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**LITERATURE REVIEW OF ECONOMIC VALUATION
OF AQUATIC PLANT CONTROL**

by

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13. ABSTRACT (Maximum 200 words) Aquatic plant control is necessary to maintain the flow of benefits for which water resources projects are constructed and operated (e.g., flood control, water supply, or recreation). The costs associated with aquatic plant control have been documented by the US Army Corps of Engineers, but little work has been performed by the Corps to evaluate the economic benefits resulting from aquatic plant control programs. This report reviewed the applicability of the project evaluation guidance, Principles and Guidelines (P&G), for the evaluation of aquatic plant control benefits. It was determined that the approach to economic valuation set out in P&G could be used for valuing aquatic plant control benefits. Corps, State, and academic studies and reports were reviewed for valuation of aquatic plant control benefits. In the majority of cases, aquatic plant control benefits received only cursory treatment. In some cases, few details of the benefit estimation procedures are offered, making it difficult to judge the reliability of the benefit estimates. The majority of project evaluations were based solely on the recreation benefits.				
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PREFACE

This study was conducted as part of the US Army Corps of Engineers Aquatic Plant Control Research Program (APCRP). Funds for the study were provided by the Headquarters, US Army Corps of Engineers (HQUSACE), under Department of the Army Appropriation No. 96X3122, Construction General. The APCRP is managed by the US Army Engineer Waterways Experiment Station (WES) under the Environmental Resources Research and Assistance Programs, Mr. J. Lewis Decell, Manager. Mr. Robert C. Gunkel, Jr., was assistant Manager for the APCRP. Technical Monitor for the study was Mr. James W. Wolcott, HQUSACE.

This study was performed under contract to Dr. Eric M. Thunberg, Department of Food and Resource Economics, University of Florida, Gainesville, FL. Mr. Jim E. Henderson, Environmental Laboratory (EL), WES, served as contract monitor. Ms. Janean C. Shirley of the WES Information Technology Laboratory edited the report.

The study was performed under the general supervision of Dr. John Harrison, Chief, EL, and Dr. C. J. Kirby, Chief, Environmental Resources Division, and under the direct supervision of Mr. H. Roger Hamilton, Chief, Resource Analysis Group.

Commander and Director of WES was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

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CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI
(metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
acres	4,046.873	square metres
miles (US statute)	1.609347	kilometres

LITERATURE REVIEW OF ECONOMIC VALUATION
OF AQUATIC PLANT CONTROL

PART I: INTRODUCTION

Background

1. Aquatic plant control is often necessary to maintain the flow of benefits for which projects are constructed and operated. The US Army Corps of Engineers, through the Waterways Experiment Station (WES), has maintained an ongoing research program directed toward development of improved methods of controlling aquatic plants. Through these research endeavors effective control strategies and their comparative costs have been well developed (Henderson 1990). However, relatively little is known with regard to the economic benefits of aquatic plant control. The purpose of this review is to examine the existing literature on economic valuation methods as they relate to benefits of aquatic plant control.

Purpose

2. In Fiscal Year 1990, a Work Unit entitled Economic Valuation of Aquatic Plant Control was initiated at WES under the Aquatic Plant Control Research Program. The objective of the Work Unit is to identify or develop methods to evaluate the benefits of aquatic plant control. This literature review was initiated to identify the conceptual basis of valuing aquatic plant control benefits and to review previous efforts on aquatic plant control valuation. The basis for valuation of control benefits and the methods identified in this review will provide guidance to further development of valuation methods in the Work Unit.

Scope

3. The focus of the review is on two types of economic valuation studies. The primary focus is on valuation of aquatic plant control benefits. Such benefits as flood control, navigation, and recreation fall into this category. In the process of the literature search, a number of articles were found that dealt with the cost savings associated with alternative aquatic

plant management strategies. These cost savings may be considered benefits. Therefore, a brief discussion of these benefit studies is included.

