATER SYSTEMS, INC. ("TWSI"), ADENUS OR ANY AFFILIATE OF ADENUS?

A.4 No.

Q.5 HAVE YOU PROVIDED TESTIMONY BEFORE ANY OTHER ADMINISTRATIVE AGENCY, LEGISLATIVE BODY, OR COURT CONCERNING* TWSI, *ADENUS OR ANY AFFILIATE OF ADENUS?

A.5 I have provided testimony through depositions in two cases related to Adenus as the contractor for the Water and Wastewater Authority of Wilson County. One deposition is related to an appeal of permit SOP-99038 by the Authority and the other is an appeal of plans denial for a collection system force main connecting additional service areas associated with the Couchville Pike Treatment Facility SOP-99037 to the Logue Road Facility SOP-99038. I also testified before the Water Quality Control Board in 2005 in a case involving the Michael Davis property in Wilson County.

Q.6 WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THIS PROCEEDING?

A.6 The purpose of my testimony is to accurately convey my knowledge of the sites that are the subject of TRA Docket No. 14-00136 – Maple Green, Cedar Hill, Summit View, and Smoky Village. I acquired this knowledge through my work for TDEC. I am also expressing my opinion regarding possible alternatives to the plans for these sites as proposed by TWSI.

Q.7 WHAT DOCUMENTS HAVE YOU REVIEWED IN PREPARATION OF YOUR TESTIMONY.

A.7 I have reviewed documents available on TRA's website relating to Docket 14-00136, documents available on the Division of Water Resources database, also known as "waterlog," that is associated with the individual sites. These documents are available at the following links:

http://environment-online.state.tn.us:8080/pls/enf_reports/f?p=9034:34001:386983027739:.and http://environment-online.state.tn.us:8080/pls/enf_reports/f?p=9001:610:15640874984614::NO::P610_SELECT_SEARCH:1. I have also reviewed Water Environment Federation Manual of Practice, FD-16 ("WEF, MOD FD-16") and Netafim's Wastewater Reuse and Drip Design Guide ("Netafim").

Q.8 ARE YOU FAMILIAR WITH THE PROPERTIES NAMED IN TWSI'S PETITION – MAPLE GREEN, CEDAR HILL, SMOKY VILLAGE, AND SUMMIT VIEW?

A.8 I have made site visits to both Maple Green and Cedar Hill in the past. I am familiar with the records and documents associated with all four sites.

Q.9 HOW DID YOU BECOME AWARE OF THESE PROPERTIES?

A.9 I remember a discussion with other TDEC staff sometime in 2013 regarding the fact that drip tubing had been installed on the berm of the lagoon at Maple Green. I became more familiar with the site after the collapse of the lagoon in January or February of 2014 and discharge to a nearby creek. I visited the site sometime in February or March of 2014. TDEC issued an Emergency Order for the site in February of 2014.

I became aware of the Cedar Hill facility in December of 2010 due to the first sinkhole collapse within the lagoon. TDEC staff inspected the facility and discovered that there was no effluent in the lagoon. TWSI repaired the lagoon after the first collapse. TDEC issued a Commissioner's Order in September of 2011 which was appealed by TWSI.

TWSI notified TDEC in May of 2013 that the lagoon was not holding again and excavation was underway. I was involved in the review of the Corrective Action Plan ("CAP") following the second lagoon failure. I visited the site sometime in early 2014. At the time of my visit, no drip lines had been installed and electricity wasn't available at the site. Most recently, TWSI submitted plans for the use of a free surface wetland to replace the failed lagoon. TDEC denied the plans in November of 2014. TWSI has appealed the plan denial.

I became aware of the Summit View facility due to a complaint received by the TRA. In April of 2014, the TRA referred the complaint to TDEC. TDEC subsequently conducted multiple inspections and eventually issued a Notice of Violation ("NOV") in July of 2014. In September of 2014, TDEC issued a Director's Order, which was appealed by TWSI.

In March of 2014, I became aware of Smoky Village after an inspection by TDEC reflected that there was extensive ponding and overflowing in the drip field.

