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Beyond Water-Quality Regulations for CAFOs? Manure Management Costs to meet Air-Quality Objectives in the Chesapeake Bay Watershed

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Key Words:

manure management, confined animals, water quality, air quality, regional optimization, Chesapeake Bay

Abstract:

Federal policy on manure management has focused on water-quality protection. However, animal agriculture is an important source of ammonia-nitrogen and other air emissions, increasing attention on air-quality concerns. Policies to address air emissions would influence both the costs of meeting water-quality objectives and environmental tradeoffs. We consider hypothetical policies at a regional level.

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Beyond Water-Quality Regulations for CAFOs? Manure Management Costs to meet Air-Quality Objectives in the Chesapeake Bay Watershed

Increasing public attention has focused on the concentration of animal waste and resulting potential impacts on environmental quality and public health. Federal regulations for confined animal operations have focused primarily, if not exclusively, on reducing the threat of nutrient runoff to surface water, with little consideration of potential air emissions. However, animal feeding operations are the largest source of ammonia emissions in the U.S., contributing to odor problems and increased particulate matter (haze). Only recently has ammonia loss been viewed as a potential problem in terms of air quality (Sweeten et al., 2000).

Federal guidelines for manure management have, in some cases, encouraged conversion of manure-nitrogen to gaseous ammonia as a means of reducing the cost of land-applying manure. Given increased attention on air quality, animal operations could face the prospect of new air-quality requirements after modifying manure management systems to comply with water-quality guidelines. Air emission controls, in turn, would decrease off-gassing and increase retention of nitrogen in recoverable manure, resulting in higher costs of meeting Federal water-quality guidelines. Today, there is growing interest in the possibility of an integrated policy response that considers interactions across water and air quality impacts that maximizes environmental benefits at lowest cost to the animal sector.

The objective of this analysis is to highlight potential costs of manure management policies in the Chesapeake Bay watershed, addressing interactions across environmental objectives for water quality and air emissions. We consider costs to the animal sector associated with both current and hypothetical expanded policies to protect water quality, evaluated with and without controls on air emissions. Policy assessment within a regional, multi-media (air/water) context offers useful insight on the cost and environmental tradeoffs under alternative policies for animal waste.

Policy context

In January, 2000, the Environmental Protection Agency and U.S. Department of Agriculture issued a joint statement concerning the management of waste from animal feeding operations (EPA/USDA Joint Unified Strategy, 1999). USDA has a stated goal that all animal feeding operations adopt nutrient management plans for handling and land-application of animal waste. In December, 2002, the EPA signed new regulations on animal waste management affecting an estimated 15,500 larger operations. A primary emphasis of recent policies is on land application of recoverable manure nutrients at crop-based rates to minimize excess nutrients available for surface-water runoff.

The costs of meeting USDA goals and USEPA regulations for improved manure management depend not only on individual farm conditions, but on *spatial* considerations involving animal operations and cropland availability for manure land application. Under the

Federal guidelines, nutrient standards for applied manure will generally reduce per-acre application rates and increase the amount of acreage required for manure spreading. For many confined animal operations with insufficient land on the farm to land-apply manure at crop-based rates, much of the manure will need to be moved off the farm. Where animal production is concentrated, manure hauling distances are determined largely by the spatial distribution of land area available for manure spreading and the level of competition among animal farms to access available land.

In most cases, measures to reduce the gaseous emissions of ammonia-nitrogen (ammonia-N) for air-quality control would increase retention of nitrogen in the recoverable manure. With the higher nitrogen content of manure, per-acre application rates of manure would need to be further reduced to avoid over-application of nutrients, resulting in more acres needed to apply a given amount of manure. Greater land requirements, in turn, would increase transportation distances and hauling costs faced by animal producers where manure-nutrient production exceeds the assimilative capacity of the land. The potential effect of air-emission controls on land requirements and competition for land resources underscores the importance of spatial factors in assessing the costs of manure management.

The spatial distribution of manure production and land available for manure application varies significantly across the nation. Kellogg, et al. (2000) and Gollehon, et al. (2001) identified areas where confined animals produce more manure nutrients than can be assimilated on cropland and pastureland in the county of production, when applied at agronomic rates. Where animal production is concentrated, animal producers may face competition for suitable land to apply manure. Several county clusters within the Chesapeake Bay watershed are among areas of the U.S. where manure nutrient production exceeds the nutrient assimilative capacity of the land (fig. 1).

The Chesapeake Bay watershed

The Chesapeake Bay is among the largest and most biologically rich estuaries in the world. The declining health of this ecosystem in recent decades has prompted Federal and State initiatives to reduce nutrient loading from tributaries that drain the watershed. Nutrient discharges to waters in the region have resulted in eutrophication and related ecological shifts that adversely affect wildlife and aquatic resources (Preston and Brakebill, 1999). Manure from confined animal operations has been identified as a primary source of both nutrient runoff to water bodies and local air emissions (Follett and Hatfield, 2001).

