Re: Land Application Requirements: separation distances

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Summary

As written, the EPA CAFO rules state "owners or operators may demonstrate to the permitting authority that a setback or vegetated buffer is unnecessary because of site-specific conditions or practices the producer is implementing." Based on current research and our discussion of best practices we believe <u>both injection and incorporation (on the date of application) should qualify as site-specific practices that will provide similar performance to EPA mandated setback distances</u>.

The results from this review gave a clear indication that manure injection will provide a similar level of reduction in nutrient transport as utilizing vegetative setback areas of 35 feet for soluble nutrients and sediment bound contaminants as would be achieved with a 35-foot vegetative buffer. As such, it is our recommendation that manure injection be considered a site-specific practice that provides equivalent performance to the mandated setback distances specified for the manure application areas of NPDES permitted sites. No additional restrictions were placed on this application method as research has consistently indicated that be placing the manure nutrients below the soil surface limits transport of the manure nutrients.

Results for manure incorporation again suggest that incorporation will provide equivalent or better performance to that of a vegetative buffer for control of water-soluble nutrients. As tillage may increase erosion in some situations its impact on transport of particulate contaminants based on literature results is less clear, however, the most applicable study for Iowa condition (performed by Allen and Mallarino, 2008) showed that incorporation significantly reduce phosphorus transport. Thus, it is our recommendation that injection, if performed on the same date as the manure application, be considered a site-specific practice that provides equivalent performance to the mandated setback distances specified for the manure application areas of NPDES permitted sites.

Introduction

Manure land application separation distances, or setbacks, are specified distances from areas that may be vulnerable to water pollution (including surface waters, open tile intake structures, sinkholes, agricultural wellheads, or other conduits to surface waters) where manure cannot be applied. The purpose of the setback is to reduce the potential for contaminants (solids, organic matter, nitrogen, phosphorus, microbes, salts, etc.) to reach surface water by increasing the distance between the contributing source area and the potential receiving water. Additionally, the setback distance can potentially improve water quality by acting as filters for water passing over and through the soil toward a water resource, providing an opportunity for solids to settle out, infiltration of runoff water to occur, and contaminants to interact with soil and vegetation and be retained in the field. In all cases, these processes are primarily focused on the transport and retention of particulate or particulate bound nutrients and contaminants, thus the focus of this review will tend to be on how these practices impact the transport of these items.

Federal law for NPDES (National Pollutant Discharge Elimination System) permitted CAFOs (concentrated animal feeding operations) requires the farmer to maintain a setback area of 100 feet from any down-gradient surface waters, open tile intake structures, sinkholes, agricultural well heads, or other conduits to surface waters where manure, litter, and other wastewaters cannot be applied. As a compliance alternative, the CAFO may elect to establish a 35-foot vegetated buffer where manure, litter, and other wastewater are not applied. Although the 35-foot buffer requires less land, it requires the farmer to take some of the field out of row-crop production whereas the 100-foot buffer does not. As an alternative to these requirements, the CAFO rules states "owners or operators may demonstrate to the permitting authority that a setback or vegetated buffer is unnecessary because of site-specific conditions or practices the producer is implementing."

Current state law in Iowa requires that no manure by land applied within 200 feet from a designated area (a designated area means a known sinkhole, or a cistern, abandoned well, unplugged agricultural drainage well, agricultural drainage well surface tile inlet, drinking water well, lake, or farm pond. It does not include a terrace tile inlet or surface tile inlet other than an agricultural drainage well surface tile inlet.), or in the case of a high-quality water resource within 800 feet. Smaller setbacks can be used if: (1) the manure is land-applied by injection or incorporated on the same date as the manure was land applied, or (2) an area of permanent vegetation cover (including filter strips or riparian buffers) exists for 50 feet surrounding the designated. The vegetative filter area cannot receive manure application. In general, the requirements set forth in Iowa state law are stricter than those required in federal law for permitted CAFO operations with several exceptions. In particular, the case where manure is injected or incorporated on the same date as it is applied requires a set-back of 0 feet in the Iowa law, but a 100-foot setback under NPDES requirements. Additionally, manure application setbacks from surface inlets to tile systems may differ as these aren't generally considered a designated area, but are specified in the NPDES requirements.

