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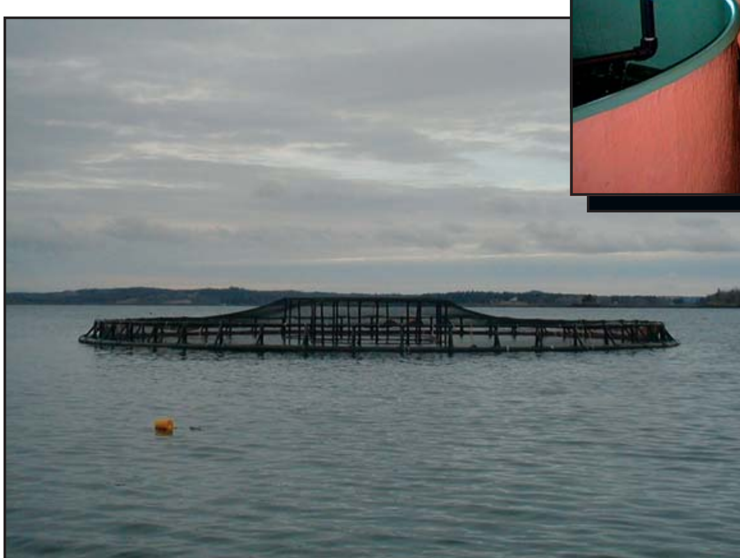
# Technical Development Document for the Final Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category (Revised August 2004)



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# Technical Development Document for the Final Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category

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# Acknowledgments and Disclaimer

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# Foreword

This document includes technical support for the rulemaking for the Concentrated Aquatic Animal Production Point Source Category. After the Administrator signed the final rule, EPA noted several changes to this document. The following chapters have been altered:

Chapter 1

- On page 1-2, corrected the total number of priority pollutants to 126 and updated the citation to 40 CFR Part 423, Appendix A.

Chapter 2

- For clarification, in table 2.2–3, under Best Management Practices, line 1h) Training, the word “system” was added to the second bullet point.

Chapter 3

- On page 3–33, the website given for the Small Business Advocacy Review Panel (USEPA, 2002b) was changed to reflect its new location on the Internet.

Chapter 8

- EPA added a call out to figure 8.2–4 in the text of Section 8.2.1.4.
- The footnote numbering was corrected.

Chapter 9

- For consistency, the heading row in Table 9.3–1 was altered. The words “Assumptions Used in Costing” were added to the title of the first column so that this table would match with all others in this chapter.

# CONTENTS

## Figures

## Tables

# CHAPTER 1
# LEGAL AUTHORITY AND REGULATORY BACKGROUND

This section presents background information supporting the development of effluent limitations guidelines and pretreatment standards for the concentrated aquatic animal production (CAAP) point source category. Section 1.1 describes the legal authority to regulate the CAAP industry. Section 1.2 discusses the Clean Water Act specifically; Section 1.3 discusses the Clean Water Act Section 304(m) consent decree; and Section 1.4 discusses the Regulatory Flexibility Act (as amended by the Small Business Regulatory Enforcement Fairness Act of 1996). Section 1.5 discusses regional, state, and municipal regulation of the industry. Section 1.6 discusses the regulatory history of the CAAP industry.

## 1.1 LEGAL AUTHORITY

EPA promulgates these regulations under the authority of Sections 301, 304, 306, 307, 308, 402, and 501 of the Clean Water Act (CWA) (33 U.S.C. §1311, 1314, 1316, 1317, 1318, 1342, and 1361).

## 1.2 CLEAN WATER ACT

Congress adopted the CWA to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters," (Section 101(a), 33 U.S.C. 1251(a)). To achieve this goal, the CWA prohibits the discharge of pollutants into navigable waters except in compliance with the statute. The CWA establishes restrictions on the types and amounts of pollutants discharged from various industrial, commercial, and municipal sources of wastewater.

Direct dischargers must comply with effluent limitations in National Pollutant Discharge Elimination System (NPDES) permits; indirect dischargers must comply with pretreatment standards. Effluent limitations in NPDES permits are derived on a case-by-case basis using the technology-based standards of the CWA, or are defined from effluent limitations guidelines and new source performance standards promulgated by EPA, as well as from water quality standards. The effluent limitations guidelines and standards are established by regulation for categories of industrial dischargers and are based on the degree of control that can be achieved using various levels of pollution control technology.

Congress recognized that regulating only sources that discharge effluent directly into the Nation's waters would not be sufficient to achieve the goals of the CWA. Consequently, the CWA requires EPA to promulgate nationally applicable pretreatment standards that restrict pollutant discharges from facilities that discharge wastewater indirectly through sewers flowing to publicly owned treatment works (POTWs), (Section 307(b) and (c), 33 U.S.C. 1317(b) and (c)). National pretreatment standards are established for those pollutants in wastewater from indirect dischargers that might pass through, interfere with, or are otherwise incompatible with POTW operations. Generally, pretreatment standards are designed to ensure that wastewaters from direct and indirect industrial dischargers are subject to similar levels of treatment. In addition, POTWs are required to implement local treatment limits applicable to their industrial indirect dischargers to satisfy any local requirements (Code of Federal Regulations, Title 40 Section 403.5, abbreviated as 40 CFR 403.5).

### 1.2.1 Best Practicable Control Technology Currently Available (BPT)—Section 304(b)(1) of the CWA

EPA may promulgate BPT effluent limits for conventional, toxic, and non-conventional pollutants. Section 304(a)(4) designates the following pollutants as conventional pollutants: 5-day biochemical oxygen demand ($BOD_5$), total suspended solids (TSS), fecal coliform bacteria, pH, and any additional pollutants so defined by the Administrator. The Administrator designated oil and grease as a conventional pollutant on July 30, 1979 (44 FR 44501). The term "toxic pollutant" means those pollutants or combinations of pollutants, including disease-causing agents, which after discharge and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will, on the basis of information available to the Administrator, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations, in such organisms or their offspring (Clean Water Act, Section 502). EPA currently lists a total of 126 toxic or "priority pollutants" in 40 CFR Part 423, Appendix A. A non-conventional pollutant is anything not included in the other two categories.

In specifying limits based on BPT, EPA looks at a number of factors. EPA first considers the cost of achieving effluent reductions in relation to the effluent reduction benefits. The Agency also considers the age of the equipment and facilities, the processes employed, engineering aspects of the control technologies, any required process changes, non-water quality environmental impacts (including energy requirements), and such other factors as the Administrator deems appropriate (CWA 304(b)(1)(B)). Traditionally, EPA has established BPT effluent limitations based on the average of the best performances of facilities in the industry, grouped to reflect various ages, sizes, processes, or other common characteristics. Where existing performance is uniformly inadequate, however, EPA may establish limitations based on higher levels of control than those currently in place in an industrial category if the Agency determines that the technology is available in another category or subcategory and can be practically applied.

### 1.2.2 Best Control Technology for Conventional Pollutants (BCT)—Sec. 304(b)(4) of the CWA

The CWA requires EPA to identify additional levels of effluent reduction for conventional pollutants associated with BCT technology for discharges from existing industrial point sources. In addition to other factors specified in Section 304(b)(4)(B), the

CWA requires that EPA establish BCT limitations after considering a two-part "cost-reasonableness" test. EPA explained its methodology for the development of BCT limitations in July 1986 (51 FR 24974). The first step in determining limits representing applications of BCT is to establish that a BCT option is technologically feasible (defined as providing conventional pollutant control beyond the level of control provided by the application of BPT). If a BCT option is found to be technologically feasible, the Agency applies a two-part BCT cost test to evaluate the "cost-reasonableness" of the BCT option. The BCT cost test consists of a POTW test and an industry cost-effectiveness test. EPA conducts the POTW test by first calculating the cost per pound of conventional pollutant removed by industrial dischargers in upgrading from BPT to a BCT candidate technology. EPA then compares this cost to the POTW benchmark, which is the cost per pound for a POTW to upgrade from secondary to advanced secondary treatment ($0.68/pound in 2003 dollars). EPA calculates the industry cost-effectiveness test by calculating the cost per pound to go from BPT to BCT divided by the cost per pound to go from raw wastewater to BPT for the industry and comparing it to 1.29, which is a 29% increase. If the BCT numbers are higher than either of these benchmarks, then the technology has failed the BCT cost test. The results of these tests, along with other industry-specific factors, are evaluated to determine BCT.

### 1.2.3 Best Available Technology Economically Achievable (BAT)—Section 304(b)(2)(B) of the CWA

In general, BAT effluent limitations guidelines represent the best economically achievable performance of facilities in the industrial category or subcategory. The CWA establishes BAT as a principal national means of controlling the direct discharge of toxic and non-conventional pollutants. The factors considered in assessing BAT include the cost of achieving BAT effluent reductions, the age of equipment and facilities involved, the process employed, potential process changes, and non-water quality environmental impacts (including energy requirements) and such other factors as the Administrator deems appropriate. The Agency retains considerable discretion in assigning the weight to be accorded these factors. An additional statutory factor considered in setting BAT is economic achievability. Generally, EPA determines economic achievability on the basis of total costs to the industry and the effect of compliance with BAT limitations on overall industry and subcategory financial conditions. As with BPT, where existing performance is uniformly inadequate, BAT may reflect a higher level of performance than is currently being achieved and may be based on technology transferred from a different subcategory or category. BAT may be based on process changes or internal controls, even when these technologies are not common industry practice.

### 1.2.4 New Source Performance Standards (NSPS)—Section 306 of the CWA

New Source Performance Standards reflect effluent reductions that are achievable based on the best available demonstrated control technology. New facilities have the opportunity to install the best and most efficient production processes and wastewater treatment technologies. As a result, NSPS should represent the most stringent controls attainable through the application of the best available demonstrated control technology for all pollutants (that is, conventional, non-conventional, and priority pollutants). In establishing NSPS, EPA is directed to take into consideration the cost of achieving the effluent reduction and any non-water quality environmental impacts and energy requirements and to consider a "no discharge" option.

### 1.2.5 Pretreatment Standards for Existing Sources (PSES)—Section 307(b) of the CWA

Pretreatment Standards for Existing Sources are designed to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of a POTW. Categorical pretreatment standards are technology-based and are analogous to BAT effluent limitations guidelines.

The General Pretreatment Regulations, which set forth the framework for the implementation of categorical pretreatment standards, are in 40 CFR Part 403. These regulations establish pretreatment standards that apply to all nondomestic dischargers (52 FR 1586 (Jan. 14, 1987)).

### 1.2.6 Pretreatment Standards for New Sources (PSNS)—Section 307(c) of the CWA

Section 307(c) of the Act requires EPA to promulgate pretreatment standards for new sources at the same time it promulgates NSPS. Such pretreatment standards must prevent the discharge into a POTW of any pollutant that might interfere with, pass through, or otherwise be incompatible with the POTW. EPA promulgates categorical pretreatment standards for existing sources based principally on BAT for existing sources. EPA promulgates pretreatment standards for new sources based on best available demonstrated technology for new sources. New indirect dischargers have the opportunity to incorporate into their facilities the best available demonstrated technologies. The Agency considers the same factors in promulgating PSNS that it considers in promulgating NSPS.

## 1.3 SECTION 304 AND CONSENT DECREE

Section 304(m) requires EPA to publish a plan every 2 years that consists of three elements. First, under Section 304(m)(1)(A), EPA is required to establish a schedule for the annual review and revision of existing effluent guidelines in accordance with Section 304(b). Section 304(b) applies to effluent limitations guidelines for direct dischargers and requires EPA to revise such regulations as appropriate. Second, under Section 304(m)(1)(B), EPA must identify categories of sources discharging toxic or non-conventional pollutants for which EPA has not published BAT effluent limitations guidelines under 304(b)(2) or NSPS under Section 306. Finally, under 304(m)(1)(C), EPA must establish a schedule for the promulgation of BAT and NSPS for the categories identified under subparagraph (B) not later than 3 years after being identified in the 304(m) plan. Section 304(m) does not apply to pretreatment standards for indirect dischargers, which EPA promulgates pursuant to Sections 307(b) and 307(c) of the CWA.

On October 30, 1989, Natural Resources Defense Council, Inc. and Public Citizen, Inc. filed an action against EPA in which they alleged, among other things, that EPA had failed to comply with CWA Section 304(m). Plaintiffs (*NRDC, et al v. Leavitt*, D.D.C. Civ. No 89-2980) and EPA agreed to a settlement of that action in a Consent Decree entered on January 31, 1992. The Consent Decree, which has been modified several times, established a schedule by which EPA is to propose and take final action for four point source categories identified by name in the Consent Decree and for eight other point source categories identified only as new or revised rules, numbered 5 through 12. EPA selected the aquatic animal production (AAP) industry as the subject for New or Revised Rule 12. Under the Decree as modified, the Administrator was required to sign a proposed rule for the aquatic animal production industry by no later than August 14, 2002, and to take final action on that proposal by no later than June 30, 2004.

## 1.4 Regulatory Flexibility Act (RFA) as Amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA)

The RFA generally requires an agency to prepare a regulatory flexibility analysis for any rule subject to notice and comment rulemaking requirements under the Administrative Procedure Act or any other statute, unless the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. Small entities include small businesses, small organizations, and small governmental jurisdictions.

For the purpose of assessing the impact of the CAAP effluent limitations guidelines rule on small entities, a *small entity* is defined as (1) a small business based on full-time equivalents (FTEs) or annual revenues established by the Small Business Administration (SBA); (2) a small governmental jurisdiction that is a government of a city, county, town, school district, or special district with a population of less than 50,000 people; and (3) a small organization that is any not-for-profit enterprise which is independently owned and operated and is not dominant in its field. The definitions of *small business* for the AAP industry are provided in SBA's regulations in 13 CFR 121.201. These size standards were updated effective February 22, 2002. SBA size standards for the AAP industry, for North American Industry Classification System (NAICS) codes 112511, 112512, and 112519, define a small business as one with a total amount of revenue of less than $750,000. For the aquarium sector of the AAP industry with NAICS code 712130, a "small business" is defined as one with a total amount of revenue of less than $6 million.

Based on the special tabulation from the 1998 Census of Aquaculture (USDA, 2000) revenue categories (less than $24,999; $25,000 to $49,000; $50,000 to $99,999; $100,000 to $499,999; $500,000 to $999,999; and more than $1 million), EPA identified approximately 4,200 small commercial aquatic animal producers, which represents more than 90% of the total AAP producers. Based on AAP Screener Survey data (Westat, 2002), EPA identified a total of 999 small entities (including 26 small Alaska flow-through facilities that are nonprofits); a total of 344 small entities that met the definition of a CAAP facility; and 48 small entities that were within the scope of the proposed rule (31 flow-through, 12 Alaska, and 5 recirculating). That is, about 95% of the total small entities or 86% of the small CAAP facilities identified in the screener data were not be within the proposed scope. Of the 36 regulated small CAAP facilities that are commercially owned, approximately 17 (which represents 5% of the total small CAAP facilities or 47% of the regulated CAAP facilities) incur compliance costs greater than 1% of aquaculture revenue and 10 small commercial entities (which represent less than

3% of the total small CAAP facilities or 28% of the regulated CAAP facilities) incur compliance costs greater than 3%.

For commercial facilities, EPA assumed that the facility is equivalent to the business. However, because sufficient data were available to determine the parent nonprofit association (and its revenues) for the small Alaska nonprofit facilities, EPA analyzed small entity impacts at the level of the parent association. EPA determined that 12 small Alaska nonprofit facilities within the scope of the proposed rule are owned by 8 small nonprofit associations. Of the six small Alaska nonprofit associations for which EPA had data, three associations incur compliance costs greater than 1% of revenues, and one association incurs compliance costs greater than 3%.

EPA is certifying that the final rule will not have a significant impact on a substantial number of small entities.

## 1.5 State, Regional, and Municipal Aquatic Animal Production Regulations

The Aquaculture Act of 1980 required that a list of regulations and permits affecting the aquaculture industry be compiled. In 1993 the United States Department of Agriculture, Cooperative States Research Service (through the Northeastern Regional Aquaculture Center) contracted with the Maryland Department of Agriculture (MDA) to accomplish this task. The organized network of state aquaculture contacts, the National Association of State Aquaculture Coordinators, was contacted for information regarding aquaculture regulations in their states. The resulting information was compiled into a report, *State/Territory Permits and Regulations Impacting the Aquaculture Industry* (Tetra Tech, 2001), which provides an overview of permits and regulations that affect the aquaculture industry, by individual state or territory, during the time at which the report was prepared. This report is available at http://www.aquanic.org/publicat/state/md/perm1.htm (MDA, 1995).

EPA evaluated *State/Territory Permits and Regulations Impacting the Aquaculture Industry* to analyze existing federal, state, and local effluent regulations related to the CAAP industry. As a part of this evaluation for CAAP facilities, EPA updated the report with readily available information, obtained primarily through Internet research. EPA further delineated the state regulations as those directly related to effluents and discharges (e.g., state NPDES permits); those related to water quality, but indirectly related to discharges (e.g., control of non-native species or pathogens); and those not related to effluents or discharges (e.g., leasing or licensing).

### 1.5.1 State Regulations

EPA updated *State/Territory Permits and Regulations Impacting the Aquaculture Industry* with information available on-line and through communications with industry representatives (Tetra Tech, 2001). The updated information was compiled in several tables and submitted as a separate memorandum (Tetra Tech, 2001).

#### *1.5.1.1 Regulations Dealing Directly with Effluents and Discharges*

EPA found permits and regulations that deal directly with effluents and discharges from CAAP facilities, including NPDES permits; permits and regulations for discharges other than NPDES (injection well, indirect discharge, POTW, sewer, etc.); pesticide regulations; waste handling regulations (sludge application, waste hauling, etc.); and a variety of miscellaneous types of regulations.

*National Pollutant Discharge Elimination System Permits*

EPA, through its NPDES Program, has set the stage for action by state environmental agencies to regulate effluent discharges from CAAP facilities. A *concentrated aquatic animal production facility* is a hatchery, fish farm, or other facility that contains, grows, or holds aquatic animals in either of the following categories, or that the Director designates as such on a case-by-case basis, and must apply for an NPDES permit:

A. Coldwater fish species or other coldwater aquatic animals including, but not limited to, the Salmonidae family of fish (e.g., trout and salmon) in ponds, raceways, or other similar structures that discharge at least 30 days/year but does *not* include:

    1. Facilities that produce less than 9,090 harvest weight kilograms (approximately 20,000 pounds) of aquatic animals per year; and

    2. Facilities that feed less than 2,272 kilograms (approximately 5,000 pounds) of food during the calendar month of maximum feeding.

B. Warmwater fish species or other warmwater aquatic animals including, but not limited to, the Ameiuridae, Cetrachidae, and the Cyprinidae families of fish (e.g., respectively, catfish, sunfish, and minnows) in ponds, raceways, or similar structures that discharge at least 30 days/year, but does *not* include:

    1. Closed ponds that discharge only during periods of excess runoff; or

    2. Facilities that produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) of aquatic animals per year.

EPA has authorized certain states to issue NPDES permits subject to minimum federal requirements. States that have not received authorization to administer the NPDES program are Alaska, Arizona, Idaho, Massachusetts, New Hampshire, and New Mexico; the remaining 44 states, as well as the U.S. Virgin Islands, have authorization to implement the NPDES program.

*Discharges*

Eleven states and territories were found to have regulations pertaining to discharges other than NPDES. These are Arkansas, Arizona, California, Guam, Hawaii, Iowa, Massachusetts, New Jersey, Oklahoma, Texas, and Washington. Regulations addressing discharges include city water and sewer municipal permits, industrial wastewater facility permits, waste discharge requirements, and permits for discharging water into injection wells, groundwater, rivers, lakes, or creeks.

Both Arizona and Massachusetts require facilities to obtain a permit before discharging waters into the ground. Several states and territories, including Guam, Hawaii, Iowa, and Texas, require permits to discharge water into an injection well. In Washington any discharger of pollutants causing below-standard water quality must apply for a modification of the state's water quality standards.

*Pesticides*

A number of states and territories were found to have regulations and permits regarding pesticide use in aquaculture, including Alabama, Arkansas, Connecticut, Delaware, Florida, Guam, Iowa, Kansas, Maryland, Michigan, Minnesota, Pennsylvania, South Carolina, Texas, and West Virginia. These regulations address pesticides and include the following issues: use and application; restrictions; record-keeping; waste collection; storage; labeling requirements; and certification, licensing, and registration.

*Waste Handling*

Four states have regulations that address waste handling of solids generated from aquaculture facilities: Illinois, Iowa, Maryland, and Minnesota. Waste handling regulations in these states address land application of sludge, disposal of sewage and solid waste, and waste hauling permits.

Illinois, Iowa, and Minnesota all have regulations that specifically address land application of sludge. These regulations require individuals to obtain a permit before applying sludge to land. Standards for application vary by state. Maryland's water supply, sewage disposal, and solid waste permit also addresses sewage sludge, including the collection, handling, burning, storage, treatment, land application, and disposal or transportation of solid waste. Sewage sludge is defined as raw sewage sludge, treated sewage sludge, septage, or any product containing these materials that is either generated or utilized in the state.

Illinois has design and maintenance criteria for runoff field application systems. These criteria, which are not classified as a permit, must be met for any party planning to discharge wastewater into a runoff field application, commonly called a vegetative filter system in Illinois. A special waste hauling permit is also required in Illinois for those individuals hauling processing wastes from aquaculture facilities or processing plants for disposal in landfills.

*Miscellaneous Permits and Regulations*

The following four states have miscellaneous permits or regulations that are related to effluents and discharges of the CAAP industry:

- Arizona has a regulation that addresses best management practices (BMPs) for animal feeding operations, which include CAAP facilities. The regulation specifically covers aquaculture facilities classified as feeding operations for the purposes of regulating discharge water quality. Arizona defines BMPs as practices that can be used to protect the quality of water discharged from aquaculture facilities.

- Georgia has a regulation specifying agricultural BMPs for protecting water quality. Although agriculture is exempted from the Georgia Erosion and Sedimentation Act, this regulation requires agricultural enterprises, such as fish farms, to conduct activities consistent with BMPs established by the Department of Agriculture. In Georgia, BMPs are management strategies for the control and abatement of nonpoint source pollution resulting from agriculture. If waters of the state are impaired by agricultural activities and there appears to be no immediate solution or mitigation, the Environmental Protection Division resolves the problem as a water quality violation.
- Massachusetts requires a Massachusetts Environmental Policy Act (MEPA) Environmental Notification Form (ENF) for any activity in any saltwater area, or any other area deemed significant (designated anti-degradation areas exist). Submission of the ENF is the first step in the environmental review of a project under the MEPA. The ENF requires the project proponent to answer specific questions regarding the likely environmental impacts of the proposed project. The ENF is submitted to the MEPA Office of the Massachusetts Executive Office of Environmental Affairs (EOEA), which determines if the likely impacts require the submission of an Environmental Impact Report (EIR). The public is encouraged to provide written comments as part of this review process. The findings of the Secretary of EOEA are written in the form of a certificate.
- Montana provides a short-term exemption from the state's surface water quality standards (3A Authorization). This authorization, which must be obtained prior to initiating a project, concerns any activity in any state water that will cause unavoidable violations of water quality standards. Authorization may be obtained from the Water Quality Bureau, or may be waived by the Department of Fish, Wildlife, and Parks during its review process. This authorization extends to aquaculture facilities.

#### *1.5.1.2 Regulations Dealing Indirectly with Effluents and Discharges*

EPA found aquaculture regulations indirectly related to effluents and discharge. These types of regulations include construction storm water permits, disease control and protection of fish and wildlife health, non-native species, water supply, and other types of regulations.

*Construction and Storm Water*

Eleven states and territories have regulations or permits that address construction and storm water runoff controls: Alabama, Delaware, Guam, Illinois, Maryland, Michigan, New Jersey, Puerto Rico, South Carolina, Vermont, and Washington. Types of permits and regulations addressed by these states and territories include construction storm water permits, erosion and sedimentation control permits, clearing and grading permits, excavation permits, storm water management and sediment reduction permits, permits for dam or pond construction or enlargement, approval for hydraulic projects, and regulations regarding extraction of materials from the earth's crust. These types of permits and regulations seek to limit environmental impacts caused by construction and earthmoving activities, such as erosion, increased water turbidity, water temperature effects, and negative impacts on aquatic life. The storm water permits and regulations are intended to help reduce the water quantity and quality impacts associated with sites during and after construction.

*Disease Control and Protection of Fish and Wildlife Health*

Sixteen states or territories have regulations or permits related to disease control or protection of fish and wildlife health: Alabama, Alaska, Arizona, Arkansas, Connecticut, Delaware, Michigan, Minnesota, Missouri, Montana, North Dakota, Nevada, South Dakota, Washington, West Virginia, and Wisconsin. Regulations or permits in this category include those that address disease control, fish importation precautions, inspection and certification of facilities and fish, and methods for proper handling, processing, and transporting of fish. Connecticut has a regulation that sets standards for shellfish depositing in tidal waters when the shellfish were imported from outside the state.

*Non-native Species*

EPA found 22 states and territories that have reported having regulations or permits dealing with importation or possession of non-native species: Alabama, Arizona, California, Colorado, Connecticut, Florida, Guam, Illinois, Indiana, Iowa, Louisiana, Michigan, Minnesota, Mississippi, Nebraska, New Hampshire, Ohio, South Carolina, Tennessee, Texas, Virginia, and Wisconsin. Types of permits and regulations dealing with non-native species include stocking licenses, general importation permits for aquatic species and plants, and restrictions on possession, sale, importation, transportation, and release of non-native species. Some states have special importation permits regarding specific species of aquatic animals such as grass carp (or white amur), crawfish, piranha, and rudd.

*Water Supply*

Regulations and permits related to water supply address water diversion, water allocation and appropriation, water well construction and drilling, water withdrawal and storage, dam construction or alteration, and use of ground, stream, or surface waters. States and territories with these types of regulations and permits include Alabama, Arizona, California, Colorado, Connecticut, Delaware, Florida, Georgia, Guam, Hawaii, Idaho, Illinois, Iowa, Kansas, Maryland, Massachusetts, Michigan, Minnesota, Montana, Oklahoma, Puerto Rico, South Carolina, Texas, Virginia, Washington, and Wyoming. These regulations are important to the aquaculture industry because water supply is an essential component for aquaculture facilities to be able to operate. Water supply is a major concern in many parts of the United States, especially in arid regions.

Two notable water supply regulations are being used in Florida and Georgia. Florida's environmental resource permit is a comprehensive regulatory program that covers any activity that might alter surface water flows. The permit also involves an evaluation of the effects the activity will have on flooding, storm water, and environmental factors such as water quality, wildlife, and habitats of wetlands and water-dependent species. Georgia's regulation regarding approval to impound or discharge in trout waters does not allow any person to construct an impoundment on primary or secondary trout waters without approval from the Environmental Protection Division. This regulation also restricts temperature elevations that might be caused by impoundments in both primary and secondary trout waters.

*Miscellaneous Permits and Regulations*

Twelve states and territories have miscellaneous regulations and permits indirectly related to effluents and discharge: California, Delaware, Florida, Hawaii, Illinois, Maryland, Minnesota, Montana, New York, Puerto Rico, Rhode Island, and Wisconsin. The regulations and permits in this category address several areas that are indirectly related to effluents and discharge, and they include the following:

- California has a streambed alteration agreement that is used to avoid or mitigate any adverse impacts on fish and wildlife resources caused by a project.
- Delaware requires an application for drainage of lands by tax ditches. This application is needed for water management and flood prevention on lands subject to overflow. Owners of land desiring drainage or protection from flooding may petition for the formation of a tax ditch to the Superior Court of the county in which all or a major portion of area to be drained or protected is located.
- Florida requires a general permit for the installation and maintenance of intake and/or discharge pipes associated with marine bivalve facilities.
- In Hawaii, a conservation district use application is required prior to undertaking any proposed use (aquafarming) of lands within the conservation district. The conservation district encompasses large areas of mountain and shoreline lands, areas necessary to protect watersheds, all submerged ocean lands, and most ancient fish ponds. Hawaii also requires zone of mixing approval for aquaculture effluent discharge into certain coastal waters. This application is made concurrently with NPDES.
- Illinois requires a construction permit for anyone constructing a new, or modifying an existing, emission source or installing any new air pollution control equipment. Anyone operating an existing emission source or air pollution control equipment must first obtain an operating permit.
- In Maryland, approval is required for all state and local agency-sponsored activities or programs affecting the critical area (1,000 feet from the mean high water line of tidal waters or the landward side of tidal wetlands).
- Minnesota requires a permit for all aeration systems installed and operated in protected waters. A private fish farm or hatchery license may contain authorization for the operation of aeration systems on protected waters without public access if the licensee owns all riparian land or all of the possessory rights to the riparian lands. A private hatchery or fish farm license application requesting authorization for an aeration system operation is subject to the same review as the aeration permit application.
- In Montana, the Flood Plain and Floodway Management Act addresses new construction in floodplains. Montana also has a stream protection permit that addresses any project, including the construction of new facilities or the modification, operation, and maintenance of an existing facility that might affect

the natural existing shape and form of any stream or its banks and tributaries. Montana's streambed and land preservation permit addresses any activity that physically alters or modifies the bed and banks of a stream.

- New York's State Environmental Quality Review (SEQR) Act does not require permits, but rather establishes a process to help the government and the public protect and improve the environment by ensuring that environmental factors are considered along with social and economic considerations in government decision-making. SEQR applies to any state, regional, or local government agency approving, undertaking, or funding a privately or publicly sponsored action. Applicants seeking project approval or funding may be required to prepare an environmental impact statement.
- Puerto Rico requires environmental impact statements for projects that might adversely affect the environment.
- In Rhode Island, a coastal resources assent or application is required for any alteration or aquaculture use activities in coastal waterways. The application is reviewed for approval, and application fees are required.
- In Wisconsin, barriers are required for the body of water used as a fish farm or part of a fish farm to prevent the passage of fish between the farm and other waters of the state.

#### *1.5.1.3 Regulations Addressing All Other Types of Aquaculture-Related Activities*

EPA found other types of aquaculture-related permits and regulations, including animal possession, licensing and permitting of CAAP activities, processing, inspection, depuration, leasing, taxes, and a number of miscellaneous regulations and permits.

*Possession*

Regulations and permits included in the possession category include stocking, propagating, cultivating, transporting, transferring, harvesting, taking, trapping, collecting, selling, trading, wet storage, and purchasing. Thirty states have regulations and permits involving the possession of animals for aquaculture-related activities: Alabama, Alaska, Arizona, California, Connecticut, Delaware, Florida, Georgia, Idaho, Iowa, Louisiana, Massachusetts, Michigan, Minnesota, Mississippi, Montana, Nebraska, New Hampshire, New Jersey, Nevada, New York, Ohio, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Vermont, Virginia, and Wisconsin.

*Licensing and Permitting*

Forty states and territories have several licensing and permitting regulations or permits associated with aquaculture: Alabama, Alaska, Arizona, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Guam, Idaho, Illinois, Indiana, Iowa, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Nebraska, Nevada, New Hampshire, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Vermont, Virginia, Washington, West Virginia, Wisconsin, and Wyoming. Regulations and permits included in this category address the actual licensing and permitting of facilities for conducting aquaculture activities. This category also contains fish and bait dealer licenses, general permits, marketing permits, permits that cover all aquaculture-related activities, and permits, certificates, or licenses for fee-fishing, boat use, registration of aquaculture operations, and education and research institutional needs.

*Processing*

Fifteen states have aquaculture-related processing regulations: Arizona, Arkansas, California, Connecticut, Florida, Georgia, Michigan, Minnesota, New Jersey, New York, Oklahoma, Pennsylvania, South Carolina, Texas, and West Virginia. Regulations or permits included in the processing category specifically address requirements for processing of aquatic animals and products, including licenses for purchasing, packing, repacking, shipping, reshipping, shucking, culling, and selling.

*Inspection*

Arizona requires inspection and certification of aquaculture facilities. Facilities are periodically inspected to ensure compliance with all laws related to aquaculture and to ensure that facilities are disease-free.

*Depuration*

Two states have regulations or permits that specifically address depuration, which is the purging of contaminants from shellfish. In Connecticut a shellfish depuration license is required for the operation of a depuration plant and the sale of processed shellfish. Florida requires a special activity license for depuration of oysters and clams in controlled purification facilities.

*Leasing*

Thirteen states have regulations or permits regarding leasing of submerged public land: Alaska, California, Connecticut, Delaware, Florida, Louisiana, Maine, New Jersey, North Carolina, Rhode Island, Texas, Virginia, and Washington. Most of the leasing regulations or permits address leasing of state or publicly owned tidal or subtidal ocean water bottoms for shellfish or oyster operations. In North Carolina, a lease is required for the use of an entire water column for the private production of shellfish.

*Taxes*

Three states have regulations or permits addressing aquaculture-related taxes. Alabama and Arkansas both require a city privilege tax for businesses inside city limits. Some cities even have specific permits for fish markets, which would otherwise be covered by a general permit. Arkansas also requires a sales and use tax permit. Any business that provides a service or merchandise must pay a deposit of $250 to receive a sales and use tax permit. A refund is granted within 6 months if that business or its sales outlets do not charge sales tax to its customers. Also included in the taxes category are Pennsylvania's sales tax and capital stock franchise tax regulations.

*Miscellaneous Permits and Regulations*

Twenty-four states and territories have miscellaneous regulations and permits that are related to other CAAP activities: Alabama, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Illinois, Indiana, Michigan, Mississippi, New York, Oregon, Puerto

Rico, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Virginia, Washington, West Virginia, Wisconsin, and Wyoming. Regulations and permits in this category address a variety of subjects and include the following:

- In Alabama, regulations cover procedures and guidelines for dealing with nuisance alligators.
- Arkansas requires a feed license for anyone who manufactures or distributes commercial feed or has their name appear on the label as a commercial feed guarantor.
- California's shellfish safety regulations cover requirements for the safe handling of shellfish. California also requires a weighmaster license for weighing, measuring, or counting any commodity and for issuing a statement used as the basis for either the purchase or the sale of that commodity or charge for service.
- Colorado requires a private easement for erecting intake/discharge structures and for dredging and filling on state-owned submerged lands.
- In Connecticut, shellfish safety regulations provide requirements for the safe handling of shellfish. Connecticut also requires shellfish transplant licenses for both the short and long term. These transplant licenses are required to relay oysters from prohibited areas into private shellfish beds in approved areas.
- Delaware requires a subaqueous lands permit, without which a person may not deposit material upon, extract material from, construct, modify, repair, reconstruct, or occupy any structure or facility on submerged lands or tidelands.
- Florida requires a special activity license for any person to use gear or equipment not authorized by the Fish and Wildlife Conservation Commission for harvesting saltwater species. Florida also requires a private easement for erecting any intake or discharge structures and for dredging and filling on state-owned submerged lands.
- Illinois requires a license for disposing of dead animals and a permit for removing undesirable fish from state waters.
- In Indiana, all manufacturers and wholesale distributors of food (excluding meat, poultry, and dairy products) must apply for a registration of business.
- In Michigan, regulations cover proper procedures for dealing with the bodies of dead animals, including composting of dead fish from aquaculture activities.
- Mississippi requires that all tilapia products offered for direct sale for human consumption have the product name specifically labeled in the manner described by the state's regulations.
- In New York, regulations control any new or expanded land use and development that is defined as a Class A or B regional project. New York also requires fish tags for identifying hatchery-raised fish and permits to install a fish screen and to remove or transfer fish.
- Oregon has numerous overlapping permits and state government regulatory permits for the kinds of aquaculture permitted in the state. To begin the permitting

process, an applicant should first contact the Oregon Department of Fish and Wildlife.

- Puerto Rico was vague in describing its specific aquaculture regulations, indicating that it has zoning and building regulations pertaining to aquaculture.
- Rhode Island may require the execution of a bond by the permittee to ensure the permittee's performance of all conditions of the permit and, in the event of failure to perform, to ensure the removal of aquaculture apparatus from the waters of the state.
- In South Carolina, harvesting equipment permits are required to use dredges, hydraulic escalators, patent tongs, or any other mechanically operated device for taking shellfish from any bottom. South Carolina also requires a license for using powerboats or other vessels equipped with commercial fishing equipment for taking shellfish.
- South Dakota's regulation on contract commercial fishing for rough and bullheads covers the bond required and activities such as supervision, equipment tagging, sale and transportation of fish, and deposition of game fish taken.
- In Tennessee, an animal damage permit is required for any person, company, or other entity desiring to destroy, or otherwise control, nuisance wildlife and charge a fee for such services.
- Texas requires shell dredging permits for all shell dredging in state-owned submerged tidelands. Aquaculture producers may be subject to other permits, licenses, or approvals.
- Virginia's food quality sanitation regulations govern the inspection of food manufacturers, warehouses and retail food stores, food product sampling, and food product label review.
- In Washington, regulations cover the identification requirements for products cultivated by aquatic farmers. Washington also has shellfish certification regulations, which cover shellfish sanitation and practices, including certificate of compliance, certificates of approval for shellfish growing areas, and certificates for culling, shucking, and packing facilities.
- All places in West Virginia that tender to the public any item for human consumption need a permit for water well installations and on-site sewage system installations.
- Wisconsin's permit for private management allows a person who owns all of the land bordering a navigable lake that is completely landlocked to remove, destroy, or introduce fish. Wisconsin also has a permit that allows a person to use a natural body of water for a fish farm.
- In Wyoming, food safety regulations cover good manufacturing practice labeling. Wyoming also requires a mining permit for removal of solid minerals from the earth for commercial purposes including some forms of aquatic animal production.

### 1.5.2 Federal Regulations

EPA evaluated other federal statutes and regulations that might affect the CAAP industry (Tetra Tech, 2001). The following federal statutes and regulations address a variety of areas that might apply to CAAP facilities:

- *Section 404 of the Federal Water Pollution Control Act of 1972 as amended by the Clean Water Act of 1977 and the Water Quality Act of 1987*: Section 404 deals with permits for dredged and filled sites. More specifically, Section 404 establishes a program to regulate the discharge of dredged and fill material into waters of the United States, including wetlands. Activities in waters of the United States that are regulated under this program include fills for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and conversion of wetlands to uplands for farming and forestry.
- *Federal Coastal Zone Management Act of 1972, as amended*: The Coastal Zone Management Act (CZMA) deals with proposed federal activities affecting a state's coastal zone. Activities include direct federal agency actions, federal licenses and permits, and financial assistance to state and local governments. The requirements of CZMA apply to all states in the "coastal zone," including parts of the Great Lakes.
- *Section 10 of the Rivers and Harbors Act (RHA) of 1899*: Section 10 states that the creation of any obstruction not affirmatively authorized by Congress to the navigable capacity of any of the waters of the United States is prohibited.
- *Federal Standard Sanitation Standards for Fish Plants*: This regulation describes an optional Quality Assurance Inspection in which U.S. Department of Commerce inspectors will, upon request, inspect processing plants and facilities, and grade aquaculture products for quality assurance (50 CFR Part 260).
- *Endangered Species Act of 1973*: This statute deals with any activity that might affect endangered or threatened species or their habitat.
- *Lacey Act Amendments of 1981*: Under this law, it is unlawful to import, export, sell, acquire, or purchase fish, wildlife, or plants taken, possessed, transported, or sold (1) in violation of U.S. or Indian law or (2) in interstate or foreign commerce involving any fish, wildlife, or plants taken, possessed, or sold in violation of state or foreign law.
- *Migratory Bird Treaty Act*: The Migratory Bird Treaty Act regulates the use of lethal control methods on migratory birds, which are causing aquaculture crop losses. USFWS issues permits for the control of these migratory birds.
- *Wild and Scenic Rivers Act*: Permits issued under the wild, scenic, and recreational rivers systems program are intended to control land use and development along river corridors specifically designated under the system and to protect and preserve the river qualities that qualified the particular rivers

designated under the system. This program is jointly managed by the USFWS and any other agency that might hold title to involved lands.

- *Section 106 of the National Historic Preservation Act of 1966, as amended through 1992*: The head of any federal agency having direct or indirect jurisdiction over a proposed federal or federally assisted undertaking in any state and the head of any federal department or independent agency having authority to license any undertaking must, prior to the approval of the expenditure of any federal funds on the undertaking or prior to the issuance of any license, as the case may be, take into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register.

## 1.6 Regulatory History of the Concentrated Aquatic Animal Production Industry

Until the current regulation, EPA had not proposed effluent limitations guidelines and standards for the concentrated aquatic animal production industry. In the early 1970s, however, EPA staff did evaluate fish hatcheries and fish farms to develop recommendations on whether the Agency should propose effluent guidelines in conjunction with the evaluation. Ultimately, EPA did not propose any such regulations because the 1977 Clean Water Act amendments had refocused the Agency's attention on establishing effluent limitations guidelines for industry sectors with effluents containing toxic metals and organics. EPA's evaluation of fish hatcheries and farms did not reveal significant contributions of toxic metals or organic chemical compounds in the wastes discharged from those facilities. That draft development document, however, did assist NPDES permit writers in the exercise of their "best professional judgment" to develop permits for those fish hatcheries and farms that were considered "concentrated aquatic animal production facilities" and thus were required to apply for NPDES permits under EPA regulations.

EPA actions to regulate concentrated aquatic animal production facilities under the NPDES permitting program date back to 1973, when the Agency proposed and promulgated NPDES permit application rules for CAAP facilities (38 FR 10960 (May 3, 1973) (proposed); 38 FR 18000 (July 5, 1973)). After some litigation over the NPDES regulations, EPA proposed and took final action to reestablish the CAAP facility requirements (NRDC v. Costle, 568 F.2d 1369 (D.C. Cir. 1977); 43 FR 37078 (Aug. 21, 1978); 44 FR 32854 (June 7, 1979)). To date, the 1979 version of the regulations has not substantively changed since then.

The NPDES regulations specify the applicability of the NPDES permit requirement to a concentrated aquatic animal production facility, the definition of which can be found in 40 CFR 122.24 and Appendix C to Part 122. To be a CAAP facility, the facility must either meet the criteria in 40 CFR Appendix C or be designated on a case-by-case basis (40 CFR 122.24(b)). A hatchery, fish farm, or other facility is a CAAP facility if it contains, grows, or holds aquatic animals in either of two categories: coldwater species or warmwater species. The coldwater species CAAP facilities must discharge at least 30 days per year; however, facilities that produce less than 9,090 harvest weight kilograms (approximately 20,000 pounds) per year and facilities that feed less than 2,272 kilograms (approximately 5,000 pounds) during the calendar month of maximum feeding are not defined as CAAP facilities. The warmwater CAAP facilities must discharge at least 30 days/year, but closed ponds that discharge only during periods of excess runoff or facilities that produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) per year are not defined as CAAP facilities (40 CFR 122 Appendix C).