4. The literature review is structured in the following manner. The theoretical basis for measuring economic benefits is presented in PART II. Special problems or considerations unique to aquatic plants and the general benefit categories associated with aquatic plant controls are discussed in PART III. PART IV provides a review of the aquatic plant economic valuation literature for each of the benefit categories identified in PART III. In instances where no published literature could be found, a brief description of economic valuation techniques that may be applicable to that benefit category is presented. PART IV concludes with a discussion of the aquatic plant literature on cost savings as part of economic valuation.

PART II: THEORETICAL BASIS FOR BENEFIT ESTIMATION

5. Economics is the study of how people make choices, that is, how people allocate scarce resources among competing uses to satisfy human wants or needs. People are assumed to express preferences for certain goods or services through their relative willingness to accept lower levels of consumption of some goods in return for higher levels of consumption of other goods. Economists observe this weighing of preferences for goods and services by the way people allocate income among alternative consumption choices. The concept of making tradeoffs among different consumption opportunities under a resource constraint, usually a budget constraint, is the theoretical foundation of the willingness-to-pay standard identified in "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies" (P&G) published by the US Water Resources Council (USWRC) in 1983. For any one set of prices, a point on an individual's demand curve for a good is determined by observing the number of units of the good the individual purchases at that price. For example, the demand for a recreational site can be determined by observing the number of visits to the site at a given entrance fee. By varying the price paid for the good, a locus of points may be mapped relating prices to quantities purchased at each price. In this manner an individual's demand curve for a given commodity may be derived.

6. The individual's demand curve is equivalent to a mapping of an individual's marginal willingness-to-pay for each additional unit of a consumption good, (water supply or a recreational trip, for example). In a market setting there will typically be only one prevailing price. For any given individual, the market price is equivalent to the marginal willingness-to-pay for the last unit of the service or commodity. However, individuals may be willing to pay an amount in excess of the market price they actually do pay in order to enjoy the commodity or resource. The incremental amount that a consumer would be willing to pay but does not have to pay is known as the consumer surplus and is a measure of the net economic benefit of providing the commodity. This point is illustrated in Figure 1. At the prevailing price, P_1 , the individual purchases Q_1 units of commodity Q . The total cost to the individual of Q_1 units is measured by the area OP_1ZQ_1 . This cost to the individual represents the market conditions, but not necessarily what the consumer is actually willing to pay for the commodity. In looking at the willingness to pay for the

commodity, the individual would have been willing to pay OP_2BQ_2 for the first Q_2 units of Q . Though the individual was willing to pay price P_2 for each unit, he did not have to pay the higher P_2 price because the actual P_1 price is lower. That is, the actual price is lower than the price the individual is willing to pay. Similarly, for the next Q_3 units of Q , the individual is willing to pay $OP_3CQ_3 - OP_3 \times Q_2$. The total amount that the individual would have been willing to pay for Q_1 units of Q is equal to the area $OAZQ_1$. The difference between what the individual actually pays and what the individual would be willing to pay is known as consumer's surplus (area P_1AZ in Figure 1). It is the consumer's surplus that provides the measure of net benefit to the consumer of providing good Q .