This leads to an important question, what is the science behind these separation distances, i.e., what level of reduction in nutrient concentrations or transport is expected by following current setback distance requirements, and do other practices exist that can be expected to provide similar reductions and should be accepted as a site-specific condition or practice? This will be explored in a series of three sections, in section one we will focus specifically on the performance of maintaining manure application setback distance. In section two,we will focus on maintaining a vegetated buffer between the manure application area and the receiving water body. Finally, in section three, we will examine other practices that may be appropriate, with specific attention given to the practice of manure injection or immediate incorporation as this is a practice specifically mentioned in Iowa law, but not mentioned in federal code.

Section 1: Manure application setback – 100 foot no-apply zone

A manure application setback specifies the minimum distance manure can be applied to a defined feature. Current EPA regulations for setback distances for NPDES permitted animal production facilities is to have a no application zone within 100 feet of the down-gradient surface waters, open tile intake structures, sinkholes, agricultural wellheads, or other conduits to surface waters (In comparison Iowa code requires a 200 feet set back from designated areas). In this option, no manure application is allowed in the setback area, but the setback area can still be used for crop production and currently there are no restrictions on the application of commercial fertilizers that can be utilized in the setback area.

In general, the objective of both 100-foot setback distance or the 35-foot setback with permanent vegetative buffer is to provide a protective strip of land that can serve to filter solids, retain nutrients, and otherwise improve surface water runoff from fields receiving manure. In so doing they reduce nutrient transport to the surface water (or other conduit to water). These practices primarily focus on limiting transport of sediment bound contaminants, but also offer some protection to soluble nutrients, namely ammonia and dissolved reactive phosphorus, by providing regions where these nutrients can potentially interact with soils that have not received recent manure application and offer either sorption mechanisms or an opportunity for infiltration to reduce overall transport.

Relatively few field-studies have specifically evaluated the performance of setbacks, or no manure application zones, had on reducing nutrient transport from fields. However, a recent study by Al-wadaey et al. (2010) was performed with the specific objective of evaluating the effect of setback distance on phosphorus and sediment in runoff from lands receiving manure application. This study was conducted on a 24 ha (59 acre) field protected with underground-outlet terraces located northwest of Lincoln, Nebraska. Field slopes in this area were 4-7%, and the soil was a well-drained silty clay loam. The experiment was run as a replicated block design (3 blocks) with seven different treatments (manure application setbacks of 0, 5, 10, 20, 30, and 40 m, and a no manure check plot). In this experiment, composted feedlot manure was applied to bare, frozen soil in February at an average rate of 74 Mg/ha. Runoff samples were collected from the riser pipe of each treatment from multiple natural rainfall events. Runoff samples were analyzed for sediment (total solids), total phosphorus, dissolved phosphorus, and particulate phosphorus (by difference between total and dissolved phosphorus). An analysis of variance was conducted using Proc Mixed (SAS Institute) to determine the effects of setback treatments on sediment, TP, DP, and PP. ISCO samplers were used on the 0 and 30 m (~100 foot) setback plots to monitor flow volumes, allowing a comparison of nutrient transport between these two treatments. These authors found no difference in runoff concentration or runoff volume between the 0 and 30 m setback treatments, but found significantly greater sediment transport from the 30 m setback plot. They attributed this finding to the manure providing organic matter, which resulted in formation of water stable aggregates and reduced erosion. Moreover, they found that different setbacks did not significantly affect phosphorus concentrations (total, dissolved, or particulate) among any of the seven treatments. This result would seem to indicate that under these conditions the manure application setback had no impact in the case of this solid manure.

Another study by Dygert (2011) on setbacks was performed to specifically evaluate the effectiveness of setback recommendations (61-m setback, ~ 200 feet) at mitigating nutrient transport following the application of liquid dairy manure from fields with low slope percent following manure applications on frozen/snow covered ground. This study was conducted near Wooster, Ohio on a field with 2% slope, under no-till management, and with corn residue on the surface. They evaluated two scenarios, a manure application with no setback and a manure application with setback, and for each case compared the runoff concentrations to that with a plot that didn't receive manure. Their treatment design required different plot sizes, making result comparison complicated; however, after proper normalization Dygert's data suggests that leaving a buffer area will significantly reduce ammoniacal nitrogen ($p = 0.09$), total phosphorus ($p = 0.07$), dissolved phosphorus ($p = 0.04$), and potassium ($p = 0.01$) concentrations as compared to not leaving a buffer strip. In this case, with a liquid manure under winter application conditions, it would seem that setbacks provide an effective means of reducing nutrient concentrations. As a point of comparison, the setback reduced ammonia concentrations by 60% on average over the 8 reported events, but had a standard deviation of 60%, with performance ranging from 0-120% reductions in ammonia concentrations. Similarly, nitrate, total phosphorus, dissolved reactive phosphorus, and potassium concentrations were reduced by 60 (100), 75 (80), 99 (72), and 115 (92) [average (standard deviation)] respectively.