Q.10 HAS TDEC DECLINED TO APPROVE A CAP FOR ANY OF THESE PROPERTIES? IF SO, WHICH ONES?

A.10 Yes. TDEC has declined plans for a Free Water Surface (FWS) wetland for Cedar Hill. Cedar Hill is discussed in more detail in Question 15 below.

Q.11 WHAT CRITERIA DOES TDEC USE TO APPROVE A CAP?

A.11 When evaluating a CAP, TDEC considers rules promulgated in support of the Water Quality Control Act, Design Criteria maintained as a compilation of accepted engineering practices, case studies, technical references and site-specific information.

Q.12 DOES TDEC TAKE COST INTO CONSIDERATION IN APPROVING A CAP?

A.12 No.

Q.13 ARE THERE PROPERTIES IN THIS PETITION FOR WHICH TDEC HAS NOT APPROVED A CAP? IF SO, WHICH ONES?

A.13 Yes, plans for Summit View are currently under review. Plans supporting a FWS wetland for Cedar Hill were denied. Cedar Hill is discussed in more detail below at Question 15.

Q.14 IS THE CORRECTIVE ACTION PLAN FOR MAPLE GREEN AN APPROPRIATE METHOD OF SOLVING THE PROBLEM? WHAT IS/ARE THE ALTERNATIVES?

A.14 The permits for the four properties which are the subject of these questions are all permitted through State Operating Permits (SOP). SOP's are used for decentralized wastewater systems where no discharge to surface water or direct discharge to ground water is permitted. There are two primary components covered in the permit; the treatment component and dispersal of the treated wastewater. Treatment is accomplished through the use of step tanks *(similar to septic tanks*) at the individual establishments and centralized secondary treatment. The most common treatment options are recirculating sand filters, lagoons, and manufactured treatment units. All of these treatment options are capable of treating domestic strength septic tank effluent to levels appropriate for land application. The dispersal component involves land application through either a drip system or spray system. The purpose of the land application component is to disperse the treated wastewater to soil areas that have appropriate characteristics to prevent discharge to surface or ground water. The amount of area needed is a function of flow from the treatment systems, soil type, and site conditions. Fundamentally, as the permitted flow rate increases so does the need for suitable soils area.

Since the failure of the lagoon at Maple Green, TWSI has installed a drip system supportive of approximately 40,000 gallons per day ("GPD"). It covers approximately 3.7 acres of areas mapped as suitable. TWSI proposed the use of a Free Water Surface (FWS) wetland to replace the failed lagoon. According to the WEF MOP FD-16, a FWS wetland is a constructed wetland for wastewater treatment where, "In FWS wetlands, the emergent vegetation is flooded to a depth of 102 to 455 mm (4 to 18 in.), … Wastewater is treated as if flows through the wetland by bacteria attached to the submerged vegetation as well as by physical and chemical processes." There is limited data available associated with the use of FWS wetlands in Tennessee. With respect to the Maple Green site, there are aspects of TWSI's design basis for the FWS wetland that are not completely understood by TDEC. TWSI's design engineer did not provide examples of similar designs and supporting performance data.

Safety Factor and Size: The design was based on a daily flow of 35,000 GPD. Monthly operational reports over the past few years show instances of daily flows in excess of

35,000 GPD (Influent flow was not measured). The site was originally permitted for 74,000 GPD. The design flow appears to coincide with the current need. In other words, there does not appear to be any excess capacity incorporated in the design.

Wetland Depth: The design is based on a depth of 2.5 feet. This is deeper than what would be expected for a FWS wetland. The WEF MOD FD-16 states that "[t]he operating depth in FWS wetlands can range from 0.1 m (4 in.) to 0.6 m (2 ft.) Design depths are typically 0.5 m (20 in.) to optimize detention time without exceeding the effective depth of emergent vegetation, which generally do not colonize at depths of 1 m or more."

Mechanical Aeration: The design incorporates mechanical aeration. The effect and use of mechanical aeration in a FWS wetland for this application is not known.