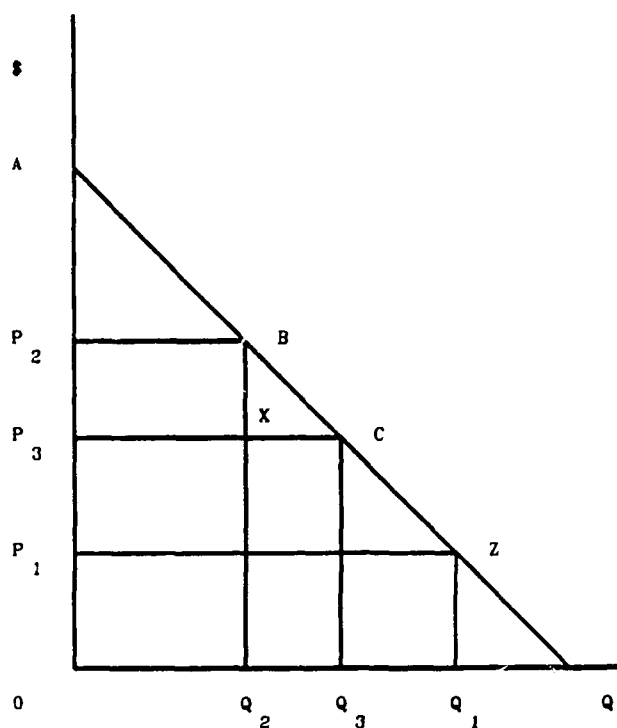


Figure 1. A simulated demand curve

PART III: SPECIAL CONSIDERATIONS AND BENEFIT CATEGORIES
FOR AQUATIC PLANT CONTROL

Delineation of RED Versus NED Benefits

7. There are two considerations that, while not unique to aquatic plant control, do nevertheless present problems in measurement of aquatic plant control benefits. First, in evaluation of benefits, the P&G require a delineation between National Economic Development (NED) and Regional Economic Development (RED) benefits. NED benefits accrue to the nation as a whole and are important to demonstrate the Federal interest in a project, expressed as a benefit to cost ratio (B/C). It is the NED benefits that are utilized in the B/C ratios on which Federal projects are evaluated. The RED benefits are changes in goods, products, and commodities resulting from a project in the region affected by project operation. In terms of aquatic plant control, it is important to understand the regional distribution of benefits for consideration of such things as cost-sharing arrangements, availability of alternatives to the project within the region, and for calculation of benefits as explained below. For existing water development projects having flood control, navigation, or water supply as the primary project purpose, the benefits of these restored services due to aquatic plant control will constitute NED benefits. However, in instances where recreation benefits are claimed, great care must be taken to distinguish between RED and NED benefits.

8. In examining recreation benefits for proposed aquatic plant control at a project, the primary consideration in distinguishing between NED and RED benefits will be the availability of substitute recreational sites and the demand conditions that exist at those sites. In instances where an excess supply of recreation services exists within a region, restored recreation opportunities at one site may attract users to the site. However, if the users were previously using other sites, only the difference between the recreationist's value for the restored site and the substitute site represents a net gain in NED.

9. The difference between NED and RED benefits can be shown by considering a recreational fisherman that has a choice between two sites. One site is currently choked with plants, but has in the past offered good fishing, while another site has no aquatic plant problems but has inferior fishing quality compared to the previous site. In the absence of aquatic plant

control, the fisherman chooses the clear but lower quality fishing lake and is willing to pay \$5 to fish at the site. Under "With" plant control conditions, the same fisherman chooses to fish at the now clear and higher quality fishing site and is willing to pay \$7 for the higher quality site. Under an RED accounting stance the full \$7 benefit may be attributable to the aquatic plant control for the region. However, of the \$7, \$5 is simply a transfer of benefits from one site to another within the region. Under an NED accounting stance, only the \$2 net gain in social benefits may be attributed to aquatic plant control. If, on the other hand, the fisherman has no other alternative and consequently stops fishing altogether, or if there is excess demand for recreational fishing sites, then the RED and NED benefits may be equivalent (or equal to \$7 in this example). In summary, the issue of delineating between RED and NED benefits depends on (a) the relative availability of substitute sites and whether there is excess demand or excess supply of regional recreational services, and (b) how the boundaries for analysis are set.

Competitive Recreation Services

10. The second problem that presents itself, once again, primarily in evaluation of recreation benefits, is in instances where the provided services are competitive. For instance, a multipurpose project may produce flood control and recreation benefits, but provision of flood storage benefits may be at the cost of reduced pool levels that diminish the quality of recreation. In the case of aquatic plants, recreational fishermen may find a certain level of aquatic plants to be desirable while recreational boaters may find any level of aquatic plants to be a nuisance. In cases such as these, evaluation of aquatic plant control benefits requires estimation of the demand for each service and determination of the optimal (i.e., benefit-maximizing) level of aquatic plant control. Figure 2 illustrates the theoretical foundations for conducting such an analysis.

11. Figure 2 shows two marginal benefit* curves superimposed in mirror image onto the same graph. The horizontal axis of Figure 2 indicates

* Marginal cost or marginal benefit is the benefit or cost of the next additional increment of a product, good, or service.