As only these two studies could be located specific to the performance of setbacks, it was not possible to develop a baseline performance standard from this option against which other potential practices could be evaluated. However, based on details provided in these manuscripts it appears that the hydrology of the runoff event was extremely important to the performance of the setback distance. In the case of Al-wadaey et al. (2010) runoff was measured from rainfall events typically larger than 1-inch, which provided enough flow for water runoff from the manure applied area to reach the tile inlet. In Dyger's study runoff samples were only from snowmelt, and they reported that many of the events weren't of sufficient size for runoff from the manure applied zone to reach the edge of the plot. This made the setbacks appear effective, but larger runoff events significantly reduced the setback's effectiveness, hence the large variation in setback performance they observed. These results would seem to indicate that the primary impact of these setbacks have on nutrient transport is prevent manure from reaching the critical area during smaller runoff events, but there effect may be limited during larger events.

A lab-study by McDowell and Sharpley (2002) seems to collaborate this stating, P loss in overland flow is affected by where manure is applied relative to flow-path length, noting specifically that there was a strong relationship between P fractions and flow-path length. However, they also noted that phosphorus loss was to large part driven by soil phosphorus concentrations. Implying that if these critical areas are still receiving phosphorus inputs from mineral fertilizer sources, the setback may not be as effective as we would otherwise anticipated.

Overall, this data suggests to me that these standard setbacks would be most effective in cases of late fall- or winter- applied manure when runoff events will predominately be from snowmelt and many of the runoff events will be small. If the manure is spring applied these setbacks would have limited impact due to the larger nature of these events causing larger runoff events and the runoff reaching the stream from the land that had received the manure.

Section 2: Manure application setback - 35 foot vegetative buffer

Grass buffers are areas located between the land receiving animal manure and streams, or other conduits to surface waters that reduce the concentration and mass of nutrients and other potential contaminants entering the receiving water. Vegetative buffers, or filter strips, are a practice that has been demonstrated to effectively reduce erosion and P movement (Dillaha et al, 1989). Binham et al. (1980) and Doyle et al. (1977) reported some of the earlier work on vegetative buffers around manure land application areas. In general, they reported reductions of 0-80%, with performance varying based on the ratio of manure land application area to vegetative buffer area and the type of contaminant (soluble versus particulate transport). In general, Binham et al.'s (1980) work with layer hen manure and 35- foot vegetated setbacks indicated that that reductions of 30% should be expected for carbon and chemical oxygen demand, 60% for total Kjeldahl nitrogen, and 80% for total phosphorus.

Since then numerous other studies on buffer strip performance have been conducted with some focusing on land that had received manure and others focusing on buffers around cropland. Although these studies provide considerable information, more recent efforts at understanding buffer strip performance has focused on using modeling to extend the results of the field studies to other situations. The most well know used of these models is the Vegetative Filter Strip Model (VFSMOD) as described in Munoz-Carpena and Parsons (2000). Dosskey et al. (2011) then used this model to evaluate the trapping efficiency for given buffer area ratios with different site conditions (slope, soil texture, and field practices). Based on this they developed a series of curves to provide trapping efficiency for different scenarios, including soil types, slopes, and contaminant types. We believe their work provides the best option for estimating the baseline performance a 35-foot vegetative buffer would provide.

In the case of the 35-foot buffer on a square 40-acre field, if all runoff drained uniformly to one edge of the field, the buffer-to-field area ratio would be approximately 0.03. Based on the chart they developed, we would anticipate that reductions in total suspended solids would be 10-80%, reductions in total phosphorus would be 5-70%, and reductions in total nitrogen would be 5-60%. As expected, these ranges are quite large, but they provide a realistic expectation for filter strips under a large range of conditions. Their results can best be summed up with the use three items from their manure script. Figure 6 (shown here as figure 1) which shows performance of vegetative buffer areas for their modeled cases, table 4 (shown here as table 1) which defines their base cases, and table 6 (shown here as table 2) which provides a set of guidelines on how to use figure 6 to predict performance buffer areas in non-base cases.