## 1.7 References


MDA (Maryland Department of Agriculture). 1995. *State/Territory Permits and Regulations Impacting the Aquaculture Industry*. Maryland Department of Agriculture. <http://www.aquanic.org/publicat/state/md/perm.htm>. Accessed September 2001.

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# CHAPTER 2
# SUMMARY OF SCOPE AND CONTENT OF THE FINAL REGULATION

This chapter presents a summary of the rule for the concentrated aquatic animal production (CAAP) industry. The rule establishes effluent limitations guidelines (ELGs) and new source performance standards based on treatment technologies or operational and management measures for the control of pollutants. Section 2.1 summarizes and discusses the applicability of the National Pollutant Discharge Elimination System (NPDES) regulations, and Section 2.2 summarizes and discusses the applicability of the effluent limitations guidelines and standards for the CAAP industry.

## 2.1 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)

The NPDES regulations define which aquatic animal production facilities are concentrated aquatic animal production facilities that are point sources subject to the NPDES permit program (see 40 CFR 122.24 and Appendix C to Part 122). A CAAP is either a facility that meets the criteria in 40 CFR Part 122 Appendix C or a facility that EPA or a state designated a CAAP on a case-by-case basis (40 CFR 122.24(b)). A hatchery, fish farm, or other facility is a CAAP facility if it contains, grows, or holds, aquatic animals in the following conditions (40 CFR Appendix C to Part 122):

> The **coldwater** species category includes ponds, raceways, or other similar structures which discharge at least 30 days/year but does not include: facilities which produce less than 9,090 harvest weight kilograms (approximately 20,000 pounds) per year; and facilities which feed less than 2,272 kilograms (approximately 5,000 pounds) during the calendar month of maximum feeding. *Coldwater aquatic animals* include, but are not limited to, the Salmonidae family of fish; e.g., trout and salmon.
>
> The **warmwater** category includes ponds, raceways, or other similar structures which discharge at least 30 days/year but does not include: closed ponds which discharge only during periods of excess runoff; or facilities which produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) per year. *Warmwater aquatic animals* include, but are not limited to, the Ameiuride, Centrarchidae, and Cyprinidae families of fish; e.g., respectively catfish, sunfish, and minnows.

EPA is not revising the NPDES regulation.

## 2.2 EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS

The effluent limitations guidelines and standards regulations establish the Best Practicable Control Technology Currently Available (BPT), Best Control Technology for Conventional Pollutants (BCT), and Best Available Technology Economically Achievable (BAT) limitations, as well as New Source Performance Standards (NSPS). EPA is not establishing national pretreatment standards for this category, which contains very few indirect dischargers. The indirect dischargers discharge mainly TSS and BOD, which the POTWs are designed to treat and which consequently, do not pass through. In addition, nutrients discharged from CAAP facilities are in concentrations lower, in full flow discharges, and similar, in off-line settling basin discharges, to nutrient concentrations in human wastes discharged to POTWs. The options EPA considered do not directly treat nutrients, but some nutrient removal is achieved incidentally through the control of TSS. EPA concluded POTWs would achieve removals of TSS and associated nutrients equivalent to those achievable by the options considered for this rulemaking and therefore there would be no pass through of pollutant in amounts needing regulation. In the event of pass through that causes a violation of a POTWs NPDES limits, the POTW must develop local limits for its users to ensure compliance with its permit.

### 2.2.1 Regulatory Implementation of Part 451 Through the NPDES Permit Program and the National Pretreatment Program

Under Sections 301, 304, 306, and 307 of the Clean Water Act (CWA), EPA promulgates national effluent limitations guidelines and standards of performance for major industrial categories generally for three classes of pollutants: (1) conventional pollutants (i.e., TSS, oil and grease, BOD, fecal coliforms, and pH); (2) toxic pollutants (e.g., toxic metals such as chromium, lead, nickel, and zinc; toxic organic pollutants such as benzene, benzo-*a*-pyrene, phenol, and naphthalene); and (3) non-conventional pollutants (e.g., ammonia-N, formaldehyde, and phosphorus).

EPA considers development of six types of effluent limitations guidelines and standards for each major industrial category, as appropriate:

| Abbreviation | Effluent Limitation Guideline or Standard |
|---|---|
| Direct Dischargers | |
| BPT | Best Practicable Control Technology Currently Available |
| BAT | Best Available Technology Economically Achievable |
| BCT | Best Control Technology for Conventional Pollutants |
| NSPS | New Source Performance Standards |
| Indirect Dischargers | |
| PSES | Pretreatment Standards for Existing Sources |
| PSNS | Pretreatment Standards for New Sources |

The effluent limitations guidelines and NSPS apply to industrial facilities with direct discharges to navigable waters. Pretreatment standards apply to industrial facilities with wastewater discharges to POTWs. As noted above, EPA is not requiring categorized pretreatment standards for the CAAP industrial category.

#### *2.2.1.1 NPDES Permit Program*

Section 402 of the CWA establishes the NPDES permit program. The NPDES permit program is designed to limit the discharge of pollutants into navigable waters of the United States through a combination of various requirements, including technology-based and water quality-based effluent limitations. This regulation contains the technology-based effluent limitations guidelines and standards applicable to the CAAP industry to be used by permit writers to derive NPDES permit technology-based effluent limitations. Water quality-based effluent limitations are based on receiving water characteristics and ambient water quality standards, including designated water uses. They are derived independently from the technology-based effluent limitations set out in this regulation. The CWA requires that NPDES permits must contain, for a given discharge, the more stringent of the applicable technology-based or water quality-based effluent limitations for any given pollutant of concern.

Section 402(a)(1) of the CWA provides that in the absence of promulgated effluent limitations guidelines or standards, the Administrator, or his or her designee, may establish technology-based effluent limitations for specific dischargers on a case-by-case basis. Federal NPDES permit regulations provide that these limits may be established using “best professional judgment” (BPJ) taking into account any effluent limitations guidelines and standards and other relevant scientific, technical, and economic information, as well as the statutory technology-based standards of control.

Section 301 of the CWA requires that BAT effluent limitations for toxic pollutants are to have been achieved as expeditiously as possible, but not later than 3 years from the date of promulgation of such limitations and in no case later than March 31, 1989. (See § 301(b)(2).) Because the 40 CFR Part 451 regulations for the CAAP industry will be promulgated after March 31, 1989, NPDES permit effluent limitations based on the effluent limitations guidelines will need to be included in the next NPDES permit issued after promulgation of the regulation. The permits must require immediate compliance with the effluent limitations. If the permitting authority wishes to provide a compliance schedule, it must do so through an enforcement mechanism.

#### *2.2.1.2 New Source Performance Standards*

New sources will need to comply with the NSPS and limitations of the CAAP rule at the time such sources commence discharging CAAP process wastewater. Because the final rule was not promulgated within 120 days of the proposed rule, the Agency will consider a discharger to be a new source if construction of the source begins 30 days after the date of publication of the Rule in the *Federal Register*.

#### *2.2.1.3 National Pretreatment Standards*

The national pretreatment standards at 40 CFR Part 403 have three principal objectives: (1) to prevent the introduction of pollutants into POTWs that will interfere with POTW operations, including use or disposal of municipal sludge; (2) to prevent the introduction of pollutants into POTWs which will pass through the treatment works or will otherwise be incompatible with the treatment works; and (3) to improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

The national pretreatment and categorical standards comprise a series of prohibited discharges to prevent the discharge of "any pollutant(s) which cause Pass Through or Interference." (See 40 CFR 403.5(a)(1).) Local control authorities are required to implement the national pretreatment program including application of the federal categorical pretreatment standards to their industrial users that are subject to such categorical pretreatment standards, as well as any pretreatment standards derived locally (i.e., local limits) that are more restrictive than the federal standards. This regulation will not establish national categorical pretreatment standards (PSES and PSNS) applicable to CAAP facilities that are regulated by 40 CFR Part 451.

### 2.2.2 Applicability of the Rule

EPA has subcategorized the CAAP point source category based on production system type. See Chapter 5 for a discussion on subcategorization. The subcategories are listed in Table 2.2–1. The rule applies to facilities that annually produce at least 100,000 pounds of aquatic animals in the following subcategories: (1) flow-through and recirculating and (2) net pens. EPA did not promulgate regulations for closed pond systems because 1) most do not discharge 30 days or more and are not defined as CAAPs; 2) because of the minimal pollutant discharges; and 3) because the pond itself acts as an effective treatment system.

**Table 2.2–1. Applicability of Final Rule to CAAP Subcategories**

| *System Type or Subcategory* | *Annual Production (lb)* | |
|---|---|---|
| | *<100,000* | *≥100,000* |
| Closed Ponds | Not Applicable | Exempt |
| Flow-through and Recirculating (Subpart A) | Not Applicable | Subject to Sections:<br>451.3(a)–(d)<br>451.11(a)–(e)<br>451.12–14 |
| Net pen (Subpart B) | Not Applicable | Subject to Sections:<br>451.3(a)–(d)<br>451.21(a)–(h)<br>451.22–24 |

### 2.2.3 Summary of Effluent Limitations Guidelines and Standards

The final regulatory option requires reporting of Investigational New Animal Drugs (INADs) and extralabel drug use. It also requires facilities to report failure in or damage to the structure of an aquatic animal containment system resulting in an unanticipated material discharge of pollutants to waters of the United States. Facilities must develop and maintain a BMP plan onsite describing how the permittee will achieve the final requirements.

#### *2.2.3.1 General Reporting Requirements*

EPA established general reporting requirements (found in 40 CFR 451.3) for the use of certain types of drugs.

The general reporting requirements apply to flow-through, recirculating, and net pen systems.

**INADs and Extralabel Drug Use**

The permittee will need to notify the permitting authority of the use in a CAAP facility (subject to this Part) of any INAD (i.e., a drug for which there is a valid exemption in effect under 512(j) of the Federal Food, Drug, and Cosmetic Act, 21.U.S.C. 360b(j)) and any extralabel drug use (i.e., when a drug is not used according to label requirements), where such use may lead to discharge to waters of the United States. Reporting is not required for an INAD or extralabel drug use when the drug is used for a different species or disease at or below the approved dose and involves similar conditions of use. For INADs:

- The permittee must provide a written report to the permitting authority of an INAD's impending use within 7 days of agreeing or signing up to participate in an INAD study. The written report must identify the INAD to be used, method of application, the dosage, and the disease or condition the INAD is intended to treat.

For INADs and extralabel drug use:

- The permittee must provide an oral report to the permitting authority as soon as possible, preferably in advance of use, but no later than 7 days after initiating use of the drug. The oral report must identify the drugs used, the method of application, and the reason for using the drug.
- The permittee must provide a written report to the permitting authority within 30 days after initiating use of the drug. The written report must identify the drug used and include: the reason for treatment, date(s) and time(s) of the addition (including duration); method of application; and the amount added.

**Failure in or Damage to the Structure of an Aquatic Animal Containment System**

The permittee needs to notify the permitting authority of any failure in, or damage to, the structure of an aquatic animal containment system resulting in an unanticipated material discharge of pollutants to waters of the United States. Any permittee must notify the permitting authority when there is a reportable failure.

- The permitting authority may specify in the permit what constitutes reportable damage and/or a material discharge of pollutants, based on a consideration of production system type, sensitivity of the receiving waters, and other relevant factors.

- The permittee must provide an oral report within 24 hours of discovery of any reportable failure or damage that results in a material discharge of pollutants, describing the cause of the failure or damage in the containment system and identifying materials that have been released to the environment as a result of the failure.
- The permittee must provide written report within 7 days of discovery of the failure or damage documenting the cause, the estimated time elapsed until the failure or damage was repaired, an estimate of the material released as a result of the failure or damage, and steps being taken to prevent a reoccurrence.
- In the event a spill of drugs, pesticides, or feed occurs that results in a discharge to waters of the U.S., the permittee must provide an oral report of the spill to the permitting authority within 24 hours of its occurrence and a written report within 7 days. The report must include the identity and quantity of the material spilled.

**BMP Plan**

EPA requires that all facilities subject to this Part develop and maintain a BMP plan describing how the permittee will achieve the final requirements. The permittee must certify in writing to the permitting authority that a BMP plan has been developed and make the plan available to the permitting authority upon request.

### *2.2.3.2 Narrative Requirements*

For the final effluent guideline, EPA is establishing narrative effluent limitations for flow-through, recirculating, and net pen systems.

*Flow-through and Recirculating Systems*

**BPT**

EPA is establishing nationally applicable effluent limitations guidelines and standards for CAAP flow-through and recirculating facilities producing at least 100,000 pounds of aquatic animals per year.

EPA based the final limitation on operation requirements to address solids controls, materials storage, structural maintenance, record-keeping, and training. These practices are widely available among the existing flow-through and recirculating system facilities.

Solids Control

The final regulation includes narrative limitations requiring solids control measures and operational practices. To control the discharge of solids from flow-through and recirculating system facilities, EPA requires the facility to employ efficient feed management and feeding strategies that limit feed input to the minimum amount reasonably necessary to achieve production goals and sustain targeted rates of aquatic animal growth in order to minimize potential discharges of uneaten feed and waste products to waters of the U.S.

In order to minimize the discharge of accumulated solids from settling ponds and basins and production systems, facilities must identify and implement procedures for routine cleaning of rearing units and offline settling basins, and procedures to minimize any discharge of accumulated solids during the inventorying, grading, and harvesting aquatic animals in the production system.

As part of the solids control requirements, facilities must remove and dispose of aquatic animal mortalities properly on a regular basis to prevent discharge to waters of the United States, except in cases where the permitting authority authorizes such discharge in order to benefit the aquatic environment. For example, federal, state, and tribal hatcheries raise fish for stocking or mitigation purposes. In some cases, these facilities have been approved to discharge fish carcasses along with the live fish that are being stocked. In these situations, the carcasses are serving as a source of nutrients and food to the fish being stocked in these waters.

Materials Storage

To address materials storage, facilities must ensure proper storage of drugs, pesticides, and feed in a manner designed to prevent spills that may result in the discharge of drugs, pesticides, or feed to waters of the United States. In the event that a spill of drugs, pesticides, or feed occurs that results in a discharge to waters of the United States, the owner or operator will provide an oral report of this to the permitting authority within 24 hours of its occurrence and a written report within 7 days. The report will include the identity of the material spilled and an estimated amount. Facilities must also implement procedures for properly containing, cleaning, and disposing of any spilled material. Many facilities may already have implemented practices that address these requirements.

Structural Maintenance

To address structural maintenance, EPA is requiring facilities to conduct routine inspections of the production system and the wastewater treatment system to identify and promptly repair any damage. EPA is not requiring any design specifications associated with the structural components of the CAAP facility; EPA is merely expecting facilities to identify practices that will ensure any existing structures are maintained in good working order. Facilities must also conduct regular maintenance of the production system and the wastewater treatment system to ensure that they are properly functioning. One of the areas of concern associated with this requirement is to minimize the occurrence of solids (especially large solids such as carcasses and leaves) from clogging screens that separate the raceway from the quiescent zone. These solids could prevent the flow of water through the screen causing water to instead flow over the screen and impair the passage of solids into the quiescent zone.

Record-keeping

EPA is requiring facilities to keep records for certain activities. Facilities must maintain records for aquatic animal rearing units documenting the feed amounts and estimates of the numbers and weight of the aquatic animals in order to calculate representative feed conversion ratios. Facilities must also keep records documenting the frequency of cleaning, inspections, maintenance, and repairs.

Training

EPA is requiring facilities to train relevant facility personnel in spill prevention. The training must include how to respond in the event of a spill and therefore ensures that proper clean-up and disposal of spilled material can be addressed. Facilities must also train staff on the proper operation and cleaning of production and wastewater treatment systems, including training in feeding procedures and equipment.

A summary of the BPT requirements for flow-through and recirculating systems is provided in Table 2.2–2 at the end of the chapter.

**BAT**

EPA is establishing BAT at a level equal to BPT for the flow-through and recirculating system subcategory. For this subcategory, EPA did not identify any *available* technologies that are economically achievable that would achieve more stringent effluent limitations than those considered for BPT. Because of the nature of the wastes generated from CAAP facilities, advanced treatment technologies or practices to remove additional solids (e.g., smaller particle sizes) in TSS that would be economically achievable on a national basis do not exist beyond those already considered.

**BCT**

EPA evaluated conventional pollutant control technologies applying its BCT cost test. EPA did not identify a more stringent technology for the control of conventional pollutants for BCT limitations that passes the BCT cost test. Consequently, EPA is not promulgating BCT limitations or standards based on a different technology from that used as the basis for BPT limitations and standards. For more details about the BCT cost reasonableness test and the BAT analysis, see the *Economic and Environmental Impact Analysis* (USEPA, 2004).

**NSPS**

After considering the technology options described in the proposed rule and Notice of Data Availability (NODA) and evaluating the factors specified in Section 306 of the CWA, EPA is promulgating standards of performance for new sources equal to BPT, BAT, and BCT. There are no more stringent technologies available for NSPS that would not represent a barrier to entry for new facilities. Because of the nature of the wastes generated in CAAP facilities, EPA has not identified advanced treatment technologies or practices to remove additional solids (e.g., smaller particle sizes) in TSS that would be affordable beyond those already considered.

EPA determined that NSPS equal to BAT will not present a barrier to entry. See Section IX of the Preamble for more discussion of barrier to entry analysis. The overall impacts from the effluent limitations guidelines on new sources would not be any more severe than those on existing sources. This is because the costs faced by new sources are generally the same as or lower than those faced by existing sources. It is generally less expensive to incorporate pollution control equipment into the design at a new facility than it is to retrofit the same pollution control equipment in an existing plant. At a new facility, no demolition is required and space constraints (which can add to retrofitting costs if specifically designed equipment must be ordered) may be less of an issue.

*Net Pen Systems*

**BPT**

EPA is establishing nationally applicable effluent limitations guidelines and standards for CAAP net pen facilities producing at least 100,000 pounds of aquatic animals per year except for net pen facilities rearing native species released after a growing period of no longer than 4 months to supplement commercial and sport fisheries.

Feed Monitoring

Facilities must minimize the accumulation of uneaten feed beneath pens through the use of active feed monitoring and management strategies. These strategies may include one or more of the following: use of real-time feed monitoring (including devices such as video cameras, digital scanning sonar, and upweller systems), monitoring of sediment quality beneath the pens, monitoring of benthic community quality beneath pens, capture of waste feed and feces, or adoption of other good husbandry practices subject to the permitting authority's approval. Real-time monitoring represents a widely used business practice that is employed by many of the salmonid net pen facilities to reduce feed costs. Net pen systems do not present the same opportunities for solids control as do flow-through or recirculating systems. Therefore, in EPA's view, feed monitoring including real-time monitoring and other practices is an important and cost reasonable practice to control solids discharges.

Facilities must employ efficient feed management strategies that limit feed input to the minimum amount reasonably necessary to achieve production goals and sustain targeted rates of aquatic animal growth in order to minimize potential discharges of uneaten feed and waste products to waters of the United States.

Waste Collection and Disposal

EPA is requiring facilities to collect, return to shore, and properly dispose of all feed bags, packaging materials, waste rope, and netting. EPA assumes net pen facilities have the equipment (e.g., trash receptacles) to store empty feed bags, packaging materials, waste rope, and netting until they can be transported for disposal.

Transport or Harvest Discharge

Facilities must minimize any discharge associated with the transport or harvesting of aquatic animals including blood, viscera, aquatic animal carcasses, or transport water containing blood. During stocking or harvesting of fish, some may die. The wastes and wastewater associated with the transport or harvest of fish have high BOD and nutrient concentrations and should be disposed of at a location where they may be properly treated.

Carcass Removal

Facilities must remove and dispose of aquatic animal mortalities properly on a regular basis to prevent discharge to waters of the United States. Discharge of dead fish represents an environmental concern because they may spread disease and attract predators, which could imperil the structural integrity of the containment system.

Materials Storage

EPA is requiring net pen facilities to ensure proper storage of drugs, pesticides, and feed in a manner designed to prevent spills that may result in the discharge of drugs, pesticides, or feed to waters of the United States. In the event that a spill of drugs, pesticides, or feed occurs that results in a discharge to waters of the United States, the owner or operator will provide an oral report of this to the permitting authority within 24 hours of its occurrence and a written report within 7 days. The report will include the identity of the material spilled and an estimated amount. Facilities must also implement procedures for properly containing, cleaning, and disposing of any spilled material.

Structural Maintenance

Facilities must inspect the production system on a routine basis in order to identify and promptly repair any damage. In addition, facilities must conduct regular maintenance of the production system to ensure that it is properly functioning. Net pens are vulnerable to damage from predator attack or accidents that result in the release of the contents of the nets, including fish and fish carcasses. EPA assumes facilities will conduct routine inspections of the nets to ensure they are not damaged and make repairs as soon as any damage is identified.

Record-keeping

Facilities must maintain records for each net pen documenting the feed amounts and estimates of the numbers and weight of aquatic animals in order to calculate representative feed conversion ratios. EPA is also requiring facilities to keep records of the net changes, inspection, and repairs.

Training

Net pen facilities must adequately train all relevant personnel in spill prevention and, in the event of a spill, how to respond to ensure the proper clean up and disposal of any spilled material. Facilities must also train staff on the proper operation and cleaning of the production systems, including training in feeding procedures and proper use of equipment.

All existing net pen facilities that are currently covered by NPDES permits are subject to permit requirements that meet the final regulatory option when the permit is reissued. However, there maybe a small number of net pen facilities in Maine that may not have taken coverage under an NPDES permit (Goodwin, 2004). EPA does not have detailed results from these unpermitted facilities, but assumes they are employing operational measures similar to those in use at the permitted net pen facilities EPA has reviewed. Therefore, EPA concludes that the BPT limits are both technically available and cost reasonable. A summary of the BPT requirement alternatives for net pen systems is provided in Table 2.2–3 at the end of the chapter.

**BAT**

EPA is establishing BAT at a level equal to BPT for the net pen subcategory. For this subcategory, EPA did not identify any *available* technologies that are economically achievable that would achieve more stringent effluent limitations than those considered for BPT. Because of the nature of the wastes generated from CAAP facilities, advanced treatment technologies or practices to remove additional solids that would be economically achievable on a national basis do not exist beyond those already considered.

**BCT**

EPA evaluated conventional pollutant control technologies applying its BCT cost test. EPA did not identify a more stringent technology for the control of conventional pollutants for BCT limitations that passes the BCT cost test. Consequently, EPA is not promulgating BCT limitations or standards based on a different technology from that used as the basis for BPT limitations and standards. For more details about the BCT and BAT economic analyses, see the *Economic and Environmental Impact Analysis* (USEPA, 2004)

**NSPS**

After considering the technology requirements described in the proposal and NODA and the factors specified in Section 306 of the CWA, EPA is promulgating standards of performance for new sources equal to BPT, BAT, and BCT. There are no more stringent best demonstrated technologies available. Because of the nature of the wastes generated and the production system used, EPA has not identified advanced treatment technologies or practices to require that would be affordable beyond those already considered.

Although siting is not addressed with the final standards, when establishing new net pen CAAP facilities the location is critical in predicting the potential impact the net pen will have on the environment. Net pens are usually situated in areas which have good water exchange through tidal fluctuations or currents. Good water exchange ensures good water quality for the animals in the nets, and it also minimizes the concentration of pollutants below the nets. EPA encourages facilities and permit authorities to give careful consideration to siting prior to establishing a new net pen facility.

EPA has concluded that NSPS equal to BAT does not present a barrier to entry. See Section IX of the Preamble for more discussion of barrier to entry analysis. The overall impacts from the effluent limitations guidelines on new source net pens is no more severe than those on existing net pens. The costs faced by new sources generally should be the same as or lower than those faced by existing sources. It is generally less expensive to incorporate pollution control equipment into the design at a new facility than it is to retrofit the same pollution control equipment in an existing facility.

Although EPA is not establishing standards of performance for new sources for small coldwater facilities (i.e., those producing between 20,000 and 100,000 pounds of aquatic animals per year), the facilities will be subject to existing NPDES regulations and permit limits developed using the permit writer's "best professional judgment" (BPJ). EPA, based on its analysis of existing data, determined that new facilities would produce 100,000 pounds of aquatic animals or more per year because of the expense of producing the aquatic animals. Generally, the species produced are considered of high value and are produced in such quantities to economically justify the production. For example, one net pen typically holds 100,000 pounds of aquatic animals or more. In reviewing U.S. Department of Agriculture's (USDA's) Census of Aquaculture and EPA's detailed surveys, EPA has not identified any existing commercial net pen facilities producing fewer than 100,000 pounds of aquatic animals per year.

Offshore aquatic animal production is an area of potential future growth. As these types of facilities start to produce aquatic animals, they should meet the new source requirements established for net pens as well as NPDES permitting.

**Table 2.2–2. Summary of Final Requirements for Flow-through and Recirculating Facilities**

| ***General Reporting Requirements*** | | ***Reference*** |
|---|---|---|
| **Drugs** | | 451.3(a) |
| 1) Reporting of intention to use INADs | • Provide the permitting authority with a written report, within 7 days of agreeing or signing up to participate in an INAD study<br>• Identify the INAD to be used, method of use, the dosage, and the disease or condition the INAD is intended to treat | 451.3(a)(1) |
| 2) Oral reporting of INAD and extralabel drug use | • Provide an oral report to the permitting authority as soon as possible, preferably in advance of application, but no later than 7 days after initiating use of the drug<br>• Identify drugs used, method of application, and the reason for adding that drug | 451.3(a)(2) |
| 3) Written reporting of INAD and extralabel drug use | • Provide a written report to the permitting authority within 30 days after initiating use of the drug<br>• Identify the drug used and include the reason for treatment, date(s) and times(s) of the addition (including duration), method of application, and the amount added | 451.3(a)(3) |
| **Structural Integrity** | | 451.3(b) |
| 1) Specification of reportable damage and/or material discharge | • The permitting authority may specify in the permit what constitutes reportable damage and/or material discharge of pollutants, based on consideration of production system type, sensitivity of the receiving waters, and other relevant factors | 451.3(b)(1) |
| 2) Oral reporting of structural failure or damage | • Provide an oral report within 24 hours of the discovery of any reportable failure or damage that results in a material discharge of pollutants<br>• Describe the cause of the failure or damage in the containment system<br>• Identify materials that have been released to the environment as a result of the failure | 451.3(b)(2) |
| 3) Written reporting of structural failure or damage | • Provide a written report within 7 days of discovery of the failure or damage<br>• Document the cause of the failure or damage<br>• Estimate the time elapsed until the failure or damage was repaired<br>• Estimate materials that have been released to the environment as a result of the failure or damage<br>• Describe steps being taken to prevent a reoccurrence | 451.3(b)(3) |
| **Spills** | | 451.3(c) |
| 1) Oral reporting of spills of drugs, pesticides, and feed | • Provide an oral report to the permitting authority within 24 hours of any spill of drugs, pesticides, and feed that results in a discharge to waters of the United States<br>• Identify the material spilled and quantity | 451.3(c) |
| 2) Written reporting of spills of drugs, pesticides, and feed | • Provide a written report to the permitting authority within 7 days of any spill of drugs, pesticides, and feed that results in a discharge to waters of the United States<br>• Identify the material spilled and quantity | 451.3(c) |

### Table 2.2–2. Summary of Final Requirements for Flow-through and Recirculating Facilities, Continued

| *Narrative Requirements* | | *Reference* |
|---|---|---|
| **Best Management Practices Plan** | | 451.3(d) |
| 1) Development and maintenance of a BMP plan on site that describes how the permittee will achieve the following five requirements: | | 451.3(d)(1)(i) |
| a) Solids control | • Employ efficient feed management and feeding strategies that limit feed input to the minimum amount reasonably necessary to achieve production goals and sustain targeted rates of aquatic animal growth in order to minimize potential discharges of uneaten feed and waste products to waters of the United States<br>• Identify and implement procedures for routine cleaning of rearing units and offline settling basins<br>• Identify procedures for inventorying, grading, and harvesting aquatic animals that minimize discharge of accumulated solids<br>• Remove and dispose of aquatic animal mortalities properly on a regular basis to prevent discharge to waters of the United States, except where authorized by the permitting authority in order to benefits the aquatic environment | 451.11(a) |
| b) Material storage | • Ensure proper storage of drugs, pesticides, and feed in a manner designed to prevent spills that may result in the discharge of drugs, pesticides, or feed to waters of the United States<br>• Implement procedures for properly containing, cleaning, and disposing of any spilled materials | 451.11(b) |
| c) Structural maintenance | • Routinely inspect production systems and wastewater treatment systems to identify and promptly repair damage<br>• Regularly conduct maintenance of production systems and wastewater treatment systems to ensure their proper function | 451.11(c) |
| d) Record-keeping | • Maintain records for aquatic animal rearing units documenting feed amounts and estimates of the numbers and weights of aquatic animals in order to calculate representative feed conversion ratios<br>• Keep records documenting frequency of cleaning, inspections, maintenance, and repairs | 451.11(d) |
| e) Training | • Train all relevant personnel in spill prevention and how to respond in the event of a spill to ensure proper clean-up and disposal of spilled materials<br>• Train personnel on proper operation and cleaning of production and wastewater treatment systems, including feeding procedures and proper use of equipment | 451.11(e) |
| 2) Make the plan available to the permitting authority upon request | | 451.3(d)(1)(ii) |
| 3) Certify that a BMP plan has been developed | | 451.3(d)(2) |

**Table 2.2–3. Summary of Final Requirements for Net Pen Facilities**

| ***General Reporting Requirements*** | | ***Reference*** |
|---|---|---|
| **Drugs** | | 451.3(a) |
| 1) Reporting of intention to use INADs | • Provide the permitting authority with a written report, within 7 days of agreeing or signing up to participate in an INAD study<br>• Identify the INAD to be used, method of use, the dosage, and the disease or condition the INAD is intended to treat | 451.3(a)(1) |
| 2) Oral reporting of INAD and extralabel drug use | • Provide an oral report to the permitting authority as soon as possible, preferably in advance of application, but no later than 7 days after initiating use of the drug<br>• Identify drugs used, method of application, and the reason for adding that drug | 451.3(a)(2) |
| 3) Written reporting of INAD and extralabel drug use | • Provide a written report to the permitting authority within 30 days after initiating use of the drug<br>• Identify the drug used and include the reason for treatment, date(s) and times(s) of the addition (including duration), method of application, and the amount added | 451.3(a)(3) |
| **Structural Integrity** | | 451.3(b) |
| 1) Specification of reportable damage and/or material discharge | • The permitting authority may specify in the permit what constitutes reportable damage and/or material discharge of pollutants, based on consideration of production system type, sensitivity of the receiving waters, and other relevant factors | 451.3(b)(1) |
| 2) Oral reporting of structural failure or damage | • Provide an oral report within 24 hours of the discovery of any reportable failure or damage that results in a material discharge of pollutants<br>• Describe the cause of the failure or damage in the containment system<br>• Identify materials that have been released to the environment as a result of the failure | 451.3(b)(2) |
| 3) Written reporting of structural failure or damage | • Provide a written report within 7 days of discovery of the failure or damage<br>• Document the cause of the failure or damage<br>• Estimate the time elapsed until the failure or damage was repaired<br>• Estimate materials that have been released to the environment as a result of the failure or damage<br>• Describe steps being taken to prevent a reoccurrence | 451.3(b)(3) |
| **Spills** | | 451.3(c) |
| 1) Oral reporting of spills of drugs, pesticides, and feed | • Provide an oral report to the permitting authority within 24 hours of any spill of drugs, pesticides, and feed that results in a discharge to waters of the United States<br>• Identify the material spilled and quantity | 451.3(c) |
| 2) Written reporting of spills of drugs, pesticides, and feed | • Provide a written report to the permitting authority within 7 days of any spill of drugs, pesticides, and feed that results in a discharge to waters of the United States<br>• Identify the material spilled and quantity | 451.3(c) |

## Table 2.2–3. Summary of Final Requirements for Net Pen Facilities, Continued

| *Narrative Requirements* | | *Reference* |
|---|---|---|
| **Best Management Practices Plan** | | 451.3(d) |
| 1) Develop and maintain a BMP plan on site that describes how the permittee will achieve the following seven requirements: | | 451.3(d)(1)(i) |
| a) Feed monitoring | • Employ efficient feed management and feeding strategies that limit feed input to the minimum amount reasonably necessary to achieve production goals and sustain targeted rates of aquatic animal growth<br>• Minimize accumulation of uneaten feed beneath the pens through active feed monitoring and management strategies approved by the permitting authority | 451.21(a) |
| b) Waste collection and disposal | • Collect, return to shore, and properly dispose of all feed bags, packaging materials, waste rope, and netting | 451.21(b) |
| c) Transport or harvest discharge | • Minimize any discharge associated with the transport or harvesting of aquatic animals (including blood, viscera, aquatic animal carcasses, or transport water containing blood) | 451.21(c) |
| d) Carcass removal | • Remove and dispose of aquatic animal mortalities properly on a regular basis to prevent their discharge into the waters of the United States | 451.21(d) |
| e) Materials storage | • Ensure proper storage of drugs, pesticides, and feed in a manner designed to prevent spills that may result in the discharge of drugs, pesticides, or feed into waters of the United States<br>• Implement procedures for properly containing, cleaning, and disposing of any spilled material | 451.21(e) |
| f) Structural maintenance | • Inspect production systems on a routine basis in order to identify and promptly repair any damage<br>• Conduct regular maintenance on the production system in order to ensure its proper function | 451.21(f) |
| g) Record-keeping | • Maintain records for aquatic animal net pens documenting the feed amounts and estimates of the numbers and weight of aquatic animals in order to calculate representative feed conversion ratios<br>• Keep records of net changes, inspections, and repairs | 451.21(g) |
| h) Training | • Train all relevant personnel in spill prevention and how to respond to spills to ensure proper clean-up and disposal of spilled materials<br>• Train staff on proper operation and cleaning of production system, including feeding procedures and equipment | 451.21(h) |
| 2) Make the plan available to the permitting authority upon request | | 451.3(d)(1)(ii) |
| 3) Certify that a BMP plan has been developed | | 451.3(d)(2) |

## 2.3 REFERENCES

Goodwin, J. 2004. *Conversation with Dennis Merrill, Maine Department of Environmental Protection*. U.S. Environmental Protection Agency, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2004. *Economic and Environmental Impact Analysis of the Final Effluent Limitations Guidelines and Standards for the Concentrated Aquatic Animal Production Industry Point Source Category*. EPA 821-R-04-013. U.S. Environmental Protection Agency, Washington, DC.

# CHAPTER 3
# DATA COLLECTION ACTIVITIES

## 3.1 SUMMARY OF DATA COLLECTION ACTIVITIES

EPA collected data from a variety of sources to characterize the aquatic animal production (AAP) industry. The main purpose of EPA's data collection efforts was to obtain information on documented environmental impacts of concentrated aquatic animal production (CAAP) facilities, as well as additional data on CAAP waste characteristics, pollution prevention practices, wastewater treatment technology innovation, and facility management practices. EPA also engaged in other data collection activities, which included literature searches; a review of the Agency's Permit Compliance System (PCS), Discharge Monitoring Reports (DMRs), and National Pollutant Discharge Elimination System (NPDES) permits; a survey of the AAP industry; EPA site visit and wastewater sampling program; and meetings with industry experts and the public.

### 3.1.1 Literature Searches

EPA evaluated the following online databases to locate technical data and information to support regulatory development: the Agency's PCS database, Aquatic Sciences and Fisheries Abstracts' database, U.S. Department of Agriculture's (USDA) aquaculture literature database AGRICOLA, and the 1998 USDA Census of Aquaculture (USDA, 2000). In addition, the Agency conducted a thorough collection and review of secondary sources, which included technical journal articles; data, reports, and analyses published by government agencies; reports and analyses published by the AAP industry and its associated organizations; and publicly available financial information compiled by both government agencies and private organizations.

EPA used the documents cited above to develop the industry profile and a survey sampling frame, and to stratify the survey sampling frame. In addition to these publications, EPA examined many other documents that provided useful overviews and analyses of the AAP industry. EPA also conducted general Internet searches on many different technical components of the AAP industry.

EPA conducted several literature searches to obtain environmental impact information on various aspects of the AAP industry, including pollutants causing environmental impacts, water quality and ecological impacts from these pollutants, non-native species impacts, and other potential impacts. EPA has included a summary of its environmental impact analysis in the public docket (USEPA, 2004). This analysis, which EPA summarized in case studies, includes primary sources such as technical journal articles, newspaper articles, and comments and information from industry experts and government contacts for AAP.

EPA also conducted separate literature searches for case studies that characterize the AAP industry, including the typical effluents associated with different production system types and species. The primary sources for these case studies were technical journal articles, and comments and information from industry experts and government contacts for AAP.

After proposal, EPA collected additional technical, scientific, and regulatory information from many sources on key issues about the CAAP industry. EPA performed targeted literature searches or other types of investigations to assess issues raised by stakeholders and commenters. These efforts included collecting additional information on net pens, chemicals (including therapeutants) used at CAAP facilities, non-native species, and water quality impacts.

### 3.1.2 Permitting Information

*Permit Compliance System*

EPA evaluated information from its PCS to identify CAAP industry point source dischargers with NPDES permits. EPA performed this initial analysis by searching the PCS, using the reported Standard Industrial Classification (SIC) codes used to describe the primary activities occurring at the site. Specifically, two SIC codes were used: 0273 (Animal Aquaculture) and 0921 (Fish Hatcheries and Preserves). Information obtained from this analysis is referred to in this document as the "PCS database."

EPA identified a total of 1,189 CAAP facilities in the PCS database. Based on the information in the database, an estimated 673 CAAP facilities have active NPDES permits. Some parameters found in the PCS data are parameters that the facility must report or monitor during use, but do not have established limits. Some parameters are monitored without set limits in order to enable the permitting authority to characterize the effluent and determine if continued monitoring is necessary. Other chemicals that appear in the PCS data have "report only" requirements where facilities report when they use specific chemicals or perform certain activities (such as cleaning tanks), which may only occur once or twice a year. Another group of parameters (such as flow, biomass, fish on hand, and fish food fed per day) are used by the permitting authority to characterize the volume of effluents and qualitative characteristics of the effluent and facility.

Table 3.1–1 provides a summary of parameters reported by CAAP facilities in the PCS database. Most facilities retrieved from the PCS are located in Florida, Idaho, Oregon, and Washington.

*Discharge Monitoring Reports*

EPA collected long-term effluent data from facility DMRs to supplement the PCS data in an effort to evaluate the achievability of requirements of the proposed rule. DMRs summarize the quality and volume of wastewater discharged from a facility under an NPDES permit. DMRs are critical for monitoring compliance with NPDES permit provisions and for generating national trends on Clean Water Act compliance. DMRs may be submitted monthly, quarterly, or annually depending on the requirements of the NPDES permit. EPA developed a DMR database by collecting information from numerous CAAP facility DMRs and combining the information into a database for analysis. That database is referred to in this document as the "DMR database."

**Table 3.1–1. Parameters in the PCS Database**

| *Parameter* |
|---|
| Ammonia |
| Backwash cycles |
| Biocides |
| Biochemical oxygen demand |
| Cadmium |
| Chemical oxygen demand |
| Chloramine |
| Chloride |
| Chlorophyll a |
| Coliform, fecal |
| Color |
| Conductivity |
| Copper |
| Diquat |
| Discharge event observation |
| Duration of discharge |
| *E. coli* |
| Fish food fed per day |
| Fish on hand |
| Floating solids or visible foam |
| Flow |
| Formalin (formaldehyde) |
| Hydrogen peroxide |
| Inorganic suspended solids |
| Lead |

| *Parameter* |
|---|
| Manganese |
| Nickel |
| Nitrogen[a] |
| Oil and grease |
| Outfall observation |
| Oxygen, dissolved |
| Ozone |
| pH |
| Phosphorus[a] |
| Potassium |
| Salinity |
| Silver |
| Sludge waste from secondary clarifiers |
| Solids, settleable |
| Solids, total dissolved |
| Solids, total suspended |
| Solids, volatile suspended |
| Stream flow |
| Temperature |
| Terramycin |
| Total production |
| Turbidity |
| Whole effluent toxicity |
| Zinc |

[a]Includes inorganic, organic, and total forms.

Indirect dischargers file compliance monitoring reports with their control authority (e.g., publicly owned treatment works (POTW)) at least twice per year as required under the General Pretreatment Standards (40 CFR Part 403). Direct dischargers file DMRs with their permitting authority at least once per year. EPA did not collect compliance monitoring reports for CAAP facilities that are indirect dischargers because (1) a vast majority of CAAP indirect dischargers discharge small volumes of wastewater and do not discharge toxic compounds, (2) this information is less centralized and more difficult to collect, and (3) many of these indirect dischargers would not be considered significant industrial users (SIUs), and might not be subject to Part 403 requirements.

EPA was able to identify facility characteristics and evaluate DMR information from 57 flow-through facilities and 2 recirculating facilities. EPA collected 38,096 data points on 126 separate parameters (including nitrogen, phosphorus, solids, flow, chemicals such as formalin and diquat, and copper). Some parameters found in the DMR data are parameters that the facility must report or monitor during use, but do not have established limits. Some parameters are monitored without set limits in order to enable the permitting authority to characterize the effluent and determine if continued monitoring is necessary. Other chemicals that appear in the DMR data have "report only" requirements where facilities report when they use specific chemicals, which may only occur once or twice a year. Another group of parameters (such as flow, biomass, fish on hand, and fish food fed per day) are used by the permitting authority to characterize the volume of effluents and qualitative characteristics of the effluent and facility.

Table 3.1–2 provides a summary of the parameters found in the DMR database. Most facilities in the database are located in Idaho, Michigan, New York, Virginia, and Wisconsin.

**Table 3.1–2. Parameters in the DMR Database**

| ***Parameter*** | ***Parameter*** |
|---|---|
| Aluminum | Lead |
| Ammonia | Manganese |
| Biochemical oxygen demand | Nitrogen[a] |
| Biomass | Oil and grease |
| BOD, carbonaceous | Outflow during cleaning |
| Cadmium | Oxidation/reduction potential |
| Calcium carbonate | Ozone |
| Chemical oxygen demand | pH |
| Chloramine-T | Phosphorus[a] |
| Chlorophyll a | Potassium permanganate |
| Chlorine | Roccal-II |
| Coliform, fecal | Settleable solids |
| Copper | Silver |
| Diquat | Sludge waste from secondary clarifiers |
| Dissolved oxygen | Solids, inorganic suspended |
| Duration of discharge | Solids, total dissolved |
| Fecal *Streptococcus* | Solids, total suspended |
| Fish food fed per day | Solids, volatile suspended |
| Fish on hand | Sulfate, total |
| Floating solids or visible foam-visual | Temperature |
| Flow | Terramycin |
| Formalin (formaldehyde) | Turbidity |
| Hydrogen peroxide | Zinc |
| Iron | |

[a]Includes inorganic, organic, and total forms.

