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

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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.

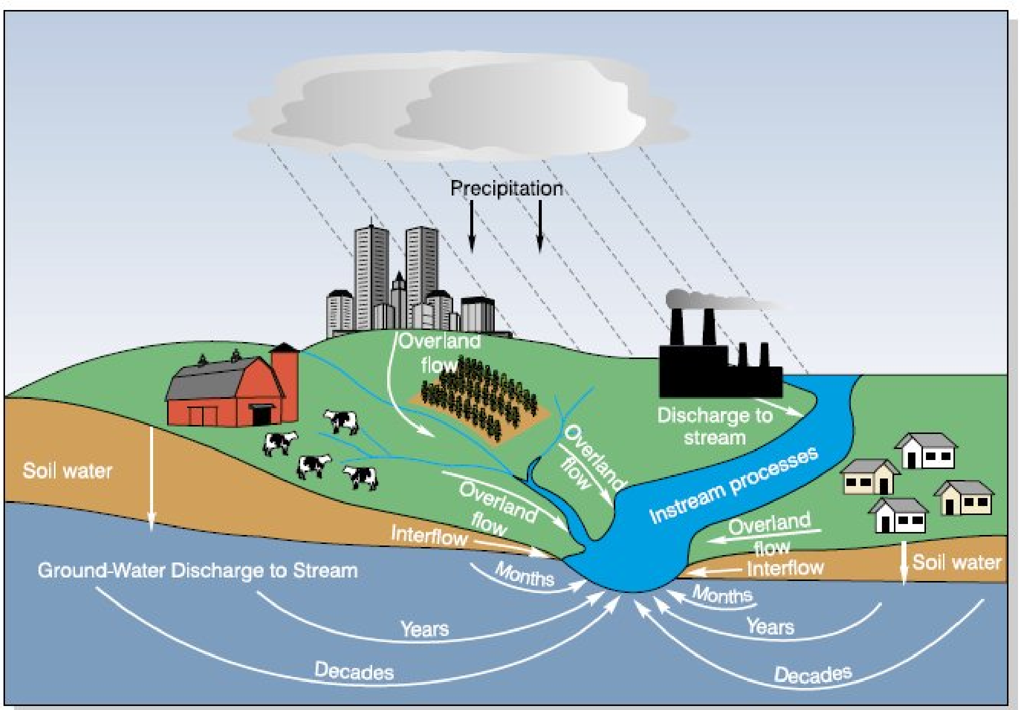

Figure 1. Generalized depiction of hydrologic cycle (from USGS, 2003).

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.