The Chesapeake Bay watershed (CBW), spanning over 160 counties in 6 states, includes 66,600 farms with an estimated 8.5 million acres of land available to receive manure. Approximately 15,900 farms in the CBW had confined animals in 1997, with an average daily inventory of about 1.6 billion pounds of feedlot beef, dairy, swine, and poultry (USDA, 1999). These animals produce roughly 93,000 tons of recoverable manure nitrogen, 44,000 tons of recoverable manure phosphorus, and 118,000 tons of ammonia-N annually. Even if confined animal operations fully utilized the crop and pasture land under their control for manure application (and data from the farm-level analysis suggest they do not), not all the manure nutrients produced could be assimilated through onfarm use only. Applying manure at agronomic rates to meet water-quality goals would require moving significant quantities of manure off animal producing farms (Ribaudo et al., 2003).

In a previous ERS analysis, the potential costs of nutrient standards for water-quality control were examined for confined animal production in the CBW (Ribaudo et al., 2003). Results from that study indicate that in areas of the watershed where confined animal production is concentrated, implementation of USEPA and USDA policies on manure nutrient management will pose considerable challenges. Only about half the manure produced can be used on-farm, with the reminder having to be transported off the farm for land application and other uses. The feasibility of land application as a regional manure-management strategy depends on the willingness of landowners to accept manure on farmland, the nutrient assimilative capacity of the regional cropland base, and the nutrient standard in effect. Ribaudo et al. estimate that more than 30 percent of crop farms in the watershed would need to accept manure in order to land-apply all the manure produced in the CBW at a rate based on the nitrogen needs of crops produced, given hauling distance assumptions embedded in the model[1]. The costs of land-applying manure are inversely related to the willingness of crop producers to accept manure (Ribaudo et al., 2003).

In this paper, we present results from an extension of the ERS regional analysis for the Chesapeake Bay watershed. Here we expand our focus on water-quality measures for manure management to consider the effect of hypothetical air-quality controls. The analysis addresses costs and environmental tradeoffs under alternative levels of policy integration for air- and water-quality protection.

Modeling framework

The regional modeling framework was developed to evaluate the effect of Federal guidelines for manure management on costs of manure hauling and land application across the Chesapeake Bay watershed. At the core of the modeling system is an optimization programming model that minimizes the total regional costs of manure management, transport, and application for use on agricultural lands, given the existing structure and scale of the animal industry and current manure storage technology. The model was designed to: 1) track optimal manure and related nutrient flows within the basin, from the farm of origin to site application and use, 2) compute regional costs of manure land application, given manure flows in the basin, and 3) provide a framework for evaluating alternative policies addressing land application standards and ammonia-N emissions, given assumptions on nutrient standards, landowner willingness-to-accept-manure, and the share of farms meeting the guidelines.

The modeling of competition for a limited landbase on which to spread manure is a central feature of the regional model that is not readily captured in a farm-level or sector-level framework. The regional specification captures competition for land by endogenizing access to spreadable land; requiring adequate area for land application of manure produced; and computing the associated regional hauling costs. Technologies that limit ammonia-N emissions

1 Applying nutrients at agronomic rates minimizes the potential for runoff or leaching to water resources.

alter regional competition by changing the costs and manure-nutrient content across manure systems and animal types.

The county serves as the primary modeling unit for the regional model. The county-level specification provides consistency with Census of Agriculture data and other data, while permitting differentiation in institutions and regulatory conditions across county and State political boundaries within the watershed. County and local data are used to capture heterogeneity in technologies and land-quality conditions across the region, though our model may not represent the conditions on any particular farm.

Total regional costs of manure management include manure transport and land-application costs, selected costs of nutrient-management plan development, and ammonia–reducing technology costs in the CBW. The model allocates manure flows between source and destination counties in the watershed to minimize the regional costs of manure management, subject to land availability for manure spreading. (For a more detailed description of the model used for water-quality analysis in Ribaudo et al. (2003), see the model technical documentation in Aillery et al. (2005).)

For this study, the regional modeling framework developed for water-quality policy analysis was extended to consider air-emission controls. Air emissions were incorporated into the modeling framework through: 1) adjustments in manure-nutrient content, 2) inclusion of treatment costs, and 3) calculation of ammonia emission levels. Changes in manure N content were calculated based on manure-nutrient adjustments by species and system technology, weighted on the share of acreage by species and system type, and the assumed use share by treatment. Changes in the N content of manure affect both the level of manure-N excess that must be transferred off confined animal farms and the rate of applied manure under an N-standard. Thus, we expect that implementation of policies to address air emission issues would affect costs to the animal sector of meeting water-quality regulations.

