CHAPTER 10

ENVIRONMENTAL BENEFITS OF PROPOSED REGULATION

10.1 INTRODUCTION

EPA anticipates several environmental benefits of the proposed concentrated aquatic animal production (CAAP) regulatory action. These include improvements in water quality and, as a consequence, increases in the recreational and non-use value of affected water bodies. The proposed minimization of releases of non-native species (through best management practices) is also anticipated to better protect aquatic ecosystems and resources. Finally, the proposed action is expected to reduce releases of drugs and other chemicals, and aquatic animal pathogens, into the environment by requiring facilities to develop and implement best management practice (BMP) plans.

EPA has quantified and monetized a subset of the anticipated benefits of the proposed action listed above. The central basis for the quantitative benefits analysis is a water quality modeling assessment that estimates water quality responses to the pollutant loading reductions under technology options described earlier in this document. Specifically, the benefits that EPA has been able to quantify are (a) water quality improvements in stream reaches downstream of flow-through and recirculating systems, and (b) improvements in the recreational use value of these same reaches. Benefits that were not quantified include water quality and ecological responses to pollutant loading reductions at net pen systems and ecological and other water resource benefits from reductions in releases of non-native species, aquatic animal pathogens, and drugs and chemicals used at CAAP facilities. EPA did not quantify or monetize these potential benefits due to lack of readily available assessment modeling tools for such an analysis. Thus, the estimated monetized benefits of the proposed action are based only on a portion of the expected environmental benefits of the proposed regulation.

10.2 BENEFITS ENDPOINTS EVALUATED

EPA considered several possible endpoints or metrics for characterizing the national environmental benefits of the proposed regulation. For receiving waters of representative CAAP facilities, EPA considered comparing baseline and post-regulatory values for specific water quality parameters for which national numeric or narrative criteria had been established (e.g., total nitrogen and total phosphorus). EPA also considered using a composite index of water quality which could, based upon a national contingent valuation survey, be related to households' willingness-to-pay (WTP) for water quality improvements. Finally, EPA considered estimating responses of key biological variables (e.g., presence of pollution tolerant or intolerant species) to water quality changes induced by the regulation. Each of these approaches require analysis of the effect of the proposed regulation on receiving waters of CAAP facilities.

Data limitations precluded detailed site-specific water quality studies for actual representative CAAP facilities. Such analyses would be needed to develop accurate baseline water quality estimates for representative CAAP facilities, which would in turn be preferable bases for benefits estimates. Instead, EPA used a water quality model to simulate a range of potential water quality changes arising from the regulation downstream of CAAP model facilities, using a range of assumed hypothetical background conditions. EPA then used this range of simulated changes to determine a potential range of national economic benefits from water quality improvements, using the composite water quality index and national contingent valuation survey results. EPA also included a qualitative discussion of potential changes in downstream water quality and the impact of these changes on stream impairment as judged by comparison to water quality criteria. These analyses are described in the following sections.

10.2.1 Water Quality Standards and Nutrient Criteria

Water quality criteria reflect the latest scientific knowledge on the effects of water pollutants on public health and welfare, aquatic life, and recreation. These criteria guide states, territories, and authorized tribes in developing water quality standards and ultimately provide a basis for controlling discharges or releases of pollutants into our nation's waterways. Ambient water quality criteria are based solely on data and scientific judgments on the relationship between pollutant concentrations and the effects on aquatic life, human health, and the environment. These criteria do not reflect consideration of economic impacts or the technological feasibility of reducing chemical concentrations in ambient water (USEPA, 2002a). Water quality criteria have been established for ammonia and dissolved oxygen. More information about these criteria is provided in Appendix F. Appendix F also includes information on BOD and solids limits established for water quality protection purposes.

Nutrient criteria represent nutrient levels that protect against the adverse effects of nutrient overenrichment in aquatic environments. The criteria are associated with preventing and assessing eutrophic conditions. Surface waters that meet nutrient criteria would have minimal impacts caused by human activities (USEPA, 2001b). EPA has developed criteria for each of several ecoregions for total phosphorus, total nitrogen, chlorophyll a, and turbidity. More information about these criteria is provided in Appendix F.

10.2.2 Water Quality for Recreational Use

Improvements in water quality change the ways people can use water bodies. Recreational use of water is highly dependent on water quality. The recreational use supported is also an indicator of other benefits derived from the water body, such as use by public water authorities and aesthetic enjoyment. Changes in the recreational use supported by waterways associated with the CAAP regulatory options forms the basis for estimating monetized benefits of the proposal.

Monetized benefits are based on incremental changes in the recreational use supported by water bodies receiving CAAP facility flows. Waters can be classified into a spectrum of permissible recreational uses from boatable, which does not require the water to be suitable for body contact, to swimmable, which requires the water to be nearly potable. A national contingent valuation survey has related changes in water quality along this spectrum to households' willingness to pay (WTP) for water quality improvements (Carson and Mitchell, 1993). EPA used this value, along with estimates of the affected water area and population, to measure the benefits of improved water quality for recreational uses.

Nutrient and solids loadings lead to biological and ecological impacts in the receiving waters. These impacts were described in Chapter 9 of this document. EPA has not separately quantified potential biological and ecological benefits arising from pollutant load reductions. EPA may explore methods for evaluating potential biological and ecological benefits from reduced CAAP pollutant loads for the final regulation.

10.3 OTHER BENEFITS NOT QUANTIFIED

There are several additional categories of potential environmental and economic benefits that EPA has not quantified for the proposed CAAP rule. The following subsections describe these potential areas. EPA believes that these unquantified benefits have the potential to be significant and may pursue quantification of these benefits for the final rule.

10.3.1 Water Quality Benefits from Net Pen Loadings Reductions

EPA estimates that large salmon net pen facilities (i.e., with annual production greater than 500,000 lb) discharge significant pollutant loadings into receiving waters, most frequently marine embayments. For a large salmon facility with an annual production of 3.6 million pounds per year, quantities of BOD_5, total nitrogen, total phosphorus, and total suspended solids discharged annually to the environment are 4,086,153; 350,242; 58,374, and 3,502,417 lbs, respectively. For comparison, the annual domestic wasteload of a city of about 65,800 individuals produces an equivalent annual load of BOD_5. In many cases, facilities may be sited such that adequate flushing prevents water quality degradation in the receiving water. EPA is aware of research that has examined environmental impacts of net pen aquaculture (e.g., Strain et al., 1995; Findlay et al., 1995), as well as recent regulatory activity to address potential environmental concerns with net pen aquaculture (USEPA, 2002c). EPA estimates that under the regulatory options set forth in the proposed CAAP regulation, substantial reductions in net pen pollutant loadings would occur. However, EPA has not evaluated the water quality, biological, recreational use, or other benefits from the loadings reductions anticipated under the proposed CAAP effluent guideline.