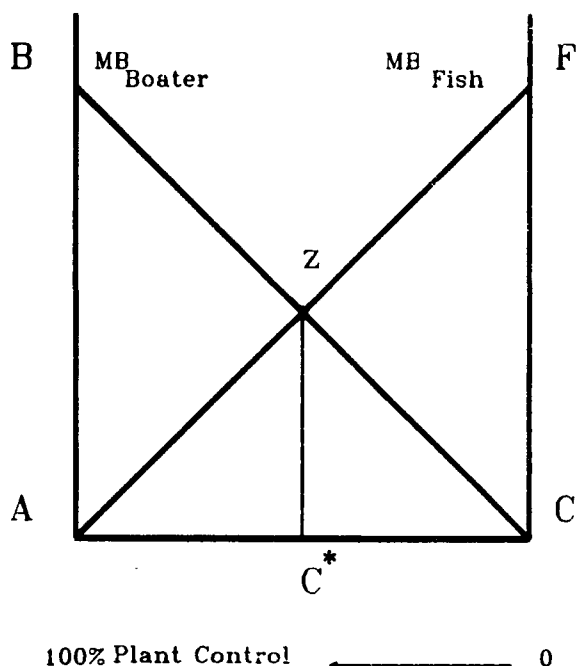


Figure 2. Plant control and benefits to boaters and fishermen

decreasing levels of plant control from left to right (line BC); thus, the downward-sloping marginal benefit curve for recreational boaters. Conversely, the marginal benefit curve for fishermen (line AF), shows an upward-sloping marginal benefit curve, that is, increasing benefits with decreasing plant control. Each marginal benefit curve may also be interpreted as a marginal opportunity cost curve for decreasing levels of aquatic plant control in the case of recreational boaters and increasing levels of aquatic plant control in the case of fishermen. That is, benefits to fishermen increase as benefits to boaters decrease.

12. Reading Figure 2 from right to left (line BC), as aquatic plant control levels are increased, the marginal benefit from increased control to recreational boaters exceeds the marginal opportunity cost to fishermen of foregone fishing services associated with the lowered levels of aquatic plants. However, once aquatic plant control levels exceed C^* , the marginal opportunity cost to fishermen of increased control exceeds the marginal benefit to recreational boaters. That is, marginal increases in benefits to recreational boaters result in costs to fishermen. The total benefits of controlling aquatic plants at C^* is equal to the areas ABZ plus BFZ (that is, the area $ABZC^* + BFZC^*$ less the foregone fishing and boating services $AZC^* + BZC^*$). Thus, under conditions of competitive recreation services, the benefit-maximizing level of aquatic plant control is determined by equating the marginal benefits of one service with the marginal opportunity costs of its competitor service.

Benefit Categories

13. An ongoing aquatic plant control program at a project makes possible a variety of economic services that may extend beyond the primary authorized purpose(s) of the project. Authorized purposes of most water

resources are one or a combination of the following: navigation, flood control, water supply, hydropower, or recreation. These are the general benefit categories normally associated with water resource projects. However, other benefits such as improved aesthetics may be provided along with an aquatic plant control program. In addition to these benefit categories the more abstract concepts of option, bequest, and preservation values may also be affected by provision of aquatic plant control. A more detailed discussion of all of these benefit categories is provided in PART IV.

PART IV: AQUATIC PLANT VALUATION LITERATURE

14. Sources for the literature search included the Aquatic Plant Control Information Retrieval System, Design Memoranda and related literature, library search, and a crosscheck of reference lists against literature that had already been obtained. Because the focus of the literature review was on valuation of aquatic plant control programs, articles or publications dealing with the economics of beneficial uses of aquatic plants or the economic outlook for retail sales of aquatic plants were eliminated from consideration. This left 16 articles that dealt with some aspect of economic valuation of aquatic plant control. The literature will be discussed by benefit category, as listed previously, in the following manner. First, the appropriate economic measurement of benefits and techniques will be discussed. Following that, the available literature will be summarized. In instances where no literature was found for a particular benefit category, a proposed approach for benefit measurement is suggested.

