MANAGING POTOMAC WATER QUALITY: EVOLVING APPROACHES[1]

By Austan S. Librach, Cameron Wiegand, Stuart Freudberg, Michael Sullivan and Robert N. Magill[2]

INTRODUCTION

The upper Potomac River Estuary is the principal focus of water quality management planning in the Washington, D.C. metropolitan area. Its drainage area of over 12,000 square miles (31,000 km^2) embraces sizeable portions of four states and the District of Columbia, and includes 87 percent of the 2400 square mile (6200 km^2) metropolitan Washington area (Figure 1). Like other estuaries that occupy submerged river valleys along the eastern seaboard of the United States, the Potomac is heavily taxed in its effort to assimilate the large pollutant loads it receives from urban, suburban and rural sources. Major problems within the Estuary are oxygen deficits related to organic wastes, and eutrophication caused by an over-enrichment of the Estuary with phosphorus and nitrogen.

The management program for the Potomac Estuary over the past several decades has been guided by the principle that, within economic limits, human impact upon beneficial uses of the Estuary should be minimized. This control program has concentrated almost exclusively on implementation of increasingly higher level of treatment at sewage treatment plants. Overall, the program has been quite successful. Significant improvements in water quality in the upper estuary have occurred during the last decade. Examination of dissolved oxygen (DO) trends over the past twelve years shows a considerable amount of improvement. Nuisance algal blooms have also not occurred since the late 1960's.

Much of the improvements observed result from the elimination of severe discharges of raw sewage from the sewer system, and an ambitious program instituted by the area's local jurisdictions in 1969 to upgrade treatment at Washington area sewage treatment plants. By 1980, 12 treatment plants, with an aggregate treatment capacity of 500 million gallons per day (mgd) (1900 X 10^6 L per day) were operating at advanced secondary treatment levels or above, with further reductions scheduled to be phased-in according to NPDES permit requirements. The total

---

[1]Presented at the March 15-20, 1981 ASCE Spring Convention, held at New York, N.Y.

[2]Mr. Librach is Director of the Metropolitan Washington Council of Governments' Department of Environmental Programs (DEP). Mr. Wiegand is DEP's Chief of Water Programs. Messrs. Sullivan and Freudberg are Water Resources Engineers, and Mr. Magill is an Environmental Planner within the same Department.

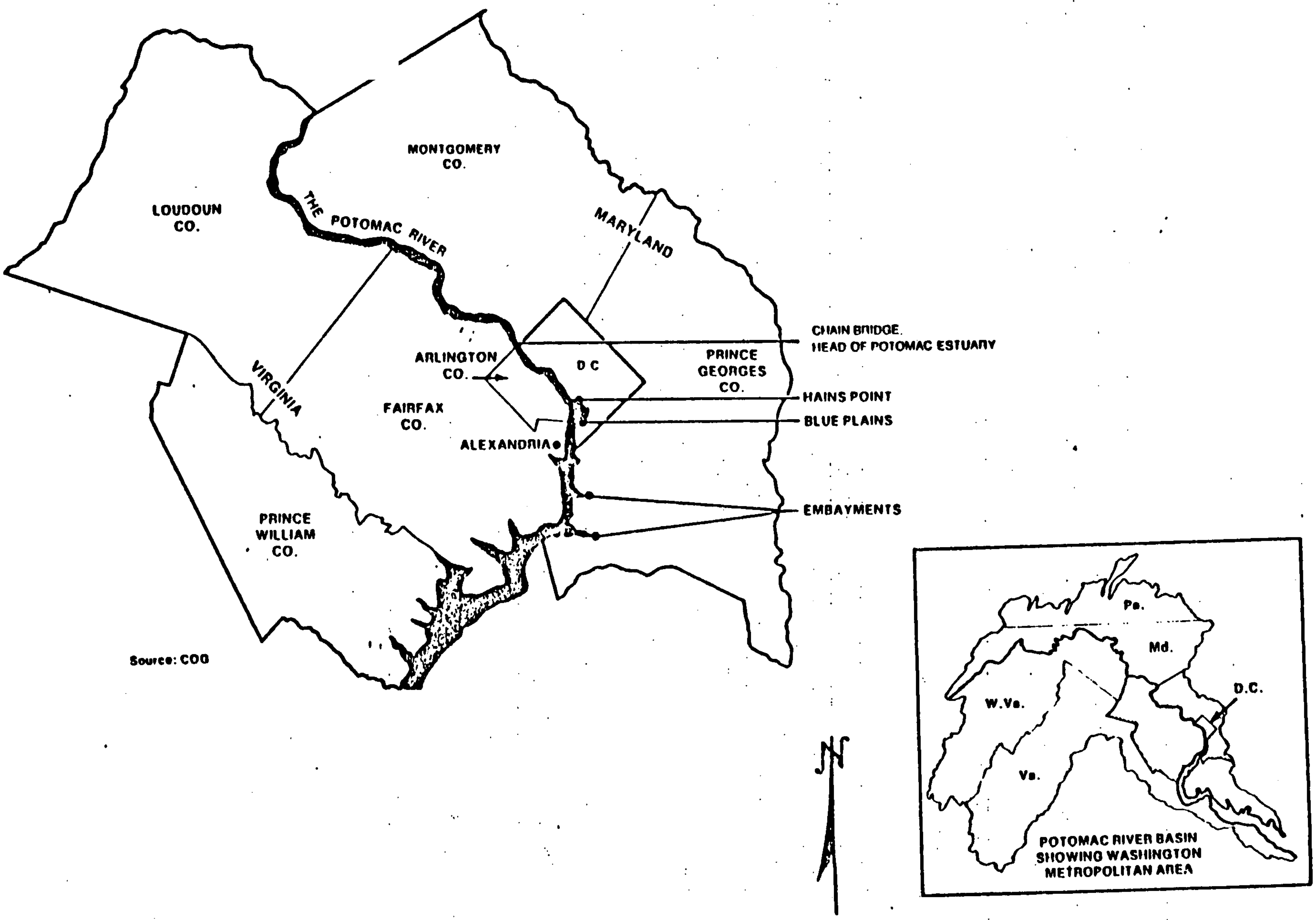


Figure 1–The Washington Metropolitan Area and Potomac River Basin

capital cost of improvements when all the improvements based on the 1969 program are completed will be over a billion dollars. Resultant annual O&M costs have approximately tripled to date and are expected to increase another fourfold by the Year 2000.

FIG. 1 The Washington Metropolitan Area and the Potomac River Basin

Despite the huge investments cited to upgrade water quality, problems remain. Water quality standards are still frequently violated, and portions of the upper Estuary have not achieved the 1983 goal of "fishable-swimmable" waters established by the Federal Clean Water Act (P.L. 92-500, as amended). Contributing to the problem are significant uncontrolled loadings of oxygen demanding material and nutrients originating from natural sources, unregulated agricultural activities, urban stormwater and other nonpoint pollution sources generated locally and upstream of the Washington region.

In view of the continued persistence of water quality problems in the Estuary and the rapidly rising costs of providing advanced wastewater treatment (AWT), there is growing interest among Washington area local governments for a reexamination of the existing management program to determine what is required to achieve Potomac River water quality goals in an economically feasible manner.

This paper presents an overview of the evolution of water quality management philosophy in the Washington area, and describes an emerging approach to comprehensive water quality management. To define the problem, the paper first assesses the total pollutant loadings to the Estuary from all sources. This is followed by an historical overview of water quality trends in the Estuary and the management response to perceived water quality problems. The estimated costs of providing increasingly higher levels of sewage treatment are then presented. And finally, the paper describes an evolving approach, based on an analysis of trade-offs between the various pollution control options available, to determine the most cost effective and practical way of achieving specific and realistic water quality objectives.

