An Overview of Potential Nutrient Load Reductions to Local Streams and the Chesapeake Bay as a Result of Bion's Waste Treatment Activities at Farm Operations in South-Central Pennsylvania

Prepared By: *Barry M. Evans, Ph.D., Penn State University, October 12, 2012*

Introduction

Bion Environmental Technologies (Bion) has recently constructed a livestock waste treatment facility at the Kreider Dairy Farm in Manheim, PA, and has another fuel conversion project proposed with the Kreider Poultry Farms as a means to cost-effectively reduce nutrient loads to the Chesapeake Bay. This researcher has prepared various technical reports for Bion dealing with the Pennsylvania Department of Environmental Protection's (PA DEP's) current nutrient modeling approach, potential adjustments to these approaches, an estimation of nitrogen loads to groundwater resources (and associated mitigation costs), and estimated nutrient credits generated by the Kreider Farms facility (1, 2, 3 and 4).

In this current document, the estimated nutrient (nitrogen and phosphorus) load reductions to local streams and the Chesapeake Bay anticipated as a result of Bion's processed dairy and layer manure are summarized in the context of local and regional load reductions stipulated as a result of both local TMDLs as well as the regional Chesapeake Bay TMDL. For this analysis, all reductions are based on the fact that loads remaining after treatment at the Kreider Farms facility are subsequently shipped to a combustion facility in Schuylkill County that is located at the very edge of the Chesapeake Bay watershed. Due to the distance of this site from the Bay, as well as operational characteristics with respect to how the residue is combusted and ash disposed of at various mined-land sites in the region, subsequent phosphorus transfers from this site are assumed to be negligible. Consequently, load reductions described below are based on calculations of what the nutrient loads delivered to local watersheds, as well as the Chesapeake Bay, would be had the animal wastes remained at the locations where they were originally generated.

Estimated Load Reductions in Relation to Local TMDLs

As previously described, the main Bion facility is located at Kreider Farms near Manheim, PA. This facility receives and treats livestock and poultry manures from the Kreider Farms operation near Manheim as well as three other farm operations located near Mt. Joy/Donegal, Mt. Pleasant and Middletown, PA (see Figure 1). Three of the four operations are located in watersheds where a TMDL (Total Maximum Daily Load) assessment has been completed by the Pennsylvania Department of Environmental Protection (PaDEP). As part of such assessments, impairments to local water bodies (in this case, streams) are typically identified, and required annual reductions in sediment, nitrogen and/or phosphorus loads are specified in order to restore the health of the watersheds. In Pennsylvania, freshwater streams are almost always considered to be "phosphorus limited" with respect to nutrient enrichment. Consequently, phosphorus reductions rather than nitrogen reductions are typically specified in local TMDLs where the cause of impairments has been identified as being due to excess nutrients.

As mentioned above, three of the four farm operations shown in Figure 1 are located in impaired watersheds where TMDL assessments have been completed. These watersheds include Chickies Creek (where the Manheim operation is located), Donegal Creek (where the Mt. Joy/Donegal operation is located), and Quittapahilla Creek (where the Mt. Pleasant operation is located). The Middletown operation is located in the Swatara Creek watershed for which a TMDL has not currently been completed. For the three watersheds in which TMDLs have been completed, annual target load reductions have been established by PaDEP for sediment and phosphorus, but not nitrogen. The phosphorus reductions established for the Chickies Creek, Donegal Creek, and Quittapahilla Creek are 39,956 pounds, 3,287 pounds, and 15,642 pounds per year, respectively (5,6 and 7). In evaluating the potential impact of anticipated nutrient reductions resulting from Bion's waste treatment facility and subsequent residue combustion, the required TMDL reductions are compared against anticipated treatment-based reductions as described below.

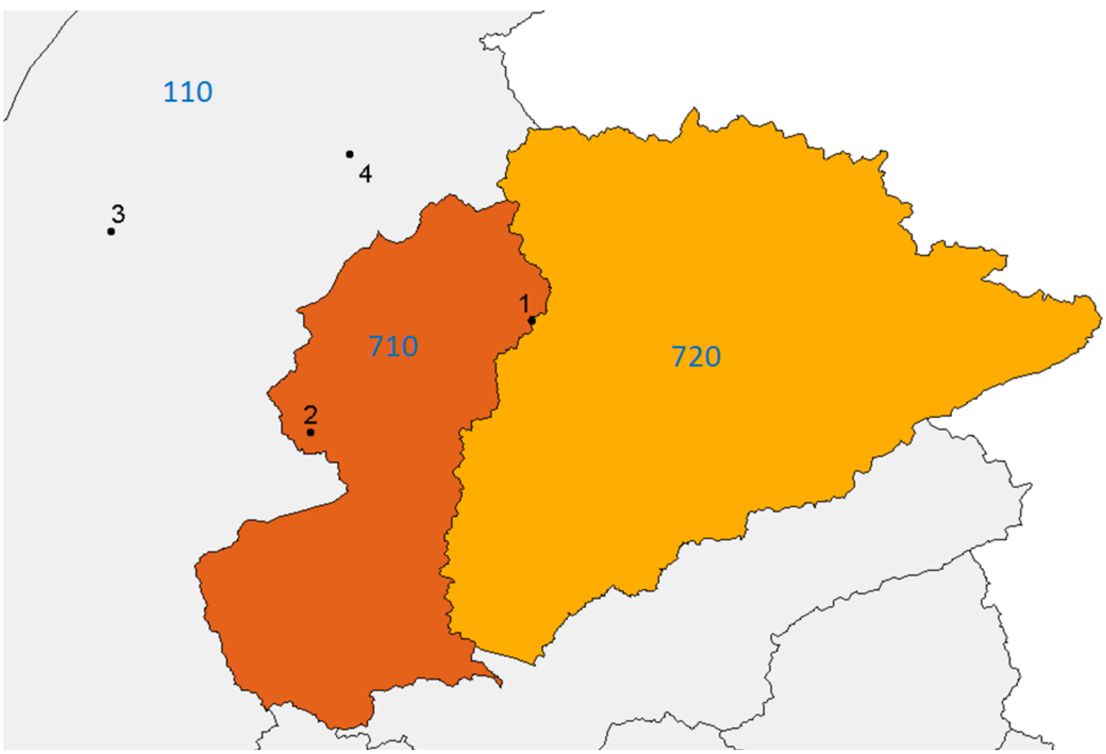

Figure 1. Location of animal operations (see also Figure 2 for regional location)

Presented in Table 1 are nutrient reductions estimated to occur as a result of Bion's treatment activities. As shown in this table, it is estimated that approximately 2,128,458 pounds of phosphorus will be removed from animal wastes on an annual basis. This reduction is obviously quite substantial; however,

Table 1. Summary of operations and gross load reductions anticipated as a result of Bion's waste treatment process.