*NPDES Permits*

EPA reviewed over 170 NPDES permits and permit applications, provided by the Agency's regional offices, to obtain information on facility type, production methods and systems, species produced, and effluent treatment practices. EPA used this information as part of its initial screening process. The Agency identified types of CAAP facilities, including pond systems, flow-through systems, recirculating systems, and net pen systems, that might be covered under the proposed regulation. In addition, EPA used information from existing NPDES permits to better define the scope of the information collection requests and to supplement other information (e.g., DMR and PCS data) collected on waste management practices in the industry. EPA compiled the information from these permits into a database, which is referred to in this document as the "NPDES database."

EPA collected NPDES permits from 174 CAAP facilities. The following summaries characterize different aspects of the CAAP facilities in the NPDES database by facility location, type of ownership, production system types, and species types. EPA evaluated 174 NPDES permits from 37 states. Table 3.1–3 lists the number of NPDES permits (in the NPDES database) in each state.

**Table 3.1–3. Number of Permitted Facilities by State**

| *State* | *No. of Permitted Facilities* |
|---|---|
| Alabama | 1 |
| Arizona | 1 |
| California | 6 |
| Colorado | 2 |
| Delaware | 1 |
| Hawaii | 1 |
| Iowa | 4 |
| Idaho | 3 |
| Illinois | 1 |
| Indiana | 1 |
| Kansas | 2 |
| Massachusetts | 9 |
| Maryland | 7 |
| Maine | 7 |
| Michigan | 12 |
| Minnesota | 4 |
| Missouri | 6 |
| Mississippi | 2 |
| North Carolina | 4 |
| North Dakota | 6 |

| ***State*** | ***No. of Permitted Facilities*** |
|---|---|
| Nebraska | 4 |
| New Hampshire | 8 |
| New Jersey | 1 |
| New York | 15 |
| Oregon | 1 |
| Rhode Island | 7 |
| South Carolina | 1 |
| South Dakota | 2 |
| Tennessee | 6 |
| Texas | 9 |
| Utah | 1 |
| Virginia | 13 |
| Vermont | 5 |
| Washington | 2 |
| Wisconsin | 2 |
| West Virginia | 5 |
| Wyoming | 12 |
| Total: 37 states | 174 |

EPA classified each facility by type of ownership (government, private, or other), often determining the type of ownership by the name of the facility. In the NPDES database, 117 of the 174 facilities are government facilities. Fifty-six CAAP facilities were privately owned and one was a tribal facility. Flow-through systems are the predominant system type in the NPDES database. EPA determined system type by searching for system descriptions in the permit, including diagrams showing specific facility components, and by analyzing information concerning outfalls. EPA determined the species type at each facility by finding specific mention of the species in the permit or attached documents. When the species type was unknown or different from the major species categories chosen (catfish, molluscs, perch, salmon, shrimp, striped bass, tilapia, or trout), EPA classified the species as “other.”

In addition, EPA categorized facilities with more than one species as “multiple.” Trout is the most common species represented in this database, with 63 facilities identified as producing this species. There are 42 facilities identified as producing multiple species, and 48 facilities identified as “other,” which is primarily game and sport fish.

*Summary of NPDES, PCS, and DMR Data*

EPA linked the data from the three databases. This provided the Agency with a description of the production systems and species at different facilities, as well as a characterization of the treatment systems at those facilities. This approach was useful for combining information from the databases to evaluate effluents from similar facilities. The linked data were used to evaluate permit limits for CAAP facilities.

### 3.1.3 Monitoring and Permit Data Analyzed Post-Proposal

To better evaluate the quality of current facility discharges compared to the proposed limits, EPA reviewed the detailed surveys to determine the number of facilities reporting NPDES permits. Of the 207 facilities that responded to the detailed survey, EPA found 125 facilities with existing NPDES permits. The facilities that responded to the detailed survey and have NPDES permits use these systems:

- 106 flow-through systems
- 13 pond systems
- 5 recirculating systems
- 1 other

EPA found that 82 of the 207 facilities that responded to the detailed survey did not report having NPDES permits:

- 37 flow-through system facilities
- 26 pond facilities
- 10 net pen facilities
- 9 recirculating system facilities

Many of these facilities are not subject to existing requirements for NPDES permits (i.e., ponds that discharge less than 30 days, warmwater facilities producing less than 100,000 pounds, and coldwater facilities producing less than 20,000 pounds).

To further assess facilities with NPDES permits, EPA asked the EPA regional offices for updated copies of permits, fact sheets, and DMR data for the 125 facilities that responded to the survey. EPA was able to get NPDES permits and monitoring data (DMR data from EPA regions or directly from the facility and PCS data) for 43 of the 125 facilities.

Once EPA had determined the scope of the rule, it found that of the 80 in-scope facilities 64 had NPDES permits and use these systems:

- 59 flow-through systems
- 5 recirculating systems

Sixteen of the 80 in-scope facilities did not have NPDES permits, including:

- 9 net pen facilities
- 5 flow-through facilities
- 2 recirculating facilities

EPA was primarily interested in reviewing information on the permit requirements and effluent monitoring data to better assess the baseline performance of facilities (i.e., current effluent treatment conditions) that are in-scope for the regulation. EPA also reviewed the NPDES permits for information about any required best management practices (BMPs) to compare with the BMPs required in the regulation. For those facilities that have BMP requirements in their current NPDES permit, EPA observed that the requirements were primarily related to developing overall facility BMP plans and to practices that addressed drugs and chemicals (Hochheimer and Meehan, 2004).

## 3.2 SUMMARY OF AQUATIC ANIMAL PRODUCTION QUESTIONNAIRE ACTIVITY

EPA determined that a survey of the industry was necessary because the existing primary and secondary sources of information available to the Agency did not contain the information necessary to thoroughly evaluate regulatory options. In particular, EPA needed facility/site-specific technical and economic information to evaluate the costs and benefits of regulation.

### 3.2.1 Background

EPA published a notice in the *Federal Register* on September 14, 2000 (65 FR 55522), announcing its intent to submit the Aquatic Animal Production Industry Survey Information Collection Request (ICR) to the Office of Management and Budget (OMB). The September 14, 2000, notice requested comment on the draft ICR and the survey questionnaires. EPA received 44 sets of comments during the 60-day public comment period. Commenters on the ICR included the National Oceanic and Atmospheric Administration, U.S. Trout Farmers Association, American Farm Bureau Federation, North Carolina State University, Louisiana Rice Growers Association, Michigan Department of Natural Resources, Mississippi Farm Bureau Federation, Idaho Farm Bureau Federation, and Freshwater Institute. EPA made significant revisions to the survey methodology and questionnaires as a result of these public comments. The survey was revised and divided into two survey phases. The first phase is the screener survey (short version), and the second phase is the detailed survey (the longer version). The two major reasons for the Agency's splitting the survey were (1) comments to the effect that the Agency would not know how much emphasis to place on rarely occurring facility types without a census and (2) the need to target specific types of CAAP facilities that could not be identified using information obtained from the databases available to the Agency at that time.

EPA published a second notice in the *Federal Register* on June 8, 2001 (66 FR 30902), announcing its intent to submit another Aquatic Animal Production Industry Survey ICR to OMB. The June 8, 2001, notice requested comment on the draft ICR and the detailed survey questionnaire. EPA received nine sets of comments during the 30-day public comment period. Commenters on the ICR included North Carolina Department of Agriculture and Consumer Services, Ohio Aquaculture Association, Catfish Farmers of America, National Aquaculture Association, National Association of State Aquaculture Coordinators, U.S. Trout Farmers Association, American Farm Bureau Federation, and Florida Department of Agriculture and Consumer Services.

EPA made every reasonable attempt to ensure that the AAP industry surveys did not request data and information currently available through existing sources of data. Before publishing the September 14, 2000, notice, EPA met with and distributed draft survey questionnaires to the Joint Subcommittee on Aquaculture, Aquaculture Effluents Task Force (JSA/AETF), which includes representatives from industry and trade associations, academia, and other interested stakeholders. After evaluating the comments received on the September 14, 2000, notice, EPA drafted a revised survey, and sent it to the JSA/AETF for review and comment. EPA worked with the JSA/AETF through conference calls and written comments to further refine the detailed survey. EPA also conducted two conference calls with the economic technical subgroup of JSA/AETF to discuss the economic and financial questions in the survey. To the extent possible, EPA incorporated comments and suggestions from these initial reviews into the survey. EPA obtained approval from OMB for the use and distribution of the screener survey on August 1, 2001 (66 FR 64817) and for the detailed survey on November 28, 2001 (67 FR 6519).

### 3.2.2 Screener Survey

#### *3.2.2.1 Description of the Screener Survey*

In August 2001 EPA mailed a short screener survey, entitled *Screener Questionnaire for the Aquatic Animal Production Industry,* to approximately 6,000 AAP facilities. A copy of the screener survey is included in the record (USEPA, 2001). The screener survey consisted of 11 questions that solicited general facility information, including confirmation that the facility was engaged in aquatic animal production, species and size category produced, type of production system, wastewater disposal method, and total production at the facility in the year 2000. EPA used the information collected through the screener survey to describe industry operations and wastewater disposal practices. EPA also used the responses to the facility production question to classify each facility as small or not-small according to the Small Business Administration regulations at 13 CFR Part 121. Ultimately, EPA used the responses to the screener survey to characterize the CAAP industry for development of the sample frame for the detailed survey.

#### *3.2.2.2 Development of Screener Survey Mailing List*

The mailing list (sample frame) for EPA's screener survey was developed by synthesizing facility information from the Dunn and Bradstreet database, EPA's PCS, contacts with EPA regional permit writers, EPA site visits, state aquaculture contacts, universities, recent issues of *Aquaculture Magazine*, assistance from the Bureau of Indian Affairs on tribal facilities, and an extensive collection of Web sites with aquaculture references. Additionally, EPA requested, but was denied, access to the facility identification data associated with the USDA's 1998 Census of Aquaculture (USDA, 2000). The mailing list EPA developed contained approximately 6,000 facilities. This number seemed to compare favorably with the roughly 5,000 facilities in the 1998 Census of Aquaculture. EPA believes that the sample frame was as current as possible, reasonably complete, and minimized duplication.

Because approximately 90% of the facilities identified in EPA's mailing list were not classified by species of aquatic animal in production, the available data were not considered to be sufficient for purposes of selecting recipients for the detailed questionnaire. Therefore, the primary purpose of the screener survey was to collect sufficient information for use in designing a detailed sample frame that would accurately characterize the CAAP industry.

#### *3.2.2.3 Response to the Screener Survey*

Approximately 6,000 facilities received the screener survey. At the time the detailed sample frame was developed, the total number of respondents was 3,273 and the number of respondents that actually produce aquatic animals was slightly over 1,700. The discrepancy between the number of surveys sent and the number of facilities reporting they are aquatic animal producers is largely attributable to the fact that the list was compiled from general industry sources and included not only producers but also processors, retailers, and the like, which are not considered to be part of the industry according to EPA's definition. The Agency believes that the facilities missed by its screener survey are likely to be small facilities that go into and out of business faster than can currently be tracked by sources outside USDA, which has confidentiality agreements that do not allow the Department to share its information with EPA.

#### *3.2.2.4 Summary of Data from the Screener Survey*

EPA used screener survey results as a basis for designing the detailed survey sample frame. The following summary of the results from the screener survey (Westat, 2002) is based on the 4,063 surveys that had been returned to EPA and analyzed as of July 2002. Appendix A provides a detailed summary of the screener survey information. Of these 4,063 surveys, 2,329 respondents indicated that they produce aquatic animals at their facility. Table 3.2–1 is a summary of facilities that produce aquatic animals by region, based on screener survey data.

**Table 3.2–1. Facilities Producing Aquatic Animals by Region[a]**

| *Region* | *Number of Facilities* | *Percentage of Facilities[b]* |
|---|---|---|
| Southern | 1,048 | 45% |
| Western | 513 | 22% |
| North Central | 382 | 16% |
| Northeastern | 333 | 14% |
| Tropical | 50 | 2% |
| Total | 2,326 | 100% |

[a] Regions are defined by categories from the USDA 1998 Census of Aquaculture (USDA, 2000).
[b] Percentages may not add to 100%, based on rounding.

States that are included within each of the USDA regions described above are summarized in Table 3.2–2.

**Table 3.2–2. States Within Each USDA Region**

| Region | States |
|---|---|
| Southern | Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, Washington, D.C. |
| Western | Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming |
| North Central | Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin |
| Northeastern | Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia |
| Tropical | Hawaii, Puerto Rico |

Data from the survey indicate that ownership type is described as sole proprietorship for approximately 41% of facilities producing aquatic animals. An additional 15% are described as Subchapter S Corporations and 13% are identified as C Corporations. Overall, close to 80% of all facilities are under private ownership. A total of 12% of the facilities were described as state hatcheries, and another 3% were federal hatcheries. Approximately 76% of all facilities produce only one species, and 16% produce two species. Catfish production dominates the AAP industry in the United States; 29% of respondents indicated that they produce catfish. Other species produced are trout (27%), other finfish (21%), salmon (9%), and molluscan shellfish (9%). Pond systems are the most common production system in use with 61% of the respondents indicating the use of ponds. Table 3.2–3 summarizes production system data based on responses to the screener survey.

**Table 3.2–3. Production Systems**

| System | Number of Facilities Using System[a] |
|---|---|
| Ponds | 1,414 |
| Flow-through raceways, ponds, or tanks | 1,040 |
| Recirculating systems | 466 |
| Net pens or cages | 195 |
| Floating or bottom aquaculture | 178 |
| Other | 118 |

[a]Note: Some respondents indicated using more than one system type; therefore, the number of systems in this data set is greater than the number of facilities that reported producing aquatic animals.

### 3.2.3 Detailed Survey

EPA designed the detailed survey to collect site-specific technical and financial information from a representative sample of CAAP facilities. The detailed survey was mailed to concentrated aquatic animal producers in June 2002. The data collected by the detailed survey were compiled and analyzed after the proposed rule was published. The data were made available for public comment in a Notice of Data Availability (NODA) that was published in the *Federal Register* on December 29, 2003 (68 FR 75068).

#### *3.2.3.1 Description of the Detailed Survey*

In June 2002, EPA mailed a detailed survey, entitled *Detailed Questionnaire for the Aquatic Animal Production Industry* to 252 AAP facilities selected from the screener respondents as described in the next section. A copy of the detailed survey is included in the record (USEPA, 2002a). The detailed survey is divided into three parts. The first two parts (Parts A and B) collect general facility, technical, and cost data. The third part (Part C) collects economic and financial information.

The first set of questions in Part A requests general facility site information, including facility contact information, facility size, and NPDES permit information. The general facility information questions also ask the site to identify and confirm that it is engaged in aquatic animal production. The second set of questions in Part A focuses on system descriptions and wastewater control technologies.

The wastewater control technology section is divided into six parts, one part for each type of production system (pond, flow-through, recirculating, net pens and cages, floating aquaculture and bottom culture, and other systems). The individual system sections have been tailored with specific questions and responses. Each of these sections asks the responder to describe (1) the system, (2) water use, (3) pollutant control practices, and (4) discharge characteristics.

Part B, the second part of the survey, asks the respondent for facility cost information. The cost information is intended to provide EPA with a complete description of all cost elements associated with the pollution control practices and technologies used at the facility. Separate tables show the details of capital and annual operating costs. The cost section also evaluates the current discharge monitoring practices, product losses, and feed information.

EPA used the information from Part B to calculate the effluent limitations guidelines and standards and pollutant loadings associated with the regulatory options that the Agency considered for final rulemaking. The Agency also used data received in response to these questions to identify treatment technologies in place; to determine the feasibility of regulatory options; and to estimate compliance costs, the pollutant reductions associated with the technology-based options, and potential environmental impacts associated with the regulatory options EPA considered for final rulemaking.

Part C, the third part of the detailed survey, elicits site-specific financial and economic data. EPA used this information to characterize the economic status of the industry and to estimate potential economic impacts of wastewater regulations. The financial and economic information collected in the survey was used to complete the economic analysis of the final effluent limitations guidelines and standards for the CAAP industry. EPA requested financial and economic information for the fiscal years ending 1999, 2000, and 2001—the most recent years for which data were available.

### *3.2.3.2 Sample Selection for the Detailed Survey*

EPA used the screener responses to select a stratified random sample to receive the detailed questionnaire. Sample criteria were designed primarily to capture facilities that produce aquatic animals and were likely to be covered by the proposed rule.

EPA also developed sample criteria to capture facilities that are out of scope (based on information in the screener survey) to validate its assumptions about the applicability of the proposed regulation. For example, the sample criteria include facilities with ponds, which are out of scope of the proposed regulation, to confirm that additional regulations for ponds are unnecessary in the final rule. Appendix A, page A11, of this document describes in detail the criteria and includes facilities that are in-scope and out of scope. The facilities selected met one of these criteria:

- Aquariums.
- Production includes alligators and total biomass exceeds 100,000 pounds.
- Production includes trout or salmon and total biomass exceeds 20,000 pounds.
- Predominant production method is ponds; predominant species is catfish; and total biomass exceeds 2,200,000 pounds.
- Predominant production method is ponds; predominant species is shrimp, tilapia, other finfish, or hybrid striped bass; and total biomass exceeds 360,000 pounds.
- Predominant production method is any method except ponds, and total biomass exceeds 100,000 pounds.

Applying these criteria to the screener survey responses resulted in 539 facilities that met these characteristics. EPA then classified the 539 facilities into 44 groups (strata) defined by facility type (commercial, government, research, or tribal), the predominant species, and predominant production method. A sample was drawn from the 539 facilities ensuring sufficient representation of facilities in each of the 44 groups. The sample drawn consisted of 263 facilities. From these 263 facilities EPA excluded 11 facilities that were duplicates on the mailing list or, after revising production estimates, did not meet the production thresholds for a CAAP facility. Detailed questionnaires were sent to 252 facilities.

### *3.2.3.3 Response to Detailed Survey*

EPA received timely responses from 215 of the 252 questionnaires. One facility provided late responses. A few completed questionnaires contained information on more than one facility. Subsequently, EPA separated that information into several questionnaires so that a single questionnaire represented an individual facility. These questionnaires with multiple facility data resulted in eight additional facilities contributing relevant data to the detailed survey. EPA excluded data from nine facilities that returned incomplete responses. For a variety of reasons predominantly due to misrepresentation in the screener survey data, these facilities would not have been subject to the proposed limitations; therefore, EPA did not pursue additional information. After separating multiple responses and excluding incomplete responses, information is available from 207 facilities. Table 3.2–4 provides a breakdown of this information.

**Table 3.2–4. Questionnaire Summary**

| ***Information Identifier*** | ***Number of Questionnaires*** |
|---|---|
| Sample frame | 263 |
| Mailed | 252 |
| Received | 216 |
| Incomplete and not followed-up | 9 |
| Received and useable | 207 |
| Received and useable plus separated | 215 |

### *3.2.3.4 Summary of Data from the Detailed Survey*

The following summary of the results from the detailed survey is based on the 215 useable surveys that have been returned to EPA and analyzed. Table 3.2–5 summarizes production system data based on responses to the detailed surveys.

**Table 3.2–5. Production Systems**

| ***Production System*** | ***Percentage of Facilities*** |
|---|---|
| Flow-through | 64 |
| Recirculating | 5 |
| Ponds | 11 |
| Net Pens | 4 |
| Other-Aquarium | 1 |
| Multiple production systems | 15 |

Table 3.2–6 summarizes the ownership type of facilities that responded to the detailed survey.

**Table 3.2–6. Ownership Type**

| ***Ownership Type*** | ***Percentage of Facilities*** |
|---|---|
| State governments | 36 |
| Federal facilities | 11 |
| Army Corps of Engineers | 1 |
| Academic facilities | 2 |
| Tribal facilities | 3 |
| Private non-profit | 1 |
| Private commercial | 46 |

Table 3.2–7 describes the type of species produced at facilities that responded to the detailed survey. Production of more than one species was reported by 19.5% of the detailed survey respondents.

**Table 3.2–7. Species Identified at Facility in Survey Sample**

| *Species** | *Percentage of Facilities* |
|---|---|
| Trout/salmon | 72 |
| Catfish | 8 |
| Tilapia | 4.5 |
| Other Finfish | 4.5 |
| Striped bass | 4 |
| Shrimp | 3 |
| Sturgeon | 1 |
| Red drum (i.e., “redfish,” “spot tail”) | 1 |
| Other (aquarium species) | 1 |
| Ornamentals | 0.5 |
| Baitfish | 0.5 |

* Based on predominant species; facility may produce more than one species.

Table 3.2–8 summaries how facilities that responded to the detailed survey are distributed geographically.

**Table 3.2–8. Geographical Distribution**

| *EPA Region* | *Percentage of Facilities* |
|---|---|
| 1 (CT, ME, MA, NH, RI, VT) | 10 |
| 2 (NJ, NY, PR, VI) | 1 |
| 3 (DE, DC, MD, PA, VA) | 6 |
| 4 (AL, FL, GA, KY, MS, NC SC, TN) | 14 |
| 5 (IL, IN, MI, OH, WI) | 11 |
| 6 (AR, LA, NM, OK, TX) | 10 |
| 7 (IA, KS, MO, NE) | 4 |
| 8 (CO, MT, ND, SD, UT, WY) | 9 |
| 9 (AZ, CA, HI, NV, AS, GU) | 13 |
| 10 (AK, ID, OR, WA) | 22 |

## 3.3 SUMMARY OF EPA’S SITE VISIT AND WASTEWATER SAMPLING PROGRAMS

### 3.3.1 Site Visits

During 2000 and 2001 EPA conducted site visits at 71 AAP facilities. Since the rule was proposed in 2002, EPA visited 17 additional sites, based, in part, on public comments regarding specific gaps in the information EPA considered at proposal. The objectives of these site visits were (1) to collect information on aquatic animal operations, (2) to collect information on wastewater generation and waste management practices used by the AAP facilities, and (3) to evaluate each facility as a candidate for multi-day sampling.

In selecting candidates for site visits, EPA attempted to identify facilities representative of various AAP operations, as well as both direct and indirect dischargers. EPA specifically considered the type of AAP operation (production method and species produced), geographic region, age of the facility, size of facility (in terms of production), wastewater treatment processes employed, and best management practices (BMPs) and pollution prevention techniques used. EPA also solicited recommendations for facilities that perform well (e.g., facilities with advanced wastewater treatment technologies) from EPA regional offices, state agencies, and the JSA/AETF. The site-specific selection criteria are discussed in site visit reports prepared for the sites visited by EPA and are summarized in this document. The sites visited reflect a cross section of the industry that is fairly complete and proportionally representative of the AAP industry as a whole. EPA recognizes that a number of AAP facilities visited during the site visits are not CAAP facilities and would not be regulated under proposed rules. However, EPA was interested in collecting information from a wider range of AAP facilities than just CAAP facilities to evaluate the diversity of the AAP industry and to determine which segments should be included in proposed regulations.

To address public comments about the lack of representation of warmwater and green water systems at proposal, EPA visited two facilities that use warmwater culture systems and four facilities that use green water systems. To address public comments about the effectiveness of microscreen treatment, especially in cold temperatures, EPA visited four facilities reporting the use of microscreen technology to treat wastewater. These four facilities were chosen from a population of 13 facilities that reported in their responses to the detailed survey that they used microscreen technology as a primary or secondary solids removal treatment system. During the visits to these four facilities, EPA observed microscreens being used to remove solids from effluent streams. EPA also evaluated how these facilities incorporated microscreens into the daily operation and maintenance activities.

Other facilities that EPA visited after proposal included several state and federal hatcheries in California, Washington, Idaho, Pennsylvania, and Utah. EPA looked at the differences in mission, operation, and management of government facilities compared to commercial facilities.

During each site visit EPA collected information on the facility and its operations, including (1) general production data and information, (2) the types of AAP wastewaters generated and treated on-site, (3) water source and use, and (4) wastewater treatment and disposal operations.

EPA used the site visit reports to prepare sampling and analysis plans for each facility that would undergo multi-day sampling. For those facilities selected for sampling episodes, EPA also collected information on potential sampling locations for wastewater (raw influent, within the treatment system, and final effluent), as well as other information necessary for developing a sampling plan for possible multi-day sampling episodes. The purpose of the multi-day sampling was to characterize pollutants in raw wastewaters prior to treatment as well as to document wastewater treatment performance (including selected unit processes).

### *3.3.1.1 Site Visit Summary*

Tables 3.3–1 and 3.3–2 summarize the different types of systems and species at the facilities that EPA visited to develop effluent guidelines for the CAAP industry.

**Table 3.3–1. Summary of System Type Visited by EPA for the Development of Aquatic Animal Production Effluent Limitations Guidelines**

| *System* | *Number of Sites* |
|---|---|
| Pond | 34 |
| Flow-through | 34 |
| Net pen | 5 |
| Recirculating | 13 |
| Shellfish—bottom and off-bottom culture | 5 |
| Other | 2 |
| Total | 93 |

**Table 3.3–2. Summary of Species Visited by EPA for the Development of Aquatic Animal Production Effluent Limitations Guidelines**

| *Species* | *Number of Sites* | *Species* | *Number of Sites* |
|---|---|---|---|
| Catfish | 12 | Alligator | 2 |
| Trout | 20 | Yellow perch | 2 |
| Striped and hybrid striped bass | 5 | Soft-shell crab shedding | 1 |
| Tilapia | 8 | Salmon | 15 |
| Ornamental | 9 | Lobster | 1 |
| Crawfish | 5 | Chinese catfish | 1 |
| Molluscs | 5 | Mullet | 1 |
| Shrimp | 7 | Milkfish | 1 |
| Red snapper | 1 | Marine | 1 |

Table 3.3–3 describes the regional distribution of sites visited by EPA.

**Table 3.3–3. Regional Distribution of Sites Visited**

| *USDA Aquaculture Center Regions* | *Number of Sites Visited* |
|---|---|
| Northeastern | 18 |
| North Central | 6 |
| Southern | 37 |
| Western | 20 |
| Tropical | 6 |

Table 3.3–4 summarizes all of the sites visited, describing the geographic area, production systems used, and treatment technologies employed at the different facilities.

## Table 3.3–4. Aquatic Animal Production Site Visit Summary

| *Date of Visit* | *City* | *State* | *Species* | *Production System* | *Reference* |
|---|---|---|---|---|---|
| 1/31/00 | Stoneville | MS | Catfish | Ponds | Tetra Tech, 2002ff |
| 1/31/00 | Indianola | MS | Catfish | Ponds | Tetra Tech, 2002o |
| 1/31/00 | Itta Bena | MS | Catfish | Ponds | Tetra Tech, 2002d |
| 2/1/00 | Robert | LA | Tilapia | Recirculating system | Tetra Tech, 2002rr |
| 2/1/00 | Denham Springs | LA | Alligators | Other—alligator huts | Tetra Tech, 2002c |
| 2/2/00 | Jeanerette | LA | Hybrid striped bass | Ponds | Tetra Tech, 2002uu |
| 2/2/00 | New Ibernia | LA | Crawfish | Ponds | Tetra Tech, 2002p |
| 2/2/00 | New Ibernia | LA | Crawfish | Ponds | USEPA, 2002e |
| 2/2/00 | Abbeville | LA | Crawfish | Ponds | USEPA, 2002d |
| 3/30/00 | Richland | PA | Trout | Flow-through | Tetra Tech, 2002g |
| 3/30/00 | Richland | PA | Trout | Flow-through | Tetra Tech, 2002bb |
| 4/11/00 | Brevard | NC | Trout | Flow-through | Tetra Tech, 2002k |
| 4/11/00 | Sapphire | NC | Trout | Flow-through | Tetra Tech, 2002pp |
| 4/12/00 | Raleigh | NC | Tilapia | Recirculating system | Tetra Tech, 2002gg |
| 4/12/00 | Plymouth | NC | Hybrid striped bass, crawfish | Ponds | Tetra Tech, 2002hh |
| 4/12/00 | Plymouth | NC | Crawfish | Ponds | Tetra Tech, 2002cc |
| 4/13/00 | Hertford | NC | Yellow perch, crab shedding, catfish | Ponds, tanks | Tetra Tech, 2002i |
| 7/10/00 | Buhl | ID | Trout | Flow-through | Tetra Tech, 2002l |
| 7/10/00 | Buhl | ID | Trout | Flow-through | USEPA, 2002c |
| 7/11/00 | Twin Falls | ID | Trout | Flow-through | Tetra Tech, 2002kk |
| 7/11/00 | Twin Falls | ID | Trout | Flow-through | |
| 7/11/00 | Twin Falls | ID | Trout | Ponds, flow-through | Tetra Tech, 2002j |
| 7/12/00 | Seattle | WA | Salmon | Net pens | Tetra Tech, 2002mm |
| 7/12/00 | Puget Sound | WA | Salmon | Net pens | |
| 7/12/00 | Bainbridge | WA | Salmon | Net pens | |
| 7/14/00 | Bow | WA | Molluscan shellfish—oysters | Flow-through, bottom culture | Tetra Tech, 2002qq |
| 7/23/00 | Blacksburg | VA | Tilapia, hybrid striped bass, yellow perch | Recirculating system | Tetra Tech, 2002tt |
| 11/27/00 | Turners Falls | MA | Hybrid striped bass | Recirculating system | Tetra Tech, 2002s |
| 11/28/00 | Mt. Desert | ME | Salmon, mussels | Net pens, off-bottom hanging culture (mussels) | Tetra Tech, 2002a |
| 11/29/00 | Birch Harbor | ME | Lobster | Other - pounds | Tetra Tech, 2002n |
| 11/30/00 | Eastport | ME | Salmon | Net pens | Tetra Tech, 2002y |
| 1/2/01 | Honolulu | HI | Ornamentals, seaweed | Flow-through | |

| Date of Visit | City | State | Species | Production System | Reference |
|---|---|---|---|---|---|
| 1/2/01 | Honolulu | HI | Tilapia, Chinese catfish | Net pen in pond | |
| 1/2/01 | Honolulu | HI | Ornamentals | Flow-through | |
| 1/2/01 | Honolulu | HI | Shrimp | Flow-through | |
| 1/8/01 | Honolulu | HI | Shrimp, ornamentals, mullett, milkfish, red snapper | Flow-through | |
| 1/10/01 | Kauai | HI | Shrimp | Flow-through | |
| 1/25/01 | Lakeland | FL | Ornamentals | Ponds | Tetra Tech, 2002z |
| 1/25/01 | Gibsonton | FL | Ornamentals | Ponds | Tetra Tech, 2002q |
| 1/25/01 | Ruskin | FL | Ornamentals | Ponds, recirculating systems | Tetra Tech, 2002ii |
| 1/25/01 | Ruskin | FL | Ornamentals | Ponds | Tetra Tech, 2002ss |
| 1/26/01 | Homestead | FL | Ornamentals | Flow-through tanks, low flow rate | Tetra Tech, 2002e |
| 1/26/01 | Miami | FL | Ornamentals | Recirculating, flow-through tanks w/ low flow rate | Tetra Tech, 2002aa |
| 3/15/01 | Greensboro | AL | Catfish | Ponds | Tetra Tech, 2002b |
| 3/16/01 | Gallion | AL | Catfish | Ponds | Tetra Tech, 2002b |
| 3/17/01 | Greensboro | AL | Catfish | Ponds | Tetra Tech, 2002b |
| 3/18/01 | Greensboro | AL | Catfish | Ponds | Tetra Tech, 2002b |
| 3/19/01 | Greensboro | AL | Catfish | Ponds | Tetra Tech, 2002b |
| 3/20/01 | Greensboro | AL | Catfish | Ponds | Tetra Tech, 2002b |
| 4/05/01 | East Orland | ME | Salmon—native endangered species | Flow-through | Tetra Tech, 2002m |
| 4/05/01 | Ellsworth | ME | Salmon—native endangered species | Flow-through | Tetra Tech, 2002u |
| 4/06/01 | Solon | ME | Salmon | Flow-through | Tetra Tech, 2002h |
| 4/06/01 | North Anson | ME | Brook trout, landlocked salmon (coho, chinook) | Flow-through | Tetra Tech, 2002r |
| 4/06/01 | Augusta | ME | Brook trout, lake trout, splake | Flow-through | Tetra Tech, 2002r |
| 7/16/01 | Harrietta | MI | Rainbow trout, brown trout | Flow-through | Tetra Tech, 2002w |
| 7/16/01 | Beulah | MI | Landlocked salmon | Flow-through | Tetra Tech, 2002ll |
| 7/17/01 | Palmyra | WI | Rainbow trout | Flow-through, earthen raceways | Tetra Tech, 2002mm |
| 7/17/01 | Dodgeville | WI | Baitfish, various species of sport fish | Ponds | Tetra Tech, 2002t |

| ***Date of Visit*** | ***City*** | ***State*** | ***Species*** | ***Production System*** | ***Reference*** |
|---|---|---|---|---|---|
| 7/18/01 | Osage Beach | MO | Various warmwater species (including bluegill, catfish, paddlefish) | Ponds | Tetra Tech, 2002jj |
| 7/19/01 | Renville | MN | Tilapia | Recirculating system | Tetra Tech, 2002dd |
| 7/30/01 | Los Fresnos | TX | Shrimp | Ponds | Tetra Tech, 2002v |
| 7/31/01 | San Benito | TX | Shrimp | Ponds | Tetra Tech, 2002v |
| 7/31/01 | San Perlita | TX | Shrimp | Ponds | Tetra Tech, 2002v |
| 7/31/01 | Rio Hondo | TX | Shrimp | Ponds | Tetra Tech, 2002oo |
| 8/01/01 | Lonoke | AR | Baitfish | Ponds | Tetra Tech, 2002f |
| 8/01/01 | Lonoke | AR | Baitfish | Ponds | Tetra Tech, 2002f |
| 8/01/01 | Lonoke | AR | Baitfish | Ponds | Tetra Tech, 2002f |
| 8/01/01 | Cabot | AR | Baitfish | Ponds | Tetra Tech, 2002f |
| 8/01/01 | Hazon | AR | Baitfish | Ponds | Tetra Tech, 2002f |
| 8/02/01 | DeValls Bluff | AR | Baitfish | Ponds | Tetra Tech, 2002x |
| 12/11/01 | Baltimore | MD | Multiple | Recirculating | Tetra Tech, 2002ee |
| 11/07/02 | Anderson | CA | Salmon, steelhead | Flow-through | Tetra Tech, 2004d |
| 11/07/02 | Manton | CA | Trout | Flow-through | Tetra Tech, 2004d |
| 11/07/02 | Paynes Creek | CA | Trout | Flow-through | Tetra Tech, 2004d |
| 11/08/02 | Rancho Cordova | CA | Trout, salmon, steelhead | Flow-through | Tetra Tech, 2004d |
| 12/17/02 | Oquossoc | ME | Salmon | Flow-through | Tetra Tech, 2003d |
| 12/18/02 | Grand Isle | VT | Trout | Flow-through | Tetra Tech, 2003f |
| 12/18/02 | Newington | NH | Marine species | Recirculating | Tetra Tech, 2003i |
| 2/10/03 | Carlisle | PA | Trout | Flow-through | Tetra Tech, 2004b |
| 2/11/03 | Groton | NY | Tilapia | Recirculating | Tetra Tech, 2003g |
| 2/12/03 | Amherst | MA | Tilapia | Recirculating | Tetra Tech, 2003e |
| 2/24/03 | Buhl | ID | Catfish, tilapia, alligators | Flow-through | Tetra Tech, 2003h |
| 2/24/03 | Bruneau | ID | Tilapia | Flow-through, recirculating | Tetra Tech, 2003c |
| 2/25/03 | Ahsahka | ID | Salmon/trout | Flow-through, recirculating | Tetra Tech, 2004a |
| 2/26/03 | Underwood | WA | Salmon | Flow-through, recirculating | Tetra Tech, 2004c |
| 2/27/03 | Kamas | UT | Trout | Flow-through | Tetra Tech, 2003j |
| 3/27/03 | York Haven | PA | Hybrid striped bass | Flow-through | Tetra Tech, 2003k |

Note: “QZ” means quiescent zone; “OLSB” means offline settling basin.

#### *3.3.1.2 Summary of Sites Visits to Facilities with Microscreens*

To observe the operation of the microscreen, EPA made site visits to a total of five facilities (three with recirculating systems and two with flow-through systems) that use microscreens. EPA visited facilities in areas that experience freezing temperatures in winter and concluded that operating a microscreen filter year round is possible because the facilities demonstrated satisfactory performance. However, unlike the assumptions for the proposal, these facilities operate the microscreen filters in indoor spaces that are protected from freezing. Their microscreens are installed in existing heated spaces or, in one case, in a recently-constructed building that houses other effluent treatment system components. The facilities using microscreens were satisfied with their performance and at least one was planning renovations that included additional microscreens (Tetra Tech, 2003d; Tetra Tech, 2003e; Tetra Tech, 2003g; Tetra Tech, 2003i; Tetra Tech, 2003j).

### 3.3.2 Wastewater Sampling

Based on data collected from the site visits, EPA selected three facilities (two flow-through systems, sampling episodes 6297 and 6460, and one recirculating system, sampling episode 6439) for multi-day sampling. Selection of the facilities was based on an analysis of information collected during the site visits, as well as the following criteria: (1) the facility performed operations representative of CAAP facilities, (2) and the facility used in-process and/or end-of-pipe treatment practices that EPA was considering for technology option selection.

EPA selected one facility for post-proposal wastewater sampling. The selected facility was a state hatchery in Pennsylvania producing coldwater species (trout for stocking enhancement) using flow-through system technology (sampling episode 6495). EPA considered this facility a good candidate for sampling because it used wastewater treatment similar to the treatment systems on which EPA based the proposed limitations. Those systems rely on primary settling of solids generated during cleaning of quiescent zones in an offline settling basin, and secondary settling of the primary effluent, and full or bulk flow from the raceways. Primary settling generally involves physical separation of particles through either quiescent zones and offline settling or a full-flow basin. Secondary settling is sequential solids removal after primary by using a second settling basin (i.e., polishing pond) or a technology unit such as a microscreen. EPA considers this facility to be representative of a well-operated facility with effective wastewater treatment. EPA sampled wastewater for five days at this facility during a time of year when the facility approached a maximum stocking density. For more information, refer to the sampling episode report for this facility (Tetra Tech, 2003b).

The Agency collected the following types of information during each sampling episode: (1) dates and times of sample collection; (2) flow data corresponding to each sample; (3) production data corresponding to each sample; (4) design and operating parameters for source reduction, recycling, and treatment; (5) technologies characterized during sampling; (6) information about site operations that had changed since the site visit or had not been included in the site visit report; and (7) the temperature, pH, and dissolved oxygen of the sampled waste streams.

Data collected from the sampling episodes contributed to characterization of the industry, development of the list of pollutants of concern, and development of raw wastewater characteristics. EPA used the data collected from the influent, intermediate, and effluent points to analyze the efficacy of treatment at the facilities and to develop current discharge concentrations, loadings, and the treatment technology options for the CAAP industry. During each sampling episode, EPA also collected flow rate data corresponding to each sample collected and production information from each associated production system for use in calculating pollutant loadings and production-normalized flow rates. EPA has included in the public record all information collected for which the facility has not asserted a claim of Confidential Business Information (CBI) or which would indirectly reveal information claimed to be CBI.

After the conclusion of the sampling episodes, EPA prepared sampling episode reports for each facility, which included descriptions of the wastewater treatment processes, sampling procedures, and analytical results. EPA documented all data collected during sampling episodes in the sampling episode report for each sampled site; the reports are in the AAP Administrative Record. Nonconfidential business information from these reports is available in the public record for this proposal. For detailed information on sampling and preservation procedures, analytical methods, and quality assurance/quality control procedures, refer to the quality assurance project plan (Tetra Tech, 2000a) and sampling and analysis plans (Tetra Tech, 2000b; Tetra Tech 2001a; Tetra Tech 2001b; Tetra Tech, 2003a) completed for the sampling visits.

#### *3.3.2.1 Pollutants Sampled*

During each multi-day sampling episode, facility influent and effluent waste streams were sampled. Samples were also collected at intermediate points throughout the wastewater treatment system to assess the performance of individual treatment units. Sampling episodes were conducted over a 12-hour or 24-hour period, depending on the production system being analyzed. Samples were obtained using a combination of composite and grab samples. EPA had the samples analyzed for a variety of conventional compounds (5-day biochemical oxygen demand, total suspended solids, oil and grease, and pH), nonconventional compounds (nutrients, microbiological contaminants, drugs, and chemicals), and toxic compounds (metals and organics). When possible for a given parameter, EPA collected 24-hour composite samples to capture the variability in the waste streams generated throughout the day (e.g., production wastewater during feeding and non-feeding periods).

Table 3.3–5 lists the compounds for which EPA sampled at the four sites. Tables 3.3-6, 3.3-7, and 3.3-8 summarize the metal, volatile organic, and semivolatile organic analytes sampled at all four visited sites.

**Table 3.3–5. Sampling Analytes**

| ***Compounds*** | ***Sampling Episode*** | | | |
|---|---|---|---|---|
| | ***6297*** | ***6439*** | ***6460*** | ***6495*** |
| Settleable solids | ✓ | ✓ | ✓ | ✓ |
| pH | ✓ | ✓ | ✓ | ✓ |
| Biochemical oxygen demand (BOD) | ✓ | ✓ | ✓ | ✓ |
| Total suspended solids (TSS) | ✓ | ✓ | ✓ | ✓ |
| Chloride | ✓ | ✓ | ✓ | |
| Total dissolved solids (TDS) | ✓ | ✓ | ✓ | ✓ |
| Total volatile solids | ✓ | ✓ | ✓ | |
| Total phosphorus | ✓ | ✓ | ✓ | ✓ |
| Dissolved phosphorus | ✓ | ✓ | ✓ | ✓ |
| Orthophosphate | ✓ | ✓ | ✓ | ✓ |
| Ammonia as nitrogen | ✓ | ✓ | ✓ | ✓ |
| Total Kjeldahl nitrogen (TKN) | ✓ | ✓ | ✓ | ✓ |
| Nitrate/nitrite | ✓ | ✓ | ✓ | ✓ |
| Chemical oxygen demand (COD) | ✓ | ✓ | ✓ | |
| Total organic carbon (TOC) | ✓ | ✓ | ✓ | ✓ |
| Oil and grease (n-hexane extractable material) | ✓ | ✓ | ✓ | ✓ |
| Sulfate | ✓ | ✓ | ✓ | |
| Metals | ✓ | ✓ | ✓ | ✓ |
| Volatile organics | ✓ | ✓ | ✓ | ✓ |
| Semivolatile organics | ✓ | ✓ | ✓ | ✓ |
| Oxytetracycline | ✓ | | | |
| Total coliforms | | ✓ | ✓ | ✓ |
| Fecal coliform | | ✓ | ✓ | |
| Fecal *Streptococcus* | | ✓ | ✓ | ✓ |
| *Aeromonas* | | ✓ | ✓ | ✓ |
| *Mycobacterium marinum* | | ✓ | ✓ | |
| *Escherichia coli* | | ✓ | ✓ | |
| *Enterococcus faecium* | | ✓ | ✓ | |
| Toxicity: Fathead minnow, *Pimephales promelas* | ✓ | ✓ | | |
| Toxicity: Cladoceran, *Ceriodaphnia dubia* | ✓ | ✓ | | |
| Toxicity: Green alga, *Selenastrum capricornutum* | ✓ | ✓ | | |

Note: A checkmark (✓) means that the listed pollutant was sampled for at that site.

