FIELD PERFORMANCE ASSESSMENT OF PREMIER TECH ECOFLO® WASTEWATER TREATMENT SYSTEMS IN VIRGINIA

SUBMITTED IN SUPPORT OF GMP 118 REQUIREMENTS

BY

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Project Report
Field Performance Assessment
Premier Tech Peat Based Bio-filter Wastewater Systems

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ABSTRACT

The performance of 21 Premier Tech ECOFLO® Model ST-650 or STB-650 wastewater treatment systems was evaluated at residential facilities installed in Type 1, 2, 3, and 4 soils (sand to clay) in Virginia. The 18 systems installed in Type 1, 2 and 3 soils were each monitored for a period of 18 months. Currently the 2 systems installed in Type 4 soil have been tested for 16 and 8 months respectively and testing is ongoing according to the protocol. One system was eliminated because of very low and unrepresentative flow. Monitoring was performed in accordance with provisions contained in Premier Tech Environment test protocol, 21 July, 2003. The monitoring was staggered indicating the varying time at which a system entered into the testing. Over 5,700 data points comprise the data set for this study.

All systems assessed met the treatment standard imposed by the test protocol (date of study approval). The treatment unit/soil mantle provided wastewater renovation meeting or exceeding the standards imposed in the protocol. The monitored parameters, five (5) day Carbonaceous Biochemical Oxygen Demand ($CBOD_5$), total suspended solids (TSS), nitrogen series and Fecal Coliform bacteria levels established in the protocol were consistently achieved at the treatment boundary imposed in the approved test protocols. Those target performance levels listed in the project test protocols were: $CBOD_5$ of 30 at a depth of 12 inches below the infiltrative surface in the test systems and at the discharge from the ECOFLO® ST(B)-650 treatment systems and a Coliform level of less than 10 CFU/100 ml with no Coliform sample exhibiting a count greater than 200 CFU/100 ml at any site at any time.

SUMMARY

The Commonwealth of Virginia, like many neighboring states, is experiencing tremendous growth in both sewered and unsewered areas. All growth necessitates use of approved wastewater treatment facilities and in unsewered areas of the Commonwealth, onsite wastewater systems are required. All onsite options utilized within the border of the Commonwealth must be approved by appropriate agencies in accordance with GMP 118. This testing was developed to comply with provisions contained in this GMP.

The primary objective of this study was to assess field performance of ECOFLO® wastewater treatment units used in conjunction with soil as a receiver for treated wastewater. This field assessment and collection of performance data is necessary to determine whether to classify the ECOFLO®/soil treatment system as "generally approved" throughout the Commonwealth. Treatment standards were established for five day Carbonaceous Biological Oxygen Demand ($CBOD_5$) and Fecal Coliform (Coliform) bacteria at specified compliance boundaries. The researcher also wished to assess phosphorus removal potential of the system.

The study was initiated in October 2003 and was completed in December 2006. A total of 21 systems were initially enrolled in the study. One was eliminated because of very low and unrepresentative flow. Eighteen (18) systems were installed in Type 1 (very sandy), 2, 3 soils and 2 systems in Type 4 (clayey). Wastewater treatment systems were monitored for 18 months (Type 1, 2 and 3 soils) and monitoring is ongoing according to the protocol for the 2 systems installed in Type 4 soil. Systems selected for inclusion in the study were selected based upon: soil type, requirement for compressed footprint system, homeowner agreement to participate, and requirement that the system was treating domestic wastewater.

The study was developed to document concentrations of Carbonaceous Biochemical Oxygen Demand and Fecal Coliform levels at a depth of 12 inches below the infiltrative surface separating the ECOFLO® system from the underlying soil. The performance standard established in the test protocol (Premier Tech Environment, 21 July, 2003) required a Fecal Coliform concentration of less than 10 CFU/100 ml with no sample exceeding 200 CFU/100 ml and a $CBOD_5$ of less than 30 mg/l at this designated performance boundary. Testing was required to monitor nitrate nitrogen at this boundary, but no performance standard was established. In addition, the study coordinator and field supervisor requested measurements of the concentration of Total Kjeldahl Nitrogen (TKN) at this performance boundary. This request follows from

knowledge that TKN (the sum of organic nitrogen and ammonium nitrogen) convert to nitrate in aerobic environments.

Each test system was monitored monthly for required parameters and quarterly for additional parameters. Over 5,700 data points represent the test information collected. Water quality testing was performed by an independent certified laboratory. Sample holding times were assessed closely to assure validity of data. Sample data and sample point locations are provided in the report.

The ECOFLO® treatment system/underlying soil system consistently provided effluent meeting performance standards established in the approved test protocol. The average or mean, median, standard deviation and 90% confidence limit for parameters measured are presented in tables which are included in the body of the report. Test results show the mean CBODs in all samples tested at the treatment unit compliance boundary for the ECOFLO® unit was 8 mg/l. Test results show the mean Coliform levels at the 12 inch compliance boundary was 2 CFU/100 ml or less for all samples. Median and 90% confidence values confirm the robustness of the treatment system. At this time the results are complete for Type 1, 2 and 3 soils. For Type 4 soil, interim information is provided and monitoring is ongoing according to the protocol.

1 INTRODUCTION

Properly sited, sized, installed, operated and maintained onsite wastewater treatment facilities are essential for millions of residents in rural and urban fringe areas of Canada, the U.S., Asia, Australia, or any area with water carry plumbing. Onsite wastewater facilities have been utilized effectively for over a century. Onsite wastewater systems were initially developed to provide wastewater treatment systems in unsewered rural areas – especially farmsteads. Today, onsite wastewater systems are utilized in sensitive receiver environments and the level of treatment technology utilized prior to dispersal into the soil and the levels of technology associated with dispersal technology have advanced dramatically in the last 25 years. These advancements have been associated with utilization of onsite wastewater systems in receiver environments that pose some limitation on the ability of natural soil to adequately treat and assimilate the constituents in a wastestream. These advanced treatment and dispersal systems require a higher level of commitment to service than a traditional system. Nonetheless, these advanced systems function well and perform well when specified and developed along with being properly managed comprehensively.

The ECOFLO® wastewater treatment systems are manufactured by Premier Tech Environment in Rivière-du-Loup (Quebec) Canada. The system consists of a down-flow peat filter system, an absorption bed, and an associated soil to serve as a receiver for treated wastewater.

My understanding of the issue involved with the use of the ECOFLO® Peat Filter in conjunction with soil based wastewater treatment and reclamation facilities in Virginia involve the:

1. Appropriate hydraulic loading rate to land
2. Vertical separation requirements between the zone of waste application and watertable or restrictive layer, and
3. The level of treatment associated with the peat filter system.

The proprietary ECOFLO® wastewater treatment units are utilized as alternatives to the non-proprietary sand filter system and other approved proprietary and non-proprietary wastewater treatment devices (home aerobic treatment units or media filters) in the Commonwealth. The sand filter system as a pretreatment unit appeared in onsite wastewater literature in the mid 1970's based on Chowdry's work with sand filters accomplished in the late 1960's through the early 1970's and Hines and Favreau's work with recirculating sand filters in the early 1970's. Review of the monitoring data from operating treatment systems (aeration systems and sand filter systems) and review of

monitoring data from the ECOFLO® peat filter suggest that this proprietary treatment facility performs more reliably that the sand filter system and selected aerobic treatment units. Data on removal of bacteria and removal of organic matter as BOD_5 appear more substantial from these proprietary peat-based units than from the sand filters. Further, the sand filter may be installed as an unmanaged option while the proprietary facilities have associated with the sale, a long term management contract. The review of performance monitoring data from the contract managed proprietary facilities (ECOFLO®) suggests a degree of reliable performance associated with a wide range of input conditions.

Monitoring data from the Massachusetts Test Center, from the Virginia test sites and from facilities in North Carolina suggest managed ECOFLO® treatment systems perform more reliably and achieve higher levels of pollutant removal than those from unmanaged systems. The management system is an essential element for developing long term sustainability in the wastewater management efforts throughout the Commonwealth.

Background

Converse and Tyler (1991) report Coliform levels below soil absorption systems receiving septic tank effluent (STE) at a distance of 1 foot from the infiltrative surface of between 290 and 1140 counts per gram dry soil. Using the conversions provided by Converse and Tyler this Coliform count is equivalent to over 100,000 counts/100 ml at a depth of 1 ft below the zone of waste application for a site receiving septic tank effluent. Penninger and Hoover (1998) report Coliform levels at a maximum Coliform count of 230 counts/ml at a distance of 3 feet from a soil based system receiving sand filter effluent. Converse and Tyler (1998) report that Coliform levels fall to below detection levels where influent applied to soil contains 10 E +4 Coliform bacteria or less following flow through 1 ft (30 cm) soil. Clearly, there exists ample evidence that soil systems remove significant levels of bacteria. Typical levels of removal suggest a 2 to 3 log reduction (99%to 99.9%) removal following migration through 1 foot of soil. Higher levels of removal are typically associated with finer textured soil as the receiver.

2 DESCRIPTION OF ECOFLO® TREATMENT SYSTEM

The ECOFLO® treatment system approved for testing under this protocol consists of a primary treatment tank (a septic tank) followed by a PSA 240 pump tank with discharge to the ECOFLO® treatment unit or an alternative gravity discharge from the septic tank to the ECOFLO® treatment unit. These ECOFLO® devices are designed to discharge into a permeable mantle and final dispersal into the underlying soil. The critical

treatment system boundaries can be described as: top of peat filter receiving septic tank effluent, base of peat filter, base of mantle, natural soil 12 inches below infiltrative surface, natural soil 10 feet from system and the ultimate boundary at adjacent surface water or underlying groundwater (this ultimate boundary was not monitored in this study).

