APPENDIX E

COST-EFFECTIVENESS ANALYSIS

As part of the process of setting effluent limitations guidelines (ELG) and developing standards, EPA uses cost-effectiveness calculations to compare the efficiencies of regulatory options for removing priority and nonconventional pollutants.[1] Although not required by the Clean Water Act, a cost-effectiveness (C-E) analysis offers a useful metric to compare the efficiency of alternative regulatory options in removing pollutants and to compare the proposed technology option with other regulatory alternatives that EPA considered.[2]

The American Society of Agricultural Engineers (ASAE) reports that the constituents present in livestock and poultry manure include boron, cadmium, calcium, chlorine, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, sodium, sulfur, zinc, nitrogen and phosphorus species, total suspended solids, and pathogens. Of these pollutants, EPA's standard C-E analysis is suitable to analyze only the removals of metals and metallic compounds. EPA's standard C-E analysis does not adequately address removals of nutrients, total suspended solids, and pathogens. To account for the estimated removal of nutrients and sediments under the final rule, the Agency developed an alternative approach to evaluate the pollutant removal effectiveness for nutrients and sediment relative to the cost of these pollutant removals. For this rule, EPA estimates the expected percentage reductions in pathogens from agricultural runoff but does not compare these removals to the costs of the regulatory controls.

The C-E analysis conducted for this rule evaluates the cost-effectiveness of removing select nonconventional and conventional pollutants, including nitrogen, phosphorus, and sediments. For this analysis, sediments are used as a proxy for total suspended solids. This analysis compares the estimated compliance cost per pound of pollutant removed to a recognized benchmark, such as EPA's benchmark for conventional pollutants or other criteria for existing treatment, as reported in available cost-effectiveness studies. The research in this area has mostly been conducted at municipal facilities, including publicly owned treatment works (POTWs) and wastewater treatment plants (WWTPs). Additional information is available based on the effectiveness of various nonpoint source controls and BMPs and other pollutant control technologies that are commonly used to control runoff from agricultural lands. Benchmark estimates were used to evaluate the efficiency of the final rule in removing a range of pollutants. This approach also allowed for an assessment of the types of management practices that will be implemented to comply with the final regulations.

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[1] A list of priority ("toxic") and conventional pollutants is provided at 40 CFR Part 401. There are more than 120 priority pollutants, including metals, pesticides, and organic and inorganic compounds. Conventional pollutants include biological oxygen demand (BOD), total suspended solids (TSS), pH, fecal coliform bacteria, and oil and grease. Nonconventional pollutants comprise all other pollutants, including nutrients; that is, they do not include conventional and priority pollutants.

[2] EPA defined cost-effectiveness similarly for Phase II of the Storm Water rule (USEPA, 1999f) and examined the incremental annualized cost of each pollution control option to the incremental pound of TSS removed annually.

The organization of this section is as follows. Section E.1 provides an introduction and describes the types and concentrations of pollutants found in animal manure and wastewater. Section E.2 summarizes EPA's estimated baseline loadings and removals of metals, nutrients, total suspended solids, and pathogens from feedlot and land application areas, for selected regulatory alternatives. Section E.3 presents an analysis of the cost-effectiveness of loadings reductions of nutrients and total suspended solids and compares the overall effectiveness of the final regulations to other options considered by EPA during the development of this rulemaking. Section E.5 concludes with a discussion of EPA's analysis that uses a standard C-E approach to analyze a subset of metallic compounds that are found in animal manure and wastewater.

More detail on the environmental damages associated with livestock and poultry operations and the pollutants in animal manure is provided in the *Environmental Assessment* (USEPA, 2000b) and the *Benefits Analysis* (USEPA, 2002k). Section 5.4 of this report summarizes EPA's estimates of the loading reductions for these pollutants. Additional information on EPA's estimated loadings and removals under post-compliance conditions is provided in the *Development Document* (USEPA, 2000a) and also in the *Benefits Analysis* (USEPA, 2002k).

E.1 POLLUTANTS OF CONCERN

E.1.1 Introduction

Manure and wastewater from animal feeding operations have the potential to contribute pollutants such as nutrients (e.g., nitrogen and phosphorus), organic matter, sediments, pathogens, metals and metallic compounds, hormones, antibiotics, and ammonia to the environment (USEPA, 2000g; USDA and USEPA, 1999). Additional information on the pollutants in animal manure and on water quality impairment and risks associated with manure discharge and runoff is provided in Section 5 of the proposed rule preamble and in the *Environmental Assessment* (USEPA, 2000g).

National and local studies have confirmed the presence of manure pollutants in U.S. waters. EPA's 1998 *National Water Quality Inventory* (USEPA, 2000h), prepared under section 305(b) of the Clean Water Act, presents information on impaired water bodies based on reports from the states. Agricultural operations, including animal feeding operations, are considered a significant source of water pollution in the United States (USEPA, 2000h). As shown in Table E-1, the agricultural sector, including crop production, pasture and range grazing, concentrated and confined animal feeding operations, and aquaculture, is the leading contributor to identified water quality impairments in the nation's rivers and streams, and the nation's lakes, ponds, and reservoirs. Agriculture is also identified as the fifth leading contributor to identified water quality impairments in the nation's estuaries (USEPA, 2000h). These data also confirm that water quality concerns tend to be greatest in areas where crops are intensively cultivated and where livestock operations are concentrated.