Site	Operation	Watershed	Operation Type	No. Head in Bion Waste Treatment	Amount of N Removed per Specified Unit[1]	Total N Removed From Waste (lbs/yr)	Amount of P Removed per Specified Unit[1]	Total P Removed From Waste (lbs/yr)
1	Manheim	Chickies Creek	Dairy cows	2,000	110 lbs N/cow-yr	220,000	45 lbs P/cow-yr	90,000
1	Manheim	Chickies Creek	Belt dry layers	1,740,000 (5,743 AEU)	336 lbs N/AEU-yr	1,929,648	94 lbs P/AEU-yr	539,842
1	Manheim	Chickies Creek	High Rise Deep Pit Layers	424,000 (1,399 AEU)	139 lbs N/AEU-yr	194,461	83 lbs P/AEU-yr	116,117
3	Middletown	Swatara Creek	Belt dry layers	2,150,000 (7,096 AEU)	336 lbs N/AEU-yr	2,384,256	94 lbs P/AEU-yr	667,024
4	Mt. Pleasant	Quittapahilla Creek	Belt dry layers	1,584,000 (5,228 AEU)	336 lbs N/AEU-yr	1,756,608	94 lbs P/AEU-yr	491,432
2	Mt. Joy/Donegal	Donegal Creek	Belt dry layers	435,000 (1,436 AEU)	336 lbs N/AEU-yr	482,496	94 lbs P/AEU-yr	134,984
2	Mt. Joy/Donegal	Donegal Creek	High rise deep pit Layers	325,000 (1,073 AEU)	139 lbs N/AEU-yr	149,147	83 lbs P/AEU-yr	89,059
	TOTALS					7,116,616		2,128,458

[1] Differences in operational characteristics account for differences in reduction rates

it must be recognized that much of this reduced load would not necessarily impact nearby streams due to the inherent immobility of phosphorus and other “removal” processes that limit the amount of this nutrient that actually reaches nearby streams. For this reason, both PaDEP and the USEPA have established watershed-based “edge-of-segment” (EOS) factors used for nutrient trading purposes and the Chesapeake Bay watershed model that represent the percent of actual “landscape loads” delivered to larger streams after various “natural” removal processes (e.g., plant uptake, soil binding, attenuation in subsurface flow, etc.) have occurred (see Table 2 and Figure 2). As can be seen from this table, the EOS factors for phosphorus are much smaller than those for nitrogen, and range from about 2-32% depending on watershed location and agricultural land cover type. It is these “reduced” loads that are represented by the TMDL-specified load reductions mentioned previously.

Table 2. Estimated EOS factors for Pennsylvania watershed segments.

Estimated Portion of Nutrient Loads Reaching the Edge of Watershed (EOS Factor)								
	Nitrogen				Phosphorus			
Watershed	Conventional Till	Conservation Till	Hay	Pasture	Conventional Till	Conservation Till	Hay	Pasture
10	36%	29%	89%	15%	10%	4%	4%	15%
20	38%	31%	34%	16%	13%	7%	5%	16%
30	43%	31%	78%	16%	11%	6%	7%	16%
40	42%	38%	60%	12%	12%	10%	7%	12%
50	50%	38%	97%	18%	15%	6%	14%	18%
60	55%	31%	78%	15%	11%	4%	16%	15%
70	45%	45%	86%	13%	27%	7%	12%	13%
80	32%	25%	75%	10%	12%	7%	7%	10%
90	45%	34%	49%	15%	11%	4%	12%	15%
100	35%	29%	32%	12%	8%	3%	5%	12%
110	31%	22%	27%	10%	9%	5%	5%	10%
120	29%	21%	20%	9%	8%	3%	4%	9%
140	30%	22%	22%	9%	25%	10%	7%	9%
160	33%	28%	59%	23%	32%	27%	7%	23%
175	33%	22%	29%	20%	5%	5%	6%	20%
180	34%	38%	58%	9%	9%	7%	4%	9%
210	46%	33%	40%	10%	11%	7%	7%	10%
450	30%	22%	16%	9%	5%	2%	2%	9%
470	25%	17%	23%	6%	22%	3%	3%	6%
700	40%	35%	37%	13%	7%	6%	5%	13%
710	28%	21%	15%	9%	6%	2%	2%	9%
720	27%	21%	16%	9%	6%	3%	3%	9%
730	23%	22%	43%	11%	15%	8%	6%	11%
740	21%	17%	50%	12%	12%	8%	8%	12%
750	47%	33%	38%	10%	13%	7%	5%	10%
800	48%	34%	34%	9%	15%	8%	11%	9%

Notes: 1. The portion of nutrient loads leaving a watershed were estimated by adding the manure, fertilizer, air deposition and mineral/residual nutrient inputs for each watershed and subtracting the estimated crop uptake from the total nutrient inputs. The remaining nutrient loads after crop uptake were then divided by the estimated loads leaving the watershed to calculate the edge of watershed percents.
2. All calculations based on watershed model simulations completed by EPA's Chesapeake Bay Program Office.