Wastewater from the facility enters the septic tank for primary settling and initial clarification. This primary treatment device provided the initial treatment separating floatable and solids from the wastewater requiring treatment in the adjacent receiver environment. Liquid enters the ECOFLO® down-flow filter through a tipping bucket that facilitates uniform dispersal of liquid onto corrugated plates which distribute liquid over the peat material in the container. Peat provides the medium where physical, chemical, and biological treatment processes reduce concentrations of pollutants in the liquid and render that residential wastewater suitable for absorption into the soil. Liquid from the peat filter enters a mantle over soil where final treatment in the designed system is realized.

3 Study Objectives

The Virginia Department of Health approved installation of the ECOFLO® treatment devices to demonstrate performance of units in a defined footprint mode. The approval was granted under GMP 118 which includes a monitoring program designed to gather performance data in order to verify that ECOFLO® technology meets the standards set by the Virginia Department of Health. The treatment or performance standard specified in the GMP was $CBOD_5$ of 30 mg/l and Coliform of 10 CFU/100 ml or less at the performance boundary. This boundary was located at a depth of 12 inches below the infiltrative surface and in the foot print of the treatment system. The general location of the monitoring points is provided in Figures 1a and 1b.

In addition, an up-gradient lysimeter was installed to assess the quality of the shallow soil moisture in the area immediately up-gradient of the treatment system. This background is critical when assessing levels of nitrate in soil systems. An additional treatment boundary was defined as the base of the ECOFLO® peat filter. Liquid samples collected at this boundary reflect the quality of the treated wastewater introduced to the soil component of the ECOFLO® treatment system.

Suction lysimeters were installed at this performance boundary and at a down-gradient boundary to assess overall performance of the treatment system. In addition, a sampling point was specified at the base of the ECOFLO® treatment unit to assess $CBOD_5$, Nitrogen, Fecal Coliform bacteria and chloride (and an occasional phosphorus test) in the liquid entering the soil system from the ECOFLO® treatment device. The primary objectives of this testing were to:

1. Assess $CBOD_5$ and Coliform levels at the prescribed performance boundary defined in the test protocol.
2. Monitor nitrogen levels in soil moisture at a depth of 12 inches below the infiltrative surface separating the created environment from the natural soil environment.

4 PROCEDURES

4.1 Site Selection Procedures

Sites selected for inclusion in the test protocol were selected to represent installations in the various soil resource groups identified in Virginia Rule (Types 1, 2, 3, and 4). Sites were selected through a partnership between Delmarva Septic Solutions (the Premier Tech representatives in Virginia) and the research team (Rubin and King). Test sites were selected to represent domestic or residential wastewater systems. Sites were also selected to insure that the various soil resource groups represented in Virginia were included in the study.

Homeowners were required to sign a document stating their willingness to participate and to grant access to their property to accomplish required monthly and quarterly sampling. As an aside, the homeowners expressed interest in the study and were very willing to open their property to the testing. Sites were selected to insure sufficient sampling data would be collected during the test period. One of the homes initially enrolled was subsequently removed from the testing due to inadequate volume of wastewater for treatment and dispersal. The home was a three bedroom facility and the owner did not generate sufficient volume of wastewater to stress the treatment system.

4.2 Field Monitoring Procedures

Figures 1a and 1b show typical ECOFLO® system installations with all monitoring devices located. Figure 1a shows a typical open bottom installation and Figure 1b shows a typical trench system. The soil moisture/shallow groundwater testing was accomplished using High Flow Porous Ceramic Cup Suction Lysimeter model 1920F1-B01M3. These are used in many groundwater sampling activities. The 1920F1 Pressure/Vacuum Soil Water Sampler consisted of a PVC body with a ceramic cup epoxy bonded at the distal end and a suction line at the proximal end. The porous ceramic cup had an outside diameter of 1.9" and is 2.0" in length. The B01M3 ceramic cup consists of a 1 bar high flow porous ceramic cup capable of transmitting bacteria from soil solution to the sample collection lysimeter. Nylon compression fittings were threaded into the top cap and were used to attach lengths of polyethylene tubing for surface access. The specified lysimeters were manufactured by Soil Moisture Inc.

Suction lysimeters were installed at the desired depth and these remained in the soil receiver at each of the sites through the entire testing period. This allowed required periodic sampling to occur with minimal disturbance to the site and soil. The samplers consisted of a porous ceramic cup and a sample collection tube. A vacuum pump was used to create a vacuum in the sampler, which allowed water from the soil to be drawn through the ceramic cup and into the sampler. The water sample was then removed from the collection tube, placed in sample bottle; the bottles were placed in a cooler and transported to the certified laboratory for analysis. Chain of custody paperwork procedures was followed. All details regarding monitoring procedures are described in the document entitled, *"Sampling Protocol for Field Testing, Sampling and Evaluation Premier Tech ECOFLO® Sewage Treatment System"* prepared by Premier Tech Environment and Delmarva Septic Solutions Inc. and approved by the Virginia Department of Health in July 2003.

4.3 Samples

After the filter bed had been in use for a period of at least four weeks, the sampling program for each site was initiated. Systems numbered 1 through 19 were sampled monthly for 18 consecutive months. Systems 20 and 21 were sampled for 8 and 16 months (monitoring is ongoing according to protocol).

Four samples were collected at each test site. These were:

- Influent of the peat filter (correspond to the septic tank effluent).
- Treated effluent from the peat bed (interface of peat bed bottom and absorption area).
- Treated effluent at a depth of 12" below the bottom of the absorption field (measured directly below the footprint of the ECOFLO® module using Lysimeter #1).
- Treated effluent at a depth of 12" below the bottom of absorption field and within the first 10 feet down-gradient of the absorption field (Lysimeter #2).
- Background soil moisture at a depth of 12" below the bottom of the absorption field to analyze for background contamination (Lysimeter #3 located up-gradient of the absorption field).

4.4 Monitoring Program

Table 1, below indicates the testing and analysis performed on each site and the frequency for each sample collected in support of this protocol. The value in parenthesis indicates the total number of samples projected by site at the end of the sampling

program. Since all systems were not monitored for 18 months, the total number of data points is slightly below the target.

Table 1: Testing and analysis

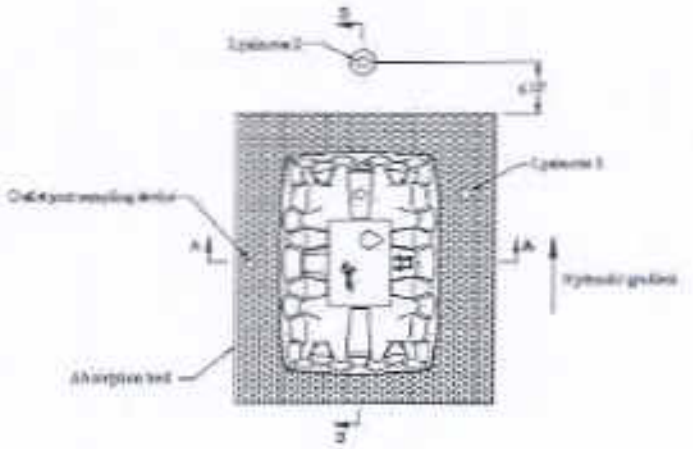
Parameter	Influent of the peat bed (septic tank effluent) ECOFLO® inlet pipe	Effluent of the peat bed (Sampling device underneath the ECOFLO® unit)	Unsaturated soil beneath the ECOFLO® foot print (12 in. below the infiltrative soil surface)	Unsaturated soil 10 feet down-gradient of the ECOFLO® footprint
CBOD5	1/month (18)	1/month (18)	-	-
TSS	1/3 months (6)	1/month (18)	-	-
Fecal Coliform	1/6 month (3)	1/month (18)	1/month (18)	1/month (18)
Chloride[1]	-	1	1	1/month (18)
Nitrate	Hach[3]	1/6 months (3)[2]	1/6 months (3)[2]	1/6 months (3)[2]
TKN	1/6 months (3)[4]	1/6 months (3)[2]	1/6 months (3)[2]	1/6 months (3)[2]

Note:

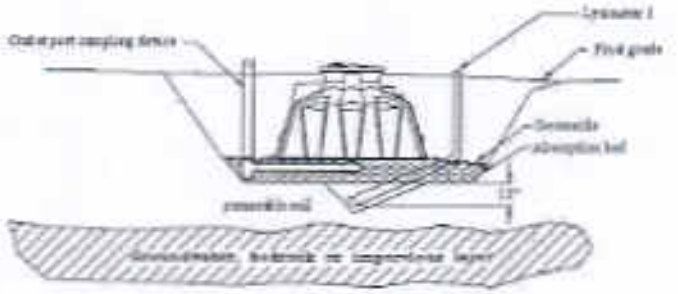
1. The tap water at each site was analyzed for the chloride one time at the beginning of the sampling program.
2. This analysis was performed only if the volume of the sample collected was sufficient for testing.
3. Qualitative field method (HACH® test strips for nitrate Cat. 27454-25 or equivalent).
4. Nitrate and TKN of septic tank effluent were analyzed only if others effluents could be performed (if sufficient sample volume was available at effluent).

