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Drip Irrigation and Peat Treatment System On-site Wastewater Nutrient Removal BMP Expert Panel Report

Chesapeake Bay Program
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EXECUTIVE SUMMARY

The Chesapeake Bay On-site Wastewater Nitrogen Removal BMP Expert Review Panel was reconvened to specifically evaluate two proposed BMPs:

1. Drip irrigation (at a higher TN reduction credit than currently given under the "Shallow-Placed, Pressure-Dosed Dispersal" BMP) and
2. Peat biofiltration systems discharging to a pad or trench

Upon review of available data, the Panel recommends creating a new, creditable BMP for Drip Irrigation, which has been shown to result in a 50 percent net TN reduction through Zone 1 in the drainfield. Qualifying characteristics for the new BMP, which are described in detail in the report, require the use of pressure-compensating emitters, maximum not to exceed loading rates for three different soil types and exclusion of the credit for drip systems installed in Type I (sand textured) soils.

The Panel recommends that peat systems discharging to a pad or trench not be included by the CBP as a new BMP. In particular, existing data were from studies not designed to explicitly address nitrogen removal and the TN results were highly variable and thus inconclusive. The data do appear to support crediting peat filters a 20 percent net TN reduction as an *ex situ* BMP, consistent with similar technologies which fall under creditable BMPs: Intermittent Media Filters and NSF Standard 40 Systems.

The Panel further recommends that the CBP track efforts underway in EPA Regions 1 and 2 to develop nitrogen sensors specific to monitoring on-site wastewater systems and to consider using such sensors (or other appropriate methods) to verify the performance of BMPs that have been approved and are being implemented in the watershed. Recommendations for outstanding research questions are also provided (the reader is further referred to the 2014 predecessor report on OWTS Nitrogen Removal BMPs and the 2016 OWTS Nitrogen Attenuation report for additional recommendations for the CBP).

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CBP	Chesapeake Bay Program
CI	Chloride
ET	Evapotranspiration
HLR	Hydraulic Loading Rate
LPD	Low Pressure Dispersal
LPP	Low Pressure Pipe
N	Nitrogen
OWTS	On-site Wastewater Treatment Systems
STE	Septic Tank Effluent
STUMOD	Soil Treatment Unit Model
TG	Texture Group
The Panel	The Chesapeake Bay On-site Wastewater Nitrogen Removal BMP Expert Review Panel
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
WQGIT	Water Quality Goal Implementation Team

1.0 INTRODUCTION

1.1 BACKGROUND

The Chesapeake Bay On-site Wastewater Drip Irrigation and Peat Treatment System Expert Review Panel (the Panel) was convened by the Chesapeake Bay Program (CBP) Office in July 2015 and coordinated via conference call approximately monthly between October 2015 and December 2016, and periodically thereafter. As required, the Panel held a Stakeholder Meeting (via web and phone conference) on April 27, 2016.

The main charge for the Panel was to review available science on the pollutant removal performance of two proposed BMPs for the on-site wastewater treatment sector in order to derive nutrient removal rates for individual practices. The two BMPs are:

- a peat treatment system with dispersal to a pad or a trench (not currently covered by an existing BMP and therefore represents a potentially new BMP for the sector)
- shallow placed (≤ 12”) drip dispersal (currently covered by the BMP of Shallow Placed, Pressure-Dosed Dispersal which combines low pressure distribution and drip dispersal into the same category with a net 38 percent TN reduction)

In its charge by the CBP, the Panel was specifically requested to:

- Review existing literature and other relevant data and supporting information to
  - determine if a generic class can be established that would encompass a range of peat treatment system technologies, and
  - determine if a higher nitrogen reduction efficiency can be assigned to the drip dispersal subset of the existing Shallow Placed, Pressure-Dosed Dispersal BMP
- Provide a definition for each treatment practice and the qualifying conditions under which a credit can be received

Beyond this specific charge, the Panel was asked to:

- Recommend procedures for reporting, tracking and verifying the recommended retrofit credits
- Critically analyze any unintended consequence associated with the credit and any potential for double or over-counting of the credit.

1.2 CHESAPEAKE BAY OWTS NITROGEN REMOVAL BMPS

The Panel followed up and built on the work done by two predecessor Expert Panels dealing with on-site wastewater treatment systems (OWTS):

1. The Chesapeake Bay On-Site Wastewater Treatment Systems Nitrogen Reduction Technology Expert Review Panel (BMP Panel), whose final report was approved by the Water Quality Goal Implementation Team (WQGIT) in July 2014 (Tetra Tech, 2014) In this report, the BMP Panel recommended that the CBP adopt eight (8) BMPs – six (6) *ex situ* BMPs and two (2) *in situ* BMPs, as summarized in **Table 1**.
2. The Chesapeake Bay On-site Wastewater Nutrient Attenuation Expert Review Panel (Attenuation Panel), whose final report was approved in October 2016 (Tetra Tech, 2016). In this report, the Attenuation Panel recommended that the CBP adopt a spatially variable approach to *in situ* nitrogen transformations between the drainfield and surface waters. This resulted in changing the baseline nitrogen reduction

performance of an OWTS from a load of 4 kg/person/year at the edge-of-drainfield and 1.6 kg/person/year delivered to surface water to the spatially variable rates summarized in Table 2.

Table 1. Summary of Net TN Load Reductions for Combined *In situ* and *Ex situ* Systems.

In Situ Practice / *Ex Situ* Practice	Conventional Baseline	Shallow, Pressure Dosed	Elevated Mound
Septic Tank Baseline	4.0 kg/p/yr (0%)	2.5 kg/p/yr (38%)	2.5 kg/p/yr (38%)
NSF 40 Class I Secondary Systems	3.2 kg/p/yr (20%)	2.0 kg/p/yr (50%)	2.0 kg/p/yr (50%)
Intermittent Media Filter	3.2 kg/p/yr (20%)	2.0 kg/p/yr (50%)	2.0 kg/p/yr (50%)
Vegetated Submerged Bed	3.2 kg/p/yr (20%)	2.0 kg/p/yr (50%)	2.0 kg/p/yr (50%)
Anne Arundel Co. IFAS	2.0 kg/p/yr (50%)	1.25 kg/p/yr (69%)	1.25 kg/p/yr (69%)
Recirculating Media Filter	2.0 kg/p/yr (50%)	1.25 kg/p/yr (69%)	1.25 kg/p/yr (69%)
Proprietary (e.g., NSF 245 certified) Systems	Varies depending on technology and testing results		

Note: Percent reductions in table entries represent net reduction from baseline of 4 kg/person/year at edge-of-drainfield.

Table 2. Recommended TN load delivery rates as a function of dominant soil texture and relative TN transmission rating for conventional on-site wastewater systems

Soil Textural Classification	USDA Soil Textures	Low TN Transmission Area	Medium TN Transmission Area	High TN Transmission Area	Very High TN Transmission Area
Sandy	Sand, Loamy Sand, Sandy Loam, Loam	1.1 kg/cap/yr	1.7 kg/cap/yr	2.3 kg/cap/yr	2.7 kg/cap/yr
Loamy	Silt loam, Clay Loam, Sandy Clay Loam, Silty Clay Loam, Silt	0.8 kg/cap/yr	1.3 kg/cap/yr	1.8 kg/cap/yr	2.1 kg/cap/yr
Clayey	Sandy Clay, Silty Clay, Clay	0.6 kg/cap/yr	0.9 kg/cap/yr	1.3 kg/cap/yr	1.5 kg/cap/yr

Note: Values represent recommended delivery to transitional zone at groundwater/surface water interface.

The results and recommendations resulting from the Panel's review of the two new BMPs could potential modify or append the list of BMPs in **Table 1**. All BMPs and their associated TN reduction credits must now be applied to the revised baseline TN load assumptions summarized in Table 2. Unless otherwise stated in this report, the findings, recommendations and processes reported in the two referenced predecessor reports apply. It is recommended that readers familiarize themselves with the predecessor reports, as this report (with the exception of the above discussion) does not explicitly address the same material (note that the July 2014 report includes several broad findings and recommendations applicable to the technologies addressed in this report).

2.0 DRIP IRRIGATION

2.1 BACKGROUND

2.1.1 Existing BMP and Request

Drip irrigation technology is explicitly addressed in the 2014 BMP report and is currently approved under the "Shallow-Placed, Pressure-Dosed Dispersal" nitrogen reduction BMP by the CBP. This BMP covers two approved families of technologies: low pressure dispersal (LPD; sometimes called low pressure pipe or LPP), and drip dispersal. Both technologies are credited with a net *in situ* TN reduction of 38 percent over baseline drainfield (now called "Zone 1" after approval of the Attenuation Panel report) reductions. Based on the adopted Zone 1 baseline (i.e., with no BMP) TN loads, a 38 percent reduction results in the loads summarized in Table 3 (second column over from the right).

A manufacturer/vendor of drip irrigation equipment requested that drip dispersal be considered separately from LPD and that data suggests that a net 50 percent reduction (versus current net 38 percent reduction) is warranted. The manufacturer provided a detailed package of information in support of the request, including published study data. However, all parties understood that any modification to the BMPs would have to apply to all similar drip dispersal technologies equally, provided they met the qualifying characteristics of the BMP. Zone 1 TN loads resulting from the proposed 50 percent credit are provided in the right-most column in Table 3.