Table E-1 also lists the leading pollutants that impair surface water quality in the United States, as identified in the *1998 Inventory*. Livestock and poultry operations are a potential source of all of these, but they are most commonly associated with nutrients, pathogens, oxygen-depleting substances, and solids (siltation). Animal operations are also a potential source of other leading causes of water quality impairment, such as metals and pesticides, and they can contribute to the growth of noxious aquatic plants due to the discharge of excess nutrients. Animal operations can also contribute loadings of priority toxic organic chemicals and oil and grease, but most likely to a lesser extent than they contribute to loadings of other leading pollutants.

Table E-2 presents additional summary statistics from the *1998 Inventory*. These data indicate that agriculture contributes to the impairment of at least 170,000 river miles, 2.4 million lake acres, and almost 2,000 estuarine square miles. Animal feeding operations are a subset of the agriculture category. The portion of impairment attributable to animal agriculture nationwide is unknown, because not all states and tribes identified sources and tribes identify specific agricultural activities contributing to water quality impacts on rivers and streams. States that specifically report potential water quality impairment attributable to animal feeding operations in the *1998 Inventory* are: Hawaii, Illinois, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Montana, Nebraska, Ohio, Oklahoma, Rhode Island, South Carolina, Tennessee, Virginia, West Virginia, Wisconsin, and Wyoming. Impairment due specifically to land application of manure is not reported. For rivers and streams, estimates from these states indicate that 16 percent of the total reported agricultural sector impairment is from the animal feeding operation industry (including feedlots, animal holding areas, and other animal operations), and 17 percent of the agricultural sector impairment is from both range and pasture grazing. For lakes, ponds, and reservoirs, estimates from these states indicate that 4 percent of the total reported agricultural sector impairment is from the animal feeding operation industry and 39 percent of the agricultural sector impairment is from both range and pasture grazing.

E.1.2 Pollutant Concentrations in Animal Manure and Wastewater

Table E-3 lists the reported amounts of macro- and micro-nutrients in livestock and poultry waste, along with documented levels of other inorganic and metallic constituents. As shown, the ASAE reports that the constituents present in livestock and poultry manure include: boron, cadmium, calcium, chlorine, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, sodium, sulfur, zinc, nitrogen and phosphorus species, total suspended solids (TSS), and pathogens (ASAE, 1993). Other research conducted by various land grant universities reports that arsenic, selenium, and other constituents are also present in some animal manures (NCSU, 1994; Sims, 1995).

Concentrations shown in Table E-3 are reported in pounds per 1,000 pounds of live animal weight per day and vary by animal species. As shown in Table E-3, poultry manure typically has a higher nutrient content than most other farm animal manure and wastewater. Actual nutrient values of manure depend on many factors, including animal size, maturity, and species; health and diet of the animals; and the feed composition and protein content of the ration fed (USDA, 1992). Additional details on the constituents in animal manure are provided in the *Environmental Assessment* (USEPA, 2000b) and the *Development Document* (USEPA, 2000a).

Table E-1. Leading Sources and Pollutants of Water Quality Impairment in the United States, 1998

Rank	Rivers & Streams	Lakes, Ponds, & Reservoirs	Estuaries
Sources [a]			
1	Agriculture (59%)	Agriculture (31%)	Municipal point sources (28%)
2	Hydromodification (20%)	Hydromodification (15%)	Urban runoff/storm sewers (28%)
3	Urban Runoff/storm sewers (11%)	Urban runoff/storm sewers (12%)	Atmospheric deposition (23%)
4	Municipal point sources (10%)	Municipal point sources (11%)	Industrial discharges (15%)
5	Resource extraction (9%)	Atmospheric deposition (8%)	Agriculture (15%)
Pollutants [b]			
1	Siltation (38%)	Nutrients (44%)	Pathogens (47%)
2	Pathogens (36%)	Metals (27%)	Oxygen-depleting substances (42%)
3	Nutrients (29%)	Siltation (15%)	Metals (27%)
4	Oxygen-depleting substances (23%)	Oxygen-depleting substances (14%)	Nutrients (23%)
5	Metals (21%)	Suspended solids (10%)	Thermal modifications (18%)

Source: USEPA, 2000h. Figure totals exceed 100 percent because water bodies may be impaired by more than one source or pollutant.
[a]Fraction of impairment attributed to each source is shown in parentheses. For example, agriculture is listed as a source of impairment in 59 percent of impaired river miles. The portion of "agricultural" impairment attributable to animal waste (as compared to crop production, pasture grazing, range grazing, and aquaculture) is not specified.
[b]Percent impairment attributed to each pollutant is shown in parentheses. For example, siltation is listed as a cause of impairment in 51 percent of impaired river miles.

Table E-2. Summary of Statistics from the National U.S. Water Quality Impairment Survey, 1998

Total Quantity in U.S.	Waters Assessed	Quantity Impaired by All Sources	Quantity Impaired by Agriculture [a]
Rivers 3,662,255 miles	23% of total (840,402 miles)	35% of assessed (291,263 miles)	59% of impaired (170,750 miles)
Lakes, Ponds, and Reservoirs 41.6 million acres	42% of total (17.4 million acres)	45% of assessed (7.9 million acres)	31% of impaired (2,417,801 acres)
Estuaries 90,465 square miles	32% of total (28,687 square miles)	44% of assessed (12,482 square miles)	15% of impaired (1,827 square miles)

Source: USEPA, 2000h.
[a]AFOs are a subset of the agriculture category. Summaries of impairment by non-agricultural sources are not presented here.

