# 6 TRIBUTARY STRATEGIES IMPLEMENTATION

***Convenor: Mr. Michael Haire***

*Toward a Sustainable Coastal Watershed:*
*The Chesapeake Experiment. Proceedings of a Conference*
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# Implementation of the Point Source Nutrient Controls in the Chesapeake Bay Watershed

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***Abstract***: Beginning with the Upper Chesapeake Bay Phosphorus Limitation Policy in 1979, the Chesapeake Bay jurisdictions have developed and implemented regional point-source control policies to improve water quality and dissolved oxygen conditions in the Bay. Most recently, the Chesapeake Bay Agreement of 1987 committed the Bay states to reduce phosphorus and nitrogen loads to the Bay by 40% by the year 2000.

This paper reviews the effectiveness of these policies in reducing point-source nutrient loads and reports on the status of state efforts to control point-source loads in response to the 1987 Agreement.

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# AGRICULTURE AND WATER QUALITY: THE ECONOMIC EFFECTS OF NUTRIENT MANAGEMENT

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***Abstract:*** Agricultural production is a major source of pollutants contributing to reduced water quality in the Chesapeake Bay. Fertilizers and pesticides leach to groundwater and run off into surface water bodies that flow into the Bay. These pollutants can be reduced through nutrient management. For example, changes in the amount, timing, source, and method of application of fertilizers can reduce both runoff and leaching of nutrients. However, these changes have potential impacts on farm revenues and costs and thus on profitability. Policies designed to encourage farmers to improve nutrient management and thus reduce pollution may be necessary if farmers are to be induced to engage in these practices.

This paper uses a linear programming model of a representative dairy farm in the Lower Susquehanna River basin to examine the potential effects of improved nutrient management on both farm profitability and pollution. The model, which was developed primarily by researchers at Virginia Polytechnic Institute, includes information about both economic parameters and site characteristics. Site characteristic data were obtained from the Area Studies Survey conducted by the Economic Research Service at of the U.S. Department of Agriculture. A hypothetical tax on nitrogen runoff is used to induce improved nutrient management. The effect of the tax on both profitability and runoff is examined. The paper draws conclusions about the potential for using nutrient management as a pollution control approach.

## INTRODUCTION

Agricultural production is a major source of pollutants contributing to reduced water quality in Chesapeake Bay (U.S. Environmental Protection Agency 1993, Maryland Department of the Environment 1993). Fertilizers and pesticides leach to groundwater and run off into surface water bodies that flow into the Bay (Donigian et al.). These pollutants can be reduced through nutrient management. For example, changes in the amount, timing, source, and method of application of fertilizers can reduce both runoff and leaching of nutrients (Huang et al. 1994, Bosch et al. 1994). Similarly, changes in crop mix and tillage can affect required nutrient applications and/or the associated runoff and leaching. However, these changes have potential impacts on farm revenues and costs and thus on profitability. Policies designed to encourage farmers to improve nutrient management and thus reduce pollution may be necessary if farmers are to be induced to engage in these practices. The effectiveness of these policies depends on the availability and cost of alternative nutrient management approaches.

This paper uses a linear programming model of a representative dairy farm in the lower Susquehanna River basin to examine the potential effects of reducing nitrogen runoff on both farm profitability and pollution. The model, which was developed primarily by researchers at Virginia Polytechnic Institute and State University (VPI), includes information about both economic parameters and site characteristics. Restrictions on nitrogen delivery are used to induce improved nutrient management. The relationship between profitability and nitrogen delivery is examined. The paper draws conclusions about the potential for using nutrient management as a pollution control approach.

**The Study Area**

The lower Susquehanna River basin is located primarily in southern Pennsylvania, with a small portion lying in Maryland (see figure 1). About 35% of the basin is engaged in agricultural activities. The region includes areas with heavy nitrogen applications, both from commercial fertilizer and manure spreading (see figure 2). For example, commercial nitrogen fertilizer was applied to 91% of the corn for grain (field corn) acres in the region, with an average application rate of 66 lbs/acre/year. Similarly, 84% of the silage acreage received commercial nitrogen applications, with an average application rate of 58 lbs/acre/year. In addition, manure was applied to 63% of the field corn acreage and 91% of the silage acreage (U.S. Department of Agriculture 1993). One of the heaviest manure spreading areas is Lancaster County, located in the southeastern part of the basin.

Because of the heavy fertilizer use in the area and the potential contribution to pollution in Chesapeake Bay, the lower Susquehanna River basin was chosen as one of several areas to be included in the Area Study Project conducted jointly by the Economic Research Service (ERS), the Soil Conservation Service (SCS), the U.S. Geological Survey (USGS), and the National Agricultural Statistics Service (NASS). The Area Study Project was developed under the President's Water Quality Initiative. In each of the study areas, survey data were collected on agricultural activities, including both field-level and whole farm data. The data relate to production technologies, cropping patterns, and agricultural activities (including conservation practices). The sample used for the survey was designed to overlap with sample points used in the National Resources Inventory (NRI), a survey conducted every 5 years by the SCS. The NRI is described in detail in Soil Conservation Service and Iowa State Statistical Laboratory (1987). The NRI collects information on physical and natural resource characteristics of the site. Linking the two surveys thus provides site-specific information on both physical and economic characteristics of farms. Availability of these data provides a unique opportunity for modeling environmental problems, such as water quality where the pollution levels depend on both physical characteristics of the land and production decisions made by individual farmers.

The major crops produced in the lower Susquehanna study area are corn (field and for silage), alfalfa, other hay, and pasture. This reflects the distribution of farm types within the area. In the area 50% of the farms are dairy farms. Of those, 39% have sales

**Figure 1. U.S. Department of Agriculture studies survey sites.**

**Figure 2. The lower Susquehanna River basin.**

between $100,000 and $249,999, and 83% have sales between $60,000 and $499,999 (U.S. Department of Agriculture 1993). Thus, this study focuses on nutrient management on a typical dairy farm in the region with net revenues between $100,000 and $200,000.

The survey results indicate that some farmers in the region are already using nutrient management practices (U.S. Department of Agriculture 1993). For example, soil nitrogen tests were used on 14% of the field corn acreage and 23% of the silage acreage. In addition, as indicated in tables 1 and 2, many farmers are already engaging in some kind of conservation tillage or other conservation practices that can reduce fertilizer runoff, such as strip cropping. Conservation tillage (reduced and no-till) is used on well over half of the corn acreage, and nearly half of the corn acreage uses stripcropping.

**An Overview of the Model**

In an effort (1) to understand better the relationship between decisions regarding agricultural practices and water quality, and (2) to aid in the evaluation of policies aimed at improving water quality, researchers at VPI are developing a linear programming model of a representative dairy farm in the Lower Susquehanna River basin region (Bosch and Heimlich 1994). VPI researchers are using the underlying model structure to study other types of farms both within the region and in other regions as well. For a discussion of this research effort, see Bosch, et al. (1994). The model is being developed as part of a cooperative agreement between ERS, VPI, and the University of Connecticut. An interim version of the model is used in this research. The model is being refined in response to comments and feedback from other researchers, therefore the results presented here are viewed as preliminary and subject to change as the model is improved. The model assumes that farmers make production decisions to maximize net revenues (i.e., revenues minus direct production costs), subject to a number of constraints (described below). These decisions in turn affect both runoff and leaching of nitrogen. The primary data sources for the economic and technological parameters of the model are the Area Study Survey, the Farm Costs and Return Survey (FCRS), the NRI, the Penn State Agronomy Guide (Serotkin 1993), and Penn State Enterprise Budgets (Department of Agricultural Economics and Rural Sociology 1993). The leaching and runoff parameters come primarily from Yagow et al. (1993).

**Table 1. Tillage types, In the lower Susquehanna River basin ( Pennsylvania, 1991)**

| Item | Corn(Field) | Corn (Silage) | All Tilled Land |
|---|---|---|---|
| Conservation Tillage: | 63 | 57 | 54 |
| No Till | 26 | 16 | 19 |
| Mulch/Other Cons. | 37 | 41 | 34 |
| Conventional Tillage: | 37 | 43 | 46 |
| Moldboard plow | 31 | 40 | 40 |
| Other Conventional | 6 | 3 | 6 |

Source: U.S. Department of Agriculture / Economic Research Service/ Resources And Technology Division

**Table 2. Conservation practicies, In the lower Susquehanna River basin (Pennsylvania, 1991)**

| Pratice | Corn (Field) | Corn (Silage) | Alfalfa | Hay | Pasture |
|---|---|---|---|---|---|
| Chiseling & subsoiling | 31 | 37 | 8 | N / A | N / A |
| Cover or green manure crop | 20 | 23 | 17 | 14 | N / A |
| Crop residue use | 44 | 39 | 15 | 7 | 20 |
| Grassed waterways | 33 | 26 | 20 | 10 | 5 |
| Stripcropping | 49 | 48 | 42 | 37 | N / A |
| Pasture & hay management | N/A | N / A | 35 | 18 | 15 |
| Planned grazing system | N/A | N / A | N / A | N / A | 15 |
| Rotations | 76 | 74 | 61 | 43 | N / A |

N/A indicates not applicable

Source: U.S. Department of Agriculture / Economic Research Service/ Resources And Technology Division

To maximize net revenues, the farmer makes decisions regarding the following:

- The size of the herd.
- The rations to be fed to the herd the possible rations are a 50-50 alfalfa-corn silage ration, a corn silage only ration, an alfalfa ration, and a haylage ration.
- The acreage for each crop the crops in the model are corn for grain, corn for silage, alfalfa, wheat, soybeans, oates, other hay, rye, and pasture.
- The crop rotation (if any) to be used.
- The tillage type to be used for each acre the possible tillages include conventional, reduced, no-till and none, although there are restrictions on the crop/tillage combinations that are allowed.
- The source of nutrients (including manure and purchased commercial fertilizer).
- The timing and method of application of nutri ents the timing refers to the season (winter, spring, summer, fall) and the method refers to whether the fertilizer is incorporated or not.
- The purchase and sale of crops.
- The amount of labor to be hired.