Table 3. Zone 1 TN Loads With and Without Shallow-Placed, Pressure-Dosed BMP

Soil Textural Grouping	USDA Soil Textures	Baseline Zone 1 TN Reduction	Baseline Zone 1 TN Load	TN Load with existing 38% BMP - Zone 1	*TN Load with proposed 50% BMP Credit*
Sandy	Sand, Loamy Sand, Sandy Loam, Loam	16%	4.2 kg/cap/yr	2.6 kg/cap/yr	*2.1 kg/cap/yr*
Loamy	Silt loam, Clay Loam, Sandy Clay Loam, Silty Clay Loam, Silt	34%	3.3 kg/cap/yr	2.0 kg/cap/yr	*1.7 kg/cap/yr*
Clayey	Sandy Clay, Silty Clay, Clay	54%	2.3 kg/cap/yr	1.4 kg/cap/yr	*1.2 kg/cap/yr*

The Panel was asked and agreed to consider a dispersal mat technology whose manufacturer requested at least the same credit approved for drip dispersal. This manufacturer sent supporting information and presented during the April 2016 stakeholder web meeting. After subsequent discussion, the Panel decided that the technology was not similar enough to drip dispersal to warrant using or extrapolating the drip dispersal data and the limited product specific data did not support a higher TN reduction. However, it appeared that the technology might fit under the existing shallow-placed, pressure-dosed dispersal BMP. Nevertheless, the manufacturer could suggest development of a new BMP although it appeared to the Panel that this particular technology was proprietary and would not necessarily apply to other manufactured products and thus not be approvable by the CBP as a creditable, non-proprietary BMP.

2.1.2 Referenced Data

A list of primary data sources and their utility for this exercise is provided in Table 4. Each reference was reviewed and important data characteristics were documented, including:

- Installation depth
- Soil texture group
- Pretreatment
- Loading rate
- Percent TN reduction
- Sampling point
- Number of sites
- Number of samples
- Data quality (H, M, L)
- Data Summary

Table 4. List of Primary References and Data Sources for Drip Dispersal Evaluation

Citation (Authors, Date)	Title	Relevance
American Manufacturing. 2014	VA REQUEST 2014 Assembled Document	N/A
American Manufacturing. 2014	Drip Dispersal as a BMP for Nitrogen Reduction	N/A
Ayres Associates (Anderson et al). 1998 and 2000	Florida Keys Onsite Wastewater Nutrient Reduction Systems Demonstration Project, Phase I and Phase II	M
Beggs, Tchobanoglous, Hills, and Crites. 2004	Modeling Subsurface Drip Application of On-site Wastewater Treatment System Effluent	L
Beggs, Hills, Tchobanoglous, and Hopmans. 2011	Fate of nitrogen for subsurface drip dispersal of effluent from small wastewater systems	H
Bohrer and Converse.2001	Soil Treatment Performance and Cold Weather Operations of Drip Distribution Systems	L
Buchanan and Hillenbrand. 2014	An Investigation for the Need of Secondary Treatment of Residential Wastewater when Applied with a Subsurface Drip Irrigation System	L
Costa, Heufelder, Foss, Milhan, and Howes. 2002	Nitrogen Removal Efficiencies of Three Alternative Septic System Technologies and a Conventional Septic System	L
Gushiken. 1995	Water Reuse through Drip Irrigation Systems	L
Hayes. 2001	Expanding the Applications of Micro-Irrigation "Drip" Treatment and Disposal Systems in Delaware	M
Hayes and Moore. 2007	Long Term Impacts of Micro-Irrigation "Drip" Systems on Delaware's Marginal Soils	M
Hepner, Linde, Weber, Smith. 2005	Alternative On-Lot Technology Research - Soil-Based Treatment Systems - Phase II Final Report	M
Hepner, Linde, Weber and Smith 2007	Reduction of Bacteriologic and Chemical Constituents of Septic Tank Effluent With Depth Using a Drip Dispersal System	H

Citation (Authors, Date)	Title	Relevance
Parzen, Tomaras and Siegrist. 2007	Controlled Field Performance Evaluation of a Drip Dispersal System Used for Wastewater Reclamation in Colorado	L
Phene and Ruskin.	Nitrate Management of Wastewater With Subsurface Drip Irrigation	L
Rubin, Green, Sinclair, Jantrania. 1994	Performance Evaluation of Drip Disposal for Residential	L
Siegrist, Parzen, Tomaras, and Lowe. 2014	Water movement and fate of nitrogen during drip dispersal of wastewater effluent into a semi-arid landscape	H
TVA. 2004	Wastewater Subsurface Drip Distribution: Peer-Reviewed Guidleines for Design, Operation and Maintenance	L
WERF. 2010	Quantitative Tools to Determine the Expected Performance of Wastwater Soil Treatment Units	L

Most of these references had previously been reviewed in support of the Shallow-Placed, Pressure-Dosed Dispersal BMP approved in 2014. However, at that time, they were reviewed as part of a larger body of research that also included results from LPD systems.

In Table 4, those references with medium (M) or high (H) relevance scores were used to support the data analyses. References were scored low (L) relevance for various reasons including lack of sufficient analytical data to quantify reductions, field testing setups or methodology that did not adequately represent conditions relevant to the Chesapeake Bay watershed, or had significant data quality limitations. **Appendix A** provides literature summaries for the papers weighted medium or high.

2.2 RESULTS AND DISCUSSION

2.2.1 Published Data

For the purpose of this section, soils have been categorized into four groups based on texture as follows:

a. Texture Group I - sand and loamy sand;

b. Texture Group II - sandy loam, loam, and sandy clay loam. Texture Group II soils are subdivided into Texture Group IIa and IIb soils.

   i. Texture Group IIa soils consist of sandy loam soils with percolation rates less than 31 minutes per inch and no structure development.

   ii. The remainder of soils within this texture group are Texture Group IIb soils;

c. Texture Group III - silt loam, clay loam, silty clay loam; and

d. Texture Group IV - sand clay, silty clay and clay.

Table 5 provides a summary of the results of the Panel's review of the primary drip dispersal references. Based on these results, the Panel concluded that the maximum TN reduction that could be supported by the data is 50 percent net TN reduction in Type II, III and IV soil textures.

Table 5. Summary of Primary References and Data Sources for Drip Dispersal Evaluation

Citation (Authors, Date)	Installation Depth	Soil Texture	Effluent Quality	Loading Rate	Sampling Points	Percent TN Reduction	Summary
Ayres Associates (Anderson et al). 1998 and 2000	10 cm (4")	S	STE	1.0 and 1.7	Drainage from lined field	34% and 26%	Three lined drip mounds were created using sand, crushed brick and expanded clay as the media, respectively. Separation to drainage-controlled water table was 24 inches. The mounds were dosed with septic tank effluent and the final effluent sampled from the drainage pipes.
Beggs, Hills, Tchobanoglous, and Hopmans. 2011	15 cm (6")	LS, SL, SiL	STE	SL: 0.058-0.074 LS: 0.084-0.280 SiL: 0.042-0.058	Suction lysimeter and free draining 18" below dispersal	63 – 95%	Nitrogen removal is especially effective in medium to fine soils and soils with shallow restrictive or capillary break layers. In these soils, a 50% nitrogen removal rate is reasonable to expect. The long term retention time in the soil column provides a great opportunity for denitrification, even with less than ideal denitrification reaction rate conditions.
Hayes. 2001	15 cm (6")	SL, L, LS	STE and secondary effluent	LS: 0.278 L: 0.189 SL: 0.228	Monitoring well	88% STE 35% secondary	Good study with some samples missed due to low water table during summer months. Reductions for secondary effluent calculated only on soil removal.
Hayes and Moore. 2007	15 cm (6")	SL, L, LS	STE and secondary effluent	LS: 0.278 L: 0.189 SL: 0.228	Monitoring well	78% STE 62% Secondary	Good study with some samples missed due to low water table during summer months and being years from original study.
Hepner, Linde, Weber, Smith. 2005	Various, 0-28 cm (0-11")		STE and Secondary	0.04-0.08	1, 2, 3, 4 feet deep	79 to 96% @ 2 ft with STE 94% Sec	See Appendix A for more detail

Citation (Authors, Date)	Installation Depth	Soil Texture	Effluent Quality	Loading Rate	Sampling Points	Percent TN Reduction	Summary
Hepner, Linde, Weber and Smith 2007	20-30 cm (8-12")	SiL	STE	0.17	1, 2, 3, 4 feet deep	85% at 1 ft depth	Three full size systems were constructed on a Readington series soil with a fragipan at 25 inches below the surface. Each system had two zones of 600 lineal feet per zone of tubing on 2 foot centers. Each system was loaded at 0.17 gallons per square foot per day for two years. Sampling occurred monthly using zero tension lysimeters at multiple locations and multiple depths. The nitrogen reduction was 85% at one foot below the drip lines.
Siegrist, Parzen, Tomaras, and Lowe. 2014	20 cm (8")	SL	STE	0.20 and 0.41	0.5, 1, 2, 3 feet deep	51%	Soil pore water was not sampled. After 12 month of operation (STE delivery), a tracer test and soil sampling was conducted to look at 3D nitrogen distribution within the footprint. ~50% nitrogen removal observed due to plant uptake and denitrification (based on nitrogen isotope).

2.2.2 STUMOD Modeling

STUMOD, developed at the Colorado School of Mines, is a spreadsheet-based model to simulate nitrogen transport in the unsaturated zone below an on-site wastewater treatment system. The model is based on fundamental principles of water movement and contaminant transport using an analytical solution to calculate pressure and moisture content profiles in the vadose zone and a simplification of the general advection dispersion equation (Geza et al., 2010). The model requires some simplifying assumptions (e.g., one dimensional vertical flow, continuous steady state dosing) but can be calibrated to site-specific data if available.