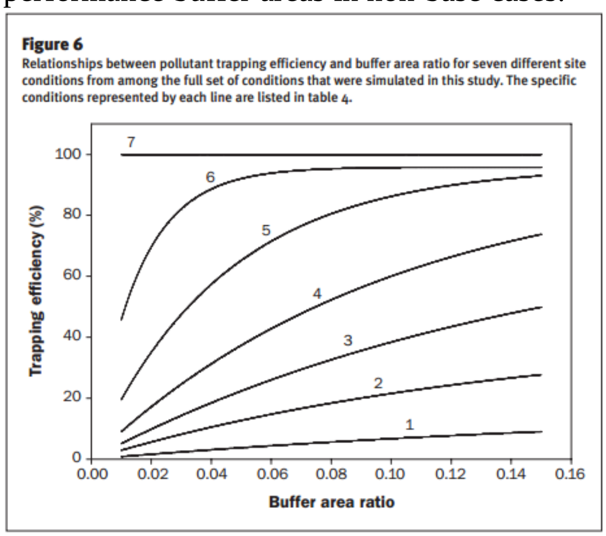

Figure 1. Modeled relationship between pollutant trapping efficiency and buffer area ratio. Results from Dosskey et al. (2011) as modeled in VFSMOD. A 40-acre field with uniform slope to one side and a 35-ft buffer on that side would have an buffer area ratio of 0.03.

Table 1. Based cases modeled by Dosskey et al. (2011).

Table 4
Simulation conditions corresponding to each line in figure 6.

Line number	Material type	Slope (%)	Soil texture class	USLE C factor*	Field length (m)
7	Sediment	2	FSL	0.50	200
6	Sediment	2	SiCL	0.15	200
5	Sediment	2	SiCL	0.50	200
4	Water	2	FSL	0.50	400
3	Water	10	FSL	0.50	200
2	Sediment	10	SiCL	0.50	200
1	Water	10	SiCL	0.50	200

Notes: FSL = fine sandy loam. SiCL = silty clay loam.

* The USLE C factor is the cover and management factor in the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978).

Table 2. Adjustment rules from Dosskey et al. (2011) for estimating vegetative buffer performance for non-base cases.

Table 6
Rules for adjusting from an initial reference line in figure 6 to a final selected line based on how much the actual field site conditions differ from the reference simulation conditions. Different rules are used depending on the pollutant type: sediments and sediment-bound pollutants or dissolved pollutants and water. For soil texture, three broad categories are recognized: coarse (sandy loam, sandy clay loam, fine sandy loam), medium (very fine sandy loam, loam, and silt loam), and fine (clay loam, silty clay loam, silt).

Variable	Adjustment rule
Sediment and sediment-bound pollutants	
Pollutant type	1 line lower (–1) from sediment to sediment-bound
Slope	1 line higher (+1) for each 2.5% lesser slope 1 line lower (–1) for each 2.5% greater slope
Soil texture	1 line higher (+1) for each category coarser 1 line lower (–1) for each category finer
USLE C factor*	1 line higher (+1) for each 0.35 lower C factor 1 line lower (–1) for each 0.35 higher C factor
Dissolved pollutants and water	
Pollutant type	No adjustment between dissolved pollutants and water
Slope	1 line higher (+1) for each 7.5% lesser slope 1 line lower (–1) for each 7.5% greater slope
Soil texture	1 line higher (+1) for each category coarser 1 line lower (–1) for each category finer
USLE C factor*	No adjustment

* The USLE C factor is the cover and management factor in the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978).

In general, their results indicate that the expected performance of the vegetative buffer area would be dependent on several site-specific characteristics, including the soil texture, the slope of field, and the amount of surface residue remaining in the field. Their results indicate that this practice would be expected to impact sediment transport (and as a result transport of contaminants attached to sediment, total phosphorus, organic carbon, organic nitrogen), but generally would only have low impact on soluble contaminants (ammonia, DRP, nitrate, etc.). As a general rule of thumb, it appears that transport of particulate bound nutrients (sediment, total P, organic carbon, organic nitrogen) would be reduced by about 10% in areas of high slope and 60% in areas of low slope, while reductions of soluble nutrients (ammonia, DRP, nitrate, etc.) would be only 5-30%.