The two sources of revenue for the farmer are the sale of livestock and their products, which depends directly on the size of the herd, and the sale of crops produced on the farm. Any production in excess of the amount needed for feed is assumed to be sold. The direct costs that the farmer incurs include the costs of

- purchasing crops for feed,
- purchasing commercial fertilizer,
- building manure storage,
- spreading manure,
- purchasing pesticides,
- hiring labor, and
- other production costs such as machinery costs, seed, lime, etc.

In making his production-related decisions, the farmer is subject to a number of constraints. These include:

- limits on the amount of cropland and the amount of total land available,
- a capacity limit on the size of the herd,
- a capacity limit on manure storage,
- required per acre pesticide application levels for each crop and tillage combination, and
- required per acre nutrient application levels for each crop.

These requirements reflect crediting for nitrogen fixation by legumes, the nutrient content of manure that is spread, and residual levels of potash and phosphate in the soil as detected by soil tests. In addition, adjustments are made to reflect volatilization, runoff, and leaching prior to crop uptake.

In addition to the resource constraints, the farmer is subject to a number of balance equations. For example, the farmer must ultimately spread all of the manure that is produced (although he can adjust the timing of the spreading through storage). In addition, he must have enough ration to feed his herd and cannot sell more of a crop than the amount that he produces in excess of his feed requirements.

The farmer's decisions regarding his crop acreages, his nutrient sources, and the timing and method of application of nutrients then combine with site characteristics to determine the amount of soluble nitrogen runoff, nitrogen loss in sediment, and nitrogen leaching from the farm. Delivery ratios based on the distance from the field to the nearest water body and the intervening land cover are then used to predict total nitrogen delivered to the water body. This includes both nitrogen from fertilizer use and natural sources such as nitrogen in precipitation and mineralization of soil organic nitrogen.

A summary of the output of the model in the absence of any specific nutrient management policy is given in the first column of table 3. This represents a preliminary estimation of the operating decisions of the farm that would maximize net returns without any government policy aimed at pollution reduction. Under this base case, the farm's net returns, i.e., returns above variable operating costs, are $138,110. The farm has a herd size of approximately 110 milking cows. It has 7.4 acres in a field corn-alfalfa rotation and 145.6 acres in a silage-alfalfa rotation, for a total of 3.7 acres of field corn, 72.8 acres of silage, and 76.5 acres of alfalfa. In addition, 17.0 acres are in continuous pasture. The farm produces alfalfa in excess of its feed requirements and sells the excess in the market. It must, however, purchase feed products from the market as well. The farm uses both cow manure and commercial nitrogen fertilizer as sources of nitrogen for the crops. Total nitrogen delivered to the nearest water body is 104.07 lbs.

### Effects of Nutrient Management

The model described above provides a tool for analyzing how improved nutrient management is likely to affect farm net returns. In particular, mapping the relationship between net returns and total nitrogen delivered to the nearest water body provides an indication of the economic impact of reductions in nitrogen delivery.

The model suggests that there is a range over which farmers can reduce nitrogen delivery while

**Table 3. Summary of cases**

| | Base Case | 10%Reduct. | 30% Reduct. | 70% Reduct |
|---|---|---|---|---|
| Net Revenue | $138,110 | $138,065 | $136,930 | $111,724 |
| Total nigtron delivered to stream | 104.1 | 93.7 | 72.9 | 31.2 |
| Total nitrogen leached | 1786.0 | 1482.5 | 1194.7 | 3500.0 |
| # of milking cows | 109.6 | 109.6 | 109.6 | 109.6 |
| <u>Feed Ration:</u> | | | | |
| corn-Silage | 109.6 | 109.6 | 109.6 | 78.1 |
| haylage | 0 | 0 | 0 | 35.5 |
| <u>Crop Acreage</u>: | | | | |
| <u>Total</u> | <u>170.0</u> | <u>170.0</u> | <u>170.0</u> | <u>122.7</u> |
| Alfalfa | 76.5 | 76.5 | 76.5 | 51.9 |
| Corn-Grian | 3.7 | 3.7 | 3.7 | 0 |
| Corn-Silage | 72.8 | 72.8 | 72.8 | 51.9 |
| Pasture | 17.0 | 17.0 | 17.0 | 18.9 |
| Rotation Acres w/ Stripcropping | 0 | 0 | 91.9 | 103.8 |
| <u>Manure Spreading:</u> | | | | |
| Winter | 0 | 80.5 | 107.6 | 0 |
| Spring | 168.4 | 189.2 | 189.2 | 0 |
| Summer | 47.4 | 47.4 | 81.6 | 378.5 |
| Fall | 162.7 | 61.4 | 0 | 0 |
| New Manure Storage | 0 | 0 | 0 | 189.2 |
| Commercial Nitrogen | 5.0 | 5.0 | 3.5 | 6.9 |

at the same time actually increasing net returns. This occurs through the adoption of no-till technology on corn. The output from the model suggests that a significant decrease in nitrogen delivery (from 235.8 lbs. to 104.07 lbs.) can be achieved through switching from conventional to no-till production of corn. The result is obtained by comparing the base case to a model run in which no-till and reduced-tillage corn acres are restricted to be zero ( thus forcing the model to choose conventional tillage for corn) Such a switch will also increase net returns from $136,462 to $138,110. Because no-till corn results in higher net returns, the base case run of the model includes no-till rather than conventional tillage for corn. Given the economic benefit from no-till, farmers can be expected to adopt this technology voluntarily. The data in table 1 regarding actual adoption of reduced or no-till provide some evidence that this is, in fact, occurring in the study region.

Further reductions in nitrogen delivery (to levels below 104.07 lbs.) are unlikely to be made voluntarily because any further reductions result in reductions in net returns. However, further reductions could be induced through government policies that either require or encourage those reductions. To analyze the economic effect of such policies, we consider hypothetical restrictions on nitrogen delivery. We consider different restrictions, ranging from a 10% reduction to a 90% reduction, and examine the impact of these restrictions on the net returns of the farm.

The net returns associated with the different restrictions are depicted in figure 3. The results suggest that farmers are able to achieve fairly large reductions in nitrogen delivery at relatively low cost, i.e., with relatively small reductions in net returns. For example, a 10% reduction in delivered nitrogen reduces net returns by only .03% (from $138,110 to $138,065). Similarly, a 50% reduction in delivered nitrogen reduces net returns by only 2.4%. Beyond 50%, however, further reductions cause much larger losses for farmers. For example, a 90% reduction in delivered nitrogen reduces net returns by over 50%.

A description of the adjustments that the farmer is predicted to make in order to reduce nitrogen delivery by the different amounts is given in table 3. As can be seen, a 10% reduction is achieved by simply changing the timing of manure spreading. Fall spreading is reduced, spring spreading is increased, and some manure is now spread during the winter as well. These changes reduce nitrogen runoff and thus nitrogen delivery. The cost comes primarily from increased labor costs.

A 30% reduction in delivered nitrogen is achieved by further changes in the timing of manure spreading (withfall spreading eliminated entirely) and by adopting strip cropping. All of the acreage in the corn for grain-alfalfa rotation is now in strip cropping, as is more than half of the acreage in the silage-alfalfa rotation. As a result, the amount of commercial nitrogen that is purchased is reduced. These changes reduce sediment loss. They thus reduce the amount of nitrogen loss in sediment, as well as the loss in runoff. Both of these effects contribute to the overall reduction in nitrogen delivery.

To achieve a 70% reduction in delivered nitrogen, more substantial changes are required, with a correspondingly larger reduction in net revenues. First, the farmer begins to idle some of his land. The total acreage in crop production falls from 170 acres to 122.7 acres. Corn for grain is no longer grown. All of the acreage in the silage-alfalfa rotation is now in strip cropping. The farmer must now purchase more feed and switches part of his feed ration to haylage. In addition, it now pays for the farmer to increase his manure storage capacity, which allows him to spread all of his manure during the summer. The combined effect is a further reduction in sediment delivery and a further reduction in the amount of nitrogen loss in both sediment and runoff. Note, however, that, in contrast to the previous cases, these reductions in delivered nitrogen are accompanied by an increase in the total nitrogen leached from the farm. This suggests that at this level of reduction a tradeoff between improvements in surface water quality and groundwater quality may exist.

**Figure 3. The impact of reduction in nitrogen on net revenue of firm.**

## CONCLUSION

This paper has used a model that combines information about both the economic and physical characteristics of a representative dairy farm in the lower Susquehanna River basin to examine the economic impacts of reductions in nitrogen delivery. The preliminary results suggest that significant reductions in nitrogen delivery are possible at no cost to the farmer through the adoption of no-till technology. In fact, adoption of no-till is predicted to result in a net increase in net farm returns. Thus, the resulting reductions in nitrogen delivery can be expected to occur voluntarily as farmers choose no-till (or reduced tillage) for purely economic reasons. However, adoption may require education and technical assistance or possibly even limited-term incentives to help overcome initial resistance due to uncertainty about the associated costs.