Vertical flow is assumed to predominate with contaminants transported by advection (the effect of dispersion is ignored). Continuous, steady state effluent application and infiltration is assumed. As the infiltration reaches steady state, the pressure profile or soil moisture profile does not change with time and a steady state concentration with depth is computed based on reaction rates (first order) for nitrification and denitrification correlated to the soil moisture profile with the effect of temperature on these transformations considered. Ammonium-nitrogen is removed through both adsorption and denitrification, while nitrate-nitrogen is removed through denitrification.

Several scenarios were simulated using STUMOD to provide insight into potential behaviors of effluent transport in drip dispersal systems and to help understand and fill in data gaps so we have a greater confidence in the recommendations. Although STUMOD is not specific to drip dispersal systems, selection of general site conditions can mimic the processes known to occur. Specifically, STUMOD incorporates ET and plant uptake, both processes that are expected to have more effect on treatment performance in a drip dispersal system compared to a traditional subsurface trench or bed. The two dimensional geometry of the infiltrative surface is not incorporated; rather the model assumes a single point of effluent application to the soil with vertical transport below (or above in the case of ET and plant uptake).

To simulate the conditions of a drip dispersal system, a point of delivery (e.g., emitter) at 9 inches (23 cm) below the ground surface was assumed with roots from vegetation extending 15 inches (37 cm) or 6 inches below the emitter. These conditions allow for the effects of ET and plant uptake for water and nitrogen losses in a drip dispersal system. The shallow water table was assumed to be 18 inches (46 cm) below the emitter. The effluent applied to the soil had a nitrogen concentration of 60 mg-N/L in the form of ammonium, simulating septic tank effluent (STE). These operating conditions were simulated for four soil textures with soil specific hydraulic loading rates (**Table 6**).

The relative effects of ET and plant uptake were evaluated by comparing different months (February or August) and different uptake rates (none or the default rate of 0.35 kg/ha/d in STUMOD). All runs with ET and plant uptake assumed the Chesapeake Bay Latitude of 37.5214 ^{o}N and a mean soil temperature of 18.5 ^{o}C. The mean temperature was not varied by month to illustrate effects of ET only (i.e., no adjustment to nitrogen transformation rates due to variable soil temperatures). All other model inputs were STUMOD default values and were not changed. Comparison of the output of these simulations provided a relative measure estimated nitrogen concentrations either 9 inches (23 cm) below the infiltrative surface or the concentration at the water table.

Table 6. Summary of Conditions and Results for STUMOD Runs

Soil Texture	Hydraulic Loading Rate* (cm/d)	Effluent Quality** (mg-N/L)	Depth to Infiltrative Surface (c,m, bgs)	Depth to Water Table (cm, bgs)	Root Depth (cm, bgs)	Uptake Rate (kg/ha/d)	ET (month)	TN (mg-N/L) at 9" below infiltrative surface	TN (mg-N/L) at 18" below infiltrative surface
Sand	1.1 (0.27)	60	23	69	37	-	-	46.96	33.67
Loam	0.81 (0.20)	60	23	69	37	-	-	39.94	24.83
Clay Loam	0.57 (0.14)	60	23	69	37	-	-	31.68	15.74
Silty Clay	0.37 (0.09)	60	23	69	37	-	-	20.19	8.53
Sand	1.1 (0.27)	60	23	69	37	0.35	2 (Feb)	41.4	29.69
Loam	0.81 (0.20)	60	23	69	37	0.35	2 (Feb)	36.2	22.5
Clay Loam	0.57 (0.14)	60	23	69	37	0.35	2 (Feb)	25.3	12.57
Silty Clay	0.37 (0.09)	60	23	69	37	0.35	2 (Feb)	16.07	6.79
Sand	1.1 (0.27)	60	23	69	37	0.35	8 (Aug)	43.26	31.02
Loam	0.81 (0.20)	60	23	69	37	0.35	8 (Aug)	37.31	23.19
Clay Loam	0.57 (0.14)	60	23	69	37	0.35	8 (Aug)	28.19	14
Silty Clay	0.37 (0.09)	60	23	69	37	0.35	8 (Aug)	17.48	7.38
Sand	1.1 (0.27)	60	23	69	37	0	2 (Feb)	43.05	30.87
Loam	0.81 (0.20)	60	23	69	37	0	2 (Feb)	37.41	23.25
Clay Loam	0.57 (0.14)	60	23	69	37	0	2 (Feb)	27.97	13.9
Silty Clay	0.37 (0.09)	60	23	69	37	0	2 (Feb)	17.31	7.31
Sand	1.1 (0.27)	60	23	69	37	0	8 (Aug)	44.42	31.86
Loam	0.81 (0.20)	60	23	69	37	0	8 (Aug)	38.15	23.71
Clay Loam	0.57 (0.14)	60	23	69	37	0	8 (Aug)	29.22	14.51
Silty Clay	0.37 (0.09)	60	23	69	37	0	8 (Aug)	18.31	7.73

* values in parentheses are in gpd/sf
** all as 60 mg-N/L as NH4
bgs = below ground surface in cm
All runs with ET and plant uptake assumed the Chesapeake Bay Latitude = 37.5214 ºN.
All runs were done assuming a mean soil temperature of 18.5 ºC. Mean temperature was not varied by month to illustrate effects of ET only (i.e., no adjustment to nitrogen transformation rates due to variable soil temperatures).

The STUMOD results illustrate effect of ET and plant uptake on nitrogen removal below an infiltrative surface. **Figure 1** shows the removal of nitrogen varied by month (as a surrogate for ET and plant uptake) and soil type. While ET and plant uptake are important nitrogen removal processes in a drip dispersal system, the soil type has a greater effect on treatment performance. It can also been seen that the impacts of ET and plant uptake on nitrogen removal in the soil decreases with depth in the soil profile.

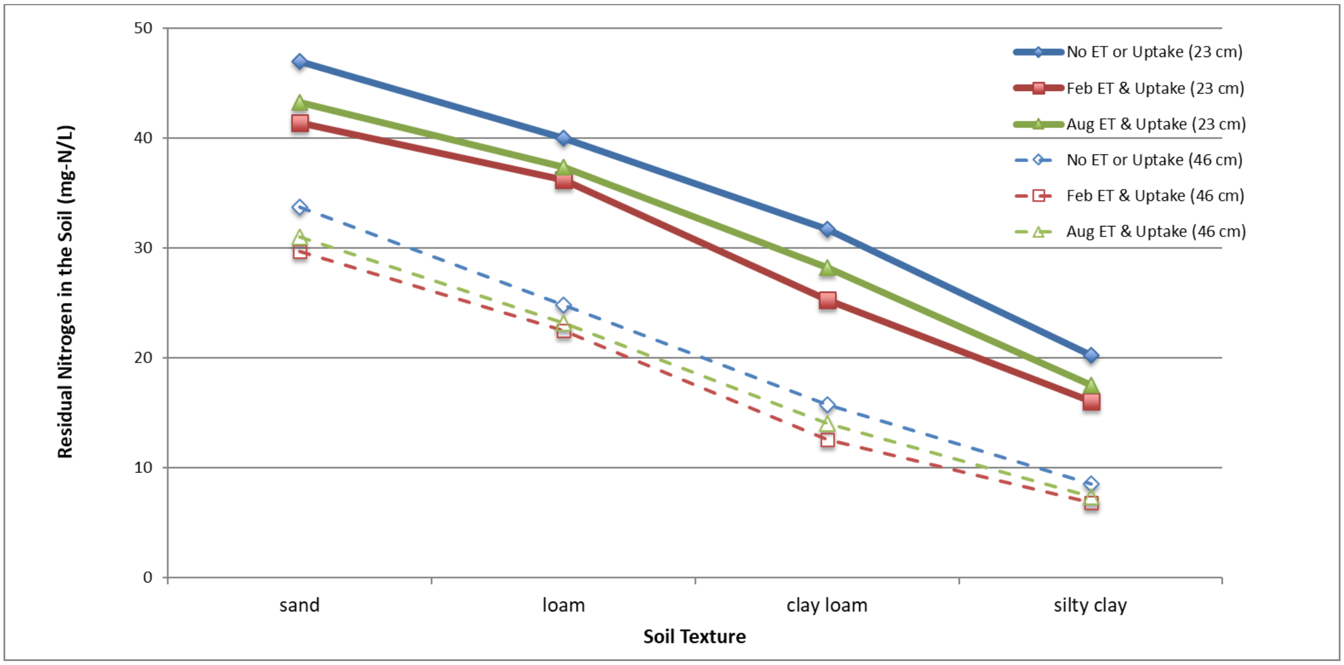

Figure 1. STUMOD results comparing ET and plant uptake by soil type

Figure 2 further illustrates the effect of ET over one year. It can be seen that for the central Chesapeake Bay latitude of 37.5214 ºN, the maximum nitrogen removal due to ET effects are expected in December – January while the minimum removal would be expected in June – July.