Section 3: Manure application – Other alternatives to setback distances

(a) Injection

As stated previously, the objective of the two previously discussed practices is to reduce nutrient transport to the surface water (or other conduit to water) primarily by reducing erosion, but also by reducing surface transport of nutrients. It has long been noted that the transport of P from agricultural areas to surface waters is primarily by runoff and erosion, and thus its transport is heavily influenced by surface soil P content and the method, rate, and timing of fertilizer and manure P application (Sharpley et al., 1993). As runoff only interacts with the very top of the soil profile, injection or immediate incorporation have both been proposed as best management practices for reducing transport of manure nutrients as it moves the manure to a zone in the soil where it will have less interaction with runoff water and therefore be less prone to transport and loss.

A recent study by Gilley et al. (2013) evaluated several different manure land application methods (broadcast, broadcast with disk incorporation, injection) for three sources of swine manures (grower pigs, finisher pigs, and sows). This study was performed at the plot-scale in Nebraska and used simulated rainfall, but offers a direct comparison of how different application methods impacted nutrient transport in surface runoff. They found that injection decreased dissolved phosphorus transport by 60%, particulate phosphorus transport by 40%, total phosphorus transport by 46%, ammonia transport by 84%, and total nitrogen transport by 20%. In general, these reductions are well within the range that we would expect to be achieved with the 35-foot vegetative buffer and indicate that injection will meet the performance requirements for reduction in transport of soluble nutrients. It also appears to provide a similar level of performance for particulate attached nutrients. Gilley et al. (2013) also compared the use of disk incorporation to surface broadcast, in this case the results indicated that incorporation decreased dissolved phosphorus by 45% but increased total phosphorus by transport by 20%. Similar results were seen for nitrogen as incorporation reduced ammoniacal nitrogen transport by 50% but increased total nitrogen transport by 24%. These results are as expected, injection placed the manure below the soil surface while minimizing soil disturbance, this resulted in a situation where the soluble contaminants were not in contact with the surface runoff and as a result, their transport was minimized. This was done while causing minimal soil disturbance, soil transport of sediment bound contaminants was also minimized. In the case of incorporation, the transport of soluble contaminants was reduced by encouraging their contact with soil particles and working it below the soil surface, but the tillage resulted in greater potential for transport of sediment bound contaminants.

A fair interpretation of this study would be that either injection or incorporation will provide a sufficient level of control of soluble contaminants to meet or exceed the performance that would be achieved with a 35-foot vegetative buffer and surface manure application. However, some level of concern or indexing of solids transport may also need to be considered in situations where tillage is performed. In this study, incorporation occurred with the slope of the plots which make have increased the erosion potential of the runoff.

A 1979 study by Ross et al. quantified the quality of runoff from land receiving either surface application or injection of liquid dairy manure. In this study Ross et al. (1979) injected manure into both sod and a tilled loam soil at depths of 15.3 and 30.5 cm and a surface application onto both the sod and tilled soil. In performing this study they evaluated three factors, these were: (1) the effect of injection versus surface application, (2) the effect of injection depth (15.3 versus 30.5 cm), and (3) the impact of surface conation (vegetated versus tilled). In their study, they found that injection reduced runoff concentrations to levels typical of those of plots not receiving manure application. This represents a substantial reduction as compared to surface application, for example COD (chemical oxygen demand) was 17x lower in the injection plots than in the surface applied plots, with the depth of injection having little effect in this study. This again provides strong evidence that injection provides a high level of reduction in nutrient transport. No difference was found in the impact of injection depth. Again, a fair interpretation of this study is that injection of manure is a more effective practice for reducing nutrient transport and runoff concentrations than a 35 foot vegetative buffer.

The final injection study we will look at is by Pote et al. (2011). This study is unique in that is was injection of a solid manure (unfortunately the unit is not yet commercially available). In their research, they found that subsurface injection reduced concentrations of nitrogen and phosphorus in runoff water by more than 90% as compared to surface application. In a paired watershed part of the study, they found that total phosphorus losses were 55% less in the watershed that received subsurface litter application than the one that received surface litter application. In the first several runoff events after litter application dissolved reactive and total phosphorus concentrations in runoff water were typically reduced by more than 80% by utilizing injection application. Again, this indicates that injection effectiveness is at or exceeds levels met by the 35-foot vegetative buffer requirement.

Overall, these studies give a clear and consistent picture that injection application will provide similar or better reduction in nutrient concentrations and transport as to those that would be obtained using the 35-foot vegetative buffer between manure application areas and surface waters (or conduits to surface waters) for soluble containments. Performance of injection on sediment bound contaminants was also promising indicating that it was also effective at reducing transport of sediment bound contaminants.