Beyond the adoption of no-till, however, further reductions in nitrogen delivery are likely to require government policies such as restrictions on allowable delivery. While such policies would impose costs on farms, the results reported here suggest that these costs would be relatively small for fairly substantial reductions in delivered nitrogen, at least for the type of dairy farm modeled here. For example, even a 50% reduction is estimated to reduce net returns for the farm by only about 2.4%. While future refinements of the model used here may produce different quantitative estimates of these costs, even a doubling of the costs would not change the general conclusion there appear to be some fairly low-cost means of achieving substantial reductions in delivered nitrogen. These include changes in the timing of manure spreading and the adoption of strip cropping. Such changes are predicted to result in a reduction of delivered nitrogen of at least 30%. Required reductions in excess of 50% might require more substantial changes in the farm's operation. For example, they might require changes in cropping patterns and eventually an idling of land. The costs of this type of adjustment are obviously higher. However, even a required reduction of 70%, which induces this type of adjustment, results in a loss of only about 20% of net revenue for the farm. Thus, while farmers are unlikely to adopt nitrogen-reducing practices (except no-till) voluntarily, government policies designed to induce them to do so do not appear to entail large costs for farmers of the type discussed here. Whether these conclusions would apply to farmers of other types remains to be seen.

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# THE EFFECT OF EROSION CONTROL PRACTICES ON PHOSPHORUS TRANSPORT FROM COASTAL PLAIN AGRICULTURAL WATERSHEDS

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***Abstract:*** Strategies for reducing phosphorus losses from cropland have generally focused on controlling soil erosion. Erosion and phosphorus surface runoff losses were measured continuously from 1984 through 1993 in adjacent field-scale coastal plain agricultural watersheds in which various widely utilized management strategies were implemented. No-till and conventional tillage practices were compared throughout the period. The effect of cereal grain winter cover crops was evaluated under both tillage regimes from 1988 through 1993. Grassed waterways were installed in both watersheds in 1990. No-till practices reduced soil losses, especially during the growing season. However, reduced erosion rates did not translate into reductions in total phosphorus losses. Winter cover crops had only minor effects on annual erosion losses, in that their primary impact coincided with a period of high residue cover in both watersheds. Soil losses from both watersheds decreased after the establishment of grassed waterways, most dramatically in the conventionally tilled watershed. However, reductions in particulate phosphorus transport were proportionately less than reductions in soil erosion, and erosion control practices demonstrated little potential for reducing dissolved phosphorus losses. Consequently, even near-complete control of soil erosion did not result in major reductions in total annual phosphorus losses. Reducing phosphorus transport from coastal plain cropland will require management of near-surface soil phosphorus concentrations.

## INTRODUCTION

As a result of the link established between nutrient loading and water quality degradation in Chesapeake Bay (U.S. Environment Protection Agency 1982), the current Bay restoration strategy has a goal of reducing both nitrogen and phosphorus inputs by 40% by the year 2000. Measurable reductions have been achieved in point-source phosphorus inputs to the Bay (Malone et al. 1993), but evidence of reductions in nonpoint source phosphorus inputs is less apparent. Estimates of nutrient inputs to the Bay from the Maryland portion of the watershed attribute over 40% of total phosphorus inputs to agricultural activities (Chesapeake Bay Program 1988), suggesting that reductions in phosphorus transport from agricultural land will be necessary if overall nutrient reduction goals for Chesapeake Bay are to be achieved.

In Maryland, initial efforts to reduce the impact of agricultural activities on Chesapeake Bay focused on educational and incentive programs to encourage implementation of practices designed primarily for reducing the movement of sediment from cropland (Staver et al. 1989). While this strategy has proven to be successful for reducing phosphorus transport into aquatic systems in agriculturally dominated watersheds predisposed to high rates of soil erosion (Forster et al. 1985), the link between soil erosion and phosphorus transport in the intensive grain/poultry producing areas located in the coastal plain region of the Chesapeake Bay watershed is less clear. Adding to this uncertainty are the likely changes in soil erosion/phosphorus transport relationships that have occurred in the last several decades owing to increases in the phosphorus content of agricultural soils in Maryland (F. Coale, University of Maryland, pers. comm.).

Long-term application of inorganic phosphorus at rates higher than crop removal rates will increase soil phosphorus levels, but even more dramatic increases occur when animal manures or sewage sludges, enriched in phosphorus relative to nitrogen, are applied to cropland at rates based on crop nitrogen requirements (Sharpley et al. 1994). The large quantities of poultry manure applied to cropland in the coastal plain region of the Chesapeake Bay watershed, as well as the utilization of cropland for application of sewage sludge (currently at rates based on crop nitrogen requirements) generated by treatment facilities in the large urban centers in the watershed, suggest that traditional erosion control practices may not be adequate for achieving desired reductions in phosphorus discharge rates from coastal plain cropland. This study investigated changes in phosphorus transport from field-scale coastal plain agricultural watersheds that occurred after implementation of several widely utilized erosion control practices.

## METHODS

This study was conducted in the Wye River drainage basin in Queen Anne's County, Maryland (38½ 55' N, 76½ 09' W). Soils at the site belong to the Elkton and Mattapex series, and are silty moderately well drained, and nearly level (0-3% slopes). Surface runoff was monitored in two naturally defined watersheds located completely within a 28 ha agricultural field from 1985 through 1993. The entire field has been planted continuously in corn for grain production since 1984, utilizing conventional tillage (CT) methods in one watershed and no-till (NT) methods in the other. Chisel plowing was the primary tillage operation employed in the CT watershed in conjunction with disking and the use of a field cultivator. Herbicides were used to control weeds in both watersheds following planting. Phosphorus was applied in a solution with nitrogen at planting in both watersheds at a rate of approximately 25 kg/ha in a band 5 cm below and 5 cm to the side of the seed. Generally, corn was planted in mid-May and grain was harvested in September. From 1984 through 1987 both watersheds remained fallow during the nongrowing season. Following grain harvest in 1988 through 1992, a rye cover crop was planted in both watersheds using a NT drill. Following corn harvest in 1990, 6 m wide grassed waterways were installed in both watersheds. For the entire study period, edge-of-field surface runoff volume was measured continuously and sampled volumetrically to determine surface runoff suspended solids (> 0.45 micron) and phosphorus transport rates (Staver et al. 1988).

## RESULTS

Differences in annual surface runoff volumes between the two watersheds were minor throughout this study. Runoff volume tended to be lower from the NT watershed during small runoff events during the growing season, but these differences were offset by slightly higher runoff volumes from the NT watershed during winter and early spring, as well as immediately following spring tillage in the CT watershed. Because precipitation patterns varied from year to year, statistical comparisons of runoff volumes after the use of winter cover crops was initiated in 1988, and after installation of grassed waterways in 1990, with baseline runoff volumes observed from 1985 through 1988 were not possible. From 1985 through 1988, annual precipitation averaged 87.8 cm, producing annual surface runoff volumes of 8.13 cm and 8.65 cm from the CT and NT watersheds, respectively, with over half of the runoff occurring from December through February (figure 1). For the 1992 and 1993 water years, during which

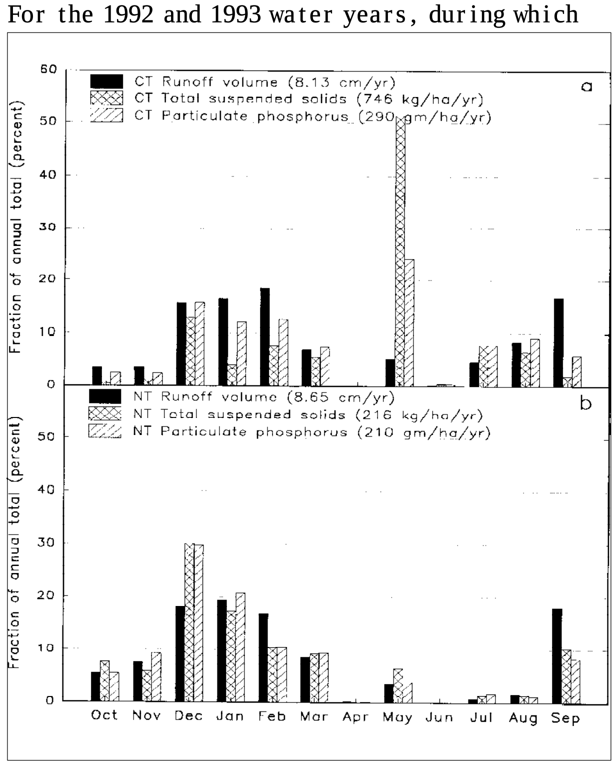


**Figure 1. Monthly fraction of annual total runoff volume, total suspended solids and particulate phosphorus transport from the conventional till (CT) and no-till (NT) watersheds from 1985 through 1988.**

winter cover crops were planted and grassed waterways were well established in both watersheds, annual precipitation averaged 92.4 cm, producing average annual surface runoff volumes of 14.14 cm and 12.24 cm from the CT and NT watersheds, respectively. Approximately half of the surface runoff from both watersheds during the 1992 and 1993 water years occurred during March (figure 2), when precipitation was approximately double long-term average rates. The higher rates of surface runoff after implementation of erosion control practices resulted primarily from changes in the distribution of precipitation during the postimplementation period, and an apparent absence of any strong negative influence of the erosion control practices on the generation of overland flow.