Lack of Supporting Data: The Division asked the design engineer on multiple occasions for examples of similar designs and supporting performance data. No similar designs or supporting data have been provided. TWSI has historically operated recirculating sand filters, manufactured treatment units and effluent lagoons.

The Division makes no prediction as to how this proposed system will perform; it merely compares the proposal to existing references. The fact that the proposed system does not completely match current wetland design recommendations does not mean that the system will not perform or perform poorly. The plans were stamped by a registered engineer and the performance of the proposed design is linked to this professional accreditation. Following several discussions with the engineer for the project and considering their request for allowance to attempt this approach, the Division approved the plans for the Maple Green site. However, as stated in the plans approval letter for the Maple Green free-surface wetland system:

> While the division is agreeable to consideration of innovative technologies, such as the wetland system proposed at Maple Green, the division is not supportive of applying this technology to multiple sites until such time that the success of the technology can be demonstrated. The division will consider applying this technology on a more wide-spread basis after a minimum of two years of performance data is collected for the Maple Green facility.

Rule 0400-40-02-.05 concerning final plans, contract drawings and specifications states:

> No such approval shall be construed as creating the presumption of correct operation nor as warranting by the Commissioner or by his representative that the approved facilities will reach the design goals.

Irrespective of the design of a treatment system, performance is the defining measure. If this type of treatment system effectively treats the wastewater to the permitted standard at the Maple Green site, it will merit further consideration and may find application at other sites such as Cedar Hill. As noted in the approval letter for Maple Green, the Division will not approve this technology for another site until the Maple Green facility has been demonstrated to be effective for two years.

Q.15 IS THE CORRECTIVE ACTION PLAN ("CAP") FOR CEDAR HILL AN APPROPRIATE METHOD OF SOLVING THE PROBLEM? WHAT IS/ARE THE ALTERNATIVES?

A.15 The original CAP proposed by TWSI contemplated relining the lagoon. The most recent proposal was a FWS wetland similar to the one designed for the Maple Green facility. The Division communicated the following to TWSI at the time of the approval of the FWS wetland for Maple Green that:

> It is the division's understanding that Adenus plans to incorporate similar wetland system designs for other facilities. While the division is agreeable to consideration of innovative technologies, such as the wetland system proposed at Maple Green, the division is not supportive of applying this technology to multiple sites until such time that the success of the technology can be demonstrated. The division will consider applying this technology on a more wide-spread basis after a minimum of two years of performance data is collected for the Maple Green facility.

The Division denied the plans for the FWS wetland to replace the lagoon at Cedar Hill because TWSI had not provided operational data to support approval. TWSI is currently appealing the decision. According to the WEF MOD FD-16 ,"[i]f planted on 1-m (3-ft) centers, a wetland system will typically take at least one to two full growing seasons to approach equilibrium and achieve expected performance objectives." Other options for the site include, but are not limited to, lining the lagoon, using a manufactured treatment system, or constructing a recirculating sand filter to accomplish appropriate treatment. To my knowledge, plans for the disposal system have never been submitted. Submission of plans for the drip system and installation of the drip system should be part of any approved CAP. I do not consider their FWS wetland submittal to be an appropriate method of solving the problem.

Q.16 IS THE CORRECTIVE ACTION PLAN FOR SMOKY VILLAGE AN APPROPRIATE METHOD OF SOLVING THE PROBLEM? WHAT IS/ARE THE ALTERNATIVES?

A.16 The proposed CAP for Smoky Village involves utilizing additional soil area on another property in the vicinity of the development. The soils on this property have been mapped by a private soil consultant and appear to conform to the Division's criteria for soil suitability. This corrective measure would appear to be appropriate per the submitted information.

Q.17 IS THE CORRECTIVE ACTION PLAN FOR SUMMIT VIEW AN APPROPRIATE METHOD OF SOLVING THE PROBLEM? WHAT IS/ARE THE ALTERNATIVES?

A.17 Engineering plans supportive of Summit View were recently submitted on April 10, 2014 to the Division for consideration. These plans propose increasing the treatment capacity of the existing recirculating sand filter and expanding the drip dispersal field to a nearby property.