Figure 1a – Typical ECOFLO® installation with monitoring components

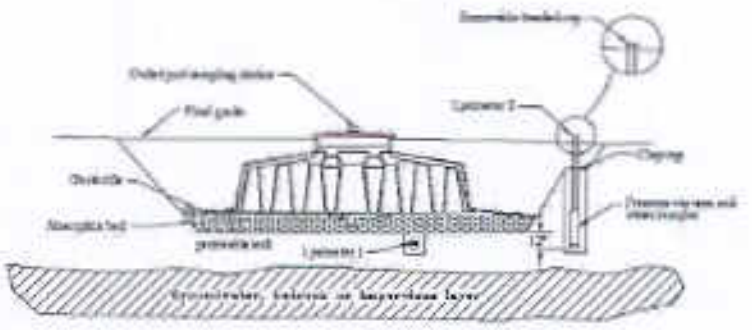
Bottomless system (ST-650)



Plan view

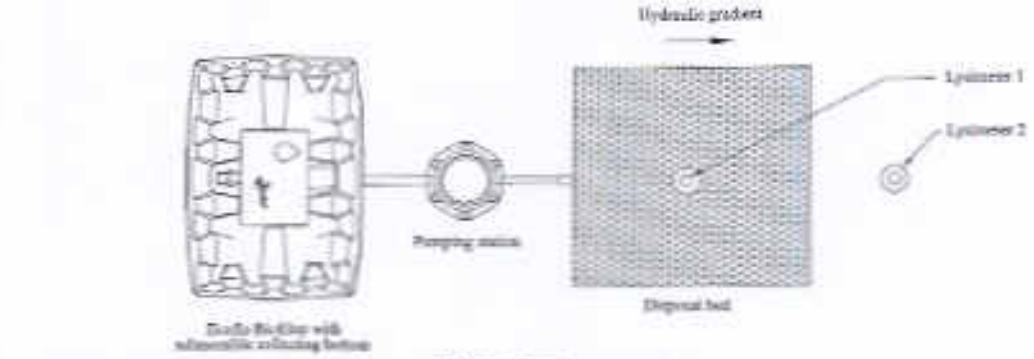


Section A-A

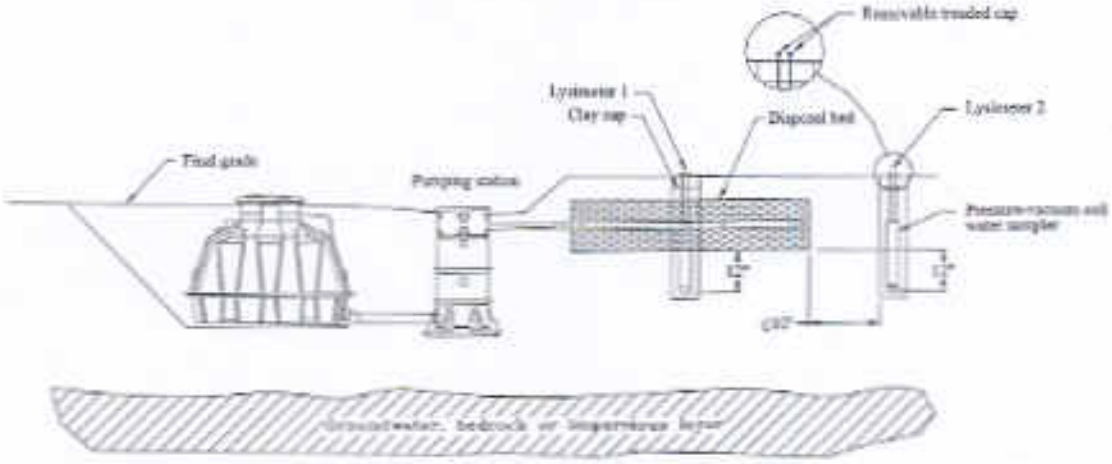


Section B-B

Figure 1b – Typical ECOFLO® installation with monitoring components
System with bottom (STB-650)



Plan view



Section view

All the samples were delivered to an independent laboratory duly certified by the Virginia Department of Health. The only exception was the nitrate from the septic tank effluent, which was completed in the field. Generally, septic tank effluent does not have any nitrate, and this was verified by a field qualitative method (HACH® test strips for nitrate Cat. 27454-25 or equivalent). Should nitrate have been detected, that may indicate groundwater intrusion into the septic tank or the line between the tank and the treatment unit.

In addition, in order to measure the potential for background contamination, an additional suction lysimeter was installed at selected sites up-gradient of the ECOFLO® treatment unit. Sampling frequency to measure the potential background contamination was determined as a function of the first sample results. If nitrate levels were high in test samples, up-gradient testing of the groundwater was initiated to assess relative contribution from wastewater as compared to background. The goal of the treatment was to insure nitrate levels in shallow groundwater did not increase by over 10 mg/l above background.

The methods specified for analysis of each test parameter are presented in the Table 2, below.

Table 2: Standard Test Methods

PARAMETERS	ANALYSIS METHOD
$CBOD_5$	SM 5210B
TSS	SM 2540D
TKN	SM 4500NorgC
Fecal Coliform	SM 9221C
Nitrate	SM 4500NO3 D
Chloride	SM 4500C1 C

Note: SM = Standard Methods for the Examination of Water & Wastewater, 18th Edition

Finally, all sites were equipped with an event counter that counted the number of tipping bucket events of the ECOFLO® distribution system. This will allow the analysis to include evaluation of the total volume of wastewater that is treated by the ECOFLO® unit and discharged into the soil.

Referencing the ECOFLO® provisional approval, Table 3, below describes the target treatment standards (performance standards) for each site examined and included in this testing protocol.

Table 3: Performance Requirements for ECOFLO® Treatment System (Filter and Soil)

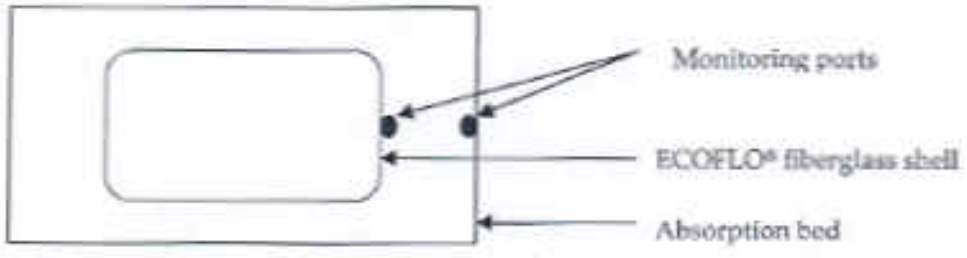
PARAMETERS	INFLUENT	EFFLUENT (PEAT MEDIA)	SOIL WATER (12" BELOW THE BOTTOM OF THE ABSORPTION FIELD)
TSS	-	-	< 30 mg/L [1]
CBOD5	>100 and <300 (for any individual samples) > 150 mg/L (average)	-	< 30 mg/L [1]
Fecal Coliform	-	-	< 10 CFU/100 ml (geometric mean) <200 CFU/100 ml (single sample)
Nitrate	No standard is established; however results may be used to demonstrate the performance.		
Chlorides	Increase compared to tap water.		

1. The TSS and CBOD5 were not analyzed in the samples collected by the lysimeters but at the effluent discharge from the peat bed. The research team assumed that if the 30 mg/L standard was achieved at the effluent from the peat bed, it was certainly less than that everywhere in the absorption bed which followed.

4.5 Ponding

Two monitoring ports were installed at each site. One just at the limit of the ECOFLO® fiberglass shell and the other at the outer limit or extent of the hydrologic boundary associated with the absorption bed. During each sampling event, the ponding depths were monitored at these two ports. Figure 2 below shows an overhead plan view with the location of the two monitoring ports.

Figure 2: Monitoring ports



5 RESULTS AND DISCUSSION

A total of 21 systems were sampled through this approved test protocol. Systems installed in Type 1, 2 and 3 soils were tested for the requisite 18 months; however the two systems installed in Type 4 soil were enrolled in the protocol late and were tested only 8 to 16 times. The testing involved assessment of the peat treatment unit and the soil environment. Measures of the quality of the liquid generated from the ECOFLO® treatment unit were collected to determine $CBOD_5$, nitrogen, and Fecal Coliform bacteria generated from the treatment unit. Measures of concentrations of soluble nutrients and Coliform bacteria in the soil receiver environment immediately below the infiltrative surface and at defined system boundaries were collected to assess potential environmental and health impacts of the total system. Data details on the soil types and results from individual sampling events, as well as a summary of the results are provided in the table presented in Appendix A.

Standard methods as listed in the approved protocol were used for all testing and analysis. Holding times were maintained properly between sampling events and testing. Sample preservation was in accordance with standard field protocol (cooling for microbiological tests and preservation for others). All samples were transported from the site to the laboratory in a cooler with adequate ice to maintain proper temperatures through the transportation process.

The summary table provides information on the testing from all systems. The mean and median values from the testing, the standard deviation of the measure, and the 90% confidence level are provided. Inclusion of the mean and median value is important when examining a long time series test. The median values have been included in reports by Tyler and Converse (1997), Hoover and Groves (2005), and these median values may be more representative of performance than the mean. In addition, the 90% confidence level indicates the values to which systems can perform under stress because of flow variation, temperature and climatic variations, changing wastewater inflow characteristics, or other influences on system performance.

5.1 ECOFLO® Peat Filter Treatment Unit Performance

$CBOD_5$: Data summarizing the treatment efficiency for the ECOFLO® treatment systems is presented in Table 4 below. These data summarize the treatment achieved in all systems enrolled in the study. Specific site data is contained in the table presented in Appendix A, previously mentioned.