Source: PaDEP (http://www.dep.state.pa.us/river/Nutrient%20Trading.htm

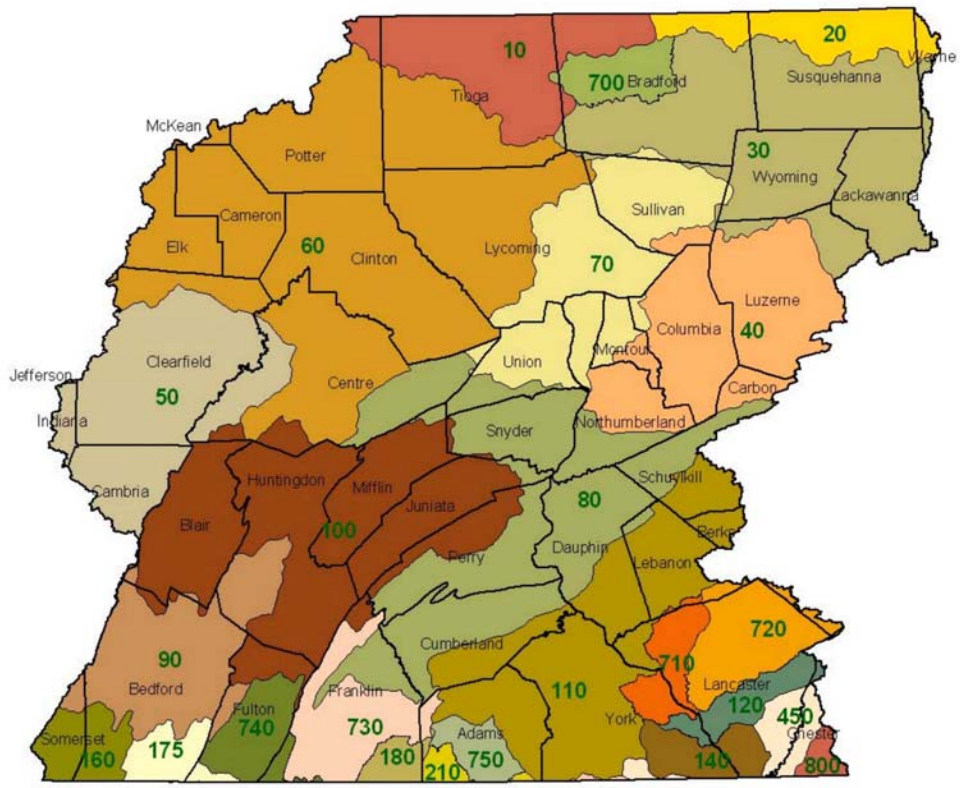

Figure 2. Location of major watersheds within Pennsylvania for which EOS factors have been estimated.

Based upon use of the EOS factors described above, the loads associated with each of the four farm operations given in Table 1 were reduced using the appropriate EOS factors provided in Table 2. As shown in Figure 1, sites 1 (Manheim) and 2 (Mt. Joy/Donegal) are located in watershed segment 710, and sites 3 (Middletown) and 4 (Mt. Pleasant) are located in watershed segment 110. For watershed segment 710, the EOS factors for phosphorus range from 2-9% for the four cover categories shown, with an average value of 4.75% (0.0475). For watershed segment 110, the EOS factor ranges from 5-10%, with an average value of 7.25% (0.0725). The "reduced" values obtained when applying these average EOS factors to the anticipated load reductions for the four farm operations are shown in Table 3.

The previous calculations are based on the assumption that the nutrients contained in the animal manures treated are totally removed from the affected watersheds and that these manures, which normally would be applied to agricultural land as a nutrient source for crops, are not replaced with commercial fertilizers. However, since it must be assumed that most of the animal wastes treated by Kreider are, in fact used as crop amendments, the replacement of nutrients in manure with those found in commercial fertilizers must be addressed as part of the current analysis.

Table 3. Summary of load reductions after EOS factors for P have been applied.

Site	Operation	Watershed	Total P Removed From Waste (lbs/yr)	Total P Load Reduction Adjusted Using EOS Factor (lbs/yr)	Final Estimated P Load Reduction (lbs/yr)[1]
1	Manheim	Chickies Creek	90,000	4,275	2,138
1	Manheim	Chickies Creek	539,842	25,642	12,821
1	Manheim	Chickies Creek	116,117	5,516	2,758
3	Middletown	Swatara Creek	667,024	48,359	24,180
4	Mt. Pleasant	Quittapahilla Creek	491,432	35,629	17,814
2	Mt. Joy/Donegal	Donegal Creek	134,984	6,412	3,206
2	Mt. Joy/Donegal	Donegal Creek	89,059	4,230	2,115
	TOTALS		2,128,458	130,063	65,032

[1]After accounting for 50% P replacement with commercial fertilizer

Land application of manure has been regulated primarily based upon nitrogen loadings to meet crop needs. However, livestock waste from dairy animals has a higher concentration of phosphorus to nitrogen related to crop requirements [8]. Data from ASABE and PSU demonstrates that using the metric of manure application from one dairy cow per acre of cropland would result in surplus phosphorus being applied at the rate of 264% and 126% for corn and corn silage, respectively; while at the same time causing a nitrogen deficit of -23% and -33% for corn and corn silage (9,10). (Note: example calculations pertaining to these estimates have been provided in Appendix A of this document).

Conservatively, it therefore can be estimated that current P loads in treated animal manures are at least twice the amount needed for crops, and that a commercial fertilizer replacement value of 50% is justifiable. Consequently, the phosphorus load reductions given earlier have been reduced further by 50%, and are presented in Table 3 as well.

For the purposes of this analysis, the cumulative TMDL-required P load reductions are compared against the cumulative adjusted load reductions estimated for the three animal operations located in the Chickies Creek, Donegal Creek and Quittapahilla Creek watersheds. (Note: in this case, the anticipated load reductions for the Middletown operation were not considered since it is not located in a watershed for which a TMDL has been developed). As shown in Table 4, it can be seen that the adjusted P load reductions exceed the TMDL-required reductions in two of the three watersheds (Quittapahilla and

Donegal Creeks), and addresses about 44 % of the TMDL load in Chickies Creek. In total, the combined phosphorus load reductions (40,852 lbs/yr) achieved via Bion's treatment processes achieve about 69% of the combined TMDL-stipulated load reductions of 58,885 pounds per year for the three affected watersheds. Additionally, the estimate shown for the Middletown operation shown in Table 3 represents another load reduction of about 24,180 pounds per year of phosphorus to local waterways.

Table 4. Load reductions specific to TMDL watersheds

Site	**Watershed**	**TMDL-Required P Reduction (lbs P/yr)**	**Waste Load Reduction (lbs P/yr)**	**Quantitative Impact**
Manheim	Chickies Creek	39,956	17,717	44.3% of TMDL
Mt. Pleasant	Quittapahilla Creek	15,642	17,814	Exceeds TMDL
Mt. Joy/Donegal	Donegal Creek	3,287	5,321	Exceeds TMDL
		58,885	40,852	69.4% of TMDL

Estimated Load Reductions in Relation to the Regional Chesapeake Bay TMDL

A region-wide TMDL was completed by the USEPA for the entire Chesapeake Bay watershed in 2010 (11). In addition to quantifying the pollutant loads from various sources and geographic locations within the watershed, this TMDL also established the load reductions required by jurisdictions (all contributing states and the District of Columbia) by the year 2025. Target reductions for each jurisdiction are based on baseline loads established by monitoring and simulation modeling by USEPA staff and estimated reductions from that baseline necessary in order to achieve healthy water quality and ecological conditions within the Chesapeake Bay itself (11). Based on USEPA's analyses, it has been determined that Pennsylvania needs to reach target nutrient delivery rates of 78,831,567 pounds per year of nitrogen and 3,599,305 pounds per year of phosphorus by 2025 (12). In a recent model run for the Bay watershed completed by USEPA staff for the year 2011, it was determined that Pennsylvania had achieved nitrogen and phosphorus loading rates of about 112,468,037 and 4,795,912 pounds per year for nitrogen and phosphorus, respectively (12). This means that while progress is being made, additional reductions of about 33,636,470 and 1,196,607 pounds per year for nitrogen and phosphorus, respectively, are still necessary in order to meet mandated targets by 2025.