The current permit is supportive of 8,000 GPD. Review of monthly operating reports indicate that the average daily flow (total monthly flow divided by the number of days in the month) does not exceed 8,000 GPD. Based on their monthly operating reports the average daily flow from October 2013 to September 2014 was around 4,220 GPD. Refer to the Direct Testimony of Britton Dotson of TDEC for additional information regarding the average daily flow of this facility.

TWSI has reported that daily flows often exceed 8,000GPD due to higher than expected flows from some of the rental units. Apparently, sufficient storage or equalization was not incorporated in the initial design to be able to accommodate the daily peak flows they are currently experiencing. In addition from review of the inspection reports, it appears the drip lines were not installed on contour. According to Netafim, "[d]ripperline must be installed along the contour of the slope (as level as possible), not up and down the slope. Otherwise, all the effluent in the dripperline will drain rapidly to the emitters at the base of the slope, which can overload the soil." Other considerations and alternatives for Summit View would be to add sufficient storage to be able to equalize flow. In other words if the flows are higher on the weekend, wastewater can be stored a period of time to allow the treatment and dispersal system to function at the design rate. Another consideration would be to evaluate the construction of the current drip field for possible improvements (contour installation, spacing for uniform coverage, crossing surface drains, etc...).

Q.18 IS THE PURCHASE OF LAND NECESSARY FOR THE SMOKY VILLAGE PROPERTY TO COME INTO COMPLIANCE WITH TDEC? IF NOT, WHAT IS THE ALTERNATIVE AND HOW MUCH WOULD IT COST?

A.18 The current soil area, as identified in the original design package, does not appear to have the capacity for managing the current wastewater flow. Therefore, additional soil area would be the most appropriate remedy, although I am unable to state exactly how much additional soil is needed. I am not an expert on costs of construction; therefore I am unable to comment on the costs of alternative methods.

Q.19 IS THE PURCHASE OF LAND NECESSARY FOR THE SUMMIT VIEW PROPERTY TO COME INTO COMPLIANCE WITH TDEC? IF NOT, WHAT IS THE ALTERNATIVE AND HOW MUCH WOULD IT COST?

A.19 I do not have enough information to evaluate necessity of a land purchase for the Summit View site. This system does not have the capacity to manage the volume of peak flows that have been experienced. Storage of peak weekend flows for treatment and dispersal through the week may be an alternate remedy. Also, thorough evaluation of the drip field for improvement is appropriate. I am not an expert on costs of construction; therefore, I am unable to comment on the costs of the alternative method.

Q.20 WITH RESPECT TO MAPLE GREEN, EXPLAIN ANY CONCERNS TDEC HAS EXPRESSED ABOUT THE PROPOSED FREE-SURFACE WETLAND TECHNOLOGY.

A.20 See response to Question 14.

Q.***21 IF TDEC IS CONCERNED ABOUT THE TECHNOLOGY, WHY DID IT APPROVE THE CAP FOR MAPLE GREEN?***

A.21 TDEC is not opposed to innovative technologies. To know whether the technology will work as presented, actual performance data is needed. Granted it is better to conduct pilot projects where there are current facilities able to accommodate existing flows. However, TDEC was agreeable to allow TWSI to take this approach provided that this approach will be limited to this site until such time that the technology is proven to be effective. This technology is discussed in greater detail in Question 14 above.

Q.22 IF TWSI DOES NOT START CONSTRUCTION ON MAPLE GREEN BY THE EXPIRATION OF THE PLANS APPROVAL, CAN THE COMPANY GET THE PLAN APPROVAL AGAIN?

A.22 The Division will fully consider reissuance if the plan expires. TWSI may request an extension before the expiration.

Q.23 DOES THIS COMPLETE YOUR TESTIMONY?

A.23 Yes.

ATTACHMENT 1

BRAD C. HARRIS RESUME

BRAD C. HARRIS, P.E.