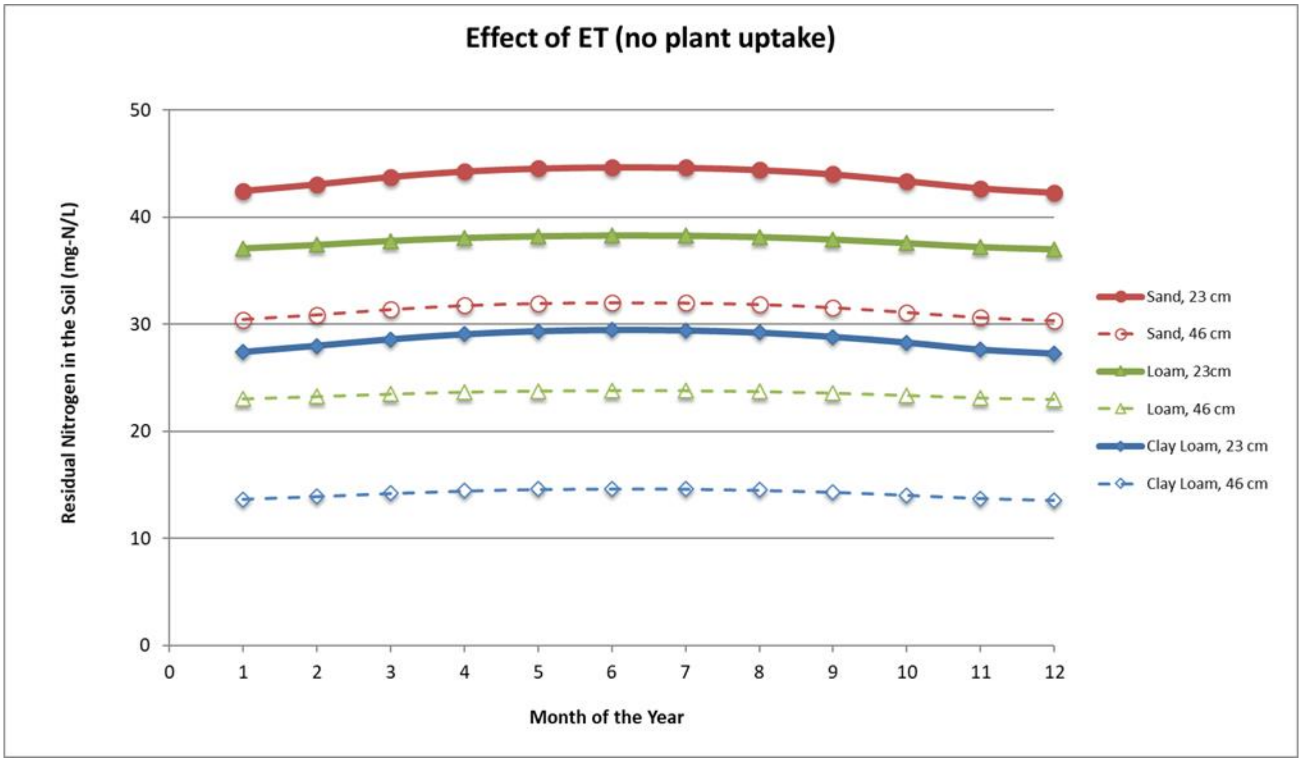

Figure 2. Seasonal effect of ET on nitrogen reduction in soil based on STUMOD results

Based on the STUMOD simulations (see **Table 6**), the relative percent difference due to ET, plant uptake, and the combined processes of ET and plant uptake can be summarized as follows:

- ET:
  - Sand: 5 – 8 percent more removal compared to simulations with no ET; effect of ET varies ~5.5 percent throughout the year
  - Loam: 4.5 – 6 percent more removal compared to simulations with no ET; effect of ET varies ~3.5 percent throughout the year
  - Clay Loam: 8 – 12 percent more removal compared to simulations with no ET; effect of ET varies ~8 percent throughout the year
  - Silty Loam: 9 – 14 percent more removal compared to simulations with no ET
- Plant Uptake:
  - Sand: 3 – 4 percent more removal compared to simulations with no plant uptake
  - Loam: 2 – 3.5 percent more removal compared to simulations with no plant uptake
  - Clay Loam: 4 – 10.5 percent more removal compared to simulations with no plant uptake
  - Silty Loam: 5 – 8.5 percent more removal compared to simulations with no plant uptake
- ET & Plant Uptake:
  - Sand: 8 – 12.5 percent more removal compared to simulations with no ET or plant uptake
  - Loam: 7 – 10 percent more removal compared to simulations with no ET or plant uptake
  - Clay Loam: 12 – 22 percent more removal compared to simulations with no ET or plant uptake
  - Silty Loam: 14.5 – 23 percent more removal compared to simulations with no ET or plant uptake

In general terms, STUMOD results suggest approximately 5 to 15 percent removal due to ET with the rate of removal varying soil type. Plant uptake had slightly less effect on nitrogen removal with approximately 2 to 10 percent nitrogen removal attributed to plant uptake alone. The combined processes of ET and plant uptake (**Figure 1**) accounted for ~7 to 23 percent removal. The STUMOD simulations support increased TN removal of 12 percent (or total removal of 50percent) due to processes unique to drip dispersal systems.

2.3 RECOMMENDATIONS

Based on the data analysis previously presented, the Panel concurs that a 50 percent net TN reduction for drip dispersal is warranted when the following conditions are met:

- The drip tubing must be installed in a natural surface horizon (e.g. A or A/B) no deeper than 12 inches from the original soil surface. Pad or bed installations are not included in this BMP.
- BMP credits are not provided for installations where sand or loamy sand soils predominate within 12 inches below effluent dispersal depth.
- There must be a minimum 18 inches of unsaturated soil depth below the infiltrative surface; however, States can require more stringent water table separation depths in accordance with their regulations.
- The site must have a stable vegetative cover.
- Landscape position is also a necessary consideration. Systems should not be sited within a closed depression, or where water tends to pond during heavy rainfall events.
- All drip system designs shall incorporate the following:
  - A vibratory plow, static plow, or trencher is most typically used to install the tubing, and soil moisture must be dry enough so that soil compaction does not occur.

- A filtration system shall be provided to protect the emitters from clogging. Filter size shall be as recommended by the manufacturer (typically 120 to 150 mesh, or 100 to 120 micron).
- An automatic flush cycle shall provide a minimum flushing velocity at the rate the tubing manufacturer recommends.
- The effluent is to be equalized and timed-dosed over a 24-hour period to maximize the fluctuation between aerated and non-aerated periods. Minimum dose volume shall be 3.5 times the volume of the drip network or zone as applicable, although 5 times the volume is recommended to ensure that at least 80 percent of the dose volume is applied while the drip network is fully pressurized.
- The system shall be designed to minimize draindown effects on the lowest lines in a zone, such as by assuring all drip laterals are hydraulically isolated.
- Air/vacuum release valves shall be provided at the high points of the feed and return lines to prevent entry of soil particles into emitters.
- Maximum emitter spacing is 2 feet along the drip tubing and normal tubing separation is 2 feet.
- Minimum drip tubing length is equal to one-half the dispersal area. .
- Emitter grid spacing should be a maximum of 24 inches (4 square feet per emitter). At least 1 linear foot of drip tubing should be required for each 2 square feet of required drip zone area. For example if 1500 ft^2 of dispersal field is required, then a minimum 1250 linear feet of drip tubing is required. The BMP shall apply only to drip irrigation systems utilizing pressure compensating emitters
- Maximum emitter flow rates should be established per soil scientist and manufacturer's recommendations based on site-specific instantaneous soil loading rate capacity.

- The net 50 percent BMP credits will only be provided for systems using loading rates as applicable for STE, regardless of effluent quality. Maximum soil texture-based area loading rates are as follows; however, States can require the use of lower rates at their discretion:
  - TG II 0.27 gpd/sf
  - TG III 0.17 gpd/sf
  - TG IV 0.12 gpd/sf

A summary of the Panel's recommendations for the Drip Dispersal BMP in comparison with the more generic, predecessor Shallow-Placed, Pressure-Dosed Dispersal BMP is provided in **Table 7**.

Table 7. Summary of Panel Recommendations versus Shallow-Placed, Pressure-Dosed Dispersal BMP

Parameter	38% BMP for Drip (existing)	50% BMP for Drip (proposed)
Depth of install	Limited to 12 inch or less	Limited to 12 inch or less
Soil Types	II, III, IV	II,III,IV
System Type	In ground	In ground
Loading Rates	Not defined	TG II 0.27 gpd/sf TG III 0.17 gpd/sf TG IV 0.12 gpd/sf Individual rates to be set by states but cannot exceed these maximums for higher reduction to be considered
Effluent Quality	Not defined	Not defined (intention is for recommendation to apply to STE as well as treated effluent)
Minimum unsaturated depth below drip tubing	Not defined	18 inches with either septic tank or treated effluent

3.0 PEAT TREATMENT WITH PAD OR TRENCH DISPERSAL

3.1 BACKGROUND

3.1.1 Existing BMP and Request

Peat treatment systems are not explicitly defined in the current list of approved CBP OWTS BMPs. However, they share significant similarities to an existing BMP category: Intermittent (Single-Pass) Media Filter. This approved BMP specifies the use of sand, gravel, or other granular media, so by definition excludes peat and other non-granular materials. For the purposes of this evaluation – and consistent with the request made of the Panel – only single-pass peat filters have been considered. Additionally, the request made for this technology was to consider the peat treatment unit and the underlying pad or trench which disperses effluent into the soil as a single, integrated unit.

Two manufacturers, Anua and Premier Tech, submitted data to support the creation of a new BMP based on peat treatment plus in-ground attenuation. The proposed BMP is:

Peat treatment units in combination with a soil dispersal trench or pad installed no deeper than 18 inches in original soil and with at least 12 inches of separation to a limiting feature such as rock or water table result in a net > 50 percent total nitrogen reduction when applied to soil at specified loading rates.