## Table 3.3–6. Metal Analytes

| ***Metal Analytes*** | | |
|---|---|---|
| Aluminum | Cobalt | Selenium |
| Antimony | Copper | Thallium |
| Arsenic | Iron | Silver |
| Barium | Lead | Sodium |
| Beryllium | Magnesium | Tin |
| Boron | Manganese | Titanium |
| Cadmium | Mercury | Vanadium |
| Calcium | Molybdenum | Yttrium |
| Chromium | Nickel | Zinc |

## Table 3.3–7. Volatile Organic Analytes

| ***Volatile Organic Analytes*** | | |
|---|---|---|
| Acetone | Dibromochloromethane | Isobutyl alcohol |
| Acrolein | 1,2-Dibromoethane | Methacrylonitrile |
| Acrylonitrile | Dibromomethane | Methylene chloride |
| Allyl alcohol | trans-1,4-Dichloro-2-Butene | Methyl ethyl ketone |
| Benzene | 1,1-Dichloroethane | Methyl methacrylate |
| Bromodichloromethane | 1,2-Dichloroethane | 4-Methyl-2-Pentanone |
| Bromoform | 1,1-Dichloroethene | 1,1,1,2-Tetrachloroethane |
| Bromomethane | trans-1,2-Dichlorethene | 1,1,2,2-Tetrachloroethane |
| Carbon disulfide | 1,2-Dichloropropane | Tetrachloroethane |
| Carbon tetrachloride | 1,3-Dichloropropane | Toluene |
| Chloroacetonitrile | cis-1,3-Dichloropropene | 1,1,1-Trichloroethane |
| Chlorobenzene | trans-1,3-Dichloropropene | 1,1,2-Trichloroethane |
| 2-Chloro-1,3-Butadiene (chloroprene) | Diethyl ether | Trichloroethene |
| Chloroethane | *p*-Dioxane | Trichlorofluoromethane |
| 2-Chloroethylvinyl ether | Ethylbenzene | 1,2,3-Trichloropropane |
| Chloroform | Ethyl cyanide | Vinyl acetate |
| Chloromethane | Ethyl methacrylate | Vinyl chloride |
| 3-Chloropropene | 2-Hexanone | *m*-Xylene |
| Crotonaldehyde | Iodomethane | *o*- and *p*-Xylene |

## Table 3.3–8. Semivolatile Organic Analytes

| *Semivolatile Organic Analytes* | | |
|---|---|---|
| Acenaphthene | 7, 12-Dimethylbenz(a)anthracene | 2-Nitrophenol |
| Acenaphthylene | 3,6-Dimethylphenanthrene | 4-Nitrophenol |
| Acetophenone | 2,4-Dimethylphenol | 2-Nitroaniline |
| Alpha-terpineol | Di-n-butyl phthalate | 3-Nitroaniline |
| 4-Aminobiphenyl | 1,4’-Dinitrobenzene | Nitrobenzene |
| Aniline | 2,4-Dinitrophenol | 5-Nitro-o-toluidine |
| Aniline, 2,4,5-trimethyl- | 2,4-Dinitrotoluene | N,N-Dimethylformamide |
| Anthracene | 2,6-Dinitrotoluene | N-Nitrosodiethylamine |
| Aramite | Di-n-octyl phthalate | N-Nitrosodimethylamine |
| Benzanthrone | Di-n-propylnitrosamine | N-Nitrosodi-n-butylamine |
| Benzenethiol | Diphenyl ether | N-Nitrosodiphenylamine |
| Benzidine | Diphenylamine | N-Nitrosomethyl-ethylamine |
| Benzo(a)anthracene | Diphenyldisulfide | N-Nitrosomethyl-phenylamine |
| Benzo(a)pyrene | 1,2-Diphenylhydrazine | N-Nitrosomorpholine |
| Benzo(b)fluoranthene | 2,6-Di-tert-butyl-p-benzoquinone | N-Nitrosopiperidine |
| Benzo(g,h,i)perylene | Ethane, pentachloro- | o-Anisidine |
| Benzo(k)fluoranthene | Ethyl methanesulfonate | o-Cresol |
| 2,3-Benzofluorene | Ethylenethiourea | o-Toluidine |
| Benzoic acid | Fluoranthene | o-Toluidine, 5-Chloro |
| Benzonitrile, 3, 5-Dibromo-4-Hydroxy- | Fluorene | p-Chloroaniline |
| Benzyl alcohol | Hexachlorobenzene | p-Cresol |
| Beta-Naphthylamine | Hexachlorobutadiene | p-Cymene |
| Biphenyl | Hexachlorocyclopentadiene | p-Dimethylamino-azobenzene |
| Bis(2-chloroethoxy)methane | Hexachloroethane | Pentachlorobenzene |
| Bis(2-chloroethyl)ether | Hexachloropropene | Pentachlorophenol |
| Bis(2-chloroisopropyl)ether | Hexanoic acid | Pentamethylbenzene |
| Bis(2-ethylhexyl)phthalate | Indeno(1,2,3-cd)pyrene | Perylene |
| 1-Bromo-2-Chlorobenzene | Isophorone | Phenacetin |
| 1-Bromo-3-Chlorobenzene | 2-Isopropylnaphthalene | Phenanthrene |
| 4-Bromophenyl, phenyl ether | Isosafrole | Phenol |
| Butyl benzyl phthalate | Longifolene | Phenol, 2-methyl-4,6-Dinitro |
| Carbazole | Malachite green | Phenothiazine |
| 4-Chloro-3-Methylphenol | Mestranol | 1-Phenylnaphthalene |
| 4-Chloro-2-Nitroaniline | Methapyrilene | 2-Phenylnaphthalene |
| 1-Chloro-3-Nitrobenzene | Methyl methanesulfonate | 2-Picoline |
| 2-Chloronaphthalene | 2-Methylbenzothioazole | P-Nitroaniline |
| 2-Chlorophenol | 3-Methylcholanthrene | Pronamide |

| *Semivolatile Organic Analytes* | | |
|---|---|---|
| 4-Chlorophenyl phenyl ether | 4,5-Methylene-phenanthrene | Pyrene |
| Chrysene | 4,4-Methylene-bis(2-Chloroaniline) | Pyridine |
| Crotoxyphos | 1-Methylfluorene | Resorcinol |
| Dibenzo(a,h)anthracene | 2-Methylnaphthalene | Safrole |
| Dibenzofuran | 1-Methylphenanthrene | Squalene |
| Dibenzothiophene | 2-(Methylthio)-benzothiazole | Styrene |
| 1,2-Dibromo-3-Chloropropane | Naphthalene | 1,2,4,5-Tetra-chlorobenzene |
| 1,3-Dichloro-2-Propanol | 1,5-Naphthalenediamine | 2,3,4,6-Tetrachlorophenol |
| 2,6-Dichloro-4-Nitroaniline | 1,4-Naphthoquinone | Thianaphthene |
| 2,3-Dichloroaniline | 1-Naphthylamine | Thioacetamide |
| 1,2-Dichlorobenzene | n-C10 (n-decane) | Thioxanthe-9-one |
| 1,3-Dichlorobenzene | n-C12 (n-dodecane) | Toluene, 2,4-Diamino- |
| 1,4-Dichlorobenzene | n-C14 (n-tetradecane) | 1,2,3-Trichlorobenzene |
| 3,3'-Dichlorobenzidine | n-C16 (n-hexadecane) | 1,2,4-Trichlorobenzene |
| 2,3-Dichloronitro-benzene | n-C18 (n-octadecane) | 2,3,6-Trichlorophenol |
| 2,4-Dichlorophenol | n-C20 (n-eicosane) | 2,4,5-Trichlorophenol |
| 2,6-Dichlorophenol | n-C22 (n-docosane) | 2,4,6-Trichlorophenol |
| 1,2:3,4-Diepoxybutane | n-C24 (n-tetracosane) | 1,2,3-Trimethoxybenzene |
| Diethyl phthalate | n-C26 (n-hexacosane) | Triphenylene |
| 3,3'-Dimethoxybenzidine | n-C28 (n-octacosane) | Tripropyleneglycolmethyl ether |
| Dimethyl phthalate | n-C30 (n-triacontane) | 1,3,5-Trithiane |
| Dimethyl sulfone | 4-Nitrobiphenyl | — |

### *3.3.2.2 Analytical Methods*

The Agency collected, preserved, and transported all samples according to EPA protocols as specified in the Sampling and Analysis Plan (Tetra Tech, 2000b; Tetra Tech, 2001a; Tetra Tech, 2001b; Tetra Tech 2003a) for each facility and in the AAP Quality Assurance Project Plan (QAPP) (Tetra Tech, 2000a).

EPA collected composite samples for most parameters because the Agency expected the wastewater composition to vary over the course of a day. The Agency collected grab samples from unit operations for oil and grease and microbiological contaminants (e.g., total and fecal coliform bacteria, fecal *Streptococcus*, *Aeromonas*, *Mycobacterium arinum*, *Escherichia coli*, and *Enterococcus faecium*). Composite samples were collected either manually or by using an automated sampler. Individual aliquots for the composite samples were collected at least once every 4 hours over each 12-hour period or 24-hour period. Samples for oil and grease were collected two or three times per day, every 4 hours, and microbiological samples were collected once a day.

EPA contract laboratories completed all wastewater sample analyses, except for the field measurements of temperature, dissolved oxygen, and pH. EPA or facility staff collected field measurements of temperature, dissolved oxygen, and pH at the sampling sites. The analytical chemistry methods used, as well as the sample volume requirements, detection limits, and holding times, were consistent with the laboratory's quality assurance and quality control plan. Laboratories contracted for AAP sample analysis followed EPA-approved analysis methods for all parameters.

The EPA contract laboratories reported data on their standard report sheets and submitted them to EPA's sample control center. The center reviewed the report sheets for completeness and reasonableness. EPA reviewed all reports from the laboratory to verify that the data were consistent with requirements, reported in the appropriate units, and in compliance with the applicable protocol.

A description of the analytical methods and nominal quantitation limits is available in Appendix B. Quality control measures used in performing all analyses complied with the guidelines specified in the analytical methods and in the AAP QAPP (Tetra Tech, 2000a). EPA reviewed all analytical data to ensure that these measures were followed and that the resulting data were within the QAPP-specified acceptance criteria for accuracy and precision.

## 3.4 U.S. Department of Agriculture Data

### 3.4.1 1998 Census of Aquaculture

The 1998 Census of Aquaculture was the first national census taken for the AAP industry. Conducted by USDA's National Agricultural Statistics Service (NASS), this census was a response to a need for accurate measurements of the rapidly growing aquaculture industry. The industry had grown from $45 million for value of products sold in 1974 to more than $978 million in 1998 (USDA, 2000).

The 1998 Census of Aquaculture was conducted to expand the aquaculture data collected in the 1997 Census of Agriculture. The Census of Aquaculture collected detailed information on on-site aquaculture practices, size of operation based on water area, production, sales, method of production, sources of water, point of first sale outlets, cooperative agreements and contracts, and aquaculture products distributed for conservation and recreation (USDA, 2000). The Census was conducted using mailed questionnaires, follow-up telephone calls, and personal interviews. EPA evaluated data from the Census.

### 3.4.2 National Agricultural Statistics Service

In addition to the Census of Aquaculture, EPA also evaluated data from USDA's NASS reports to characterize current trends in AAP production in the United States by evaluating data on inventory and sales by size category for catfish and trout, the two leading sectors in the AAP industry.

Before the 1998 Census, NASS tracked the catfish and trout industry through reports on monthly catfish processing, reports on quarterly catfish production, and annual catfish and trout surveys (USDA, 2000). The first catfish processing reports were published in February 1980. Surveys for catfish production were also initiated in 1980 but were then discontinued in 1982 because of funding shortages. Currently, the NASS catfish production survey is conducted twice a year in Mississippi, Alabama, Arkansas, and Louisiana and annually in nine additional states.

### 3.4.3 Animal and Plant Health Inspection Service: Veterinary Services and the National Animal Health Monitoring System

The Animal and Plant Health Inspection Service (APHIS) has conducted several studies, which EPA used to characterize production practices in the AAP industry. A 1995 report, *An Overview of Aquaculture in the United States* (USDA, 1995), describes the diverse U.S. aquaculture industry, reviews trends in industry development, and discusses regulatory complexities facing the industry. EPA reviewed this report to develop a more comprehensive understanding of the AAP industry in the United States and develop industry profiles for various species.

The National Animal Health Monitoring System (NAHMS) is sponsored by USDA through the APHIS's Veterinary Services (VS). VS collaborated with USDA's NASS to implement a two-part study of food-size catfish producers in Alabama, Arkansas, Louisiana, and Mississippi. The first part of the study, *Catfish '97: Part I: Reference of 1996 U.S. Catfish Health and Production Practices* (USDA, 1997a), provides information on disease and production of food-size catfish. The second part of the study, *Catfish '97: Part II*, *Reference of 1996 U.S. Catfish Management Practices* (USDA, 1997b), describes catfish production management practices. EPA reviewed both studies to collect information to develop the catfish industry profile.

EPA used information from NAHMS to further characterize the catfish industry in the United States and describe current disease management issues and practices. (Refer to Chapter 4, Industry Profiles, for more information on the catfish sector of the AAP industry.)

### 3.4.4 Economic Research Service

The U.S. Department of Agriculture's Economic Research Service (ERS) publishes *Aquaculture Outlook*, a semi-annual report that analyzes aquaculture imports and exports and consumption of aquaculture products in the United States. EPA used data from this report to evaluate trends in markets for AAP products and to develop a description of factors that affect the AAP industry and influence domestic AAP markets, including competition from international competitors. Species covered in the report include catfish, trout, tilapia, salmon, shrimp, molluscs, and ornamental fish.

## 3.5 SUMMARY OF OTHER DATA SOURCES

Other data sources used to characterize the AAP industry include information from the Joint Subcommittee on Aquaculture, BMP guidance documents developed by governmental and other organizations, data from the Small Business Advocacy Review Panel, and public participation.

### 3.5.1 Joint Subcommittee on Aquaculture

The Joint Subcommittee on Aquaculture (JSA) serves as a federal interagency coordinating group to increase the overall effectiveness and productivity of federal aquaculture research, transfer, and assistance programs. Membership includes the U.S. Secretary of Agriculture, the U.S. Secretary of Commerce, the U.S. Secretary of the Interior, the U.S. Secretary of Energy; the U.S. Secretary of Health and Human Services, the Administrator of the Environmental Protection Agency, the Chief of Engineers, the Administrator of the Small Business Administration, the Administrator of the Agency for International Development, the Chairman of the Tennessee Valley Authority, the Director of the National Science Foundation, the Governor of the Farm Credit Administration, and the other heads of federal agencies as appropriate. JSA is a statutory committee that operates under the aegis of the National Science and Technology Council (NSTC) of the Office of Science and Technology Policy in the Office of the Science Advisor to the President. JSA reports to the NSTC's Committee on Science, which is one of five research and development committees NSTC has established to prepare strategies and budget recommendations for accomplishing national goals.

JSA's Aquaculture Effluents Task Force (AETF), created in September 1999, assisted EPA in the development of effluent guidelines by gathering technical information to develop industry profiles and assess regulatory options. The Task Force convened a Technical Information Exchange Forum hosted by the Department of Commerce, National Oceanic and Atmospheric Administration. The Forum included the participation of each of the Task Force's 14 technical subgroups. EPA consulted with JSA's Task Force throughout the effluent guideline development process. The Task Force provided a vehicle for coordinating and facilitating stakeholder input, and its participants represented a range of interests, experiences, and expertise in the AAP industry.

### 3.5.2 Other Government Agencies

EPA and representatives from USDA, FDA, and DOI held meetings to discuss this regulation. EPA met with USDA's APHIS to discuss how APHIS and the industry might be affected by or affect requirements on the AAP industry implemented by EPA in this rule. EPA and the FDA's Center of Veterinary Medicine met to discuss the new drug approval process and to clarify FDA's environmental assessment requirements for the substances over which FDA has jurisdiction. EPA also met with Fish and Wildlife Service representatives to discuss aquatic nuisance species and the regulatory authority various agencies have over such species. EPA also met with representatives from state and local governments to discuss their concerns regarding AAP facilities and how EPA should approach these facilities in regulation.

### 3.5.3 BMP Guidance Documents Developed by Governmental and Other Organizations

A number of states, including Alabama, Arizona, Arkansas, Florida, Hawaii, and Idaho, were found to have recommended BMPs for AAP. In addition, BMPs have also been developed for specific types of aquatic species. BMPs are addressed in manuals or regulations, depending on the state. Data were collected from in-house resources and through Internet research. An example of technical guidance on BMP development is

*Best Management Practices for Flow-through, Net Pen, Recirculating, and Pond Aquaculture Systems* (Tucker et al., 2003). This guidance document provides examples of existing BMP plans and state regulations, as well as technical information that can be used in facilities' BMP plan development. Information is provided for four production system types and ranges from guidance on site selection, to solids and feed management, to facility operation and maintenance.

#### *3.5.3.1 Alabama*

Dr. Claude Boyd and his colleagues, with funding from the Alabama Catfish Producers (a division of the Alabama Farmers Federation), have developed a set of BMPs for aquaculture facilities in Alabama. The BMPs are described in a series of guide sheets that have been adopted by USDA's Natural Resources Conservation Service (NRCS) to supplement the Service's technical standards and guidelines (Auburn University and USDA, 2002). The NRCS technical standards are intended to be referenced in Alabama Department of Environmental Management rules or requirements that are promulgated for aquaculture in Alabama. The guide sheets address a variety of topics, including reducing storm runoff into ponds, managing ponds to reduce effluent volume, erosion control in watersheds and on pond embankments, settling basins and wetlands, and feed management.

#### *3.5.3.2 Arizona*

Arizona's BMPs for feeding operations regulation covers aquaculture facilities classified as feeding operations for purposes of regulation of discharge water quality (ARS 49-245-47; Section 318 CWA).

The Arizona Department of Environmental Quality has rules that regulate aquaculture through three general, goal-oriented BMPs. These BMPs address manure handling, including harvesting, stockpiling, and disposal; treatment and discharge of aquaculture effluents containing nitrogenous wastes; and closing of aquaculture facilities when they cease operation (Fitzsimmons, 1999).

Compliance with these BMPs is intended to minimize the discharge of nitrates from facilities without being too restrictive for farm operations. The draft document *Arizona Aquaculture BMPs* describes BMPs that can minimize nitrogen impacts from aquaculture facilities. A list of information resources is also provided for additional information about Arizona aquaculture and BMPs (Fitzsimmons, 1999).

#### *3.5.3.3 Arkansas*

The Arkansas Bait and Ornamentals Fish Growers Association (ABOFGA, n.d.) developed a list of BMPs to help its members make their farms more environmentally friendly. More specifically, the Association provides a set of BMPs that help to conserve water, reduce effluent, capture solids, and manage nutrients. Members may voluntarily agree to adopt the BMPs on their farms (ABOFGA, n.d.).

#### *3.5.3.4 Florida*

Florida's aquaculture certificate of registration and BMP regulation requires any person engaging in aquaculture to be certified by the Florida Department of Agriculture and

Consumer Services and to follow BMPs (Ch 5L-3.003, 5L-3). *Aquaculture Best Management Practices*, a manual prepared by the department, establishes BMPs for aquaculture facilities in Florida. By legislative mandate (Chapter 5L-3), the BMPs in the manual are intended to preserve environmental integrity, while eliminating cumbersome, duplicative, and confusing environmental permitting and licensing requirements. When these BMPs are followed, aquaculturists meet the minimum standards necessary for protecting and maintaining offsite water quality and wildlife habitat. All certified aquaculturists are required to follow the BMPs in Chapters II through X of the manual, which address federal permitting; construction; compliance monitoring; shipment, transportation, and sale; water resources; non-native and restricted non-native species; health management; mortality removal; and chemical and drug handling (FDACS, 2000).

#### *3.5.3.5 Hawaii*

Hawaii developed a practical BMP manual to assist aquaculture farmers in managing their facilities more efficiently and complying with discharge regulations. The manual, *Best Management Practices for Hawaiian Aquaculture* (Howerton, 2001), is available from the Center for Tropical and Subtropical Aquaculture.

Hawaii is also developing a BMP for traditional use of a *loko kuapa*-style Hawaiian fish pond. Because of changes in the land tenure, decreases in native population, total loss of traditional pond management practices, and benign neglect, fishpond production has declined in Hawaii. Although Hawaii's fishpond production efficiency is too low to justify the economic cost, Hawaii is making major efforts to restore and put into service several of these traditional structures as sustainable development demonstrations and as opportunities for maintaining ties to a nearly extinct element of cultural heritage (SOEST, n.d.).

#### *3.5.3.6 Idaho*

In combination with site-specific information, *Idaho Waste Management Guidelines for Aquaculture Operations* can be used to develop a waste management plan to meet water quality goals. Such a waste management plan would address Idaho's water quality concerns associated with aquaculture in response to the Clean Water Act and Idaho's Water Quality Standards and Wastewater Treatment Requirements. The manual is also intended to assist aquaculture facility operators in developing BMPs to maintain discharge levels that do not violate the state's water quality standards (IDEQ, n.d.).

#### *3.5.3.7 Other BMP Guidance Documents*

BMPs have also been developed for specific species, including shrimp, hybrid striped bass, and trout. The Global Aquaculture Alliance, in *Codes of Practice for Responsible Shrimp Farming*, has compiled nine recommended codes of practice that are intended to serve as guidelines for parties who want to develop more specific national or regional codes of practice or formulate systems of BMPs for use on shrimp farms. These codes of practice address a variety of topics, including mangroves, site evaluation, design and construction, feeds and feed use, shrimp health management, therapeutic agents and other chemicals, general pond operations, effluents and solid wastes, and community and employee relations (Boyd, 1999). The purpose of the document is to provide a framework for environmentally and socially responsible shrimp farming that is voluntary, proactive, and standardized. The document also provides a background narrative that reviews the general processes involved in shrimp farming and the environmental and social issues facing the industry (Boyd, 1999).

*The Hybrid Striped Bass Industry: From Fish Farm to Consumer* is a brochure that provides guidance to new and seasoned farmers in the proper handling of fish from the farm to the consumer. Although the brochure is primarily geared toward providing quality fish products to consumers, the information it provides about the use of drugs and chemicals, including pesticides and animal drugs and vaccines, could be used to benefit the environment (Jahncke et al., 1996).

The Trout Producer Quality Assurance Program of the U.S. Trout Farmer's Association (USTFA) is a two-part program that emphasizes production practices that enable facilities to decrease production costs, improve management practices, and avoid any possibilities of harmful drug or other chemical residues in fish. Part 1 discusses the principles of quality assurance, and Part 2 provides information about the highest level of quality assurance endorsed by the USTFA. Although the program addresses a variety of subjects related to trout production, the discussion on waste management and drugs and chemicals can be applied to protecting the environment (USTFA, 1994).

### 3.5.4 Other Industry-Supplied Data: Small Business Advocacy Review Panel

EPA collaborated with the Small Business Advocacy Review Panel (SBAR), which convened on the proposed effluent limitations guidelines and standards for the CAAP industry. Section 609(b) of the Regulatory Flexibility Act (RFA), as amended by the Small Business Regulatory Enforcement Fairness Act of 1996, requires that a panel be convened prior to publication of the Initial Regulatory Flexibility Analysis that an agency may be required to prepare under the RFA.

The Panel, with input from Small Entity Representatives (SERs), analyzed issues related to small entities. These issues included an estimate of the number of small entities to which the proposed rule will apply; a description of reporting, record-keeping, and other compliance requirements and an estimate of the classes of small entities that may be subject to the requirements; identification of federal rules that might duplicate, overlap, or conflict with the proposed rule; alternatives to the proposed rule that accomplish the stated objectives and minimize significant economic impacts of the proposed rule on small entities; and any impacts on small entities.

Before convening the Panel, EPA had several discussions, meetings, and conference calls with small entities that will potentially be affected by the proposed rule. Between August and October 2001, EPA held discussions with members of JSA's Aquaculture Effluents Task Force (AETF) to identify potential SERs. EPA invited 16 aquatic animal producers and two university professors to serve as potential SERs for the pre-panel outreach process. In November 2001, EPA mailed a packet of background materials about the rulemaking process to potential SERs. On December 12, 2001, EPA held a meeting/conference call in Washington, DC, with small entities potentially affected by the proposed rule. The SERs provided comments on materials provided by EPA. Their comments were used to update existing information collected by EPA and to revise the proposed regulatory options for the CAAP industry.

A Panel Report is included in the public record supporting this rulemaking (USEPA, 2002b) and can be accessed on-line at http://yosemite.epa.gov/opei/Sbrefa.nsf/(PDFView)/4406/$file/pnl25b.pdf?OpenElement.

### 3.5.5 Summary of Public Participation

The public participated in the rulemaking process through several mechanisms, such as public meetings, outreach to AAP industry representatives, conference calls, and information exchange by mail.

EPA encouraged the participation of all interested parties throughout the development of the CAAP effluent limitations guidelines and standards. EPA conducted outreach to the major trade associations through the JSA/AETF (whose membership includes producers, trade associations, federal and state agencies, and academic and environmental organizations). EPA also participated in ten JSA/AETF meetings and gave presentations on the status of the regulation development. In addition, EPA met with environmental groups, including the Natural Resources Defense Council, SeaWeb, and Environmental Defense, concerning this proposal.

When the AAP industry was first identified as a candidate for rulemaking, EPA met with industry associations and environmental groups and representatives from state and local governments to solicit their opinions on the issues that the Agency should consider as it moved toward rulemaking.

EPA held three public meetings in Washington, DC, Seattle, Washington, and Atlanta, Georgia in October and November of 2002. During these public meetings, EPA summarized the proposed rule and provided the public with a chance to ask questions about the proposed rule. Summaries of the public meetings are available in the public record (Mosso, 2002a; Mosso, 2002b; Mosso, 2002c).

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# CHAPTER 4
# INDUSTRY PROFILES

## 4.1 OVERVIEW OF THE INDUSTRY

Aquaculture in the United States began in the 1850s as a commercial enterprise when fish culturists developed the technology needed to spawn and grow brook trout. Several culturists who became proficient in fish raising techniques found that they could sell their fish for a profit (Stickney, 2000b). Today, the aquaculture industry in the United States encompasses the production of finfish, shellfish, crustaceans, reptiles, other aquatic animals, and aquatic plants. These plants and animals are produced for a variety of reasons, including as food, pets, bait, and sportfish; for ornamental and display purposes; as research and test organisms; and to enhance natural populations. EPA has broadly defined aquatic animal production (AAP) to include any production of aquatic animals and is not including aquatic plant production in the definition. The following chapter describes AAP in the United States, including systems used to produce aquatic animals and many of the aquatic animals produced.

As valuable commercial fisheries began to decline in the latter half of the 19th century, there was a growing concern about the stock depletion. Spencer F. Baird, who was affiliated with the Smithsonian Institute, worked with Congress to create a federal fisheries agency (Stickney, 2000b). The nation’s first federal conservation agency, the U.S. Fish & Fisheries Commission, was established in 1871. Known today as the National Marine Fisheries Service, the agency is responsible for marine commercial fisheries, while the U.S. Fish and Wildlife Service (USFWS) is responsible for freshwater fish, whose use is primarily recreational. The two agencies share responsibility for anadromous fish such as chinook and coho salmon.

After the U.S. Fish & Fisheries Commission was established, fish culture activities developed quickly. By the end of 1871, 11 states had established fish commissions; by 1877 there were fish commissions in 26 states. To further expand fish culture activities, Baird instructed Livingston Stone to set up an egg collection facility in California on the McCloud River. Prior to this facility, fish culturists transported fish via the newly established transcontinental railway from the east to the west coast. The striped bass and the American shad became most successful (Hartman and Preston, 2001). These species were exported around the world as well. Many people were optimistic that the work of artificial propagation of foodfishes, the introduction of promising exotic species, and the redistribution of native fishes to new waters could ensure an increased and sustainable food production in the nation’s natural water bodies, in particular the Great Lakes and the oceans.

The goals of public fish hatcheries, often referred to as conservation hatcheries, differ from the goals of private commercial fish hatcheries. Conservation hatcheries produce fish for stocking in public waters to enhance or restore recreational or commercial fisheries. Private, for-profit hatcheries produce fish for several purposes, including food, bait, use in the aquarium trade, and use in stocking private waters (Westers, 2001). Generally, public hatcheries focus on the "wild" qualities of the fish produced. Fish produced for enhancement purposes are produced to retain genetic integrity and characteristics needed to survive in the wild. On the other hand, most private hatcheries focus on maximum production to meet economic goals. Commercial producers emphasize genetic selection for fast growth and adaptation to culture conditions. These differences in goals are reflected in the variety of production strategies generally applied by public and private programs.

### 4.1.1 Development of Federal, State, and Local Hatchery Programs

Expansion continued and by 1949, 46 of the states counted a total of 522 hatcheries, while the federal system had 99 hatcheries in 43 states. At the same time, however, stocking programs came under scrutiny. Stocking of fingerling-size trout had replaced the early fry stocking programs, but even fingerling stocking, in most instances, produced dismal returns. At the same time, angling pressure increased. To meet angler demand many states launched into stocking catchable-size trout. It was now possible to feed the fish dry prepared diets, giving hatcheries the opportunity to greatly expand production in terms of biomass and numbers. This expansion required greater hatchery capacity.

Public fish hatcheries became extremely popular with the public at large, as many became favored places to visit. Such facilities became firmly entrenched in local communities, making it politically difficult to discontinue their operations. Hatcheries attracted not only tourists, but also people interested in sportfishing opportunities, especially the stocking of catchable trout.

Both state and federal governments established research facilities, which made significant contributions to the advancement of fish culture in the United States. State fish hatchery facilities made significant advances in developing of prepared feeds, identifying diseases and treatments, advancing engineering design for water systems, and identifying or developing methods to measure and control water quality (Stickney, 2000b).

In 1973, the Endangered Species Act became a catalyst for shifting the goals of some public hatcheries from stocking sport fish to propagating endangered and threatened species. Today the USFWS considers its primary responsibility to be fish resource restoration and maintenance, while the states' responsibility is to supply fish for the enhancement of sportfishing opportunities. As a consequence, many federal hatchery facilities have either been closed or transferred to the state.

Currently, 28 USFWS hatcheries are involved in the restoration of threatened or endangered species. Maintaining the genetic integrity of these aquatic organisms is considered a high priority (Hartman and Preston, 2001). Despite this goal, 49 states use non-native sport fish species, and some states rely entirely on non-native species for recreational sportfishing (Schramm and Piper, 1995).

An example of a successful state hatchery program is the restoration of red drum in the Gulf of Mexico. The Texas Parks and Wildlife Department releases 20–30 million juvenile red drum fingerlings annually into coastal bays (Pennell et al., 2001). It has been estimated that since 1990, the abundance of red drum 1 to 5 years of age is double the population prior to the 1980s. The success of this fishery might also have been affected by the closing of the commercial fishery in 1981 when red drum was declared a game fish.

Both federal and state hatcheries serve as a tool for fisheries management to develop and maintain recreational, commercial, and tribal fisheries; supply year-classes to supplement natural reproduction; introduce new species; and restore endangered or threatened species.

Put-and-take stocking, or stocking that increases angler opportunities through the release of harvestable-size fish, is still an important activity in many state hatchery programs. State hatcheries stocked more than 60 million catchable trout in 1980. That same year the federal hatchery system released 11.9 million catchable trout. Coldwater fish make up the largest stocking program; 252 state and 36 federal hatcheries produce salmonids. More than 500 million coldwater fish are stocked annually, and according to Radonski and Martin (1986), this number falls 38 million short of the amount required to meet angler demands. Most salmonids stocked are Pacific salmon species released as smolts into various river systems connected to the Pacific Ocean. In the Columbia River Basin, more than 90 state and federal hatcheries raise and release some 190 million juvenile Pacific salmon annually (Schramm and Piper, 1995).

Total estimated production of all salmonid species for stocking in public waters is 35–42 million pounds annually. In terms of numbers of fish stocked on an annual basis, coolwater fish, including walleye, northern pike, and yellow perch, are the most abundant. At least 47 states have programs for stocking coolwater fish. In the 1983–1984 season, over 1 billion walleye fry were stocked in the United States, followed by 42 million northern pike and 13 million yellow perch. Finally, approximately 43 states have warmwater stocking programs for primarily largemouth bass. Other warmwater fish species stocked to restore or enhance fisheries are smallmouth bass, bluegill, sunfish, crappies, striped bass, hybrid striped bass, channel catfish, flathead catfish, and blue catfish (Smith and Reeves, 1986).

### 4.1.2 Development of Commercial Aquatic Animal Production

Commercial foodfish production in the United States began to grow in the 1960s. Before that time, AAP was generally limited to trout production. The trout industry in Idaho began to expand, as did production of warmwater species in southern states, particularly catfish production (Stickney, 2000b). Interest in commercial AAP gained popularity at several universities, including the University of Washington and Auburn University. The expansion of faculties' expertise and research activities in commercial AAP led to an increased body of knowledge about fish life cycles, production methods, and husbandry practices. Commercial AAP benefited from new research activities and strong university programs. In the mid-1980s, the U.S. Department of Agriculture (USDA) created five regional aquaculture centers that represent the Western, North Central, Southern, Northeastern, and Tropical/Subtropical Regions. Building on academic interest in commercial AAP and state and federal hatchery experiences, commercial foodfish production in the United States has grown over the past 30 years.

Idaho dominates trout production with cultured rainbow trout. Relying on cold spring water, the trout industry has been developed primarily around the Magic Valley region of Idaho using water from subterranean rivers (Stickney, 2000b). Initiated by research at USFWS laboratory facilities in Stuttgart, Arkansas, and in Marion, Alabama, channel catfish became the dominant species for production in the southern United States. Although the catfish industry was originally centered in Arkansas, falling water tables in the early 1970s limited expansion potential. Instead, catfish farmers moved to the Mississippi Delta region with its flat topography and shallow water table. Today Mississippi leads catfish production in the United States; however, catfish are produced in all southern states. Limited catfish production occurs in other states, such as California and Idaho. Though once considered of interest as food only in southern states, today the catfish industry has developed a national market through an aggressive marketing campaign (Stickney, 2000b). In addition to trout and catfish, other freshwater fish and shellfish are also raised commercially in the United States, including hybrid striped bass, tilapia, and crawfish.

Salmon production developed in the 1970s in Puget Sound, Washington, with the production of pan-sized coho. Research to expand net pen production originally focused on coho and chinook. Researchers, charged with maintaining threatened native stocks of Atlantic salmon in Maine, experimented with producing Atlantic salmon in the Pacific Northwest and discovered that Atlantic salmon were better suited for production in captivity than salmon species indigenous to the Pacific. Today, salmon culture continues to grow in Maine, whereas in Washington salmon production has leveled off and even declined in recent years. Salmon net pen culture is illegal in Oregon and Alaska; however, salmon ranching, the production of smolts for release and recapture as adults, is permitted.

Commercial marine fish production in the United States remains limited. A few commercial facilities produce red drum in Texas, and there are a few commercial operations for the production of summer flounder (Stickney, 2000b). Marine shrimp culture is well established in the United States; Texas is the leading producer. Some mollusc production, including oysters, mussels, and clams, occurs on the Atlantic, Gulf of Mexico, and Pacific coasts of the United States.

## 4.2 SYSTEM TYPES

### 4.2.1 Ponds Systems

#### *4.2.1.1 Levee Ponds*[1]

Regions of the United States with relatively flat land and sufficient clay in the soils are usually well suited for constructing levee ponds for producing aquatic animals. A levee pond is constructed by creating earthen levees from excess soil that is covering the future pond bottom. It can be constructed as a single unit or as a singular part of a group of ponds in which the levees often serve as common walls for more than one pond. The tops of levees are maintained, at least on one side, so that the operator can move equipment and vehicles along the pond bank for feeding and harvesting. Assistance in pond design and construction is sometimes available from local offices of the USDA's Natural Resources Conservation Service (NRCS).

Water supplies for levee ponds are typically wells, located on-site at a facility. Some facilities rely on pumped or free-flowing water from surface water bodies such as lakes, streams, or coastal waters. Those relying on surface waters, however, must be careful not to introduce undesirable species or organisms into the culture ponds. Water might need to be screened or filtered as it is pumped into the pond. Rainwater falling directly on the pond is also captured and can be a source for maintaining water levels. For those systems that rely on well water, water conservation and rainwater capture are important management tools to minimize pumping costs.

Like watershed ponds, the size and shape of levee ponds are determined by the available land, its topography, and its underlying soils. Levee pond size varies from less than 1 to more than 25 acres, but most ponds for foodfish production are 4 to 16 acres. Smaller ponds may be used for broodstock holding and fry or seed production because they are easier to manage for these purposes than larger ponds. Larger levee ponds are typically more difficult to manage and harvest than smaller ones, but they are more economical to construct. The average depth of a levee pond is about 4 to 5 feet.

Drainage structures on a levee pond have two functions. The first is to provide a conveyance for overflow, which regulates the water level in the pond. If a pond captures excessive rainfall, the overflow structure allows the excess water to drain before it overflows the levees that enclose the pond. In some pond facilities (e.g., baitfish facilities), overflow pipes connect the ponds so water can be transferred between adjacent ponds to conserve water.

The second function of drainage structures is to allow the complete draining of the pond. The drainpipe is located in one of the levee walls just below the grade of the pond bottom. Some ponds have a drainage structure that functions as both an overflow control and a drain. For example, the structure can be in the form of a standpipe that swivels or a

[1] Some of the information for this section was adapted from T. Wellborn and M. Brunson, *Construction of Levee-type Ponds for Fish Production*, publication no. 101 (Southern Regional Aquaculture Center, Stoneville, Mississippi, 1997).

riser structure. Other ponds have separate overflow pipes and drains. If the drain has a valve, the valve remains closed at all times until the pond is drained.

In catfish ponds, which represent more than half of the ponds in production in the United States, as well as other high-density production ponds such as ponds for hybrid striped bass and shrimp, the use of mechanical aeration is common throughout the growing season. Stationary mechanical aerators are strategically positioned in the pond to maintain sufficient dissolved oxygen (DO) levels throughout the entire pond. In the event of extreme low-oxygen conditions, supplemental emergency aeration might be required. Emergency aeration is usually provided by using tractor-driven mechanical aerators.

Fish harvest takes place using seines that can be stretched across the entire pond. The mesh size of the seine allows smaller fish to escape to be harvested at a later date. After being seined into a section of the pond, the fish are removed from the pond with a net attached to a scale and boom. After being simultaneously removed and weighed, the fish are loaded into live haul trucks for shipment to a processing facility.

Levee ponds are the most commonly used method of production for channel catfish. Hybrid striped bass and shrimp are also commonly grown in levee ponds. Any species amenable to pond culture can be grown in a levee pond; for example, crawfish, shrimp, baitfish, ornamentals, sport fish, and perch. The following are some examples of different production practices in levee ponds:

> *Channel catfish*. Channel catfish fingerlings are produced in nursery ponds, which are smaller than production ponds. Feed-trained fry are stocked into the ponds, usually in the spring of the year. These ponds are managed to ensure that plankton blooms are also available as a source of natural food until the fry become proficient at using the artificial diet as their sole source of food. Fingerlings are grown in the ponds for about 5 to 9 months and then harvested by seining during the colder seasons and transferred to growout ponds. The nursery pond is eventually drained, and any remaining fish are killed to prevent cannibalism of the fry by larger fish.
>
> Foodfish production varies among farms, but it can involve crops of single cohorts or multiple cohorts. For the single-cohort cropping system, fingerlings are stocked, grown to market size, and then harvested. The pond is cleaned of all fish (by draining or killing the remaining fish), and a new cohort is put into the pond to repeat the cycle. Multiple cohorts can be cropped by selectively harvesting larger fish and understocking with fingerlings. This approach allows the operator to use most of the water for many years between draining events.
>
> Both fingerlings and foodfish are typically fed with mechanical feeders that blow the feed across the surface of the pond. With respect to stocking density, producers usually try to achieve a maximum biomass of about 6,000 pounds/acre. Mechanical aeration is required to maintain adequate water quality and oxygen

levels in the ponds. Most catfish farmers use paddlewheel aerators to supply sufficient aeration for production.[2]

*Penaeid shrimp*. Levee ponds are also commonly used for the production of penaeid shrimp. The ponds are filled in the spring of each year, and the larval shrimp are stocked in the ponds. The shrimp are fed by broadcasting feed into the ponds with mechanical feeders or by hand feeding out of a boat criss-crossing the pond. Shrimp production ponds are also aerated to maintain sufficient levels of DO. After the shrimp are harvested in the fall, the ponds are drained and left to dry. This oxidizes the organic matter and reduces the likelihood of disease problems from growing season to growing season. Most shrimp facilities use surface water as a source and screen the inlets to prevent predators from entering the ponds. Because many of the shrimp grown in the United States are non-native species, escapement and disease are concerns for regulatory agencies. Outlets are screened to prevent escapement. Water is reused by draining it to ditches and pumping or conveying it back into the ponds from the ditches.

*Crawfish*. Levee ponds are also used in crawfish production. Managing crawfish production ponds is different from managing other pond production systems. Crawfish ponds are shallow, with an average depth of 18 to 24 inches. They are drained every spring to begin the reproduction process. As the water is drained from the ponds, the crawfish burrow into the pond bottom and produce their young. A forage crop is planted to provide food for the crawfish when the ponds are flooded in the fall; rice is a common forage crop. After the growing season, the rice is harvested, and the rice stubble is left in the field. The field is then flooded to a depth of about 1.5 feet. The crawfish come out of their burrows and feed on the decaying vegetation. Crawfish are harvested by using baited traps.