635 Fruit Valley Road • Rockvale, TN 37153 • (615) 532-5367

PROFESSIONAL EXPERIENCE

MANAGER LAND-BASED UNIT, DIVISION OF WATER RESOURCES CURRENTLY
Tennessee Department of Environment and Conservation
(312 Rosa L. Parks Ave., 11th Floor, Nashville, TN 37243)

1. LAND-BASED UNIT TECHNICAL PROGRAMS ADMINISTRATION

- Responsible for technical guidance related to Decentralized Wastewater Systems, Concentrated Animal Feeding Operations, Bio-Solids, and Subsurface Sewage Disposal Programs
- Establishing and interpreting Unit policies and procedures
- Responding to citizen and legislative inquiries
- Representing the Unit of the Division in an official capacity with the engineering community and technical associations

2. STAFF SUPERVISION

- Responsible for 9 technical staff
- Managing personnel actions including promotions, disciplinary actions, performance evaluations, reductions in force, and employee training
- Responsible for maintaining a positive and productive work environment for Division staff

DEPUTY DIRECTOR, DIVISION OF GROUND WATER PROTECTION 1/2011-6/2013
Tennessee Department of Environment and Conservation
(401Church St., 10th Floor, Nashville, TN 37243)

1. DIVISION ADMINISTRATION

- Assisting the Director in the day to day operation of the Division
- Establishing and interpreting Division policies and procedures
- Responding to citizen and legislative inquiries
- Representing the Division in an official capacity with the engineering community and technical associations

2. RESPONSIBLE FOR BUDGET ADMINISTRATION AND TRACKING

- Monitoring division expenses and collections
- Projecting budget shortfalls and /or surpluses, including developing a series of spreadsheets to track revenue and predict budget trends in real time
- Developing countermeasures to align Division activities with budget expectations
- Assisting the Director with budget preparation

2. STAFF SUPERVISION

- Responsible for 72 employees (2 Environmental Program Managers, 6 Field Office Managers, 6 Asst. Field Office Managers, 3 Soils Consultants, and 54 Environmental Specialists)
- Managing personnel actions including promotions, disciplinary actions, performance evaluations, reductions in force, and employee training
- Responsible for maintaining a positive and productive work environment for Division staff

BRAD C. HARRIS, P.E.

635 Fruit Valley Road • Rockvale, TN 37153 • (615) 532–5367

ENVIRONMENTAL PROGRAM MANAGER, ENVIRONMENTAL PROTECTION SPECIALIST, DIVISION OF GROUND WATER PROTECTION 3/2003-12/2010
Tennessee Department of Environment and Conservation
(401 Church St., 10th Floor, Nashville, TN 37243)

1. MANAGE STATEWIDE EXPERIMENTAL SUBSURFACE SEWAGE DISPOSAL (SSD) SYSTEM PROGRAM

- Working independently across the state evaluating site conditions, soil suitability, and the feasibility of proposed engineering plans for the issuance of experimental SSD permits
- Individually representing the Department with engineers, homeowners, and contractors
- Reviewing the use of experimental products, conducting project and system analysis, and establishing engineering design standards for the experimental program
- Performing engineering plan reviews and construction inspections

2. MANAGE STATEWIDE SOIL AND SITE REVIEWS FOR DECENTRALIZED ONSITE WASTEWATER SYSTEMS

- Working with state soils consultants and wastewater utilities in the field to gather necessary soil data for state operating permit applications involving decentralized drip disposal systems
- Performing engineering plan reviews and preparing technical reports advising engineers and utilities regarding acceptable design standards, regulatory requirements, and soil limitations of proposed developments
- Performing construction inspections

3. TECHNICAL RESEARCH AND REGULATION WRITING

- Reviewing technical reports and research, compiling results and presenting findings
- Preparing official responses to manufacturers and engineering firms regarding technical proposals and new products
- Primary author of regulations for the use of individual home advanced wastewater treatment units and drip disposal systems for Tennessee
- Member of the Water Pollution Control technical committee for decentralized drip disposal systems
- Guest speaker at various technical conferences (TN Association of Utility Districts, TN Onsite Wastewater Association)

4. SUPERVISION OF ENVIRONMENTAL SPECIALIST

- General oversight of employee actions and performance
- Preparing job plans and performance evaluations
- Conducting performance reviews with employees

5. INSTRUCTOR

- State instructor for Cross Connection Control certification
- State instructor for new employee training

BRAD C. HARRIS, P.E.