10.3.2 Reductions in Escapements

A reduction in the incidences of escapements may have the potential to have economic and ecological benefits because of the large impacts that non-native aquatic species can have, as described in Chapter 9. In addition, sources indicate that equipment-related failures, catastrophic events, and accidents are major causes of escapements from marine aquaculture facilities (Ministry of Agriculture, Food and Fisheries, n.d.). In the proposed CAAP regulation, EPA proposes to require BMPs to minimize potential escapement of non-native species. Although EPA expects reductions in escapements as a result of this requirement, the Agency has not quantified potential environmental or economic benefits from reductions in releases of non-native species from CAAP facilities. EPA may explore methods for evaluating benefits for the final regulation.

10.3.3 Reductions in Drugs and Other Chemicals

EPA's proposed rule requires some regulated facilities develop and implement Best Management Practices (BMP) plans which, among other elements, specifies that facilities' BMP plans must ensure the storage of drugs and chemicals to avoid inadvertent spillage or release into the aquatic animal production facility. Moreover, EPA proposes to require that CAAP permittees comply with reporting requirements under certain situations involving the use of extra-label and unapproved drugs and chemicals at the CAAP facility. EPA expects that implementation of these two provisions of the proposed rule will lead to reductions in releases of drugs or chemicals that may have occurred as a result of inadvertent spillage or release. EPA has not quantified either baseline quantities of drugs and chemicals released to the environment, or potential environmental or economic benefits that might arise from the proposed requirements. EPA may pursue a quantitative benefits analysis for the final regulation.

10.4 BENEFITS MODELING APPROACH

At the time of the proposed rule, EPA focused on modeling CAAP industry impacts to streams and rivers. This enables the quantification of water quality and recreational use benefits for flow-through and recirculating facilities, which are primarily located on streams and rivers, but not for net pen systems which are primarily located in embayments, reservoirs, and other non-riverine systems. Thus, some of the potential benefits associated with the proposed regulation are not captured by this modeling approach. The focus on developing a method for assessing impacts to streams and rivers was shaped by limited availability of environmental and economic modeling tools and data required to quantify benefits other than stream-based water quality and recreational use benefits.

This preliminary focus is reasonable because the majority of CAAP facilities throughout the nation discharge to streams and rivers. Based upon a preliminary analysis of NPDES permit data (data not shown), approximately 87 percent of the facilities contribute to streams and rivers; 8 percent to reservoirs and lakes; and 5 percent to estuaries, bays, and coastal areas. Moreover, among the water bodies identified as "impaired" or included on states' Clean Water Act Section 303(d) and for which CAAP is cited as one of the potential sources of impairment, rivers and streams are identified more frequently than other water body types (see Chapter 9, section 9.2.3, of this document). Finally, CAAP impacts on rivers and streams can be more completely assessed in a less complex manner (e.g., with a one-dimensional water quality model) than for other water body types – an important consideration when a large number of facility types and scenarios must be evaluated. Nevertheless, EPA believes that environmental benefits from reduced pollutant loadings from net pen facilities may be significant and intends to pursue methods for characterizing these benefits for the final rule.

10.4.1 Water Quality Modeling and "Prototype" Case Study

EPA applied the QUAL2E model to quantitatively assess the water quality-related impacts to receiving stream waters from the proposed CAAP rule. QUAL2E (Enhanced Stream Water Quality Model) is a one-dimensional water quality model that allows both dynamic and steady state flow, providing simulation of diurnal variations in temperature, algal photosynthesis, and respiration (Brown and Barnwell, 1987). The basic equation in QUAL2E solves the advective-dispersive mass transport equation. Water quality constituents simulated include conservative substances, temperature, bacteria, BOD, DO, ammonia, nitrate and organic nitrogen, phosphate and organic phosphorus, and algae (Brown and Barnwell, 1987).

Definition of "Prototype" Stream Hydrology and Hydraulics

To model the impacts of CAAP facilities on receiving waters of flow-through and recirculating systems, EPA developed a "prototype" case study using a range of background flow and water quality conditions. Briefly, a set of model facilities, representing different species, effluent flow rates, and system types (i.e., flow-through and recirculating) was used to reflect the characteristics of the potentially regulated population of facilities. The results of this "prototype" case study for this set of model facilities were then extrapolated based on number of facilities of each type to form a national estimate of water quality-based benefits of the proposed CAAP regulation.

In order to develop the prototype case study, adequate facility location and water quality, hydrology, and hydraulic characteristics for the relevant streams were required. At the time of proposal, such data were available for the Central and Eastern Forested Uplands ecoregion. Although case studies should ideally be developed for all regions in which potentially regulated CAAP facilities are found, sufficient data were not available at time of proposal. The results of the prototype case study should therefore be interpreted with caution. The restricted geographic scope of the analysis is thought to be less of a limitation for flow-through systems because most flow-through systems are located on upland streams such as those used in the analysis described below. EPA intends to explore enhanced approaches to evaluating water quality benefits of CAAP regulation, including expanding the case study approach to other regions in which CAAP facilities are found.

A stream network was developed for a typical system representative of those characteristics most common in the Central and Eastern Forested Uplands ecoregion. Receiving water bodies in the mountains of North Carolina were selected for survey, and the hydraulic and hydrology attributes of those streams in the region that receive CAAP discharges were analyzed. Sources of data utilized for this study included streamflow data, land use data, RF1 stream coverages in GIS, NPDES permit information, and gage data provided by USGS and the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) modeling system (USEPA, 2001a).