The cost of emission control policies reflect the individual treatment costs for the three technologies considered—alum, incorporation, and lagoon covers (discussed under Model Scenario Analysis section). Emissions were calculated ex-post by treatment scenario at both the storage facility (pre-haul) and field levels, for both regulated and non-regulated farms. Facility emissions are exogenous to the model, based on total manure production allocated across manure storage systems. Field emissions on regulated farms are calculated based on endogenously derived values for total land-applied manure (net industrial uses and that exceeding land capacity) and the rate of applied manure in receiving counties. Field emissions on non-regulated farms were calculated from that portion of manure not explicitly addressed in the model optimization.

Model data

Three primary data sources form the basis of the CBW model data set: the 1997 Census of Agriculture and the National Land Cover Dataset from USGS support the basic model structure; and the National Emission Inventory from EPA is the source of the ammonia-N emission values. Farm-level Census data were used to generate county-level measures of animal operations and animal-units, total manure production, surplus recoverable manure, manure-nutrient content, and potential assimilative capacity of the land for applied manure nutrients. The National Land Cover Dataset (NLCD) was used to define the spatial pattern of land available for manure spreading and to simulate the spatial distribution of livestock operations. A discussion of Census and NLCD data use in the modeling system is available in Aillery et al., (2005).

Model data on ammonia-N emissions were developed from system loss values presented in EPA's National Emission Inventory (NEI). For each of the manure handling systems, ammonia-N loss and retention are reported for animal confinement area, manure storage area, and land application area, based on a mass-balance approach. Starting from an excreted level of nitrogen in the manure, we assume that each unit of nitrogen will either be lost to the atmosphere or be land applied for crop use[2]. Ammonia losses were aggregated for CBW model use based on losses from animal confinement and manure storage areas (termed "facility" losses) and subsequent losses during field application (termed "field losses"). The coefficients for ammonia-N losses were then derived at the facility and field levels, with losses expressed as a share of manure nitrogen available to the crop (and not as a share of excreted levels).

The shares of ammonia-N losses were then mapped to recoverable manure nitrogen available for plant use from Kellogg et al., (2000) to estimate the ammonia-N losses at each stage of the manure handling system[3]. Excreted manure nitrogen levels were derived from this mapping procedure for 1997 animal stocks in the CBW. For scenarios evaluating alternative technologies to reduce ammonia-N emissions, the process operated in reverse. From the calculated excreted nitrogen quantities, revised facility and field losses were subtracted to estimate a revised level of nitrogen available for crop use relative to the values in Kellogg et al., which constitute the core of the model data.

The NRCS Cost and Capabilities Assessment was the primary source of cost data for nutrient management plan components (USDA, NRCS, 2003). Manure hauling and application charges were based on published literature (Pease et. al., 2001; Fleming et. al., 1998), supplemented with data from the NRCS Cost and Capabilities Assessment. Transportation charges reflect a base rate per wet ton (loading/unloading and application) and hauling cost per ton-mile, by manure system type, hauling mode, and distance interval. Per-acre costs of manure incorporation/injection were based on an Iowa State Farm Survey (2001). The baseline values assume that 40 percent of cropland acres currently incorporate manure, derived from information obtained from the USDA ARMS hog and dairy surveys.

Annual costs associated with improved manure-management practices to reduce ammonia-N emissions were: alum—$26.77 per poultry animal unit (AU) plus the additional hauling costs from adding an additional 10 percent to the weight of the litter; lagoon covers—$0.72 per AU for biofilter covers and $5.76 per AU for impervious covers; and incorporation/injection—$6.00 per acre. For a detailed description of the cost data, see

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[2] This assumption ignores direct discharge to water and accidental spills, which are not believed to be significant.
[3] The values in Kellogg, et al. were derived from the Census of Agriculture, and are the basis for manure estimates in the model.

Appendix 4-A in Ribaudo et al. (2003) or the technical documentation in Aillery and Gollehon (2004).

Model scenario analysis

The objective of this analysis is to highlight potential costs of manure management policies in the Chesapeake Bay watershed, addressing interactions across environmental objectives for water quality and air emissions. The general approach involves a comparison of costs to the animal sector under three broad policy conditions, representing alternative levels of integration across water- and air-quality controls (Table 1):

Policy 1 — Animal farms meet nitrogen-based land application standards for water-quality improvement, without consideration of ammonia-N emissions;

Policy 2 — Animal farms meet land application standards and adopt ammonia-N emission controls simultaneously (air and water goals coordinated);

Policy 3 — Animal farms adopt ammonia-N emission controls for air-quality improvements, with only Concentrated Animal Feeding Operations (CAFOs) meeting land application standards.