635 Fruit Valley Road • Rockvale, TN 37153 • (615) 532–5367

PRIOR 2003 JOB HISTORY

- Production Associate, Manufacturing, Chassis Supply Partners (Bridgestone), Columbia, TN
- Production Supervisor, Manufacturing, Writer's Tape Service, Nashville, TN
- Production Associate, Manufacturing, International Comfort Products Corp, Lewisburg, TN
- Electrician's Apprentice, Commercial Construction, Lewisburg Plumbing and Heating, Lewisburg, TN

EDUCATION

BACHELOR OF SCIENCE IN CIVIL ENGINEERING Tennessee Technological University	1996 Cookeville, TN
GRADUATE Marshall County High School	1990 Lewisburg, TN

WORK RELATED TRAINING

• Choices (Equal Employment Opportunity) (2007)	State of Tennessee
• Policies and Practices for Supervisors (2006)	State of Tennessee
• Managing Performance (2006)	State of Tennessee
• Performance Evaluation (2006)	State of Tennessee
• Respectful Workplace for Managers (2006)	State of Tennessee
• Performance Evaluation Rater Training (2006)	State of Tennessee
• Writer's Workshop for Official Response Writers (2008)	State of Tennessee

TECHNICAL PROGRAMS

Microsoft Office: Word, Excel, Power Point

LICENSES AND CERTIFICATIONS

- Licensed Professional Engineer in Tennessee - #111880
- State Certified in Cross Connection Control - #6722
- Tennessee Level 2 Certification in Erosion Prevention & Sediment Control

ATTACHMENT 2

WATER ENVIRONMENT FEDERATION MANUAL OF PRACTICE, FD-16, 2010

pages 383, 384, 438, 448

1.0 TYPES OF CONSTRUCTED WETLANDS

In this manual, *wetlands* are defined as ecosystems where the water surface is at or near the ground surface for long enough each year to maintain saturated soil conditions and related vegetation. The major wetland types with potential for water quality improvement are swamps, which are dominated by trees, bogs that are characterized by mosses and peat, and marshes that contain grasses and emergent macrophytes.

The three major types of constructed wetlands for wastewater treatment are

- Free-water-surface (FWS) wetlands,
- Subsurface-flow (SSF) wetlands, and
- Vertical-flow wetlands.

Process descriptions of each of these three types of treatment wetlands are provided in the following section. There are two patented approaches to wetlands treatment that are also described.

1.1 Free-Water-Surface Wetlands

In FWS wetlands, the emergent vegetation is flooded to a depth of 102 to 455 mm (4 to 18 in.), as illustrated in Figure 9.1. Wastewater is treated as it flows through

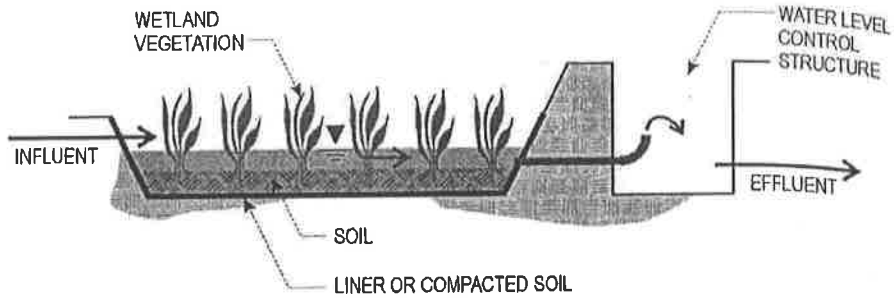

Figure 9.1 Free-water-surface constructed wetlands.

the wetland by bacteria attached to the submerged vegetation as well as by physical and chemical processes. Typical vegetation in FWS wetlands includes cattails, reeds, sedges, and rushes. An FWS wetland system usually consists of multiple channels constructed over an impermeable liner or low-permeability compacted soil (Crites and Tchobanoglous, 1998).