Table E-3. Nutrients, Metals, and Pathogens in Livestock and Poultry Manures

Constituent	Sector						
	Beef	Dairy	Veal	Hog	Broiler	Layer	Turkey
	(average pounds per 1,000 pounds live animal weight per day)						
Mass of animal	793.7	1410.9	200.6	134.5	992.1	4.0	4.0
Manure (wet basis)	58	86	62	84	85	64	47
Urine	18	26		39			
Density (lbs/ft^3)	1000	990	1000	990	1000	970	1000
Total Solids	8.5	12.0	5.2	11.0	22.0	16.0	12.0
Volatile Solids	7.2	10.0	2.3	8.5	17.0	12.0	9.1
BOD (5-day)	1.6	1.6	1.7	3.1		3.3	2.1
COD (5-day)	7.8	11.0	5.3	8.4	16.0	11.0	9.3
pH	7.0	7.0	8.1	7.5		6.9	
Nitrogen (Total Kjeldahl)	3.40e-01	4.50e-01	2.70e-01	5.20e-01	1.10e+00	8.40e-01	6.20e-01
Nitrogen (Ammonia)	8.60e-02	7.90e-02	1.20e-01	2.90e-01		2.10e-01	8.00e-02
Phosphorus (Total)	9.2e-02	9.4e-02	6.6e-02	1.8e-01	3.0e-01	3.0e-01	2.3e-01
Orthophosphorus	3.0e-02	6.1e-02		1.2e-01		9.0e-02	
Potassium	2.1e-01	2.9e-01	2.8e-01	2.9e-01	4.0e-01	3.0e-01	2.4e-01
Calcium	1.4e-01	1.6e-01	5.9e-02	3.3e-01	4.1e-01	1.3e+00	6.3e-01
Magnesium	4.9e-02	7.1e-02	3.3e-02	7.0e-02	1.5e-01	1.4e-01	7.3e-02
Sulfur	4.5e-02	5.1e-02		7.6e-02	8.1e-02	1.4e-01	
Sodium	3.0e-02	5.2e-02	8.9e-02	6.7e-02	1.5e-01	1.0e-01	6.6e-02
Chloride		1.3e-01		2.6e-01		5.6e-01	
Iron	7.8e-03	1.2e-02	3.3e-04	1.6e-02		6.0e-02	7.5e-02
Manganese	1.2e-03	1.9e-03		1.9e-03		1.0e-03	2.4e-03
Boron	8.8e-04	7.1e-04		3.1e-03		1.8e-03	
Molybdenum	4.2e-05	7.4e-05		2.8e-05		3.0e-04	
Zinc	1.1e-03	1.8e-03	1.3e-02	5.0e-03	3.6e-03	1.9e-02	1.5e-02
Copper	3.1e-04	4.5e-04	4.8e-05	1.2e-03	9.8e-04	8.3e-04	7.1e-04
Cadmium		3.0e-06		2.7e-05		3.8e-05	
Nickel		2.8e-04				2.5e-04	

Table E-3. Nutrients, Metals, and Pathogens in Livestock and Poultry Manures (continued)

Constituent	Sector						
	Beef	Dairy	Veal	Hog	Broiler	Layer	Turkey
	(average pounds per 1,000 pounds live animal weight per day)						
Lead				8.4e-05		7.4e-04	
Arsenic	na	na	na	6.9e-04	4.8e-04	5.5e-06	na
Total coliform bacteria (colonies)	29	500		21		50	
Fecal coliform bacteria (colonies)	13	7.2		8		3.4	0.62
Fecal streptococcus bacteria (colonies)	14	42		240		7.4	

Source: ASAE, 1993. Arsenic values are from NCSU, 1994. Converted from reported (lb./yr./1,000 lb. animal weight) values of 0.002 (layers), 0.176 (broilers), and 0.252 (hogs). All values are in pounds unless otherwise noted.

E.2 ESTIMATED POLLUTANT REMOVALS

For this analysis, EPA has estimated the expected reduction of selected pollutants for each of the regulatory options considered. These estimates measure the amounts of nutrients, sediments, and metals originating from animal production areas that are removed under a post-regulation scenario (as compared to a baseline scenario) and do not reach U.S. waters. Additional information on EPA's estimated loadings and removals under post-compliance conditions is provided in the *Development Document* (USEPA, 2002) and the *Benefits Analysis* (USEPA, 2002k) that support the rulemaking.

USDA estimates that in 1997 manure generation from all livestock and poultry production totaled 1.1 billion tons, of which about one-half (0.5 billion tons of manure) was generated by operations with confined animals, using an approach described in Kellogg et al. (2000, 2002) and Lander (1998).[3] More information on these estimates are presented in the rulemaking record. Table E-4 shows these estimates broken out by major subcategory.

Of this total, USDA estimates that operations that confine livestock and poultry animals generate about 500 million tons of manure annually (as excreted). This compares to EPA estimates of about 0.15 billion tons (wet weight) of human sanitary waste produced annually in the United States, assuming a U.S. population of 285 million and an average waste generation of about 0.518 tons per person per year. By this estimate, all confined animals generate 3 times more raw waste that is generated by humans in the United States. EPA is regulating close to 60 percent of all manure generated by operations that confine animals. Of the estimated amount of nutrients generated by these operations that is in excess of cropland

[3] USDA's estimates do not include manure generated from other animal agricultural operations, such as sheep and lamb, goats, horses, and other miscellaneous animal species.

needs, EPA's regulation will account for nearly 70 percent of manure generated by these operations. For more information on EPA's human waste estimates, see information in the record (USEPA, 2002m).[4]

Section 5.4 of this report summarizes EPA's estimates of the loading reductions for these pollutants. The series of summary tables in that section show EPA's aggregated estimates of loadings from all contributions, including the land application area and the production area. Results are shown for operations with more than 1,000 AU and a subset of affected operations with between 300 and 1,000 AU that are defined as CAFOs under the existing NPDES regulations. Post-regulatory conditions are modeled by EPA and expressed in terms of baseline loadings and reductions compared to baseline conditions (pre- versus post-regulatory). Loadings and reductions are modeled for total nitrogen, total phosphorus, and TSS. Under this approach, EPA also simulates loadings and reductions for six selected metallic compounds that are present in animal manure (cadmium, copper, nickel, lead, zinc, and arsenic) and also pathogens (expressed as fecal coliform bacteria and fecal streptococcus).