The number of farms potentially included in efforts to control ammonia-N emissions is likely to be an important consideration in policy development. Accordingly, we focus here on the number of farms included under a given policy (extensive margin), rather than on variation in the intensity of farm emission controls (Table 1). We evaluate three groups of potentially regulated farms: (1) CAFOs only (or those farms currently regulated to meet water-quality objectives); (2) all CAFOs and half the remaining Animal Feeding Operations (AFOs) for a given county; and (3) all AFOs. The set of 'CAFO-only' farms represents about 20 percent of the animal units (AUs) in the CBW. The spatial distribution of CAFO operations varies significantly across the counties within the watershed, with the share of AUs on CAFO operations ranging from 0 (for about half the counties) to as high as 80 percent. The set of farms termed 'CAFOs & half AFOs' would include, on average, 60 percent of the region's AUs, accounting for 50 to 90 percent of animal units by county. (The 'All AFOs' set of farms, including all confined-animal operations within the region, is equivalent to the farm set modeled in Ribaudo et al. (2003).)

We analyze hypothetical ammonia-N emission controls involving the following set of technologies and practices, and assumptions on technology/practice use:

- <u>Incorporation/injection</u>: Manure is incorporated or injected on 100 percent of acres receiving manure from poultry, dairy and feedlot beef operations that are subject to air-emission controls (ie., in the set of 'potentially regulated farms' for air emissions). We assume that lagoon liquid from dairies and feedlot beef operations is surface-applied so that it is possible to inject the liquid with current technologies; swine lagoon waste is generally sprayed and is not typically incorporated. Under current conditions, incorporation is assumed to occur on 40 percent of the cropland for soil-nutrient retention and odor control, based on data from the ARMS hog and dairy surveys. This practice has the effect of reducing ammonia emissions on acres currently treated.

- Lagoon covers: Impervious lagoon covers are added to all dairy, swine and feedlot beef operations using lagoon-based manure storage systems (and subject to air-emission controls). The base model conditions assumes that no lagoons are covered.
- Alum: Alum is used by all poultry operations (subject to air-emission controls) as an additive to the manure in the poultry house. The base model condition assumes no alum use.

In this analysis, we assume that farms meeting nutrient application standards for land applied manure will apply manure at a rate based on a nitrogen (N) standard. Farms in locations with high soil-phosphorus concentrations and runoff vulnerability may be required to base manure applications on a phosphorus standard, which generally decreases manure applied per acre (Ribaudo et al., 2003). While the effects of manure land application on phosphorus-limiting soils is an important concern in the Chesapeake Bay region, air emission controls would interact primarily with manure-nitrogen concentrations and thus our focus is on changes in costs to meet an N standard[4]. To further reduce the dimensions of our analysis here, we hold the parameter for landowner willingness-to-accept-manure at a single rate of 30 percent.

Interactions across environmental control measures

The effect of alternative scenarios on 1) total ammonia-N emissions, and 2) the quantity of manure applied according to land application standards, is illustrated in figure 2. Each line on figure 2 represents a specific policy that defines air- and water-quality controls, while the points on the line represent the number of farms included under the policy; that is, the effect of policy changes at the extensive margin.

Ammonia emissions from all animal feeding operations in the Chesapeake Bay watershed currently total about 117,000 tons per year, including 27,100 tons (23 percent) from manure produced on CAFOs. Under current Federal water-quality regulations for CAFOs, roughly 19 percent of total manure produced in the basin is land-applied to meet nutrient standards. Requiring additional farms to meet water-quality objectives, without consideration of air quality (Policy 1), would expand the quantity of manure applied according to nutrient standards by as much as 3 million tons (‘All AFOs’), with little change in ammonia-N emissions (fig. 2).

Requiring air-quality controls for CAFOs, given current Federal regulations for water quality, would result in a reduction of ammonia emissions of 10,000 tons per year, or roughly 8.5 percent of total basin emissions. Ammonia emission reductions would increase with an expansion of farms complying with air-quality controls. Meeting land application standards and

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4 Increasing the nitrogen content of manure by adopting emission controls does not increase the acreage needed for land application when meeting a phosphorus standard. In fact, the increased nitrogen in the manure reduces the supplemental nitrogen usually required.

adopting air-quality controls simultaneously (Policy 2) would reduce annual ammonia-N emissions by as much as 34,000 tons (38 percent), while increasing manure applied under land application standards by the same 3 million tons as in Policy 1. With only CAFOs meeting land-application standards, adopting air-emission controls (Policy 3) would reduce ammonia-N emissions by as much as 50,000 tons (43 percent) with all farms controlling air emissions.