As shown in Table 1, estimates for nitrogen removal have also been made for the processing of animal manures by Bion's waste treatment facility near Manheim and subsequent transfer of residues to a combustion site for further reduction. Similar to phosphorus, these estimates needed to be adjusted using appropriate EOS factors for nitrogen as shown in Table 2. In this case, however, updated EOS factors recently derived by Evans (3) to support the generation of nitrogen trading credits for Bion's waste treatment facility were used. More specifically, nitrogen-specific EOS values of 87.4% (0.874), 75.1% (0.751) and 76.2% (0.762) were used for sites 1 and 2 (Manheim and Mt. Joy/Donegal), site 3 (Middletown) and site 4 (Mt. Pleasant), respectively. The EOS-adjusted load reductions for nitrogen for the four animal operations are shown in Table 5 along with the previously-described reductions for phosphorus. In this table, an additional factor (a "delivery factor") has also been applied to account for the uptake and removal of nitrogen and phosphorus loads as they travel from the point where they are introduced to larger streams near watershed segments 710 and 110 to the Chesapeake Bay. These rates are specified for each location at the bottom of the table.

Also, as discussed for phosphorus earlier, the nitrogen load reductions described above needed to be further adjusted to account for the replacement of manure N shipped out of the area with commercial fertilizer N. For the purpose of this analysis, it is assumed that all of the nitrogen that would have been available from the initial amount removed prior to applying the EOS and large-stream delivery factors (i.e., the amount of 7,116,616 lbs/yr shown in Table 5) would have to be replaced with that available from the use of commercial fertilizers. In this case, the "replacement value" for N in commercial fertilizers becomes a little more complicated to estimate, and different adjustments had to be made for dairy and poultry manures as described below.

Prior to the installation of Bion's treatment facility at Kreider Farms, approximately 50% of the N available in dairy manure was lost via volatilization before land application. Of the remaining amount, the Penn State Agronomy Guide (which is used extensively for manure management planning throughout Pennsylvania) suggests that only about 30% is available to crops (13). With regard to poultry wastes, in the case of "high rise deep pit layers", approximately 67% of the N in this type of waste was also lost prior to collection for land application, and of the remaining amount, only about 15% is bio-available to crops according to the Agronomy Guide. In the case of belt dry houses, about 21% is volatilized before land application, and about 15% is bio-available to crops. Based on the above numbers, the amount of N that would have to be replaced with commercial fertilizers is about 810,040 lbs/yr. Consequently, the "starting" point for calculating further reductions is estimated as 7,116,616 – 810,040 = 6,306,576 lbs/yr. After applying the appropriate EOS and large-stream delivery factors given in Table 5, this results in a total reduction value of 3,479,963 lbs/yr as also shown in Table 5.

As can been seen from this table, it is estimated that Bion's treatment facility and subsequent processing via combustion and land application will result in reductions of approximately 3,479,963 and 28,354 pounds of nitrogen and phosphorus, respectively, that are delivered to the Bay on an annual basis. From the previous discussion above, it can be seen that these reductions represent about 10.3% (3,479,963 / 33,636,470) and 2.4% (28,354 / 1,196,607) of the annual nitrogen and phosphorus load reductions, respectively, from Pennsylvania that USEPA has determined are still necessary between now and the year 2025.

Table 5. Summary of operations and associated load reductions anticipated as a result of Bion's waste treatment process.

Site	Operation	Watershed	Total N Removed From Waste (lbs/yr)	Total N Replaced (lbs/yr)[1]	Adjusted Total N w/Replacement (lbs/yr)[2]	Total P Removed From Waste (lbs/yr)	Total P Removed w/Replacement (lbs/yr)[3]	EOS-Adjusted N Load (lbs/yr)[4]	EOS-Adjusted P Load (lbs/yr)[5]	N Load Adjusted Further with DF (lbs/yr)[6]	P Load Adjusted Further with DF (lbs/yr)[7]
1	Manheim	Chickies Creek	220,000	16,500	203,500	90,000	45,000	177,859	2,138	124,501	932
1	Manheim	Chickies Creek	1,929,648	228,663	1,700,985	539,842	269,921	1,486,661	12,821	1,040,662	5,590
1	Manheim	Chickies Creek	194,461	9,626	184,835	116,117	58,059	161,546	2,758	113,082	1,202
3	Middletown	Swatara Creek	2,384,256	282,534	2,101,722	667,024	333,512	1,578,393	24,180	1,303,753	10,542
4	Mt. Pleasant	Quittapahilla Creek	1,756,608	208,158	1,548,450	491,432	245,716	1,179,919	17,814	551,022	7,767
2	Mt. Joy/Donegal	Donegal Creek	482,496	57,176	425,320	134,984	67,492	371,730	3,206	260,211	1,398
2	Mt. Joy/Donegal	Donegal Creek	149,147	7,383	141,764	89,059	44,530	123,902	2,115	86,731	922
			7,116,616	810,040	6,306,576	2,128,458	1,064,229	5,080,009	65,032	3,479,963	28,354

[1] Amount of N replaced from commercial fertilizers as described in text
[2] Adjusted N load removed after subtracting replacement N
[3] Assumes 50% of the manure P is replaced by commercial fertilizer P
[4] N EOS factors used: 0.874 (Manheim and Mt. Joy/Donegal), 0.751 (Middletown), and 0.762 (Mt. Pleasant)
[5] P EOS factors used: 0.0475 (Manheim and Mt. Joy/Donegal), 0.0725 (Middletown and Mt. Pleasant)
[6] N "large-stream" delivery factors used: 0.700 (Manheim and Mt. Joy/Donegal), 0.826 (Middletown), and 0.467 (Mt. Pleasant)
[7] P "large-stream" delivery factors used: 0.436 for all sites

Other Anticipated Benefits

In addition to the nutrient reductions associated with meeting the requirements of the Chesapeake Bay and local TMDLs, other benefits will also accrue as a result of Bion's plans to process and remove nutrients from the four sites discussed above. Specifically, the treatment activities described will help alleviate problems with the build-up of phosphorus in local soils, as well as help mitigate problems caused by elevated nitrate concentrations in groundwater resources that serve as sources of local drinking water supplies.