POLLUTANT LOADINGS TO THE ESTUARY

The timing and delivery of pollutant loads and their impact on the river ecosystem is not easy to predict or quantify. Wastewater from sewage treatment plants and other point discharges represents a relatively steady day-to-day influx at many points along both the free flowing and estuarine Potomac. In contrast, nonpoint loads from stormwater runoff and combined sewer overflow loads are extremely transient and variable. Both respond directly to runoff produced by precipitation and snow-melt. The generation of nonpoint pollutants ranges from nearly no contribution at all during dry periods to the largest and most important source of pollutants during major runoff events. Similarly, combined sewer overflows typically do not occur unless some type of runoff is generated, but overflows represent the most severe form of localized pollution when they do occur.

The variability of background loads is also significant in attempting to understand total loads to the Estuary. On an annual basis, mean monthly Potomac River flow varies by a factor of six between the spring maximum and fall minimum, and more than a three order of magnitude variation in river flow has been observed between such extreme events such as Tropical Storm Agnes in 1972 and the basinwide drought of the mid-1960's. Nonpoint pollution loadings vary in a manner similar to the flow fluctuations. For example, recent analysis has shown that annual nonpoint loads to the Estuary can easily vary by a factor of two between wet and dry meteorological years (Sullivan, Freudberg, Wiegand, 1980).

Improvements in our understanding of the source and magnitude of all pollutant loads to the Estuary has enabled a more complete accounting of these loads. This accounting is critical to selecting the most suitable control programs. Estimated average annual loads to the upper 50 miles of the Potomac Estuary for various years projected to the Year 2000 are presented in Figure 2. Point source loadings represent all permitted discharges to the upper Estuary and its tributaries below Chain Bridge, the head of the Estuary. Five stages of loadings from point source discharges are presented to reflect implementation, over time, of NPDES discharge permits to the Estuary. Nonpoint source loadings represent loads generated in tributaries below Chain Bridge that drain directly to the Estuary. These estimates represent average annual loads for a typical or average rainfall year. They are based on current (1980) and forecasted (2000) land use patterns.

FIG. 2 Average annual pollutant loads to the Upper Potomac Estuary

Potomac loadings at Chain Bridge in Figure 2 are estimates of average annual pollutants delivered to the Estuary from the middle and upper Potomac Basin above the Washington, D.C. area. Estimates are based on an analysis of U.S. EPA and USGS data taken at Chain Bridge during the late 1970's. Primarily nonpoint in origin, these loadings are delivered to the Estuary by the free-flowing Potomac River in both dissolved and suspended form. It is estimated that less than twenty percent of these loads are generated within the metropolitan Washington, D.C. area. The majority originate upstream of the metropolitan area from a variety of sources, including municipal and industrial discharges; urban, agricultural, mining and forestry nonpoint sources; and natural weathering processes at work within the basin.

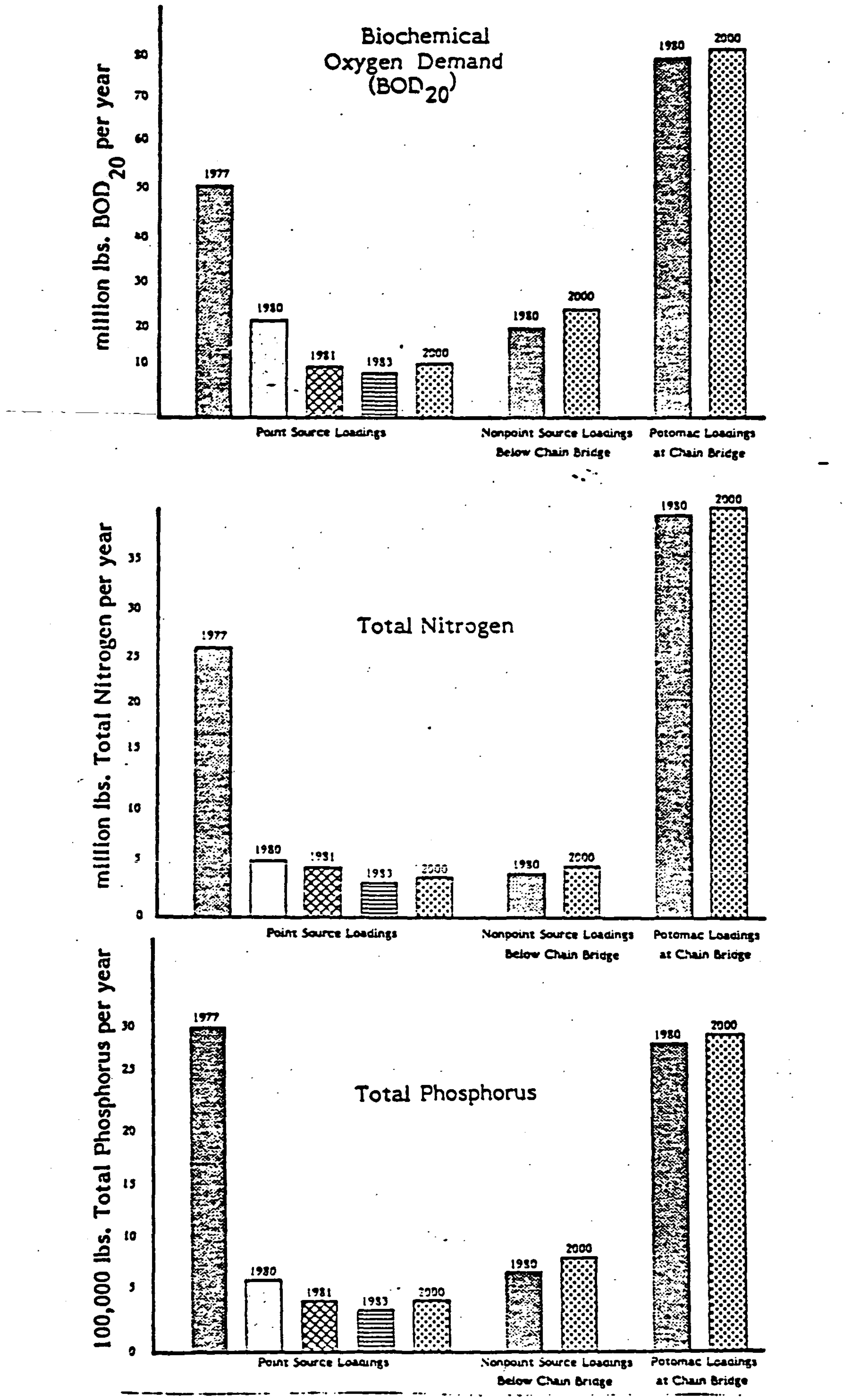


Figure 2–Average Annual Pollutant Loads to the Upper Potomac Estuary

The slight increase for the Year 2000 indicates an increase in nonpoint loadings from metropolitan Washington area watersheds above Chain Bridge. Otherwise, these loadings were held constant.

A conclusion that may be drawn from Figure 2 is that the overall magnitude of future point source loadings will be relatively small compared to existing and projected local nonpoint and upstream loadings, especially if current sewage treatment plant permit requirements remain in effect.

BASIS OF THE REGION'S PRESENT POINT SOURCE CONTROL PROGRAM

The control of pollutants entering the Potomac Estuary has occupied the attention of policy makers, government agencies and individuals for many decades. Particular interest has centered on the upper 50 miles (80 km) of the 115 mile (186 km) long estuary, where the principal discharges and population centers are located. The U.S. Public Health Service first surveyed the upper Estuary in 1925 and concluded that the danger of contracting sewage-borne diseases made swimming unsafe anywhere in the Washington, D.C. area. Concern regarding high bacteria counts, algal blooms and noxious odors led to the construction, in 1935, of the Blue Plains primary treatment plant in the District of Columbia. Shortly thereafter, Arlington County constructed another though much smaller primary plant, and Blue Plains began to serve other communities in Maryland and Virginia. By 1940, all of the area's major sewage discharges were receiving primary treatment.

The region experienced rapid population growth during and after World War II. A metropolitan Washington population which stood at 575,000 in 1938 had by 1943 increased to 1.1 million. Point source loadings also increased sharply to the point where waste loads entering the Potomac after treatment in 1943 actually exceeded, by one-third, the loadings experienced prior to construction of the Blue Plains and Arlington treatment facilities. By 1956, when secondary treatment was introduced at Blue Plains, treated wasteloads entering the Potomac were double the untreated level recorded in the early 1930's.