The results indicate that current Federal manure management policies that focus on water-quality alone have a neglible impact on ammonia emissions at a regional scale. Adding air-quality controls targeting 'CAFOs only' would result in a relatively small reduction in total basin emissions. Expansion in air-quality controls to non-CAFOs would substantially reduce emissions from the animal sector, with potentially sizeable reductions depending on the number of farms meeting land-application and air-emission standards. When meeting standards simultaneously for water and air quality, the potential declines in ammonia-N emissions would be 5 to 10 percent less than achieved when focusing on air-emission reductions solely for non-CAFOs (fig. 3). The relative reduction in the effectiveness of air-control practices is attributable to the spreading of manure with higher nitrogen content over more acres, as additional farms are called on to meet both water- and air-quality goals. However, air-quality controls in the absence of land application standards could result in further over-application of manure-nitrogen on affected farms, with implications for water quality.

Costs of improved manure management with emission controls

An overview of the cost tradeoffs in managing manure for dual environmental objectives shows the effect of 1) policy coordination and 2) scope of policy coverage for the CBW. Estimated regional costs ranged from $23 million to as much as $170 million, depending on the policy and number of farms affected (fig. 3). Total estimated ammonia-N emissions ranged from 118,000 tons to 67,000 tons, while acreage with manure applied at an N standard ranged from 20 to 100 percent of total acres receiving manure.

<u>Policy 1 — Land application standards, without air emission controls.</u> The costs associated with current USDA goals and USEPA regulations for water quality depend in large part on the number of operations expected to meet land application standards. Model results indicate that the total cost of land-applying manure at an N-standard (assuming a producer willingness-to accept manure on 30 percent of crop and pasture lands) would range from $23 million to $130 million, increasing as the number of operations meeting the standard expands from CAFOs only to all AFOs[5] (Policy 1 in figure 3). The addition of half of non-CAFO AFOs to the set of animal farms meeting an N-standard would increase the regional cost by about $58 million, to $81 million. Land-applying manure to meet an N standard on all remaining AFOs would increase the regional cost of manure application by an additional $50 million, to $130 million.

<u>Policy 2 — Simultaneous land application standards with air-emission controls.</u> When requirements for limiting ammonia-N emissions are added to Federal water-quality requirements

5 Results here are very similar but not identical to those in Ribaudo et al. (2003), with the differences due to model and data improvements.

for CAFOs (Policy 1), the total estimated cost of land-applying manure from CAFOs increases by $12 million, with a decline in air emissions of 10,000 tons (fig. 3). The cost increase under air-emission reduction scenarios reflects both the cost of implementing practices plus the increased costs of applying manure under a land application standard. Increased costs primarily reflect increased manure hauling cost to access the additional acreage needed for spreading manure, given the higher nutrient content of the manure.

Modeled costs are greatest where land application standards are applied simultaneously with air-emission controls to all AFOs. Costs increase and air emissions decline as the number of farms included under the policy increase from CAFOs only to all AFOs. In addition, the increased land requirements exhausts the model's available land faster, resulting in more manure that cannot be land applied. (The CBW model indicates insufficient land to receive all manure from farms included under the 'CAFOs & half AFOs', and 'all AFO' scenarios; disposal costs are not assigned to this excess manure in the model.) Including air-control technologies on a large number of farms greatly intensifies the competition for land to spread manure and increases the likelihood that non-land alternatives would be needed for manure disposal.[6] While it is possible to achieve both water- and air-quality objectives simultaneously, increases in farms covered under the policy are increasingly costly to the animal sector.

Policy 3 — Air emission controls, with land application standards on CAFOs only. This scenario assesses the case where ammonia-emission controls for alternative farm sets are added to current Federal water-quality regulations which apply to manure produced on CAFOs only. Where air-emission controls are limited to CAFOs, this policy formulation yields the same solution as observed under Policy 2—a reduction in air emissions of 10,000 tons and a $12 million cost increase. However, as the number of farms under this policy increases, air emissions decline while costs increase at a rate greatly reduced from policies requiring that land application standards be met (fig. 3). Lower costs reflect the absence of competition for land from non-CAFO AFOs, which would not be required to meet nutrient standards for applied manure. While ammonia-N reductions may be achieved at lower costs under such a policy, limiting land application standards to manure produced on CAFOs would limit potential water-quality benefits within the region.

Costs expressed per ton of air-emission reduction reflect the importance of interactions across water- and air-quality policies. If CAFOs were required to meet air-emission controls in addition to water-quality regulations, the change in costs to the animal sector are estimated at $1,500 per ton of emission reduction. Increases in the number of farms subject to air-quality controls have a varying effect on costs per emission reduction, depending on the reach of nutrient standards for applied manure in the basin. An increase in non-CAFO farms subject to land application standards would raise the cost per ton of emission reductions, reflecting increased competition for land and higher transport costs among animal feeding operations. In contrast, the cost per emission reduction would decline if land application standards apply only

6 Options for manure disposal include applying more to land by increasing the willingness of crop farmers to accept manure, increasing manure diverted to industrial processes, reducing the number of animals, adjusting the diet of animals to reduce manure nutrients, or transporting manure beyond the 100-mile maximum transport radius assumed in the model.

to manure from CAFOs. In this case, there would be no cost adjustments due to increased land competition, and the increase in emission reductions would more than offset the cost of emission practices on non-CAFO farms.