Flood Control

15. Flood control benefits are defined as the value of flood damages avoided (USWRC 1983). Simply stated, the benefit estimation procedure requires a simulation of flood damages under "With" and "Without" project conditions. The resulting difference between the two conditions provides a measure of flood control benefits. For aquatic plant control programs, the conceptual basis for benefit measurement and the procedures for estimating benefits are no different. Valuing the flood control benefits of aquatic plant control is determined by how the efficiency of an existing system or waterway is diminished by the presence of the plants.

16. Huser (1968) is the only example in the literature surveyed that even mentions flood control in the context of aquatic plant control efforts. In describing a South Florida Flood Control District project, the author identifies the primary purpose of the project to be flood control. Without control of aquatic plants the author states that all project benefits would be eliminated. Thus, the value of the flood control benefits attributable to aquatic plant control are equal to the flood control benefits for the entire project under a "With" plant control condition, or \$30.5 million annually.

17. Although Huser (1968) correctly identifies the link between the presence of aquatic plants and diminished project efficiency, the assumption that all project benefits will be eliminated is improbable. Therefore, the stated \$30.5 million benefit estimate is likely to be much overstated. Of course, it must be recognized that the author's intent was to be speculative, no attempt was made to evaluate the benefits and costs of any particular plant control plan.

Commercial Navigation

18. The conceptual basis for measuring commercial navigation benefits is in the reduced value of resources dedicated to the transport of commodities (USWRC 1983). This definition is equivalent to measuring the reduced costs of transporting commodities as a measure of project benefits. The sources of transportation benefits for aquatic plant control are the same as for any other navigation project. Aquatic plant infestations increase travel time, and may require switching to higher cost waterways or other means of transport. The evaluation procedures used for navigation projects are applicable to evaluating aquatic plant control programs.

19. Of the literature surveyed, Huser (1968) and US Army Corps of Engineers, Baltimore District (USAED, Baltimore) (1986) estimate navigation benefits of aquatic plant control. Huser (1968) estimates an annual benefit of \$51,000 while the USAED, Baltimore provides an estimate of \$24,000 in annual program benefits. Huser's estimate suffers from the same problems mentioned earlier, that is, overstatement of benefit losses. The \$24,000 in annual benefits claimed by the Baltimore District is based on lost time in transit to commercial fishing boats. Although in this latter case a number of simplifying assumptions were made, the general approach taken was consistent with P&G evaluation guidelines and is defensible as a rough estimate of navigation benefits.

Water Supply

20. The conceptual basis for measuring water supply benefits is society's willingness-to-pay for the additional services that result from additional sources of water supply (USWRC 1983). For aquatic plant control the same general conceptual basis applies. However, for existing water supply

projects there may be two sources of benefits: increased capacity and cost savings. In instances in which aquatic plants reduce the capacity of the project to deliver water, the value of the restored capacity may be attributable to aquatic plant control. However, it may also be the case that water supply can be maintained under aquatic plant infestations but only at a higher cost. The benefit of control is equal to the difference between water supply costs under "With" and "Without" plant control conditions. As long as this cost saving exceeds the cost of the aquatic plant control program a net gain in benefits is realized. No examples were found in the literature search that attempted to measure water supply benefits for an aquatic plant control program.

Hydropower Generation

21. The conceptual basis for measuring power generation benefits is society's willingness-to-pay for the additional power (USWRC 1983). Once again, the same general basis and procedures for measuring power generation benefits used for other water resources projects apply to evaluation of aquatic plant control. The principal source of benefits of aquatic plant control is the value of the restored power generation capacity and any cost savings associated with the lowered aquatic plant levels. No examples of attempts to relate aquatic plant control benefits to hydropower generation were found in the surveyed literature.