In 1956, Congress passed a second Water Pollution Control Act, which established the "Enforcement Conference" approach as a means to achieve better pollution management in interstate waters. The first Federal-State Enforcement Conference on the Potomac River was convened by the U.S. Public Health Service in August 1957. The Conference met again in 1958 and produced advisory recommendations for a joint program of remedial action for D.C., Maryland and Virginia pollution discharges in the Washington region. Principal among the recommendations was a goal to reduce discharges of biochemical oxygen demand materials (BOD) by 80 percent and a commitment to disinfect all sewage effluent.

Implementation of the joint Federal-State program recommended by the Conference was severely impeded by a number of institutional problems. As the region's population and sewage generation increased, the Estuary continued to exhibit poor water quality. Dissolved oxygen values in the upper Estuary were below existing Maryland standards. The late 1960's also recorded significant phytoplankton blooms and accompanying nuisance mats of floating blue-green algae, particularly during periods of low flow. Concerns as to the Estuary's declining water quality prompted the convening of a second Potomac Enforcement Conference in 1969.

An extremely ambitious program for the removal of phosphorus and nitrogen from sewage plant effluents was proposed. Conference recommendations included the imposition of strict effluent load limitations in terms of pounds per day of BOD, total phosphorus, and total nitrogen for waste treatment facilities discharging to the upper Estuary, and specific removal levels (96 percent BOD, 96 percent phosphorus and 85 percent nitrogen) for ten treatment plants discharging to tributaries and embayments of the Potomac.

The wasteload allocations for the Potomac plants were determined using early estuarine water quality models applied to dissolved oxygen data of 1965-66 and 1968-69. Calculations indicated that in order to meet Estuary dissolved oxygen standards, the 5-day BOD load from discharges would have to be reduced from the existing discharge of about 150,000 lbs/day (68,000 kg/day) to 16,500 lbs/day (7500 kg/day). To achieve a phytoplankton chlorophyll-a goal of 25 micrograms per liter (μg/l) to arrest accelerated Estuary eutrophication (maximum mid-summer values of 400 μg/l were observed in the late 1960's), wastewater loading allocations were set which called for stringent reductions in effluent concentrations of nitrogen and phosphorus (Thomann, Fitzpatrick, 1980).

Modeling calculations at the time made no allowance for loadings from nonpoint sources and combined sewer overflows. Model assumptions were based simply on a steady state, minimum stream flow condition (seven-day, ten-year low flow). This condition was typically used as a representative "worst case" for calculating allowable loadings. Pollutant contributions from sources other than point sources were accounted for indirectly by including a margin of safety in assigning wasteload allocations to individual discharges and subsequently in NPDES permits by including combined sewer overflows within the original wasteload allocation.

Some participants in the 1969 Conference warned that there was insufficient understanding of the behavior of nitrogen and phosphorus in relation to their impacts on water quality in the Estuary to warrant such a program. Nonetheless, these recommendations were confirmed in a 1970 Memorandum of Understanding adopted by area local jurisdictions, the District of Columbia, and the Virginia and Maryland pollution control agencies. They became the basis for subsequent expansion and upgrading of treatment plants in the Washington, D.C. area (Bower, Bandler, 1975).

The strict discharge requirements established by the 1969 Enforcement Conference were later incorporated into the NPDES discharge permits issued to each local sewage treatment plant as a result of the Federal Clean Water Act. The primary focus of abatement activities has been the Washington, D.C. Blue Plains Treatment Plant, the major single point source input to the Estuary. (Approximately 309 mgd (1160×10^6 L/day) of the current 445 mgd (1680×10^6 L/day) sewage treatment plant loadings are from Blue Plains. The plant's NPDES permit issued in 1974 called for a staged reduction in BOD, phosphorus and Total Kjedahl Nitrogen (TKN) to AWT effluent levels of 5 mg/l BOD_5, 0.22 mg/l P, and 2.4 mg/l TKN).

As of 1980, all treatment plants discharging to the upper Estuary had achieved advanced secondary treatment levels. The Blue Plains plant and five additional plants are scheduled to achieve AWT levels in the next few years.

DEVELOPING NEW MANAGEMENT APPROACHES

Figure 3 illustrates the marked reduction in point source loadings of oxygen demanding materials (BOD_5) delivered to the upper Potomac Estuary that has resulted from the upgrading of area wastewater treatment facilities called for by the 1969 Enforcement Conference. It can be seen that the BOD_5 load has decreased almost 90 percent from 1968-79 to 1981. Although trend data is limited, Figure 4 shows recent improvements recorded in upper Estuary dissolved oxygen levels under a range of summer fresh water inflows. This trend can likely be attributed to reductions in wastewater effluent concentrations achieved in the last ten years.

FIG. 3 Daily BOD Loadings to the Upper Potomac Estuary from Major Wastewater Treatment Plants

FIG. 4 Dissolved Oxygen Trends in the Upper Potomac Estuary

Though the recent improvements in Estuary DO levels have been welcomed, it has also been acknowledged that these gains have involved tremendous federal and local capital expenditures. From a management standpoint and given the substantial costs incurred thus far, serious questions are now being raised in the region as to the need to proceed still further down the line to full NPDES permit implementation when there still has been no clear and prior determination as to the cost-effectiveness of doing so. These questions are being raised, in part, because the traditional and rigidly interpreted approach for setting water quality standards and wasteload allocations called for by federal regulations and adhered to in establishing effluent requirements for Estuary discharges, provided for very little flexibility. Left unaddressed with this approach are difficult questions concerning