Pollutant loadings estimates are provided in terms of both estimated "edge-of-field" loadings and "at-stream" loadings. EPA estimates edge-of-field loadings using a simulation modeling approach based on representative model CAFOs used to estimate compliance costs of the final regulations, as described in *Development Document* (USEPA, 2000a, 2002). This model uses estimates of manure generation and information on cropping systems specific to animal operations under various pre- and post-regulation model simulation conditions. Model CAFOs take into account differing conditions at representative operations. These conditions include animal type, production region, facility size, current management systems and practices, and regionally based physiographic conditions regarding soil, rainfall, hydrology, crop rotation, and other factors. Edge-of-field loadings are differentiated by broad animal sector categories (cattle, dairy, hog, and poultry). More details on these models and a summary of the estimated loadings and post-compliance reductions are provided in the *Development Document* (USEPA, 2000a, 2002).

Edge-of-field loading estimates are used as inputs to EPA's water quality modeling framework that simulates the potential amount of pollutant loadings that reach U.S. waterways (measured as rivers and streams). The resultant loading estimates are referred to in EPA's analysis as "at-stream" loadings. Information on EPA's fate and transport model and a comparison of edge-of-field loadings and pollutants that reach U.S. waters is provided in the *Benefits Analysis* (USEPA, 2000d, 2002k). This analysis indicates that roughly 80 percent of all land applied manure runoff of nitrogen, phosphorous, and sediments (edge-of-field) reach U.S. waters (at-stream) (USEPA, 2000d, 2002k). The level of nutrients reaching U.S. waters can be explained by differing assumptions on a variety of levels, including manure generation by animal species, the share of animals in confinement, and losses due to volatization and management practice, as well as other factors, including rounding and truncation error and assumptions regarding background levels. Because EPA's at-stream estimates are not differentiated by broad animal sector categories (but reflect the total across all sector), the Agency uses the edge-of-field pollutant

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[4] A direct comparison of the environmental and human health impacts of these quantities is not possible because of different waste characteristics and waste-handling practices and regulations. The disposal of animal waste typically involves land application of all the manure without an associated point source discharge (if properly applied), and it has been largely unregulated. Human sanitary waste, by contrast, is typically treated at a wastewater treatment plant. The liquid effluent is discharged after treatment to surface water and the residual solids (sludge, or biosolids) are land applied, landfilled, or incinerated. Both the effluent and the biosolids are highly regulated (USEPA, 2002m).

loading reductions adjusted by the delivery rates (expressing the change between edge-of-field and at-stream concentrations) to determine the at-stream loading reductions for use in the cost-effectiveness analysis. This allows EPA to differentiate the cost-effectiveness among the four broad sector groups.

E.3 COST-EFFECTIVENESS ANALYSIS: NUTRIENTS AND SEDIMENTS

For this analysis, EPA estimated average cost-effectiveness values that reflect the increment between no revisions to the current regulations and the final regulatory requirements in the final regulations. Estimates reflect the cost-effectiveness of removing selected non-conventional and conventional pollutants, including nitrogen, phosphorus, and sediments. For this analysis, sediments are used as a proxy for TSS. All costs are expressed in pre-tax 2001 dollars. Estimated compliance costs used to calculate the cost-effectiveness of the final regulations include total estimated costs to CAFOs and costs to the permitting authority.

This analysis does not follow the methodological approach of a standard C-E analysis. Instead, it compares the estimated compliance cost per pound of pollutant removed to a recognized benchmark, such as EPA's benchmark for conventional pollutants or other criteria for existing treatment, as reported in available cost-effectiveness studies. A review of this literature is provided in Section E.3.1 and is based on an assessment of the types of management practices that would be implemented to comply with the final regulations. Section E.3.2 presents the results of EPA's analysis and compares these results obtained for the final regulations with other regulatory alternatives considered by EPA during the development of this rulemaking.

E.3.1 Review of Literature

To evaluate the cost per pound removal of nutrients and sediments, EPA reviewed the available information on pollutant removal costs for nutrients and sediments. This research can be broadly grouped according to estimates derived for industrial point sources and various nonpoint sources, including agricultural operations. In general, the point source research provides information on technology and retrofitting costs—and in some cases, cost per pound of pollutant removed—at municipal facilities, including POTWs and WWTPs. This research differs from other cost-effectiveness estimates, because it uses actual cost data collected at a particular facility undergoing an upgrade. Other cost-effectiveness information is available based on the effectiveness of various nonpoint source controls and best management practices (BMPs) and other pollutant control technologies that are commonly used to control runoff from agricultural lands. Typically, this information uses a modeling approach and simulates costs for a representative facility.

For this analysis, EPA assumes the following benchmark values to evaluate cost-effectiveness. For nitrogen, EPA uses a cost-effectiveness benchmark established by the Agency's Chesapeake Bay Program to assess the costs to WWTPs to implement system retrofits to achieve biological nutrient removal. This nitrogen benchmark estimate is approximately $4 per pound of nitrogen removed. For phosphorus, EPA assumes a cost-effectiveness benchmark of roughly $10 per pound based on a review of values reported in the agricultural research of the costs to remove phosphorus using various nonpoint source controls and management practices. For sediments, EPA uses a POTW benchmark for conventional pollutants removed (total suspended solids and biological oxygen demand) of about $0.73 per pound. More information on these benchmark values is as follows.