Although erosion control practices appeared to have only minor effects on surface runoff volume from the experimental watersheds, effects on sediment transport were much more evident. During the 1985-88 baseline period, total suspended solids (TSS) concentrations were consistently lower in runoff from the NT watershed, particularly when major runoff events occurred soon after corn planting (figure 3). Total suspended solid losses from the NT watershed were approximately 29% of those observed from the CT

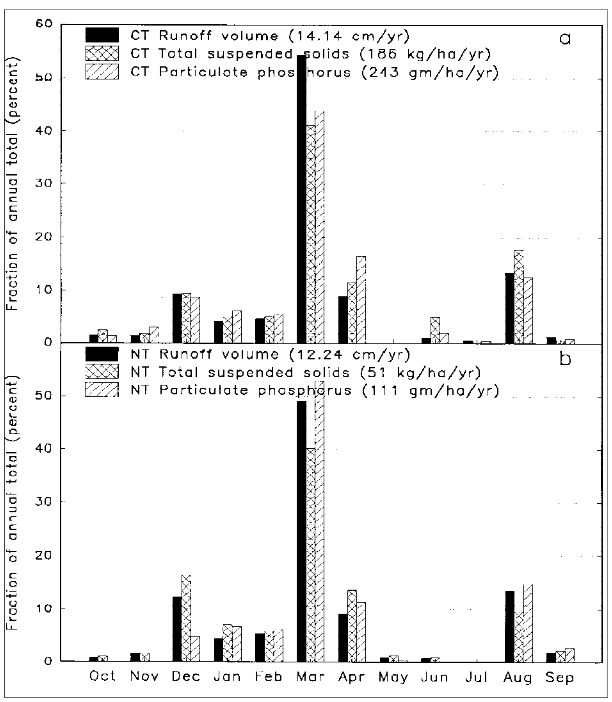


**Figure 2. Monthly fraction of annual total runoff volume, total suspended solids and particulate phosphorus transport from the conventional till (CT) and no-till (NT) watersheds for the 1992-93 water years.**

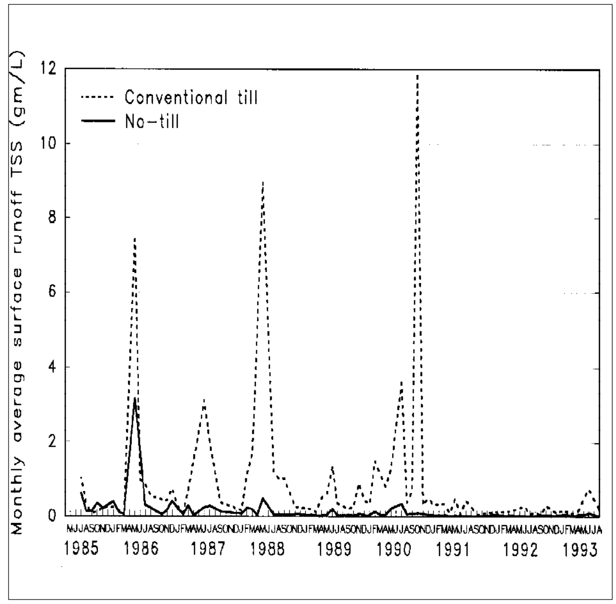


**Figure 3. Average monthly edge-of-field total suspended solids (TSS) concentration in surface runoff from the conventional till and no-till watersheds from May 1985 through September 1993.**

watershed. The largest differences were observed in May, when over half of the TSS losses occurred in the CT watershed as compared to only 6% in the NT watershed (figure 1). In the fall of 1990, the highest TSS concentrations observed in the entire study period were observed in the CT watershed when an intense storm occurred immediately after installation of the grassed waterway. After the waterways became well established, TSS concentrations were consistently low in both watersheds. Despite the higher annual rates of surface runoff during the 1992 and 1993 water years, annual TSS losses from both watersheds decreased approximately 75% relative to baseline conditions (figure 2). These reductions are somewhat misleading in the case of the CT watershed, given the lack of runoff during the high erosion potential postplanting period of the 1992 and 1993 water years. If May data are discounted, for the remaining months TSS loads from the CT watershed only decreased approximately 50% from the 1985-88 baseline observation period to the 1992-93 water years.

Differences in particulate phosphorus transport between the two watersheds during the 1985-88 baseline period were much less than were differences in TSS transport (figure 1). While annual TSS losses from the NT watershed averaged only 29% of those from the CT watershed, particulate phosphorus losses were approximately 72% of those from the CT watershed. The average phosphorus concentration of particulate matter transported in surface runoff during this period was 0.039 and 0.097% for the CT and NT watersheds, respectively. This suggests that the higher TSS concentrations in surface runoff from the CT watershed were attributable to the transport of particles having a relatively low phosphorus concentration. The variable relationship between TSS and particulate phosphorus transport was especially evident in May when over half of the TSS discharge, but only 24% of the particulate phosphorus discharge occurred from the CT watershed (figure 1).

The approximately 75% reduction in TSS transport rates that occurred in both watersheds from the 1985-88 baseline period to the 1992-93 water years resulted in much less dramatic reductions in particulate phosphorus transport (figure 1 and 3). Particulate phosphorus transport rates declined only 16 and 47% from the CT and NT watersheds, respectively, after the use of winter cover crops was implemented and grassed waterways were established in both watersheds. This suggests that the added management practices were most effective in preventing the movement of particles that had relatively low phosphorus concentrations. For the entire study period, the event volume-averaged phosphorus concentration of particulate matter in surface runoff decreased as TSS concentration increased (figures 4a and 5a), probably owing to the larger fraction of small phosphorus-rich particles that were transported in surface runoff when TSS concentrations were low, relative to when TSS concentrations were elevated. The water year average phosphorus content of particulate matter also decreased as average TSS concentration increased (figure 6), varying approximately by a factor of five in both watersheds. As a result of the decreasing particulate phosphorus concentration as TSS concentrations increased, surface runoff total phosphorus concentrations were only weakly tied to TSS concentrations (figures 4b and 5b).

Surface runoff dissolved phosphorus concentrations in the NT watershed were consistently higher than those in the CT watershed throughout the entire 9-year observation period (figure 7). Increased dissolved phosphorus transport from the NT watershed more than offset the reductions in particulate phosphorus transport resulting from the use of NT methods. NT methods did tend to reduce total edge-of-field phosphorus discharge during summer months, primarily as a result of lower runoff volumes, and higher particulate phosphorus losses from the CT watershed during intense summer convective storms. Neither winter cover crops or grassed waterways appeared to dramatically affect dissolved phosphorus concentrations in either watershed. Despite the differences in runoff patterns, volume-averaged surface runoff dissolved phosphorus concentrations were approximately 0.43 mg/L in the CT watershed during the 1985-88 baseline period as well as during the 1992-93 water years, and increased slightly in the NT watershed from 0.88 to 1.05 mg/L. As a result of only minor changes in dissolved phosphorus concentrations, surface runoff dissolved phosphorus transport increased between the baseline and treatment periods in proportion to the increase in runoff volume. As a result of decreases in particulate phosphorus transport, the ratio of dissolved to total phosphorus transport in surface runoff increased from 0.55 to 0.72 in the CT watershed, and from 0.78 to 0.92 in the NT watershed from the 1985-1988 baseline period to the 1992-93 water years. In both watersheds, total phosphorus concentrations were more closely tied to dissolved phosphorus concentrations (figure 8) than to TSS levels (figures 4b and 5b).

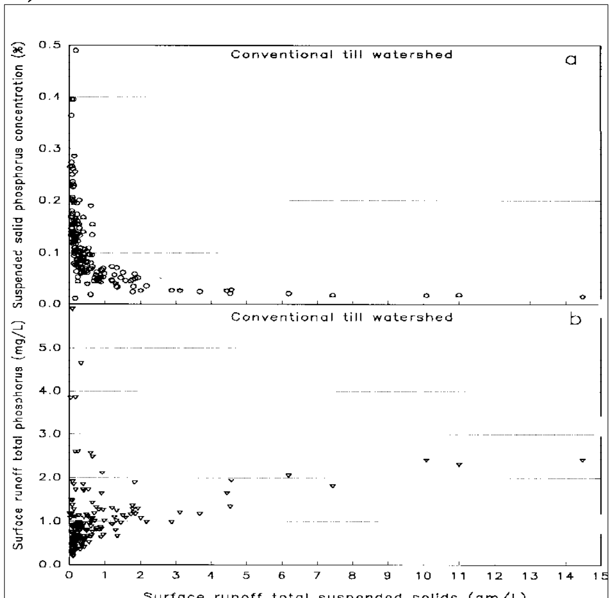


**Figure 4. Volume-averaged phosphorus content of suspended solids in surface runoff (a) and total phosphorus concentration (b) as functions of total suspended solids concentrations in all runoff events from the conventional till watershed from May 1985 through September 1993.**

**Figure 5. Volume -averaged phosphorus content of suspended solids in surface runoff (a) and total phosphorus concentration (b) as functions of total suspended solids concentrations in all runoff events from the no-till watershed from May 1985 through September 1993.**

**Figure 6. Volume-averaged phosphours content of suspended solids in surface runoff from the conventional till and no-till watersheds for the water years, from 1985 through 1993.**