#### 4.2.1.2 Watershed Ponds[3]

In much of the United States, watershed ponds are built to capture storm water runoff, which serves as the primary water supply for the pond. Although often not ideal for use as AAP ponds, watershed ponds can be constructed in hilly areas that are not suitable for levee ponds. Watershed ponds are constructed by building earthen dams, or levees, to trap water in a topographic depression within the landscape. Another construction technique uses two- or three-sided ponds that are constructed parallel to hills bordering creeks. Watershed ponds constructed for AAP may sometimes differ from those used as general farm ponds or those used to control large volumes of runoff from agricultural or other types of watersheds. The goal of AAP watershed pond site selection and construction is to have a pond that allows the owner ease of management and harvesting. The USDA's NRCS has design criteria for watershed ponds, and local offices often offer site-specific design assistance.

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[2] Information adapted from C. Tucker, Channel Catfish Culture, in the *Encyclopedia of Aquaculture*, 2000. ed. R.R. Stickney, pp. 153-170. John Wiley and Sons, NY.

[3] Some of the information for this section was adapted from J. Jensen, *Watershed Fish Production Ponds: Site Selection and Construction*, publication no. 102 (Southern Regional Aquaculture Center, Stoneville, Mississippi, 1989).

Like levee ponds, the local topography determines the size and shape of watershed ponds constructed for AAP. On gently sloping or rolling landscapes, the watershed pond is sited and constructed to capture enough water to maintain adequate water levels throughout the year and to minimize the need for water sources other than runoff. On steeper slopes or if available land permits, one or more ponds can be constructed in series to capture larger volumes of runoff during rainy seasons. Another technique for steeply sloped terrain is to divert excess water around the watershed pond. The ponds are constructed with relatively flat bottoms for ease of harvest with seines. The levees are constructed with top widths that are sufficient to drive trucks and other farm equipment on, primarily for feeding and harvesting. Costs for watershed pond construction depend primarily on the amount of soil moved to create levees and smooth pond bottoms.

Depending on the contributing watershed, these ponds could be rather large (in excess of 20 acres). Experience has shown, however, that ponds smaller than 20 acres are easier to manage and harvest than larger ponds. Ponds that are too small (less than about 5 acres for foodfish production) also are not as desirable, especially from a harvesting perspective. Extra labor is required to harvest multiple small ponds to collect enough fish to make centralized processing efficient. The pond size is a function of the watershed, annual and seasonal rainfall, available land, and production goals. Pond depths are kept below 10 feet to facilitate harvesting, enhance aeration and mixing, and meet other pond management needs.

Drains are usually installed in the watershed pond to allow the operator to completely drain the pond when the production strategy requires draining. Watershed ponds are also equipped with overflow pipes to drain smaller volumes of excess water from the ponds during runoff events. The overflows may be piped to adjacent ponds that are constructed and operated in series. At sites in Alabama, for example, up to five watershed ponds were observed in series. A properly designed watershed pond also includes an emergency spillway, which is a low spot along a levee that is grassed and maintained to control runoff. The emergency spillway is sized according to expected runoff volumes, depending on local climatic conditions and the size of the watershed.

The quantity of water available from runoff events for a watershed pond depends on the size of the contributing watershed, frequency and duration of rainfall events, and land use characteristics of the watershed. These factors also greatly influence the quality of water entering the pond during rainfall events. Large watersheds typically collect more water than smaller ones and might present the opportunity for more pollutants to accompany the runoff into the ponds. The frequency and duration of rainfall events have obvious implications on the quantity of water available for the ponds and the amounts that might overflow. (Heavier and more frequent rainfall produces more water.) Watersheds with land uses like roads, houses, and agricultural cropland present different water quality inputs to watershed ponds. For example, roads contribute oil and other petroleum products, metals, and potentially large amounts of suspended solids to watershed ponds.

Management strategies for watershed ponds for AAP depend primarily on the size and type of fish. Watershed ponds are used primarily for the production of catfish, as well as other warmwater and coolwater species such as hybrid striped bass, sunfish, yellow perch, ornamental fish, baitfish, and many sport and game fish. The species and life stage (e.g., fry, fingerling, or food-sized fish) will determine relative densities and many management practices, as shown in the following examples:

> *Catfish food-sized fish*. These fish are often stocked to achieve maximum densities of about 5,000 to 6,000 pounds/acre. They can be harvested and understocked with smaller fish to maintain higher biomass and longer periods between draining; complete draining usually occurs once every 7 to 10 years. Ponds are aerated to maintain DO and water quality. Fish are fed once or twice daily with mechanical feeders.
>
> *Hybrid striped bass food-sized fish.* These fish are often stocked to achieve maximum densities of about 5,000 to 6,000 pounds/acre. They must be completely harvested before restocking. (The ponds are drained between harvest and stocking or are treated with a piscicide to remove remaining fish.) Ponds are usually drained annually or biennially, depending on stocking size, and are aerated to maintain DO and water quality. Fish are fed once or twice per day with mechanical feeders.
>
> *Baitfish*. Baitfish are often stocked to achieve a desired number of fish per acre to maintain size requirements at harvest. The overall densities are typically less than 300 to 500 pounds/acre. Ponds must be completely harvested before restocking, and they are usually drained annually for maintenance; aeration is used to assist in harvest. Fish are fed minimally to supplement natural food as well as provide nutrients to the pond for natural food production. They are fed by hand or with mechanical feeders. Feeding may also be used to concentrate the fish to facilitate harvesting.

### 4.2.2 Flow-through Systems[4]

Flow-through systems consist of single- or multiple-pass units with constantly flowing culture water, and they commonly use raceways or tanks (circular or rectangular). Raceways typically are long rectangular tanks constructed of earth, concrete, plastic, or metal. Sizes vary depending on topography and the operational goals of the facility. Some sizes commonly used are 80 feet long, 8 feet wide, and 2.5 feet deep (trout); 100 feet long, 10 feet wide, and 3 feet deep (trout and catfish); or a series of cells 30 feet long, 10 to 20 feet wide, and about 3 feet deep. Many raceways are constructed to reuse the flowing water several times by passing the water through multiple units before discharging it.

Circular or rectangular tanks are also used with constantly flowing water, and they are made from concrete, plastic, or metal. They can be above the ground or placed in the ground, and most use gravity to maintain flows. The primary difference between raceways and tanks is the flow pattern within the containment structure. Raceways tend to have plug flows of water along the length of the raceway. Tanks establish varying flow patterns, depending on the inlet and drain configurations, and the volume of water used.

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[4] Information for this section was adapted from J. Avault, 1996a. *Fundamentals of Aquaculture* (AVA Publishing, Baton Rouge, Louisiana).

Circular tank systems are operated to enhance solids removal, while raceways allow settling of solids within a portion of the rearing unit.

Flow-through systems are found throughout the United States, wherever a consistent volume of water is available. Most flow-through systems use well, spring, or stream water as a source of production water. The water source is chosen to provide a constant flow with relatively little variation in rate, temperature, or quality.

Flow-through systems are the primary method used to grow salmonid species, such as rainbow trout. These species require high-quality coldwater with high levels of DO. Flow-though systems are located where water is abundant, which enables farmers to efficiently produce these types of fish. Some other species cultured using flow-through systems are hybrid striped bass, tilapia, and ornamentals.

Facility size for flow-through systems can vary tremendously. Facilities can range from small earthen or concrete raceway systems producing about 2,000 pounds of fish per year to much larger facilities with production levels in the millions of pounds per year.

Most flow-through systems require supplemental oxygen or aeration to maintain sufficient levels of DO in the culture water. The source water might require oxygenation to be suitable for production, or as water is reused in serial units, oxygenation or aeration might be required. In some cases, facilities use mechanical or passive aeration devices to increase the DO concentration of the culture water. Other facilities might add on-site generated or liquid oxygen to supplement DO levels.

Because many flow-through systems have relatively constant temperatures all year, the fish can be fed year-round. Feeding systems for flow-through systems vary significantly by size and management objectives. Small operators might choose to hand-feed all fish, use demand feeders in different areas of the production facility, or have a mechanical system to deliver feed to the different raceways. Large operators typically use some kind of mechanical feeding system to distribute feed at the desired intervals to meet production goals.

Flowing water in flow-through systems is expected to carry away accumulating waste products, including feces, uneaten feed, and other metabolic wastes. The flowing water and swimming fish help move solids down through the raceway. Raceway systems typically have quiescent zones at the tail ends of the raceways. The quiescent zones allow solids to settle in an area of the raceway that is screened off from the swimming fish. Baffles, or other solids-flushing enhancements, help move solids to the quiescent zones without breaking them into smaller particles. The settled solids are then regularly removed from the quiescent zone by vacuuming or gravity. Flow-through systems with tanks sometimes use self-cleaning or concentrating devices to collect solids and allow them to be efficiently removed from the system. Most facilities store the collected solids in settling basins, convey the solids to a dewatering process, or hold the solids in a storage tank for future disposal.

### 4.2.3 Recirculating Systems

Recirculating systems are highly intensive culture systems that actively filter and reuse water many times before it is discharged. These systems typically use tanks or raceways to hold the growing animals and have extensive filtration and support equipment to maintain adequate water quality. Recirculating systems use biological filtration equipment to remove ammonia from the production water. Solids removal, oxygenation, temperature control, pH management, carbon dioxide control, and disinfection are other common water treatment processes used in recirculating systems. The size of the recirculating system depends primarily on available capital to fund the project and can be designed to meet the production goals of the operator.

Recirculating systems can be used to grow a number of different species. They can be used anywhere in the country because a relatively small volume of water is needed to produce a unit of product. Thus, the facility can economically temper the water to optimal production temperatures. Recirculating systems grow various species of fish in controlled environments year-round. Species commonly grown in such systems include hybrid striped bass and tilapia.

Feeding regimes in recirculating systems vary significantly from operation to operation. Some operators feed by hand once or twice per day, whereas other operators use automatic feeders to feed the fish at specified intervals throughout the day.

The water treatment processes are designed to minimize water requirements, which leads to small-volume, concentrated waste streams. A typical recirculating facility has one or more discrete waste streams. Solids and backwash water removed from the production system create an effluent that is high in solids, nutrients, and biochemical oxygen demand (BOD). Most systems add make-up water (about 5% to 10% of the system volume each day) to dilute the production water and to compensate for evaporation and other losses. In addition, some overflow water, which is dilute compared to the solids water, is discharged.

Recirculating system facilities use a variety of methods to treat, hold, or dispose of the solids collected from the production water. Some facilities send the collected solids, and some overflow water, directly to a publicly owned treatment works (POTW) for treatment. Other facilities pretreat in settling ponds or other primary treatment systems to concentrate solids and send a more dilute effluent to the POTW. Still others concentrate solids and then land-apply the solids slurry when practical. The overflow water may be directly discharged, land-applied, or otherwise treated.

### 4.2.4 Net Pens and Cages

Net pens and cages are suspended or floating holding systems in which some cultured species are grown. These systems may be located along a shore or pier or may be anchored and floating offshore. Net pens and cages rely on tides, currents, and other natural water movement to provide a continual supply of high-quality water to the cultured animals. In most locations, net pens are designed to withstand the high-energy environments of open waters and are anchored to keep them in place during extreme weather events. Strict siting requirements typically restrict the number of units at a given site to ensure sufficient flushing to distribute wastes and prevent degradation of the bottom below and near the net pens.

Net pens use a floating structure to support nets, which are suspended under the structure in the water column. The net pens vary in shape but are typically circular, square, or rectangular on the water surface. Their size also varies, depending on the available surface area and depth. For example, a net pen facility that EPA visited in Maine had 10 adjoining square units, each with a surface area of about 250 square feet and a depth of about 40 feet.

A common practice in net pen culture is to use two nets—a containment net on the inside and an outer predator net to keep out predators, such as seals. The predator net also adds protection to minimize the risk of underwater escapement. At the surface, jump nets are used to keep fish from jumping out of the net pen. The jump nets extend several feet above the surface around the perimeter of the net pen. Bird nets are also suspended above the surface of the net pens to prevent bird predation. Cage culture uses floating cages or baskets that are usually much smaller than net pens. The shape of cages varies, and plastic and other corrosion-resistant materials are usually used to construct them.

For cage and net pen culture, the mesh size of the netting used to contain the fish should be large enough to prevent critically reduced water flows when fouling occurs, but small enough to keep the cultured fish inside the structure. Most nets and cages are cleaned mechanically with brushes and power washers. Antifoulants have limited use in the United States. A few have been approved for foodfish production, but those typically show minimal effectiveness.

Net pens and cages are used primarily in the coastal areas of the United States to grow anadromous or near-coastal species of finfish. The species most commonly cultured in net pen and cage operations are anadromous salmonid species like Atlantic salmon *(Salmo salar)*. Other Pacific salmon species, including pink (*Oncorhynchus gorbuscha*), chum (*Oncorhynchus keta*), chinook (*Oncorhynchus tshawytscha*), sockeye (*Oncorhynchus nerka*), and coho (*Oncorhynchus kisutch*), are either grown in net pens for part of their life cycle, prior to release into the open ocean for final growout, or grown to food-size (chinook and coho). Other species, such as steelhead trout (*Oncorhynchus mykiss*), cobia *(Rachycentron canadum),* and redfish (*Sciaenops ocellata),* also can be cultured in net pen operations.

Feeding practices include hand feeding and use of a variety of mechanical feeders. Operators of small cages with a low biomass of fish mostly rely on hand feeding, which necessitates placing the cages near shore with access from land, a dock, or a small boat. Most net pen systems contain a large biomass of fish (e.g., 30,000 fish with a harvest weight of about 8 to 10 pounds each) and require the use of mechanical feeders. For net pens that are single structures without supporting walkways, barges and boats with feed blowers are used to take feed to the net pens and dispense feed, usually once or twice a day. Bad weather can impede this method of feeding. Other facilities may use a stationary blower to deliver feed to each net pen in a group of pens. To control overfeeding, many facilities use underwater cameras to monitor feed consumption.

Most net pens are regularly inspected by divers. The divers look for holes in the nets, dead fish, and fouling problems. State regulatory programs require benthic monitoring at many net pen sites to ensure that degradation is not occurring under or around the net pens.

### 4.2.5 Floating and Bottom Culture Systems[5]

The production of bivalves in the United States involves several different methods, which are selected based on variables such as species, location, and legal or political issues. The commercial growout of bivalves always relies on naturally occurring foods that are present in the water in which the bivalves are placed. The key to successful floating and bottom culture is sufficient tides and currents to move water containing natural food to the shellfish. The water movement must also move wastes away from the growing shellfish and minimize the accumulation of sediment. Harvests can be made with divers, lifting gear, or conventional shellfishing techniques. The basic growout techniques use the intertidal areas above mean low water (but within the tidal reach) and the subtidal areas (areas always submerged). Those techniques can be further subdivided into techniques that use the bottom and those that use the water column. Some species are better suited for off-bottom culture (e.g., mussels); other species (e.g., clams and oysters) may be grown in either bottom or off-bottom growout systems. The specific locations of a growing area and that area's tidal characteristics (e.g., whether it is intertidal or subtidal) dictate the choice of intertidal versus subtidal growout. Other factors, such as legal restrictions, social pressure, waterway use, and aesthetics, might dictate the culture method.

One popular bottom culture technique places the shellfish directly on the bottom in beds. Clams tend to dig into the bottom substrate, while oysters and mussels remain on top of the substrate. When predation is a problem, the shellfish are placed in mesh bags or covered with mesh to keep the predators away from the growing crop. Bottom culture techniques require a relatively firm bottom to keep the shellfish from sinking too deep into the substrate. Bottom culture does not work when excessive sediment settles over the shellfish beds and smothers the crop. Shellfish can also be placed in trays, nets, or racks positioned directly on the bottom.

Off-bottom culture techniques include suspending shellfish from longlines on strings or racks. Longlines can also be used to suspend the shellfish in bags or racks. Floats are sometimes used to suspend strings, bags, or trays of shellfish in the water column. Racks of strings are a popular off-bottom method of growing mussels.

### 4.2.6 Other Systems: Alligator Farming

The only species of alligator commercially produced in the United States is the American alligator *(Alligator mississipiensis)*. Alligator production, which takes place primarily in Louisiana and Florida, is a relatively new business that is still undergoing many changes.

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[5] The information for this section was adapted from J. Kraeuter, et al., 2000, Preliminary Response to EPA's Aquaculture Industry Regulatory Data Development Needs, Molluscan Shellfish Technical Subgroup.

Alligator production facilities usually consist of corrugated metal buildings constructed on top of concrete slabs with walls that form a tank. The buildings are insulated to reduce heating costs during the winter. To maintain the desired temperature, heated water is circulated through a piping network encased in the concrete floor. The drainage structures for alligator production facilities differ greatly from facility to facility, but most have a single drain for each alligator pen in the production area. These pen drains usually combine to form a main drain, which conveys wastewater to the wastewater treatment operations for the facility.

Alligator feeding regimes have changed significantly since alligator farming first began. Currently, most alligators are fed a manufactured diet consisting of pelleted feed with the same feedstocks used for finfish feeds.

Cleanliness of the growout areas is important to the production of high-quality skins for eventual sale. Most alligator pens are cleaned every other day using a high-pressure hot-water spray, sometimes combined with small amounts of bleach to reduce the risk of bacterial infection. Water drained from the growout areas is usually discharged to a singular treatment lagoon or a series of lagoons before it is land applied for its fertilizer value.

## 4.3 PRODUCTION DESCRIPTION BY SPECIES

### 4.3.1 Catfish

Representing nearly half of the total AAP in the United States for all species, production of channel catfish (*Ictalurus punctatus*) is the largest AAP enterprise in the country. In 2000, more than 656 million pounds of channel catfish were produced commercially. In 2001, sales increased to over 670 million pounds (USDA, 2002). Production is concentrated in the southeastern United States: Mississippi, Alabama, Arkansas, and Louisiana account for 97% of the total domestic catfish production (USDA, 2002). Catfish growers in 13 select states had sales of $443 million in 2001, down 12% from the previous year (USDA, 2002). Prices per pound dropped from $0.75 in 2000 to $0.65 in 2001.

The original range of channel catfish extended from northern Mexico through the states bordering the Gulf of Mexico and up the Mississippi River and its tributaries (Tucker, 2000). Today, the channel catfish can be found throughout the world as a sport fish and an AAP product. A native North American freshwater fish, the channel catfish is a bottom dweller with a preference for a substrate of sand and gravel. Its natural habitat is sluggish to moderately swift rivers and streams; however, channel catfish also thrive in ponds and lakes.

Between 1955 and 1965 most of the growth in commercial catfish culture occurred in southeast Arkansas. Farmers discovered that raising fish could be a profitable alternative to growing traditional crops like rice and cotton. By 1975, the industry began to expand quickly, particularly in Mississippi, where profits from traditional agriculture were in decline. Aquaculture offered farmers an opportunity to diversify their crop production and use land that did not successfully support row crops. Cooperation among farmers helped create the infrastructure needed to support catfish production, including the development of large feed mills and fish processing plants. In 1968, the creation of a national grower's association, the Catfish Farmers of America, also enhanced the growth of the industry. In 1986 the Catfish Institute, an association of catfish farmers, processors, and feed manufacturers, launched a national marketing campaign, further strengthening the industry.

Today most catfish farms are family farms or partnerships. According to the USDA, about 88% of catfish farms are small businesses with annual sales of less than $750,000 (USDA, 2000). Of the 1,370 catfish farms in the United States, 38% reported annual revenues of less than $25,000. Catfish production plays a significant role in the southeastern United States, a region that continues to be one of the more economically challenged regions in the country.

#### *4.3.1.1 Production Systems*

Facilities and culture practices vary within the southeast region. Many studies on catfish farming have focused on practices in northwest Mississippi (Tucker et al., 1996; Tucker and van der Ploeg, 1993) and west-central and central Alabama (Boyd et al., 2000; Schwartz and Boyd, 1994b). There are fewer studies on catfish farming practices in Louisiana and Arkansas, the other two leading producers of commercial catfish, or on practices in other states with catfish farms.

In the southeastern United States, the two major catfish-producing areas are (1) the Mississippi River Alluvial Valley, which includes northwest Mississippi, southeast Arkansas, and northeast Louisiana, and (2) west-central Alabama and east-central Mississippi (JSA, 2000a). Because of the flat topography and an available groundwater source, many catfish farms in the Mississippi River Alluvial Valley use levee (embankment) ponds. Levee ponds are built by removing dirt from the area that will become the pond bottom and using that dirt to build levees around the pond perimeter. In west-central Alabama and east-central Mississippi, some catfish farms use watershed ponds. Watershed ponds take advantage of hills and sloping terrain to build a pond by damming an existing drainage area to capture rainwater and runoff from the watershed. Many watershed ponds also require an additional source of water to supplement rainwater and runoff.

Overall, by operation size in acres, about 90% of all commercial catfish ponds in production in the United States are levee ponds; the remaining 10% are watershed ponds (USDA, 1997).

*Levee Ponds*

Ponds in northwest Mississippi are predominantly levee ponds. Most ponds are rectangular with about a 3:1 to 5:1 ratio of length to width with an average pond size of between 8 and 15 acres of water surface. For ease of harvest, most pond depths range from 3 to 5 feet. The height of the levee is 1 to 2 feet above normal water stage (freeboard and storage) (JSA, 2000a).

*Watershed Ponds*

In west-central Alabama and east-central Mississippi, commercial catfish farms use both levee and watershed ponds. The average size of ponds in this region is 10 to 12 acres. The average maximum depths are 7 feet at the pipe and 3 feet on the shallow end. The height of the levee for a watershed pond is around 3 feet above normal water stage. Watershed ponds can expect more input from rainwater and runoff because a larger natural watershed area drains into the pond. A levee pond has a smaller "watershed" contained within the slopes of the levee.

About 75% of the commercial catfish ponds in west-central Alabama are watershed ponds. The remaining 25% of the ponds in this region are levee ponds, filled with water pumped mainly from groundwater wells (JSA, 2000a). About half of the ponds in east-central Mississippi are watershed ponds, and the other half are levee ponds or hybrid watershed-levee ponds that primarily use water pumped from nearby streams or other surface water supplies rather than from groundwater supplies (JSA, 2000a).

#### *4.3.1.2 Culture Practices*

Catfish AAP in ponds involves four phases: (1) broodfish production, (2) hatchery production, (3) fry nursery production, and (4) growout production (JSA, 2000a). Broodfish are held in ponds and allowed to randomly mate each spring. Spawning occurs when the water temperature rises above 70 °F. Fertilized eggs are then taken to a hatchery, where they hatch under controlled conditions. The fry are raised in the hatchery for 5 to 15 days and are then transferred to a nursery pond, where they are fed a manufactured feed throughout the summer and fall. Fingerlings weighing 0.7 to 1.4 ounces are seined from the nursery pond and transferred to the foodfish growout ponds in winter or spring, where they are fed a manufactured feed until they reach the size desired for processing, usually 1 to 2 pounds. In the southeastern United States, 18 to 30 months (two or three growing seasons) are required to produce a food-size channel catfish from an egg (JSA, 2000a). Within the industry, some farmers specialize in producing fingerlings. The fingerlings are then sold to farmers who specialize in growing food-size fish. Many farmers combine all aspects of production by having broodfish ponds, a hatchery, fry nursery ponds, and growout ponds. In the catfish industry, fish are usually harvested from growout ponds with long seine nets pulled by tractor-powered reels. The fish are transferred to live-haul trucks in a basket connected to a crane. Using different mesh sizes, the seines are designed to capture market-sized fish and allow smaller fish to remain in the pond. The captured fish are then transported to processing plants or directly to market.

Broodfish ponds represent about 2% of the total pond area devoted to catfish production. Although some farmers harvest and drain broodfish ponds every fall to replace poor breeders and adjust the sex ratios, most broodfish ponds in northwest Mississippi are drained only every 1 to 5 years (Tucker, 1996). Instead of draining the pond every year, broodfish are inspected by seining the pond. In Alabama very few commercial hatcheries remain in operation (Boyd et al., 2000). Most fingerlings stocked in Alabama ponds are imported from Mississippi.

After a short stay in the hatchery, the fry are moved to a nursery pond for further growth. Nursery ponds are stocked with approximately 100,000 to 300,000 fry/acre. Because recently transferred fry are weak swimmers, farmers prepare a natural plant food source for fry that are too weak to swim to the areas where feed is offered (Tucker, 2000). After a month or so, as the fry approach 2 inches in length, they are referred to as fingerlings. Fingerlings ranging in age from 5 to 9 months and weighing 0.7 to 1.4 ounces are harvested from the nursery ponds and placed in growout ponds. The nursery ponds are harvested by seining each pond several times over 1 to 3 months The mesh size of the seine grades the fish by size, releasing smaller fingerlings back into the nursery pond for further development.

Nursery ponds are usually drained each year to remove all fish from the pond. Fingerlings are removed from the pond to prevent cannibalism of fry in the next cycle of fingerling production (Tucker, 2000). Nursery ponds represent approximately 10% of the total pond area in commercial production. Because these ponds are drained each year between crops, water use is higher in nursery ponds than in broodfish or foodfish growout ponds (Tucker and Hargreaves, 1998).

Broodfish and nursery pond practices remain fairly constant throughout the industry, but foodfish culture practices often vary among different farms based on production goals and the economics of different production strategies. There are two fundamental production variables in foodfish growout: fish stocking density and cropping system (Tucker and Robinson, 1990). Stocking densities in growout ponds range from 4,000 to more than 12,000 fish/acre and average about 6,000 fish/acre. The cropping system refers to the stocking-harvest-restocking schedule. The two cropping systems in commercial catfish production are clean harvest and understocking (or multiple-batch). In the clean harvest system, farmers keep only one year-class of fish in the pond at one time. Fingerlings are stocked and grown to the desired harvest size (1 to 2 pounds/fish). Faster-growing fish are selectively removed by seining the pond in two to four separate harvests over several months until all of the fish are removed. After the harvest, the pond is often restocked without draining in order to conserve water and to reduce time lost between crops (Tucker, 2000).

The understocking or multiple-batch system has more than one year-class of fish (with three or four distinct size-classes of fish) after the first year of production. Multiple-batch harvesting is the predominant production type, accounting for 89.2% of foodfish harvest (USDA, 1997). At first the pond is stocked with a single year-class of fingerlings. Faster-growing fish are selectively harvested using large-mesh seines, and fingerlings are added to replace the harvested fish. Most commercial catfish ponds in Alabama use multiple-batch systems and harvest with seines (Boyd et al., 2000). This process of selective harvest and understocking (adding fingerlings) continues for years without draining the pond. After several cycles, the pond contains several year-classes of fish with a range of sizes from recently stocked fingerlings to fish that might be several years old.

The clean harvest system produces fish more uniform in size than fish from understocked ponds, and processors prefer uniform sizes (Tucker and Robinson, 1990). Inventory records are also easier to keep with the clean harvest system because populations are reset at zero after each crop cycle. With the clean harvest system, feed conversion efficiencies are better because larger fish, which convert feed to flesh less efficiently, are not carried over into the next production cycle. The advantage of the understocking system is that more ponds will have market-size fish at any one time than with clean harvest crops. This is important because it provides a farmer with other harvest options if a pond is temporarily unacceptable for processing because of factors like algae-related off-flavors or ongoing losses due to infectious disease.

Water use practices have shifted in the catfish industry in recent years. Today farmers use water more conservatively. Before 1985, many catfish ponds in northwest Mississippi were regularly refilled with pumped water (Tucker and Hargreaves, 1998). Farmers believed that "flushing" the pond improved productivity. Research by McGee and Boyd (1983), however, showed that "flushing" was generally not beneficial. Today almost all catfish ponds in northwest Mississippi are managed as "static" systems with very little water exchange except from heavy rain creating overflow. In another study in Alabama (Seok et al., 1995), in a period of 3 years, three ponds were harvested annually by draining and three were harvested without draining. There were no differences in net production, average fish size at harvest, or feed conversion rates; however, in the undrained ponds, concentrations of chlorophyll *a* and total ammonia nitrogen were higher. This study has reinforced the practice of harvesting without draining, a management practice that is now common throughout the catfish industry.

Daily management practices for both crop systems are similar. Today, foodfish ponds are usually drained only when a levee needs to be repaired or when there is a need to adjust the inventory by completely removing all fish. Table 4.3–1 shows that most commercial ponds remain in production for 3 to 10 years between renovations before being drained, and the average time between pond drainings is over 6 years (USDA, 1997). On average, producers drained ponds less often (every 6.4 years) at operations where 90% or more of the ponds were levee ponds than at operations with a smaller percentage of levee ponds (every 4.7 years). Smaller operations (measured by acreage) drained ponds more often regardless of predominant pond type. During renovation the pond bottom is dried and the dried clay is broken by disking the bottom. Dried material is scraped from the bottom and used to rebuild the levee and restore the proper pond slope.

**Table 4.3–1. Number of Years Between Drainings By Pond Type and Operation Size**

| *Operation Size (Ac)* | *Pond Type*[a] | | | | | |
|---|---|---|---|---|---|---|
| | *Levee Ponds* | *Standard Error* | *Watershed/ Mixture Ponds* | *Standard Error* | *All* | *Standard Error* |
| 1–19 | 3.1 | (± 0.4) | 2.4 | (± 0.5) | 2.9 | (± 0.3) |
| 20–49 | 5.9 | (± 0.5) | 2.6 | (± 0.8) | 5.1 | (± 0.5) |
| 50–149 | 6.1 | (± 0.3) | 8.4 | (± 1.7) | 6.5 | (± 0.4) |
| 150 or more | 8.7 | (± 0.4) | 9.7 | (± 0.7) | 8.8 | (± 0.4) |
| All | 6.4 | (± 0.2) | 4.7 | (± 0.8) | 6.1 | (± 0.2) |

[a]Pond type for the operation was classified levee if at least 10% of the operation's ponds were reported as levee ponds. Otherwise, the pond type was classified as "Watershed/Mixture."
Source: USDA, 1997.

*Feed Management*

Feed allowances in growout ponds average between 75 to 125 pounds/acre/day during late spring and early summer (Tucker, 2000). Feeding activity declines as water temperatures drop in late fall, with feeding rates declining to less than 25 pounds/acre/day during midwinter; however, feeding allowances may be higher during unusually mild winters. A report from the USDA's Animal and Plant Health Inspection Service (APHIS) found that 87.5% of operations with fish on hand during winter fed their foodfish during winter, with 62.8% feeding 3 or more days per month (USDA, 1997). Operators identified water temperature and levee condition as being very important criteria in determining winter feeding schedules.

The cost of feed depends on its quality and contents. The conversion of feed protein to fish protein is important because protein is the most expensive feed ingredient, based on the amount of protein in the feed and the cost of the protein used. In most catfish feed, a portion of the protein comes from fish meal and sometimes other animal sources. In recent years, the industry has improved upon earlier catfish feeds. Modern feeds contain less crude protein and a much smaller percentage of animal protein (Boyd and Tucker, 1995).

The feed conversion ratio (FCR) is a measure of the feeding efficiency. It is calculated as the ratio of the weight of feed applied to the weight of the fish produced:

$$FCR = \frac{\text{Dry weight of feed applied}}{\text{Wet weight of fish gained}}$$

Commercial catfish farms in Mississippi typically achieve an FCR of 2.04 to 2.40 (Boyd and Tucker, 1995). Much lower FCRs (in the 1.3 to 1.5 range) can be reached in research ponds under conditions where fish are less crowded, have less wasted food, and live in water with better aeration than is found on most commercial farms (Boyd and Tucker, 1995). The FCR is an important tool that operators use for measuring the efficiency of the system. If stocking rates are too low, efficient feeding becomes more difficult (fish are too spread out), and thus increasing the stocking density would improve FCR. When stocking and feeding rates are increased to the point where water quality is negatively impacted, however, FCR increases (poorer efficiency). As the growing season progresses, the fish grow and require more feed. As feeding rates increase, water quality tends to deteriorate as a result of excessive phytoplankton (microscopic algae), increased oxygen demand, and high concentrations of nutrients, including total ammonia nitrogen. In ponds that use the multiple-batch system, removing marketable fish and adding new fingerlings, the feeding rate might remain more constant because the number of pounds of foodfish per acre levels out as large fish are removed and small fish are added.

*Health Management*

High fish densities and stressful environmental conditions can lead to the outbreak and rapid spread of infectious diseases in channel catfish ponds. Bacterial diseases account for most of the losses of fingerlings in nursery ponds, whereas foodfish in growout ponds are most often affected by proliferative gill disease (PGD), caused by the myxosporean parasite, and "winter-kill syndrome," a disease associated with external fungal infections

(Tucker, 2000). PGD occurs most often in spring and autumn when temperatures are between 60 and 68 °F. There is no treatment for the disease, but farmers can reduce losses by maintaining high DO levels during an outbreak. "Winter-kill syndrome" is common when temperatures fall below 60 °F. Mortality rates from this fungal infection can be high, and the conditions that contribute to its outbreak are not well understood. There is no cost-effective treatment available for fungal infections in large commercial ponds.

The channel catfish virus (CCV) affects young catfish and can lead to large losses in hatcheries or nursery ponds. The virus causes channel catfish virus disease (CCVD), and fish less than 1 month old are most susceptible. There is no cure for CCVD, but losses can be reduced by controlling water temperature in hatcheries and reducing stress in fry or fingerling populations by maintaining relatively low stocking densities, avoiding stressful handling, and preventing adverse environmental conditions (Plumb, 1994a; Winton, 2001).

Three bacterial diseases are significant to channel catfish AAP because they can cause large losses: enteric septicemia of catfish, columnaris disease, and motile aeromonad septicemia.

Enteric septicemia in catfish (ESC) is one of the leading bacterial diseases in commercial catfish production. This disease costs the industry millions of dollars annually in fish mortalities and expenditures for preventive measures and therapeutic treatments (Plumb, 1994b; Winton, 2001). Only two Food and Drug Administration (FDA)-approved drugs, oxytetracycline (Terramycin) and sulfadimethoxine-ormetroprim (Romet), are effective against ESC. Today farmers rely more on vaccination and management practices to reduce stress to prevent ESC rather than drug treatments.

Two other bacterial diseases are often encountered in channel catfish production: motile *Aeromonas* septicemia (MAS), a ubiquitous disease of many freshwater fish species, and columnaris, caused by *Flexibacter columnaris*. MAS is typically caused by one of several gram-negative, motile bacteria that are members of the genus *Aeromonas*, such as *A. hydrophila*, *A. sobria*, and *A. cariae*. Occasionally, various species of *Pseudomonas*, especially *Pseudomonad fluorescen*s, can cause a form of disease that is indistinguishable from MAS (Winton, 2001).

Most columnaris infections in channel catfish are mixed infections with other bacteria, especially ESC and MAS. Initial columnaris infections are usually the result of mechanical or physiological injuries or environmental stress. MAS is also a stress-mediated disease. Treatment with a 1% to 3% salt solution or 2 to 4 milligrams/liter of potassium permanganate reduces the incidence of post-handling infections.

Infectious disease is a significant problem in catfish production that is primarily controlled by preventing the poor water quality conditions that lead to outbreaks. Pond culture of catfish prohibits the use of most drugs and pesticides for treatment because of the high cost of treating the large water volume. Sick fish tend not to eat, so the few FDA-approved medicated feeds are limited in their effectiveness.

Some algae and bacteria that grow in catfish ponds produce odorous organic compounds that can give the fish undesirable off-flavors. Synthesized by blue-green algae, geosmin, an earthy-smelling compound, and 2-methylisoborneol, which has a musty smell, are the two most common causes of off-flavors in pond-raised catfish (Tucker, 2000). To prevent off-flavored fish from reaching the market, fish are taste-tested before harvest. In Alabama it is a common practice to treat ponds with copper sulfate to control blue-green algae and off-flavor in ponds. Studies show that copper precipitates rapidly in ponds and is unlikely to be a concern in effluents (Boyd et al., 2000).

#### *4.3.1.3 Water Quality Management and Effluent Treatment Practices*

*Water Quality in the Production System*

In catfish ponds, the most important constituents of potential effluents are nitrogen, phosphorus, organic matter, and settleable solids (JSA, 2000a). These materials are a direct or indirect product of feeds added to the ponds to promote rapid fish growth. Farmers need relatively high stocking and feeding rates to reach profitable levels of production. Although catfish are able to convert more feed into flesh than warm-blooded animals, nutrient use is not as efficient. Less than 30% of the nitrogen and phosphorus added to the pond in feed is recovered in the harvested fish (JSA, 2000a). The remainder of the nutrient load stays in the pond system as fish waste. Inorganic nutrients in fish waste stimulate the growth of phytoplankton, which in turn stimulate the production of more organic matter through photosynthesis. For both watershed and levee ponds, nitrogen and phosphorus compounds and organic matter are present in the pond water throughout the growout period and represent potential pollutants if discharged.

Fish wastes contain nitrogen, phosphorus, and other nutrients required for plant growth. The input of these nutrients, particularly in the summer growing season, stimulates the growth of plant communities in catfish ponds. Although some ponds may develop rooted aquatic plants, the most common plant form is phytoplankton (Tucker, 1996). Phytoplankton are producers as well as users of oxygen. They also assimilate ammonia as a nitrogen source of growth (Tucker, 1996). Phytoplankton can be beneficial to the catfish pond system; however, a pond with high levels of phytoplankton biomass might use more oxygen than it produces, resulting in a community deficit of DO.

Catfish need sustained levels of DO. Ideally, minimum DO concentrations need to be between 4 and 5 milligrams/liter to maintain the health of the fish (Tucker, 1996). Aerators are one of the most common control technologies used in the catfish industry to improve water quality. Mechanical aerators improve the quality of the water in the pond by continually mixing the water and preventing thermal stratification. Aeration also adds DO to the system. By enhancing DO concentrations, aeration increases the capacity of ponds to assimilate organic matter through aerobic processes. Higher DO concentrations also increase the nitrification rate of ammonia to nitrate, which is then lost from the pond through denitrification. In addition, aeration and water circulation influence rates of phosphorus loss from the system. The interface between water and sediment in aerated ponds appears to be sufficiently oxidized to enhance rates of inorganic phosphorus removal from pond water and reduces the availability of phosphorus for phytoplankton (JSA, 2000a). Furthermore, circulation can also improve water quality by increasing nutrient uptake by phytoplankton. Water circulation increases the aggregate exposure of phytoplankton cells to light, resulting in an increase in phytoplankton growth rates, which in turn increases the nutrient uptake.

Over time natural processes in the pond lower the concentrations of nitrogen, phosphorus, and organic material. If water is retained in catfish ponds over a period of time, biological, chemical, and physical processes remove some of the waste generated by fish. Some of the organic matter from phytoplankton production and fish waste is oxidized in the natural process of microbial decomposition (JSA, 2000a). Total nitrogen levels in catfish pond waters are lowered as nitrogen is lost from the water column as organic matter with nitrogen particulates is decomposed on the bottom of the pond. Nitrogen is also lost from the water as a gas through denitrification and volatilization. Finally, total phosphorus concentrations in the water are lowered as phosphorus is lost to the pond bottom soils as particulate organic phosphorus and precipitates of calcium phosphates.

*Effluent Characteristics*

The major components of concern from catfish pond effluents are solids, organic matter, phosphorus, and nitrogen. Based on these components, the major potential impact on receiving waters is the possibility of eutrophication. The impact on the receiving waters will depend on the volume and concentration of substances in the effluent in relation to the flow rate of the receiving body of water and the timing of the effluent discharge (JSA, 2000a).

Watershed ponds and levee ponds, as well as the different production practices used by different facilities, influence water use practices and water quality in the ponds. In turn, water quantity and quality affect the discharge volume and the characteristics of the water discharged, or effluent, from catfish production. Effluent from a pond may be discharged intentionally. For example, a pond might be periodically drained for harvest or maintenance. Ponds might also discharge water though unplanned events, such as overflow due to excessive rainwater and runoff.

General characteristics of overflow from catfish ponds in northwest Mississippi are described in a study (Table 4.3–2) that examines long-term changes in the quality of effluents from typical commercial catfish ponds (Tucker et al., 1996). Water samples were taken from 20 ponds in Washington County in northwest Mississippi over a 2-year period beginning in summer 1991. These ponds represented typical culture practices of ponds used to produce catfish in the area. Samples were taken in August (summer), November (autumn), February (winter), and May (spring). Samples were collected from the top 12 inches of the surface of the pond and the bottom 12 inches of the pond at a site adjacent to the discharge pipe. Samples were taken at two different depths because water can be discharged from ponds at either the surface or the bottom, depending on the type of discharge pipe. Samples were analyzed for BOD, chemical oxygen demand, total ammonia, total nitrogen, nitrite, nitrate, total phosphorus, soluble reactive phosphorus, suspended solids, and settleable solids.

**Table 4.3–2. Means and Ranges of Potential Effluents Parameters from 20 Commercial Channel Catfish Ponds in Northwest Mississippi from Summer 1991 Through Spring 1993**

| *Season* | *Settleable Solids (mL/L)* | *Suspended Solids (mg/L)* | *Total Nitrogen (mg N/L)* | *Total Ammonia (mg N/L)* | *Total Phosphorus (mg P/L)* | *Biochemical Oxygen Demand (mg $O_2$/L)* |
|---|---|---|---|---|---|---|
| Summer 1991 | 0.20 (0–0.90) | 127 (40–225) | 6.1 (2.1–14.1) | 1.22 (0.01–3.19) | 0.54 (0.23–1.24) | 26.1 (14.6–41.2) |
| Autumn | 0.02 (0–0.25) | 80 (20–225) | 6.1 (2.9–10.8) | 2.63 (0.05–6.35) | 0.26 (0.14–0.58) | 9.7 (1.9–29.7) |
| Winter 1992 | 0.06 (0–0.70) | 109 (51–194) | 5.1 (2.1–8.8) | 0.86 (0.04–3.85) | 0.34 (0.13–0.62) | 13.7 (5.7–20.3) |
| Spring | 0.11 (0–1.35) | 123 (72–204) | 4.5 (1.8–6.7) | 1.06 (0.04–3.04) | 0.31 (0.15–0.56) | 14.8 (8.2–27.1) |
| Summer | 0.09 (0–0.58) | 117 (47–175) | 7.0 (2.6–10.9) | 0.71 (0.03–2.02) | 0.51 (0.26–0.87) | 21.2 (10.5–36.4) |
| Autumn | 0.02 (0–0.15) | 93 (41–175) | 6.9 (3.8–10.4) | 2.76 (0.07–8.10) | 0.35 (0.15–1.03) | 12.3 (5.4–34.0) |
| Winter 1993 | 0.01 (0–0.03) | 93 (39–165) | 5.5 (0.6–8.8) | 1.48 (0.02–5.14) | 0.34 (0.14–0.62) | 11.9 (4.8–22.9) |
| Spring | 0.12 (0–0.70) | 135 (46–289) | 5.2 (1.5–7.9) | 2.21 (0.03–4.44) | 0.37 (0.24–0.58) | 14.9 (8.5–25.5) |

Source: Tucker et al., 1996.
Note: Ranges are in parentheses.