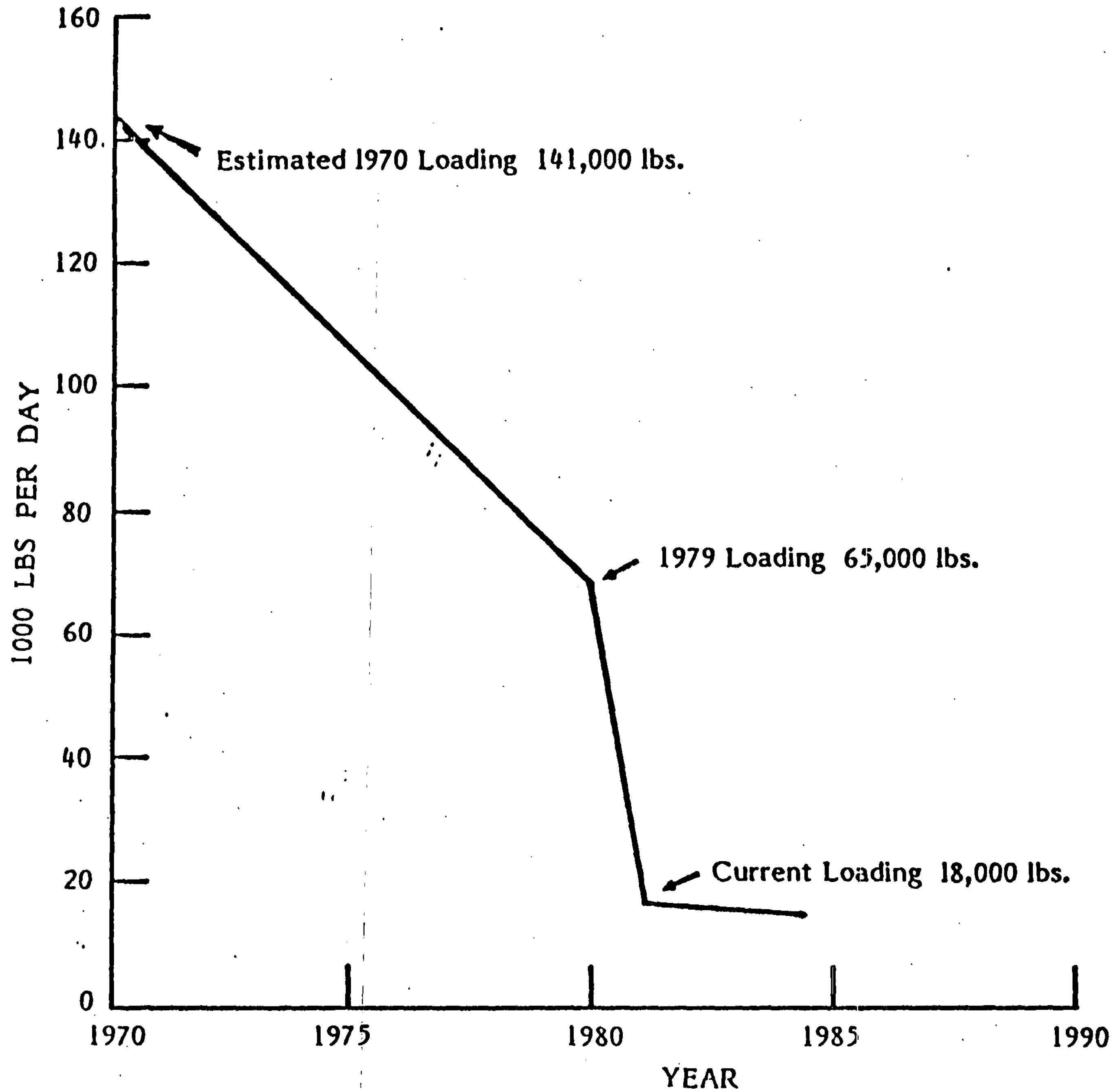


Figure 3–Total Daily BOD_5 Loading to the Potomac by Major Wastewater Treatment Plant Discharges

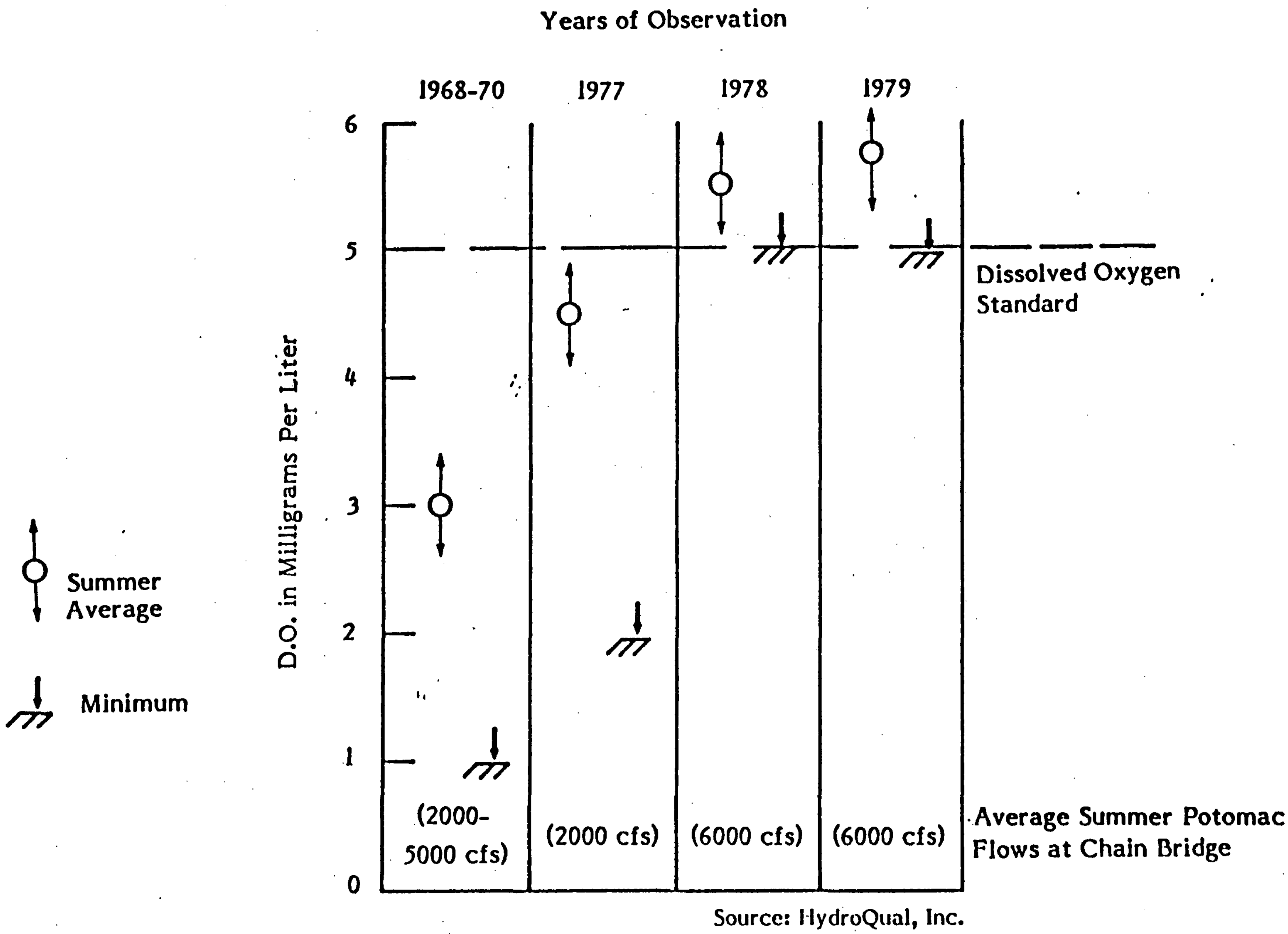


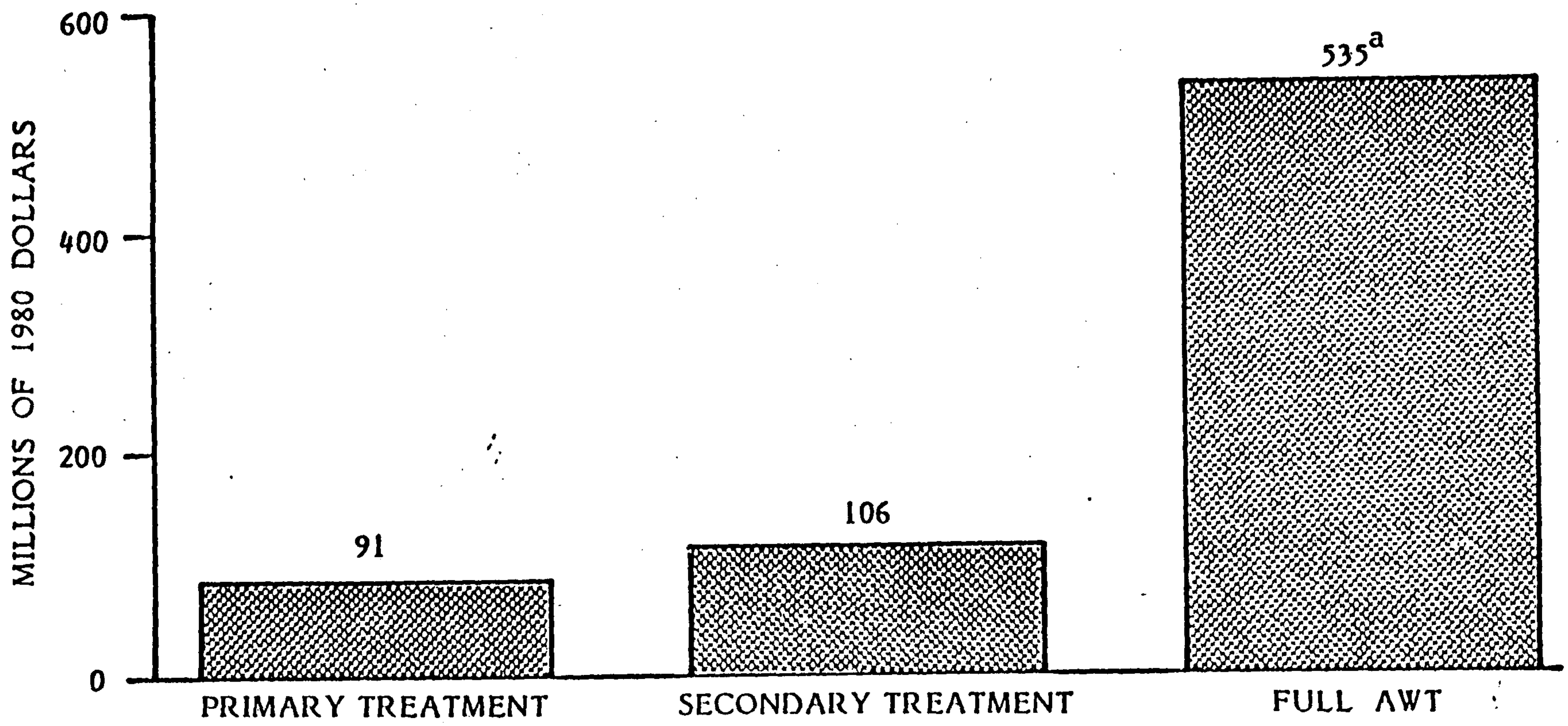
Figure 4–Dissolved Oxygen Trends in the Upper Potomac Estuary