## CONCLUSION

These studies suggest that edge-of-field reductions in soil erosion in coastal plain watersheds cannot be accurately translated into reductions in phosphorus transport by utilizing a linear phosphorus/soil relationship. As soil erosion rates are reduced, the phosphorus content of suspended solids in surface runoff tends to increase as a consequence of retention of larger particles with a relatively low phosphorus content. Thus, reductions in surface runoff phosphorus transport tend to be less than would be expected based on reductions in the transport of suspended particulate material. Even though NT methods were found to reduce edge-of-field suspended particulate matter transport by approximately 75% relative to rates in a CT system, reductions in particulate phosphorus transport were much more modest. Likewise, when the use of winter cover crops and a grassed waterway were added to a tilled system, large reductions in particulate matter transport had little effect on particulate phosphorus transport. The combination of NT methods, winter cover crops, and a grassed waterway did reduce particulate phosphorus transport approximately 60% relative to a setting where no erosion control practices were implemented. Surprisingly, additional erosion control practices were as effective for reducing particulate phosphorus loads from the NT watershed as from the CT watershed. Despite the general findings that reductions in particulate matter transport from coastal plain agricultural systems have proportionately lesser impacts on particulate phosphorus transport, it should be noted that sediment constitutes the primary nonpoint-source pollutant of streams and rivers (National Research Council 1992), resulting in habitat degradation independent of the effects of associated nutrient inputs (Berkman and Rabeni 1987). Thus, the greater than 90% reduction in sediment transport that was achieved through the use ofNT methods, winter cover crops, and grassed waterways is of environmental significance, even though the reduction did not result in equivalent percentage reductions in phosphorus transport.

Although the use of erosion control practices resulted in major reductions in edge-of-field surface runoff transport of particulate matter and to a lesser extent particulate phosphorus, these practices did not reduce surface runoff dissolved phosphorus concentrations. NT methods actually increased surface runoff dissolved

**Figure 7. Monthly volume-averaged dissolved and total phosphorus concentrations in surface runnoff from the conventional till (a) and no-till (b) watersheds from May 1985 through September 1993.**

**Figure 8. Volume-averaged surface runoff total phosphorus concentration as a function of total dissolved phosphorus concentration in all surface runoff events from the conventional till (a) and no-till (b) watersheds from May 1985 through September 1993.**

and total phosphorus concentrations relative to those in the tilled watershed. Owing to the limited mobility of phosphorus in these soils, phosphorus fertilization of the top 5 cm of the soil profile and leaching of phosphorus from plant residues to the soil surface combine to concentrate phosphorus levels in the top 5 cm of the soil profile in the absence of tillage (figure 9). Because surface runoff phosphorus concentrations are determined primarily by soil phosphorus levels in the top 5 cm of the soil profile (Sims 1993; Sharpley et al. 1994), NT practices increased dissolved phosphorus concentrations, even though average phosphorus concentrations in the top 30 cm of the soil profile were similar to those in the CT watershed. It is likely that higher phosphorus concentrations near the soil surface also contributed to the generally higher phosphorus content of particulate matter transported from the NT watershed.

These studies suggest that the 40% reduction in nonpoint-source phosphorus discharge being sought in the Chesapeake Bay restoration effort cannot be achieved for coastal plain cropland through implementation of erosion control practices alone. However, because runoff volume and erosion potential for a given pattern of precipitation are both largely determined by soil texture and topography, erosion potential should give an indication of where runoff volume is sufficient to transport significant quantities of dissolved phosphorus. Thus, the potential for reduction of dissolved phosphorus transport will generally be greatest on the same cropland where an erosion potential exists. The soils in the experimental watersheds investigated in this study are classified predominantly in hydrologic group C, indicating a greater potential for surface runoff than many of the more coarse-textured soils utilized for crop production in the costal plain. However, even though the soils at the study site have a higher potential to generate surface runoff than many coastal plain soils, the rates of soil erosion observed in the absence of any erosion control practices indicate a low potential for phosphorus transport in the ranking system recently developed by Sharpley et al. (1994). Recent studies in the coastal plain (Mozaffari and Sims 1994) have indicated that phosphorus enrichment of upper soil horizons has not reached sufficient levels to result in phosphorus transport beyond the crop rooting zone (i.e., into shallow groundwater). This suggests that in the near term, only negligible changes in nonpoint phosphorus discharge can be accomplished through changing management practices on flat coarse-textured soils, regardless of current soil phosphorus levels, and that overall there is a very limited potential for reducing nonpoint-source phosphorus discharge from coastal plain cropland.

**Figurg 9. Soil phosphorus concentration (Mehlich-1) in the top 30 cm of the soil profile in the conventional till and no-till watersheds following corn harvest in 1992.**

If reductions in surface runoff phosphorus transport are to be achieved, the transport of dissolved phosphorus will need to be addressed. Reductions in dissolved phosphorus transport in surface runoff will require management of phosphorus levels in uppermost soil horizons. Unfortunately, one of the most effective and widely utilized methods for controlling erosion, NT, may actually increase phosphorus levels in upper soil horizons. Periodic tillage may be useful for reducing elevated near-surface phosphorus concentration that develop in the absence of tillage. However, of greater importance is the need for more intensive management of phosphorus inputs. Recent surveys of soil test results indicate that over 60% of soils tested in Maryland have soil phosphorus levels in the range where phosphorus fertilizers have minimal effects on plant growth (Sims 1993). This suggests that rates of phosphorus fertilization could be reduced on many tracts of cropland without affecting production. While this is straightforward where inorganic fertilizers are used, it is more difficult in the case of poultry manure and sewage sludge, which are widely applied to cropland in the coastal plain region of the Chesapeake Bay watershed. Crop nutritional requirements as well as harvest removal rates dictate a supply ratio of nitrogen: phosphorus of approximately 6:1 on a weight basis, which is more than double the ratio of plant-available nitrogen:phosphorus in poultry litter (Sims 1987) and most sewage sludge applied to cropland in Maryland (T. Blair, Md. Depart. Environ., pers. comm.) Application rates of animal manures and sewage sludge to cropland in Maryland currently are determined by crop nitrogen requirements, resulting in phosphorus fertilization rates that are several times greater than annual crop needs. Long-term repeated applications of poultry litter to coastal plain cropland have been shown to raise soil phosphorus concentrations to levels well above the highest values observed in the experimental watersheds (Mozaffari and Sims 1994), suggesting the potential for surface runoff dissolved phosphorus concentrations higher than those observed in this study. Redistribution strategies are needed that minimize continued overapplication of phosphorus to cropland prone to surface runoff, particularly where soil phosphorus levels are adequate for crop production. Currently there is little information on changes in surface runoff phosphorus concentrations in response to reduced phosphorus application rates. However evidence that soil phosphorus levels decrease very slowly even with elimination of phosphorus applications (McCollum 1991) suggests that changes in nonpoint source dissolved phosphorus discharge will take many years to achieve, even with effective management of phosphorus inputs.

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# COST IMPLICATIONS OF MARYLAND'S TRIBUTARY STRATEGIES

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***Abstract:*** As the next major step in the continuing effort to restore Chesapeake Bay, the states of Maryland, Virginia, and Pennsylvania and the District of Columbia have made a commitment to develop and begin implementing specific nutrient reduction strategies for each of their tributaries. The State of Maryland has been partitioned into ten tributaries, and draft strategies have been developed for each one. Estimating the cost of the Tributary Strategies begins with acknowledging what is meant be "cost" in a broad sense. Such a broad definition is often associated with a formal cost benefit analysis that recognizes various lost opportunity costs and costs of nonmarket goods. Maryland's cost accounting effort takes the more restricted interpretation of costs as expenditures associated with specific activities that reduce the nutrient loads. This paper describes the methodology and limitations of Maryland's Tributary Strategies cost evaluation. The cost evaluation distinguishes costs associated with ongoing activities from those that are prompted by meeting the quantitative goals of Tributary Strategies. Historic mechanisms for funding costs imply a distribution of costs among private and public sectors; however, a governor-appointed panel on funding the Tributary Strategies may recommend alternative funding mechanisms that alter the distribution of costs.

## INTRODUCTION AND DISCUSSION

The 1992 reevaluation of the Chesapeake Bay Agreement reaffirmed the goal of reducing controllable nutrients flushed into the Bay to 40% below the 1985 levels. This goal is to be met by the year 2000 and maintained at or below that level each year thereafter. To attain this goal, a watershed-based approach has been adopted in which each participating state is to develop separate nutrient reduction strategies for each of its major subwatersheds of the Chesapeake Bay watershed. Maryland has been partitioned into ten watersheds, and a draft nutrient reduction strategy has been developed for each. The Maryland Department of the Environment (MDE) is the agency assigned to lead this joint effort with the governor's office, the departments of Agriculture and Natural Resources, and the Office of Planning.

The draft nutrient reduction plans, called Tributary Strategies, are designed to meet the 40% reduction goal in each of ten subwatersheds. Control practices in the strategies fall into three categories: wastewater treatment plants with flows exceeding 500,000 gal/day (point sources), control practices on developed land and agricultural land, and natural resource protection (e.g., forest management, riverbank protection). The strategies require upgrading all treatment plants with design flows of 500,000 gallons per day, and continuing existing state regulatory programs and existing incentive programs. In watersheds having a gap remaining in meeting nutrient goal reduction, additional activities were selected on the basis of cost-effectiveness. Practical limitations governing the expected level of participation in each of the voluntary activities were factored into the strategies.