Pond effluents varied from pond to pond, season to season. Typically the quality of potential effluents was poorest in the summer, with high concentrations of solids, organic matter, total phosphorus, and total nitrogen. This same trend was confirmed by other studies of catfish pond water quality (e.g., Tucker and van der Ploeg, 1993).

Long-term changes in quality of effluents in typical commercial catfish ponds in central and west-central Alabama are described in a study (Table 4.3−3) by Schwartz and Boyd (1994b). They collected water samples during February, May, August, and November of 1991 and 1992 from 25 commercial catfish ponds using the same sampling method used in the study described above. Samples were analyzed for 5-day biochemical oxygen demand ($BOD_5$), total ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, soluble reactive phosphorus, nitrite, nitrate, total ammonia, suspended solids, volatile solids, and settleable solids.

**Table 4.3–3. Means and Ranges of Potential Effluent Parameters from 25 Commercial Channel Catfish Ponds in Central and West-Central Alabama from Winter 1991 Through Autumn 1992**

| *Season* | *Settleable Solids (mL/L)* | *Suspended Solids (mg/L)* | *Kjeldahl Nitrogen (mg N/L)* | *Total Ammonia (mg N/L)* | *Total Phosphorus (mg P/L)* | *Biochemical Oxygen Demand (mg $O_2$/L)* |
|---|---|---|---|---|---|---|
| Winter 1991 | 0.06 (0–0.33) | 81 (22–202) | 3.7 (0.9–9.2) | 0.7 (0.07–2.47) | 0.25 (0.04–0.57) | 9.0 (1.2–21.9) |
| Spring | 0.05 (0–0.40) | 52 (5–134) | 4.4 (1.8–10.6) | 1.07 (0.02–3.45) | 0.21 (0.07–0.37) | 6.5 (2.4–21.4) |
| Summer | 0.19 (0–1.80) | 96 (14–240) | 5.0 (1.7–11.3) | 0.85 (0.05–4.71) | 0.36 (0.12–0.75) | 10.7 (4.3–20.3) |
| Autumn | 0.03 (0–0.54) | 103 (18–232) | 6.1 (2.2–11.5) | 1.86 (0.10–8.07) | 0.46 (0.12–1.85) | 18.1 (6.1–35.6) |
| Winter 1992 | 0.01 (0–0.10) | 29 (1–100) | 1.9 (0.6–3.7) | 0.27 (0.03–1.08) | 0.09 (0–0.31) | 9.2 (5.5–17.5) |
| Summer | 0.15 (0–0.28) | 102 (10–308) | 3.9 (1.6–8.4) | 1.89 (0.06–3.30) | 0.19 (0–0.47) | 8.0 (1.4–15.9) |
| Autumn | 0.03 (0–0.25) | 73 (14–337) | 6.0 (2.2–14.0) | 1.91 (0.09–5.26) | 0.27 (0.06–0.83) | 7.6 (1.2–23.4) |

Source: Schwartz and Boyd, 1994b.
Note: Ranges are in parentheses.

Settleable solid concentrations were highest during the summer and were generally greater in the surface waters. Phytoplankton were the major source of suspended solids in the samples. The other effluent parameters (e.g., suspended solids, TKN, BOD, total ammonia, and total phosphorus) generally cycle throughout the year. These effluent parameters are usually lower in the spring, increase through the summer, peak in the fall, and then decrease in the winter.

Overall, concentrations of settleable solids and suspended solids were similar in Alabama and Mississippi catfish ponds. Concentrations of Kjeldahl nitrogen in Alabama ponds and total nitrogen in Mississippi ponds are not directly comparable because of a difference in analytical methods; however, if nitrogen compounds not measured in the Kjeldahl analysis are accounted for, values for total nitrogen are probably similar in both studies. Concentrations for total phosphorus and BOD are somewhat higher in ponds in Mississippi. This is probably a result of the higher fish stocking and feeding rates commonly used in Mississippi, which might lead to higher standing crops of phytoplankton (Tucker et al., 1996).

Schwartz and Boyd (1994a) also conducted a study to describe the quality of effluents drained for harvest. This study was conducted in three watershed ponds at the Alabama Agricultural Experiment Station near Auburn. Ponds were stocked with 4,000 fingerling channel catfish per acre and were fed a pelleted commercial feed during the growing season and intermittently during the winter. This study showed that concentrations of TKN, BOD, and settleable solids were fairly constant throughout the draining phase. As the pond level was lowered and the seining phase began, these variables increased in concentration. Total ammonia nitrogen, soluble reactive phosphorus, and total phosphorus steadily increased during the draining phase and then sharply increased during the seining phase. Increases in phosphorus were likely a result of sediments being stirred up. The rise in total ammonia-nitrogen concentrations was likely a result of metabolic wastes, becoming more concentrated in a decreasing volume of water.

Draining a pond for harvest concentrates fish into a relatively small volume of water, causing sediments to be stirred up by the fish and the nets. Water discharged during harvest contains solids and other substances from the disturbed sediments and is, therefore, different from typical pond water (JSA, 2000a). The findings from this study suggest that the best way to minimize impacts from effluents from ponds drained for harvest is to harvest ponds as quickly as possible, and either to not discharge the water during the seining process or to discharge this highly contaminated water into a settling basin or retention pond (JSA, 2000a). As noted in the report prepared by the Technical Subgroup for Catfish Production in Ponds for the Joint Subcommittee on Aquaculture, most ponds are not drained for harvest (JSA, 2000a). Draining ponds for harvest is practiced mostly in watershed ponds that have deep areas near the dam that prevent harvest by seining. Watershed ponds are common in areas such as west-central Alabama and east-central Mississippi, but overall they constitute a small proportion of ponds used in catfish farming.

*Current Industry Effluent Treatment Practices*

In addition to natural processes in ponds that help improve water quality by reducing levels of organic material and concentrations of nitrogen and phosphorus, catfish farmers also play a role in improving in-pond water quality through best management practices (BMPs).

Effluent volume from levee ponds is lowered by two common management practices in the catfish industry. The practices, which include keeping the pond water level below the level of the drain and not draining water between crops, significantly reduce the volume of water discharged (JSA, 2000a).

As demonstrated in a study by Tucker et al. (1996), reuse of water for multiple crops results in significant savings in water use and also reduces overall effluent volume. This study modeled the effect of water reuse on mass discharge of nutrients and organic matter for levee ponds operated at three intervals (1, 3, and 5 years) between total pond drainings and managed with and without storage potential. Harvesting fish without draining the ponds between crops substantially reduced the average volume of water discharged each year, and the reduction was greatest when ponds were also managed to maintain storage potential. For ponds not managed to maintain surplus water storage, the model indicated that using the ponds for 5 years before draining reduced the annual average waste discharge by approximately 45% compared to annually drained ponds. When ponds were managed for surplus water storage, discharge of nutrients and organic matter was reduced relative to annually drained ponds by more than 60% when ponds were used for 5 years between drainings. Currently, the average time between production pond drainings is more than 6 years.

The following is a summary of common practices in the catfish industry and the ways in which they affect effluent quality.

*Draining practices*. Draining practices are a function of harvest practices. Water is most commonly drained from a pond to facilitate harvests, prevent predation in fingerling ponds, or maintain pond banks and bottoms. Catfish production is characterized by infrequent drainings. Although nursery ponds are drained annually, growout ponds are drained once every 5 to 10 (or more) years. When the water is used for several years between draining events, effluent volumes are significantly reduced.

*Harvest practices*. Fish raised in ponds are typically harvested using seines that can be stretched across the entire pond. Catfish are usually harvested with seine nets without draining the ponds. Some watershed ponds require partial draining before harvest to capture fish in the deeper end of the pond adjacent to the dam (Tucker et al., 2002). Ponds harvested without draining have reduced effluent volumes. Draining and seining also affect effluent pollutant loads.

*Feed management*. Feed management is one of the most important practices that can influence water quality in the pond system. By managing feed, farmers manage the amount of nutrients in the form of fish waste and uneaten feed that are added to the pond system. Water quality in catfish ponds is directly related to the amount of feed added to the ponds. Uneaten feed contributes only to lowering of water quality, not to fish growth.

*Water quality management*. Catfish need sustained levels of DO at 4.0 milligrams/liter or above. Most catfish farmers use paddlewheel aerators to supply sufficient aeration for production. Mechanical aeration is required to maintain adequate water quality and oxygen levels in the ponds. Mechanical aerators improve the quality of the water in the pond by continually mixing the water and preventing thermal stratification. Aeration also adds DO to the system. By enhancing DO concentrations, aeration increases the capacity of ponds to naturally assimilate organic matter through aerobic processes.

*Overflow management*. Ponds can be managed to store precipitation and minimize the need for expensive pumped ground or surface water. The practice of preventing overflow by capturing rainwater is common throughout the catfish industry. By maintaining pond depths at 6 to 12 inches below the height of the overflow structure, about 160,000 to 325,000 gallons of storage capacity per surface acre of the pond is available to capture direct rainfall. When more water is stored, less water is released through overflows and smaller amounts of potential pollutants are released. Capturing rainfall and reducing the amount of overflow reduce the need for pumping additional water into a pond to compensate for water lost to evaporation and infiltration.

### 4.3.2 Trout

The production of trout represents the second largest sector of total AAP in the United States. In 2000, the total value of all trout sales, both fish and eggs, was $75.8 million

(USDA, 2001). Idaho leads trout production in the United States and accounted for 53% of the total value of trout sold in 2000. Pennsylvania, North Carolina, and California are the other leading trout-producing states. Trout distributed for restoration, conservation, and recreational purposes, primarily from state and federal hatcheries, had an estimated value of $60.9 million for both eggs and fish distributed.

Trout are cultured both for foodfish production and to stock recreational facilities. Rainbow trout (*Oncorhynchus mykiss*) is the most common species cultured for AAP; however, brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) are also raised in AAP facilities. Trout belong to the group of fishes called salmonids, which are coldwater fishes that also include Atlantic salmon and Pacific salmon. Rainbow trout were originally native to North American rivers draining into the Pacific Ocean. Brook trout are native to an area that extends from the northeastern coast of North America, west to the Great Lakes, and south through the Appalachian Mountains. The brown trout, a native of European waters, was first introduced into the United States more than 100 years ago. Because of their popularity as both a sport fish and a source of food, all three species of trout are now widely distributed and cultured around the world (Avault, 1996b.).

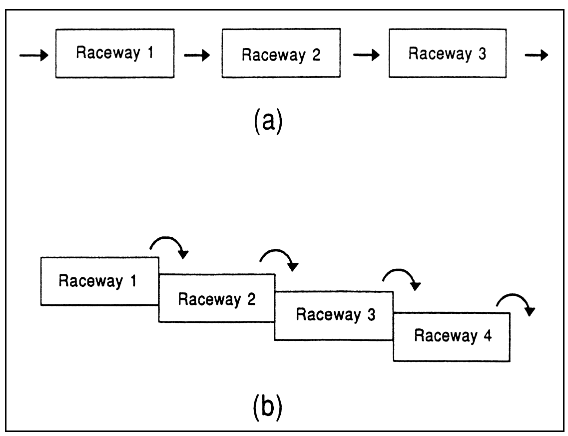
Rainbow trout culture became a farming business in the early 1900s, with a third of the farms operating as fee-fishing operations (Hardy et al., 2000). In Idaho, the first commercial trout farm was started in 1909 near Twin Falls. This area is known for its abundant spring water with a constant temperature from the Eastern Snake River Aquifer. In the early 1950s, trout farming expanded greatly, supported in part by the development of pelleted feeds. Farms no longer had to prepare their own feed, and production costs decreased. During the growth phase of the 1950s and 1960s, individual operators, including egg producers, growers, fish processors, distributors, and feed manufacturers, dominated the U.S. trout farming industry. Over the past decade, the industry has become more consolidated and vertically integrated. Today the most common trout farming businesses combine farming, processing, and sales. Egg production and feed manufacturing have remained specialized businesses.

Individuals and sport fisher groups originally began trout production to replenish wild stocks in natural waterways. These private hatcheries eventually evolved into the current state and federal hatchery system. State and federal hatcheries produce a number of species for restocking programs, while private commercial trout producers focus on food production of rainbow trout. Public hatcheries generally focus on the quality of the fish produced. Fish produced for enhancement purposes are produced to retain genetic integrity and characteristics needed to survive in the wild. Private hatcheries focus on maximum production to meet economic goals. Commercial producers emphasize genetic selection for fast growth and adaptation to culture conditions. These differences in goals are reflected in the different production strategies applied by public and private programs.

Trout production is the largest component of the inland stocking program. In 1982, some 200 million trout were stocked from more than 200 state and federal fish hatcheries, with states contributing roughly 80% of this total.

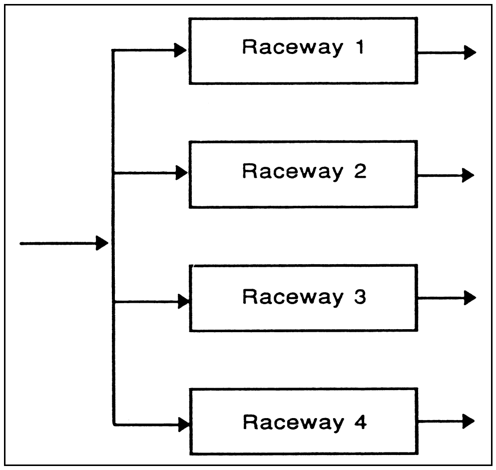
#### *4.3.2.1 Production Systems*

Most trout production facilities use flow-through systems. Flow-through systems are raceways, ponds, or tanks through which water flows continuously. Commonly, they are earthen or concrete rectangular troughs with varied dimensions and angles of pitch to allow a shallow stream of water to flow directly from one end to the other. The most common configuration for multiple raceways is either in series or in parallel. When constructed in series (Figure 4.3–1), water enters the upper raceway and then exits into a second raceway just downstream. This gravity-driven flow continues to the last raceway in the series. When raceways are constructed in parallel (Figure 4.3–2), the water source splits to flow through multiple raceways arranged parallel to each other. The water then exits the raceways into a common outflow pipe. Many large flow-through farms use a combination of the series and parallel configurations (Lawson, 1995a), shown in Figure 4.3–3. In North Carolina, raceways for trout production are typically 3 feet deep, 8 feet wide, and 40 to 60 feet long; most commercial facilities in North Carolina use concrete raceways (Dunning and Sloan, n.d.) In the southeastern United States, concrete raceways are also the most common rearing unit for commercial trout farms (Hinshaw, 2000). In Idaho the most common rearing unit is a concrete raceway with dimensions of 10 to 18 feet wide, 80 to 150 feet long, and 2.5 to 3.5 feet deep (IDEQ, n.d.).



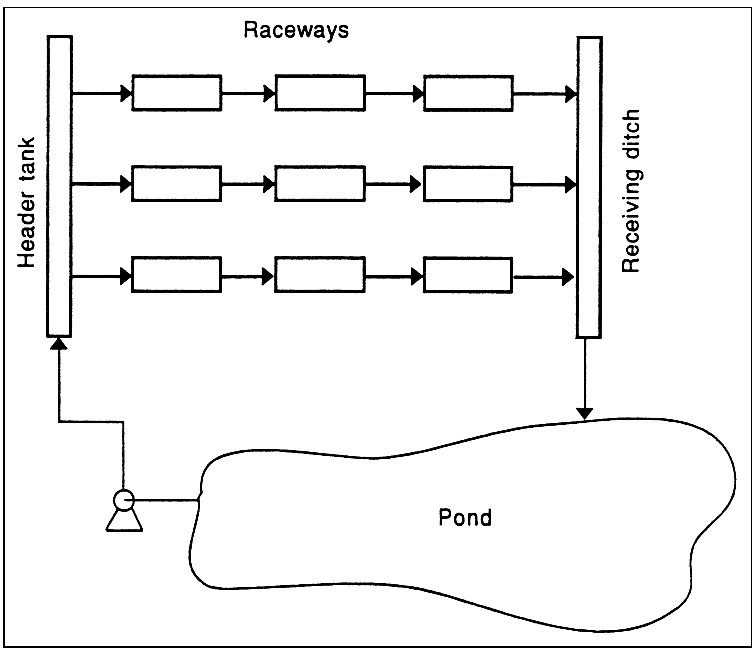

Source: Lawson, 1995a.

**Figure 4.3–1. Raceway Units in Series (a) on Flat Ground and (b) on Sloping Ground**




Source: Lawson, 1995a.

**Figure 4.3–2. Raceway Units in Parallel**




Source: Lawson, 1995a.

**Figure 4.3–3. Combination Series and Parallel Raceway Units with Water Recirculation**

### *4.3.2.2 Culture Practices*

After fertilization and water-hardening, eggs are transported to incubation systems where they are incubated undisturbed until the eyed stage (about 14 days at a water temperature of 50 °F). Handling the eggs before the eyed stage damages and kills the sensitive embryos. There are several incubation methods for trout eggs. Eggs can be placed in wire baskets or rectangular trays suspended in existing hatchery troughs. Partitions between the trays force the water to flow up through the eggs from below before spilling over into the next compartment. Water is passed through the baskets or trays, and the newly hatched fry drop through the mesh to the bottom of the trough. The second method of incubation uses specially designed hatching jars placed in rows in hatchery troughs. The third method uses vertical flow incubators, which are widely used for trout eggs. Water is introduced at one end of the top tray and flows up through the screen bottom, circulating through the eggs. The water then spills over the tray below and is aerated as it drops.

Eggs hatch in the trays and remain there until they are ready to feed. Fungal growth can affect incubation. To prevent fungal growth, it is common to treat eggs with formalin (a 37% solution of formaldehyde) at a concentration of approximately 1 part formalin to 600 parts water for 15 minutes, every 1 to 3 days (Cain and Garling, 1993). Because of the specialized skill and labor involved in spawning, as well the high cost of maintaining broodstock, many trout farmers buy eggs for incubation rather than producing their own (Cain and Garling, 1993). In the North Central Region (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin), 92% of all purchased rainbow trout eggs come from outside the region, predominantly from western states. Farmers can also purchase fingerlings from hatching facilities that specialize in incubation and fry growout.

Trout emerge from eggs with a reserve of food in a yolk sac. At this stage, they are referred to as yolk-sac fry, or alevins, and they continue to live off and obtain nutrition from their yolks for approximately 20 days at 50 °F or 10 days or less at 60 °F (Hardy et al., 2000). When the fish begin to swim up to the surface, the thin yolk sac has been absorbed, and they begin to seek food actively. If incubation does not occur in a rearing trough, sac fry are transferred to a trough shortly after hatching. Troughs for raising fry are usually 12 to 16 feet long, 12 to 18 inches wide, and 9 to 12 inches deep. Fry are typically stocked at a rate of 1,000 to 2,000 fry per square foot of trough surface area. Flow rate and temperature also affect stocking rates. The water level in the fry trough should be kept shallow until the fish begin to "swim up." When fry reach about 2 inches, they are ready for transfer to larger, deeper fingerling tanks. Fish are usually held and fed in fingerling tanks until they reach a length of about 3 inches, and then they are moved to outdoor raceways for final growout.

The maximum amount of fish in pounds that a volume of water in a raceway can support is referred to as the carrying capacity. The carrying capacity of a culture unit depends on water flow rate, water volume, water temperature, DO concentration, pH, and fish size. From the time fingerlings (about 3 inches) are stocked in raceways until they reach marketable size (12 to 16 inches), they must be graded periodically to sort the fish into similar size groups and improve feeding efficiency. Trout are typically graded four times during a production cycle. Using a rectangular frame with evenly spaced bars of aluminum tubing, PVC pipe, or wooden dowels, the grader is placed in the inflow end of the raceway and moved toward the outflow end. This crowds larger fish in the outflow area so they can be removed and stocked in another raceway with fish of similar size.

Trout are harvested by using a bar grader as described above. As the fish are crowded into a small area of the raceway, they are dipped out with a hand net or a combination of a hand net and fish pump. The ease of harvesting fish from raceways makes this type of rearing unit very popular for flow-through systems. Round tanks use crowding screens specifically designed for the tank.

*Feed Management*

Early life stages such as fry are usually hand fed. Fry need many regular feedings throughout the day; they are often observed and fed only what they can consume in a short amount of time to prevent overfeeding. Fish in production raceways may be fed with mechanical feeders or demand feeders (IDEQ, n.d.). Mechanical feeders typically deliver a predetermined amount of feed to the fish. Commercial feeder designs range from stationary units to truck-mounted units. Automatic designs, like spring-loaded belts or auger-driven feeders, deliver small amounts of feed at any one time. This method restricts fish to a set amount of food each day. Demand feeders allow fish to feed to satiation. This method allows fish to choose how much feed is needed and when feed is released. Fish activate the suspended feeder, dispensing small amounts of feed, by bumping a rod that extends to the water.

In the United States, consumers expect trout to have white meat, so they are fed diets lacking the carotenoid pigments that give trout and salmon fillets their typically red color (Hardy et al., 2000). In nature, these pigments are present in their food through natural sources such as krill, yeast, or algae, or through astaxanthin, the carotenoid pigment found in the wild, produced by chemical synthesis. In Europe and Chile, trout are expected to have pigmented meat, so the feed for these fish is supplemented with astaxanthin.

Feed, including its manufacture, storage, and delivery to the fish, is one of the most important aspects of trout AAP waste management (IDEQ, n.d.). Research by Boardman et al. (1998) showed that using high-energy feed may reduce the amount of solids leaving the system. The study showed that effluents of basins receiving standard trout grower feed generally contained higher levels of total suspended solids (TSS) than those receiving high-energy feed. Further analysis showed that effluents of basins receiving the standard grower trout feed had lower levels of TKN than those receiving a high-energy feed.

*Health Management*

Bacterial gill disease (BGD) is one of the most common diseases of cultured trout (Piper et al., 1982). Sudden lack of appetite, orientation in rows against the water current, lethargy, and riding high in the water are typical signs of BGD. Crowding, mud and silt in the water supply, and dusty starter diets are stress factors that contribute to outbreaks of the disease. The most important factor contributing to BGD is the accumulation of fish metabolic wastes due to crowding. To treat the disease, facility operators correct unfavorable water conditions, reduce stress, and use constant flow treatments with salt (NaCl), or Chloramine-T at 8 to 10 milligrams/liter (under an FDA-sponsored Investigational New Animal Drug (INAD) application) for 1 hour for 2 or 3 days. Furunculosis, another common bacterial fish disease, is generally considered a disease of salmonids. Once an infected population of trout has overcome the disease, some of the survivors become carriers. Stress and poor water quality conditions can reduce the resistance of fish, and carrier fish can experience chronic or acute infections. Healthy rearing conditions, sanitation, and use of pathogen-free fish help control furunculosis. If the bacterium is sensitive to Terramycin (oxytetracycline), facility operators can use medicated feed. Facilities may also use Romet-30. Vaccination against furunculosis can also be effective (Plumb, 1994c).

Fish health management in rainbow trout farming is based on prevention; once a disease outbreak occurs, it is difficult to treat or control (Hardy et al., 2000). Farmers keep raceways clean, use high-quality feed, prevent overcrowding, minimize disease vectors, and vaccinate stocks. Vaccination has been very effective in preventing some important diseases in rainbow trout (Hardy et al., 2000). Birds are a common disease vector because they move from farm to farm and eat diseased fish. Most farms in Idaho use netting to restrict birds' access to trout raceways. Use of antibiotics delivered in feed to treat rainbow trout is not a common practice. Antibiotic use is limited by cost and by the regulation of their use in trout farming. Only two antibiotics (Terramycin and Romet-30) have been approved for use in the United States for fish, and they are not typically effective against many trout diseases. According to reports from site visits conducted by EPA, several trout production facilities in Idaho use vaccination programs to prevent disease rather than treating sick fish with antibiotics (Tetra Tech, 2002a; Tetra Tech, 2002b).

#### *4.3.2.3 Water Quality Management and Current Treatment Practices*

*Water Quality Management Practices*

Flow-through systems require large inputs of high-quality, oxygenated water. In the trout culture industries in the northeast and northwest United States, freshwater springs are the most common source of water because of their relatively low and constant water temperatures (Lawson, 1995b). Water supplies may also come from surface waters such as streams, rivers, and irrigation returns. In western North Carolina, most water supplies come from surface waters that have been diverted for use by the facility (Tetra Tech, 2002a).

Concrete raceways have the advantage that there is no erosion of the sides, as happens with earthen ponds or raceways. This also means that these raceways can be operated at higher flow rates. The water flowing in delivers the needed oxygen to the fish while carrying away the dissolved metabolic waste products as the water exits the pond, or they are passed on to the pond below if raceways are positioned in series. These metabolic waste components must be kept within safe concentrations for the fish being raised. Concentrations of un-ionized ammonia-nitrogen need to be controlled to limit the impacts of this highly toxic compound.

DO is another important limiting factor in flow-through systems. These systems often use gravity aerators to supplement the oxygen supply. Gravity aerators are often called waterfall aerators or cascades (Lawson, 1995c). They use the energy released when water loses altitude to transfer oxygen. Based on local topography, if a sufficient gradient exists, gravity fall is a common method for aerating flow-through systems. Man-made gravity aerators include components such as weirs, splashboards, lattices, or screens, which break up water to increase surface area and oxygen transfer. For example, facilities may use a combination of splashboards and weirs between raceways to create gravity aerators. Aeration or oxygenation can minimize the impact of DO as a factor limiting production. The greater the flow of water through the raceway, the more oxygen is delivered and the more fish can be supported.

In a study conducted by Boardman et al. (1998), three trout farms in Virginia were selected to represent fish farms throughout Virginia (Table 4.3–4). Sampling and monitoring (Table 4.3–5) at all three sites revealed that little change in water quality between influents and effluents occurred during normal conditions at each facility. Raceway water quality, however, declined during heavy facility activity like feeding, harvesting, and cleaning. During a 5-day intensive study, high TSS values were correlated with feeding events. TKN and ortho-phosphate (OP) concentrations also increased during feeding and harvesting activities. Overall, most samples taken during this study had relatively low solids concentrations, but high flows through these facilities increased the total mass loadings.

**Table 4.3–4. Site Characteristics of Trout Farms**

| ***Characteristic*** | ***FARM*** | | |
|---|---|---|---|
| | ***A*** | ***B*** | ***C*** |
| Average production (lb/yr) | 59,965–80,027 | 59,965 | 175,045–250,002 |
| Fish type | Rainbow, brook | Rainbow | Rainbow, brook, brown |
| # Raceways in use (total #) | 3 (7) | 14 (14) | 24 (31) |
| Feeding practice | Automated (pull string) | Hand (measured) | Hand (measured) |
| Reported feed conversion ratios (FCRs) | 1.6 | 1.6–2 | 1.2–1.8 |
| Concrete/earthen-lined | Concrete | Both | Both |
| Water source | Spring | Spring | Spring |
| Labor | 1 person | 1 person | 4–6 people |
| Pollutants regulated | TSS, $NH_3$-N, SS | TSS, $BOD_5$, SS | TSS, $BOD_5$, $NH_3$-N, SS |
| Treatments | Sediment traps | None | Sediment traps |

Source: Boardman et al., 1998.

**Table 4.3–5. Water Quality Data**

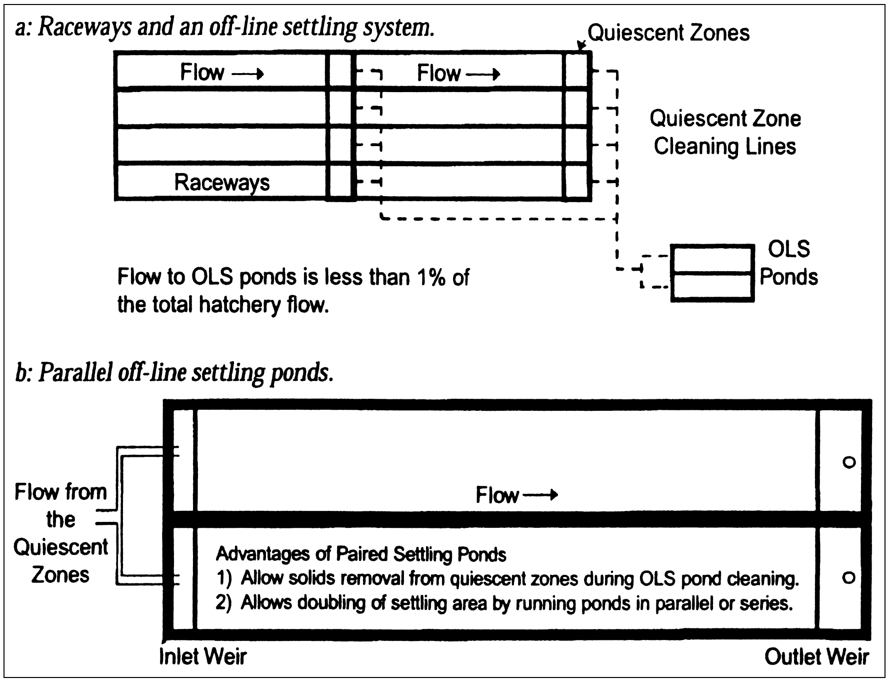
| ***Parameter*** | ***FARM A*** | | | ***FARM B*** | | | ***FARM C*** | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***Inlet*** | ***Within Farm*** | ***Outlet*** | ***Inlet*** | ***Within Farm*** | ***Outlet*** | ***Inlet*** | ***Within Farm*** | ***Outlet*** |
| Flow (mgd) | 1.03–1.54 (1.18) | | | 4.26–9.43 (6.39) | | | 9.74–10.99 (10.54) | | |
| DO (mg/L) | 9.2–14.2 (10.6 | 3.2–13.3 (7.0) | 5.7–9.5 (8.5) | 8.2–11.5 (10.5) | 5.8–10.8 (8.6) | 6.8–9.6 (7.9) | 9.4–10.6 (10.5) | 4.8–9.7 (7.6) | 7.2–9.4 (8.1) |
| Temp (ºC) | 10.5–13 (12.2) | 11.5–15 (13) | 11–15.5 (12.9) | 6–12.5 (9.7) | 6–14 (9.1) | 5–16.5 (11.4) | 8.5–13.5 (10.5) | 8–14 (11.0) | 8.5–14 (10.4) |
| pH (SU) | 7.1–7.4 (7.3) | 7.0–7.4 (7.2) | 7.3–7.8 (7.5) | 7.3–7.6 (7.5) | 7.2–7.6 (7.4) | 6.9 | 7.3 | 7.1–7.6 (7.3) | 7.8 |
| TSS (mg/L) | 0–1.1 (0.2) | 0–30.4 (3.9) | 0.8–6 (3.2) | 0–1.8 (0.5) | 0–43.7 (5.3) | 1.5–7.5 (3.9) | 0–1.5 (0.3) | 0–28 (7.1) | 4.1–62 (6.1)[a] |

| **Parameter** | **FARM A** | | | **FARM B** | | | **FARM C** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Inlet** | **Within Farm** | **Outlet** | **Inlet** | **Within Farm** | **Outlet** | **Inlet** | **Within Farm** | **Outlet** |
| SS (ml/l) | ND[b] | | 0–0.04 (0.02) | ND | | 0.01–0.08 (0.04) | ND | | 0.04–0.08 (0.07) |
| $BOD_5$ (mg/L) | 0–1.25 (0.7) | 0.5–3.9 (1.5) | 0.96–1.9 (1.3) | 0–1.4 (0.5) | 0.3–7.2 (2.1) | 0.6–2.4 (1.2) | 0–2.0 (1.1) | 0.4–7.5 (2.5) | 0.5–1.8 (1.3) |
| DOC (mg/L) | 0.93–4.11 (2.1) | 0.9–7.9 (2.9) | 1.5–2.4 (1.9) | 0.91–2.56 (1.6) | 1.2–8.1 (2.7) | 1.2–3.1 (1.9) | 1.1–2.7 (2.0) | 1.1–11.1 (2.4) | 1.5–3.8 (2.3) |
| $NH_3$-N (mg/L) | 0.6 | 0.2–1.1 (0.5) | 0.5–0.6 (0.6) | 0.2 | 0.06–1.1 (0.5) | 0.45 | 0.03 | 0.03–2.2 (0.4) | 0.02–0.17 (0.1) |

[a] Two outliers were not included in the calculation of mean.
[b] ND: Non-detect
Source: Boardman et al., 1998.
Note: Averages are in parentheses.

Quiescent zones are the primary areas where solids are collected in a raceway. These zones are downstream of the rearing area, without fish, which allows bio-solids to settle undisturbed while intact and large in size (IDEQ, n.d.). Typically, quiescent zones are part of each trough or raceway; their dimensions account for the settling velocity of particles. The swimming activity of larger fish helps move solids downstream into settling zones. The most common method of solids removal from quiescent zones is through a vacuum head (IDEQ, n.d.). Usually, standpipes in each quiescent zone connect to a common 4- to 8-inch PVC pipe, which carries the slurry of water and solids to the offline destination. In *Idaho Waste Management Guidelines for Aquaculture Operations* (IDEQ, n.d.), the state recommends cleaning quiescent zones as often as possible, with a minimum of twice per month on lower raceway sets and once per month on upper raceway sets. Last-use quiescent zones should be cleaned most frequently.

Offline settling (OLS) ponds are settling zones that receive the water and solids slurry from the quiescent zones (Figure 4.3–4). These ponds can be earthen or concrete and are the second settling zone in the solids collection system. Quiescent zones, in combination with OLS ponds, are the most commonly used solids collection and removal system for trout farming in Idaho (IDEQ, n.d.). Flow to OLS ponds is usually very small when compared to the total facility flow. OLS pond effluent is typically less than 1.5% of the total flow during daytime working hours and less than 0.75% averaged over 24 hours. The depth of a typical OLS pond is 3.5 feet, but some are deeper. Depth is not required for settling efficiency but is required for solids storage. The Idaho Department of Environmental Quality recommends that, at a minimum, OLS ponds should be cleaned every 6 months In Idaho most trout production operators remove the solids from OLS ponds when TSS levels approach 100 milligrams/liter. Many facilities in the state have several OLS ponds, which are linked together to improve solids collection. When one pond is undergoing solids harvest, the other is receiving solids from the quiescent zones. To remove the solids, the inflow is diverted to another OLS pond, and the supernate from



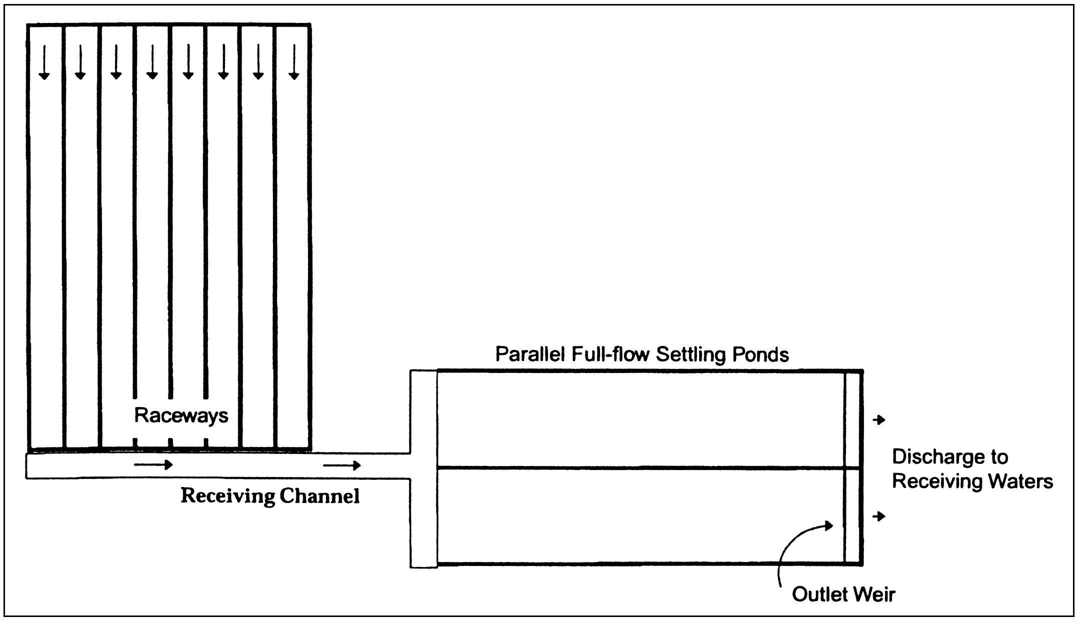

Source: IDEQ, n.d.

**Figure 4.3–4. Offline Settling Ponds**

the pond being harvested is moved to an adjacent pond. Earthen ponds are allowed to dry for a few days, and the solids are removed by a backhoe from the pond bank. In a concrete pond, the OLS pond has a ramp where a front-end loader can enter the pond to remove solids.

Some trout facilities use full-flow settling (FFS) ponds (Figure 4.3–5), which may not include quiescent zones or OLS ponds. The FFS system has one or two large settling zones, which collect the solids from the water flow for the entire facility. Instead of removing solids from individual raceways or troughs, the water from all of the rearing units combines and enters the FFS pond, where the solids are collected. FFS ponds are typically used by smaller facilities with low flow volumes.

In the study of Virginia trout farms by Boardman et al. (1998), waste solid accumulations in quiescent zones were monitored to quantify the capacity and trapping efficiency of the units. Solids were found to accumulate at a rapid rate (more than 7,800 centimeters/day or 256 feet/day); however, the trapping efficiency of the units was found to be extremely low when taking into account the FCRs and typical utilization rates of production fish. High overflow rates, particle degradation, flow spikes, and high sludge banks led to scouring of waste solids and a point of maximum capacity for the sediment trap.




Source: IDEQ, n.d.

**Figure 4.3–5. Use of Full-Flow Settling Ponds to Treat 100% of the Flow From the Fish Farm Before it is Discharged**

*Sludge Treatment and Disposal*

Once solids are removed from OLS ponds or FFS ponds, they are stored or used in ways that minimize their impact on groundwater or surface waters. In Idaho, land application of collected solids to cropland has become the easiest and most widely adopted technique to dispose of wastes and recycle nutrients from trout production settling ponds (IDEQ, n.d.). Regulations vary from state to state, but most allow for aquacultural solid wastes to be applied to land because of minimal concentrations of metals, pathogens, and toxic substances in the sludge. The rate at which sludge may be applied to land varies based on soil type, plant type, odor issues, and sludge nutrient content.

Composting is another popular sludge disposal and treatment option (Boardman et al., 1998). When large areas of land are not available for land application or transportation costs for disposal are high, composting represents a good alternative (IDEQ, n.d.). Because of high costs, landfills are one of the least common means of disposing of solid wastes from concentrated aquatic animal production (CAAP) facilities; however, some states are required to take their sludge to a landfill, where the states regulate the waste as industrial, rather than agricultural, waste (Boardman et al., 1998).

### 4.3.3 Salmon

Two distinct sectors influence salmon AAP: production for foodfish and production for stocking to restore wild stocks for conservation and recreation. In the United States, private salmon farming for foodfish production began in Washington state in the early 1970s with farms producing pan-sized coho salmon (*Oncorhynchus kisutch*) in marine net pens (Roberts and Hardy, 2000).

Public hatchery stocking programs are dominated by production of coldwater fish (salmonids). Most salmonids stocked in the United States are Pacific salmon released as smolts into various river systems connected to the Pacific Ocean. In the Columbia River Basin, more than 90 state and federal hatcheries raise and release roughly 190 million juvenile Pacific salmon annually (Schramm and Piper, 1995).

Atlantic salmon dominates commercial production in the United States. Although salmon was traditionally sold smoked or canned, today most salmon is sold frozen or fresh. According to the 1998 Census of Aquaculture (USDA, 2000), 45 farms produced salmon commercially in the United States, producing more than 110 million pounds in food-size fish. In 1998 the salmon AAP sector generated more than $103 million in revenue (USDA, 2000). The 1998 Census of Aqaculture data show that three states, Alaska with 19 farms, Maine with 12 farms, and Washington with 9 farms, are the largest producers of salmon in the United States (USDA, 2000). Alaska, which prohibits private farming of all fish species, has 19 salmon hatcheries that are operated as private nonprofit corporations. They raise smolts and release them into the wild, where they are later harvested from the ocean in a practice called ocean ranching.

Both Atlantic and Pacific salmon belong to the Salmonidae family, which also includes trout and whitefish. Atlantic salmon has its own genus, *Salmo*, while the five primary species of Pacific salmon belong to the genus *Oncorhynchus*. In the United States, there are five species of Pacific salmon: pink (*O. gorbuscha*), chum (*O. keta*), sockeye (*O. nerka*), chinook (*O. tshawytscha*), and coho (*O. kisutch*).

Wild salmon begin their life cycle as eggs in the gravel of cold, freshwater rivers and streams. When females reach freshwater spawning grounds, they use their caudal fin to excavate a nest, or redd, in the gravel riverbed. Females deposit their eggs in layers as they are fertilized by the male salmon. The female covers the eggs with gravel and guards the nest for up to 2 weeks. In 2 to 6 months, the eggs hatch into translucent hatchlings called alevins and obtain nutrition from their yolk sacs. After 3 to 4 months, the inch-long salmon fry emerge from the gravel and begin foraging for food in the river. As the fry grow into fingerlings, they move to a lake to mature as fingerlings before smoltification. Chum and pink salmon spend little time (1 to 3 months) in freshwater before moving to sea. Chinook begin to move to sea within 6 months, while coho usually stay in freshwater for up to 1 year, and sockeye salmon stay in freshwater for 1 to 3 years.