the seasonal aspects of certain designated water uses requiring protection, and the frequency and importance of standards' violation. Questions as to the costs of control mechanisms to avoid such violations were also unaddressed. Thus while cost considerations were extremely important to decisions related to treatment plant sizing and location, they were not considered from the standpoint of water quality improvements achieved per dollar expended.

The need for a comprehensive evaluation of such considerations has become increasingly apparent. Capital costs of reaching final NPDES permit advanced treatment levels at the Blue Plains facility, for example, will exceed $500 million. As shown in Figure 5, capital costs increase dramatically as permit levels of 94-98 percent removal are approached. Operating costs are also expected to increase four-fold as area facilities proceed from secondary to AWT treatment processes (Sullivan, Freudberg, Wiegand, 1980). The major and yet unanswered question which must be addressed, as local governments move to final stages of facility construction, is whether these additional expenditures are warranted in terms of additional water quality benefits to be achieved.

FIG. 5 Comparison of Capital Costs for Different Treatment Levels at Blue Plains Sewage Treatment Plant

Along with these cost issues, some concerns have also been raised as to whether exclusive emphasis on technology-based point source management solutions will be sufficient to resolve remaining Estuary eutrophication problems. The significance of nonpoint source loadings and loadings from sources upstream of the Washington, D.C. area was earlier identified in Figure 2. Nutrient loadings by source are further presented in Figure 6. As shown, the magnitude of annual upstream and local nonpoint sources of nutrient loadings far exceeds annual point source contributions. Such annual loading comparisons must, of course, be interpreted with some caution since the period of greatest stress on the Estuary has historically been during mid-to-late summer when fresh water inflows as well as nonpoint nutrient loads may be at their lowest levels while, in a relative sense, point source loads are greater. However, there is also some evidence which suggests that spring nonpoint and upstream nutrient loads deposited in Estuary sediments and released back to the water column in the summer during periods of low dissolved oxygen may well be the controlling factors in producing algal blooms and other associated estuary ecosystem imbalances.



		Primary Treatment	Secondary Treatment	Full AWT
PERCENT REMOVAL	BOD_5	35 %	85 %	97 %
	NITROGEN	10 %	10 %	94 % (Summer)
	PHOSPHORUS	10 %	10 %	98 %

Figure 5–Comparison of Capital Costs at Blue Plains Sewage Treatment Plant

[a] Projected expenditures. Approximately $100 million of this amount represent as yet [illegible] removal facilities.

FIG. 6 Nutrient Loadings to the Upper Potomac Estuary
(1980 Annual Loadings)

Evidence that the nonpoint load may have significant adverse impacts on Estuary water quality has led to recent efforts to characterize the extent to which such loads could be controlled. Nonpoint analysis to date relevant to the Potomac Estuary were discussed in detail in a recent paper (Sullivan, Freudberg, Wiegand, 1981). Six scenarios for controlling nonpoint pollution in metropolitan Washington were analyzed. Most of the controls investigated focused on those urban nonpoint controls which could be most practically implemented in concert with new development in the Washington region. The paper concluded that nonpoint controls could be more cost-effective on a pollutant per pound removed basis than point source controls, and that the possibility of a "trade-off" between point and nonpoint controls merited more detailed analysis.

Cost-benefit and loading source/impact considerations such as described above have increasingly prompted those responsible for management of water quality in the Estuary to seriously question the wisdom or practicality of relying on advanced wastewater treatment to achieve the greatest marginal improvement in Estuary water quality. Concurrent interest has been stimulated in evaluating whether a more cost-effective management approach exists which will lead to continued water quality improvement at less expense for area jurisdictions.

An investigation of possible management pollution approaches is currently underway. It involves two main areas of examination: first, a comprehensive look at exactly what water quality levels can affordably be achieved; and second, the previously cited "trade-off" analysis of control measures, notably nonpoint source controls, that could possibly make significant contributions to improved water quality at less expense than advanced wastewater treatment. The following sections further describe the management concepts and decision-making tools being factored into this examination.

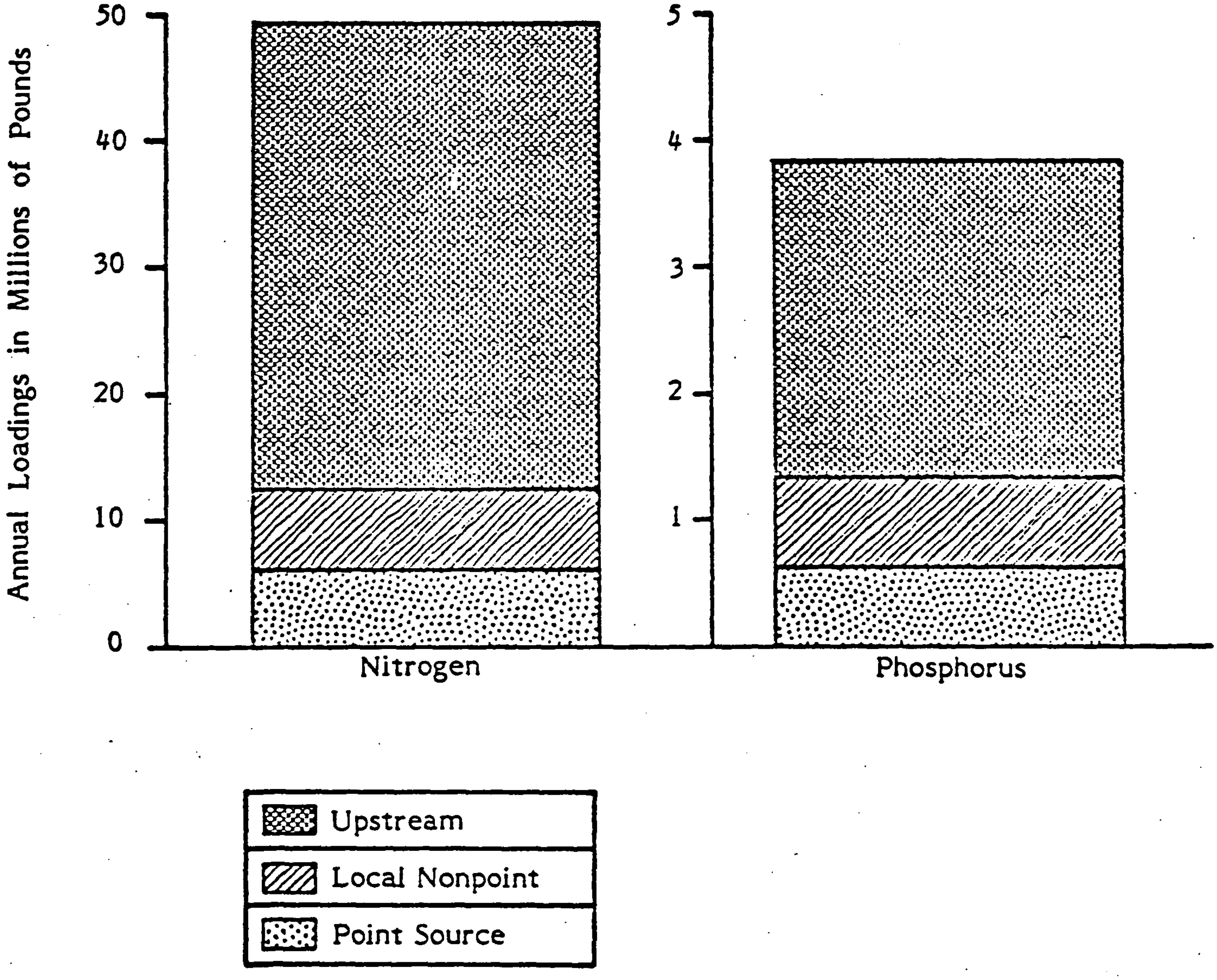


Figure 6–Nutrient Loadings to the
Upper Potomac Estuary (1980 Annual Averages)

New Concepts in the Application and Interpretation of Water Quality Standards

While the adhering to the national goal of achieving fishable and swimmable waters by 1983, the evolving management approach for the Potomac Estuary will likely propose a broadened consideration of water quality standards and goals.