Table 4: Mean, Median, Standard Deviation (SD), 90% Confidence Limits and Percent for $CBOD_5$ in Influent to and Effluent from ECOFLO® Peat Filter at Sites in Virginia (as mg/l), n = 332

	Influent	Effluent	% Removal
Mean $CBOD_5$ and (SD)	186 (113)	8 (8)	96
Median $CBOD_5$	170	6	96
90% Confidence Limit	343	16	95

The mean and median $CBOD_5$ values observed in all samples from the ECOFLO® treatment unit were 8 mg/l and 6 mg/l respectively. The value below which 90% of the $CBOD_5$ values fell was 16 mg/l. Based on these test data, the $CBOD_5$ removal exceeds the required performance level established in the test protocol. Examination of all data indicates the maximum $CBOD_5$ values observed through all testing were encountered at the Pride of Virginia facility. This facility is a somewhat atypical residential facility with migrant labor providing services to a seafood processing operation. Nonetheless, the mean and median values of $CBOD_5$ from this facility met the standards imposed through the approved test protocol. The 90% confidence limit of testing from this facility was 30 mg/l. and that is the standard imposed through the protocol. Even under conditions of duress, the ECOFLO® unit treated liquid to the required standard.

The maximum $CBOD_5$ observed through the testing were detected at the Palmer residence, the Stevens – Jeff residence and at Pride of Virginia (A). The high values do not seem correlated with anticipated low temperature, high rainfall, or other conditions that would facilitate an increase in $CBOD_5$. The values associated with these excursions cannot be explained by data assessment only. The high values experienced at the Stevens residence do seem to occur during a cool season, but not all high values are represented in the cool season only. The ponding height at the central support is also not an indicator of the high $CBOD_5$ potential. Systems exhibiting significantly higher ponding height achieve high levels of $CBOD_5$ removal. Further, wastewater flow to the systems is not excessive during periods where these excursions in $CBOD_5$ were observed.

In contrast to these maximum values, minimum values observed through the testing were 2 to 3 mg/l and the frequency of these low values was greater than the frequency of the higher values. This suggests that the curve representing all data is skewed toward the higher levels of treatment observed in the bulk of the data represented. The ECOFLO® treatment unit does meet the conditions imposed for effluent $CBOD_5$ concentration through the test protocol.

Fecal Coliform: The treatment standard imposed on the ECOFLO® treatment system required a Fecal Coliform level of 10 CFU/100 ml following flow through 12 inches of soil below the treatment unit. Data collected during the testing at the base of the treatment unit suggests that the peat treatment unit itself was capable of achieving a 1.5 to 2 log reduction (95% to 99%) in Coliform counts following flow through the filter only. This was achieved without disinfection. Performance data regarding the filter only are presented in Table 5, below.

Table 5: Mean, Median, and 90 % Confidence Limits for Fecal Coliform Bacteria in Influent to and Effluent from ECOFLO® Peat Filter at Sites in Virginia (as CFU/100 ml), N = 301

	Influent	Effluent	Removal (log)
Mean F. Coliform	34,262	1,029	1.5
Median F. Coliform	57,900	920	1.8
90% Confidence Limit	240,200	34,300	0.8

This is an impressive reduction in bacteria count, but does not meet the standard imposed for the entire process. Consequently, the peat filter effluent does not meet standards and the soil system is required to provide the additional treatment required to meet performance standards imposed through this protocol. See additional results from 12 inches of soil treatment where performance boundaries need to be and are met.

TSS: total suspended solids represent a good measure of the potential solids content in liquid applied to soils. High levels of solids in effluent tend to facilitate clogging of fine pores in soil and this can result in some reductions in permeability. The peat filter affords excellent removal of TSS. Influent concentrations to the filter surface were measured as a mean of 34 mg/l. Effluent generated from the peat treatment unit contained a TSS mean value of 6 mg/l and a median value of 4 mg/l. This skewness in the curve suggests that the peat filter typically generates a TSS value of 4 mg/l or less. This is critical when potential for soil clogging is considered. These low TSS values facilitate long term successful operation of the land based component of the system. No performance standard was established for total suspended solids.

Nitrogen (as TKN and nitrate): The Total Kjeldahl Nitrogen (TKN) represents the sum of organic nitrogen and ammonium nitrogen in a sample. These forms of nitrogen convert to nitrate nitrogen when soil conditions are aerobic. Since aerobic soil conditions are a condition associated with siting an on-site wastewater system on a property, the organic nitrogen and ammonium contained in a sample will convert to nitrate. Treatment efficiency indicating the level of nitrogen transformation and potential removal for the peat filter is presented in Table 6, below.

Table 6: Median, Standard Deviation, and 90% Confidence Limits for TKN and Nitrate in Influent to and Effluent from ECOFLO® Peat Filter at Sites in Virginia (as mg/l), n = 82 for TKN and n=324 for NO_3

	Influent	Effluent
Mean TKN and (SD)	51 (42)	10 (14)
Median TKN	42	4
90% Confidence	83	25
Mean NO_3 and (SD)	1 (1)	22 (17)
Median NO_3	1	21
90% confidence	1	48

The levels of nitrogen present in the treated effluent generated by the peat filter suggest significant nitrogen removal through the peat filter during the test period.

No nitrate nitrogen is expected in septic tank effluent. A detectable nitrate level in liquid applied to the filter would suggest intrusion of groundwater into the system. No evidence of elevated nitrate was observed in the testing. The elevated nitrate present in the peat filter effluent indicates that the filter is functioning as an aerobic treatment system. The conversion of the organic and inorganic nitrogen (as ammonium) to nitrate is expected in a properly functioning aerobic filter. The average nitrogen in the effluent is the combination of TKN and nitrate, the sum of these is the total nitrogen. The mean total nitrogen in the peat filter effluent was 32 mg/l and this represents a 38.5% reduction in total nitrogen through the filter component of the system. This is a significant reduction in the nitrogen present in the liquid to be applied to the soil.

5.2 Soil Treatment System Performance

The ECOFLO® treatment system consists of a peat filter to condition liquid prior to discharge to the soil system. The soil serves as the final receiver for the liquid generated at the residential facilities examined in this study. The soil serves as a buffer between shallow groundwater and adjacent surface water. These elements of the aquatic environment constitute the final receiver for materials applied to land, but performance standards are imposed where property owners can be held accountable for maintaining a mandated level of system performance.

The test protocol approved in 2003 established performance standards at a location 12 inches below the infiltrative surface separating the natural soil system from the ECOFLO® peat filter component. The filter system consisted of a fiberglass enclosure containing the peat filter media and a permeable infiltration bed placed on the soil

surface. The compliance boundary for the treatment system was the soil solution 12 inches below the footprint of the ECOFLO® treatment unit. This performance allowed flow through only 12 inches of natural unsaturated soil before compliance was imposed. Compliance at this boundary assures compliance further down-gradient. A second sampling point was established 120 inches (10 feet) from this initial compliance boundary. This second sampling location was established to assure no potential for contamination down-gradient from the system because of deep flow which may migrate below the initial compliance boundary and rise toward the soil surface down-gradient of the system.

Samples of soil moisture were extracted from the sites utilizing suction lysimeters. These are standard monitoring devices for assessing performance of land based waste treatment systems. Parameters assessed to assure compliance at this treatment boundary were $CBOD_5$ and Fecal Coliform Bacteria. Nitrate was established as a "monitor only" parameter.

$CBOD_5$: The sample protocol required a $CBOD_5$ of 30 mg/l at 12 inches below the infiltrative surface. In lieu of testing soil moisture levels where confounding parameters may skew results, the research team chose to sample effluent entering the soil system. The samples were collected at the discharge from the peat filter. The mean, median, and 90% confidence values for $CBOD_5$ indicate that the performance standard was achieved over 90% of the time at the peat filter system boundary. The research team inferred that compliance at the filter discharge would result in compliance at the specified performance boundary. This performance level of 30 mg/l in the ECOFLO® peat filter effluent was achieved over 90% of the time during this study. The performance of the filter was discussed in the previous section.

Nitrate: Nitrate nitrogen levels of 10 mg/l or higher in groundwater violate the primary drinking water standard. Since untreated groundwater can be used as a source of drinking water, regulatory agencies have established the 10 mg/l level as a typical compliance value for land-based wastewater treatment systems. Nitrate is formed as ammonium nitrogen which is biologically oxidized to nitrate. This biological conversion occurs in aerobic soil. The soil into which land-based wastewater systems is placed must be aerobic in and around the zone of wastewater application. These aerobic conditions encourage formation of nitrogen.

Background nitrate levels were assessed at all facilities. These background levels represent the nitrate levels in areas uninfluenced by the wastewater system; areas located up-gradient from the treatment system. Water flows along gravity gradients

and the groundwater from these up-gradient lysimeters (L3) will migrate toward the wastewater treatment system.

Nitrate and TKN concentrations in the shallow groundwater indicate excellent removal for nitrogen through the treatment process. Table 7, below summarizes the nitrogen levels in treatment units by soil resource group.