To develop the streamflow characteristics of the prototype stream, the following procedure was used. First, USGS streamflow gages located in the North Carolina mountains were reviewed. All CAAP facilities identified in BASINS for the study area are located only on tributaries of the RF1 stream coverage. Therefore, all USGS stream gages located on RF1 stream mainstems, or water bodies receiving substantial flow from tributaries, were removed from the collection of gages under review. Also, all streamgages located below lakes or dams were also removed from the review, since such obstructions to the natural streamflow would affect results from the analysis. The set of remaining streamgages was further reduced by removing those with certain flow criteria which were inconsistent with those for streamgages associated with CAAP facilities in this region. Of the remaining USGS stream gages that met the defined criteria, 12 gages provided sufficient streamflow, depth, and velocity data to determine average depth and velocity verses flow relationships. These relationships and resulting regression equations were utilized in the QUAL2E model to simulate the characteristic hydraulic conditions of the typical CAAP receiving waters in the study area:

$$depth = 0.524 \times Flow^{0.1295}$$
$$velocity = 0.391 \times Flow^{0.2212}$$

where *depth* = stream depth (m)
velocity = streamflow velocity (m/s)
Flow = streamflow (m^3/s)

Baseflow in the model stream is assumed to increase with stream distance. This function is the driving force for much of the dispersion, settling, and dilution processes that control constituent concentrations and their respective longitudinal variations within the stream during low flow. To estimate the gradual increase in baseflow as a function of stream distance, a typical stream in the North Carolina mountains was assessed in GIS using BASINS. The selected stream met the same flow criteria used in the aforementioned hydraulic analysis. Contributing drainage areas were measured at varying locations along the length of the stream, and a correlation was made between distance and size of watershed. Assuming the size of the watershed is proportional to streamflow, a relation between distance downstream and magnitude of flow could be estimated. The resulting equation was used to predict the gradual increase in streamflow corresponding to the segmented distance in the QUAL2E model.

$$Flow(down) = Flow(up) \times 1.16^{d}$$

where *Flow(down)* = downstream flow (m^3/s)

Flow(up) = upstream flow (m^3/s)
d = distance between upstream and downstream locations (km)

Typical values that describe evaporation, temperature correction factors for model calculations, biological processes, climatological influence, and decay and settling or water quality constituents were selected from the literature and using professional judgment (Brown and Barnwell, 1987; Chapra, 1997; Bowie et al., 1985). Parameters were selected based upon the assumed applicability to the study area. Due to the lack of data for a specific site, and since the predictive capability of the QUAL2E model is not to be descriptive of a single stream segment but rather a range of typical scenarios under varying conditions, calibration of the QUAL2E model and the associated parameters (beyond inspection of results for reasonableness according to professional judgment) was not performed for proposal. However, a more thorough calibration and validation of the model can be provided once sufficient water quality data is collected for a specific stream segment and facility discharge.

Definition of Background Flow and Water Quality in the Prototype Receiving Water

To account for differences in background concentrations in the model stream, "low" and "high" background stream water quality scenarios were determined. To estimate the "low" scenario (representing relatively pristine water quality) water quality data was accessed from a typical upland water quality gage maintained by the State of North Carolina (station C1370000). This station is within a primarily wooded tributary in the North Carolina mountains, and has no discharges or other obvious influences within its vicinity that might influence water quality observations within the stream. As a result of data analysis, the water quality concentrations shown in Table 10-1 were assumed. Dissolved phosphorus was assumed as 1 percent of total phosphorus observations and organic phosphorus was assumed to be 75 percent of total phosphorus[1]. Also, nitrate and nitrite concentrations were assumed to constitute 95 percent and 5 percent, respectively, of the combined nitrate + nitrite observations at the gage[2]. Concentrations for the "high" scenario, intended to represent relatively high background

---

[1] This assumption was based on PCS and DMR monitoring data that show similar ratios.

[2] This was also based on PCS and DMR monitoring data indicating similar ratios.

concentrations of pollutants, were developed based upon an analysis of water quality data from a sample of stream gages in watersheds of North Carolina that encompass a variety of land uses and that are associated with CAAP facilities (see Appendix G).

Table 10-1

Model Stream Background Concentrations

Scenario	BOD_5 (mg/L)	TSS (mg/L)	NH_3 (mg/L)	Organic N (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	Dissolved P (mg/L)	Organic P (mg/L)	DO (mg/L)
Low	0.4	15	0.04	0.15	0.02	0.4	0.001	0.003	6.63
High	3.86	45	0.28	0.57	0.05	0.78	0.159	0.013	6.63

The background concentrations shown in Table 10-1 were modeled with steady state stream flows of both 15 cfs and 30 cfs to represent a range of summer flow conditions in the hypothetical stream. The modeled combinations are described in Table 10-2. These flows were chosen to represent a range of summer low-flow conditions on the "prototype" stream.

Table 10-2
Background Flow/Hydrology Scenarios Used in the Modeling

	Background Water Quality 1 "Low"	Background Water Quality 2 "High"
Background Flow 1	Flow = 15 cfs BOD_5 = 0.4 mg/L TSS = 15 mg/L NH_3 = 0.04 mg/L Organic N = 0.15 mg/L NO_2 = 0.02 mg/L NO_3 = 0.4 mg/L Dissolved P = 0.001 mg/L Organic P = 0.003 mg/L DO = 6.63 mg/L	Flow = 15 cfs BOD_5 = 3.86 mg/L TSS = 45 mg/L NH_3 = 0.28 mg/L Organic N = 0.57 mg/L NO_2 = 0.05 mg/L NO_3 = 0.78 mg/L Dissolved P = 0.159 mg/L Organic P = 0.013 mg/L DO = 6.63 mg/L

	Background Water Quality 1 "Low"	**Background Water Quality 2 "High"**
Background Flow 2	Flow = 30 cfs BOD_5 = 0.4 mg/L TSS = 15 mg/L NH_3 = 0.04 mg/L Organic N = 0.15 mg/L NO_2 = 0.02 mg/L NO_3 = 0.4 mg/L Dissolved P = 0.001 mg/L Organic P = 0.003 mg/L DO = 6.63 mg/L	Flow = 30 cfs BOD_5 = 3.86 mg/L TSS = 45 mg/L NH_3 = 0.28 mg/L Organic N = 0.57 mg/L NO_2 = 0.05 mg/L NO_3 = 0.78 mg/L Dissolved P = 0.159 mg/L Organic P = 0.013 mg/L DO = 6.63 mg/L

Definition of Pollutant Loading Scenarios

For each regulatory option, EPA estimates the pollution reduction from operating and maintaining specific techniques and practices. EPA traditionally develops pollution loads that are either facility-specific or specific to a "model" facility, described below. Facility-specific compliance loads require detailed information about many, if not all, facilities in the industry. These data typically include production, capacity, water use, wastewater generation, waste management operations, monitoring data, geographic location, financial conditions, and any other industry-specific data that may be required for the analyses. EPA then uses each facility's information to estimate the loads or impact associated with new pollution controls.

When facility-specific data are not available, EPA develops model facilities to provide a reasonable representation of the industry. Model facilities are developed to reflect the different characteristics found in the industry, such as the size or capacity of an operation, type of operation, geographic location, mode of operation, and type of waste management operations. These models are based on data gathered during site visits, information provided by industry members and their associations, and other available information. EPA estimates the number of facilities that are represented by each model. Pollutant loads and their impacts are estimated for each model facility. The model facility approach was chosen for estimating compliance pollutant loads, impacts, and associated benefits for the CAAP industry.