Integral to this process is a recognition that the Estuary is a highly dynamic system with significant spatial and temporal variability. In this context, absolute statements that a given water quality standard shall never be violated, while perhaps easier to interpret and enforce, represent an overly simplistic and perhaps misleading measure of water use protection.

The Estuary's use as a resource also varies according to seasonal and other temporal factors. Swimming and other forms of water-contact recreation are an example. However, standards are typically established for strict year round compliance. Consideration of the seasonal and temporal aspects of water use protection in the development, application and interpretation of water quality standards is clearly warranted.

The fact that the water quality standards themselves are somewhat arbitrary is also an important consideration when evaluating the suitability of a receiving water for a particular use designation. The standards are usually based on a series of toxicity experiments in which an indigenous population of fish is exposed in laboratory tanks to a range of concentrations of a "harmful" constituent for a somewhat arbitrarily determined duration of time (often 96 hours). An absolute water quality standard is then set at a concentration value below which some percentage (usually 50 percent) of the population die during the duration of the test. Noss and Marks (1981) among others have recently questioned the technical assumptions behind selection of the 50 percent lethality figure, and have suggested that other factors such as morbidity, spawning ability, or growth rates should also be considered in setting standards. Noss and Marks have also presented a conceptual model of an improved process for setting standards which would maintain use of laboratory toxicity or other experiments as a scientific basis, but would also add equally important cost/benefit and political feasibility considerations as part of the standard-setting and water quality evaluation process.

Another difficulty with present receiving water quality standards and criteria and their interpretation is that there usually is not any scientific correlation between the standards and wastewater treatment levels required in discharge permits issued to individual treatment plants. The 1977 Clean Water Act Amendments prescribed specific levels of point source control based upon technical feasibility of achievement rather than on receiving water quality impact. The Act presumed that the level of control would be high enough to enable standards to be met. While application of this technology-based approach has likely been responsible for recent improvements in upper Estuary water quality (see Figure 4), there have been no corresponding determinations showing that it is also the most cost effective means of pollution management. Recent thinking suggests an alternative and more comprehensive approach to future Potomac Estuary pollution management decisions that establishes a link between treatment levels and water quality impact over a broad range of naturally occurring flow, rainfall, temperature and loading conditions. It also broadens the concept of "treatment level" to include local nonpoint source, combined sewer overflow and upper Potomac Basin controls in addition to traditional point source controls.

Return Frequency Considerations in Water Use Protection

A key element introduced for consideration would be the notion of frequency of compliance with a given water quality standard. Traditionally, the analysis of compliance has been to see whether a standard -- the dissolved oxygen standard, for example, would be violated anywhere at anytime, based on analysis with a calibrated and verified water quality model. However, due to various natural and human-induced phenomena -- including photosynthesis, respiration, temperature, river flow, tidal influence, variation in pollution loads -- the dissolved oxygen values measured in the Estuary fluctuate over a wide range on daily, weekly, and seasonal time scales. Spatial variations in dissolved oxygen longitudinally along the Estuary and with depth in the water column are also pronounced.

As a new approach, it is proposed that considerations in the selection of the most suitable management option could be substantially broadened to weigh Estuary responses under a wide range of seasonal flow, temperature and loading conditions. Managers would be presented with an array of options constructed with a Potomac water quality model (see later section for discussion) that simulates Estuary responses under various conditions. Figure 7 depicts the frequency of compliance for one hypothetical array of controls (Alternatives A-D) under different river flow regimes. In the example, Curve A might represent the most stringent set of controls and D the least stringent. Since it is known how frequently a given seven-day flow occurs, the decision-maker would then have enough information to know that for a certain expenditure level, the dissolved oxygen standard would be met, say 95 percent of the time over a specified period of years, or conversely, that violations of the standard would be expected at a given frequency. The consequence of such violations and the impairment of water quality uses could then be weighed against such factors as the timing and severity of use impairment and the cost of the abatement option.

FIG. 7 Hypothetical Frequency of Compliance Curves for Various Treatment Alternatives

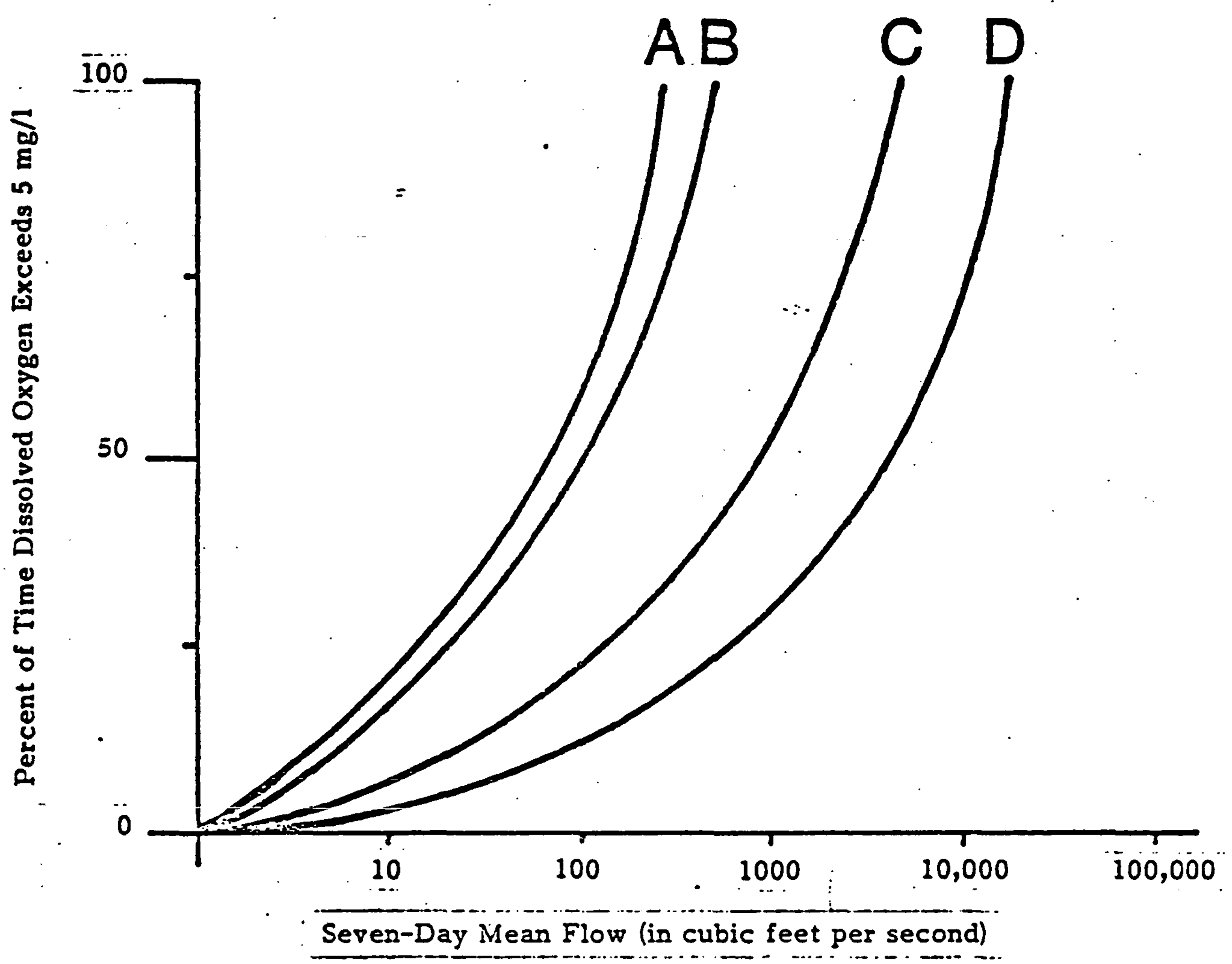


Figure 7–Hypothetical Frequency of Compliance Curves for Various Treatment Alternatives