3.1.2 Referenced Data

Two data sets were submitted, one from each manufacturer:

- Bord Na Mona. 1999/2014. VA Demonstration Project Report for PURAFLO Peat Biofilter (VA PURAFLO Study)
- Belanger, M. 2014. VA Monitoring Program Summary for ECOFLO TN Removal (VA ECOFLO Study)

The data were collected in Virginia as part of a study to evaluate BOD and TSS reduction, but TN data were also collected. Samples were collected of the septic tank effluent (applied to the peat filter), at the base of the peat filter (treatment unit effluent), and approximately one foot below the pad or trench dispersal system. Systems were installed in all four soil texture groups.

Other references were reviewed but not used in the analysis, primarily because of study issues that limited their usefulness for this exercise (e.g., not including samples taken beneath the pad or not having paired influent and effluent samples).

3.2 RESULTS AND DISCUSSION

In the VA PURAFLO and ECOFLO (Bord Na Mona and Belanger) studies, Puraflo and Ecoflo peat media filters installed on gravel absorption fields (pad or trench) were sampled for Total Nitrogen (TN) reduction efficiency. Samples were collected prior to the treatment unit (influent), immediately following the treatment unit (effluent), and from a sample well/chamber 12 inches below the dispersal pad or trench in the absorption area.

Before data could be analyzed, all raw data had to be converted into a numerical format recognizable by Excel. Those conversions were performed as follows:

1. If a datum had a comma (,) instead of a decimal point (.), that comma was replaced with a decimal point (e.g., 0,5 → 0.5).

2. If a datum was recorded as “< X”, where “X” represented a quantification or detection limit, it was changed to a value equal to X/2 (e.g., < 0.5 → 0.25).

The initial TN reduction analyses were conducted on paired TN data: Influent/Effluent, Effluent/Absorption Field, Influent/Absorption Field. TN reductions were calculated across the treatment unit (Influent/Effluent), across the dispersal pad/trench (Effluent/Absorption Field), and total across both the treatment unit and dispersal pad/trench (Influent/Absorption Field).

The possibility existed that Absorption Field TN concentrations were reduced by groundwater dilution, thereby indicating greater TN reductions across the absorption field than actually occurred. To examine this possibility, the TN reduction analyses were repeated with the concentration of chloride (Cl^-) in an Absorption Field sample compared to that in the Effluent applied to that absorption field. A reduction in Cl^- concentration across the absorption field was assumed due to groundwater dilution, and that dilution would be assumed to have an identical effect on the Absorption Field TN concentration.

The repeat analyses also required paired data: Effluent TN with Cl^-/Absorption Field TN with Cl^-. The reduction in Cl^- concentration across the absorption field (due to dilution) was calculated for each pair of data, and the Absorption Field TN concentration was adjusted in response to that dilution according to the following rules:

1. If the calculated Cl^- reduction was negative (i.e., the Cl^- concentration was higher in the Absorption Field sample than in the Effluent sample), the Absorption Field TN concentration was not adjusted, since no mechanisms were known that would increase Cl^- and TN concentrations as effluent dispersed through the absorption field.

2. If the adjusted Absorption Field TN concentration exceeded the Effluent TN concentration, it was set equal to the Effluent concentration, since no mechanisms were known that would increase the Absorption Field TN concentration above that which was applied to the absorption field.

Table 8 presents the loss of TN from the septic tank through the peat treatment unit. **Table 9** and **Table 10** present the losses through the soil and the overall loss (septic tank effluent to the well below the dispersal pad/trench), accounting for dilution in the wells below the dispersal pad/trench. All tables present only paired (in/out) data points. A complete summary of the data analysis is provided in **Appendix B**.

Table 8. TN Reduction through Treatment Unit (paired data sets only)[1]

	Puraflo	Ecoflo
Count	91	68
Minimum	-88.5%	-89.7%
Maximum	99.0%	92.5%
Mean	**22.4%**	**23.8%**
Standard Deviation	38.2%	45.9%

[1] Treatment unit removal = (Septic tank effluent – Treatment unit effluent)/Septic tank effluent. Data with more than a negative 100% reduction dropped.

Table 9. TN Reduction for Soil Texture Groups I and II (paired data sets only) adjusted for dilution

	Texture Group I				Texture Group II			
	Puraflo		Ecoflo		Puraflo		Ecoflo	
	Soil Removal[1]	Overall[2]	Soil Removal[1]	Overall[2]	Soil Removal[1]	Overall[2]	Soil Removal[1]	Overall[2]
Count	14	10	1	No data	23	19	4	4
Minimum	-117.3%	-32.2%	0.8%		-49.2%	-205.8%	0.0%	46.8%
Maximum	94.0%	89.1%	0.8%		99.2%	99.6%	95.0%	93.5%
Mean	33.4%	**23.3%**	0.8%		35.7%	**43.4%**	51.9%	**72.3%**
Standard Deviation	51.9%	45.1%			50.8%	71.1%	41.5%	19.9%

[1] Soil removal = (Peat unit effluent – pad/trench well)/Peat unit effluent
[2] Overall = (STE-pad/trench well)/STE

Table 10. TN Reduction for Soil Texture Groups III and IV (paired data sets only) adjusted for dilution

	Texture Group III				Texture Group IV			
	Puraflo		Ecoflo		Puraflo		Ecoflo	
	Soil Removal[1]	Overall[2]	Soil Removal[1]	Overall[2]	Soil Removal[1]	Overall[2]	Soil Removal[1]	Overall[2]
Count	18	10	3	3	No data	No data	14	11
Minimum	-30.2%	9.1%	27.6%	-45.5%			0.0%	-45.5%
Maximum	92.0%	90.2%	87.6%	94.1%			95.0%	94.1%
Mean	26.1%	**50.5%**	64.9%	**37.3%**			46.2%	**51.2%**
Standard Deviation	34.8%	26.2%	32.6%	73.3%			37.6%	44.4%

[1] Soil removal = (Peat unit effluent – pad/trench well)/Peat unit effluent
[2] Overall = (STE-pad/trench well)/STE

The TN reduction through the treatment unit was extremely variable and the paired data sets did not substantiate a reduction through the treatment units (Table 8) greater than the 20-percent TN reduction credit currently given to Intermittent Media Filters.

To assess the overall efficiency of the proposed BMP, the overall reduction in TN between the septic tank effluent and the soil under the dispersal pad/trench is the critical piece. The results for this overall TN reduction can be found in the column titled "Overall" in **Table 9** and **Table 10**. Based on these results, only the Ecoflo data set in Texture Group II soils results in a mean TN reduction greater than 60 percent (the equivalent of a net 50 percent reduction). However, note that the data set only includes 4 data points. Additionally, it should be noted that the standard deviations reported confirm the observation of high TN reduction variability between paired datapoints, implying that all results are inconclusive.

3.3 RECOMMENDATIONS

The Panel recommends that single-pass peat treatment systems plus dispersal not be included as an OWTS sector BMP in the Chesapeake Bay Program at this time. The Panel encourages the collection of additional paired, dilution corrected data to strengthen the statistical significance of the dataset and further inform the performance of this technology. NSF 40 certified peat treatment units already fall under an ex-situ BMP that assigns a 20 percent TN reduction to the treatment unit alone.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The Panel recommends that drip irrigation systems that meet the design and installation criteria in Section 2 be approved as a BMP for reducing nitrogen within the drainfield (Zone 1) by 50 percent. This recommendation adds a new BMP to those already approved by the CBP.

Upon a review of available field data on single-pass peat filtration systems discharing to a pad, the Panel recommends not adding a new creditable BMP. In particular, the data were not sufficient to establish a reduction greater than 20 percent through the filtration unit, which is already creditable if the peat system qualifies as an existing *ex situ* BMP (e.g., NSF Standard 40 system or Intermittent Media Filter). Additional data, particularly if it is collected as part of a well-designed study specifically targeted to measure nitrogen reductions across the treatment unit and pad, may qualify peat filtration and dispersal to a pad as a stand-alone BMP in the future (the existing data came from studies primarily focused on measuring reductions in BOD and TSS, with nitrogen only measured an incidental parameter). However, the existing data that were reviewed exhibited an extremely high level of variability and thus statistical uncertainty.

In reviewing these two proposed BMPs, the Panel suggests that the CBP consider the following developments and potential future studies moving forward:

- US EPA Regions 1 and 2 are currently sponsoring a nitrogen sensor challenge intended specifically to improve monitoring of on-site wastewater systems. The Panel recommends that the CBP track this effort to determine whether the resulting sensors might help provide better data for future studies and verification efforts. The Panel also recommends that the CBP take a more proactive approach to verifying the performance of nitrogen removal BMPs that have been installed in the Chesapeake Bay Watershed. The sensors currently being developed and tested could add significant value to such an effort.
- With regards to *in situ* BMPs, there is scientific uncertainty about the impacts of saturated conditions within the dispersal area on nitrogen. For example, an argument could be made that systems featuring *in situ* BMPs that provide full nitrification would more effectively remove nitrogen by denitrification if they discharged into saturated soil conditions, particularly if the soils were high in organic carbon as would be expected of surficial soil layers. More research in fluctuating water table environments would therefore be worthwhile. Future studies should continue to collect chloride data in order to separate the impacts of groundwater dilution from mass removal. Future studies should also measure soil carbon as it should be an important characteristic for nitrogen removal.

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APPENDIX A. DRIP IRRIGATION REFERENCE SUMMARY

Relevant literature listed in Table 5 is summarized below.