In a report recently prepared by researchers at Penn State University, an upward trend in the concentration of soil phosphorus has been documented in several areas in Pennsylvania, particularly in the south-central and southeast regions (14). In this case, areas with higher concentrations have been positively correlated with areas of intensive agricultural production, especially where excess animal manures are applied as a fertilizer and/or waste disposal alternative. Consequently, it is expected that any reductions in phosphorus loads applied to agricultural land, as will occur with Bion's treatment activities, would contribute to reductions in soil P build up in these areas.

As previously described, these treatment activities are expected to result in significant decreases in nitrogen loads being applied to these areas as well. As summarized in an earlier report by Evans (4), increased nitrogen loads from animal wastes have been shown to result in elevated nitrate concentrations in groundwater in many areas around the country. (Note: a copy of this report has been included in Appendix B of this current document). Such impacts are especially critical in areas where groundwater is used for local drinking water supplies. In these instances, elevated nitrate levels have oftentimes resulted in added expenses to water suppliers that are subsequently passed on to local consumers. For example, in Lancaster County, PA it has been reported that more than 140 water supply systems have had to implement some level of nitrate removal because nitrate concentrations were consistently above the USEPA standard (15). It stands to reason, therefore, that the degree of nitrogen removal expected from Bion's treatment activities at the four areas identified would most certainly have a positive impact on groundwater nitrogen concentrations in these areas.

Conclusion

Treatment of animal manures by various control measures implemented by Bion at four animal operations in south-central Pennsylvania are expected to result in significant impacts to nutrient loads delivered to local streams as well as to the Chesapeake Bay. On an annual basis, the combined reductions of phosphorus loads due to these measures are expected to achieve about 69% of those mandated for three watersheds for which local TMDLs have been completed by PaDEP. Similarly, these measures are estimated to achieve approximately 10.3% of the annual nitrogen load reduction and 2.4% of the annual phosphorus load reduction mandated for Pennsylvania by the recently-implemented Chesapeake Bay TMDL. These control measures are also anticipated to result in decreased soil P build-up as well as decreased nitrate concentrations in groundwater resources used for local drinking water supplies.

References Cited

1) Evans, B.M., 2010. Analysis of EOS Factors Used by DEP. Prepared for Bion Environmental Technologies, 5pp.
2) Evans, B.M, 2011. Appropriate EOS Loading Rates and Factors as Used Within the Chesapeake Bay Watershed Model and by PaDEP for Nutrient Trading as Applied to Kreider Farms Current Operations. Prepared for Bion Environmental Technologies, 18 pp.
3) Evans, B.M., 2012. Updated Site-Specific EOS and Delivery Factor Determinations for Kreider Farms Operations. Prepared for Bion Environmental Technologies, 21 pp.
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5) PaDEP, 2001. Total Maximum Daily Loads (TMDLs) Development Plan for Chickies Creek Watershed, 71 pp.
6) PaDEP, 2000. Total Maximum Daily Load (TMDL) for Nutrients and Sediments in the Donegal Creek, Lancaster County, 32 pp.
7) PaDEP, 2000. Total Maximum Daily Loads (TMDLs): Quittapahilla Creek, Lebanon County, 94 pp.
8) Zaimes, G.N and R.C. Schultz, 2002. Phosphorus in Agricultural Watersheds: A Literature Review. Dept. of Forestry, Iowa State University, 116 pp.
9) American Society of Agricultural Engineers, 2005. Manure Production and Characteristics. ASAE D384.2, 20 pp.
10) See PSU web sites http://extension.psu.edu/cmeg/facts/agronomy-facts-12 and http://extension.psu.edu/cmeg/facts/agronomy-facts-13
11) Chesapeake Bay TMDL document available at http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html
12) See http://stat.chesapeakebay.net/?q=node/130&quicktabs_10=2 for load details.
13) See http://extension.psu.edu/agronomy-guide
14) Kogelmann, W.J., H. Lin and R.B. Bryant, 2002. A Statewide Assessment of the Impacts of P-Index Implementation in Pennsylvania. Report to Pennsylvania State Conservation Commission, Penn State University, 64 pp.
15) Bergman, R., 2011. Reducing Nitrogen and Phosphorus and protecting Drinking Water Sources. EPA Communique, J. Amer. Water Works Assoc., pp. 28-31.

APPENDIX A: Nitrogen and phosphorus balance calculations for dairy manure prepared by George Bloom of Bion

MEMORANDUM

BION

DATE: October 8 2012

TO: Dominic Bassani

FROM: George Bloom

RE: Calculations for Nitrogen and Phosphorus use for 50 acres of Crops with 50 milk cows

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Phosphorus. Using ASABE P content for a 1,400 milk cow of 0.17 lb P/d and adjusting the unit value for an assumed live weight of 1,300 lb, the same as used at KDF, the manure from 50 milk cows (1,300 lb live wt) would contain approximately 2,881 lb P/yr. The 2,881 lb P/ yr equals 6,602 lb P_2O_5/yr (1 lb P = 2.2915 lb P_2O_5). According to the document entitled "Managing Phosphorus for Crop Production" on the Penn State Extension web site, the annual P_2O_5 requirements for a Corn yield of 125 ton/acre and a Corn Silage yield of 21 tons/acre are 50 and 105 lb/acre, respectively.

Using the P_2O_5 crop removal rates from Penn State with 50 acres of corn and corn silage, the P_2O_5 removal rate would be 2,500 lb P_2O_5/year for corn and 5,250 lb P_2O_5/year for corn silage. The 6,602 lb P_2O_5/yr contained in the manure from 50 milk cows provides 264% of the amount of P_2O_5 required for corn and 126% of the amount of P_2O_5 required for corn silage. Reference Table 1 – Phosphorus, following:

Table 1 – Phosphorus.

Crop	**50 Acre P_2O_5 Use, lb/yr**	**P_2O_5 Available 50 milk cows, lb/y**	**Excess P_2O_5,lb/yr**	**P_2O_5 % Produced v. Crop Uptake**
Corn (bu)	2,500	6,602	4,102	264%
Corn silage (T)[1]	5,250	6,602	1,352	126%
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Nitrogen. Using ASABE N content for a 1,400 milk cow of 0.99 lb N/d and adjusting the unit value for an assumed live weight of 1,300 lb, the same as used at KDF, the manure from 50 milk cows (1,300 lb live wt) would contain approximately 16,777 lb N/yr. Assuming that 30% of the nitrogen excreted is used by the crops and 70% lost to the atmosphere during storage, handling, etc. the N available for crop uptake from 50 milk cows is 5,033 lb/yr. According to the document entitled "Managing Phosphorus for Crop Production" on the Penn State Extension web site, the annual N requirements for Corn and Corn Silage yields referenced above for P would be 130 and 150 lb/acre, respectively. As shown in Table 2, under these assumptions the manure from 50 milk cows does not have sufficient Nitrogen to meet crop demands for 50 acres. This is why nutrient management plans had been used based on Nitrogen over applied Phosphorus to fields, resulting in high soil P concentrations and P in runoff.