Application of Improved Estuary Models

To be able to incorporate loading source, cost-effectiveness and return frequency considerations into the assessment of future management options for the Estuary, it was recognized that new water quality modeling tools were needed to define and assess an optimal mix of point, nonpoint, combined sewer overflow and upper basin controls. Financed by a combination of federal and local government support, a Potomac Estuary model is now under development which represents a state-of-the-art approach in the area of eutrophication kinetics. Model simulations will supplement the traditional seven-day, ten-year low flow, quasi-steady event with seasonal, annual, or even multi-year scenarios as considerations in determining a management strategy.

The rationale for examining longer term events includes recognition of the fact that the eutrophication process takes place on week-to-week time scale, rather than hour-to-hour; that the low flow event does not permit proper analysis of the impact of nonpoint loads on Estuary water quality; and finally that achievement of improved water quality in the Estuary is masked by focusing on one arbitrarily selected worst-case event.

Kinetic functions of the model include both water column and sediment reactions for dissolved and particulate fractions of the important phosphorus, nitrogen, and mineral nutrients, as well as the capability to model the population dynamics of two phytoplankton and two zooplankton groups. The model is one-dimensional, vertically and tidally-averaged, and is designed to be run in a continuous simulation mode. The model framework is designed specifically to permit determination of water quality resulting from various management strategies for all loading sources to the Estuary. With its assistance, it is hoped that a lasting long-term cost-effective approach to improving and maintaining the water quality in the Potomac Estuary will be devised.

Figure 8 depicts the conceptual elements of a proposed management approach for the Estuary. As suggested in the foregoing discussion, the new approach would replace the traditional one of almost exclusive reliance on point source control. Introduction of important and heretofore often ignored considerations such as the timing of water uses needing protection; timing and frequency of water quality standards' violations and their significance to the uses being protected; and the costs of meeting or not meeting standards for alternative return periods are included. The new approach would make possible the identification of cost-effective management options. As available data suggests, these may well include an optimized mix of point, nonpoint, combined sewer overflow and upstream source controls.

FIG. 8 Comparison of Water Quality Management Processes

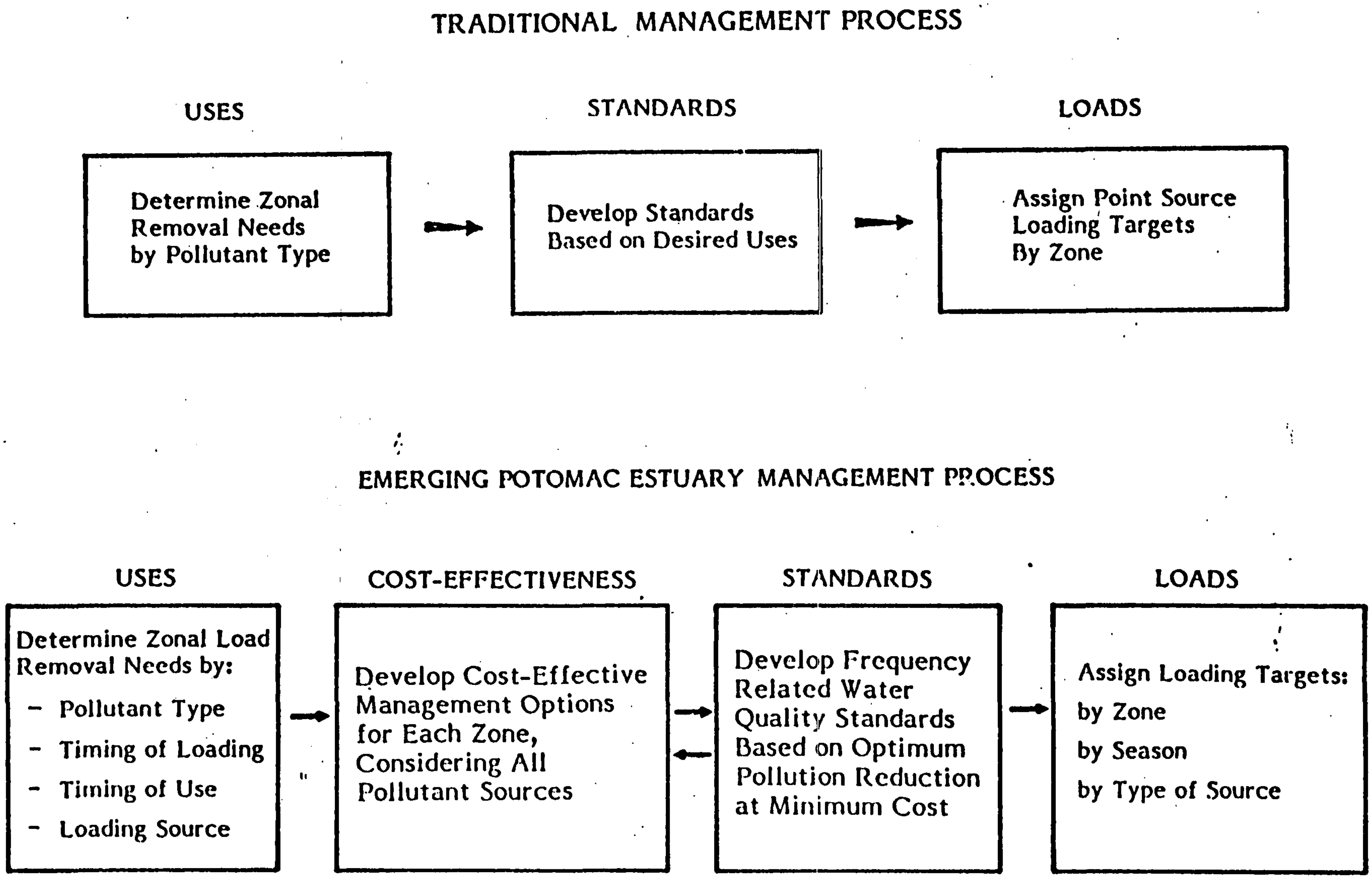


Figure 8–Comparison of Water Quality Management Processes

INTEGRATION WITH RELATED LOCAL AND BASINWIDE ACTIVITIES

Local Watershed Management Activities

Recognizing that nonpoint loadings may have significant impacts, both on important water uses within individual watersheds and on the Potomac Estuary itself, Washington area governments established a coordinated approach to local watershed management. It is directed at setting local nonpoint pollution abatement priorities within the context of the region's overall water quality control program.

Management priorities were first established by comparing and ranking metropolitan area watersheds in terms of the magnitude of their existing and forecasted pollutant loadings (MWCOG, 1979). The ranking process employed application of quantitiative criteria to 42 individual watersheds in the region based on simulations of current (1977) and forecasted (2000) average annual total and unit area nonpoint loads, total and percent change between current and forecast conditions, and stream channel erosion potential. In addition, qualitative criteria which addressed instream as well as Estuary receiving water impacts were taken into consideration. Based upon this analysis, each watershed was assigned a "critical watershed" priority ranking as shown in Figure 9.