EPA developed three technology-based options (Options 1, 2, and 3) and estimated pollutant loadings under each of these Options using an engineering model. The CAAP engineering model estimates loadings for different facility systems (e.g., flow-through or recirculating), species (e.g., trout, tilapia, or hybrid striped bass), and sizes under these technology Options. Option 1 and Option 2 are grouped for this case study because they estimate the same pollutant loadings (Option 2 adds a health management plan, but does not reduce the loadings estimated with Option 1). Option 3 adds solids polishing to reduce effluent loadings further.

EPA evaluated treatment-in-place at surveyed facilities and determined that the majority have in place all or most of the technology and practices that would be required by the lowest technology Option. However, to estimate the benefits of the regulation for the few facilities that have no treatment in place, EPA also estimated loadings in the absence of treatment ("Raw effluent"). Again, the loadings included under "Raw effluent" estimates are wastes generated in an CAAP system based on feed inputs, which were acquired from literature reviews. Only a minority of CAAP facilities lack some form of treatment. The majority of CAAP facilities employ some form of effluent treatment. The pollutant reductions estimated with Option 1/Option 2, and Option 3 were taken from literature reviews and sampling data. A wastewater treatment model was then used to obtain treatment efficiencies for the reductions, which are expressed in loads. The loadings were converted to concentrations to accommodate the requirements of the QUAL2E model. The conversion equations for flow-through and recirculating systems, along with example calculations for both, are described in Appendix H.

Three pollutant concentrations scenarios (Raw, Option 1/Option 2, and Option 3) were each modeled for different species types and facility production sizes (medium and large). Table 10-3 summarizes the effluent concentrations modeled for each model facility, by option and facility type. The effluent flow for each of the model facility types is summarized in Table 10-4, along with a summary of the total number of facilities for each facility type. Several scenarios of the model CAAP discharge and stream were simulated using a low-flow, steady state procedure in the QUAL2E model framework. The stream was divided into 3 segments, each consisting of 20 computational elements for iterative water quality calculations. The values in Tables 10-1, 10-2, 10-3, and 10-4 were combined to create a variety of scenarios of effluent flows and concentrations and background stream flows and concentrations.

Table 10-3

Modeled Untreated and Treated Effluent Concentrations for Flow-Through and Recirculating Systems

	BOD_5 (mg/L)	**TSS (mg/L)**	**NH_3 (mg/L)**	**Organic N (mg/L)**	**NO_2 (mg/L)**	**NO_3 (mg/L)**	**Dissolved P (mg/L)**	**Organic P (mg/L)**	**DO (mg/L)**
Raw effluent (Flow-Through)	11.172	9.576	0.010	0.014	0.001	0.023	0.056	0.053	5.0
Opt 1/Opt 2 (Flow-Through)	2.876	5.453	0.010	0.014	0.001	0.023	0.056	0.050	5.0
Opt 3 (Flow-Through)	1.773	4.985	0.009	0.014	0.001	0.022	0.056	0.047	5.0
Raw effluent (Recirculating)	1,838.66	1,576.00	1.58	2.36	0.20	3.77	11.37	8.67	5.0
Opt 1/Opt 2 (Recirculating)	1,537.10	237.98	0.73	1.09	0.09	1.74	9.22	7.02	5.0
Opt 3 (Recirculating)	768.56	95.19	0.36	0.54	0.05	0.87	9.22	3.51	5.0

Example Water Quality Modeling Output

Water quality modeling output were generated for the 30-km “prototype” downstream reach for each model facility (listed in Table 10-4) under the 4 different background water quality and flow scenario described earlier in this section. Pre- and post-regulatory dissolved oxygen, BOD, TSS, and nutrient concentrations were simulated. Figure 10-1 presents an example of simulated BOD downstream of a medium-sized Trout Stockers Flow-Through model facility. For this example, background (receiving water) flow is assumed to be 30 cfs and background water quality is assumed to be relatively pristine (“low” scenario in Table 10-2). Output similar to this for all model facility species/size combinations listed in Table 10-4, for all four different background water quality and flow scenarios (Table 10-2), and for the parameters BOD, TSS, and DO, were generated.. These ouput were considered in a discussion (Section 10.5.1) of potential contributions of facility effluents to stream impairment, expressed as possible exceedences of water quality criteria values. These output were also used as inputs to the monetized benefits calculation described in Section 10.5.2.