Ayres Associates. 1998. *Florida Keys Onsite Wastewater Nutrient Reduction Systems Demonstration Project, Phase I Report.* Delivered to Florida Department of Health in March 1998 with funding from USEPA under Cooperative Agreement #X994393-93-0.

Ayres Associates. 2000. *Florida Keys Onsite Wastewater Nutrient Reduction Systems Demonstration Project, Phase II Addendum.* Delivered to Florida Department of Health in April 2000 under HRS Contract #CO013.

- In Phase I, septic tank effluent was applied to lined beds with drip irrigation dispersal. There were three beds with different media: sand, expanded clay (LECA) and crushed brick. The influent TN averaged 34.51 mg/l and the loading rate to the beds was approximately 1.0 gpd/ft^2. The effluent from the beds were sampled for TN over approximately one year. The TN removal rates were 38.7 percent for crushed brick, 33.4 percent for the expanded clay, and 34.1 percent for the sand.
- In Phase II, the loading rates were increased to 1.7 gpd/ft^2. The influent TN averaged 36.74 mg/l. The effluent from the beds were sampled for TN over approximately one year. The TN removal rates were 14.8 percent for crushed brick, 20.8 percent for the expanded clay, and 25.9 percent for the sand.
- This study is supportive of not extending the N reduction credit to texture group I soils.

Beggs, R.A., D. Hills, G. Tchobanoglous, and J. Hopmans. 2011. Fate of nitrogen from subsurface drip dispersal of effluent from small wastewater systems. *Journal of Contaminant Hydrology* 126: 19-28.

- The authors constructed container tests with a total depth of 115 centimeters (approximately 45 inches) of sandy loam, loamy sand, and silt loam soils. They installed drip lines at 15 centimeters (6 inches) with suction lysimeters 30 and 45 inches below the drip lines. They applied STE at the rates summarized in Table A-1.

Table A-1. Loading Rates for Container Tests.

Container	Texture	Organic Matter (%)	Phase 1 Loading Rate (cm/day)	Phase 2 Loading Rate (cm/day)
South	Sandy Loam	0.52	0.315	0.239
Middle	Loamy sand	0.28	0.529	0.343
North	Silt loam	1.33	0.237	0.170

Source: Beggs et al. (2011)

- The authors reported N removal rates from 63 to 95 percent. They used the data to calibrate a HYDRUS model to predict denitrification rates in these soils.
- The study concluded that "nitrogen removal is especially effective in medium to fine soils and soils with shallow restrictive or capillary break layers. In these soils, a 50 percent nitrogen removal rate is reasonable to expect" (Beggs et al. 2011). The authors provided recommended design rates of denitrification based on the model runs of 10 percent for loamy sand, 30 percent for sandy loam, and 50 percent for loam or clay loam.
- This paper supports the exclusion of sands from the BMP, but not the exclusion of loamy sands. However, the consensus of the OWTS Expert Panel is that there is an insufficient amount of directly measured evidence to support the inclusion of sand and loamy sand soils in this BMP at this time.

Hayes, J.G. 2001. Expanding the Applications of Micro-Irrigation "Drip" Treatment and Disposal Systems in Delaware. *On-Site Wastewater Treatment, Proc. Ninth Natl. Symp. on Individual and Small Community Sewage*

Systems (11-14 March 2001, Fort Worth, Texas, USA), ed. K. Mancl., St. Joseph, Mich. ASAE 701P0009.(doi:10.13031/2013.6067).

- Four drip systems were installed at a depth of 6 to 8 inches in coarse loamy soils at single family homes. Three systems dispersed septic tank effluent and one systems used a Bio-microbics FAST treatment unitThe depth to seasonal high water table varied form 0 inches to 20 inches. Two to four wells were installed at each site at a total depth of 1.5 m with screening starting at 30 cm.
- The sites with septic tank effluent averaged 96 mg/l total nitrogen applied to the soil while the FAST unit averaged 21.9 mg/l. Well data suggests 88 percent N removal from the sites receiving septic tank effluent and 35 percent at the site receiving treated effluent.

Hayes, J.G, and A. Moore. 2007. Long Term Impacts of Micro-Irrigation “Drip” Treatment and Disposal Systems on Delaware’s Marginal Soils. In *Proceedings of Eleventh Individual and Small Community Sewage Systems Conference*, Warwick, RI.

- This study is a continuation of the 2001 study referenced above.
- The authors installed shallow drip systems (15 to 20 centimeters deep) in coarse-loamy soils (see table below) that are somewhat poorly drained, but relatively permeable. They also installed shallow wells at each site to obtain groundwater samples. Well depths were 1.5 meters, with screening at 30 centimeters. Table A-4 summarizes the characteristics of each site and system.

Table A-4. Site and System Characteristics.

Site	Soil Class[1]	Permeability	SHWT	System Type
1	Aquic Hapludult	30 mpi	50 cm	Drip
2	Typic Endoaquult	30 mpi	28 cm	Drip
3	Aquic Hapludult	60 mpi	50 cm	Drip
4	Typic Umbraquult	60 mpi	0 cm	Drip with ATU

Source: Hayes and Moore (2007)
[1]Coarse-loamy
mpi = minutes per inch

- The sites receiving STE averaged 54 mg/L TN applied to the soil. The highest TN reported from the wells was 11.4 mg/L, which suggests a 78 percent reduction of TN. The site receiving the treated effluent had an applied TN of 20.8 mg/L, with the highest reported TN in the wells being 7.72 mg/L or a 62 percent reduction in TN.

Hepner, L., D. Linde, C. Weber, and D. Smith. 2005. Alternative On–Lot Technology Research-Soil-Based Treatment Systems. Delaware Valley College, New Britain, PA.

- The authors ran multiple studies to evaluate different technologies. The authors reviewed studies utilizing drip or LPD in surface soils. All of these studies used leachate samples collected below the effluent application point.
- The authors applied nitrified secondary effluent (42.5 mg/L TN) at a rate of 0.056 gpd/sf to a surface drip system in a poorly drained Chalfont series soil with a restriction at 13 inches and estimated percolation rate of 70 to 200 minutes per inch (mpi). They collected leachate samples from 2 and 4 feet below the drip lines over a period of 2 years. Over 88 samples of nitrate-N and ammonia-N were collected. The authors noted a 94 percent reduction at the 2-foot depth and a 96 percent reduction at the 4-foot depth. However, the samples might have been impacted by dilution due to the distance between the collection point and the application point.

- The authors installed drip irrigation at an 8-inch depth in a wooded site with a Readington series soil that contained a fragipan horizon at 25 inches and a reported 20 to 60 mpi percolation rate. The application rate was not specified. The authors applied STE with a TN concentration of 42.5 mg/L and collected leachate samples at 1, 2, 3, and 4 feet below the drip lines. Over 55 samples were collected at each depth for ammonia-N and nitrate-N, with more samples collected at the 1-foot depth (89 samples minimum). Data from the 1- and 2-foot depths was evaluated for this BMP. At a foot, the leachate had an 84.5 percent reduction from the STE. At the 2-foot depth, the reduction was calculated as 80 percent. This is a large, robust data set that spans multiple seasons. The lower reduction at the 2-foot depth is likely due to accumulation of effluent at the fragipan layer.
- The authors installed LPD in a surface gravel bed/mound and dispersed STE to a Lansdale soil characterized as deep and well-drained, with a percolation rate of 11 to 18 mpi. The loading rate was calculated as 0.5 gpd/sf to the mound base. Researchers collected leachate samples at 1, 2, 3, and 4 feet below the soil surface. At a foot the TN reduction was 28 percent (n = 49). At 2 feet the reduction was 45 percent. The fact that this was a highly permeable soil could account for the lower reductions of TN reported.
- The authors installed drip irrigation using a chisel plow at 9 to 11 inches in a Chalfont series soil, with redox at 11 inches and rock fragments at 25 inches. They applied STE (42.5 mg/L TN) at a rate of 0.08 gpd/sf May through November and at 0.04 gpd/sf December through April and took leachate samples for ammonia-N and nitrate-N at 2 and 4 feet below the drip tubing. They reported 91 percent TN removal at the 2-foot depth and 93 percent removal at the 4-foot depth (n = 83). Note that the results for both loading rates are combined.
- The authors installed drip irrigation with a chisel plow at 9 to 11 inches, with redox at 11 inches and rock fragments at 25 inches. They applied STE (42.5 mg/L TN) at a rate of 0.08 gpd/sf from May through November and at a rate of 0.04 gpd/sf from December through April. They injected air through the drip system after the effluent had been applied. The addition of the air chase differentiates this design from the one used in the study summary above. Researchers took leachate samples at 2 and 4 feet below the drip tubing and analyzed them for ammonia-N (n = 123 at 2 feet and 66 at 4 feet) and nitrate-N (n = 118 at 2 feet and n = 64 at 4 feet). At 2 feet, the samples indicated a 93 percent reduction. At 4 feet the samples supported a reduction of 89 percent. Again the data from the two loading rates is combined.
- The authors installed drip irrigation with a chisel plow at 9 to 11 inches, with redox at 11 inches and rock fragments at 25 inches. They applied STE (42.5 mg/L TN) at a rate of 0.08 gpd/sf from May through November and at a rate of 0.04 gpd/sf from December through April. The site was covered with no-till corn. Researchers took leachate samples at 2 and 4 feet below the drip tubing and analyzed them for ammonia-N (n = 128 at 2 feet and 90 at 4 feet) and nitrate-N (n = 127 at 2 feet and 92 at 4 feet). The samples indicated a 79 percent TN reduction at 2 feet. At 4 feet, the samples supported a reduction of 72 percent. Again, the data from the two loading rates is combined.
- The authors installed drip irrigation with a chisel plow at 9 to 11 inches, with redox at 11 inches and fragments at 25 inches. They applied STE (42.5 mg/L TN) at a rate of 0.08 gpd/sf from May through November and at a rate of 0.04 gpd/sf from December through April. The site was maintained as pasture. Researchers took leachate samples at 2 and 4 feet below the drip tubing and analyzed them for ammonia-N (n = 98 at 2 feet and 87 at 4 feet) and nitrate-N (n = 100 at 2 feet and 88 at 4 feet). The samples indicated a 96 percent reduction at 2 feet. At 4 feet, the samples supported a reduction of 96 percent. Again, the data from the two loading rates is combined.