Table 7: Mean, Median, Standard Deviation and 90% Confidence Level for TKN and Nitrate in Lysimeters Installed in ECOFLO® Absorption Field (L1), 10 Feet Down-Gradient (L2) and Up-Gradient (L3) (as mg/l) by Soil Resource Type

	L1	L2	L3 (Background)
Type 1 TKN Mean (SD)	3 (7)	4 (11)	2 (3)
Type 1 TKN Median	1	1	1
Type 1 TKN 90%	5	8	4
Type 2 TKN Mean (SD)	1 (2)	0.9 (1.2)	0.5 (0.6)
Type 2 TKN Median	1	0.3	0.3
Type 2 TKN 90%	3	3	1
Type 3 TKN Mean (SD)	6 (9)	3 (10)	1.0 (1.4)
Type 3 TKN Median	1	1	0.4
Type 3 TKN 90%	21	2	3
Type 1 NO_3 Mean (SD)	7 (10)	3 (6)	4 (5)
Type 1 NO_3 Median	2	1	4
Type 1 NO_3 90%	21	13	10
Type 2 NO_3 Mean (SD)	6 (8)	4 (6)	2 (3)
Type 2 NO_3 Median	3	1	1
Type 2 NO_3 90%	19	10	6
Type 3 NO_3 Mean (SD)	2 (2)	1 (1)	2 (3)
Type 3 NO_3 Median	1	0.5	1
Type 3 NO_3 90%	6	3	3

The mean and median background nitrate levels from systems tested are 3 mg/l and 1 mg/l respectively. Peak nitrate values in selected residences are detected at levels as high as 20 mg/l. These background values violate the standards imposed in the testing. Assessment of the high nitrate levels associated with individual treatment systems correlate well with the high background levels observed for nitrate in selected systems. For example, the 21 mg/l nitrate levels observed in the Beatley system monitoring wells are located in an area with a background nitrate of 14.4 mg/l. Similarly, high background levels are associated with other excursions. This is discussed below.

Testing accomplished at the 12 inch compliance boundary indicates that the systems tested achieved this treatment standard. The mean and median nitrate nitrogen levels for all systems tested were 5 mg/l and 2 mg/l respectively. The 90% confidence limit was 19 mg/l. This suggests that, although the systems met the 10 mg/l limit imposed, the curve is skewed toward the higher levels. The higher levels of nitrate detected appear correlated slightly with the coarse textured sandy and loamy soils. This is consistent with potential for rapid movement of air into the soil profile to create air rich environments encouraging nitrification. The finer textured soils (clay loams and clays) transmit air at slower rates and there is potential for denitrification in these finer textured soils. Consequently, the nitrate levels appear slightly lower in the heavier textured soils than the coarser textured materials.

Testing in the boundary located 120 inches (10 feet) down-gradient indicates that nitrate levels fall significantly. Mean and median nitrate levels in these down-gradient wells are 3 mg/l and 1 mg/l respectively. These levels are well within property boundaries and compliance is assured at property lines.

Levels of nitrate in the system monitoring wells at the Beatley residence, Pittman residence, Stephen Ford residence and Reed residence are associated with abnormally high levels of nitrate in the shallow groundwater up-gradient from the on-lot wastewater treatment systems. Adjusting the system monitoring levels by removing the background nitrate concentration results in compliance with treatment system standards at the Beatley residence, but not at others. Clearly, background nitrate does influence system performance and compliance.

Correlation between nitrate levels in shallow soil moisture samples does not appear related to ponding in the soil at the fringe of the system boundary. Examination of the nitrate levels and ponding depth does not appear to demonstrate a correlation between saturated soil and nitrate concentrations.

Statistical sampling suggests compliance with the nitrate requirement for groundwater. Mean and median values for nitrate are below the drinking water standard at the compliance boundary. Since nitrate was a "monitor only" parameter, no compliance with a performance standard is required, only compliance with federally mandated groundwater standards at groundwater.

Fecal Coliform Bacteria: Fecal Coliform bacteria are indicators of human fecal contamination. Levels of Fecal Coliform bacteria at the established compliance

boundary located 12 inches below the infiltrative surface indicate excellent removal of this public health indicator. The standard required a geometric mean of 10 CFU/100 ml and no single sample containing a Coliform count in excess of 200 CFU/100 ml.

A performance standard was specified for Fecal Coliform bacteria in the shallow soil moisture. Table 8, below presents results from the Coliform testing by soil resource type.

Table 8: Mean, Median and 90% Confidence Level for Coliform Bacteria in Lysimeters Installed in ECOFLO® Absorption Field (as CFU/100 ml) by Soil Resource Type

	L1	L2	L3 (background)
Type 1 Coliform Mean	2	2	2
Type 1 Coliform Median	2	2	2
Type 1 Coliform 90%	2	2	2
Type 2 Coliform Mean	2	2	2
Type 2 Coliform Median	2	2	2
Type 2 Coliform 90%	2	2	2
Type 3 Coliform Mean	2	1	1
Type 3 Coliform Median	2	1	2
Type 3 Coliform 90%	2	2	2
Type 4 Coliform Mean	1	1	2
Type 4 Coliform Median	1	1	2
Type 4 Coliform 90%	2	2	2

Examination of the monitoring data indicates most samples contain a Coliform level of 1 CFU/100 ml to 2 CFU/100 ml. The highest level detected reliably was 170 CFU/100 ml. Coliform counts reported in excess of the target performance standard are associated with sampling or laboratory problems (field collection notes are available upon request). Re-sampling at those residential facilities where excursions from the Coliform standard were present indicate compliance.

Soil systems are effective in removing Fecal Coliform bacteria. The processes critical to Coliform bacteria attenuation ongoing in the soil environment include physical separation or filtering which separate bacteria from the soil solution. This facilitates the biological processes required for attenuation of bacteria and includes natural die-off, predation, and consumption. Bacteria and other microorganisms present in human waste and potentially threats to public health and environmental quality are most suited for survival in the human host. Moisture levels, temperature, food supply, and

lack of predators render the human digestive system an ideal host for these microorganisms. When discharged into the environment, bacteria and other microorganisms that populate the human gut encounter conditions very hostile for their survival. The soil system typically provides a 2 to 3 log reduction in Coliform bacteria count per foot of soil material through which wastewater moves. The reductions encountered at the 12 inch level are comparable to those achieved as septic tank effluent moves through an equivalent of 2 to 3 feet. The ECOFLO® treatment system serves as a surrogate for soil where high levels of bacterial attenuation are required and limited soil exists to provide this desired result.

Bacteria levels in the septic tank effluent tested in this study ranged widely through the study. Bacteria levels as low as 280 counts/100 ml were reported in the septic tank effluent testing. These low values are atypical of domestic wastewater. Higher values reported as 200,000 to 1,000,000 counts/100 ml are more representative of domestic wastewater. The peat treatment unit reduced these bacteria levels by 90% to 99% (1 to 2 log reduction). The soil system reduced these bacteria concentrations by an additional 99.9%. This is equivalent to a 5 or 6 log reduction in Coliform bacteria levels through the ECOFLO®/soil system. The system is defined as the peat filter unit, a permeable infiltration layer below the filter, and 12 inches of natural soil. This combination results in excellent treatment. The performance standard imposed at commencement of this study was achieved at the designated performance boundary. Coliform bacteria removal was demonstrated successfully at the 20 systems tested in Virginia.

Process indicator assessments: process indicators include measures that can be taken instantly at a site. These represent real time indicators for system performance. The most common of the process indicators assessed are flow, pH, dissolved oxygen (D.O.), and conductivity. Wastewater flow from each of the facilities was measured with a metered tipping bucket. The mean and median wastewater flows to the systems tested were 156 and 127 gallons per day respectively. These are generally low flows for residential facilities. The skewness of the data suggests that the flows tend to be more conservative than typically utilized for the design of residential wastewater systems.

The wastewater flows at Pride of Virginia (B) are higher than design. These high wastewater flows may account for the deviations in treatment efficiencies noted at this facility. The CBODs levels in several of the monitoring events reflect values higher than collected at facilities with lower flows. This process indicator could be used as a surrogate to assess system performance. When flows are in excess of those planned, treatment efficiency often declines.

Supplemental Monitoring – Phosphorus: phosphorus levels were monitored in soil moisture samples extracted from areas adjacent to ECOFLO® treatment units in Virginia. Phosphorus is emerging as a water quality concern in many freshwater systems. The phosphorus concentrations in effluent applied to shallow subsurface wastewater systems were measured at selected ECOFLO® test sites as a part of the test protocol for the Premier Tech system monitoring. Systems were selected to include soil types represented in the test protocol. There was no requirement to test phosphorus as a component of the original approved test protocol. These levels were measured to assess the potential for phosphorus removal in the peat wastewater systems. The system is defined as the peat filter and the soil material underlying the peat system. Results in total phosphorus concentrations at septic tank effluent, peat filter effluent and Lysimeter #1 are presented in Appendix B, Table 1S, and the results in phosphates from the three lysimeters (#1, 2 and 3) are presented in Table 2S (Appendix B). The detection level for the test methods utilized was 0.02 mg/L

Phosphorus levels detected in the septic tank effluent applied to the peat treatment units ranged from 4.9 mg/l to 7.1 mg/l. The peat filter reduced these influent concentrations to 3.8 mg/l to 6.5 mg/l. This is approximately a 10% reduction through the peat filter. Samples of the soil moisture removed at Lysimeter 1 typically contained a total phosphorus level below or equal to 0.2 mg/L in total phosphorus and below or equal to 0.1 mg/L in phosphates. This indicates that the soil system is an excellent medium for attenuating phosphorus. This phosphorus attenuation potential will become more critical where eutrophication of surface waters becomes an issue of local concern.