Table E-4 summarizes the cost-effectiveness values for nutrients and sediments reported in the studies that EPA reviewed for its analysis. A wide range of costs per pound of pollutant removed is estimated by those studies where estimates span both point sources and nonpoint sources, as well as those where estimates span a range of municipal, urban, and agricultural practices. Annualized costs also vary widely depending on various factors, such as the type of treatment system or practice evaluated, and whether the costs are evaluated as a retrofit to an existing operation or as construction of a new facility.

A series of case studies were compiled by researchers at Virginia Tech, who evaluated total costs for biological nutrient removal (BNR) retrofits at WWTPs throughout the Chesapeake Bay watershed (Randall et al., 1999). These case studies were compiled to estimate a range of costs per pound of nitrogen removed at these facilities. This research was commissioned by EPA's Chesapeake Bay Program and was conducted with the assistance of the Maryland Department of the Environment and the Public Utilities Division of Anne Arundel County. As part of this work, BNR retrofit costs were estimated for 51 WWTPs located in Maryland, Pennsylvania, Virginia, and New York. The final report in this series compares these costs to the projected change in effluent total nitrogen concentrations, assuming that the influent flow meets the design or projected flow after 20 years (Randall et al., 1999). As shown in Table E-4, this study concludes that the costs of nitrogen removal are very plant-specific, with the costs per pound of addition nitrogen removal ranging from $0.79 per pound to $5.92 per pound (Randall et al., 1999).[5] The range of these estimates is comparatively narrow given that the study examines a single retrofit category across similar facilities. The time frame for this analysis ranges from 1995 to 1998 according to the available case study data for each WWTP. A 20-year capital renewal period is assumed; interest and inflation rates of 6 and 3 percent, respectively, are used (Randall, 2000). The primary emphasis in this study is nitrogen, since the cost to upgrade for phosphorus removal is both configuration- and site-specific (Randall, 2000).[6]

Based on this analysis and other data from the Maryland Department of the Environment, EPA's Chesapeake Bay Program Office has derived a cost-effectiveness value for BNR of $3.64 per pound of nitrogen removed, as shown in Table E-4 (Wiedeman, 1998). Based on this information and the results of the Randall study, EPA's cost-effectiveness analysis assumes that an estimated cost to remove nitrogen of less than $4 per pound demonstrates cost-effectiveness.

A number of other studies have been conducted to assess the cost-effectiveness of various state-level programs to reduce nutrients in Wisconsin (NEWWT, 1994), Vermont (LCBP, 2000), and North Carolina (Tippett and Dodd, 1995). In Wisconsin, a series of studies were conducted to compare the cost-effectiveness of point and nonpoint source controls across 41 subwatersheds in the Fox-Wolf watershed (NEWWT, 1994). These studies estimated the cost of reducing phosphorus and TSS loads from municipal treatment facilities and agricultural sources. Baseline projections were compared to necessary reductions to meet future water quality objectives, as mandated by that State's current regulations. The base year for the analysis is 1990. Phosphorus removal costs for rural sources are

[5]The costs per pound of additional nitrogen removed were flow-weighted to determine the average for each state and for all plants evaluated.

[6]For conventional plug-flow activated sludge configurations, all that is required for phosphorus removal is the installation of relatively low-cost baffles and mixers; for oxidation ditches, the addition of an anaerobic reactor separate from the ditch is needed (Randall, 2000).

estimated at $9.64 per pound, whereas municipal treatment facilities are associated with an average annual cost of $165 per pound of phosphorus removed (NEWWT, 1994).

The Lake Champlain Basin Program (LCBP) conducted a similar study to evaluate costs to meet Vermont's water quality goals. The study estimated phosphorus removal costs ranging from $270 to more than $1,000 per pound at a large municipal facility, compared to $440 to $544 per pound of phosphorus removed using agricultural BMPs (LCBP, 2000). The base year for this analysis is 1995. Another study by Research Triangle Institute assessed the cost-effectiveness of agricultural BMPs for North Carolina's nutrient trading program. Estimated costs ranged from $2.72 to $135.17 per pound of phosphorus removed using anaerobic lagoons, and $0.36 to $34.27 per pound of phosphorus removed for land application practices (Tippett and Dodd, 1995). Estimated costs reflect the wide range of costs associated with land application, given preexisting practices at different types of operations. Costs summarized for this analysis span 1985 to 1994. Estimated values are shown in Table E-4. Observations by researchers at Virginia Tech who estimated removal costs for nitrogen at WWTPs conclude that it will cost about the same to remove a pound of phosphorus as it costs to remove a pound of nitrogen, if removing only one nutrient. If the facility is upgraded to remove both nitrogen and phosphorus, the cost typically will be only slightly more than the cost to remove nitrogen alone (Randall, 2000).

For this analysis, EPA assumes a benchmark of $10 per pound to remove phosphorus. This estimate is a conservative estimate given the range of estimates in the literature (Table E-4). Since the 2001 Proposal, EPA has obtained additional research estimates that further justify use of the benchmark value for phosphorus. Faeth (2000) measures the cost per pound of phosphorus removed for controls under different policy scenarios for both point source and agricultural conservation practices.[7] Estimates are based on three case studies: Minnesota River, Saginaw Bay, and Rock River. For point sources, Faeth estimates a range of costs from $10.40 to $23.90 per pound of phosphorus removed, averaging about $18 per pound removed. Estimates for agricultural sources range from $9.50 to $16.30 per pound of phosphorus removed, averaging $10.50 per pound removed.