Table 2 – Nitrogen.

Crop	50 Acre N Use, lb/yr	N Available 50 milk cows, lb/yr	Excess N,lb/yr	N % Produced v. Crop Uptake
Corn (bu)	6,500	5,033	-1,467	77%
Corn silage (T)[1]	7,500	5,033	-2,467	67%

References:

1) American Society of Agricultural Engineers, 2005. Manure Production and Characteristics. ASAE D384.2, 20 pp.
2) See PSU web sites http://extension.psu.edu/cmeg/facts/agronomy-facts-12 and http://extension.psu.edu/cmeg/facts/agronomy-facts-13

Appendix B: Groundwater nitrogen / drinking water document prepared by Barry M. Evans, Ph.D.

MEMO: Discussion of Potential Groundwater Nitrogen Impacts and Mitigation Costs in Areas Surrounding the Kreider Farms Operations

From: Dr. Barry M. Evans, Penn State University

Date: May 25, 2012

Introduction

Ground water enters the Chesapeake Bay via two main pathways—as base flow to streams that drain to the Bay or as discharge from shallow aquifers directly to the Bay and its tidal tributaries. The latter occurs primarily in areas relatively close to the Bay itself (i.e., essentially those lowland areas that occur along the edges of the Bay). Therefore, the first pathway is the primary one for the bulk of the land areas within the Chesapeake Bay watershed. In this case, stream water is defined to consist of overland flow, interflow, and ground-water discharge (see Figure 1). Overland flow is rain or snowmelt that flows directly over the land surface and into streams. In general, overland flow represents a small fraction of the water in streams and enters the streams within hours or days of a storm or snowmelt event. Interflow, which basically consists of water that has infiltrated from the surface and moves though the soil zone, is delivered to a stream during, or shortly after, storms (usually on the order of days or weeks). Ground-water discharge, or base flow, enters the streams from deeper aquifers underlying the relatively shallow soil layer, and provides the largest percentage of the streams' annual flow (more than 50 percent on average) in the Chesapeake Bay Watershed (1). The residence time of the ground water in an aquifer can range from months to decades before discharging to streams. From this discussion, it can be seen that water infiltrating into the ground can take from hours to decades to move to "downstream" water bodies, and that the depth to which such water has infiltrated will influence this "lag" time.

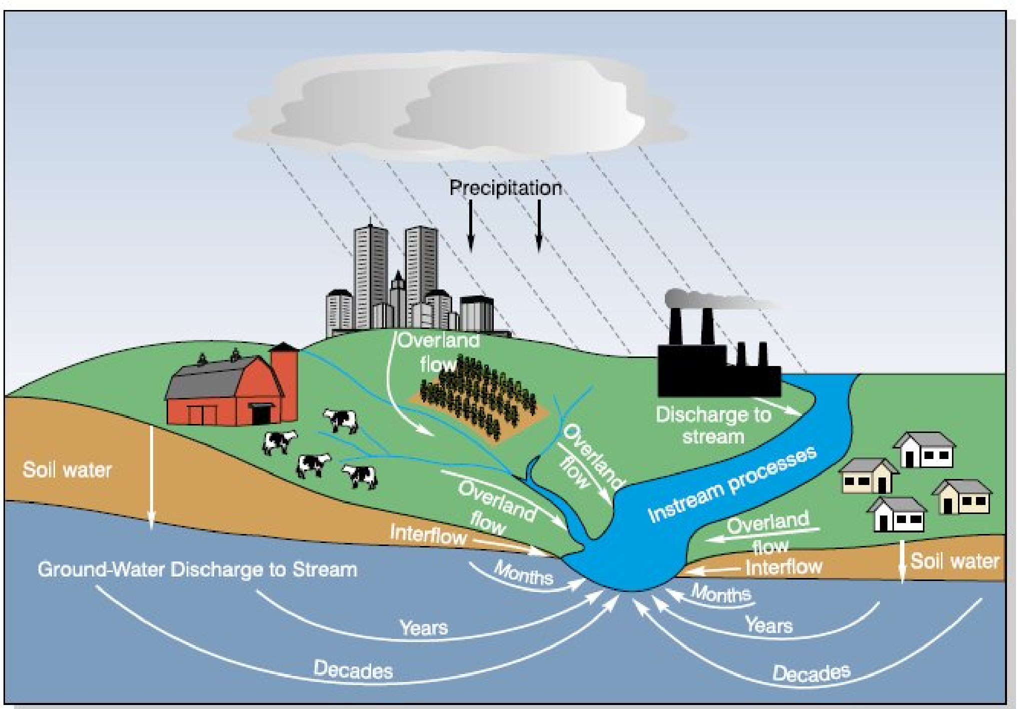

Figure 1. Generalized depiction of hydrologic cycle (from USGS, 2003).

As has been documented at length in the literature, nitrogen that is "generated" or "applied" at the land surface moves to nearby water bodies via all three of the specific pathways mentioned above (overland flow, shallow sub-surface flow [interflow], or deeper ground water [aquifer] discharge), and the relative proportions of the total amount are directly related to the depths at which the nitrogen contained in infiltrating surface water leaches below the ground surface. In the case of the Chesapeake Bay, it has been estimated that about 48 percent of the nitrogen load is delivered to streams (and then to the Bay) via deeper ground water discharge (1). In total, it is likely that only about 10-15% of the nitrogen that is delivered to the Bay is via the overland flow/stream pathway, with the remainder being transported via interflow and ground water flow to streams, and then to the Bay (2). As discussed below, this has significant ramifications with respect to the concentration of nitrogen in underlying aquifers that are tapped by wells for community water supplies.

Regional Nitrogen Levels

Nitrogen loads delivered to the Chesapeake Bay have long been known to be a primary cause of water quality problems (e.g., nuisance algae, oxygen depletion, etc.) associated with that body of water as well as other surface waters (e.g., lakes and streams) within the Bay's drainage area. However, excess nitrogen loads to ground water can also lead to potential water quality problems, particularly if such water is used as a source of drinking water. Specifically, elevated concentrations of nitrogen in drinking water (principally in the form of nitrates) can lead to a health problems such as called methemo-globinemia ("blue baby syndrome"), thyroid cancer and various birth defects (3). To safeguard against potential health threats, the USEPA has set the maximum concentration level for nitrate-nitrogen in drinking water at 10 milligrams per liter (mg/l). It has been shown, however, that some of the health problems mentioned can occur even at concentrations below this mandated standard (4).