Many parties have a stake in the way these strategies are developed and implemented. They include many elements of state government, local elected officials and program staff, a variety of business sectors (developers, agriculture, forestry, industry and commerce), and nongovernmental organizations, as well as individuals. To date, parties have participated in the development of the strategies through numerous public meetings, written comments, and intergovernmental staff work sessions. The commitment of local jurisdictions has been formalized in a highly publicized agreement signed by Maryland's governor and county leaders.

Significant scientific and planning resources have been expended to bring us to where we are today. Measurable progress has been made over the past decade primarily owing to the ban on phophorus in detergents and the upgrading of wastewater treatment plants. Nevertheless, Maryland has more than half way to go in reaching the 40% nitrogen and phosphorus goals, and each additional percentage point is more costly than the last. Maryland currently has feasible strategies; however, their success depends on engendering the collective will to implement them. The success or failure of the Tributary Strategies rests on implementing a set of workable funding schemes, which have yet to be identified. Methods of funding the strategies are being investigated this summer, 1993 by a governor appointed panel of individuals from the financial, business, academic, and public interest sectors.

This paper addresses the more limited issue of the cost implications of the Tributary Strategies as opposed to the means of funding these costs. In actuality, costs and funding mechanisms are coupled because the cost of an activity may change depending on the funding mechanism used; we all know a car costs less if you pay cash than if you take out a loan. Nevertheless, the subtleties and complexities of the Tributary Strategies cost evaluation warrants separate attention.

## Defining Costs

The common interpretation of the term "cost" does not hold up well when considering an undertaking as complex as Maryland's strategy to reduce nutrients. In this section, some of the many faces of the word "cost" are presented to provide an appreciation for the difficulty in answering the seemingly simple question of "how much will the Tributary Strategies cost"?

### *Broad and Narrow Definitions of "Cost"*

Estimating the cost of the Tributary Strategies begins with acknowledging what is meant by "cost" in a broad sense. Such a broad definition is often associated with a formal cost benefit analysis that recognizes various lost opportunity costs and costs of nonmarketable goods. Suppose sediment from a construction site results in the loss of fish in a stream that otherwise would have been good for fishing. Suppose further that a kid from far away visits his uncle who has promised some good fishing, but the kid fails to catch any fish owing to the earlier sedimentation event. This failed fishing trip represents a cost for which some economists might assign a dollar cost. Alternatively, one could assign a value to the beneficial aspects of the healthy stream and water bodies that it feeds.

Some might argue that performing an accounting of all costs and benefits is appropriate in developing a strategy. The current cost accounting effort, however, uses a more restricted interpretation of costs. Roughly speaking, costs have been defined as the expenses associated with specific activities that reduce the nutrient loads.

The following rationale supports the choice of this more limited definition of "cost." A benefit/cost analysis is most appropriate for deciding whether or not to carry out a large project. Such a decision was made when Maryland entered into the Chesapeake Bay Agreement. The 1992 reevaluation further supported this initial decision. Thus, the large decision has already been made and reaffirmed. The issue addressed by the Tributary Strategies is how to implement this earlier decision in a way that is efficient and equitable, which does not require a benefit/cost approach.

### *A "Cost-Effectiveness" Definition of Cost*

Grappling with the term "cost" did not stop at setting this narrow scope on the definition. First, during the development of the Tributary Strategies, it was necessary to define unit cost estimates for each of the nutrient control options. The estimates were used to identify the most cost-effective levels of activities needed to meet the 40% goal. Development of these unit costs was subject to strict time constraints, which necessitated making some simplifying assumptions and disregarding the costs of mandatory elements of the strategy (regulated activities). As a consequence, the resulting set of cost estimates was limited in use to making relative comparisons among alternative nutrient control options on a technology basis. The existence of these unit costs resulted in some confusion among parties outside of the strategy development process because, on the face of it, the unit cost estimates could be multiplied by the total applicable acreages to arrive at a "total cost." This "total cost", however, is not an accurate estimate because the unit cost estimates were not all inclusive.

### *A Preliminary Cost Evaluation*

When it came time to address the elusive question of the absolute cost of the Tributary Strategies, the cost of each nutrient reduction activity was evaluated from a broader standpoint than simplified unit cost estimates. This cost evaluation exercise had the potential to change the cost-effectiveness ranking of the options; however, the general trend was to increase the unit costs while maintaining the relative order among activities.

Costs were to be partitioned among federal, state, local, and private sources of funds. In some cases the methods used to generate the estimates differed from those used in the development of unit costs. This was done to accommodate the distribution among funding sources, to make use of new information, or because more accurate esitmates could be developed with little additional effort. Again, as with the unit cost estimation exercise, time constraints limited the sophistication of these cost estimates.

This effort was both a refinement of the unit costs and an opportunity to account for cost elements that were omitted from the unit cost estimations. As an extreme example of an omission, it was not necessary to determine cost estimates for several existing mandatory activities because, as regulatory requirements, they had to be part of the strategy regardless of cost. State-regulated stormwater management, erosion and sediment control, and forest conservation programs fall into this category. In general, where possible, administrative costs were also included in the cost estimates. (As noted in the section on "caveats" below, some omissions still remain.)

Another interpretation of the cost arrises when one asks, "What exactly are 'the Tributary Strategies'?" While conducting the cost evaluation, it was recognized that many existing programs with nutrient reduction benefits would proceed regardless of whether or not the state embarked on a Tributary Strategies campaign. Costs associated with these on-going activites represent a baseline. Thus, a cost accounting convention was adopted that recognizes two classes of activities, that provide benefits that count toward reaching the 40% nutrient reduction goal. *Planned activities* are the baseline of activities that would occur regardless of the Tributary Strategies effort. *Tributary Strategy activities* are additional actions needed to meet the 40% nutrient reduction goal. Tributary Strategy activities may be an expansion of an ongoing activity or a new activity. This somewhat artificial accounting construct allows new costs to be distinguished from the baseline costs.

### More Ways to Express Costs

Two basic cost categories are operations costs and capital costs. These two types of costs may be defined by how they are funded. Operations costs are associated with activities that are funded without borrowing, and capital costs are funded by borrowing.

Typically, capital costs are associated with expensive projects that entail construction. Buying a house, while not a project per se, is a capital expense that serves as a familiar model for exploring the different ways, in which capital costs can be expressed. If asked how much your house costs, you can answer in at least three ways. The price may be $150,000. If you secure a loan, the house may cost $325,000 in principle and interest. Perhaps the most meaningful expression of this cost is some statement of your mortgage payment, say $12,000 per year.

The cost associated with the Tributary Strategies is subject to this same issue of expressing capital costs; however, it is further complicated. Because the method of paying for the Tributary Strategies has yet to be determined, the cost cannot be determined without making assumptions about what the capital costs are. In theory, the total cost estimate could be reduced by hundreds of millions of dollars in interest payments if the state legislature were to temporarily raise taxes rather than use debt financing to pay for the Tributary Strategies. Even if the traditional capital projects are financed by debt, assumptions about interest rates can substantially alter the cost estimate.

### Some Caveats

Regardless of how costs are expressed, some underlying caveats must be noted. It is essential to recognize that a number of activities accounted for in the strategies are motivated primarily by objectives other than nutrient control. One example is stream bank erosion control, which is done primarily to protect natural habitats. Another is septic system maintenance, which is motivated by public health concerns. If other, more cost effective options were made mandatory or received special funding, these less costeffective activities might not be selected as elements of a nutrient reduction strategy. Because these on-going activities do provide nutrient reduction benefits, however, they must appear in the nutrient load accounting and, therefore, must appear in the cost accounting as well. Such activities bias the strategy cost estimate upwards because they include costs for unrelated benefits that are, practically speaking, inseparable from the nutrient control cost.

Recall that the current draft strategies are composed of mandatory programs plus the most cost effective nutrient reduction options that combine to reach to goal. Another caveat is that, although an option included in the strategy may be very cost effective in theory, practical funding limitations for that activity might make it very difficult to implement. It is conceivable that other activities that are less cost effective may be easier to fund, and thus, could eventually replace a current element of the strategy.

Another caveat is that some of the current cost estimates may not be comprehensive enough. Two noteworthy examples suggest that more thought may be needed in this area. Some have argued that setting aside land to construct stormwater management ponds for new developments represents a lost opportunity cost. For instance, the land could be used for another housing unit that could be sold to increase the profit. This lost profit could be viewed as a cost. The current cost estimate for stormwater management on new developments does not include the lost opportunity cost of having to build a pond instead of a house.

A similar situation arises when land is set aside for stream buffers. In cases where the land is being used for agricultural production, the current cost estimate for stream buffers does not include the opportunity cost of forgone profits from lost crop acreage. An analogous, yet less pronounced, opportunity cost occurs on nonagricultural land where stream buffers could be planted.

Despite the similarity between these two activities, there is a distinct difference. Stormwater management on new development is a regulatory requirement, but planting stream buffers is voluntary. For both of these activities, the costs associated with outlaying money for construction or planting have been included in current cost estimates however, the opportunity costs for other uses of the land have been omitted. If the costs for these two activities are reevaluated at a future date, an argument exists for counting the opportunity costs associated with stream buffers, but continuing to omit the opportunity costs associated with constructing stormwater control devices on newly developed land. In particular, the opportunity costs for stormwater management are like sunk costs, which are not considered in making decisions. For voluntary activities, like stream buffers, the lost crop production profits influence the decision to participate in the activity. Thus, it is unlike a sunk cost and may be more appropriate to include in a cost accounting.