EPA's benchmark to compare the potential costs per pound of sediments removed is the cost reasonableness test the Agency established in developing technology-based effluent limits for conventional pollutants (see 51 FR 24982). This benchmark measures the cost per pound of TSS and BOD removed for an "average" POTW with a flow of 2.26 million gallons per day (USGPO, 1986).[8] Indexed to 2001 dollars, these costs are about $0.73 per pound of TSS and BOD removed. EPA used this benchmark to evaluate the estimated cost per pound of TSS removed by municipalities in a recent EPA rulemaking, which estimated the range of costs for stormwater controls to be between $0.04 to $0.18 per pound of TSS removed (USEPA, 1999f). The Northeast Wisconsin Water for Tomorrow studies estimate average cost to reduce TSS of $0.008 per pound removed from rural land and $4.61 per pound removed at municipal treatment facilities (NEWWT, 1994).

[7] Point source performance requirements and conventional subsidies for agricultural BMPs, respectively.

[8] The technologies used for secondary treatment at POTWs removes both TSS and BOD at the same time. Estimating only the tons of TSS removed from secondary treatment is not possible.

Table E-4. Summary of Pollutant Removal Cost Estimates and Benchmarks

Type of Pollutant	Low Estimate	High Estimate	Treatment Type	Literature Sources
	($ per pound removed)			
Total Nitrogen (TN)	$0.79	$5.92	WWTPs	Randall et al, 1999
	--	$3.64	WWTPs	Wiedeman, 2000
	$0.91	$9.53	Ag lagoon	Tippett and Dodd, 1995
	$0.09	$2.18	Ag land application	Tippett and Dodd, 1995
Total Phosphorus (TP)	$5.76	$16.29	Conventional subsidies for agricultural BMPs	Faeth, 2000
	$10.38	$23.89	PS performance requirements	Faeth, 2000
	$9.64	$165.00	Ag (low) to municipal (high)	NEWWT, 1994
	$270.34	$1,179.35	Large PS facility (0.2 mg/L)	LCBP, 1995
	$439.99	$544.32	Agricultural BMPs	LCBP, 1995
	$2.72	$135.17	Ag lagoon	Tippett and Dodd, 1995
	$0.36	$34.27	Ag land application	Tippett and Dodd, 1995
Total Suspended Solids (TSS)	$0.01	$4.61	Ag.(low) to municipal (high)	NEWWT, 1994
	--	$0.25 [a]	POTWs (BOD and TSS)	USGPO, 1986
	$0.04	$0.18	Urban Stormwater Controls	USEPA, 1999f

[a/] TSS and BOD removals (1976 dollars). Indexed to 2001 dollars, costs are about $70 per pound removed.
Full citations are provided in references. Time frames of dollar values shown vary by source (shown below).
Notes summarize timeframe of analysis, study assumptions (where available), and range of sources/treatment.
Faeth, P. (2000): Case-studies in Minnesota River, Saginaw Bay, Rock River. Study include estimates under permit trading scenarios (not shown in table).
Randall et al. (1999): 1995-1998; 6% interest and 20-year capital renewal; BNR retrofits at WWTP only.
NEWWT (1994): 5% interest and 20-year capital renewal; low bound is agricultural BMPs and high bound is municipal treatment facilities.
Tippett and Dodd (1995): No discount rate was applied, and annual cost equals total lifetime costs adjusted by design life (varies by practice); "Ag lagoon" signifies aerobic lagoon and "Ag land" is land application (both with varying increasing overapplication of land applied manure under preexisting conditions). Cost-effectiveness values that assume direct discharge of animal wastes are not shown.
LCBP (2000): 1995: No discount rate was applied, and annual cost equals total lifetime costs adjusted by design life (varies by practice); low bound is agricultural BMPs and high bound is larger industrial point sources.

E.3.2 Cost-Effectiveness Results

Table E-5 shows the results of EPA's cost-effectiveness analysis for across all subcategories under both Option 1 and Option 2. Results are shown in terms of the average cost-effectiveness, reflecting the increment between no regulation and these two regulatory options. For this rule, EPA estimates an average cost-effectiveness of nutrient removal ranging from about $2 per pound to $3 per pound of nitrogen removed (pre-tax, 2001 dollars) between Option 1 and Option 2. For phosphorus removal, removal costs range from about $6 per pound to $7 per pound of phosphorus removed under these two options. All values are based on approximated "at stream" concentrations.

EPA's estimated cost-effectiveness to remove nitrogen falls within the estimated range of removal costs and is less than the average benchmark value assumed for this rule. For phosphorus, EPA assumed a cost-effectiveness benchmark of roughly $10 per pound based on a review of values reported in the agricultural research of the costs to remove phosphorus using various nonpoint source controls and management practices. EPA's estimated cost-effectiveness to remove phosphorus under this rule also falls below the $10 per pound benchmark value, indicating that the requirements are cost-effective. This is particularly true when compared to the reported cost to remove phosphorus at industrial point source dischargers, where reported average costs are twice that for agricultural sources and often exceed $100 per pound of phosphorus removed. For sediments, EPA's estimated per-pound removal cost is low compared to EPA's POTW benchmark for conventional pollutants for some options. Based on these results, EPA concludes that these regulatory options demonstrate cost-effectiveness.

Table E-5 shows the results of EPA's analysis by major subcategory groupings (cattle, dairy, hogs, poultry) for both Option 1 and Option 2. As shown, removal costs vary by commodity sector. In general, the cost to remove a pound of nitrogen or phosphorus is greatest in the hog and dairy sectors.