The potential for the delivery of excessive nitrogen loads to both surface and ground waters is particularly high in geographic regions that are intensively cultivated and/or have large farm animal populations such as south-central Pennsylvania. In many cases, various best management practices (BMPs) such as riparian buffers, conservation tillage and cover crops are oftentimes used to reduce nitrogen loads delivered to surface water bodies. However, in some instances, the use of particular BMPs (e.g., conservation tillage), while reducing nitrogen loads associated with surface erosion and surface water runoff, may actually *increase* surface water infiltration, thereby increasing the delivery of nitrogen to local ground water resources (5). In areas where excess nitrogen loads are not adequately reduced via the utilization of proper control measures, public water supply systems oftentimes have to resort to expensive water treatment processes such as ion exchange or reverse osmosis in order to meet the 10 mg/l drinking water standard set by the USEPA (3, 6, 7). For example, in Lancaster County, PA it has been reported that more than 140 water supply systems have had to implement some level of nitrate removal because nitrate concentrations were consistently above the USEPA standard (8).

Nitrate-Nitrogen Levels Near Kreider Farms

Figure 2 shows a map that was developed by staff at the PA Department of Environmental Protection (DEP) using data from a large number of well samples collected between 1979 and 2001. As illustrated by the legend, the different colors represent a range of nitrate concentrations in ground water, with red and orange tones depicting the highest concentrations. Figure 3 shows an enlarged portion of this map centered on the four different operations associated with Kreider Farms (1 = Manheim, 2 = Donegal, 3 = Middletown, and 4 = Mt. Pleasant). The Manheim site is where Bion has its' main waste processing facility, and the other three are sites from which manure is sent to Manheim for processing.

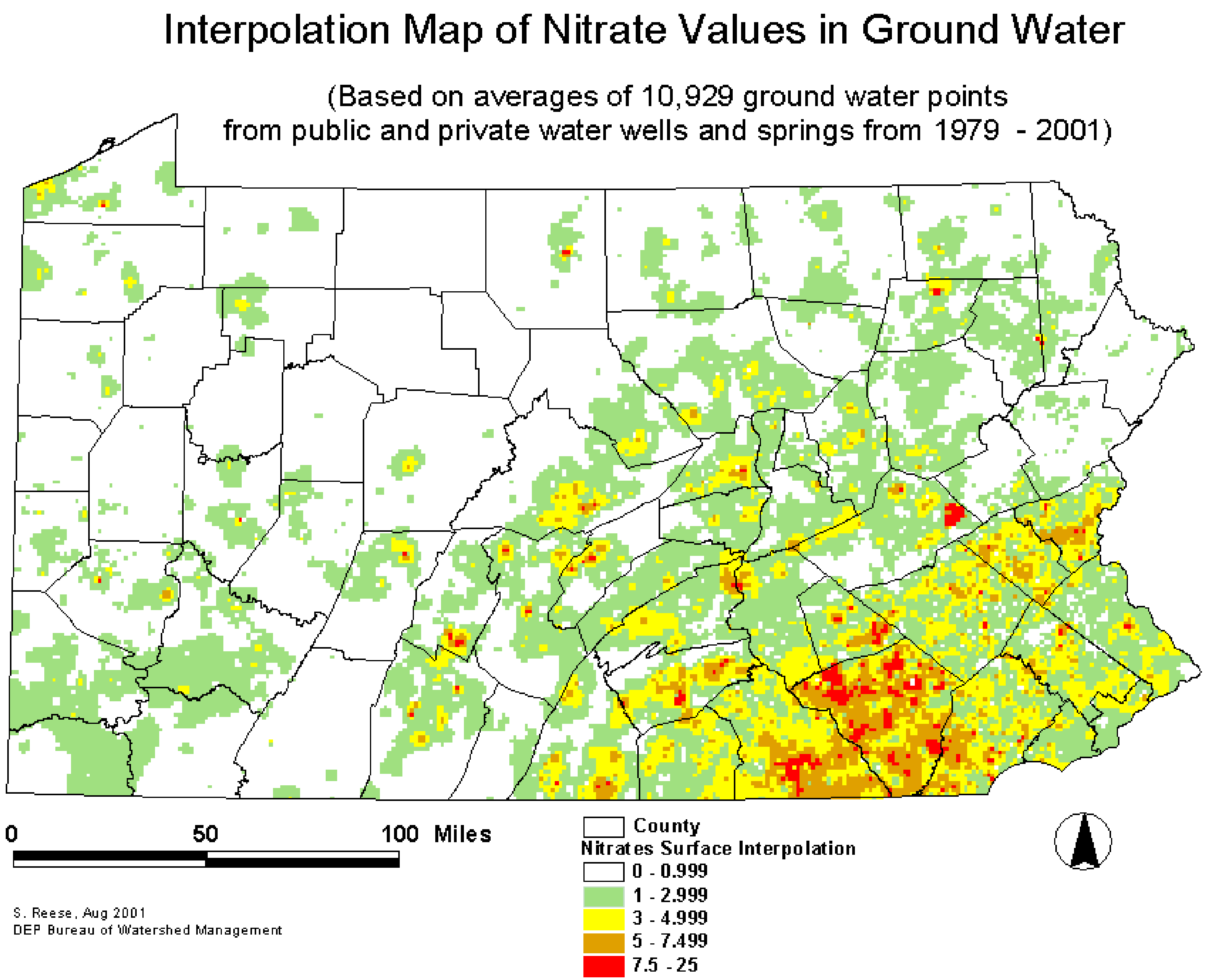

Figure 2. Map of statewide ground water nitrate levels produced by Pennsylvania Department of Environmental Protection.

From the map shown in these figures it can be seen that these sites are located in or near areas with some of the highest ground water nitrate concentrations in the state. Given that excess manure in these areas would normally be applied to surrounding pasture and cropland, it can be assumed than any reductions in nitrogen loads to these areas would potentially contribute to beneficial reductions in groundwater nitrogen as well.