Free-water-surface wetlands can achieve 5-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS) concentrations less than 20 mg/L, as well as reducing total nitrogen below 10 mg/L. Nitrification and denitrification are the responsible processes for nitrogen reduction. In most FWS-constructed wetlands, nitrogen removal is limited by lack of oxygen transfer in the nitrification step (IWA, 2000). At a minimum, primary treatment is required to remove settleable solids prior to the wetland treatment system. Free-water-surface wetland systems require mosquito management to prevent nuisance conditions (Crites et al., 2006).

In addition to secondary wastewater treatment functions, FWS wetlands can be designed and used for tertiary effluent polishing while providing a community amenity for bird watching, hiking, and jogging. Constructed wetlands designed for these purposes generally have a greater percentage of open water areas to attract waterfowl and to create a visually appealing environment. An excellent example of this is located in Arcata, California, where an attractive tertiary treatment wetland is highly valued by the local community.

Free-water-surface wetlands for municipal wastewater treatment are listed in Table 9.1. The larger unit areas are for tertiary treatment or water reuse wetlands.

1.2 Subsurface-Flow Wetlands

An SSF wetland is illustrated in Figure 9.2. Wastewater is treated as it flows through a gravel or sand media planted with emergent wetland vegetation. Treatment occurs through biological, physical, and chemical processes as the water moves laterally through the media. Because of subsurface flow, this process has also been called *vegetated submerged beds*. Subsurface-flow wetlands are usu-

Water quality improvements can be expected through these components and can be estimated using the models presented in this chapter and with deep water zones analyzed with appropriate facultative pond models. The open water zones in such a system should not be larger than a 2- to 3-day detention times each to prevent the development of algae; these habitat components should be followed by a densely vegetated wetland unit with a short residence time for final polishing before final discharge.

4.4.1 *Process Design Criteria for Free-Water-Surface Wetlands*

The major design parameters are depth, detention time, loading rate, and aspect ratio. Typical design criteria are presented in Table 9.20.

4.4.1.1 Depth

The operating depth in FWS wetlands can range from 0.1 m (4 in.) to 0.6 m (2 ft). Design depths are typically 0.5 m (20 in.) to optimize detention time without exceeding the effective depth of emergent vegetation, which generally do not colonize at depths of 1 m or more.

4.4.1.2 Detention Time

The detention time in FWS wetlands depends on the limiting design parameter. For BOD and nitrate removal, the detention time can be relatively short, as shown in Table 9.20. If the removal of algae (pond TSS) is the limiting design

TABLE 9.20 Typical design criteria and expected effluent quality for FWS constructed wetlands (adapted from Crites and Tchobanoglous, 1998).

Item	Unit	Value
Design parameter		
Detention time	d	2–5 (BOD) 7–14 (N)
BOD loading rate	kg/ha·d	<110
Hydraulic loading rate	mm/d	25–125
Water depth	m	0.1–0.6
Open water zone percent	% of total area	20–30
Aspect ratio		2:1 to 4:1
Mosquito control		Required
Harvesting interval	yr	3–5
Expected effluent quality*		
BOD_5	mg/L	<15
TSS	mg/L	<15
TN	mg/L	<10
TP	mg/L	<5

* Expected effluent quality based on a BOD loading equal to or less than 110 kg/ha·d and typical settled municipal wastewater.

structure for this purpose. However, they require an adjacent deep water zone to prevent vegetation encroachment, and, in northern climates, the risk of freezing is greater than that with a submerged manifold.

5.5 Vegetation

The presence of vegetation and litter in the wetland system is critical for successful performance, but establishing this vegetation is probably the least familiar aspect of wetland construction for most contractors. In recent years, a number of specialty firms have emerged, providing the necessary expertise for selecting and planting vegetation in these systems. Using such a firm is recommended for large-scale systems if the construction contractor does not have prior wetland experience.