For both of these activities, the land value has also been omitted from the cost estimate. For the stormwater management activity, the land is essentially sold by the developer and its value is again like a sunk cost, which can be omitted according to the argument above. For stream buffers, the land may reside in the possession of the original owner or the owner may want to have the land purchased by the government or a land preservation trust. If the buffer is forested, the owner may seek a Forest Conservation and Management Program tax break, which represents a cost in terms of lost tax revenue. As a future refinement of the Tributary Strategies cost estimate, a range of costs could be developed for the stream buffer land value.

### A Cost Estimate

"How much will the Tributary Strategies cost?" Because the Chesapeake Bay Agreement necessitates a loading cap at 40% of the estimated 1985 nutrient load, the veritable answer is an infinite amount of money over a long time. Most people, however, implicitly qualify this question with their own interpretation of what is meant by "the Tributary Strategy". One qualification is that the time horizon for meeting the 40% goal is the year 2000. Moreover, people typically want an annual figure even if the costs are not expected to be distributed uniformly in time. Thus, a more precise question is, "On average, what will it cost per year to reach the 40% goal in the year 2000?" A separate question, not addressed in this paper, is "What will it cost each year to maintain the 40% cap?"

With the qualifications discussed above, an educated guess at the total cost of meeting the 40% nutrient reduction goal ranges from \$1.5 billion to \$2 billion (plus any finance costs) over 6 years. Almost 80% of these costs represent a continuation of ongoing efforts, leaving between \$300 million and \$400 million in new costs.

The cost figure of particular importance is the revenue shortfall or "gap" that must be funded to meet the goal. In addition to the new resource needs, some of the ongoing efforts are expected to have funding shortfalls, which range from \$100 to \$250 million. Together, the new activities plus the shortfall for ongoing activities range from \$400 to \$650 million.

To derive an average annual funding gap that accounts for financing costs, assume that 60% of the funding gap represents capital costs. Assuming a 15-year capital recovery period and 6% interest, the average annual cost through the year 2000 ranges from \$50 million to \$85 million. This rough estimate is used as the hypothetical annual cost for the analyses below.

### Cost Implications

#### *Meeting the Commitment with a Voluntary Approach*

Maryland's governor and county leaders have made a goodwill commitment to implementing the Tributary Strategies to meet the nutrient reduction provision of the Chesapeake Bay Agreement. The governor has also promised local jurisdictions that he would not impose any new unfunded mandates. One could interpret the nutrient reduction effort as an old unfunded mandate that dates back to the signing of the Chesapeake Bay Agreement. Regardless of the interpretation, meeting the commitment to implement the Tributary Strategies will require additional revenue from all sectors of the community or transfers from lower priority programs. Without an aggressive acceleration of funding or a shift in priorities, the 40% nutrient reduction goal is unlikely to be achieved by the year 2000.

Because the Tributary strategies are being implemented on a voluntary basis, economics, political pressure, and goodwill will be the three driving forces. In cases where goodwill dominates, free riding is apt to occur. That is, some will pay for the benefits that others receive for free, which represents an inequity. Many aspects of the Bay and its tributaries represent nonmarketable public goods. Some would argue that the proper role of state government in this case would be to protect the common good in an equitable manner, which implies creating a level playing field through the use of mandated actions. The voluntary approach, however, is reasonable given the scope and experimental nature of the current strategies. This will allow the flexibility for the tributary strategies to evolve as new insights are discovered.

#### A Sense of Scale

To place the strategy into perspective, consider the estimated shortfall of funds needed to meet the nutrient reduction goal by the year 2000 ($50 million to $85 million per year). Given that there are about 5 million people in Maryland, the cost per person would be between $10 and $17 a year. This translates to between $26 and $44 per year for the average household. On a daily basis, this equates to about the cost of a newspaper, or is a little more than the cost of a month of cable TV service or an annual magazine subscription.

Because these are average estimates, some families would pay more and some would pay less. For a family purchasing a newly constructed home, there might be a few hundred dollars embedded in the cost to cover the contractor's erosion control practices during construction. Perhaps owners of boats kept at a marina would pay an annual deposit, which would be returned in part each time they pumped their septage at a designated pumping station. In the more typical situation, a family's annual costs would be spread out among a number of fairly nominal costs such as a new stormwater management fee of $15a year, and perhaps a slight increase in parking fees owing to parking garages passing on their new stormwater management fees, a few extra dollars in sales tax for lawn fertilizer, or perhaps a new excise charge on the professional lawn care bill, maybe an increase of $2 a month in the wastewater bill or a similar annual charge for owners of septic systems, perhaps a fraction of a cent increase in the property tax per $100 of assessed value or a flat $2 bump-up in the income tax table.

From this perspective, the scale of the funding problem is not too striking. A number of less-fortunate families would be burdened by such costs; however, they are likely to experience below-average costs. Furthermore, provisions, similar to those employed by power utilities, could be designed into any charge system to accommodate such situations. This rough analysis suggests that cost is not a technical limitation to implementing the Tributary Strategies; however, a political barrier remains to be overcome.

#### Distribution of Costs

Many cost evaluations investigate equity issues regarding how costs will be distributed among the various affected sectors. They identify how much the state contributes, how much is borne by local jurisdictions, what costs various business sectors must bear, and so on. To a large extent, such analyses perpetuate what can be called the fallacy of cost distributions. A complete analysis should show that utltimately consumers and taxpayers bear most of the cost. Both state and local governments pass their costs on to the general public, as does the building industry. The real question is, which sectors will bear the responsibility of raising funds from the general public?

The most pronounced exception to the rule that "the general public ultimately pays the cost" arises in parts of the agricultural sector. In most cases, farmers are price takers, meaning that they sell their products at market price, which may be set by those not affected by environmental responsibilities. As a consequence, some farmers may not be able to pass on their costs for nutrient controls, unlike home builders whose market generally allows them to increase their prices to recoup costs for environmental controls.

When specific funding mechanisms are considered in detail, issues of cost distribution become further refined. For instance, one might ask if a particular funding scheme will distribute the costs equitably between residenton large versus small lots. Such analyses are beyond the scope of this paper.

### Transfers Versus New Money

In view of the significant shortfall of funds, the voluntary aspect of the Tributary Strategies effort, coupled with pledges of no unfunded mandates, is likely to result in funding transfers. The illustration for costs borne by a typical family suggest that generating new revenues would be fairly painless. If, however, fiscal constraints and policy commitments to "no new taxes" warrant transfers of funds away from existing programs, all state programs should be considered. As noted earlier, some of the programs that are less cost effective from a nutrient reduction standpoint are included in the nutrient balance primarily to ensure a complete accounting. These programs are motivated by needs other than nutrient reduction, such as habitat restoration, which plays a significant role in the Chesapeake Bay restoration effort. In a sense, these programs are like any other state program, except that they also have some nutrient reduction benefits associated with them. Thus, it would be an error to view these less cost effective programs differently than other state programs when considering how to transfer funds to pay for the funding shortfalls.

### Economic Implications

No sophisticated input/output modeling has been performed regarding the wider economic implications of the Tributary Strategies. Nevertheless, a qualitative analysis can be surmised. Because the Strategy is voluntary, it is unlikely that it will cause negative economic impacts. More likely, the strategy elements that are implemented will stimulate economic activity.

Several of the options have the potential to generate economic activity. The use of certified private consultants to develop and revise agricultural nutrient management plans represents a growing area of the private sector. Bolstering the stormwater management and sediment and erosion control programs could create 60 new jobs at the local level of government. Furthermore, increased compliance would imply the need for more materials used to implement these activities, some of which are provided by Maryland-based businesses. An aggressive septic system maintenance program could result in expanding business opportunities for private septage pumping companies. Construction companies stand to do more business if the wastewater treatment plan upgrade are funded.

For each of these primary economic activities there are secondary and tertiary activities, as people with new jobs spend the money they earn for goods and services that are unrelated to the nutrient control effort.

## CONCLUSION

The shortfall in funds to meet the 40% nutrient reduction goal by the year 2000 appears to be attainable, being roughly $26 to $44 per household a year. Current professional judgement suggests that without a major funding effort, the Tributary Strategies will not be implemented by the year 2000. The current political atmosphere is unfavorable to raising new revenues. This is likely to result in a delay of strategy implementation and transfers of funds from programs of lower priority. If transfers are sought to pay for the Tributary Strategies, all state programs should be open to consideration rather than just those programs listed as potential Tributary Strategies options. This is because some of the less cost-effective options are motivated primarily by benefits other than nutrient reduction.

Because the Strategy is a voluntary effort, actions that are economically detrimental are unlikely to be pursued vigorously. Many of the activities that are likely to be promoted by the strategy have the potential to promote jobs in the construction sector, the new private agricultural planning sector, the septic maintenance providers, and local government.