Recreation

22. The conceptual basis for valuing recreation benefits is the individual's willingness-to-pay for each increment of recreational services provided by a water resources project (USWRC 1983). The presence of aquatic plants may diminish the flow of recreation services provided by an existing water resource project, waterway, or river system. Thus, the benefit of aquatic plant control for recreation is the value of the restored recreation services under the "With" plant control condition. There are three accepted economic techniques for measuring recreation benefits: Travel Cost Method, Contingent Valuation Method, and Unit Day Values (USWRC 1983). Each of these methods is applicable to valuation of aquatic plant control programs.

23. In the majority of the reviewed literature, recreation benefits were the major or only benefit that was estimated. Huser (1968) estimated annual recreation benefits of \$1.8 million attributable to aquatic plant control. The State of Louisiana (1989) estimated the annual recreational fishing benefits alone of their aquatic plant control program to be \$809,202,307. In both instances the basis for these benefit estimates for recreation is quite tenuous. The problem with the former article has already been discussed. In the case of the latter benefit estimate, the State of Louisiana claims maintenance of 3,059,366 acres* of open waterway through aquatic plant control efforts. Benefit estimates are then computed using an assumed value of \$23/fishing effort and 11.5 fishing efforts per acre. The product of effort value, effort per acre, and number of acres maintained yields the estimate of \$809 million. Although the methods by which these figures were determined are not presented, this appears to be a gross overstatement of recreation benefits attributable to aquatic plant control.

24. The fundamental problem with the State of Louisiana benefit computations is the lack of a clear relationship between acres of aquatic plants actually treated and the marginal change in fishing trips taken as a result. In essence the analysis is equivalent to a before and after analysis instead of a clear examination of "With" versus "Without" project conditions. In this case all recreational values are erroneously attributed to aquatic plant control.

Unit day value studies

25. The remaining literature on recreation benefits either uses the Unit Day Value Method or estimates changes in expenditures under "With" and "Without" plant infestation or plant control programs. Using the Unit Day Value Method, the Baltimore District (1986) estimated aquatic plant control recreation benefits to be \$2,691,000 annually. The Baltimore District also used a Lost Income Approach to estimate recreation-industry-related benefits of \$4,000,000 and \$232,300 annually for marinas and tourist cruises, respectively. Recreation values for 11 Florida sites were estimated by the USAED, Jacksonville (1976), based solely on recreational fishing values. These values ranged between \$132.20 and \$1,050/acre/year. Benefit-cost ratios for the same study ranged between 1.8 and 36.6 using Unit Day Values. In studies

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

published in 1985 and 1989, the State of Texas used Unit Day Values to estimate recreational fishing benefits from clearing boat lanes. The 1985 study (State of Texas 1985) reported annual benefits per boat lane ranging from \$2,200 to \$29,400 at five Texas lakes, assuming different use levels. The estimated B/C ratios ranged between 2.2 and 6.2. The 1989 study (State of Texas 1989) included 11 Texas lakes that were all located within a 150-mile radius of at least one major metropolitan area. Annual recreational fishing benefits per boat lane at these lakes ranged from a low of \$22,100 to a high of \$56,100. The estimated B/C ratios ranged between 22.6 and 116.9 depending upon whether herbicide or mechanical treatments were applied.

Expenditure and Survey Methods

26. Two studies attempted to determine the relationship among hydrilla infestations, angler success rates, and angler expenditures (University of Florida 1986; Colle et al. 1987). These papers report no differences in angler success rates regardless of aquatic plant infestation levels. Angler expenditures, however, dropped at the study sites from \$1.02 million in 1974 prior to infestation to \$112,000 in 1977 when aquatic plants covered 97 percent of the lake surface. Colle et al. (1987) report B/C ratios for aquatic plant control at the site that range between 121:1 and 0.3:1. These B/C ratios were computed by dividing total angler expenditures for a given year by the total program costs for the same year. Thus, the reason for the 0.3 B/C ratio is that it is for the year of heaviest plant infestation, and so the year of largest control expenditures.