6 CONCLUSIONS

Performance standards were imposed on the ECOFLO® treatment system for Carbonaceous Biochemical Oxygen Demand and Fecal Coliform bacteria. Monitoring data indicates that the systems assessed met the treatment standards imposed over 90% of the time. No reliability was imposed in the protocol and the 90% confidence level is generally considered stringent.

The performance level imposed for CBOD$_5$ at the interface between the man-made environment and the soil infiltrative surface was established as 30 mg/l. This treatment level was achieved. This parameter was measured at the discharge from the peat filter.

The limit for Fecal Coliform bacteria established at a depth of 12 inches below the infiltrative surface was 10 counts or colony forming units (CFU)/100 ml with no sample exceeding 200 CFU/100 ml. This treatment level was achieved.

A "monitor only" standard was imposed for the nitrogen series as TKN and NO_3. An additional nutrient parameter was added by the researcher. Shallow groundwater monitoring indicates that nitrogen removal achieved shallow groundwater levels of nitrate and TKN near 2 mg/l. This meets drinking water standards. Supplemental monitoring indicated excellent removal for phosphorus. Total phosphorus levels in shallow groundwater samples never exceeded 0.2 mg/l.

Based on a review of the data collected, the systems installed in Type 1, 2 and 3 soils achieved the performance levels established in the test protocol. For Type 4 soil, monitoring is ongoing according to protocol.

Respectfully Submitted;

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Biological and Agricultural Engineering
North Carolina State University

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APPENDICES

A – Data table
B – Phosphorus results

APPENDIX A

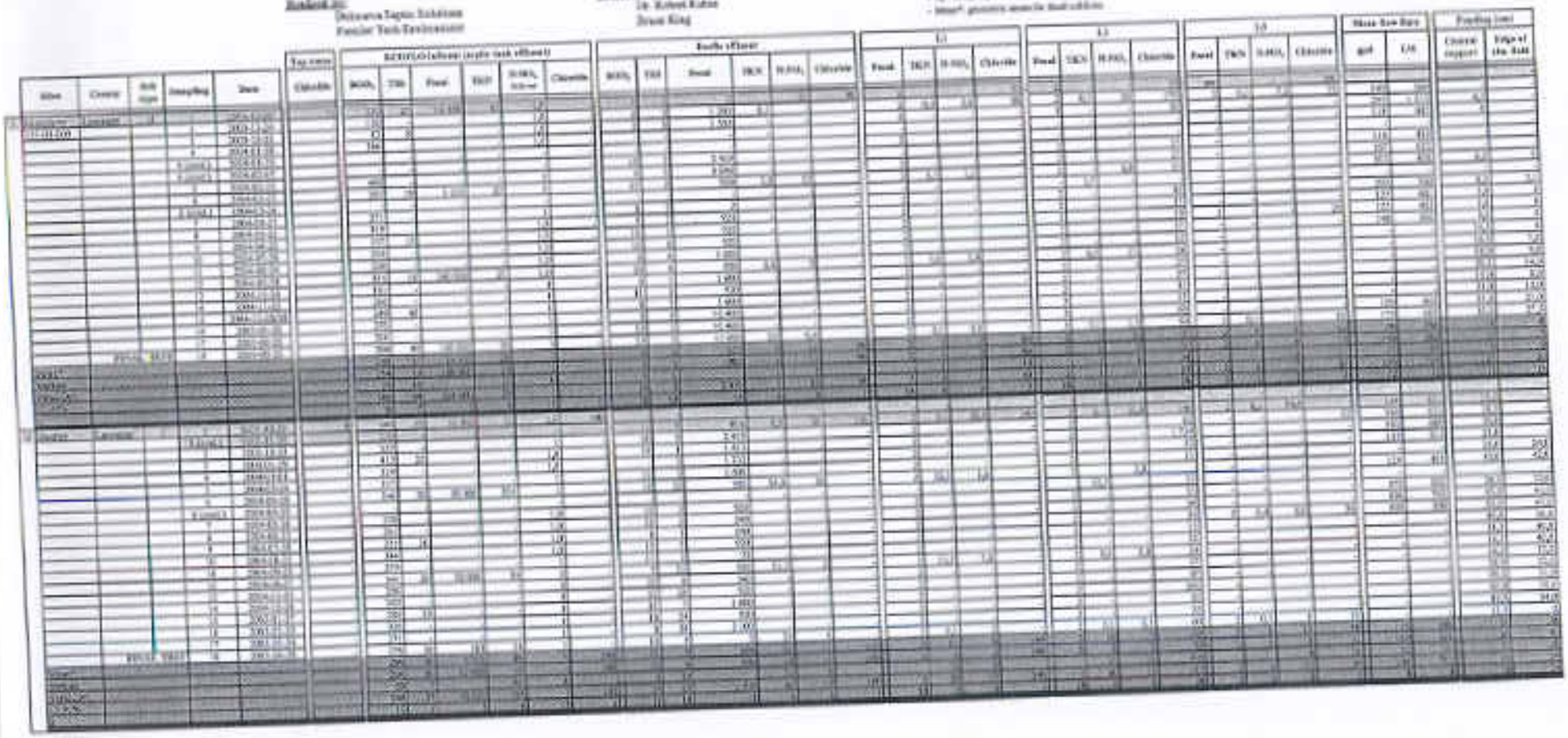
Data table

VIRGINIA
Monitoring Protocol

Analysed by:
Delaware Tapia Solutions
Premier Tank Environment

Collection taken all
Dr. Robert Rubin
Jesse King

Notes
- [illegible]
- [illegible]
- [illegible]
- ww: ww water
- dg - sampling + laboratory problems
- blue* - grooves, more in final collection



VIRGINIA
Monitoring Protocol

Realized by:
Delmarva Septic Solutions
Premier Tech Environment

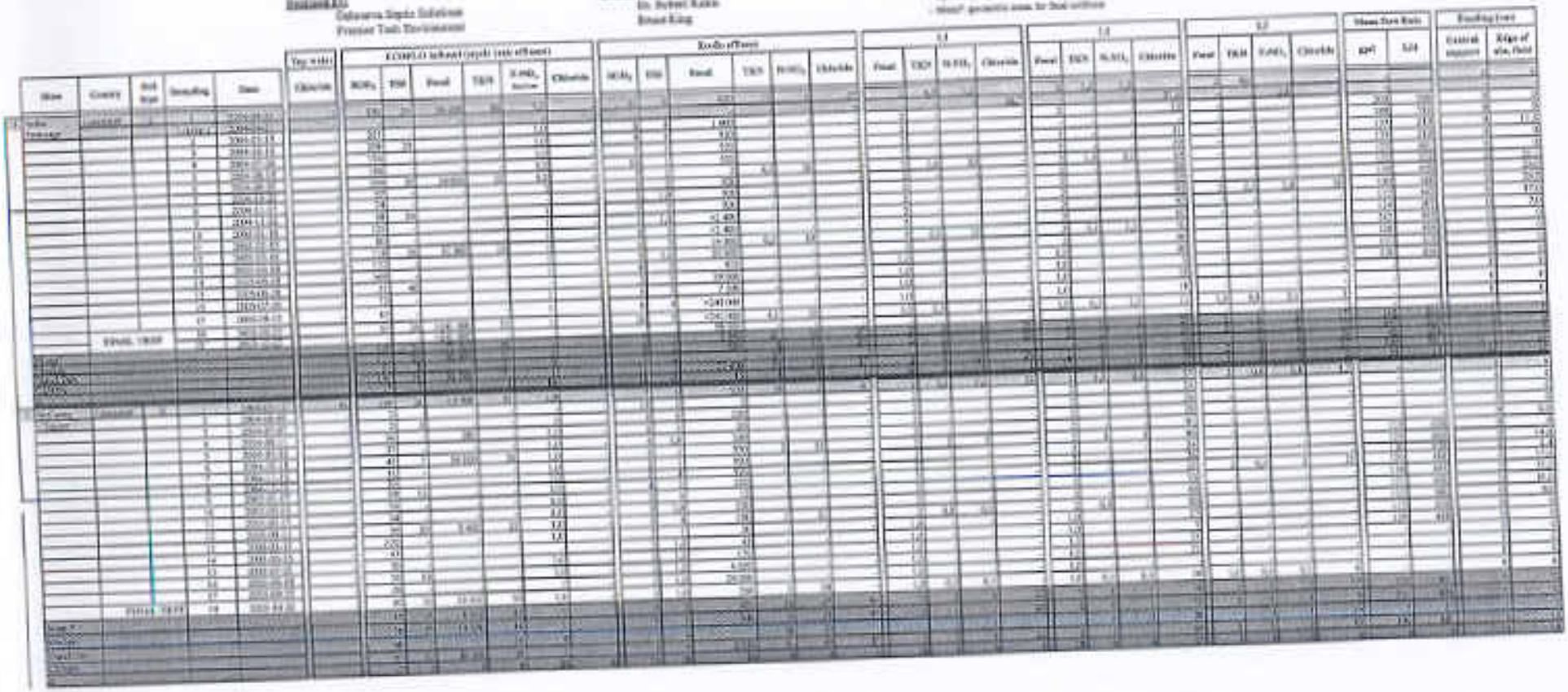
Collaboration of:
Dr. Robert Rubin
Bruce King

Notes:

Site	County	Soil type	Sampling	Date	Tap water: Chloride	ECOFLO (influent/septic tank effluent): BOD5	TSS	Fecal	TKN	N-NO3	Chloride	Biofilter effluent: BOD5	TSS	Fecal	TKN	N-NO3	Chloride	L1: Fecal	TKN	N-NO3	Chloride	L2: Fecal	TKN	N-NO3	Chloride	L3: Fecal	TKN	N-NO3	Chloride	Water flow data: gpd	L/d	Ponding level: Central support	Edge of the field
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Updated [illegible] 2007