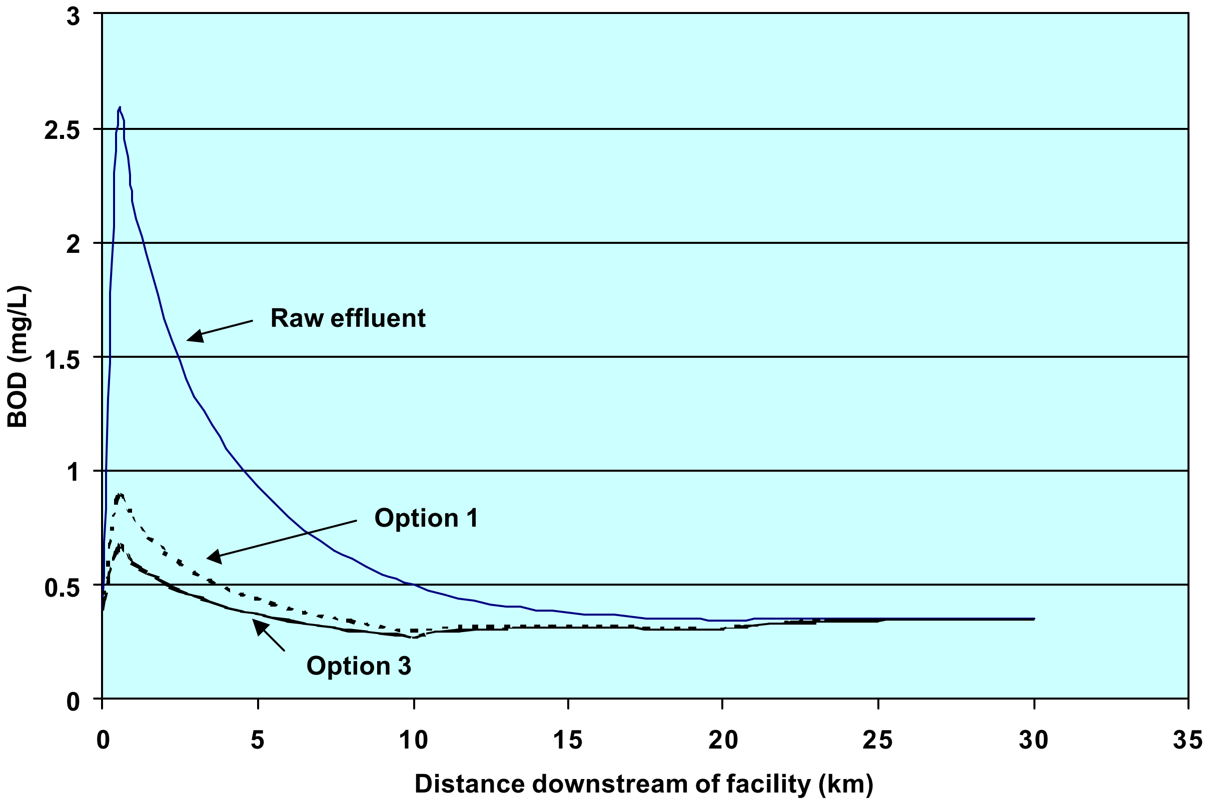
Table 10-4

Effluent Flows

Facility Type	Facility Size	Effluent Flow	
		(ft^3/s)	(m^3/s)
Salmon Flow-through	Medium	-	-
	Large	92.7	2.6
Striped Bass Flow-through	Medium	2.7	0.0
	Large	-	-
Tilapia Flow-through	Medium	6.02	0.2
	Large	22.28	0.5
Trout Flow-through	Medium	4.7	0.1
	Large	47.2	1.3
Trout Stockers Flow-through	Medium	4.9	0.1
	Large	20.7	0.6
Striped Bass Recirculating	Large	0.1	0.003
Tilapia Recirculating	Large	0.05	0.001

Figure 10-1

Example QUAL2E output for simulated BOD concentrations downstream of a medium trout stockers flow-through facility on the "prototype" stream



10.4.2 Extrapolation to National-Scale Impacts

For the national monetized benefits calculation, it was necessary to extrapolate monetized benefits that were obtained from the “prototype” water quality modeling results for each model facility, described in Section 10.4.1, to all flow-through and recirculating systems nationwide that fall under the scope of the proposed regulation. Information on the total number of facilities for each facility type, derived from the AAP screener survey described earlier in this document and from USDA’s Census of Aquaculture (USDA, 2000), were used to perform this extrapolation. The calculation of monetized benefits arising from water quality improvements at each model facility, and the extrapolation to a national benefits estimate, are described in Section 10.5.2.

10.5 ESTIMATED WATER QUALITY BENEFITS

10.5.1 Water Quality Standards and Nutrient Criteria

EPA briefly reviewed the results of the QUAL2E “prototype” case study analyses for individual model facilities, described in Section 10.4.1 to gain some insight as to whether CAAP facilities could potentially contribute to water quality criteria exceedences and whether the proposed controls could reduce these exceedences. The results suggested that the modeled flow-through and recirculating systems may, under certain background receiving water conditions, contribute to water quality impairments in receiving waters. EPA compared simulated stream water quality in the receiving waters (such as the output shown in Figure 10-1) with national ambient water quality standards that have been established for the protection of aquatic life. Results (Hochheimer and Mosso, 2002) from these initial evaluations show that nutrients, such as total phosphorus (TP), added to streams from CAAP facilities can lead to changes in the observed impairment (as measured by changes in impaired stream length) for different background water quality scenarios. For example, the length of impaired stream ranged from 3.5 to 12.5 km for untreated wastes from model CAAP facilities located on the simulated stream reach. When the regulatory scenarios were imposed on the model facilities, the length of impaired stream was reduced by 0.5 to 2.5 km in smaller facilities and up to 4.5 km in larger facilities.

For other parameters (dissolved oxygen, total nitrogen (TN), and ammonia), the simulated model CAAP facility discharges did not cause impairments relative to the criteria chosen, even when discharging “raw” effluent. This was a common result when a facility with relatively small effluent volumes or pollutant concentrations was assumed to be located on a stream with relatively high background pollutant concentrations and higher flow rate.

Modeling results such as these may be useful for EPA in evaluating water quality changes arising from the proposed CAAP rule in streams and rivers in the context of national (or other) water quality criteria. However, EPA recognized several limitations with the initial case study analysis approach for evaluating water quality standards and nutrient criteria. Presently, there is not an efficient methodology to assign a monetary value to reductions in nutrients for receiving waters. Furthermore, EPA has not considered water quality effects when multiple facilities discharge to the same receiving waters. In addition, the models were not calibrated with site-specific data, which are needed to provide accurate absolute values of modeled baseline and post-regulatory water quality, and therefore the results may be more amenable for analyses that are less sensitive to baseline conditions. Consequently, EPA primarily used the model results for evaluating and monetizing recreational benefits, described in the following section, which require changes in the water quality variables. EPA intends to continue to refine this modeling approach for wider, national application. EPA also intends to create additional model stream case studies to reflect a wider range of stream conditions to better simulate “real world” scenarios.

10.5.2 Recreational Use Benefits

The facility modeling described above also provided estimates of changes in water quality measures in terms of stream lengths. These measures, BOD, DO, and TSS, are also indicators of the type of recreation which may be permitted in the waters. That is, they locate the water body in the spectrum of uses from boatable to swimmable described in Section 10.2.2. If the proposed regulation improves these measures, then more demanding uses may be safely enjoyed and the value of the water body to society increases. With the information from the facility models, estimates of how society values changes in recreational use, and estimates of the population affected, it is possible to place a monetary value on the changes anticipated from the regulation. The method is discussed in some detail below.

Each use category can be defined in terms of a set of water quality indicators. In past benefits assessments, categories were defined discretely so that if all of the indicator measures exceeded all of the criteria for a given use, then the water body could be used for that use. Vaughan (1986) developed a water quality criteria ladder that describes criteria for four types of recreational use (none, boating, fishing, or swimming). For example, a water body with a biological oxygen demand (BOD) between 3 and 4 mg/l is suitable for boating and fishing but not for swimming. All of the indicators must achieve the proscribed level for the water body to support a given level of use. Thus, if the water body had a fecal coliform count greater than 2,000 per 100 ml, even though its BOD was between 3 and 4 mg/l, it would be classified as not boatable because of the high coliform count. With the discrete water quality ladder, the overall use category is the least demanding use supported by any of the water quality indicators.

Once the use of the water body is defined by the Vaughan ladder, the public willingness to pay for changes in use category can be estimated. Carson and Mitchell (1986) conducted a national contingent valuation survey which sought households′ willingness to pay for improvements in the quality of the nation's waters in terms of a use ladder. This survey characterized households′ annual willingness to pay for improvements in freshwater resources from their baseline conditions to fishable and swimmable conditions. The survey sought values for discrete changes from one use category to another which corresponded with the Vaughan water quality ladder.