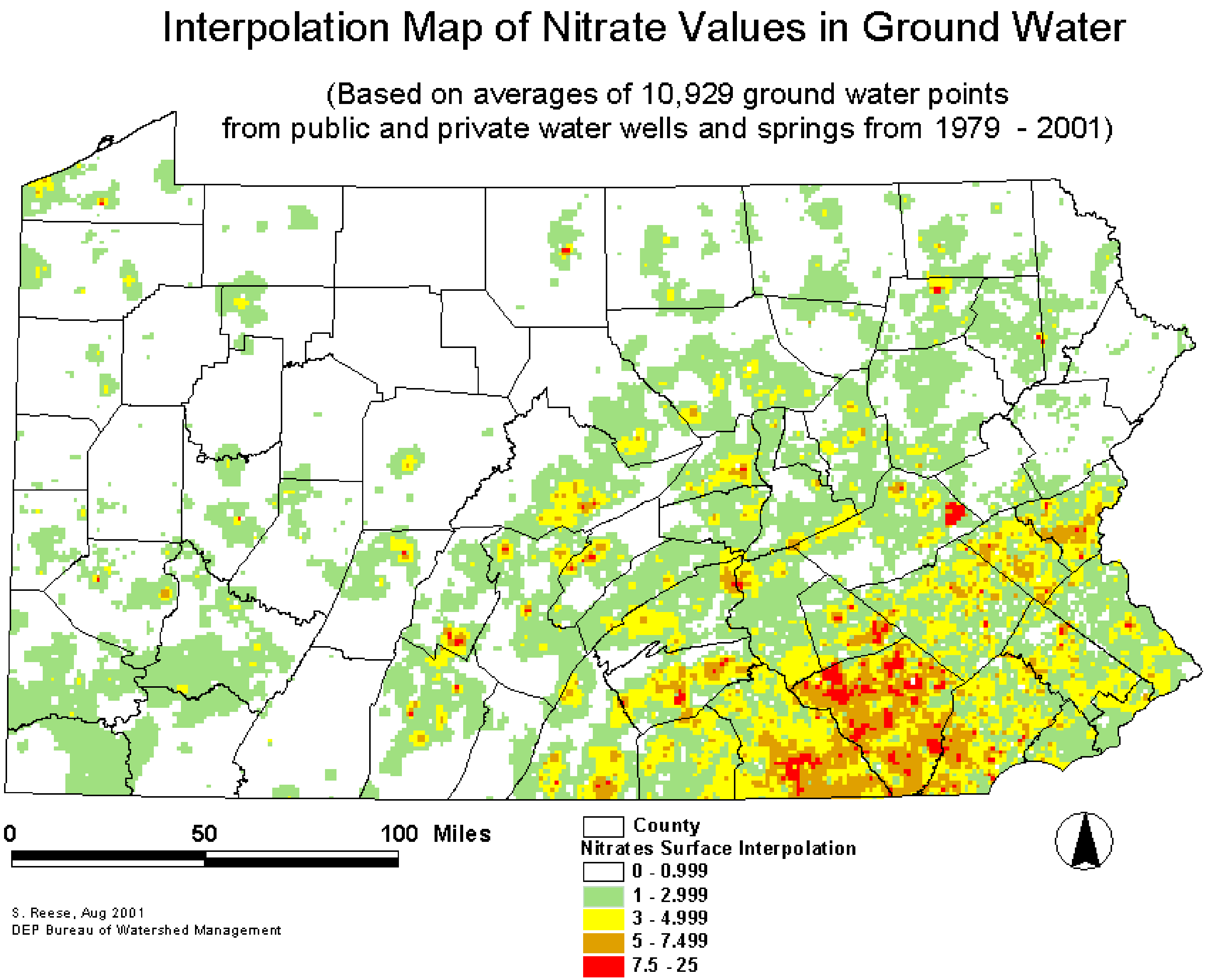

Figure 2. Map of statewide ground water nitrate levels produced by Pennsylvania Department of Environmental Protection.

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.

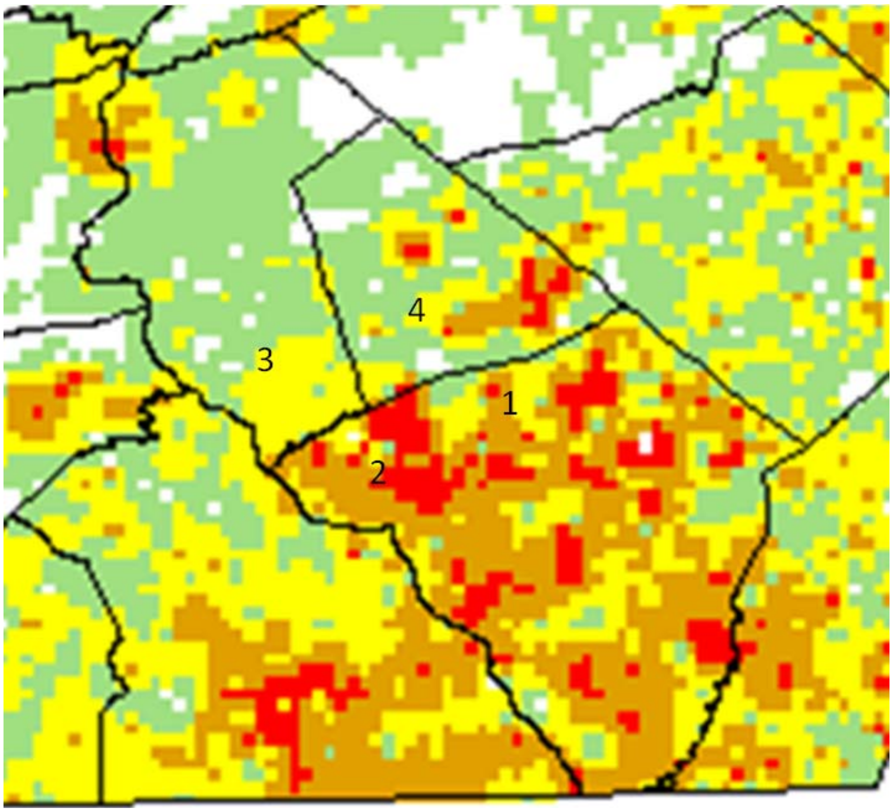

Figure 3. Enlarged area from depicting the various Kreider Farms operations.

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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