VIRGINIA
Monitoring Protocol



VIRGINIA
Monitoring Protocol

Evaluated by:
Delaware Septic Solutions
Pioneer Tech Environment

Collaboration of:
Dr. Robert Rubin
Bruce King

Notes:
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- dp - sampling or laboratory problem
- [illegible]

Site	County	Soil Type	Sampling	Date	Tap water: Chloride	Effluent: BOD_5	Effluent: TSS	Effluent: Fecal	Effluent: TKN	Effluent: $N\text{-}NO_3$	Effluent: Chloride	Effluent: BOD_5	Effluent: TSS	Effluent: Fecal	Effluent: TKN	Effluent: $N\text{-}NO_3$	Effluent: Chloride	L1: Fecal	L1: TKN	L1: $N\text{-}NO_3$	L1: Chloride	L2: Fecal	L2: TKN	L2: $N\text{-}NO_3$	L2: Chloride	L3: Fecal	L3: TKN	L3: $N\text{-}NO_3$	L3: Chloride	Flow: gpd	Flow: L/d	Ponding: Trench support	Ponding: Edge of the field
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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VIRGINIA
Monitoring Protocol

Analyzed by:
Delaware Septic Solutions
Premier Tech Environment

Collaboration of:
Dr. Robert Rubin
Bruce King

Notes:
- 1.1: 12 active participants for review of the 2-cycle operation limit.
- 1.2: 12 active participants for 12-cycle operation limit and 10 that meet the last interval for determination limit.
- 1.3: No analysis or measure for biochemical contamination
- ww: as water
- dp: sampling or laboratory problem
- Mean*: geometric mean for fecal coliform

Site	County	Soil type	Sampling	Date	Trip water	SCDHPSS influent (septic tank effluent)						Recirculation effluent						1.1				1.2				1.3				Mean flow data		Pumping cycle	
					Chloride	BOD_5	TSS	Fecal	TKN	$N\text{-}NO_3$ before	Chloride	BOD_5	TSS	Fecal	TKN	$N\text{-}NO_3$	Chloride	Fecal	TKN	$N\text{-}NO_3$	Chloride	Fecal	TKN	$N\text{-}NO_3$	Chloride	Fecal	TKN	$N\text{-}NO_3$	Chloride	gpd	L/t	Interval (approx)	Ridge of elec. field
1	Greene	Hyden Loam	1	1	1/1/2016	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
				2	1/2/2016																											
				3	1/3/2016																											
				4	1/4/2016																											
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				30	1/30/2016																											
				31	1/31/2016																											
	Mean* / Geom																															
	Median																															
	Min																															
	Max																															
2	Pittsylvania	Chewacla Loam	2	1	1/1/2016	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
				2	1/2/2016																											
				3	1/3/2016																											
				4	1/4/2016																											
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	Mean* / Geom																															
	Median																															
	Min																															
	Max																															

VIRGINIA
Monitoring Protocol

Studied by:
Delmarva Septic Solutions
Premier Tech Environment

Collaboration of:
Dr. Robert Rubin
Bruce King

Notes:
[illegible]

Site	County	Soil type	Sampling	Date	Tap water: Chloride	ECOFLO influent (septic tank effluent): BOD_5	TSS	Fecal	TKN	NO_3-N	Chloride	Ecoflo effluent: BOD_5	TSS	Fecal	TKN	NO_3-N	Chloride	L1: Fecal	TKN	NO_3-N	Chloride	L2: Fecal	TKN	NO_3-N	Chloride	L3: Fecal	TKN	NO_3-N	Chloride	Water flow rate: gpd	L/d	Ponding: [illegible]	[illegible]
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VIRGINIA
Monitoring Protocol

Produced by:
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Premier Tech Environment

Collaboration of:
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Bruce King

Notes:
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- [illegible]
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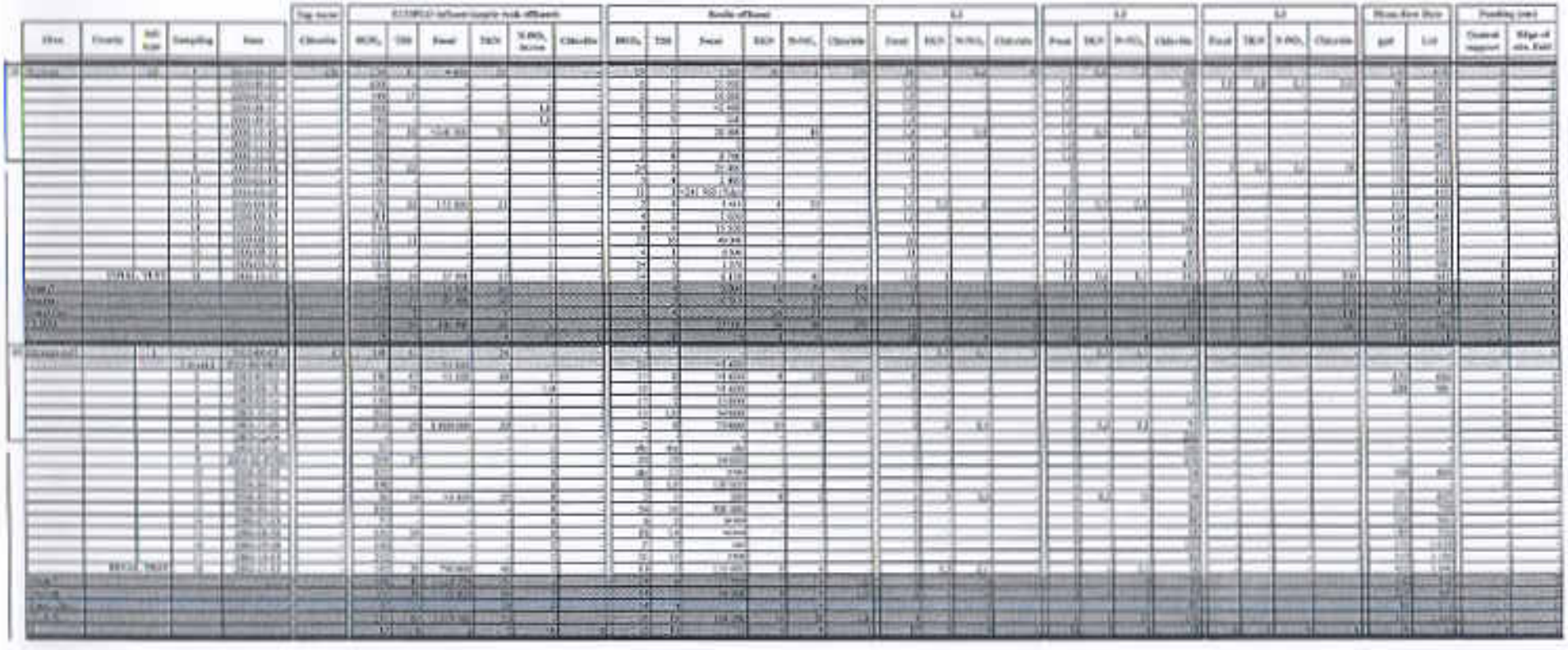
- [illegible]
- eg.: sampling or laboratory problems
- Mean* geometric mean for fecal coliform



VIRGINIA
Monitoring Protocol

Prepared by:
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Frasier Tank Environment

Collaboration of:
Dr. Robert Rubin
Bruce King

Notes:
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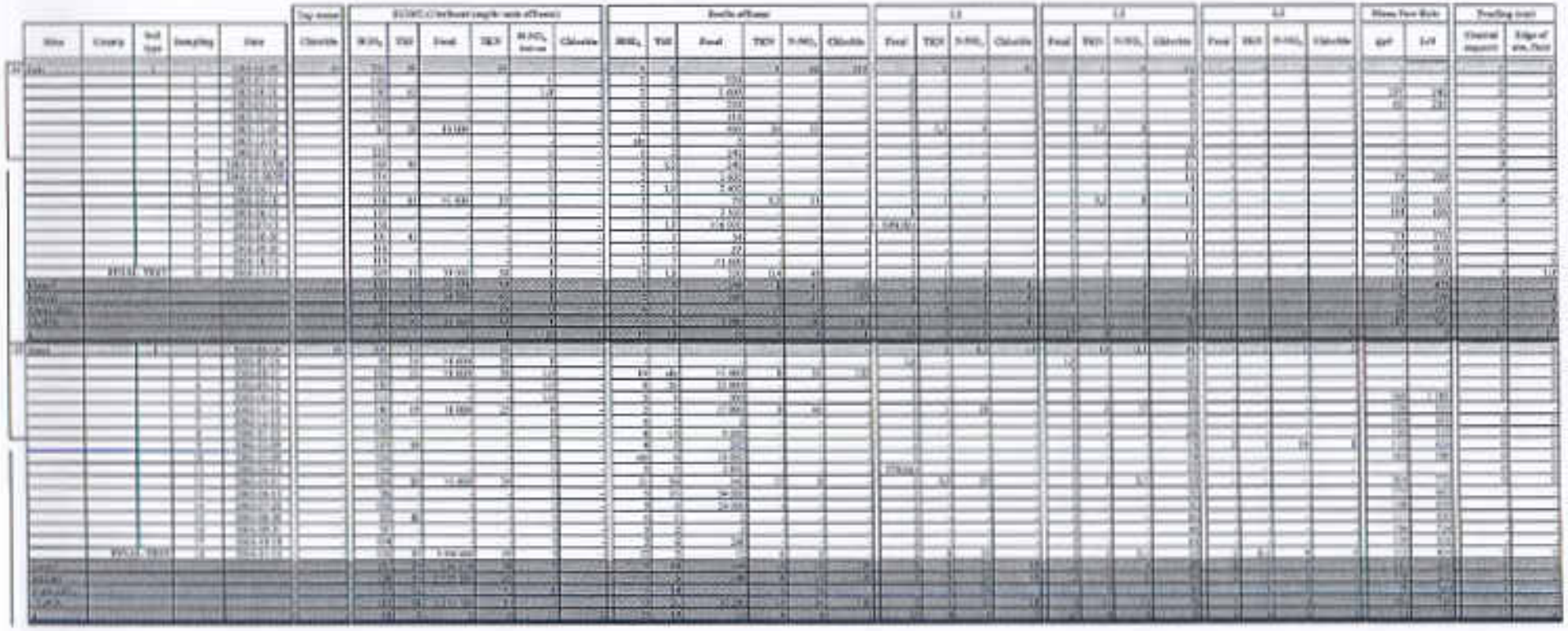
- [illegible]
- [illegible]
- var. as noted
- dp - sampling at laboratory preference
- Mean* - geometric mean for fecal coliform