Several regulatory impact analyses have operationalized the Vaughan/Carson and Mitchell approach to estimate the value of benefits from proposed regulations. When the proposed regulation causes a reach to change category, the household annual willingness to pay from the Carson and Mitchell study is applied to estimate the benefits of the change. Carson and Mitchell (1993) also established that families value water quality changes in their own region more highly than generic national improvements. In past benefit assessments, EPA has attributed two-thirds of the willingness to pay value to households within the state and one-third to households elsewhere. As specific information about where facilities are located was not available at this time, EPA treated all of the benefits estimated in this assessment as being distant from individual households. Thus, only one-third of the Carson and Mitchell willingness to pay amount is applied. As the Carson and Mitchell willingness to pay refers to improvement in ALL of the nation's waters, the benefits are also scaled by the proportion that the length of streams improved in the model facilities analysis is to the total length of all streams in the U.S. These assumptions greatly reduce the level of benefits estimated for this proposed rule.

A Continuous Measure of Benefits

One criticism of the water quality ladder approach is that a rule is only credited with a benefit when it results in a change from one category to another. Thus, even if a regulation causes significant improvements in water quality, if it does not result in a change in use, no benefits are attributed to it. When a marginal change in water quality measures results in a change in use category, large benefits are ascribed to it. This critique is unimportant for major rules affecting many point sources of pollution. It is more significant for rules affecting non-point sources where the diffuse nature of the contaminant makes it unlikely a single rule will shift use categories for many reaches. There has been considerable debate about how to measure benefits continuously in the non-point emissions context.

As an alternative to the stepwise ladder approach, EPA has adopted a change in a single unified index as an indicator of water quality improvement for valuation for this proposed regulation. The Water Quality Index (WQI) combines information from four water quality measures rather than using only the limiting lowest quality criterion to define use category. For this benefit valuation, the model facilities analysis generated estimates of changes in BOD, dissolved oxygen, and TSS. Fecal coliforms were assumed to be unaffected by the proposed rule. These estimates were converted into a WQI based on work by McClelland (1974). McClelland developed a method whereby water quality indicators are converted from whatever units are appropriate for the indicator, e.g., mg/l, NTU, to a single index of water quality valued from zero to 100. One hundred indicates excellent water quality in terms of that particular measure. The conversion equations for each measure are of different, non-linear functional forms and segmented so they cannot be expressed in simple equations. EPA has developed spreadsheet functions which accomplish the conversion (Miles, 2002, personal communication). Once all of the indicators are in the same index units, they can be combined into a single index of overall water quality. This combined WQI is a geometrically weighted average of its four components, such that

$$WQI= DOI^{0.333}\ FEC^{0.314}\ BOD^{0.216}\ TSS^{0.137}+ 0.5$$

Where DOI, FEC, BOD, and TSS are water quality indexes for dissolved oxygen, fecal coliforms, biological oxygen demand, and total suspended solids. The weighting exponents were derived by McClelland (1974) using a Delphi approach among water quality experts.

EPA developed a simple method to map the WQI onto the Vaughan water quality ladder in the Meat Products Industry Economic Analysis (USEPA, 2002b). The same method was used to translate changes in combined WQI into changes in water use for this assessment. The mapping is based on the observed combined WQI calculated for all stream reaches in the RF3 database. Each reach is classified as to use category so the average WQI for each use category in the baseline file can be calculated. Assuming WQI values are normally distributed within each use category, placing the upper bound for the category at the mean plus one standard deviation should ensure that 84 percent of observations will fall below the upper bound. Tests with the baseline data indicated that this method of assigning values by WQI tends to assign a lower value than other mapping approaches. Table 10-5 shows the lower threshold WQI for each category. A more detailed description of the mapping and testing is in the Meat Products Industry Economic Analysis (USEPA, 2002b).

Table 10-5

Criteria and Values

Use Category	Lower Threshold (WQI)	Household Annual WTP[a] ($ 1999)	Rate, R ($/WQI, 1999)
No Use	**---**	**---**	**$ 3.10**
Boatable	**79.0**	**$ 245**	**$ 11.91**
Fishable	**94.4**	**$ 429**	**$ 44.92**
Swimmable	**99.0**	**$ 634**	**---**

Source: EPA Meat Products Industry Economic Analysis; WTP values from USEPA, 2001b, CAFOs Economic Analysis.

[a] Total annual willingness to pay for upgrading all U.S. freshwater bodies from baseline quality to the next designated use category, i.e. annual WTP is $634 to move all sub-swimmable waters to use category 3, swimmable.

The Carson and Mitchell willingness to pay values were updated to 1999 values for the recent Concentrated Animal Feeding Operations (CAFOs) regulation benefit assessment to account for changes in income and the value of the dollar. The CAFOs assessment, however, valued only changes in use categories. The continuous WQI method requires that the Carson and Mitchell willingness to pay values be converted to continuous measures of benefits. This rate of change for each use category is calculated so that the total willingness to pay at each breakpoint is equal to the total in the Carson and Mitchell study and shown in Table 10-5. The "no use" category is arbitrarily spread over the whole range from 0 to 79.[1] No value is associated with improvements above the swimmable level, which is a very small range. With each step, the rate of increase in benefits is roughly four times higher than the previous step.

Thus the average household would be willing to pay $3.10 for a one point change in WQI from 50 to 51 in all of the nation's rivers, i.e. an improvement in water quality within the "no use" category. The same household would be willing to pay $11.91 for a one point change in WQI from 83 to 84 in all of the nation's rivers, i.e. an improvement in water quality within the boatable category. Changes that cross category boundaries are valued at the rate for each portion of the categories included. Table 10-6 illustrates the WQI values and changes for the medium size trout stocker flow-through facility, discharging into a stream with high water quality, B.G. 1, and low flow, 15 cfs. The change in WQI for km 29.0 shows the non-linearity of the valuation method. The three point change from a baseline value of 76 to the Option 1/Option 2 value of 79 is valued at $9.30, three times $3.10 the per point value for changes in the non-usable category. The four point change from 76 to 80 for Option 3 is valued at $21.21, three times $3.10 plus $11.91, since the fourth point is in the more valued boatable category. Clearly, the larger values occur in reaches with better water quality.

Each set of WQI values represents the conditions in a 0.5 km reach of the model stream. Thus, the total of the WTP values is the average value per household for that level of change in all of the nation's waters in terms of half kilometers. The bottom of Table 10-6 illustrates the calculation from WQI to benefit value. To place the value on a kilometer basis the total is divided by two. This total value for the model stream was scaled up by the number of facilities identified as similar to the model facility. There were 57 facilities judged to be similar to the medium flow-through trout stocker model facility. This value must then be weighted by the proportion of the nation's waters represented by the

---

[1] Mitchell and Carson described non-boatable waters in graphic terms so their value for the change may be an overestimate. However, few water bodies approach a zero WQI, so much less than the full value for the improvement from not usable to boatable can ever be attributed to the regulation.