Wetland plants can be established from seeds, root and rhizome material (tubers), seedlings (sprigs), and locally obtained clumps. Using seeds is a low-cost, high-risk endeavor. Hydroseeding was marginally successful in the FWS wetland system at Gustine, California, and in the SSF system at Mesquite, Nevada. In both cases, supplemental hand planting was used.

Sometimes, clumps of existing wetland species can be harvested from local drainage ditches or other acceptable sources. In these cases, most of the stem (to approximately 0.3 m [1 ft]) and leaves are stripped off, and the material is planted in clumps of a few shoots. Root and rhizome material can be obtained in the same manner. If sufficient lead time is available, an on-site nursery can be established so that seedlings or clumps are available on schedule for planting.

A number of commercial nurseries have been established in recent years; they can furnish and plant various species in various forms (e.g., seeds, roots–rhizomes, and seedlings). When selecting such a nursery, a source with a climatic zone similar to the intended site should be used. Commercial seedlings have been used successfully for a number of projects. For large projects, using seedlings allows existing mechanical agricultural equipment for planting to be used. For example, a mechanical tomato planter can easily be adapted for planting wetland seedlings.

Planting in the spring provides the most successful results for seedlings, root–rhizome stock, or clumps. The planting density can be as close as 0.3-m (1-ft) centers or as great as 1 m (3 ft). The higher the plant density, the more rapid will be the development of a mature and completely functional wetland system. However, high-density plantings can significantly increase construction costs. If planted on 1-m (3-ft) centers, a wetland system will typically take at least one to two full growing seasons to approach equilibrium and achieve expected performance objectives.

Planting seedlings or clumps is the simplest because the green part goes up. Some experience with rhizomes is needed to identify the node that will be the future shoot. Soil moisture should be maintained after planting seeds or any of these other materials. The water level can be increased slowly as new shoots de-

ATTACHMENT 3

NETAFIM'S WASTEWATER REUSE AND DRIP DESIGN

GUIDE 2012, p. 28

DRAINBACK CONSIDERATIONS

When the dosing cycle ends, much of the effluent remaining in the system will drain out of the dripperline. The effluent will drain to the lowest parts of the dripperline zone, and even on a nominal (1%) slope, this could cause localized soil overloading. It is important to anticipate where the effluent will flow when the dosing event ends. There are a number of design approaches that address this issue, but the important thing to remember is that caution should be taken to ensure that draindown of the effluent toward the bottom of the slope is minimized.

One of the reasons why Bioline dripperline is a good solution on slopes is due to its pressure compensation feature. Bioline drippers deliver the same flow from 7 to 58 psi, so changes in pressure at the dripper due to elevation-created pressure variances do not affect the delivery rate of the drippers.

Other products allow additional flow anywhere higher pressures exist and as such, the soil can become saturated very quickly at the base of the slope. With Bioline, all areas of the slope are dripped at the same rate. There is no need to increase field size with Bioline. Simply use as much of the slope as possible to deliver to. (See Figures 11 & 12).

Install With the Contour: Dripperline must be installed along the contour of the slope (as level as possible), not up and down the slope. Otherwise, all the effluent in the dripperline will drain rapidly to the emitters at the base of the slope, which can overload the soil.

Feed from the Bottom of the Field: As a rule, drip fields on a slope should be fed from the bottom. This technique will prevent the main lines and manifolds from draining to the field during rest periods. This strategy assumes that the field is uphill from the supply line. The supply manifold should "stair step" through a series of check valves, with a limited number of lines between each check valve. Check valves limit the down gradient flow of the water when the pump shuts down.

Less Frequent, Longer Doses: In more highly permeable soils with no restrictive conditions, longer dosing duration and decreased dosing frequency can help minimize the effects of drainback by reducing the number of cycles per day.

Zone Valves Location: To prevent mainline and submain drainage into the drip dispersal fields, zone valves should be installed as close as possible to the distribution field to minimize the volume of effluent subject to drainback. Local regulations often prohibit effluent from mains and submains draining into the drip fields during periods of rest.

Deeper Line Burial: Another way to manage potential drainback issues and the chance of surfacing is to bury the dripperline deeper. While this is not an optimal solution, it will at least dose the effluent deeper into the soil.