As the next major step in the continuing effort to restore Chesapeake Bay, the states of Maryland, Virginia, and Pennsylvania and the District of Columbia have made a commitment to develop and begin implementing specific nutrient reduction strategies for each of their tributaries. The state of Maryland has been partitioned into ten tributaries, and draft strategies have been developed for each one. Estimating the cost of the Tributary Strategies begins with acknowledging what is meant by "cost" in a broad sense. Such a broad definition is often associated with a formal cost benefit analysis that recognizes various lost opportunity costs and costs of nonmarket goods. Maryland's cost accounting effort takes the more restricted interpretation of costs as expenditures associated with specific activities that reduce the nutrient loads. Maryland's Tributary Strategies cost evaluation distinguishes costs associated with ongoing activities from those that are prompted by meeting the quantitative goals of the Tributary Strategies. Historic mechanisms for funding costs imply a distribution of costs among private and public sectors; however, a governor-appointed panel on funding the Tributary Strategies may recommend alternative funding mechanisms that alter the distribution of costs.

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# Maryland's Tributary Strategies—Using Science to Support Chesapeake Bay Watershed Management

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***Abstract:*** The most specific pollution control effort in the Chesapeake Bay region is the commitment to reduce controllable sources of nitrogen and phosphorus by 40%. Each of the states in the region is pursuing this goal through an effort termed the "Tributary Strategies" which is focusing attention on the rivers that discharge to the Bay and that are the primary recipients and transporters of nutrients. Meeting the nutrient reduction goal will involve the participation and commitment of resources by citizens, businesses, and all levels of government. Involvement and commitment by these stakeholders can only be achieved through an understanding of the problems and their solutions. In many cases, providing this understanding requires the translation of complex technical information into a form understood by citizens and managers. In Maryland's Tributary Strategies approach, various levels and types of information have been produced for target citizens, elected officials, local governments, and business interests. The nature of this material and the experiences in using are discussed.

## INTRODUCTION

Proceeding with Chesapeake Bay restoration requires continuing political support from three constituencies: elected officials, implementation officials (e.g., regulators at the state and local levels), and grass-roots involvement to maintain political support.

Having heard from many citizens that the Bay ecosystem was being degraded, elected officials were ready to be convinced that there was a problem requiring a solution. It fell to the scientific community to define the problem and proposed a solution. Monitoring and research in the late 1970s and early 1980s presented three issues; excess nutrients leading to eutrophication, excess sediment erosion and deposition, and toxics. Eutrophication was the most pervasive problem and was exacerbated by the Bay's physical characteristics of a deep central basin and tendency to stratify. Fortunately this problem was well-understood and many tools were available to contribute to the solution, convincing legislators and regulators that there were politically acceptable solutions. Convincing the public, especially increasingly technically proficient environmental groups, was not difficult because they were already demanding that something needed to be done. Reaching agreement on the priorities and magnitude of the necessary actions was more difficult and continues today.

It should be understood, however, that while adequate scientific foundations and technical support are necessary, they probably are not sufficient to maintain momentum in the restoration effort. The special role played by Chesapeake Bay in the history, recreation, and livelihoods of people in the surrounding states is requisite to maintaining the support necessary for funding the restoration and institutionalizing the process and structure.

## BACKGROUND

Several major scientific milestones have contributed to the scientific foundation and credibility of the Bay restoration effort. These include the validation of the perception that the Bay's degradation is real; recognition that the solution must be regional; acceptance, reevaluation, and subsequent affirmation of a quantitative goal; and widening the restoration focus from the Bay's mainstream to its watershed. The reevaluation and previous work led to the 1992 Amendments to the 1987 Chesapeake Bay Agreement which required development, of specific, quantitative, watershed-based strategies to continue the restoration effort.

**Identifying and Demonstrating the Problem**

Recognition of the regional nature of the problem and solutions led to the first regional Chesapeake Bay Agreement.

Development of monitoring programs were required by the 1987 Agreement and needed to be both long-term and comprehensive. Four purposes needed to be served:

1.) More and more current information was needed to better evaluate the current status of the Bay, especially with respect to water quality and eutrophication factors. This would confirm earlier conclusions as to the nature and severity of the problem.

2.) The monitoring data collected must be appropriate for trend analysis to determine the effective ness of management actions.

3.) The monitoring program needed to contribute to our understanding of Bay processes to direct management actions most effectively,

4.) It needed to contribute to the reevaluation of the nutrient reduction goal required by the 1987 Agreement.

**The 40% Strategy**

Although the signatories agreed to the 40% reduction goal in the 1997 Agreement, there was sufficient uncertainty surrounding that number that a scientific reevaluation of the goal was called for in 1991. It was anticipated that by 1991 additional data would be been collected and the original static, one-dimensional model would be expanded to more realistically represent knowledge and understanding of Bay dynamics.

**Reevaluation of the Strategy and the 1992 Amendments**

The reevaluation was based on bringing together modeling, monitoring, and research. A key component of the reevaluation was the three-dimensional, dynamic, water quality model. The model provided a technical decisionmaking tool that was considered objective and therefore politically acceptable.

Various sets of scenarios were run that included different amounts of reduction for both nutrients, different amounts for each nutrient, and reductions in different regions of the Bay.

The model results indicated that a 40% reduction in controllable nutrient loads would result in a 20% reduction in dissolved oxygen anoxic volume days (a measure of the volume of water multiplied by the number of days that volume was below 1% dissolved oxygen). This result was considered a sufficiently significant improvement to validate and reaffirm the 40% goal. It also indicated that the most would be gained by reductions in Maryland's loads.

**The Tributary Strategies**

Maryland has since taken aggressive action in developing plans to achieve the required nutrient reduction. The magnitude and costs of the nutrient reduction suggested that political support would be essential and therefore that the process for developing the nutrient strategies would need extensive public involvement, which would require the communication of technical findings to the public in such a way as to demonstrate that both the problem and solutions were correctly defined. Because of the potential costs, all reductions needed to be shown to be both required and cost effective and relevant to the ultimate goal of increased living resources.

**The Process**

A process that provided for a series of informational and interactive meetings with both the public and local governments was deemed most appropriate. A parallel effort was developed by the Maryland Department of Agriculture, which assembled agricultural tributary strategy teams in each watershed to provide additional feedback on the details of agricultural aspects of the strategy.

These teams, consisting (depending , on the watershed) of Soil Conservation District personnel, farmers, Farm Bureau members, extension service personnel, etc., helped to determine current levels of agricultural best management practices (BMPs), which BMPs were likely to be most effective and most readily accepted by the local farm community, and what levels of implementation could be considered feasible.

Three series of public meetings were held. The first was strictly educational, and presented in a nontechnical way, the foundation for our understanding of the Bay's problems and a description of the probable solution. Significant time was allowed for questions, but there was no real discussion. The second meeting presented quantitative information on land use, nutrient sources population, potential fish spawning areas, and submerged aquatic vegetation acreage in each watershed.

At the third meeting , the options for nutrient reduction (BMPs and management options such as waste water treatment plant upgrades) and relative costs were discussed in small groups. Feedback was sought on what the local people thought would work best, which alternatives were not presented but should have been, and how the people viewed the relative costs.

Numerous questions were raised about where the load estimates came from and the efficiencies of the BMPs for nutrient reduction. A single statewide meeting was held to explain the watershed model and how the data were derived. Most of the participants left this meeting satisfied that the Bay restoration and nutrient reduction strategy was well-founded and technically credible. Questions about the derivation of the loads were significantly reduced after this meeting, and convincing participants, especially the technical farm community, of the validity of the effort was probably essential to continuing the process in a productive manner.

At this point, two rounds of meetings were held with local governments to review our understanding of current implementation levels, work out application levels for the BMPS, and develop a clear understanding of how the process would continue and what the role of local governments would be. There were again numerous technical questions regarding land use estimates, WWTP upgrades, and, most frequently, funding.

Again, convincing participants of the technical sufficiency was difficult. However, eventually agreement was reached that the quantitative decisions were accurate enough to allow the process to proceed.

## RESULTS

The result of the process is a "strategy" for each of the watersheds that includes more than 90% of Maryland and all of its Chesapeake Bay watershed. The strategy is a series of policy statements and quantitative goals. The policies include upgrading all sewage treatment plants greater than 500,000 gallons to biological nutrient removal for nitrogen (or equivalent) and provide for complete inspection and enforcement of sediment and erosion control, and storm water management regulations. Chemical phosphorus removal was already in place at most plants, but would be required if not in place.

One of the key results of the meetings with local governments was general acceptance of the numbers (e,g., land use. BMP efficiency and feasibility, estimated load reduction) as a valid starting point. Critical to this acceptance was the admission by the state agencies that the numbers "were not perfect" and that there would be future opportunities for revision of the numbers as better data became available.

## CONCLUSION

Scientific and technical information surrounding the Chesapeake Bay restoration and leading to the Tributary Strategies for nutrient reduction played a critical role in the political as well as the scientific development of these efforts.

The first was to clearly define the problem and to begin to understand the possible solutions. Without a defined problem, it would have been far more difficult to gather the funding necessary for the monitoring , modeling, and research programs that provided for definition of some potential solutions.

Definition of a simple and simply stated goal, i.e., a "40% reduction", was also critical to maintaining support because it provided focus, and a solution that most could understand, at least in a general way.

The second aspect of technical requirements was the provision by the water quality model of a technically sound basis for allocating reductions to each jurisdiction. However, equally important was the perception that the model provided an objective allocation that was not politically based. The model also provided a basis for supporting the nutrient reductions, because officials could clearly state what the results of the reductions would be: a 20-25% reduction in the volume and duration of anoxic water and a resulting improvement in the Bay's habitat for living resources.

Finally, it was critical to be able to convince both the citizens who would bear the costs and the local governments responsible for much of the implementation that the entire effort had a sound technical basis and that results could be predicted with an acceptable level of accuracy.