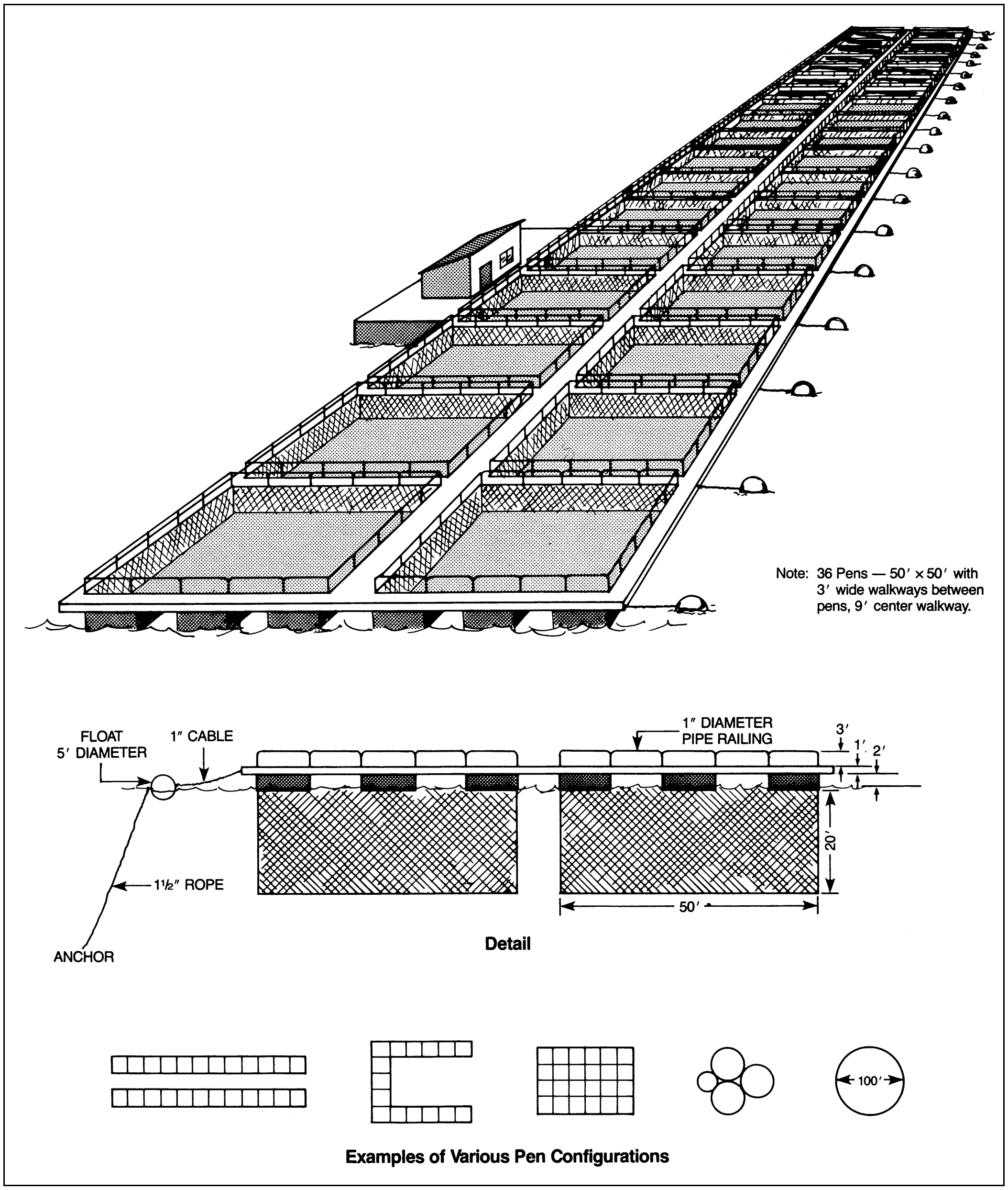
When they reach 2 inches in length, Pacific salmon begin feeding on insects, worms, and other invertebrates. As they develop dark vertical bar markings, they are called parr. At about 6 inches, Pacific salmon begin moving to sea. The physiological changes salmon make to switch from a freshwater to a saltwater environment are collectively called smoltification. After smoltification, salmon remain in the sea for 1 to 5 years, depending on the species, feeding and growing to sexual maturity and then returning to freshwater streams to spawn. Atlantic salmon parr may remain in freshwater for as long as 8 years before moving to sea (Weber, 1997). Most salmon species die after spawning, but Atlantic salmon can spawn several times, returning to the sea between events.

#### *4.3.3.1 Production Systems*

There are two types of salmon AAP, salmon farming and salmon ranching (or ocean ranching). Salmon farming involves two phases: (1) the freshwater hatchery phase for the incubation of eggs and the raising of juveniles to the smolt stage and (2) the seawater phase, in which the salmon are grown out to market size, usually in floating pens (Clarke, 2000). Salmon ranching, which is practiced primarily in Alaska, is an alternative form of AAP that involves the release of smolts from hatcheries and the harvest of adults returning from the ocean.

The hatchery or freshwater stage begins when fertilized eggs are placed in hatcheries operated with oxygenated water. Salmon hatcheries generally use flow-through systems; some partial recirculation systems are used to conserve heat during egg incubation. Stacked trays, upwelling jars, or troughs may be used as egg incubators. The salmon life cycle makes it possible for fish farmers to raise juvenile salmon in land-based tank and raceway operations before growing them out in marine environment net pens or cages. Young fish are raised in upland hatcheries until they become smolts; on the west coast, however, parr are often placed in estuarine pens of reduced salinity, and some fish are raised to maturity in freshwater. Smolts are then transferred to net pens (i.e., salmon farming), where they remain for 1 to 2 years until they reach market size. In Alaska, Pacific salmon (coho and chinook) are commonly raised in marine net pens for periods of 1 to 6 months before release by public agencies or Native American tribes for enhancement projects. These fish are stocked as late parr or smolt and released after growing in the pens (i.e., salmon ranching). Holding salmon later than their normal smolt outmigration timing causes them to residualize in the nearshore waters, a technique used to enhance the sport fishery.

Generally, flow-through systems are used in the hatchery phase for the production of smolts. Raceways, tanks, or ponds are used to grow juvenile salmon until they undergo smoltification. Saltwater production normally begins after smoltification when the salmon are moved to net pen systems, which is the dominant production mode in saltwater salmon farming in coastal waters (Figure 4.3–6). The advantages of net pen cage farm systems in marine environments are relatively low capital cost per unit of rearing volume, reduced risks of stock loss through system failure and low DO, and access to large volumes of relatively high quality water without pumping costs (Karlsen, 1993). The primary disadvantages of marine net pen systems are increased risks due to storm damage; a complicated, lengthy, and expensive permitting process; a reduced ability to manipulate environmental conditions such as water temperature; and a potentially increased risk of predation and disease transmission from wild animals.




Source: WDF, 1990.

**Figure 4.3–6. Example of a Fish Farm and Various Pen Configurations**

### *4.3.3.2 Culture Practices*

Broodstock may be collected from the wild or raised at a hatchery facility. The goals of a hatchery program raising salmon to be released into the wild are different from the goals of a hatchery raising salmon for commercial production. Domestication is an important characteristic for salmon raised for commercial production, but hatcheries want to avoid the domestication of salmon that are to be released into the wild (Pepper and Crim, 1996). For enhancement production, broodstock should be chosen from wild stocks. For commercial foodfish production, broodstock may be either collected from the wild or bred and raised at a hatchery facility.

There are several types of incubators, but generally they all have a container with sufficient water flowing through it and some type of screened enclosure to prevent eggs and larvae from being washed away (Billard and Jensen, 1996). After hatching, the salmon, now called alevins, have a large yolk sac reserve. As they near the completion of the yolk absorption, alevins leave the substrate and become free-swimming fry (Pennell and McLean, 1996). The timing of emergence occurs as the alevins complete the absorption of the yolk sac. Emergence is influenced by factors such as light, substrate type, and changes in temperature and oxygen concentrations.

The initial presentation of food is a critical stage in salmon culture because it marks the transition between incubation and raising (Pennell and McLean, 1996). The fry are then transferred to rearing units. Flow-through raceways, both earthen and concrete, are the most common rearing units used for juvenile salmon culture (Pennell and McLean, 1996).

*Production for Release*

Pacific salmon species dominate production for release. Alaska hatcheries incubate approximately 100 million sockeye salmon eggs per year. Most of the fry are stocked into lakes not accessible to wild salmon and allowed to develop into smolts under natural conditions (Clarke et al., 1996). Atlantic salmon are more challenging to cultivate for release because of their slower growth rates and large smolt size. Most smolt production hatcheries use elevated temperature to speed incubation, advance the time of the first feeding, and optimize feeding during the summer (Clarke et al., 1996).

*Production for Commercial Culture*

For Atlantic salmon, smolt production for either stock enhancement or commercial AAP is most efficient when done in the shortest amount of time to minimize costs (Clarke et al., 1996). Atlantic salmon usually require 2 years of growth to reach the smolt stage in nature, but in commercial production, practices have allowed facilities to produce smolts in the first year by manipulating favorable temperatures, using high-energy feed, and applying good husbandry practices to minimize stress and disease (Clarke et al., 1996).

After smoltification, salmon for foodfish production are transferred to net pens for growout to market size. After the smolts are introduced to saltwater net pens, farmers monitor the progress of the salmon as they adjust to saltwater. Atlantic salmon, which can be especially sensitive, may need several days to resume proper feeding and acclimate to the net pens (Novotny and Pennell, 1996).

*Harvest Practices*

A decade ago, the growout phase in net pens required at least 2 years. Today, salmon can reach harvest size in 10 to 15 months after their transfer to net pens. Changes in feed formulation, feed pelletizing technology, the introduction of effective vaccines, and the domestication of farmed salmon stocks has shortened the time needed to grow salmon to harvest size (Roberts and Hardy, 2000). Today, after 12 to 18 months in net pens, fish are ready to harvest at weights ranging from 5 to 11 pounds (Novotny and Pennell, 1996). Because the salmon market is driven by quality of fish, farms emphasize quality control for harvest. Prior to harvesting, fish go through a period of starvation to reduce the fat content in the muscle tissue and the flora in the gut. This practice increases the shelf life of the salmon product (Novotny and Pennell, 1996). Fish are crowded into one corner of the pen and then pumped out with a fish pump or fish escalator and through a grader.

*Feed Management*

Feeding practices include hand feeding and a variety of mechanical feeders (Novotny and Pennell, 1996). Smaller cages with a low biomass of fish rely mostly on hand feeding. This requires cages placed nearshore with land access, a dock, or a small boat. Most net pen systems contain a large biomass of fish (e.g., 30,000 fish with a harvest weight of about 8 to 10 pounds) and require the use of mechanical feeders. For net pens that are single structures without supporting walkways, barges and boats with feed blowers take feed to the net pens and feed, usually once or twice a day. Bad weather can impede this method of feeding. Other facilities use a stationary blower to deliver feed to each net pen in a group of pens. To control overfeeding, many facilities also use underwater cameras to monitor feed consumption (Nash, 2001).

*Health Management*

To prevent transmission of diseases, salmonid eggs are sometimes disinfected at the time of fertilization or at the eyed stage. The common treatment used is the iodophor Povidine with a 1% to 2% concentration of active iodine, which is similar to iodine but not as corrosive (Billard and Jensen, 1996). About 1 quart of solution with 100 parts per million (active iodine) is applied to every 2,000 eggs for a period of 10 minutes, followed by a rinsing. Formalin is also used to prevent the spread of fungus (*Saprolegnia)* infections in eggs.

Freshwater salmonid diseases that have been observed in Pacific salmon hatcheries in the Pacific Northwest include furunculosis, bacterial gill disease, bacterial kidney disease, botulism, enteric redmouth disease, coldwater disease, columnaris, infectious hematopoietic necrosis, infectious pancreatic necrosis, viral hemorrhagic septicemia, and erythrocytic inclusion body syndrome. Pacific salmon hatcheries have also had outbreaks of a large number of parasitic infections like gyrodactylus, nanophyetus, costia, trichodina, ceratomyxosis, proliferative kidney disease, whirling disease, and ichthyophonis (Nash, 2001). Atlantic salmon are especially susceptible to furunculosis. The frequency of pathogen occurrences varies geographically. For example, a greater percentage of Alaska hatcheries tested positive for infectious hematopoietic necrosis, viral hemorrhagic septicemia, furunculosis, and ceratomyxosis between 1988 and 1992 than hatcheries located in other western states.

In the past, oral delivery of oxytetracycline in the feed was the standard treatment. Today, the use of vaccines is a common industry practice. Immersion and injected vaccines have been so successful and so commonly used that antibiotic treatment is infrequent (Novotny and Pennell, 1996).

Several drugs have been approved by the FDA for use in salmonid AAP (FDA, 2002). Oxytetracycline is approved for use in Pacific salmon for marking skeletal tissue and for use in salmonids to control ulcer disease, furunculosis, bacterial hemorrhagic septicemia, and pseudomonas disease. Sulfadimethoxine is approved for use in salmonids to control furunculosis. Tricaine methanesulfonate is approved for use as a sedative or as an anesthesia, and formalin is approved for use in salmon culture to control protozoa (*Chilodonella, Costia, Epistylis, Ichthyophthirius, Scyphidia, Trichodina* spp.) and monogenetic trematodes. Formalin is also approved for use on salmon eggs to control fungi of the family Saprolegniaceae.

#### *4.3.3.3 Water Quality Management*

*Hatchery Water Quality Characteristics*

Like other flow-through systems, hatcheries for salmon smolt production rely on a clean water supply with a consistent temperature. Water quality management in the system, including the raceways, directly affects the quality of effluents and the volume of discharge released from the rearing unit.

In a study by Kendra (1991), salmonid hatchery effluents from 20 different facilities (11 state and 9 commercial) in Washington state were monitored during the summer low-flow season. Relative to source water, effluents from salmonid hatcheries had elevated levels for temperature, pH, solids, ammonia, organic nitrogen, total phosphorus, and oxygen demand. Cleaning events elevated concentrations of solids, nutrients, and oxygen demand (Table 4.3–6). Salmonid smolts in Washington are typically released from state hatcheries through the drawdown of the rearing unit or pond. Near the completion of the release event, samples indicated increases in solids, nutrients, and oxygen demand. As the pond depth decreased, fish crowding increased the amount of disturbed accumulated sediments.

This study (Kendra, 1991) also measured the impact of effluent on receiving waters and found that benthic communities below hatchery outfalls were different from those located upstream or farther downstream. Three of the four hatchery discharges in the benthic community study caused a depression of taxa sensitive to organic pollutants. Several mayfly and stonefly species were eliminated below the outfall, as well as elmid beetles. Some invertebrates, such as mollusc families, planarians, and oligochaetes, were enhanced by the hatchery discharge (Kendra, 1991). As a result of this study, the hatchery National Pollutant Discharge Elimination System (NPDES) permit limits in Washington were revised to include primary settling of solid wastes as a minimum requirement for all hatcheries.

**Table 4.3–6. Hatchery Effluent Quality During Cleaning and Drawdown Events**

| *Cleaning Events* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | *Units* | *Yakima Trout Hatchery (Single Raceway)* | | *Aberdeen Trout Hatchery (Multiple Raceway Composite)* | | *Drawdown Event, Naselle Salmon Hatchery (Rearing Pond)* | | |
| | | *Normal* | *Cleaning* | *Normal* | *Cleaning* | *Prior to Drawdown* | *Drawdown Midpoint* | *Drawdown Near End* |
| pH | SU | 7.4 | 7.6 | — | — | 7.6 | 6.7 | 7.1 |
| DO | mg/L | 4.4 | 6.8 | 8.4 | 7.7 | 9.8 | 7.0 | 12.1 |
| TSS | mg/L | 1 | 88 | 1 | 12 | 7 | 30 | 94 |

| Variable | Units | Cleaning Events: Yakima Trout Hatchery (Single Raceway) | | Aberdeen Trout Hatchery (Multiple Raceway Composite) | | Drawdown Event, Naselle Salmon Hatchery (Rearing Pond) | | |
|---|---|---|---|---|---|---|---|---|
| | | Normal | Cleaning | Normal | Cleaning | Prior to Drawdown | Drawdown Midpoint | Drawdown Near End |
| Total volatile suspended solids | mg/L | 0 | 69 | <1 | 8 | 3 | 8 | 25 |
| Settleable solids | mL/L | <0.1 | 2.5 | <0.1 | 0.1 | <0.1 | 0.3 | 1.1 |
| Total Kjeldahl nitrogen | mg N/L | 0.43 | 1.7 | 0.20 | 0.82 | 0.30 | 0.52 | 1.3 |
| Total phosphorus | mg P/L | 0.22 | 4.0 | 0.03 | 0.56 | 0.03 | 0.30 | 0.11 |
| Chemical oxygen demand | mg/L | 6 | 130 | 6 | 21 | 6 | 18 | 56 |
| Biochemical oxygen demand (5-day) | mg/L | 3 | 32 | 4 | 12 | <3 | 3 | — |

Source: Kendra, 1991.

### *Net Pen Water Quality*

In a study by the Washington Department of Fisheries (WDF, 1990) to evaluate the environmental impacts of commercial culture of fish in net pens, several water quality parameters were analyzed and potential impacts on the surrounding environment were evaluated. The EIS study by the Washington Department of Fisheries concluded that fish farms were not likely to have a significant impact on DO levels in Puget Sound except during the summer or autumn at sites that had low background DO levels and did not have adequate flushing (WDF, 1990). Overall, field measurements indicated that the area affected by low DO levels was less than 165 feet around the net pen structures.

Salmon net pens might also cause or increase phytoplankton blooms by increasing localized nutrient enrichment (Weston, 1986). Excessive phytoplankton growth can cause eutrophication. In a summary of experiments and modeling for phytoplankton impacts, the WDF assessment concluded that nutrients added by net pen operations were not likely to adversely affect phytoplankton abundance in Puget Sound. Model results for five 500,000 pounds/year farms showed an average increase of 0.0085 milligrams/liter in nitrogen concentrations in winter conditions, or less than 1% increase in total nitrogen concentrations (Table 4.3–7). During the summer, the model predicted a 2% increase in phytoplankton biomass. The study did note, however, that poorly flushed bays are more sensitive to nutrient loading and that areas identified as nutrient-sensitive should limit total fish production. The study also recommended locating farms to minimize the overlap of near-field conditions from multiple farms.

**Table 4.3–7. Effect of Five Fish Farms in an Embayment on the Nitrogen, Phytoplankton, and Zooplankton Concentrations for Summer and Winter Conditions Based on the Kieffer and Atkinson Model (1988)**

| | ***Dissolved Nitrogen (mg/L)*** | | ***Phytoplankton (mg/L)*** | | ***Zooplankton (mg/L)*** | |
|---|---|---|---|---|---|---|
| | ***Ambient*** | ***Increase*** | ***Ambient*** | ***Increase*** | ***Ambient*** | ***Increase*** |
| Winter | 1.5 | 0.0085 | 0.012 | 0 | 0.003 | 0 |
| Summer | 0.012 | 0 | 0.186 | 0.004 | 0.186 | 0.004 |

Source: WDF, 1990.

In a technical memorandum prepared by the National Oceanic and Atmospheric Association (NOAA) (Nash, 2001), the report identified three key issues of net pen salmon farming in the Pacific Northwest that appear to carry the most risk: the impact of bio-deposits (uneaten feed and feces), the impact on benthic communities of the accumulation of heavy metals in sediments below the net pens, and the impact on nontarget organisms from the use of therapeutic compounds (pharmaceuticals and pesticides) at net pen farms.

Sediment deposits beneath net pen operations affect benthic communities. Biodeposits from uneaten feed and fish fecal matter settle onto sediments near net pens and affect the chemistry of the sediment and the benthic community (Nash, 2001). Sedimentation from salmon farms changes the total volatile solids and sulfur chemistry in the sediments in the immediate area surrounding the net pens. At sites with poor water circulation, deposit accumulations can exceed the aerobic assimilative capacity of sediments, leading to reduced oxygen tension and significant changes in the benthic community. The accumulation of organic wastes in the sediments can also change the abundance and diversity of the benthic infaunal communities.

The impact on benthic communities of the accumulation of heavy metals in the sediments below the net pens was also identified as a significant impact from salmon farming (Nash, 2001). Both copper, from marine antifouling compounds used on net pens, and zinc, from fish feeds, can be toxic in their ionic forms to marine organisms. Higher concentrations of sulfide in the sediment reduce the availability of both copper and zinc, which could make the observed concentrations near net pens nontoxic.

Results from a sampling program in the Broughton Archipelago in British Columbia confirmed that organic waste material was accumulating at a rate faster than the rate of decomposition beneath salmon net pen farms (Deniseger and Erickson, 1998). Sediments from 30 active fish farms were surveyed for physical and chemical characteristics. Researchers found that material accumulations can be significant (greater than about 1 foot). Sedimentation affects the benthic community by creating anaerobic conditions, which can persist for up to 1.5 years or more (Erickson, 1999, personal communication). Additional information about net pen water quality is available from Mosso et al., 2003.

*Current Treatment Practices in Net Pen Systems*

The same advantages that make the net pen systems favorable for production are also the characteristics that limit the use of treatment practices. Net pens are open systems that use natural water currents and tides for water supplies and flushing. Relative to pond and raceway facilities, net pen systems have several advantages, including the following: land requirements are minimal, construction and capital costs are generally lower, and there are virtually no pumping costs (Weston, 1992). From an effluent treatment perspective, however, net pen culture creates unique challenges. Because the effluent is not confined, treatment of dissolved wastes does not appear possible, and the treatment or removal of solid wastes has several technical difficulties (Weston, 1992). For the most part, the industry relies on dispersal and dilution of waste by natural water currents to maintain water quality for fish production and to minimize environmental impacts (Weston, 1992). The most effective way of reducing water pollution from net pen facilities is to minimize the loss of feed (Bergheim et al., 1991)

Most net pens are inspected by divers on a regular basis. The divers look for holes in the nets, dead fish, and fouling problems. State regulatory programs require benthic monitoring at many net pen sites to ensure that degradation is not occurring under or around the net pens. Other current requirements include video recordings in the spring and fall of the bottom beneath and adjacent to the cages; biennial sediment redox layer depth determinations (which measure sediment chemistry) during the fall; monitoring and reporting monthly feed use; and monitoring and reporting water quality, nutrients, and phytoplankton at farfield sites at four separate water depths. Prior to placement in pens, Atlantic salmon smolt/juveniles must be marked to link the identity of each fish to the facility. In Maine, reproductively viable non-North American Atlantic salmon stocks and transgenic salmonids are prohibited at CAAP facilities (USEPA, 2002).

BMPs required for fish pen operations in Maine include mortality removal; prohibition of disposal of feed bags or other solid wastes into U.S. waters; prohibition of discharge associated with pressure washing of nets; operation of facilities to minimize the concentration of net-fouling organisms; prohibition of biocides, tributyltin compounds, and storage of predator control or containment nets on the sea floor; minimizing the loss of unconsumed food and food fines from pens; reporting requirements for events such as fish kills, algal blooms, and confirmation of fish infected with infectious salmon anemia or other transmittable disease; and damage to a net pen that could result in salmon escapement. BMPs for disease control include using FDA-approved drugs. Unapproved drugs, including drugs in the INAD program, are prohibited. There is also a reporting requirement for all drugs discharged within 30 days of application (USEPA, 2002).

### 4.3.4 Striped Bass

Striped bass (*Morone saxatilis*) were originally produced and stocked in freshwater impoundments primarily for recreational purposes. Interest in hybrid striped bass for foodfish production in the United States began in the late 1970s. Production of food-size hybrid striped bass in the United States grew from about 1 million pounds in 1990 to more than 10 million pounds in 1996 (Harrell and Webster, 1997).

One of four *Morone* species, the striped bass is a major sport and commercial species native to the Atlantic and Gulf coasts of the United States, with stockings that have expanded its range throughout much of North America (Kohler, 2000a). The other *Morone* species are white bass *(M. chrysops*), yellow bass (*M. mississippiensis*), and white perch (*M. americana*). When a reproducing population of striped bass was discovered in landlocked Santee Cooper Reservoir in South Carolina, fisheries biologists were interested in stocking striped bass in reservoirs for sport fishing and as a predator to control underutilized forage species. *Morone* hybridization programs began in the 1960s and focused on combining characteristics of recreational trophy fish with adaptability to landlocked freshwater systems (Kohler, 2000a).

In 1965, Robert Stevens, of the South Carolina Wildlife Resources Department, initiated the production of hybrid striped bass by crossing striped bass with white bass. The first hybrid striped bass cross, of the striped bass female with the white bass male, was initially called the original cross-hybrid striped bass, but it is now referred to as the palmetto bass. The reciprocal hybrid striped bass cross of the white bass female with the striped bass male is called the sunshine bass. Of the various crosses and backcrosses made, only the hybrid of a striped bass crossed with a white bass has gained wide acceptance as a cultured species.

#### *4.3.4.1 Production Systems*

The industry has two main components: fingerling production and growout production. Some farmers are involved in both sectors, but most farms focus on either fingerling or growout production.

Hybrid striped bass are frequently sorted by size, or phases, to keep fish of similar size together and prevent cannibalism. Hybrid striped bass fry and phase I (approximately 0.2 inches) fingerlings in ponds feed on zooplankton until they reach about 0.2 inches in size, when they must be trained to accept artificial feeds to decrease the chances of cannibalism. Often fish are harvested, graded, and stocked into tanks for training on feed and then are reintroduced into growout ponds as phase II fish (Harrell, 1997).

Foodfish are often stocked to achieve maximum densities of about 5,000 to 6,000 pounds/acre. They must be completely harvested before restocking. The ponds are drained between harvesting and restocking. To avoid draining the ponds, some farmers treat the ponds with a piscicide (a pesticide like Rotenone, used to kill fish) to eliminate remaining fish before restocking. Ponds are usually drained annually or biennially, depending on stocking size. Ponds are aerated to maintain DO and water quality. Fish are fed once or twice daily with mechanical feeders. Like catfish, hybrid striped bass production is concentrated in the southeastern United States and includes North Carolina, South Carolina, Florida, and Virginia.

Millions of *Morone* fingerlings are produced annually in state and federal hatcheries for stock enhancement and in private hatcheries as seed stock for foodfish production and fee fishing operations (Harrell and Webster, 1997). The fingerlings are stocked in earthen ponds, flow-through systems, closed recirculating systems, and net pens for growout. Today, foodfish production is based primarily on the production and raising of hybrid *Morone*. Although other striped bass hybrids have been created for potential foodfish production or have been used for stocking recreational programs, today only the palmetto bass and the sunshine bass are raised for production (Harrell and Webster, 1997).

In 1995 the Northeast Regional Aquaculture Center funded a survey conducted by the Striped Bass Growers Association and the University of Maryland to collect information from producers on the state of the striped bass industry (Harrell and Webster, 1997). The survey indicated that 66% of striped bass/hybrid striped bass producers use earthen ponds, 15% use tanks, 10% use net pens, and 9% use raceways for production. Of the producers culturing fish in tanks, most used flow-through systems (67%), while 22% used closed recirculating systems and 11% had the capability for both.

Stocking density for ponds differs between production of foodfish and production of fish for population enhancement efforts. Phase I fingerling ponds for population enhancement programs are stocked at a higher density, and fish are harvested at a smaller size than in ponds at foodfish growout operations. Stocking densities of striped bass larvae for population enhancement efforts range from about 50,000 to 600,000 per acre, and fish are harvested at sizes from 200 to 1,600 fish/pound (Harrell, 1997). In growout ponds stocking densities range from about 74,000 to 150,000 larvae/acre, with harvest sizes from 45 to 130 fish/pound (Harrell, 1997).

#### *4.3.4.2 Culture Practices*

*Hatchery Phase*

Unlike production of most cultured species, hybrid striped bass production typically relies on fertile wild broodfish to begin the production process. Striped bass broodstock are usually collected during spawning migrations in river headwaters above and below dams using electrofishing or gillnets (Kohler, 2000a). Another way to develop broodstock is to raise larvae or fingerlings in captivity until they reach reproductive age (Sullivan et al., 1997). Producers use hormones to induce spawning and then collect the eggs. Semen is then added to a mixture of eggs and water for fertilization. Embryos are incubated in aquaria, Heath trays, or MacDonald-type jars (Kohler, 2000a). Development is temperature-dependent; at 60.8 to 64.4 °F, the embryos begin to hatch 1 to 2 days after fertilization. By the fifth day, depending on the water temperature, the larvae absorb their yolk sacs. At this stage, they are known as fry until they metamorphose into juvenile phase I fish.

*Phase I in Ponds*

Successful phase I production requires a proper fertilization plan to ensure that the right zooplankton communities are present. Before phase I ponds are stocked with fry, they are drained, refilled, and fertilized with a mixture of organic fertilizers (such as cottonseed meal and alfalfa hay) and inorganic fertilizers (such as ammonium nitrate and phosphoric acid). The stocking density is dependent on the production goal. If the purpose of stocking is population enhancement, fry are stocked at a higher density to produce a greater number of smaller fish at harvest. Population enhancement programs need high quantities of fish to meet the management objectives of stocking a certain number of fish per acre of a reservoir or number of fish per mile of a river (Harrell, 1997). Fingerling producers stock fish at lower densities to produce larger fish. Producers buying fingerlings for growout want as large a fingerling as possible so that the fish can reach market size faster. Fry are fed salmon starter feeds by day 21 at a rate of 5 to 10 pounds/acre/day. Producers use progressively larger feed sizes and increase the ration sizes as the fish grow. Phase I usually takes 30 to 45 days when fish reach total lengths of 1.0 to 2.0 inches and weigh about 0.03 ounces (Kohler, 2000a). Survival rates greater than 15% for white bass and sunshine bass and greater than 45% for striped bass and palmetto bass are considered successful for phase I production. Phase I is the period during which the fish primarily feed on live food, mostly zooplankton; however, toward the end of this phase, the fish become more piscivorous. If supplemental feeding has not been initiated, cannibalism can cause high production losses.

*Phase II in Ponds*

Harvested phase I fingerlings are graded to separate out fish that are less than 1.0 inch total length (TL). Larger fish that are greater than 2.0 inches TL are also graded out to prevent cannibalism. The separated size groups are stocked in separate ponds. Unlike phase I, fertilizers are not used in phase II ponds. Because the fish are being fed manufactured feed, there is no need to stimulate zooplankton growth. Phase II describes striped bass and hybrid bass fingerlings from the time of phase I harvest until they are 1 year old (Harrell, 1997). Many growout farmers purchase phase I fish and stock them in their ponds for phase II and phase III growout. Some producers market phase II fish; these fingerlings are primarily sold to government agencies for enhancement stocking or to net pen operations. Harvesting smaller ponds (< 2.5 acres) for phase II fish is similar to harvesting phase I fish. Ponds are drained down, and producers use seine nets to harvest the fish. This is a common practice for fish used for enhancement purposes, where fish are loaded directly into a transport unit (Harrell, 1997). Larger ponds are too expensive to drain and harvest at one time, so many farmers have started using large haul seines similar to those used by the catfish industry, and fish loading pumps to move fish between ponds. The pumps can be connected to graders that sort the fish by size and return smaller fish to the pond being harvested for further growout.

*Phase III in Ponds*

Phase III production is not common in enhancement production efforts, so most of the available information on actual production efforts in ponds comes from the industry itself, not from scientific literature (Harrell, 1997). Phase III growout is basically the second year production of striped bass and hybrid striped bass to a market-size fish. Most of the time, fish are harvested before the beginning of the third growing season, and the ponds are prepared to receive a new crop of phase II fish to repeat the cycle. Production ponds for final growout are usually larger than phase I and phase II ponds. Most phase III ponds are about 5 to 6 acres, with a range between 1 and 10 acres (Harrell, 1997). Since most growout operations do not have the facilities to completely draw down a pond and hold the harvest in tanks until the fish can be sold, producers harvest their ponds weekly or biweekly (Harrell, 1997). Haul seines are pulled through the pond, and fish are crowded into live cars. Producers can also use boom nets and then load fish into hauling trucks for transport to a processing plant. Fish can also be quickly killed with an ice brine or electrical shock; then the individually are graded and sorted into shipping containers.

*Other Systems Used to Culture Hybrid Striped Bass*

Flow-through systems and recirculating systems are also used to culture hybrid striped bass. For hybrid striped bass production, the advantages of flow-through or recirculating systems include better control over water quality and the health of the fish, growing seasons that are independent of climatic influences, easier fish handling and harvests, and flexibility for extended harvests, resulting in year-round sales.

A small percentage of hybrid striped bass production relies on freshwater cage culture methods, which are generally restricted to small-scale operations where pond water resources are not conducive to seining or ponds are already inhabited by other fish. Phase II fingerlings are stocked through openings in the cage top, which also allow for feeding and harvesting. With fish confined in the cages, the culturist can readily observe their behavior and health and more easily feed, manage, and harvest.

*Feed Management*

When hybrid striped bass are cultured in tanks or other confined systems, automatic feeders are often used to dispense feed at regular intervals. In larger systems, such as ponds, blowers are more commonly used to dispense the food across a wider area. Finding a cost-effective feed for striped bass and hybrid striped bass is very important because feeding cost can be one of the largest variable expenses of producing these species (Gatlin, 2001). Protein is an essential element in hybrid striped bass diets. It is important to maintain the proper ratio of protein to energy to ensure that the fish synthesize the protein and use it for growth instead of metabolizing it for energy. An excess of energy can reduce intake and result in decreased growth. Because protein is the most expensive component of many AAP diets, it is not economical to supply excess protein. In a feeding trial at Kentucky State University, one group of juvenile sunshine bass raised in cages was fed a diet with 41% protein and a protein-to-energy ratio of 99 milligrams protein/kilocalorie energy, a second group was fed a diet with more protein and higher protein-to-energy ratios, and a third group was fed a diet with 41% protein and a lower protein-to-energy ratio. The results for the first two groups were similar. The decrease in protein in the third group's diet did not limit growth; however, it did cause increased fat deposition, which can cause a decreased meat yield in the final product (SRAC, 1998).

Fry and phase I fingerlings in ponds feed on zooplankton until they reach about 0.2 inches in size, when they must be trained to accept artificial feeds to decrease the chances of cannibalism. Often fish are harvested, graded, and stocked into tanks for training on feed and then can be reintroduced as phase II fish in growout ponds (Harrell, 1997). Because feeding observation is an important method of determining overall stock health, floating feed is most often preferred, except during the winter. In winter months, sinking feed is used so that fish will not have to rise to the surface for floating feed and be exposed to extreme temperature changes (Harrell, 1997).

Initially, phase II fish need to eat about 15% to 25% of their body weight per day, given in two separate feedings. Once the fingerlings reach 0.06 pounds, daily feeding rates are gradually decreased to about 2% to 3% of their body weight in two separate daily feedings (Harrell, 1997). Tractor-drawn blowers are often used to deliver the feed at large operations, but demand and automatic feeders can also be used in pond culture (Hochheimer and Wheaton, 1997).

Although hand feeding and demand feeders have been used in some flow-through systems, automated mechanical feeders are most commonly used for both recirculating and flow-through systems. These feeders include towed blowers, stationary broadcast or blower feeders, and automated feed delivery systems (Hochheimer and Wheaton, 1997).

*Health Management*

There appears to be no difference between pure strains of striped bass and hybrid striped bass with respect to the fishes' susceptibility to diseases. Striped bass diseases are caused by viruses, bacteria, fungi, protozoa, and metazoan parasites. Except for viruses and parasitic worms, most of the infectious agents trigger diseases only when striped bass are stressed or injured. Since striped bass and their hybrids are extremely susceptible to environmental stress, the best ways to prevent infectious diseases are to follow good AAP practices and health management practices, including an emphasis on maintenance of good water quality, use of optimum stocking densities, provision of adequate feed and good nutrition, maintenance of optimum temperature, and use of proper fish handling procedures (Plumb, 1997).

Viruses known to infect striped bass include the lymphocystis virus, infectious pancreatic necrosis virus (IPNV), and striped bass aquareovirus. Because viruses do not severely threaten striped bass, little is done to control virus outbreaks. Fish infected with lymphocystis are simply removed from a production facility; it is not practical, however, to remove fish infected with IPNV. In either case, the facility can be dried thoroughly or disinfected with chlorine (200 milligrams/liter) to kill any residual virus. There is not adequate information about striped bass aquareovirus to manage and control outbreaks (Plumb, 1997).

Bacteria cause the most serious debilitating infections of cultured striped bass. No bacterial diseases are unique to striped bass, but some bacteria have more serious effects on striped bass than on other cultured fish. Bacterial diseases affecting striped bass are MAS, *Pseudomonas* septicemia, Columnaris, Pasteurellosis, Edwardsiellosis, Vibriosis, Enterococcosis, Streptococcosis, Mycobacteriosis, and Carnobacteriosis (Plumb, 1997).

Control of bacterial diseases is best achieved through maintaining a high-quality environment and preventing conditions stressful to the fish. Sterilization of nets, buckets, and other production tools prevents cross-contamination between culture units. In recirculating water or open water supplies, ultraviolet (UV) radiation and ozone disinfection can reduce bacteria. Some drugs have proven effective in treating bacterial infections in striped bass. Although none of the therapeutic agents are FDA-approved, bathing fish in sodium chloride (0.5% to 2% for varying times) or potassium permanganate (2 to 5 milligrams/liter for an hour to indefinitely) and feeding fish medicated feed have been successful in treating bacterial infections. Medicated feed containing oxytetracycline (Terramycin) has been fed at a rate of 2.5 to 3.5 grams/45 kilograms of fish per day for 10 days for treatment, and medicated feed containing Romet-30 (sulfadimethoxine-ormetoprim) has been fed at a rate of 2 to 3 grams/45 kilograms of fish per day. Romet-30, however, might not be effective against Streptococcosis (Plumb, 1997).

Less is known about fungal diseases than about other diseases affecting striped bass because of the difficulty in identifying fungi and the fact that fungi are sometimes secondary pathogens to other diseases, injuries, or environmental stress. A few fungi that are known to cause infections in striped bass are *Saprolegnia parasitica* and related species, which cause "water mold," and *Branchiomyces* species, which causes "gill rot." Treatments of fungal infections with formalin, copper sulfate, and potassium permanganate have been used, but are often unsuccessful. Preventing fungal infections on eggs is possible through daily treatments of formalin at a rate of approximately 600 milligrams/liter for a 15-minute flush (Plumb, 1997).

#### *4.3.4.3 Water Quality Management and Effluent Treatment Practices*

*Pond Systems*

In a study in South Carolina (Tucker, 1998), water samples were collected and analyzed from 20 commercial hybrid striped bass ponds (Table 4.3–8). In an attempt to provide a broad representation of the industry, researchers included large and small operations, as well as ponds from both the coastal plain and piedmont areas of the state. Most of the commercial ponds sampled were freshwater ponds, but some saltwater ponds were also represented in this study. Overall, water quality parameters varied considerably from pond to pond. The $BOD_5$ of samples ranged from 2 to 60 milligrams/liter, and suspended solids and volatile suspended solids were typically high but variable. Generally, concentrations for many of the variables were higher in the pond samples than in the water source samples.

**Table 4.3–8. Means and Ranges for Selected Water Quality Variables from Hybrid Striped Bass Ponds in South Carolina**

| *Variable* | *Mean* | *Range* |
|---|---|---|
| Suspended solids (mg/L) | 49 | 0–370 |
| Volatile suspended solids (mg/L) | 29 | 0–135 |
| Biochemical oxygen demand (mg/L) | 11.5 | 1.4–64.4 |
| Kjeldahl nitrogen (mg/L) | 7.1 | 0–97.0 |
| Total ammonia (mg N/L) | 0.95 | 0.02–7.29 |
| Nitrite (mg N/L) | 0.07 | 0–2.94 |
| Nitrate (mg N/L) | 0.36 | 0–4.61 |
| Total phosphorus (mg P/L) | 0.31 | 0–1.9 |
| Soluble reactive phosphorus (mg P/L) | 0.02 | 0–0.18 |

Source: Tucker, 1998.

The South Carolina study also compared water quality in fingerling ponds and growout ponds. Fingerlings were usually produced in smaller ponds, and although average aeration rates were similar for fingerling and growout ponds, water exchange was less in fingerling production. Biomass and feeding rates were lower in fingerling ponds, as were parameters associated with particulate matter and nutrients. Overall, the quality of effluents from hybrid striped bass ponds varied greatly from pond to pond. The study did not find any significant seasonal variation in quality, but researchers noted that the sampling protocol might have affected the measure of true seasonal effects. Concentrations of suspended solids, total nitrogen (including total ammonia), and BOD were the water quality variables most elevated relative to the source water and would have the greatest impact on receiving bodies of water.

*Other Production Systems*

Water management in intensive systems, such as flow-through and recirculating systems, must address the full range of water quality parameters that could affect fish health and growth. Parameters to consider are continuous flow, adequate oxygen, consistent temperature, waste removal from the culture space, acceptable ranges of ammonia levels, control of parasite populations, and elimination of all other stress factors. Nearly all intensive systems include simple settling as part of the water management system to remove solids from the effluent stream, whether the water is to be reused in the system or discharged. Simple settling has proven adequate in removing the relatively dense waste solids from hybrid striped bass production (Hochheimer and Wheaton, 1997).

Because net pen culture practices rely on the water quality of the site at which the pens are located, there is little information on water management practices for hybrid striped bass production. Cages can be moved around within the pond, but generally they are of such small size that any water quality effects are negligible.

### 4.3.5 Tilapia

Tilapia are indigenous to Africa. In the 1940s they were introduced into Caribbean nations and, as a result, also entered Latin America and the United States. By the late 1950s the species had become the main focus of AAP research at Auburn University. Tilapia have been raised in most, if not all, U.S. states. Species cultured in the United States include Nile tilapia (*Oreochromis niloticus*), blue tilapia (*O. aureus*), Mozambique tilapia (*O. mossambicus*), Zanzibar tilapia (*O. urolepis hornorum*), and various hybrids of these species (Popma and Masser, 1999). In states where the growing season is not long enough to produce tilapia before winterkill occurs, production takes place in greenhouses or other buildings where supplemental heat is available. Since tilapia are still considered exotic, some states have restrictions on tilapia culture. In Arizona, California, Colorado, Florida, Hawaii, Illinois, Louisiana, Missouri, Nevada, and Texas, a permit may be required to culture tilapia, or the fish may be raised only if the species of interest appears on a list of approved fishes (Stickney, 2000c).

Most species of tilapia are mouthbrooders. Males construct nests in pond bottoms, females extrude eggs into the nests, males fertilize them, and females scoop them up in their mouths. Egg incubation (about 1 week) and hatching of fry take place in the female's mouth, and fry stay in the mouth during yolk sac absorption. Once fry are ready to forage for food, they stay in a school around the female and go back into her mouth at any sign of danger. The fry remain in a school for several days after leaving the shelter of the female and stay around the edges of the pond where the water is warmest.

Mozambique tilapia can mature as early as 3 months after hatching; blue and Nile tilapia mature after approximately 6 months (Stickney, 2000c).