Given estimates of generally lower removal costs for nutrients, Option 1 may be considered more cost-effective than Option 2 (where removal costs are estimated to be higher). See Table E-5 and E-6. Results shown in these tables also present the incremental cost-effectiveness of Option 2 relative to Option 1. Incremental cost-effectiveness is the appropriate measure for comparing one regulatory alternative to another for the same subcategory. In general, the lower the incremental C-E value, the more cost-efficient the regulatory option is in removing pollutants. As shown in the table, Option 1 may be considered more cost-efficient relative to Option 2 since the incremental cost between Option 2 from Option 1 is higher than that the average cost-effectiveness for Option 1.

The results presented here do not show the average or incremental cost-effectiveness estimates for other regulatory options considered by EPA during the development of this rulemaking, including Option 3 and Option 5. This analysis was provided in the Proposal EA evaluating these options, indicating that these alternative options were less cost-effective and less cost-efficient than both Option 1 or Option 2. These general conclusions should hold for the final rule analysis as well. For the final rule, the total costs of Options 3 and 5 are higher than that estimated for Option 2 (see cost estimates provided in Table 3.5 in Section 3 of this report); also EPA does not expect a corresponding substantial change in the estimated pollutant reductions for these options, as compared to Option 2 (see summary tables presented in Section 5.4 of this report). Given generally higher costs and roughly similar reductions for these alternative options, as compared to Option 2, these options are likely less cost-effective and less cost-efficient at removing nutrients than both Option 1 and Option 2.

Table E-6 shows the results of EPA's cost-effectiveness analysis of removing sediments. Under Option 2, EPA estimates the cost-effectiveness of sediment removal at $0.30 per pound (pre-tax, 2001 dollars). This estimated per-pound removal cost is low compared to EPA's POTW benchmark for conventional pollutants of about $0.70 per pound of TSS and BOD removed. Sediment removal costs under Option 1, however, are considerably greater than for Option 2 (because of much lower estimated removals for that option, see summary tables in Section 5.4). The average cost-effectiveness for this option is estimated at nearly $2.70 per pound of sediment removed (thus exceeding EPA's benchmark).

Table E-5. Cost-Effectiveness Results: Nutrients ($2001), Option 1 & Option 2

Option/ Scenario	Total Cost [a]	Nitrogen			Phosphorus		
		Removals	Avg. C-E	Increm. C-E	Removals	Avg. C-E	Increm. C-E
	($mill.)	(mill. lbs.)	($/lb. removed)		(mill. lbs.)	($/lb. removed)	
Option 1: All Subcategories							
>1000 A	$115.5	72.6	$1.59	----	20.8	$5.55	---
300-1,000 AU	$19.1	4.8	$3.98	----	1.3	$14.28	---
>300 AU	$134.5	77.4	$1.74	----	22.1	$6.07	
Option 1: Individual Sectors							
Cattle [c]	$22.3	36.7	$0.61	----	11.9	$1.87	---
Dairy	$71.0	15.3	$4.65	----	3.5	$20.40	---
Hog	$8.8	0.3	$32.92	----	0.1	$105.26	---
Poultry [c]	$32.4	25.0	$1.30	---	6.7	$4.83	---
Option 2: All Subcategories							
>1000 A	$278.3	83.4	$3.34	$15.00	42.9	$7.03	$8.67
300-1,000 AU	$37.7	6.0	$6.25	$15.11	4.1	$10.93	$8.80
>300 AU	$316.0	89.5	$3.53	$15.02	47.0	$7.34	$8.69
Option 2: Individual Sectors							
Cattle [c]	$93.9	39.0	$2.41	$32.14	17.8	$5.29	$12.20
Dairy	$150.2	16.1	$9.32	$94.02	5.9	$26.00	$34.51
Hog	$33.0	4.0	$8.18	$6.43	7.3	$8.04	$6.02
Poultry [c]	$38.9	30.3	$1.28	$1.22	16.3	$2.54	$0.75

Source: USEPA. "Incremental C-E" measures Option 2 as incremental to Option 1.
[A] Costs are pre-tax and indexed to 2001 dollars using the Construction Cost Index (ENR, 2000, 2002).
[b] "Cattle" includes beef, heifer, and veal operations. "Poultry" includes broiler, egg, and turkey operations.

Table E-6. Cost-Effectiveness Results: Sediments ($2001), Option 1 & Option 2

Option/ Scenario	Total Cost [a/]	Sediments Removed	Average Cost-Effectiveness	Incremental Cost-Effectiveness
	($mill.)	(million lbs.)	(average $ per pound removed)	
Option 1: All Subcategories				
>1000 AU	$115.5	1,327.8	$0.09	---
300-1,000 AU	$19.1	7.1	$2.69	---
>300 AU	$134.5	1,334.9	$0.10	---
Option 2: All Subcategories				
>1000 AU	$278.3	1,626.6	$0.17	$0.54
300-1,000 AU	$37.7	85.3	$0.44	$0.24
>300 AU	$316.0	1,711.9	$0.18	$0.48

Source: USEPA.
[a/] Costs are pre-tax and indexed to 2001 dollars using the Construction Cost Index (ENR, 2000, 2002).

E.4 COST-EFFECTIVENESS ANALYSIS: TOXIC POLLUTANTS

EPA decided not to conduct a more traditional C-E analysis for selected toxic pollutants for the final regulations, given that these compounds are present in trace amounts in animal manure (see Table E-3). Nevertheless, this section provides a brief summary of EPA estimates of the weighted pound-equivalent removals for selected toxic pollutants. These estimates provide a means to evaluate the appropriateness of whether EPA should conduct a more traditional C-E analysis for selected toxic pollutant removals given that the principal pollutants of concern for this rule are nutrients and sediments.