27. Computing B/C ratios in the above manner is inappropriate because it is based on an incorrect definition of benefits. Appropriate computation of B/C ratios would have accounted for the change in angler expenditures at the site under "With" plant control conditions using the 1977 "Without" plant control expenditures as a base. To illustrate, in 1977 the authors report angler expenditures of \$112,000, this is the "Without" project condition. Over the next two years, under "With" plant control conditions, total angler expenditures were \$1,435,900 while project costs totalled \$104,600. The benefits of the plant control program are the increased recreational services provided or \$1,323,900 (\$1,435,900 - \$112,000) and the B/C ratio is the total program benefits divided by program costs, or 12.65:1. However, it is also possible that this B/C ratio is overstated because it fails to consider whether the increased expenditures represent NED or RED benefits. That is, if anglers were simply choosing to fish at alternative sites, then the use of the

full value of expenditures as a benefit measure is consistent with an RED accounting stance. Proper accounting under NED requires an estimate of the amount of increased expenditures that represents a transfer of expenditures from other sites. The NED benefits would be the difference between total angler expenditures net of any transfer effects.

28. Milon, Yingling, and Reynolds (1986) used a Contingent Valuation survey to estimate angler's willingness-to-pay for aquatic plant control. The authors used a combination of mail and intercept surveys to determine anglers' knowledge of aquatic plant problems and to ascertain their willingness-to-pay for a specified aquatic plant control program. Both local and nonlocal fishermen in two Florida lakes were surveyed. The payment mechanism used was a special aquatic plant stamp that would be required of all anglers using the lakes. Results indicate that the total willingness-to-pay was \$386,063 (1985 dollars). Although no control program costs are reported, if average control costs reported in Colle et al. (1987) (which covered one of the same lakes) for the 1980-1982 period are used, the average annual B/C ratio would be 2.37:1.

29. Using a similar approach and a nearly identical survey instrument, Milon and Welsh (1989) used a Contingent Valuation survey to assess angler perceptions of aquatic plant control problems and willingness-to-pay for an aquatic plant control program in Lake County, Florida. The authors found that willingness-to-pay for aquatic plant control ranged between \$50,000 and \$176,000 on an annual basis.

Aesthetic Quality Benefits

30. Aesthetic values are included in the P&G under the Environmental Quality (EQ) Account. Although the general category of EQ is not required to be quantified, the economic literature provides a number of examples and techniques in which such effects are quantified (Freeman 1979; Hufschmidt et al. 1983; Randall 1981). For the case of aquatic plant control, aesthetics may be an important component of willingness-to-pay for landowners along a lake's shore or for recreational users of a lake. For landowners, economic methods based on land sale prices or lot characteristics have been applied to measure aesthetic values (Graves et al. 1988) or changes in environmental quality (Batie and Mabbs-Zeno 1985; Shabman and Bertelson 1979). The Contingent Valuation Method is also another technique that may be applied to ascertain

willingness-to-pay for aesthetic qualities of natural resource sites (Rowe, D'Arge, and Brookshire 1979; Brookshire, Ives, and Schulze 1976).

31. Milon (1989) provides the only example in the aquatic plant literature of a study that attempted to measure the aesthetic values of aquatic plant control. Using a technique called the "sale-resale" method, Milon (1989) estimated the proportional reduction in the sale price of houses along a lakeside development in Florida due to the presence of aquatic plants. By regressing the ratio of initial sale to resale prices against sale prices and a dummy variable representing years "With" and years "Without" aquatic plant infestations, the share of the effect of the infestation on sale prices can be identified. The study results found no statistically significant difference in sale-resale prices under "With" and "Without" aquatic plant infestation conditions.

Option, Existence, and Bequest Values

32. In recent years increasing attention has been paid in the economics literature to values such as option, existence, and bequest values (Walsh, Loomis, and Gillman 1984; Smith 1987). In each of these cases the objective is to account for the value that those individuals that are not current users of a resource might nevertheless be willing to pay to assure its continued presence. Option value is the value that one might hold in order to preserve the option to use a resource in some future time period. Existence value might be held for a resource by an individual just by the knowledge that it exists. The value an individual holds for endangered species protection is an example of existence value. Bequest value is related to option and existence value in the sense that individuals may desire that the option to use a resource or the existence of a resource ought to be maintained for future generations.