Conclusions

The cost of potential Federal policies for manure management is examined for the Chesapeake Bay watershed, with scenarios involving alternative combinations of 1) land-application standards to limit water-pollution potential and 2) ammonia-N emission controls to improve air quality. Simulation results bring to light a key policy challenge—strides to meet one goal may impede the other. Viewing manure-nitrogen in a mass-balance framework helps to establish the tradeoff across policy formulations, as nitrogen is either applied to farmland for plant utilization or emitted to the atmosphere in the form of ammonia-N emissions. While policies can be designed to encourage progress towards both air- and water-quality improvement goals, these options could involve higher costs for manure management than animal operators face under single-objective policies.

We estimate the current annual cost of Federal water-quality regulations for CAFOs in the CBW at about $23 million—with CAFOs accounting for about 20 percent of manure produced in the Chesapeake Bay watershed. Adding ammonia-N controls for these farms would increase the cost of manure management by $12 million, a 50-percent increase, for a less than 10-percent reduction in ammonia emissions. Achieving reductions in ammonia-N emissions above the 10-percent reduction achievable on CAFOs may not be possible without increasing the types of farms subject to air-emission controls. Similarly, achieving water-quality goals for the animal sector may not be possible without increasing the share of manure subject to land-application standards. Costs to the animal sector would increase if additional farms were required to meet environmental goals for air and water quality. In general, it would cost less to increase the share of manure managed under air-emission controls than to increase the share of manure managed to meet land-application standards for water quality. It would cost more—and substantially more for larger numbers of farms—to achieve water-quality and air-quality objectives simultaneously.

In summary, costs to the animal sector—and potential environmental gains and tradeoffs—would depend on the interaction of manure management policies for air and water quality. Requiring additional AFOs to reduce air emissions, without accompanying land application restrictions, could result in overapplication of manure-nitrogen on those farms, with implications for water quality. However, expansion in compliance with land application standards for manure-nitrogen would substantially increase the cost of air- and water-pollution abatement. Potential cost impacts are greatest where animal production is concentrated and manure quantities approach or exceed the assimilative capacity of the existing land base, increasing competition for land needed for manure spreading. Under these conditions, the reliance on land application as a regional manure management solution may not be sufficient. Other policy measures, involving increased landowner acceptance of manure, industrial uses for manure, subsidies for long-range transport of manure from the watershed, or even reductions in herd size, may also warrant consideration.

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Table 1. Environmental policy focus and scope

		Policy Scope			
Policy identification and focus	Policy Description	Farms included*	Graph symbol (see figs 4-2 and 4-3)	Animals on farms meeting N-based nutrient standards	Animals on farms with air quality controls
				% of AU	*% of AU*
Policy 1: Water quality emphasis	Meet nutrient standards without air-quality controls	CAFOs only	•	20%	0%
		CAFOs + ½ AFOs	●	60%	0%
		All AFOs	⬤	100%	0%
Policy 2: Equal emphasis	Meet nutrient standards with air-quality controls	CAFOs only	•	20%	20%
		CAFOs + ½ AFOs	●	60%	60%
		All AFOs	⬤	100%	100%
Policy 3: Air-emission emphasis	Air-quality controls imposed with nutrient standards only where currently required	CAFOs only	•	20%	20%
		CAFOs + ½ AFOs	●	20%	60%
		All AFOs	⬤	20%	100%

* CAFOs refer to 'potential' CAFOs, based on USDA estimates.