Hepner L., D. Linde, C. Weber, and D. Smith. 2007. Reduction of Bacteriologic and Chemical Constituents of Septic Tank Effluent with Depth Using a Drip Dispersal System, *In Proceedings of Eleventh Individual and Small Community Sewage Systems Conference*. Warwick, RI.

- Three full size systems were constructed on a Readington series soil (fine-loamy, mixed, active, mesic Oxyaquic Fragiudalf) with a fragipan at 25 inches below the surface. The authors evaluated drip dispersal of STE installed 8 to 10 inches deep in a Reading series soil Each system had two zones of 600 lineal feet per zone of tubing on 2 foot centers. Each system was loaded at 0.17 gallons per square foot per day for two years. Sampling occurred monthly using zero tension lysimeters at multiple locations and multiple depths. The nitrogen reduction was 85 percent at one foot below the drip lines.

Siegrist R.L., R. Parzen, J. Tomaras, and K.S. Lowe. 2014. Water movement and fate of nitrogen during drip dispersal of wastewater effluent into a semi-arid landscape. *Water Research* 52(2014)178-187

- The authors evaluated drip dispersal of STE installed at 8 to 12 inches deep in an Ascalon sandy loam soil profile. Two zones were loaded at either 0.13 or 0.25 gal/ft^2/day with each zone having either native vegetation or Kenticky bluegrass sod cover.
- After one year of operation, a ^{15}N tracer test was conducted to evaluate 3-dimensional nitrogen fate and transport in the soil. After tracer delivery, soil samples were collected at 6, 12, 24, and 36 inches below ground surface both along (parallell) to the drip tubing and perpendicular to the tubing. A total of 30 samples were collected.
- Results indicated that only a portion of the effluent water dispersed migrated downward in the soil (approx. 34 percent or 64 percent for Zone 1 or 2, respectively) based on precipitation and evapotranspiration at the Test Site. However, water filled porosities were high (>85 percent) throughout the soil profile even for the lower STE loading rate (Zone 1). Approximately 51 percent of the N applied during the tracer test was estimated to be removed by plant uptake and denitrification.

APPENDIX B. PEAT TREATMENT SYSTEM DATA ANALYSIS

ECOFLO

ABBREVIATIONS: INF = Influent to ATU EFF = Effluent from ATU L1 = Sample collection well 12" beneath the absorption field

PRIOR TO ADJUSTMENT FOR PAD WELL DILUTION

	TN Reduction Soil Texture Group I			TN Reduction Soil Texture Group II			TN Reduction Soil Texture Group III			TN Reduction Soil Texture Group IV			TN Reduction All Soil Texture Groups		
	INF to EFF	EFF to L1	INF to L1	INF to EFF	EFF to L1	INF to L1	INF to EFF	EFF to L1	INF to L1	INF to EFF	EFF to L1	INF to L1	INF to EFF	EFF to L1	INF to L1
Count =	3	4	3	25	24	23	13	12	12	4	3	3	71	69	65
Minimum =	7.0%	-39.1%	-29.4%	-570.5%	-130.3%	-27.4%	-610.9%	35.6%	-45.5%	-14.7%	62.7%	57.2%	-6438.5%	-205.3%	-203.8%
Maximum =	70.4%	94.0%	94.5%	92.5%	98.7%	99.4%	92.2%	98.5%	99.1%	53.0%	96.1%	97.1%	92.5%	99.4%	99.4%
Mean =	**28.9%**	**26.7%**	**50.2%**	**0.2%**	**51.7%**	**66.1%**	**-9.6%**	**82.9%**	**82.1%**	**25.3%**	**79.9%**	**81.8%**	**-84.5%**	**63.1%**	**68.8%**
Standard Deviation =	36.0%	58.1%	69.1%	129.8%	59.8%	35.5%	184.2%	20.1%	41.1%	29.1%	16.7%	21.5%	773.0%	55.1%	49.5%

AFTER ADJUSTMENT FOR PAD WELL DILUTION

	TN Reduction Soil Texture Group I			TN Reduction Soil Texture Group II			TN Reduction Soil Texture Group III			TN Reduction Soil Texture Group IV			TN Reduction All Soil Texture Groups		
	INF to EFF	EFF to L1	INF to L1	INF to EFF	EFF to L1	INF to L1	INF to EFF	EFF to L1	INF to L1	INF to EFF	EFF to L1	INF to L1	INF to EFF	EFF to L1	INF to L1
Count =	0	1	0	4	4	4	3	3	3	2	2	2	11	14	11
Minimum =		0.8%		-28.8%	0.0%	46.8%	-610.9%	27.6%	-45.5%	-14.7%	9.3%	3.7%	-610.9%	0.0%	-45.5%
Maximum =		0.8%		47.3%	95.0%	93.5%	52.1%	87.6%	94.1%	53.0%	16.0%	57.4%	53.0%	95.0%	94.1%
Mean =		**0.8%**		**23.3%**	**51.9%**	**72.3%**	**-169.8%**	**64.9%**	**37.3%**	**19.2%**	**12.7%**	**30.5%**	**-33.2%**	**46.2%**	**51.2%**
Standard Deviation =				35.9%	41.5%	19.9%	382.0%	32.6%	73.3%	47.9%	4.8%	38.0%	193.7%	37.6%	44.4%

PURAFLO

ABBREVIATIONS: PT = Pump Tank (ATU influent) SC = Sample Chamber (ATU effluent) PW = Pad Well (Sample collection well beneath pad)

PRIOR TO ADJUSTMENT FOR PAD WELL DILUTION — SINGLE-PASS

	TN Reduction - Soil Texture Group I					TN Reduction - Soil Texture Group II					TN Reduction - Soil Texture Group III					TN Reduction - Soil Texture Group IV					TN Reduction - All Soil Texture Groups				
	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2
Count =	23	14	0	12	0	37	23	2	21	0	23	18	0	11	0	12	0	0	1	0	96	55	2	45	0
Minimum =	-163.4%	-117.3%		-11626.4%		-409.0%	-49.2%	86.2%	-205.8%		-178.8%	-30.2%		31.5%		-74.3%			98.2%		-409.0%	-117.3%	86.2%	-11626.4%	
Maximum =	99.0%	94.0%		89.1%		91.5%	99.3%	93.3%	99.7%		74.6%	95.1%		93.8%		94.2%			98.2%		99.0%	99.3%	93.3%	99.7%	
Mean =	**3.6%**	**40.8%**		**-949.0%**		**18.1%**	**38.5%**	**89.7%**	**49.5%**		**22.6%**	**52.7%**		**67.8%**		**30.2%**			**98.2%**		**13.2%**	**43.7%**	**89.7%**	**-211.2%**	
Standard Deviation =	66.9%	57.9%		3362.9%		77.7%	52.1%	5.0%	68.0%		52.4%	34.8%		20.9%		47.9%					76.6%	48.2%	5.0%	1741.3%	

PRIOR TO ADJUSTMENT FOR PAD WELL DILUTION — RECIRCULATING 1:1

	TN Reduction - Soil Texture Group I					TN Reduction - Soil Texture Group II					TN Reduction - Soil Texture Group III					TN Reduction - Soil Texture Group IV					TN Reduction - All Soil Texture Groups				
	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2
Count =	0	0	0	0	0	10	8	0	7	0	0	0	0	0	0	0	0	0	0	0	10	8	0	7	0
Minimum =						-90.9%	-90.7%		-248.5%												-90.9%	-90.7%		-248.5%	
Maximum =						95.4%	84.1%		88.9%												95.4%	84.1%		88.9%	
Mean =						**36.2%**	**5.4%**		**12.3%**												**36.2%**	**5.4%**		**12.3%**	
Standard Deviation =						65.7%	71.6%		120.3%												65.7%	71.6%		120.3%	

AFTER ADJUSTMENT FOR PAD WELL DILUTION — SINGLE-PASS

	TN Reduction - Soil Texture Group I					TN Reduction - Soil Texture Group II					TN Reduction - Soil Texture Group III					TN Reduction - Soil Texture Group IV					TN Reduction - All Soil Texture Groups				
	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2
Count =	10	14	0	10	0	19	23	2	19	0	10	18	0	10	0	0	0	0	0	0	39	55	2	39	0
Minimum =	-163.4%	-117.3%		-32.2%		-409.0%	-49.2%	79.8%	-205.8%		9.1%	-30.2%		9.1%							-409.0%	-117.3%	79.8%	-205.8%	
Maximum =	50.4%	94.0%		89.1%		91.5%	99.2%	90.7%	99.6%		74.6%	92.0%		90.2%							91.5%	99.2%	90.7%	99.6%	
Mean =	**-24.3%**	**33.4%**		**23.3%**		**12.4%**	**35.7%**	**85.3%**	**43.4%**		**37.3%**	**26.1%**		**50.5%**							**9.3%**	**32.0%**	**85.3%**	**40.1%**	
Standard Deviation =	67.9%	51.9%		45.1%		105.7%	50.8%	7.7%	71.1%		17.9%	34.8%		26.2%							83.5%	45.8%	7.7%	56.1%	