This analysis follows the guidelines of the standard C-E analysis commonly used by EPA to compare the efficiency of regulatory options for effluent guidelines in removing priority and non-conventional pollutants. More detailed information is provided in the Proposal EA (USEPA, 2001a). EPA's standard C-E analysis evaluates cost-effectiveness as the incremental and average annualized cost of a pollution control option in an industry (or industry subcategory) per incremental and total pound equivalent of pollutant (i.e., pound of pollutant adjusted for toxicity) removed by that control option. This analysis involves the following seven steps:

1. Determine the pollutants of concern (priority or other pollutants).
2. Estimate relative toxic weights for these pollutants.
3. Define the regulatory pollution control options.
4. Calculate pollutant removals for each control option.
5. Determine the total annualized cost for each control option.
6. Calculate cost-effectiveness values (and adjust to 1981 dollars).
7. Compare cost-effectiveness values.

For this discussion, EPA addresses only steps 1 and 2. However, Section 5.3 of this report summarizes how the pollutant loadings estimated for the final regulations are calculated for each animal sector under each regulatory option for comparison with baseline loadings (steps 3 and 4). For more information, see the *Development Document* (USEPA, 2002). Total costs of the rule are presented in Section 3.3 (step 5).

For this C-E analysis, EPA identified six toxic pollutants of concern (step 1), including arsenic, zinc, copper, cadmium, nickel, and lead. Factors considered in selecting these pollutants included toxicity, frequency of occurrence in wastestream effluent, and amount of pollutant in the waste stream (USEPA, 2002). As shown in Table E-3, this is a subset of all the toxic compounds reported to be present in farm animal manures (which vary by animal type). Therefore, the cost-effectiveness results presented here are conservative (i.e., a higher per-pound removal value is estimated than would be the case if all metals were considered in this analysis).

In C-E analyses, pollutant removals are measured in toxicity normalized units called "pounds-equivalent," where the pounds-equivalent removed for a particular pollutant is determined by multiplying the number of pounds of a pollutant removed by each option by a toxocity weighting factor (TWF) for each pollutant. These factors are used to account for differences in toxicity among pollutants and to adjust the estimated pollutant loading values to account for the fact that different pollutants have different potential effects on human and aquatic life (e.g., a pound of zinc in an effluent stream has a different effect than a pound of arsenic).

The TWF is the sum of two criteria-weighted ratios: the "benchmark/old" copper criterion divided by the human health criterion for the particular pollutant and the "benchmark/old" copper criterion divided by the aquatic chronic criterion. TWFs for pollutants are derived using ambient water quality criteria and toxicity values.[9] The factors are standardized by relating them to a "benchmark" toxicity value that was based on the toxicity of copper when the methodology was developed.[10] For most pollutants, TWFs are derived from chronic freshwater aquatic criteria. In cases where a human health criterion has also been established for the consumption of fish, the sum of both the human and aquatic criteria are used to derive toxic weighting factors. More information is in Appendix E of the Proposal EA.

Table E-7 presents the TWFs for the regulated pollutants used in this C-E analysis (step 2) and the resultant pound-equivalent estimates for the six metallic compounds (cadmium, copper, nickel, lead, zinc, and arsenic). These estimates are measured in terms of in-stream concentration and have been adjusted from EPA's estimated "edge-of-field" estimates assuming that about 70 percent of land applied manure reached U.S. waters. As was d one for nutrients and sediments, this estimate is based on extensive simulations of EPA's water quality model developed for this rulemaking. This analysis indicates that roughly 70 percent of all land applied manure metal constituents reach U.S. waters (measured as rivers and streams). For more information, see Appendix E of the Proposal EA and also the *Benefits Analysis* (USEPA, 2000d, 2002k).

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[9]Human health and aquatic chronic criteria are maximum contamination thresholds. Units for criteria are micrograms of pollutant per liter of water. Most values are those reported in the toxicology literature.

[10]Although the water quality criterion has been revised (to 12.0 µg/L), all C-E analyses for effluent guideline regulations continue to use the "old" criterion of 5.6 µg/L as a benchmark so that cost-effectiveness values can continue to be compared to those for other effluent guidelines. Where copper is present in the effluent, the revised higher criterion for copper results in a TWF for copper of 0.467 rather than 1.0.

The resultant weighted pound-equivalent removals of these pollutants are less 200,000 pounds, or less than one-tenth of one million pounds-equivalent (Table E-7). Table E-7 shows results for both Option 1 and Option 2. The magnitude of these reductions is low compared to those estimated for other effluent guideline regulations where priority pollutants are the primary pollutants of concern. These findings are consistent with the fact that these substances exist in trace amounts in animal manure and wastewater. Table E-3 shows estimates by ASAE of the concentration of these pollutants in animal waste.

Table E-7. Total Metal Removals ("At Stream" Concentrations)

Metal	TWF	Option 1		Option 2	
		Lb.	Lb.-Eq.	Lb.	Lb.-Eq.
		(millions of pounds or pounds-equivalent)			
Zinc	0.05	0.0905	0.0043	0.0936	0.0044
Copper	0.63	0.0174	0.0110	0.0194	0.0122
Cadmium	2.60	0.0009	0.0024	0.0013	0.0035
Nickel	0.11	0.0080	0.0009	0.0091	0.0010
Lead	2.20	0.0059	0.0131	0.0081	0.0178
Arsenic	4.00	0.0042	0.0167	0.0085	0.0341
Total	**NA**	**0.1270**	**0.0484**	**0.1401**	**0.0730**

Source: TWFs are calculated by EPA and are based on freshwater chronic criteria for copper (USEPA, 2000j). Pound removals are estimated by EPA (USEPA, 2002). Pounds-equivalent are calculated by multiplying the estimated pound of removals by the TWFs shown here.