Table 10-6

Example of Application of Water Quality Index Use

Trout Stockers, Flow-through Facility, Medium Size,
Receiving waters flow 15 cfs, High water quality, i.e., B.G. 1

	Water Quality Index (WQI)			Willingness to Pay for Change	
Km	Baseline	Option ½	Option 3	Option ½	Option 3
30	80	80	80	-	-
29.5	75	78	79	9.30	12.40
29.0	76	79	80	9.30	21.21
28.5	77	80	81	18.11	30.02
28.0	78	81	81	26.92	26.92
27.5	79	81	82	23.82	35.73
27.0	80	82	82	23.82	23.82
26.5	80	82	82	23.82	23.82
26.0	81	83	83	23.82	23.82
25.5	81	83	83	23.82	23.82
25.0	81	83	83	23.82	23.82
24.5	82	83	83	11.91	11.91
24.0	82	83	84	11.91	23.82
23.5	82	84	84	23.82	23.82
23.0	83	84	84	11.91	11.91
22.5	83	84	84	11.91	11.91
22.0	83	84	84	11.91	11.91
21.5	83	84	84	11.91	11.91
21.0	83	84	84	11.91	11.91
20.5	84	84	84	-	-
20.0	84	84	85	-	11.91
19.5	84	84	84	-	-
19.0	83	84	84	11.91	11.91
18.5	83	84	84	11.91	11.91
18.0	83	84	84	11.91	11.91
17.5	83	84	84	11.91	11.91
17.0	83	84	84	11.91	11.91
16.5	84	84	84	-	-
		No change Km 16.0-9.0			
8.5	84	84	84	-	-
8.0	83	84	84	11.91	11.91
7.5	83	83	83	-	-
		No change Km 8.0-4.0			
3.5	83	83	83	-	-
3.0	83	84	84	11.91	11.91
2.5	84	84	84	-	-
		No change Km 2.0-0.0			
Total				$397.11	$459.76
Total/2				$198.55	$229.88
Number of facilities of model type			x 57	11318	13103
Total km of streams in U.S.			/1,067,019	0.0106	0.0123
Out-of-Locality factor			x 0.33	0.0035	0.0041
Total Households in U.S.			x 103,874,000	$363,584	$420,944

Source: EPA Analysis

length of the prototype stream improved in the model analysis. EPA assumed that each reach is valued equally and divided the total value by the total number of stream kilometers in the nation.

Carson and Mitchell found that households placed a greater value on changes in water quality close to home where they were likely to have access to and use the water resource. As specific information on the location of each facility is not available at this time, EPA could not identify the number of households that would consider each facility as local. As a conservative assumption, EPA assumed that all of the reaches would be considered non-local and so receive only one third of the total WTP. In the trout stocker example, this process resulted in an estimated benefit value per household of 0.35 cents and 0.41 cents for Option 1/Option 2 and 3, respectively. EPA scaled this value up by the number of households in the country in 1999, 103.9 million (U.S. Census Bureau, 2000), to yield national benefits for this class of facility. The values derived for all classes of facilities in this way were then summed to yield a national estimate of benefits.

The Mitchell-Carson WTP values represent annual household values in 1999 dollars. EPA has no intuition as to the timing of these benefits and no dynamic modeling was undertaken to suggest variation in benefits through time. Thus, the estimate of total benefits represents a typical year once the proposed regulation is in place. When the same discount rate is used to calculate both the present value and annualized value of a stream of equal flows through time, the annual flow is the same as the annualized value. So, the total benefits stated may be considered an annualized value for any time period and any discount rate (unless different discount rates are to be used for the present value and annualization calculations).

As discussed in Section 10.4, each facility model was run with two flow regimes, 15 and 30 cfs, and two ambient quality levels in the receiving waters. This resulted in four different benefit estimates for each model facility under each option. The largest benefits occurred when CAAP facility outflow was a substantial portion of the total stream flow and when the regulation resulted in substantial improvement in the quality of the outflow. The maximum among the four estimates was considered the high end of the range of benefits and the minimum was considered the low end of the range. Each model facility type was considered separately and all of the minima and maxima summed to yield the national range of benefits in 1999 dollars.[1]

Benefit Valuation Results

As discussed above, data was only available at this time to estimate benefits of flow-through and recirculating systems. Table 10-7 shows the overall benefits if Option 1/Option 2 and 3 are applied to all of the facilities in the current database. Eleven facilities do not achieve Option 1/Option 2 standards.[2] Implementing the Option 1/Option 2 BMPs for these facilities would improve water quality in their receiving streams and generate a benefit of $16,000 to $77,000. Implementing Option 3 for all facilities includes upgrading those facilities not up to Option 1/Option 2 standards and installing solids polishing at 13 large facilities. It would generate benefits of $34,000 to $207,000. Table 10-7 shows the benefits that could be achieved if the standards of Option 3 were applied to all medium and large facilities.

The proposed option, however, applies Option 1/Option 2 standards to medium sized facilities while requiring Option 3 BMPs for large facilities. Table 10-8 shows how the benefits of the two options are combined to generate a total benefit estimate for the Proposed Option. The Option 1/Option 2 and Option 3 columns in Table 10-8 show only those benefit values which will be realized under the proposed option. Thus, all of the medium sized facilities show no benefits from Option 3 since this option will not apply to them and all of the large facilities show no benefits for Option 1/Option 2 since they will meet Option 3 standards.

---

[1] Different elements of the development of the regulation have required re-statement of the results in various constant dollar base years. The 1999 constant dollar results are shown above to maintain the direct connection with the CAFO and Meat Products documentation. Results may be re-stated in any base year using the consumer price index for all urban consumers (CPI-U).

[2] The database contains 100 facilities. Thirteen (13) are large, and 87 medium sized. One large and 10 medium sized facilities do not use Option 1/Option 2 BMPs. So, 77 medium sized facilities in the database already comply with Option1/Option2 in the baseline and will not generate any additional benefits as a result of the proposed rule. The 13 large and 10 non-compliant medium facilities are the basis for this assessment.