VIRGINIA
Monitoring Protocol

Notes:

Analysis by:
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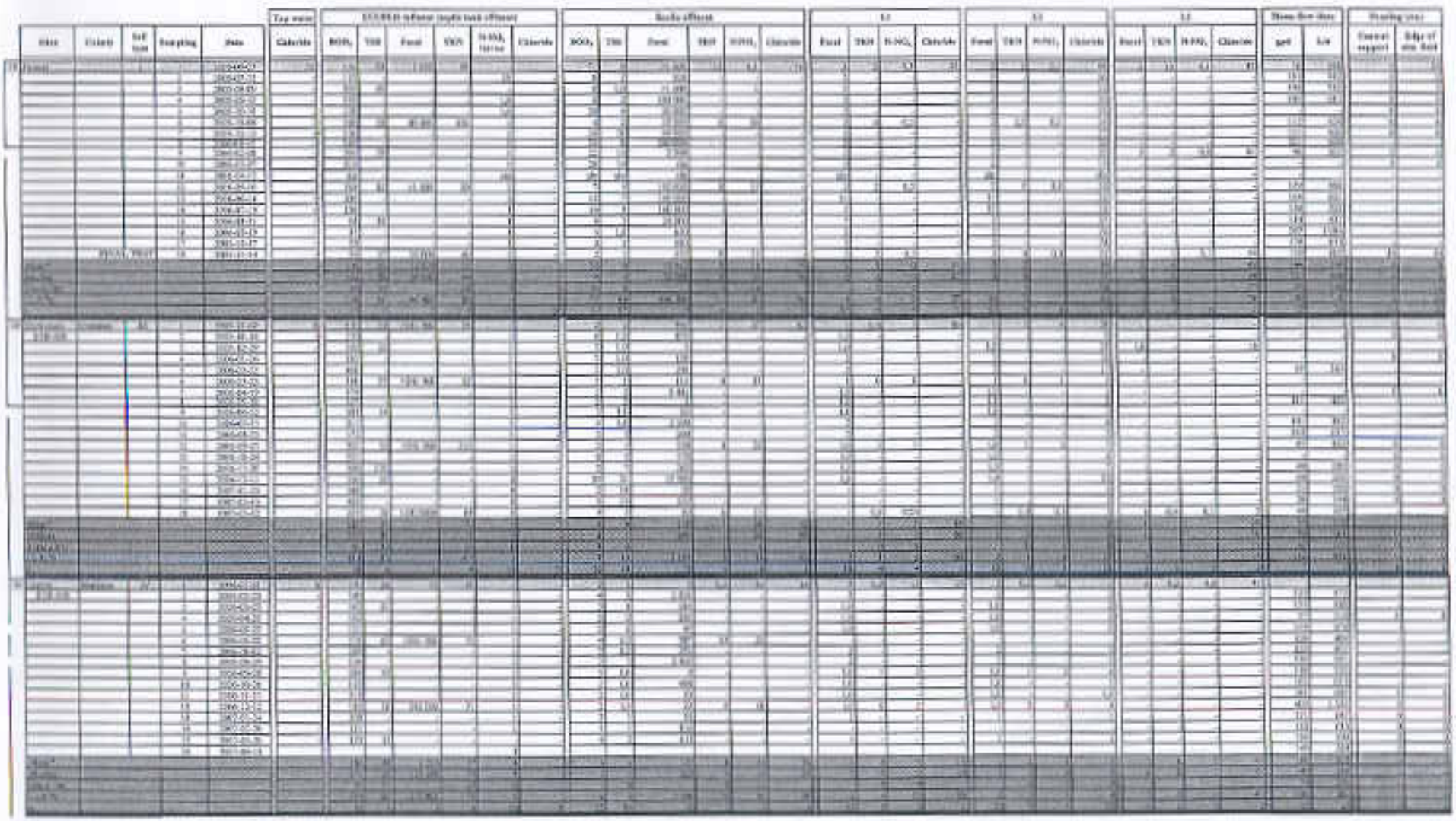
Powder Tank Environmental

Collaborators at:
Dr. Robert Hubbs
Bruce King



VIRGINIA
Monitoring Protocol

Produced by:
Delaware Septic Solutions
Premium Tank Environment

Collaborators at:
Dr. Robert Rubin
Bruce King

Notes:
- [illegible]
- [illegible]
- [illegible]
- no: as used
- op: sampling or laboratory problems
- Mean*: geometric mean for these variables

Mon	County	Soil type	Sampling	Days	Up water Chloride	ECOTLO influent (septic tank effluent)						Media effluent						L1				L2				L3				Mass Free Rate		Floating mark	
						BOD_5	TSS	Fecal	T&N	N-NO_3 mean	Chloride	BOD_5	TSS	Fecal	T&N	N-NO_3	Chloride	Fecal	T&N	N-NO_3	Chloride	Fecal	T&N	N-NO_3	Chloride	Fecal	T&N	N-NO_3	Chloride	gpd	L/d	Chemical required	Edge of area check

VIRGINIA
Monitoring Protocol

Realized by:
Delmarva Septic Solutions
Premier Tech Environment

Collaboration of:
Dr. Robert Rubin
Bruce King

Notes:
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

Site	County	Soil type	Sampling	Date	Tap water	Influent						Ecoflo effluent						L1				L2				L3				Water flow data		Ponding	
					Chloride	BOD_5	TSS	Fecal	TKN	$N\text{-}NO_3$	Chloride	BOD_5	TSS	Fecal	TKN	$N\text{-}NO_3$	Chloride	Fecal	TKN	$N\text{-}NO_3$	Chloride	Fecal	TKN	$N\text{-}NO_3$	Chloride	Fecal	TKN	$N\text{-}NO_3$	Chloride	gpd	[illegible]	Center of [illegible]	Edge of [illegible] field
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX B

Phosphorus results table

Table 1S: Phosphorus Concentrations in Influent to, Effluent from, and Shallow Groundwater at Selected ECOFLO® Peat Wastewater Treatment Systems (as mg/l)

Site	Soil Type	STE	PFE	% Removal	Lysimeter #1 (12" under peat filter)
Site 1, 01-04	2	7.1	6.5	8.5	0.1
Site 1, 04-04	2	5.3	4.5	15.1	0.1
Site 1, 11-04	2	6.7	5.7	14.9	0.1
Site 1, 01-05	2	4.9	3.8	22.4	0.1
Site 2, 01-04	1	6.4	4.9	23.4	0.2
Site 2, 04-04	1	5.3	4.7	11.3	0.1
Site 2, 11-04	1	7.1	6.7	5.6	0.2
Site 2, 01-05	1	6.8	6.0	11.8	0.1
Site 6, 04-04	1	5.2	4.9	5.8	0.1
Site 6, 11-04	1	4.9	4.5	8.2	0.1
Site 6, 01-05	1	5.5	5.1	7.3	0.1

Table 2S: Phosphate Levels as Ortho-Phosphorus or Soluble Phosphorus in Lysimeter Samples Collected below Soil Mantle and Background (as mg/l)

Site	Soil Type	Lysimeter 1 (12" under peat filter)	Lysimeter 2 (10 ft apart)	Lysimeter 3 (Background)
Site 1, 01-04	2	0.02	0.02	0.02
Site 1, 04-04	2	0.02	0.02	0.02
Site 1, 11-04	2	0.02	0.02	0.02
Site 1, 01-05	2	0.02	0.02	0.02
Site 2, 01-04	1	0.10	0.02	0.03
Site 2, 04-04	1	0.07	0.02	0.02
Site 2, 11-04	1	0.02	0.02	0.02
Site 2, 01-05	1	0.05	0.02	0.02
Site 6, 04-04	1	0.02	0.02	0.02
Site 6, 11-04	1	0.02	0.02	0.02
Site 6, 01-05	1	0.05	0.02	0.02
Site 12, 2-05	3	0.02	0.02	0.03
Site 12, 5-05	3	0.05	0.02	0.02
Site 12, 9-05	3	0.03	0.02	0.02
Site 12, 12-05	3	0.02	0.02	0.02