33. The concept of option, existence, and bequest value in valuation of aquatic plant control has a somewhat different context than that usually associated with public programs. Under usual public planning and operations situations, the decision-making process centers on whether to develop or not develop a natural resource. Under these circumstances, option, existence, and bequest values normally are associated with the "Without" project condition. However, for aquatic plant control, the issue is one of restoring or maintaining the flow of services or benefits from a water resources project or natural

waterway or lake. That is, an aquatic plant control program preserves the productive recreation, aesthetic, and other qualities of a natural resource. In this case, option, existence, and bequest values are relevant only under "With" project conditions.

34. Even though option, existence, and bequest values are at least theoretically possible, to date, attempts to measure them as components of value distinct from use value have not been particularly successful. At this time, economic techniques to measure option, existence, or bequest values make it very unlikely that inclusion of these benefit categories in an aquatic plant evaluation would be feasible. In point of fact, however, it also seems extremely unlikely that the economic feasibility of any aquatic plant control program will hinge on the magnitude of option, existence, or bequest values.

Cost Savings as Economic Benefits

35. The literature reviewed to this point represents a specific type of benefit evaluation that falls into the general category of project evaluation or feasibility. A different type of project evaluation occurs in instances where modifications are made to ongoing control programs in an effort to reduce costs. The cost savings may be considered as the benefits of the revised program and the costs of implementing the revisions may be considered the project costs. A comparison of program benefits and implementation costs would determine the merit of implementing the new program. The surveyed literature dealing with this type of benefit evaluation is briefly summarized below.

36. Tisdell, Auld, and Menz (1984) review some basic considerations in evaluating a biological control program. The authors point out the need to consider aspects of different biological control strategies as well as the research and development costs of biological control agents in determining the cost of implementing a biological control program. Andres (1977) compares biological and chemical control strategies in Semmes Lake, Fort Jackson, South Carolina. The author found that an insect control program attained satisfactory control at a cost of \$600 per year as compared to \$7,500 per year using chemical treatment.

37. Osborne (1982) compared the cost of using grass carp and chemical control methods. The author found that the grass carp reduced control costs by a factor of 2 to 5 over that for chemical control programs. The author

also found that the cost of using grass carp, once established, declined over time while the cost of chemical control remained relatively static. Shireman, Colle, and Canfield (1986) compared the cost of using grass carp to chemical control methods in sport fishing ponds. The authors used a series of small ponds in which specific plant biomass levels were maintained. The authors found that regardless of treatment method the harvestable biomass of sport fish was unaffected. The authors also found that the grass carp was significantly less costly at all target levels of control and that the difference between control costs became increasingly large as the target control level increased.

38. Unlike the above, Koegel and Livermore (undated) examined alternative means for reducing the capital investment requirements for mechanical harvesting systems. The authors evaluated a system designed to take advantage of a flowing system to allow mechanically harvested weeds to float to concentrated collection sites. The authors found that such a system costs between \$13.52 and \$20.28 per acre to operate depending upon the frequency of cutting. The authors conclude that substantial cost savings are feasible; however, no other mechanical control programs are offered for comparison.

PART V: SUMMARY

39. Valuing the benefits of aquatic plant control can be approached using the same economic bases and methods that are used for other water resources projects (USWRC 1983). The conceptual approach for the different benefit categories identified in P&G can be applied to the benefits derived from an aquatic plant control program. In valuing aquatic plant benefits, care should be taken to distinguish between benefits accruing to the nation as a whole, the NED benefits, and the regional benefits, the RED benefits. Some benefits, especially recreation, may exhibit competitive behavior. That is, increases in one benefit category through a certain level of aquatic plant control may result in decreases in another benefit category for that same level of control.

40. The literature search identified limited published material dealing with valuation of aquatic plant control. In the majority of the surveyed literature, estimation of aquatic plant control benefits received only a cursory treatment. In most cases, few details of the benefit estimation procedures are offered, making it difficult to judge the reliability of the benefit estimates. In only one instance was more than one benefit category vigorously pursued. The majority of project evaluations were based solely on recreation benefits. While relatively large recreation benefits tend to be generated, consideration to other project benefits may be warranted.

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