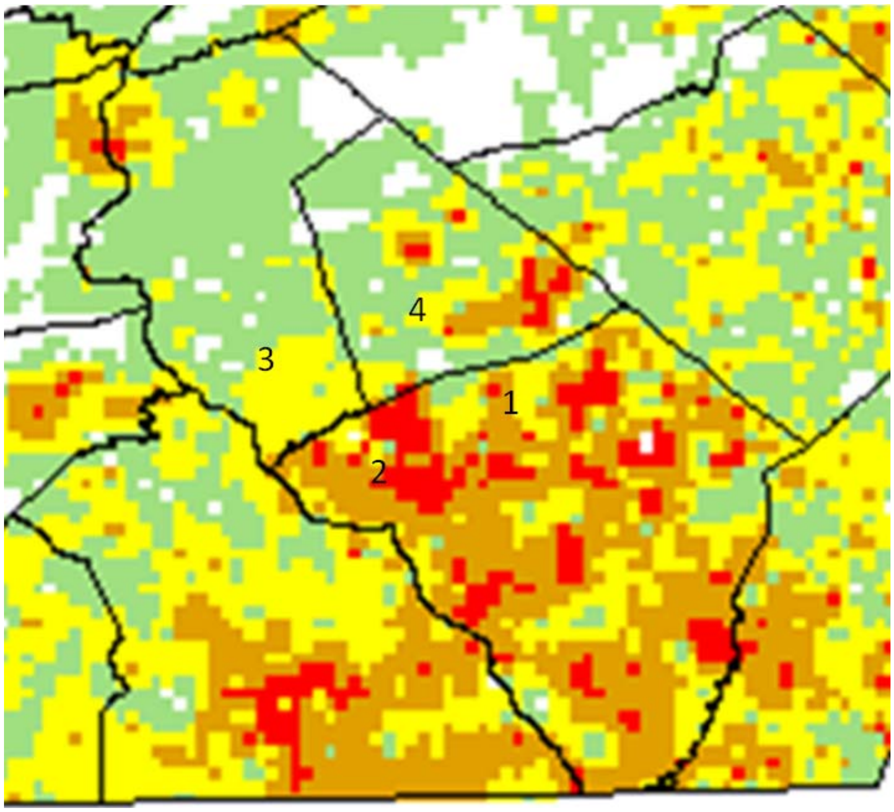

Figure 3. Enlarged area from depicting the various Kreider Farms operations.

Cost of Nitrate-Nitrogen Removal from Drinking Water

While a number of water treatment technologies may be employed to remove excess nitrates from drinking water (e.g., ion exchange, reverse osmosis, nanofiltration, and electrodialysis), the most common process used by far is ion exchange (6, 9). The cost for this type of treatment (which is also typically the least expensive option available) has been reported to range from about $1.40 to $3.19 per 1000 gallons of finished water (9, 10, 11). Although it is useful to know the cost per pound of nitrate-nitrogen removed in order to compare it against other control measures (e.g., agricultural BMPs) for which such information is known, costs for water treatment are not typically presented in this format. However, as shown below, it is possible to estimate this per unit cost using a few basic assumptions.
As discussed earlier, the EPA standard for nitrate-nitrogen in drinking water has been set at 10 mg/l. If it can be assumed that a given public water supply system would not install a nitrate removal system until concentrations are at or near this level, then the cost per pound of nitrate-nitrogen can be estimated using this standard as a basis of calculation as follows:

3.785 liters = 1 gallon
10 mg/l of N = 37.85 mg of N per gallon (or 0.00003785 kg N per gallon)

(0.00003785 kg N/gal) * (2.205 lbs/kg) = 0.00008345925 lbs of N per gallon

Given the above calculations, the number of gallons of finished water per pound of nitrate-nitrogen can then be calculated as:

1/0.00008345925 = 11981.9 gallons per pound of nitrate-nitrogen

Finally, given the treatment cost range cited above (i.e., $1.40-3.19 per 1000 gallons of finished water), the cost range per pound of nitrate-nitrogen removed can be estimated as:

(11,981.9/1000) * 1.4 = $16.77 to (11,981.9/1000) * 3.19 = $38.22

In turn, as discussed below, this treatment cost can be compared against the per unit removal cost for other control measures that might otherwise be utilized to remove nitrogen from the load that would potentially be delivered to the Chesapeake Bay or to local surface and ground water sources.

Comparison of N Removal via Water Treatment versus Other Control Measures

With respect to addressing the problem of excess nitrogen in drinking water, there are two basic approaches that can be utilized: 1) reduce nitrogen loading to a local ground water resource by implementing "site-level" control measures, or 2) remove the nitrogen via the use of water supply treatment options as described previously. With both approaches, there are reported per unit N removal costs that can be compared to determine those measures which are most cost effective. Stephenson et al (12) have reported that agricultural BMPs which can be used to reduce nitrogen loads from cropland cost in the range of $8-$2,800 per pound of nitrogen removed, with nutrient management typically being more cost-effective with a range of $8-$54 per pound removed. As shown earlier, nitrogen removal at water treatment plants ranges from about $16-38 per pound removed. From these estimates, it appears that agricultural BMPs may or may not be more cost-effective than nitrogen removal at water treatment plants depending on the particular BMP used. Nutrient management, for example, may be more cost-effective based on the cost ranges presented.
In contrast, the cost associated with Bion's waste treatment technology ranges from about $8-$10 per pound of nitrogen removed. When compared with either of the removal approaches described above, it appears that it would certainly be more cost-effective to remove nitrogen at the source (as is done with Bion's process) rather than to remove it at greater expense at a water treatment plant. It also compares quite favorably with the range of costs cited for agricultural BMPs.

Water Resource Management

Within Pennsylvania, the quality of surface and ground water resources are primarily regulated by the Department of Environmental Protection (DEP). And within DEP, water quality issues pertaining to these two resources are essentially dealt with by two Bureaus within the Office of Water Management. The Bureau of Point and Non-Point Source Management is the primary group responsible for managing programs related to the assessment of water quality problems within surface waters of the state, whereas the Bureau of Safe Drinking Water is responsible for addressing problems associated with drinking water, including water supplies drawn from ground water sources. While staff from these two bureaus interact at various levels, there is not necessarily close programmatic coordination when it comes to implementing corrective measures that affect both nitrogen loads to the Bay as well as problems with sub-surface drinking water supplies. It is clear, however, that various "above surface" measures can be undertaken to reduce nitrogen build-up in ground water resources of the state.

While nitrogen reductions that result from such measures are currently considered and recognized in state and federal Chesapeake Bay-related programs that monitor pollutant loads to the Bay as well as local water bodies, these same programs do not always recognize the benefits that accrue to community water systems. In other words, a reduction of nitrogen loads to local ground water resources will not only result in a decrease in nitrogen loads transported via subsequent stream flow to the Bay, it will also potentially result in lower operating costs to community drinking water systems that might otherwise have to install costly treatment systems to remove excess quantities of nitrogen in order to protect the health of local populations.

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