FIG. 9 Ranking of Washington Area Watershed Study Priorities

The ranking system served as a basis for selecting watersheds where more detailed water quality assessments were warranted. Nonpoint source modeling tools were also developed and a consistent set of nonpoint source loading rates identified for local use to ensure that individual studies would be conducted in a reasonably consistent manner. This approach facilitated the "transferability" of study results and ensured that resulting local watershed management programs would be sensitive to broad regional water quality problems.

To date, five local watershed assessments have been completed and two more are underway. In composite, watershed study data will provide more detailed quantification of regional and local nonpoint pollution problems; assist in identification of loading targets and control needs; and augment nonpoint source information applied in the Potomac Estuary trade-off analysis previously described.

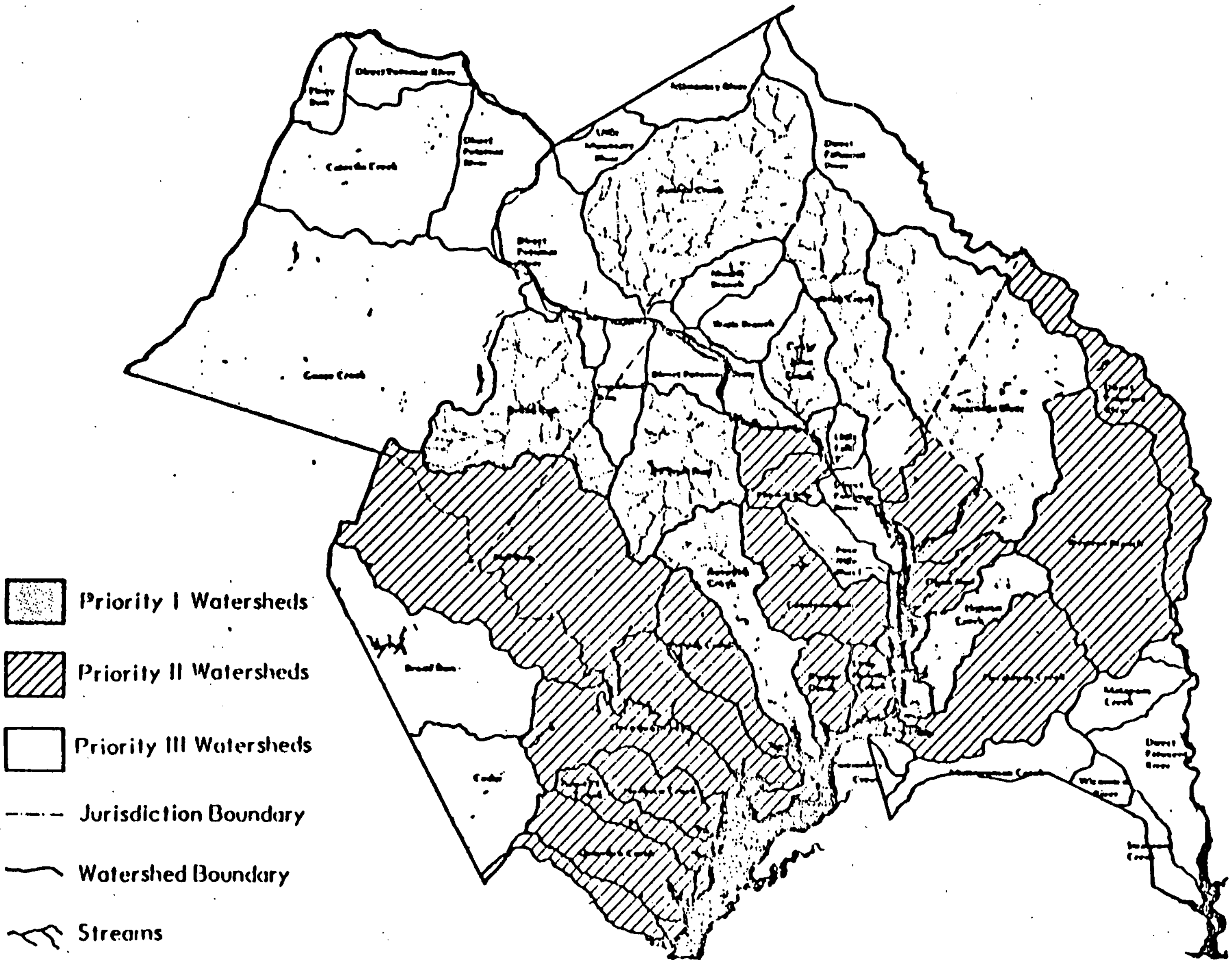


Figure 9-Ranking of Washington Area Watershed Study Priorities

Upper Potomac Basin Activities

The magnitude of average annual pollutant loadings to the Potomac Estuary from sources upstream of the Washington, D.C. area is evident in Figures 2 and 6. These loads are not suprising, however, considering the large size of the Potomac Basin and the diverse activities it supports. Much of the upstream load is the result of natural weathering and erosive processes. However, a large portion can also be attributed to agricultural and extractive activities, while comparatively small amounts are due to point source discharges upstream of metropolitan Washington.

The importance of upstream nonpoint source loads underscores the need for effective and increased upstream use of agricultural runoff controls, basic soil conservation practices and other nonpoint control practices that minimize the human-induced portion of this problem. The trend towards no-till farming in the upper Basin is pronounced and may ultimately help to reduce nutrient and sediment loadings transported to the upper Estuary. However, there may well be a parallel trend occurring—away from contour framing and soil conservation practices towards intensive farming—which could offset the gains of no-till. The success of upstream abatement programs are a critical concern to the health of the Estuary. Downstream jurisdictions have emphasized the importance of these efforts and will be closely watching the implementation process.

CONCLUSIONS

Research indicating the significance of nonpoint source loads delivered to the upper Potomac Estuary, coupled with a growing recognition that scarce economic resources must be applied in the most cost-effective manner, has fostered an interest in broadening the focus of the region's water quality control program. As suggested in Figure 8, a new management approach is evolving that may eventually replace the region's traditional and almost exclusive reliance on control of point source loadings to meet rigidly defined and interpreted water use definitions and quality standards. This new approach is more flexible and practical in its consideration of the impacts, controllability, and costs to control all loading sources. The approach would employ return frequency and economic considerations in tandem with sophisticated water quality model simulations to help identify the most cost-effective management solutions.

Such techniques include assessment of the timing of water uses needing protection; the timing and frequency of water quality standards' violations and their significance to the uses being protected; and the costs of meeting or not meeting standards for alternative return periods. The new strategy will make possible identification of cost-effective management options which, as available data suggests, may well include some optimized mix of point, nonpoint, combined sewer overflow, and upstream controls rather than continued singular emphasis on high technology and costly advanced wastewater treatment.

To support a long-term management strategy, a state-of-the-art eutrophication model for the Potomac Estuary is under development. Using a frequency of occurrence approach, variations in future water quality in the Estuary will be predicted for various levels of pollutant control from all sources for varying costs. The strategy providing the greatest water quality benefit at the minimum cost will be selected to guide management of the Estuary into the next century.

APPENDIX 1 - REFERENCES

Bower, B., Blackburn, A., "Dollars and Sense", Interstate Commission on the Potomac River Basin, Bethesda, Md., Sept. 1975.

Metropolitan Washington Council of Governments, Department of Environmental Programs, "Analysis of Nonpoint Source Pollutants in the Washington Area and the Selection of Critical Watersheds", Washington, D.C., 1979.

Noss, Richard R., Marks, David H., "Improving the Development of Water Quality Standards", Journal, Water Pollution Control Federation, Volume 53, Number 4.

Sullivan, M., Freudberg, S., Wiegand, C., "Strategies for Considering Point and Nonpoint Control Tradeoffs for the Upper Potomac Estuary", Proceedings of a Technical Symposium on Nonpoint Pollution Control, Tools and Techniques for the Future, Interstate Commission on the Potomac River Basin, ICPRB Tech. Pub. 81-1, Jan. 1981, pp. 225-244.

Thomann, R.V., Fitzpatrick, J., "Overview of Potomac Estuary Modeling, Tasks I and II - Dissolved Oxygen and Eutrophication", HydroQual, Inc., Mahwah, N.J., Aug. 1980.