Figure 1. The Chesapeake Bay watershed with location of manure production, 1997

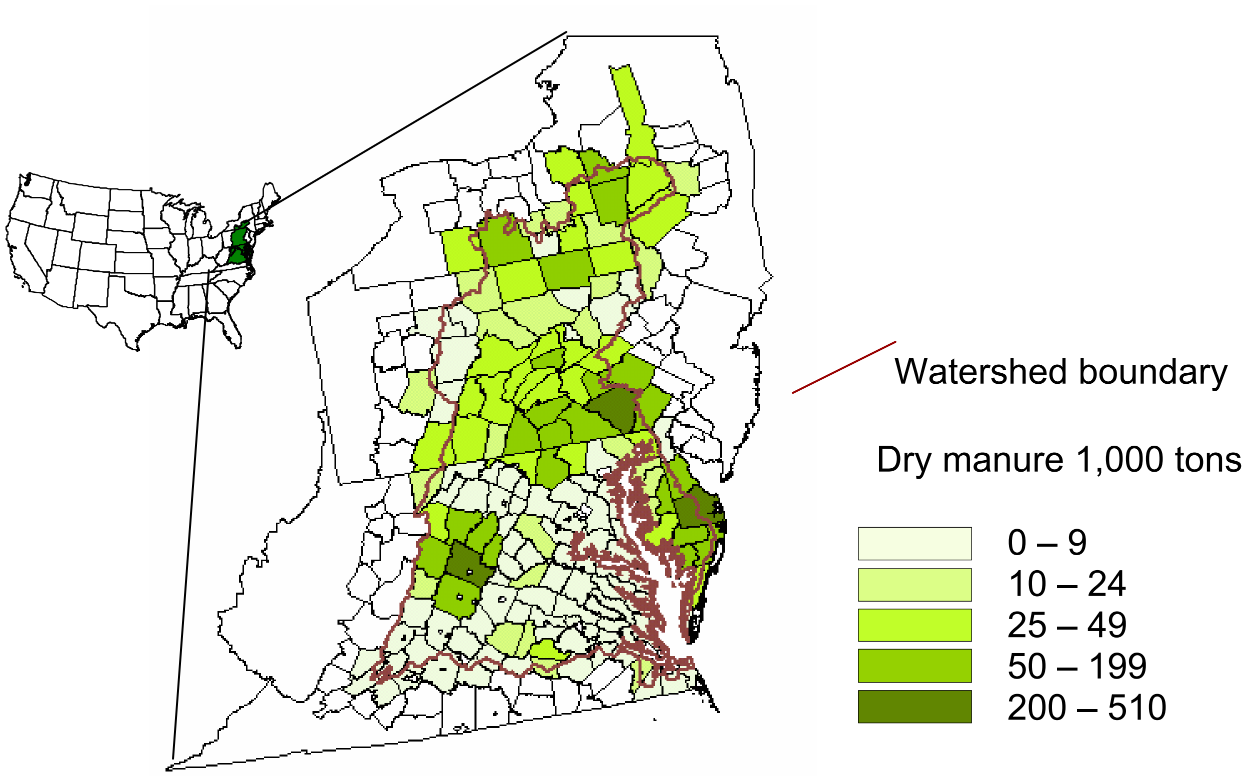
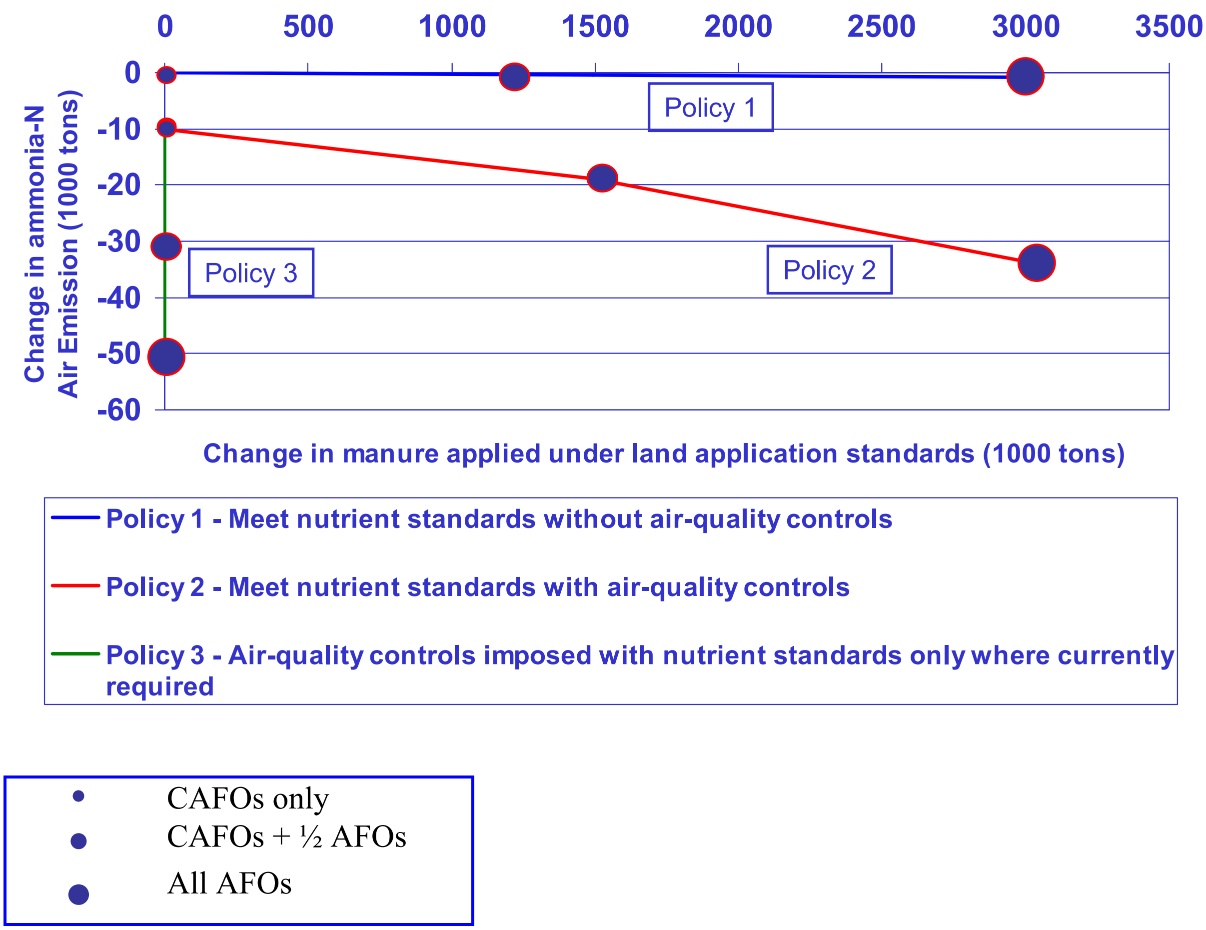
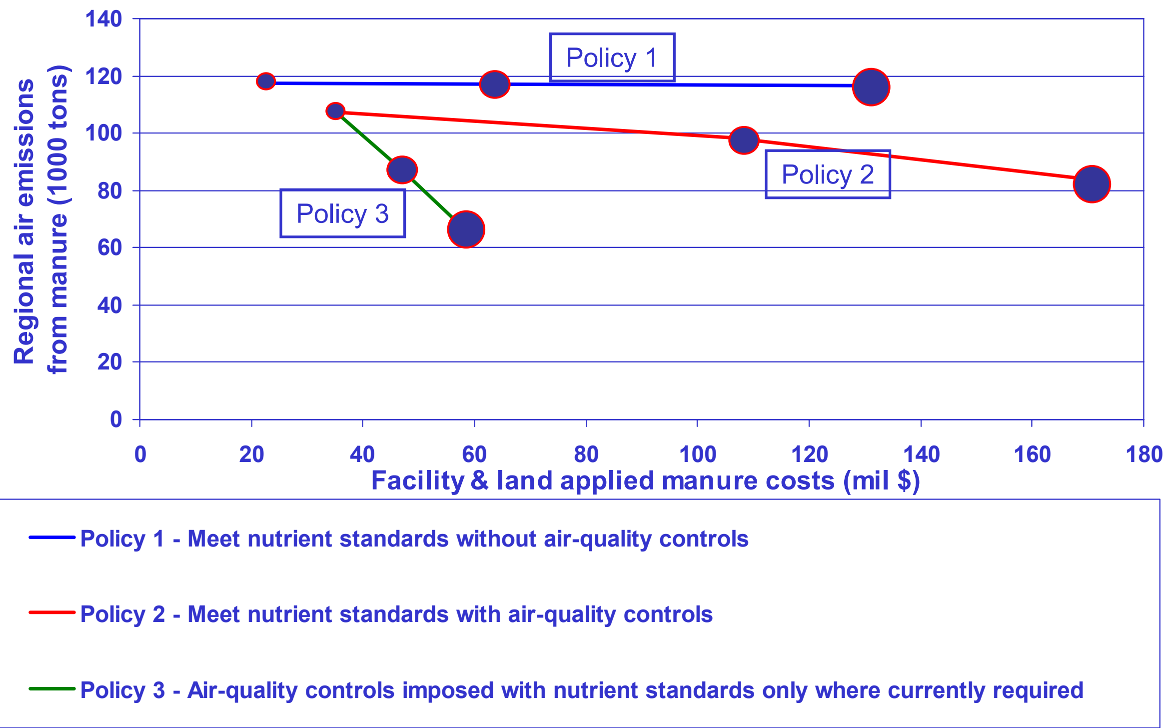


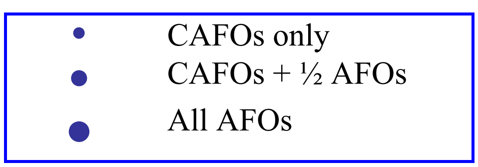
Figure 2. Tradeoffs in measures of environmental improvements for water and air – for alternative policies and number of farms, Chesapeake Bay Watershed



* Measured relative to current policy conditions in which potential CAFOs are required to meet land application standards and air emission controls are not required of any farms.
Assumes a nitrogen standard, with 30% of land willing to accept manure.

Figure 3. Modeled costs and ammonia-N emissions – for alternative policies and number of farms, Chesapeake Bay Watershed





* Costs include manure land application and air emission controls.
Assumes a nitrogen standard, with 30% of land willing to accept manure.