AFTER ADJUSTMENT FOR PAD WELL DILUTION — RECIRCULATING 1:1

	TN Reduction - Soil Texture Group I					TN Reduction - Soil Texture Group II					TN Reduction - Soil Texture Group III					TN Reduction - Soil Texture Group IV					TN Reduction - All Soil Texture Groups				
	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2	PT to SC	SC to PW#1	SC to PW#2	PT to PW#1	PT to PW#2
Count =	0	0	0	0	0	7	8	0	7	0	0	0	0	0	0	0	0	0	0	0	7	8	0	7	0
Minimum =						-90.9%	0.0%		-90.9%												-90.9%	0.0%		-90.9%	
Maximum =						72.1%	66.2%		82.1%												72.1%	66.2%		82.1%	
Mean =						**11.7%**	**26.3%**		**37.7%**												**11.7%**	**26.3%**		**37.7%**	
Standard Deviation =						64.3%	29.8%		58.6%												64.3%	29.8%		58.6%	

Appendix G (07 18 2018)

Technical Requirements to Enter Advanced On-Site Wastewater Treatment Practices into Scenario Builder and the Phase 6 Watershed Model

Presented to Watershed Technical Workgroup for Review and Approval: July 19, 2018

Background: In October, 2015, a second Onsite Wastewater Treatment Expert Panel was convened to review additional BMPs for the sector. The purpose of this technical appendix is to describe how the Onsite Wastewater Treatment Expert Panel's recommendations will be integrated into the modeling tools including NEIEN, Scenario Builder and the Watershed Model.

Q1. What are the efficiency reductions a jurisdiction can claim for the new advanced on-site waste treatment systems (advanced septic systems) in the Phase 6 Watershed Model?

A1. The original 2014 panel's recommendations include 20 distinct combinations of in situ and ex situ practices that reduce septic nitrogen loads beyond a conventional septic system. The information in the table below is found in Appendix G in the 2014 Panel report. The NEW BMPs from the second panel are highlighted below.

Table 1. Percent Nitrogen Reductions for New Septic System Treatment BMPs

NEIEN BMP Name	Scenario Builder BMP Name	Percent Nitrogen Reduction
Septic Effluent with Shallow Pressure	Septic Effluent with Enhanced In Situ	38%
Septic Effluent with Elevated Mound	Septic Effluent with Enhanced In Situ	38%
Septic Effluent with Advanced Drip Dispersal	Septic Effluent with Advanced In Situ	50%
NSF 40	Secondary Treatment with Conventional In Situ	20%
NSF 40 with Shallow Pressure	Secondary Treatment with Enhanced In Situ	50%
NSF 40 with Elevated Mound	Secondary Treatment with Enhanced In Situ	50%
NSF 40 with Advanced Drip Dispersal	Secondary Treatment with Advanced In Situ	60%
IMF	Secondary Treatment with Conventional In Situ	20%
IMF with Shallow Pressure	Secondary Treatment with Enhanced In Situ	50%
IMF with Elevated Mound	Secondary Treatment with Enhanced In Situ	50%
IMF with Advanced Drip Dispersal	Secondary Treatment with Advanced In Situ	60%

Constructed Wetland	Secondary Treatment with Conventional In Situ	20%
Constructed Wetland with Shallow Pressure	Secondary Treatment with Enhanced In Situ	50%
Constructed Wetland with Elevated Mound	Secondary Treatment with Enhanced In Situ	50%
Constructed Wetland with Advanced Drip Dispersal	Secondary Treatment with Advanced In Situ	60%
RMF	50% Denitrification Unit with Conventional In Situ	50%
RMF with Shallow Pressure	50% Denitrification Unit with Enhanced In Situ	69%
RMF with Elevated Mound	50% Denitrification Unit with Enhanced In Situ	69%
RMF with Advanced Drip Dispersal	50% Denitrification Unit with Advanced In Situ	75%
IFAS	50% Denitrification Unit with conventional In Situ	50%
IFAS with Shallow Pressure	50% Denitrification Unit with Enhanced In Situ	69%
IFAS with Elevated Mound	50% Denitrification Unit with Enhanced In Situ	69%
IFAS with Advanced Drip Dispersal	50% Denitrification Unit with Advanced In Situ	75%
Proprietary Ex Situ	50% Denitrification Unit with Conventional In Situ	50%
Proprietary Ex Situ with Shallow Pressure	50% Denitrification Unit with Enhanced In Situ	69%
Proprietary Ex Situ with Elevated Mound	50% Denitrification Unit with Enhanced In Situ	69%
Proprietary Ex Situ with Advanced Drip Dispersal	50% Denitrification Unit with Advanced In Situ	75%

Q2. What technologies qualify for the reductions listed in the table above?

A2. Qualifying technologies are listed below.

Secondary Treatment– Pre-treatment practices are those occurring prior to dispersing effluent into the soil treatment unit. Secondary ex situ systems include: certified, NFS 40 Class I or equivalent systems; intermittent media filters (IMF); and constructed wetlands (p. 29-30). Additional details about these systems are provided in the expert panel report.

50% Denitrification Units– Pre-treatment practices are those occurring prior to dispersing effluent into the soil treatment unit. 50% Denitrification ex situ systems include: recirculating media filters (RMF);

Anne Arundel County Integrated Fixed-Film Activated Sludge (IFAS). Many proprietary treatment systems also exist that offer 50% denitrification (p. 30). The proprietary treatment systems that fall into this category will generally be verified through a two step process that includes a controlled test condition and then a field test condition. Additional details about these systems are provided in the 2014 expert panel report.

Proprietary Systems – There are some proprietary systems that may offer significant denitrification benefits above the 50% reduction threshold discussed above. Proprietary system manufacturers who wish to have their system considered for greater than a 50% reduction will be considered on a case by case basis and would require ongoing field verification of the reduction value in most cases. Additional details about these systems and the recommended protocol for third-party testing can be found in Section 3.2.1 of the 2014 report.

Enhanced In Situ – In situ processes are those occurring after ex situ treatment, within the soil treatment unit. These practices include shallow-placed, pressure-dosed dispersal units and elevated sand mounds with pressure-dosed dispersal (p. 31). Additional details about these systems are provided in the expert panel report

Advanced In Situ – In situ processes are those occurring after the ex situ treatment, within the soil treatment unit. This advanced practice includes drip dispersal systems only when designed in accordance with the details provided in the 2018 expert panel report to produce a gross 60% TN reduction.

Q3. How do these new BMPs interact with the existing reductions for disconnections, septic pumpouts and de-nitrification systems?

A3. The septic disconnection (sewer connection) BMP will be simulated prior to any existing or new septic BMPs. The panel recommended that the 5% credit for septic pumpouts for conventional septic systems should remain within the modeling tools. The panel recommended this credit should only be reported once every five years for any given system, and the credit should only apply in the model for the year reported. Additionally, the panel recommended septic pumpout credits should not be available for systems claiming a credit through a BMP above p. 29).

The septic de-nitrification BMP currently in the model will be replaced by the 9 new system types that also reduce N by 50%. Jurisdictions should no longer report the de-nitrification BMP for progress or planning purposes. Existing de-nitrification systems in the model will remain in the model until NEIEN data is updated by jurisdictions to reflect the type of ex situ and in situ practices being used. Septic pumpouts will still be available on historically reported systems with de-nitrification.

Q4. What do jurisdictions need to report in NEIEN in order to receive credit for the new onsite treatment practices in the modeling tools?

A4. Jurisdictions should report the NEIEN BMP names listed in Table 1 above, as well as the location of the systems and the date the systems were installed.

Q5. How will the reductions be applied to septic systems in the current modeling tools?

A5. The efficiency reductions listed in Table 1 above will be applied to conventional septic systems within the modeling tools. These reductions will result in lower edge-of-stream nitrogen loads from the modeled, conventional septic systems. Please note that each of the system types is mutually exclusive meaning that a jurisdiction should only report one practice type per septic system. Please also note that septic pumpouts and the current septic de-nitrification practices are also mutually exclusive with each of the system types and should not be reported in conjunction with these new BMPs.

Q6. In what order will Scenario Builder credit all of the septic BMPs?

A6. Table 2 below lists the unique Scenario Builder BMP names that will now be associated with septic systems, and places these names in the order in which Scenario Builder will credit the BMPs.

Table 2. Order of Credit for Septic System BMPs in Scenario Builder

Scenario Builder BMP Name	Percent Nitrogen Reduction
Septic Disconnections (Existing)*	N/A
50% Denitrification Units with Advanced In Situ	75%
50% Denitrification Units with Enhanced In Situ	69%
Secondary Treatment with Advanced In Situ	60%
Secondary Treatment with Enhanced In Situ	50%
50% Denitrification Units with Conventional In Situ	50%
Septic Effluent with Advanced In Situ	50%
Septic Effluent with Enhanced In Situ	38%
Secondary Treatment with Conventional InSitu	20%
Septic De-Nitrification (Existing)**	50%
Septic Pumpouts (Existing)**	5%

*The existing Septic Disconnection BMP is simulated prior to any other septic BMPs.
**The existing Septic Pumpout and Septic De-Nitrification BMPs cannot be submitted along with any of the new systems treatment practices described in this document.