(b) Incorporation

A 2008 study by Allen and Mallarino utilized swine manure and sites located within Iowa to evaluate how application rate, incorporation, and timing of rainfall impacted phosphorus losses with surface runoff. Their results indicated that incorporating the manure with tillage resulted in significantly lower runoff P concentrations and loads. On average they found that incorporation reduced phosphorus concentrations in runoff by 50% for total phosphorus and by over 80% for dissolved phosphorus, which exceeds estimated reductions achieved with vegetative buffer strips. Their results are generally consistent with existing research as incorporation places the manure P below the zone of interaction between the soil and incoming rainfall and runoff, reducing dissolved reactive phosphorus (Wither et al., 2001; Tabbaraa, 2003; Haq et al., 2003; Daverede et al., 2004).

Another recent study (Pote et al., 2003) focused on the water-quality effects of incorporating poultry litter, in this case into grassland soils. In this study, they had four treatments, a control (no litter), a surface applied litter, a surface-applied litter to aerated soil, and a surface applied followed by knife incorporation to minimize disturbance of the soil structure by using a knife tool for injection. This work was performed on field plots with 8-10% slopes, silt loam soil, and well-established grass forage. They found that in all cases adding litter increased infiltration, but results weren't significant. In this case, incorporation of the litter reduced dissolved organic carbon transport by 58%, total dissolved solids transport by 36%, and total suspended solids transport by 57%. Nitrogen and phosphorus transport were also successfully reduced by 44% for nitrate-nitrogen, 83% for ammoniacal-nitrogen, and 81% for total Kjeldahl nitrogen and by 89% and 85% for dissolved reactive phosphorus and total phosphorus respectively. Surface application also reduced transport of these items, but to a much lesser extent, only resulting in a 11% reduction in dissolved carbon transport, a 36% reduction in dissolved solids, and a 57% reduction in suspended solids. In the second case, they evaluated the performance of soil aeration followed by surface application. They found nitrogen and phosphorus transport reductions were 6% (nitrate-nitrogen), 25% (ammoniacal-nitrogen), 28% (total Kjeldahl nitrogen), 13% (dissolved reactive phosphorus), and 9% for total phosphorus. These results suggest that low disturbance incorporation into perennial vegetation can be very effective at reducing nutrient transport and is roughly equivalent to 35-foot filter strips, but the performance of aeration followed by surface application isn't quite equivalent.

Again, these studies indicate that incorporation is a valuable technique for reducing the transport of water-soluble nutrients and contaminants as their interaction with the soil reduces their transport. However, results on sediment bound nutrients and contaminants are less clear, given that the tillage for incorporation reduces surface cover. In some cases, this can lead to increased erosion, and as a result, an increase in the transport of sediment bound cartilages, in others this didn't appear to be an issue.

Conclusions

This document was written to provide a science-based assessment on the use of manure setbacks, or separation distance requirements as well potential management practices that might provide similar performance to the mandated setback distances.

Overall, the results from this review gave a clear indication that manure injection will provide a similar level of reduction in nutrient transport as utilizing vegetative setback areas of 35 feet for soluble nutrients. Moreover, it also tended to provide similar levels of control of sediment bound particles to what would be achieved with a 35-foot vegetative buffer, though this level of control may be impacted by items such as soil disturbance and slope (as would the performance of a 35-foot vegetative buffer). As such, it is our recommendation that manure injection be considered a site-specific practice that provides equivalent performance to the mandated setback distances. No additional restrictions were placed on this application method as research has consistently indicated that be placing the manure nutrients below the soil surface limits transport of the manure nutrients.

Results for manure incorporation again suggest that incorporation will provide equivalent or better performance to that of a vegetative buffer for control of water-soluble nutrients. As tillage may increase erosion in some situations its impact on transport of particulate contaminants based on literature results is less clear, however, based on the Iowa study by Allen and Mallarino (2008) incorporation significantly reduced phosphorus concentrations and transport in runoff water.

As written, the EPA CAFO rules state "owners or operators may demonstrate to the permitting authority that a setback or vegetated buffer is unnecessary because of site-specific conditions or practices the producer is implementing." Based on current research and our discussion of best practices we believe both injection and incorporation (on the date of application) should qualify as site-specific practices that will provide similar performance to EPA mandated setback distances.

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