Table 10-7
National Benefits from CAAP Facility Regulatory Options when Applied to All Facilities
(Annualized difference from baseline; 2000 constant dollars)

Subcategory	Annual Production Level (lbs)	Option 1		Option 3	
		Minimum	Maximum	Minimum	Maximum
Flow-Through	100,000 to 475,000	$12,249	$66,188	$24,242	$160,430
	>475,000	$4,117	$10,984	$6,897	$25,400
Recirculating	100,000 to 475,000	$0	$0	$0	$0
	>475,000	$0	$0	$3,242	$21,564
Total		$16,367	$77,172	$34,381	$207,394

Note: Entries may not sum due to rounding.
Source: EPA Analysis

Table 10-8
National Benefits from the Proposed Option
(Annualized difference from baseline; 2000 constant dollars)

Subcategory	Annual Production Level (lbs)	Option 1		Option 3		Proposed	
		Min.	Max.	Min.	Max.	Min.	Max.
Flow-Through	100,000 to 475,000	$12,249	$66,188	$0	$0	$12,249	$66,188
	>475,000	$0	$0	$6,897	$25,400	$6,897	$25,400
Recirculating	100,000 to 475,000	$0	$0	$0	$0	$0	$0
	>475,000	$0	$0	$3,242	$21,564	$3,242	$21,564
Total		$12,249	$66,188	$10,139	$46,964	$22,389	$113,152

Note: Entries may not sum due to rounding.
Source: EPA Analysis

The annualized national monetized benefits for the change from baseline to the post-regulatory condition for the proposed option are estimated to range from $22,000 to $113,000 (2000 dollars). Almost half of the benefits are attributable to the medium sized trout stocker flow-through facility model that encompasses 7 of the 23 facilities included in this assessment.

The Carson and Mitchell survey question requested an overall value so the total willingness to pay based on their survey results may be considered to include aesthetic and non-use values, as well as recreational and other use values.

10.6 UNQUANTIFIED BENEFITS

EPA has quantified and monetized a subset of the anticipated benefits of today's proposed action as described in this chapter. In summary, the central basis for the quantitative benefits analysis is a water quality modeling assessment that estimates water quality responses to the pollutant loading reductions under technology options described earlier in this document. Specifically, the benefits that EPA has only been able to quantify and monetize are improvements in the recreational use value of these same reaches.

Several potential benefits associated with the proposed regulation were not quantified. These include water quality and ecological responses to pollutant loading reductions at net pen systems; and ecological and other water resource benefits from reductions in releases of non-native species, aquatic animal pathogens, and drugs and chemicals used at CAAP facilities. EPA did not quantify or monetize these important benefits due to lack of assessment modeling tools readily available for such an analysis. For these reasons, as well as for the assumptions that were made in the benefits monetization calculations due to lack of data on facility locations (see section 10.5.2), the estimated monetized benefits of the proposed regulatory action are believed to represent a lower bound of potential benefits of the proposed regulation.

10.7 REFERENCES

Bowie, G.L., W.B. Mills, D.B. Porcella, C.L. Campbell, J.R. Pagenkopf, G.L. Rupp, K.M. Johnson, P.W.H. Chan, and S.A. Gherini. 1985. *Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling*. 2d ed. EPA-600-3-85-040. Environmental Research Laboratory, Athens, GA.

Brown, L.C., and T.O. Barnwell, Jr. 1987. *The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and User Manual.* EPA 600-3-87-007. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Carson, R.T. and R.C. Mitchell. 1986. *The Use of Contingent Valuation Data for Benefit/Cost Analysis in Water Pollution Control*, Final Report. Resources for the Future, Washington, DC.

Carson, R. T. and R.C. Mitchell. 1993. The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Quality Water. *Water Resources Research* 29(July):2445-2454.

Chapra, S.C. 1997. *Surface Water Quality Modeling*. McGraw-Hill, NY.

Findlay, R.H., Watling, L., and L.M. Mayer, 1995. Environmental Impact of Salmon Net-Pen Culture on Marine Benthic Communities in Maine: A Case Study. *Estuaries* 18(1A):145-179.

Hochheimer, J. and D. Mosso. 2002. Technical Memorandum: Revised North Carolina Prototype Facility Case Study. Tetra Tech Inc., Fairfax, VA.

McClelland, N. I. 1974. *Water Quality Index Application in the Kansas River Basin*. Prepared for U. S. Environmental Protection Agency -Region VII.

Miles, A., Center for Environmental Analysis, Research Triangle Institute. Personal Communication April 8, 2002.

Ministry of Agriculture, Food and Fisheries. n.d. *Summary of Marine Escape Reports: 1989-2000. Government of British Columbia.* <http://www.agf.gov.bc.ca/fisheries/escape/escape_resorts.htm>. Accessed April 19, 2002.

Strain, P.M., D.J. Wildish, and P.A. Yeats. 1995. The Application of Simple Models of Nutrient Loading and Oxygen Demand to the Management of a Marine Tidal Inlet. *Marine Pollution Bulletin* 30(4):253-261.

U.S. Census Bureau. 2000. *Statistical Abstract of the U.S.: 2000*. <http://www.census.gov/prod/www/statistical-abstract-us.html>. Accessed June 17, 2002.

USDA (U.S. Department of Agriculture). 2000. *1998 Census of Aquaculture*. U.S. Department of Agriculture, National Agriculture Statistical Services, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2001a. *Better Assessment Science Integrating point and Nonpoint Sources: BASINS Version 3.0 User's Manual,.* EPA 823-H-01-001. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2001b. *Environmental and Economic Benefit Analysis of Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations*. EPA-821-R-01-002.

Chapter 4, Modeling of Improvements in Surface Water Quality and Benefits of Achieving Recreational Use levels. U.S. Environmental Protection Agency, Office of Water, Washington, DC. January 2001.

USEPA (U.S. Environmental Protection Agency). 2002a. *Ammonia Fact Sheet: 1999 Update*. U.S. Environmental Protection Agency, Office of Water, Washington, DC. <http://www.epa.gov/ost/standards/ammonia/factsheet.html>. Accessed April 2002.

USEPA (U.S. Environmental Protection Agency). 2002b. *Economic Analysis of Proposed Effluent Guidelines for the Meat and Poultry Products Industry.* EPA-821-B-01-006. Chapter 7, Environmental Benefits. U.S. Environmental Protection Agency, Office of Water, Washington, DC. February 2002.

USEPA (U.S. Environmental Protection Agency). 2002c. National Pollutant Discharge Elimination System Permit no. ME0036234, issued to Acadia Aquaculture, Inc. Signed February 21, 2002.

Vaughan, W. J. 1986. *The RFF Water Quality Ladder, Appendix B* in Robert Cameron Mitchell and Richard T. Carson, *The Use of Contingent Valuation Data for Benefit/Cost Analysis in Water Pollution Control*, Final Report. Resources for the Future, Washington, DC.