Although many tilapia species are produced as foodfish, some species, such as *Tilapia zilli*, are herbivorous and have been used to control aquatic vegetation in irrigation canals and sewage lagoons. Other more colorful tilapia species have been marketed as aquarium fishes in the ornamental market. Some salt-tolerant tilapia and hybrids have become the focus of new interest in tilapia production in coastal ponds and marine cages in the Bahamas and some Caribbean nations (Stickney, 2000c).

Tilapia have become one of the most commonly cultured species in the world. The 1998 Census of Aquaculture estimated that 116 farms produced 11.5 million pounds of tilapia, with a total of 137 farms producing food-size tilapia with a value of more than $23 million (USDA, 2000). The top five states for tilapia production in the United States are (in descending order) California, Maryland, Texas, Idaho, and Florida. Many culturists prefer to raise blue tilapia and Nile tilapia over the Mozambique tilapia because the former have better dress-out percentages, later maturity, and a more desirable flesh color (Stickney, 2000c).

#### *4.3.5.1 Production Systems*

Three primary types of production systems are in use at tilapia farms: ponds, flow-through production, and recirculating systems. Ponds and recirculating systems are the more common systems used for tilapia production in the United States, while flow-through systems are less common. In the southern United States, tilapia are sometimes raised in cages or net pens in lakes, large reservoirs, farm ponds, rivers, cooling water discharge canals, and estuaries; however, cage culture is a less common production system for tilapia.

Tilapia's intolerance of coldwater limits its production potential in outdoor systems throughout most of the United States. Only southern Florida, Texas, Puerto Rico, Hawaii, and other Pacific islands have climates suitable for year-round outdoor pond production (Rakocy, 1989). Enclosed greenhouses are also used in some parts of the country, and in temperate climates tilapia must be grown indoors with heated water. Operators must either heat their airspace and influent water or use alternative sources of warmwater, such as recycled wastewater that has been used to cool power plants or geothermally heated water (Rakocy and McGinty, 1989).

Ponds for tilapia production are similar to pond systems developed for other warmwater AAP species such as catfish and shrimp. Tilapia ponds require a design conducive to draining because fish harvest is difficult to perform without removing some or all water from the pond (Rakocy and McGinty, 1989). Tilapia are also cultured in flow-through systems. Circular tanks are the most common rearing unit for flow-through tilapia production because they have superior flow characteristics with fewer low-flow "dead spots" than rectangular tanks (Rakocy, 1989). Recirculating systems for tilapia production are similar to flow-through systems in terms of tank design, aeration, feeding, fish handling, and solids removal; however, water discharge is minimal with the operation of a recirculating system. Recirculating systems are widely used to produce tilapia for the live fish market because recirculating systems can be used for year-round production. Recirculating systems can also reduce water-heating costs and transportation costs because facilities can be located near large metropolitan market areas.

#### *4.3.5.2 Culture Practices*

Tilapia are often bred in recirculating systems because spawning is more easily observed and controlled in small tanks than in other systems. Ten to twenty days after tilapia broodstock spawn, fry begin to swim away from the mouth-brooding female fish. Fry can be collected with dip nets from the brood tank for stocking in nursery tanks (Rakocy, 1989).

Male tilapia are preferred for intensive food fish culture because they grow more quickly than female fish. Female fish divert energy from growth to producing eggs, and mouth-brooding females generally do not eat while holding young in the mouth. It is possible to produce all male fish with certain hybrids of *Oreochromis* species. Feeding newly hatched female fry with feed treated with male hormones inverts the sex of female tilapia to change them into reproductively functional male tilapia. Androgens such as methyl testosterone are used to invert the sex of female fry (Kohler, 2000b). Other methods include using a combination of hormones to produce “supermale” tilapia with double Y (YY) chromosomes instead of XY chromosomes. These YY males can be crossed with normal XX female fish to produce all male progeny. Researchers also have been experimenting with triploid (fish that have three sets of chromosomes and are unable to reproduce) and tetraploid fish (fish that have four sets of chromosomes that can be mated with diploid fish to produce triploids) to produce faster growing fish without the use of hormone treatments (Kohler, 2000b).

Fitzpatrick et al. (2000) treated fry with methyl testosterone at a concentration of 60 milligrams/kilogram in their feed for 4 weeks beginning at the initiation of feeding. The treated fry were raised in three 16-gallon tanks that contained no soil or gravel, 11 pounds of soil, or 11 pounds of gravel, respectively. Methyl testosterone water levels peaked at approximately 3.6 nanograms/milliliter at 28 days after the onset of feeding. The concentration of methyl testosterone in water decreased to background levels (nondetect to 0.02 nanograms/milliliter) in 1 to 2 weeks after the end of treatment with methyl testosterone-impregnated food in those tanks containing soil or gravel. The concentration of methyl testosterone in the tank containing no soil or gravel remained above background levels for 3 weeks after the end of treatment with methyl testosterone-impregnated food (Fitzpatrick et al., 2000). Methyl testosterone degrades when exposed to light or high temperatures. In addition, bacteria and fungi can metabolize methyl testosterone; therefore the light, temperature, and microbial degradation in an outdoor pond setting degrade methyl testosterone.

The soil concentration of methyl testosterone in the tank with soil was 6.1 nanograms/gram at the end of the 28-day treatment period. This level decreased to approximately 3 nanograms/gram at 8 weeks after the end of the treatment period (cessation of experiment). The methyl testosterone soil background level was 0.5 nanograms/gram at the beginning of the experiment. The methyl testosterone levels in the gravel tank ranged from 22.9 to 99.2 nanograms/gram of fine sediment at 8 weeks after the end of the treatment period. The authors suggested that the slow degradation of methyl testosterone in soil and gravel might have occurred because the sediments acted as a trap for methyl testosterone (Fitzpatrick et al., 2000).

Stocking density for tilapia fry in flow-through systems can be maintained at as high as 750 fry per square foot. Once fish reach approximately 1 pound, recommended stocking levels drop to about nine fish per square foot (Rakocy, 1989). Most tilapia raised for foodfish are harvested when they reach 1 pound. Depending on the quantity of food and aeration inputs, tilapia can be raised from fry to harvestable sizes in 7 to 8 months (Rakocy, 1989). Tilapia are more difficult to capture in seines than many other species of cultured freshwater fish because they have a tendency to jump over, or burrow under, nets (Rakocy and McGinty, 1989). Only 25% to 40% of tilapia in a small pond are usually harvested by seine nets. Complete or partial pond draining is usually necessary to harvest all the tilapia in a pond (Rakocy and McGinty, 1989). Tilapia in recirculating systems are usually harvested by crowding the fish into one part of the tank. The fish are then dipped out of the tank with nets or pumped out.

*Feed Management*

In pond production tilapia are able to feed on naturally occurring green algae, blue-green algae, zooplankton, benthic invertebrates, and decomposing organic matter. Many operators, however, supply tilapia with commercially prepared feeds using mechanical feeders to encourage faster growth.

Because tilapia can thrive on naturally occurring foods in ponds, they can be integrated into catfish pond culture during the summer months when water temperatures are above 50 °F. The stocked tilapia produce a second crop of fish without the producer incurring additional feed costs. Raising tilapia with catfish also might have the additional benefit of reducing off-flavor problems that can occur in traditional catfish farming because tilapia consume the blue-green algae that often cause an off-flavor problem (Rakocy and McGinty, 1989). Labor costs associated with sorting the catfish and tilapia at harvest, however, may reduce net profits for the operator.

Tilapia raised in flow-through systems are fed commercially prepared feeds using mechanical feeders. Adult fish are usually fed 3 to 6 times per day, at a rate of approximately 1% to 3% of their body weight per day. Under ideal conditions, with high-quality feeds, FCRs approaching 1.5 are possible with tank-raised tilapia (Rakocy, 1989). Tilapia in recirculating systems are also fed high-protein, commercially prepared feeds that optimize growth. Generally, the fish are fed using automatic feeders, which dispense food from above the tank.

*Health Management*

Three types of water-conditioning chemicals are commonly added to commercial recirculating systems for tilapia production. Sodium bicarbonate, or an alternative alkalinity source such as sodium hydroxide, is often added to replace alkalinity lost to nitrification in the biofilter (Loyless and Malone, 1997; Malone and Beecher, 2000; Tetra Tech, 2002c). Salt (sodium chloride) is added the system to prevent the occurrence of brown blood disease, which occurs in fish when water contains high nitrite concentrations. With this fish disease, nitrite enters the bloodstream through the gills and turns the blood to a chocolate-brown color. Hemoglobin, which transports oxygen in the blood, combines with nitrite to form methemoglobin, which is incapable of oxygen transport. Brown blood cannot carry sufficient amounts of oxygen, and affected fish can suffocate despite adequate oxygen concentration in the water (Tetra Tech, 2002c). Calcium chloride is used to simultaneously provide chlorides and increase calcium hardness in soft water areas.

#### *4.3.5.3 Water Quality Management and Effluent Treatment Practices*

*Pond Systems*

Tilapia become susceptible to disease when water temperatures are below 65 °F or when levels of ammonia, pH, and DO fall beyond recommended ranges. Tilapia are more tolerant of low DO levels than many other cultured foodfish species (Stickney, 2000c). Tilapia grown at low densities may not benefit from artificial aeration under normal pond conditions; however, supplemental aeration is recommended when growing tilapia in intensive pond culture systems with high fish densities (Papoutsoglou and Tziha, 1996; Rakocy and McGinty, 1989).

Tilapia ponds are drained to harvest fish, to adjust fish inventories, or to repair ponds. At the start of pond draining for harvest, pond water effluent characteristics can be expected to be similar to production water characteristics. Fish harvest by seining, however, stirs up sediments at the bottom of the pond. In fertilized tilapia ponds, sediments are likely to contain significant quantities of nitrogen and phosphorus. As draining and seining continue, effluent water quality can be expected to deteriorate (Tucker, 1998).

There is little mention in the literature of pond effluent treatment practices specifically for tilapia. If tilapia, however, are held in earthen ponds similar to those used for other freshwater fish, effluent management practices developed for catfish, crawfish, and hybrid striped bass can be expected to apply to tilapia culture. Tucker (1998) outlines some general pond culture effluent management guidelines: use high-quality feeds to reduce waste; provide adequate aeration and water circulation to avoid pond stratification; minimize water exchange during the growing season; leave excess storage capacity to capture rainfall and minimize overflow; harvest ponds without draining; and if draining is necessary for harvest, hold the last 10% to 20% of the water for 2 to 3 days prior to discharge to allow time for solids to settle.

*Flow-through Systems*

Flow-through systems must be managed to provide sufficient volumes of water to supply fish with oxygen and remove solid and dissolved wastes; therefore, these systems have a high demand for water.

There is little information concerning effluent treatment in tilapia flow-through systems; however, it is likely that common solids removal practices for other flow-through systems, including screens and settling basins, are common for tilapia flow-through production as well.

*Recirculating Systems*

Tilapia are hardy, disease-resistant fish, but when water temperatures are too low, they lose their resistance to disease and stop growing. In indoor recirculating systems, the optimal water temperature for tilapia production is 82 to 86 °F (Rakocy and McGinty, 1989). In temperate climates, water used in recirculating systems needs to be heated, especially during winter months. Alternatives to heating municipal or well water include using geothermically heated water (Rakocy and McGinty, 1989) or using heated effluents from electric power generating stations (Rakocy, 1989).

Many growers aerate recirculating systems with oxygen from liquid oxygen tanks leased from commercial suppliers. Tilapia grown in a recirculating system in North Carolina are supplemented with approximately 0.5 pounds of liquid oxygen per pound of food added to the system (Tetra Tech, 2002c). High-density systems that use enriched oxygen sources must also provide for a means of carbon dioxide stripping to prevent pH depression in the circulating waters (Grace and Piedrahita, 1994). Some recirculating system design guidelines advocate direct aeration of tanks (Malone and Beecher, 2000; Sastry et al. 1999) or indirect aeration through the use of airlift pumps (Parker, 1981; Parker and Suttle, 1987; Reinemann and Timmons, 1989). In these blown air systems, oxygen addition and carbon dioxide stripping are reasonably balanced, and a separate carbon dioxide stripping process is not employed (Loyless and Malone, 1998).

Some of the water in recirculating systems must be discharged daily to remove solid wastes. In general, effluents from recirculating systems are more concentrated than wastewater from flow-through or pond systems. The total daily volume of effluents from recirculating systems is typically orders of magnitude smaller than effluents from flow-through systems of similar capacity that do not reuse water. Small discharge volumes make wastewater more economical to treat and in some cases alleviate the need to discharge to receiving waters. A recirculating system used to grow tilapia in North Carolina discharged such small quantities of wastewater that evaporation from an on-site aerobic waste lagoon exceeded the rate of wastewater inflow during summer months (Tetra Tech, 2002c).

### 4.3.6 Other Finfish

#### *4.3.6.1 Largemouth Bass*

Largemouth bass *(Micropterus salmoides)* are said to be the most sought after freshwater sport fish in the United States. State and federal hatcheries produced 21 million largemouth bass for sport fish stocking in 1995 and 1996 (Heidinger, 2000). It is estimated that commercial hatcheries produced approximately the same amount. A limited number of adult bass are used as foodfish by some consumers (mainly centered around large cities), but it can take 2 to 3 years to grow bass to an adequate food-fish size.

The geographic range of largemouth bass is limited by temperature because they can be stressed at low temperatures (around 36 to 39 °F). These temperatures can occur in the winter in culture ponds located at the latitude of southern Illinois.

There are two subspecies of largemouth bass, the northern largemouth bass (*M. salmoides salmoides*) and southern Florida largemouth bass (*M. salmoides floridanus*). Genetic tests are required to tell the two species apart because they cannot be differentiated by a visual inspection. It is important to know which species one is working with during production because the southern subspecies is not as tolerant of low temperatures as the northern subspecies can be (Heidinger, 2000).

*Production Systems*

Various methods are used to produce largemouth bass. Most producers stock broodfish in ponds to spawn, although some are stocked in raceways or net pens, allowing the producer to be in greater control of production. Ponds are usually rectangular and less than 6 feet deep with no obstructions. Ponds are drained and completely dried in the fall to get rid of predacious insects, fishes, and diseases. Some operators sow winter rye in the pond to serve as an organic fertilizer after spring flooding. Agricultural lime can be added if the pond bottom soil is too acidic. Ponds should not be filled more than 14 days before stocking to prevent the buildup of predacious insects. Well water or surface water, which is filtered through 52 mesh/inch saran socks, are both acceptable for filling the ponds (Davis and Lock, 1997).

*Culture Practices*

Fry are left in the spawning ponds or moved to rearing ponds and fed zooplankton and aquatic insects. When the fish are fingerlings, they are raised at a low density on insects, or they can be trained in tanks to eat a prepared diet. Fingerlings (1.5 to 2.0 inches) are seined from nursery ponds, graded to uniform sizes, and stocked in round or rectangular flow-through tanks for feed training. Stocking density can be high, with a range from 200 to 500 fish/cubic foot (Tidwell et al., 2000). Fingerlings that are trained to eat the prepared diet grow faster than those feeding on insects, and the trained bass can then be moved to ponds, net pens, or raceways until they reach the desired size.

Bass are most often harvested by trapping, seining, or draining the pond. Fingerlings are generally harvested 2 to 4 weeks after stocking, when they are approximately 1.5 inches in length, to lessen the chances of cannibalism. Although cannibalism is possible at any time, it is more likely to occur if fry are stocked at different ages and sizes and if there is a shortage of food. If at any time it is found that no appropriate invertebrates are present in the pond as a food source, the bass must be harvested regardless of size (Heidinger, 2000).

During training periods in tanks, largemouth bass are extremely susceptible to external parasites and the bacterial disease columnaris (caused by *Cytophagus columnaris*). Affected fish are treated immediately through medicated feed (terramycin). The use of salt baths of 0.5% to 1.0% for up to 1 hour is another practice used to reduce stress from handling and grading and to reduce the incidence of infectious diseases (Tidwell et al., 2000).

#### *4.3.6.2 Smallmouth Bass*

Smallmouth bass *(Micropterus dolomieui)* are popular sport fish found in many parts of the United States and are essentially nonmigrating fish. The species requires growing temperatures from 50 to 70 °F and spawning temperatures of 58 to 62 °F; the upper lethal temperature reported is 95 °F (Illinois-Indiana Sea Grant, n.d.). Ponds are the most common production system used for smallmouth bass culture (Illinois-Indiana Sea Grant, n.d.).

#### *4.3.6.3 Carp*

Several species of carp *(*family Cyprinidae*)* have been cultured in the United States. The government stopped stocking common carp (*Cyprinus carpio*) in the United States in the late 1800s because of problems associated with the species, such as damage due to erosion caused by the fish digging into the pond banks. Many reproducing populations, however, became established from early stocking programs and are still plentiful today. Although common carp are cultured as foodfish in other countries, there is a very small demand for them as foodfish in the United States. The fish have many small bones and often have poor flavor. There is a very small amount of commercial production of bighead carp (*Aristichthys nobilis*) and silver carp (*Hypopthalmichthys molitrix*), but that production is insignificant. Various carp species are banned in some U.S. States because they are considered to be exotic species.

The grass carp (*Ctenopharyngodon idella*) is commercially produced in the United States primarily for use in controlling aquatic vegetation. This species is very controversial because of concerns that it might also consume desirable vegetation and reproduce and become established in areas where it is not desired. Since the species is banned in many states and controversial in others, commercial producers began producing triploid grass carp (fish that have three sets of chromosomes and are unable to reproduce). Triploid grass carp are beneficial in controlling vegetation, and they die after a few years, so the decision can then be made whether to restock. Some states that had banned carp have made exceptions and allow stocking of the sterile triploid grass carp as long as the producers can certify that the fish are 100% triploid (Stickney, 2000a).

*Culture Practices*

Production of sterile triploid grass carp includes subjecting fertilized eggs to a pressure treatment that makes the eggs hold onto an extra set of chromosomes. The process involves placing the eggs in a stainless steel container and subjecting them to 8,000 psi (pounds per square inch) of hydrostatic pressure. The eggs hatch after an incubation period of 2 to 3 days, and the fish feed off of their attached yolk sacs. After 3 days, the fish can be fed hard-boiled egg yolks followed by commercial fish food and brine shrimp larvae as they grow. After a week in the hatchery, the young fish should be transferred to larger ponds, which should be fertilized to encourage zooplankton growth for a food source. After the fish reach approximately 1.5 inches in length, they begin to eat green plant material. The fish can undergo blood testing to determine whether they are triploid and sterile when they are 2 to 3 inches in length (Imperial Irrigation District, 1998).

#### *4.3.6.4 Flounder*

The summer flounder (*Paralichthys dentatus*) is a foodfish found along the east coast of the United States, from Maine to Florida (Bengtson and Nardi, 2000). The winter flounder (*Pseudopleuronectes americanus*) is a foodfish found along the east coast of North America, from the state of Georgia to Labrador, Canada. The species has been exploited for more than a century and is now considered overexploited due to its decline over the past 20 years. Hatchery production of winter flounder was first attempted in the late 1800s by the U.S. Fish and Fisheries Commission in an attempt to try to rebuild wild populations that were in decline. Those hatcheries released tens of millions of larvae before closing in the 1950s. Some of the techniques developed at those hatcheries are still in use today, now that declining stocks, coupled with a demand for quality flatfish, have once again motivated attempts to culture winter flounder (Howell and Litvak, 2000).

*Production Systems*

Commercial hatchery production of summer flounder in recirculating or flow-through tanks began in 1996, after 6 years of government funding for research and development for cultural practices of the species. So far, only wild-caught broodstock have been used in commercial production, but hatcheries are working on domesticating them (Bengtson and Nardi, 2000).

Researchers and fish culturists of winter flounder have looked to information on production techniques for summer flounder for guidance. There are, however, some differences in culture techniques for the two species. Hormonal injections to induce spawning seem to be used more in winter flounder production than in summer flounder production. Static, flow-through, and *in situ* systems have all been used to raise winter flounder larvae, though static systems have been used only in research, not for commercial production. In larval flow-through systems, 100-liter circular tanks are supplied with seawater that has been filtered and treated with ultraviolet light and kept at ambient temperatures and salinities. One *in situ* system was tried in Rhode Island with favorable results. It consisted of an open-mesh enclosure (406 cubic feet in size) suspended from a surface flotation collar. The mesh size was small enough to keep larvae in while still allowing their natural food to enter the enclosure. The estimated time for growth to market size is 2 to 4 years. This time might be shortened in an AAP setting due to optimal fixed conditions used there, and the growout systems used would be similar to those for summer flounder (land-based tanks or raceways and net pens) (Howell and Litvak, 2000).

*Culture Practices*

Ideally, captured summer flounder broodstock are held for several months to allow them to adjust to their new surroundings and nonliving food diet before spawning is initiated. Some hormonal injections have been tried to induce spawning, but the most widely used method is hand-stripping the ripe fish. It is a high priority to develop methods for natural spawning since hand-stripping fish is highly stressful to the fish and might not be the best method for gathering the highest-quality eggs. After eggs and milt are stripped from the females and males, the gametes are combined in beakers where fertilization takes place. The embryos are placed in cylindrical containers of seawater. Hatched larvae can be taken from the incubation containers and put into rearing tanks, where they feed on rotifers. Survival rates are higher in rearing tanks to which algae have been added.

After larvae go through metamorphosis and settle to the bottom of the rearing tanks, they should be transferred to juvenile rearing tanks where they can become accustomed to an artificial diet and grow out to about 2 grams before being netted and graded into larger tanks. Tanks may be round or square and range in size from 106 to 212 cubic feet. Raceways should have rounded corners (known as D-ended). Regular cleaning of tanks and removal of uneaten feed and feces are extremely important.

Summer flounder can grow to about 5 grams in five months and are then ready for transfer to a growout operation. It has not been determined what systems and procedures work best for growout production, but recirculating systems and net pens have both been tested by certain companies. The U.S. government has funded some of those projects and hopes to compare growth and quality of the fish grown in the two types of systems, as well as qualitative and quantitative cost production differences for the two systems. The estimated time for growth to market size is 24 to 28 months (Bengtson and Nardi, 2000).

#### *4.3.6.5 Paddlefish*

Paddlefish *(Polyodon spathula)* are prehistoric fishes used as foodfish and as a source of eggs, or roe, for caviar. They are found in 22 states on the Mississippi River Basin and the adjacent Gulf Coast drainage. Overfishing, habitat modification, and contamination by polychlorinated biphenyls (PCBs) and chlordane have caused paddlefish numbers to decline. Paddlefish are protected against illegal roe collection through their listing on the United Nations' Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES).

*Production Systems*

Paddlefish can be raised in ponds or raceways. In pond production, survival rate ranges from 30% to 80%. In raceways, the survival rate increases to approximately 50% to 80%. Paddlefish broodstock are usually obtained from the wild because they take 7 to 9 years to mature. They are generally raised in circular tanks with an average diameter of 8 feet, allowing them to swim continuously and aerate their gills; however, tanks can be larger.

*Culture Practices*

Approximately 2 weeks before propagation, ponds to be used for paddlefish fry are completely drained and dried. After propagation, the ponds are filled with water from a well or from a reservoir that filters water through a saran sock. Organic fertilizers, such as rice bran or cottonseed, soybean, and alfalfa meals, are recommended for use in the nursery ponds to achieve a total nitrogen amount of 40 pounds/acre. During the initial fertilization period, large zooplankton such as *Daphnia* species should be inoculated into the pond at a concentration of eight *Daphnia* per gallon. It is recommended that ponds be covered with netting to prevent bird predation of fry.

Propagation of paddlefish can be achieved artificially. The fertilized eggs are placed in incubation jars, where fry hatch in approximately 6 days. The fry absorb residual yolk in 5 to 6 days, after they are ready to eat external food such as *Daphnia*. Once water temperatures are higher than 65 °F, fry can be stocked at a rate of 25,000 fish/acre in the prepared (fertilized) earthen ponds, where they feed on the *Daphnia* or insect larvae. At the age of about 5 to 6 weeks old, the fry's gill rakers develop, allowing them to filter-feed. Their diet can be supplemented during this time with trout/salmon crumbles (50% protein) at a rate of 15 pounds/acre, and after about 3 to 4 weeks, when the fish are 3 inches, they can eat 1/16-inch extruded pellets. In about 6 months, fish can grow to up to

14 inches long and 0.33 pounds in weight. The fish can be harvested easily with gill nets or seines.

Paddlefish fingerlings (less than 10 inches) can also be cultured in raceways or flow-through systems. If groundwater is used, it should be aerated and heated to more than 72 °F. Surface water may also be used, but it needs to be filtered and also aerated and heated if needed. Because strong sunlight can cause sunburn and mortality in paddlefish, outdoor raceways should be covered with 95% shade cloth, which may also offer some protection against bird predation. Like fry raised in ponds, fry in raceways can be trained to eat a sinking diet of trout/salmon crumbles (more than 50% protein), and after about 3 to 4 weeks, when the fish are 3 inches long, they can eat 1/16-inch extruded pellets. The pellets can be provided by automatic feeders every 15 to 20 minutes for about 7 to 10 days; then both automatic and hand feeding can be used to feed every 2 hours until the fish are stocked into ponds or reservoirs.

Initially, fry can be stocked in raceways at eight fish per gallon, but as they grow, fish should be reduced to lower concentrations to prevent crowding. After 2 weeks, fry should be about 2 inches in length and should be reduced to 2.5 fish per gallon. At 4 weeks after stocking, fish should be about 4 inches and should be reduced to 0.75 fish per gallon. If fish start “billing”—swimming at the surface with their paddles out of the water—they are demonstrating that they are stressed by high densities. Reducing densities generally stops this behavior (Mims et al., 1999).

#### *4.3.6.6 Sturgeon*

Atlantic, shortnose, lake, and white sturgeons (*Acipenser oxyrhynchus, A. brevirostrum, A. flurescens,* and *A. transmontanus*, respectively) are prehistoric anadromous fish used as foodfish and a source of roe for caviar. Sturgeons were once abundant, but habitat modification and overfishing, combined with the species’ slow reproductive rate, have dramatically reduced sturgeon populations (Friedland, 2000). White sturgeons are found in North America from Ensenada, Mexico, to Cook Inlet, Alaska (PSMFC, 1996), while Atlantic sturgeons are found from Florida to Labrador, Canada, and shortnose sturgeons range from Florida to New Brunswick, Canada (Friedland, 2000).

*Production Systems*

Sturgeon culture facilities are usually land-based tank systems. Producers can use recirculating systems during different production cycle phases. Sturgeon producers can also use gravity-flow linear raceways and discharge water to water bodies, preventing the escapement of cultured fish through the use of screens and settling ponds (Doroshov, 2000).

Bird predation is a significant problem in pond culture, especially for small sturgeons. Netting over ponds can help prevent bird predation, but recirculating systems or flow-through systems may be more economical for the growout of small sturgeons to market size. Larger sturgeons (1 pound or larger) are less vulnerable to bird predation due, in part, to the fact that the larger fish are almost entirely benthic (Bury and Graves, 2000).

*Culture Practices*

Sturgeon culture is difficult because of the complexity of replicating the species' natural spawning and raising activities. Minor surgery is required for internal examination of the fish to determine their sex and level of maturity, and eggs must be closely monitored to determine when they can be successfully fertilized (Government of British Columbia, n.d.).

Migrating Atlantic sturgeons are captured with gill nets, transported to hatcheries, and placed in either 0.25-acre freshwater earthen ponds or round fiberglass tanks. The fish are held for 12 to 13 days before spawning is induced by intramuscular injections of acetone-dried or fresh sturgeon pituitary gland extract. Eggs and sperm are mixed for 1 to 2 minutes, and fertilized eggs are stirred and washed for 10 to 30 minutes before being placed in MacDonald hatching jars. Yolk sacs are absorbed by fry 9 to 11 days after hatching, and the fry are then fed a diet of ground beef liver mixed with salmon mash, supplemented with live *Artemia* nauplii (Conte et al., 1988).

Lake sturgeons can be artificially spawned and then raised in floating cages or net pens. Spawning lake sturgeons are dip-netted from the Fox and Wolf Rivers in central Wisconsin. Sperm and eggs are collected from the fish, and the fish are then released. Eggs are fertilized and placed in MacDonald hatching jars. The fry absorb their yolk sacs within 10 days after hatching, after which the fry actively swim and feed on live brine shrimp nauplii. When the fry reach a length of about 1 inch, they begin feeding on larger zooplankton (Conte et al., 1988).

Shortnose sturgeons are captured with gill nets or by electro-fishing and transferred to cylindrical tanks at the hatchery. Females are held for 3 to 4 weeks, and males up to 6 weeks, before spawning is induced by intramuscular injections of acetone-dried or fresh sturgeon pituitary gland extract. Eggs and sperm are collected and mixed, and fertilized eggs are incubated in MacDonald hatching jars or Heath Techna trays. Eggs are treated daily with formalin (1,670 milligrams/liter for 10 minutes using a constant-flow method) to prevent fungus development. Larvae are raised in fiberglass and aluminum troughs. The troughs are 8 feet long, 1.5 feet wide, and 8 inches deep, and they are connected to a flow-through freshwater system, which has regular applications of formalin (1.775 milligrams/liter for 1 hour) and occasional applications of streptomycin/penicillin. After 1 week, larvae are fed live *Artemia* nauplii and salmon starter meal. After the larvae absorb their yolk sacs, ground beef liver is added to the diet as are supplemental experimental feeds and commercial semi-moist and dry rations.

Juvenile shortnose sturgeons are raised in 0.5-acre outdoor ponds (mean depth about 5 feet) where they feed on the ponds' benthic fauna and supplemental dry rations. They can also be raised indoors in 12-feet-diameter, 2.5-feet-deep fiberglass tanks connected to a freshwater recirculating system, where they feed on beef liver, squid, earthworms, polychaete worms, dry salmon and trout rations, experimental diets, and later on trout crumbles. Tanks are preferred because producers have more control of the water quality in tanks than in ponds.

Adult shortnose sturgeons are held in 0.5-acre ponds or cylindrical and raceway tanks (with a volume of 190 to 2,300 gallons) supplied with recirculated water. Tank-held adults feed on fish, squid, molluscs, crustaceans, worms, and beef liver; pond-held adults do not receive supplementation (Conte et al., 1988).

Bacterial agents that cause diseases in sturgeon include *Aeromonas hydrophilia*, *A. sobria, Pseudomonas* spp., *Edwardsiella tarda*, *Yersinia ruckeri*, *Streptococcus* spp., and, rarely, *Flavobacterium columnariae*. Factors that may predispose cultured sturgeon to bacterial diseases include stress factors, such as handling, and water quality problems, such as low DO levels, traces of hydrogen sulfide, and accumulation of organic loads on the bottom of holding tanks. *Streptococcus* spp. can be treated with erythromycin (100 milligrams/kilogram body weight daily for 10 days), and *Edwardsiella tarda* can be treated with daily oxytetracycline baths (Francis-Floyd, 2000).

#### *4.3.6.7 Sunfish Family*

Sunfish are produced for sport and foodfish, forage fish for predators including bass, and stocker fingerlings for recreational ponds. The sunfish family *(Centrarchidae)* is exclusive to North America and includes 30 species, the most popular of which are the bream (*Lepomis* spp.) and crappie (*Pomoxis* spp.).

Species from the genus *Lepomis* are commonly referred to as bream, sunfish, sun perch, or panfish. Only 4 out of the 11 *Lepomis* species are extensively cultured as sport fish. They are the bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), warmouth (*Lepomis gulosus*), and green sunfish (*Lepomis cyanellus*). The bluegill is probably the most well known of all sunfish species and has been stocked throughout North America as a game fish. It is most abundant in shallow, eutrophic lakes and ponds but can also be found in streams. The redear, also known as “shellcracker” and “chinquapin,” has also been stocked throughout North America as a game fish or used as a companion to bluegill in controlled systems, but it prefers sluggish waters. The warmouth, or “goggle-eye,” occupies sluggish waters and is not usually used to stock recreational waters. Its main use is for the production of hybrids with other primary *Lepomis* species. Green sunfish are also known to hybridize with other *Lepomis* species. They are found in a wide range of habitats (from ponds and lakes to river systems) and are perhaps the most adaptable and abundant of all the sunfish species.

The most popular size for stocking of bluegills, redears, and sunfish hybrids is 50 millimeters. Bluegills and redears are stocked as forage species for largemouth bass and also for sportfishing. There has also been newfound interest in using bluegills, redears, and some sunfish hybrids in nontraditional markets such as foodfish for human consumption and use in fee-fishing operations.

The two *Pomoxis* species, the black crappie (*Pomoxis nigromaculatus*) and white crappie (*Pomoxis annularis*), are cultured for stocking ponds, lakes, and reservoirs. Black crappies are common in Quebec and Manitoba provinces in Canada, the northern and eastern portions of the United States, and as far south as Florida and Texas. White crappies are common in southern Ontario, Canada, in Minnesota and states eastward, and as far south as the Gulf of Mexico.

*Production Systems*

Most culture of sunfish occurs in ponds. Spawning ponds should be less than 3 acres and 2 to 5 feet deep, with a smooth, evenly sloped bottom. It is recommended that the ponds be filled at least 2 to 4 weeks before spawning activity commences and that the ponds be completely free of any other fish species. A plankton bloom should also be established before the spawning activity begins. This can be accomplished through the use of organic or inorganic fertilizers. Groundwater is the preferred water source for production ponds, and the water level can be manipulated by drainpipes (Brunson and Robinette, 2000).

*Culture Practices*

It is critical to properly identify broodfish used for sunfish culture to ensure that the desired offspring are produced because *Lepomis* species have a tendency to hybridize. *Lepomis* broodfish spawn very soon after optimum temperatures have been reached. A powder or mash is usually the first food given, and then feed particles matched to the size of the fish are given as the fish grow. The fish are grown out to at least 2 inches before harvesting because smaller-sized fish stress easily (Brunson and Robinette, 2000).

Both *Pomoxis* species are cultured similarly. Usually, 2-year-old crappies are put into ponds to spawn, and they are given fathead minnows, threadfin, or gizzard shad as forage. Spawning and egg incubation proceed naturally in the open ponds. After crappie eggs hatch, the fish can be transferred to small raceways to be trained to accept prepared rations or pelleted feeds. They are then harvested as fingerlings.

Care needs to be taken during harvesting because handling stress can increase the incidence of columnaris disease. It has been found that harvesting fingerlings during winter can reduce handling stress, and that black and hybrid crappies endure handling stress better than white crappies (Brunson and Robinette, 2000).

#### *4.3.6.8 Walleye*

Walleye *(Stizostedion vitreum)* are raised as foodfish and for stocking purposes. Most commercial harvest of wild walleye in North America occurs on the Canadian shore of Lake Erie and in isolated lakes of western Ontario and the Canadian Prairie Provinces. In the United States, some tribes harvest a small amount of walleye on the Great Lakes for subsistence and also commercial purposes.

*Production Systems*

Several types of culture systems are used, including pond culture, tandem pond-to-tank culture, pond-to-tank-to-pond culture, cage culture, and intensive culture. In any of the culture systems, walleye eat diatoms, rotifers, and copepod nauplii, cyclopoid copepods, or small soft-bodied cladocerans when the fish are young. As they grow, their diet switches to larger cladocerans and then to immature aquatic insects.

Fingerling walleye can be produced in drainable ponds, with levees on all four sides, or undrainable ponds, which include farm and ranch ponds, shallow natural lakes, marshes, borrow pit ponds, and dug ponds. Drainable ponds are prepared by seeding pond bottoms with an annual rye grass, if there is adequate time between pond drainage and the next production cycle, or drying and disking the ponds if seeding is not possible. Additions of agricultural lime ($CaCO_3$) may be necessary to increase alkalinity, and additions of caustic (hydrated) lime ($Ca(OH)_2$) may be necessary to kill parasites after pond drainage. Ponds may be filled with groundwater or surface water, but surface water must be filtered so that unwanted organisms are not introduced to the pond. There is little information on pond culture in undrainable ponds. It is known that stocking densities in undrainable ponds are much less than in drainable ponds; however, there is a wide range of stocking densities in both types of ponds.

Tandem pond-tank culture is used to grow phase II fingerlings because it is hard to raise a large number of walleye to sizes over 4 inches in ponds (unless forage fish are added). Fingerlings are transferred from ponds to indoor culture tanks after they are accustomed to formulated feed diets and are raised to a size of 5 to 8 inches

In pond-to-tank-to-pond culture, phase II fingerlings are pond-raised and overwintered. In early spring they are transferred to cages in small ponds (0.16 acres), where they are put on formulated feed diets. Feed-trained fingerlings are then returned to ponds, where they remain on the manufactured feed diet, and raised for a few years to produce food-size fish. This culture method is uneconomical because of high mortality rates in all stages of the culture process (between fry stocking and fingerling harvest, during overwintering in ponds, during transfer of fingerlings from ponds to cages and to formulated feed diets, and during transfer back to ponds and another overwintering).

Walleye can also be raised in cages tethered to piers, docks, or rafts. This culture method has been used in water-filled gravel and rock quarries, natural and artificial lakes, and farm ponds. It has been used to raise fry to fingerlings, phase I pond-raised fingerlings to phase II fingerlings for enhancement stocking, and food-size fish. The survival rate of fingerlings from summer to fall is higher if feed-trained fingerlings are used instead of trying to train pond-raised fingerlings to take commercial feed in the cages.

Intensive culture refers to raising finfish in flowing water systems, such as flow-through systems, at a high density, and it encompasses single-pass (one-use), serial-reuse (stair-step raceway), and recirculating systems. These systems use high exchange rates of water, which allows for a good supply of oxygen in the culture tank and removal of dissolved wastes such as ammonia. Intensive culture is most often used to adjust phase I fingerlings to formulated feed and then to grow them to fall fingerlings. The feed-trained fingerlings can reach a marketable food-size when raised in intensive culture. Advantages of intensive culture include raising the fish indoors under optimum conditions, raising the fish where space or water supply is limited, and acclimating fingerlings or fry to formulated feed rations under controlled conditions (Summerfelt, 2000).

### *Culture Practices*

In drainable and undrainable ponds, fingerlings can be partially harvested by trapping or seining; however, in drainable ponds, they are most often harvested all at once by being drained into a catch basin. A distinctive characteristic of walleye fingerlings is their attraction to light, allowing for easy capture in light traps to monitor populations. After the fish cease to have an attraction to light (when they are around 1.6 inches in size), sampling can be done through nighttime seining (Summerfelt, 2000).

Culture practices for raising walleye to food-size include combinations of the above-mentioned systems. Phase I fingerlings can be raised in ponds until the fish are about 1.25 to 2.5 inches in length, at which time they must be harvested so that fish density can be determined. The phase I fingerlings need to be trained to accept formulated feed, and this can be initiated in intensive culture systems or in ponds. Ponds must be restocked at densities suitable for growth of the fish to a larger size, and then fingerlings can be raised through the end of the growing season to an average size of 5 to 8 inches, when they are known as phase II fingerlings (Summerfelt, 1996). Phase II fingerlings must be overwintered in adequately aerated ponds and can reach sizes of 12 to 14 inches by the end of the second summer in southern Iowa and the middle to end of the third summer in more northern locations (Summerfelt, 1996). Disadvantages to pond culture of food-size walleye include the length of time for the fish to grow out to market size, potential winterkill, and potential summerkill in instances of prolonged high temperatures (Summerfelt, 1996).

Walleye can be raised to food-size in flow-through systems, such as raceways or circular tanks, as long as the tanks are covered to reduce intense sunlight, to which walleye are sensitive. The greatest limitation of these flow-through culture systems is the necessity for available water sources with desirable water temperature. Flow-through systems must have a plentiful supply of water in the 66 to 77 °F range because growth rates diminish to nearly zero at temperatures lower than 60 °F. Intensive culture has a much higher survival rate than ponds for growout of walleye to food-size (Summerfelt, 1996). Fry can be cultured intensively by feeding them brine shrimp or formulated feed, and then grown out to food-size. Another option is to transfer phase I fingerlings raised in ponds into intensive culture systems to be habituated to formulated feed (Summerfelt, 1996).

Recirculating systems are another choice for raising walleye to food-size. The systems can be used throughout North America, with new water use minimized to around 5% or less of the total system volume per day and fish stocked at high densities and raised on pelleted feeds (Summerfelt, 1996). Recirculating systems are advantageous because the controlled water temperature allows for a 12-month growing season. These systems also have low water requirements relative to production capabilities, produce a small volume of concentrated waste, and offer the opportunity to locate facilities near major markets.

#### *4.3.6.9 Yellow Perch*

Yellow perch *(Perca flavescens)* is a popular food fish with high market demand. It is a coolwater species found in the Great Lakes region and Canada. Yellow perch harvests from the Great Lakes surpassed 33 million pounds/year in the 1950s and 1960s, and market demand kept up with the large supply. In the 1980s and 1990s, harvests fell to between 11 million and 17.6 million pounds/year. Commercially cultured yellow perch now add to the supply, and the market demand is high for them because of their freshness and because of concerns regarding microcontaminants in wild-caught fish (Manci, 2000).

*Production Systems*

Most commercial yellow perch production is conducted in ponds, but there is also potential for cage culture (KSUAP, n.d.). Ponds are prepared by adding organic fertilizer to stimulate the growth of zooplankton, which acts as a food source for newly hatched fry (Wallat and Tiu, 1999).

*Culture Practices*

It takes about 18 months to grow yellow perch to a harvest size of 0.25 pounds. Some research has indicated that stocking yellow perch at high densities could be advantageous to production because the high densities stimulate feeding activity and allow for maximum growth (KSUAP, n.d.).

### 4.3.7 Baitfish

Baitfish is the term used to describe live fish sold as fishing bait or as "feeders," which are fish fed to ornamental fish and to invertebrates with piscivorous food habits (Stone, 2000). More than 20 species are caught in the wild and used for bait, but fewer species are raised on farms. Farmers face strong price competition from wild-caught bait, which has negatively affected the profitability of baitfish farming. If farm-raised fish cannot be supplied at a competitive price, the result is increased harvest pressures on wild stocks to meet market demands (Stone et al., n.d.). The common farm-raised species are the golden shiner (*Notemigonus crysoleucas*), the fathead minnow (*Pimephales promelas*), and the goldfish (*Carassius auratus*) (Stone, 2000). The baitfish industry is one of two non-food production sectors in U.S. AAP. (The other sector is ornamental fish production.) According to the 1998 Census of Aquaculture, the baitfish industry generated $37.5 million in total sales with 275 growers throughout the country (USDA, 2000).

According to the Census of Aquaculture, Arkansas leads the industry in production of baitfish in the United States, with 62 growers and $23 million in total sales; however, it is believed that the number of farms and the value of the industry are higher than the Census figures indicate. For example, Collins and Stone (1999) estimated the 1998 value of Arkansas baitfish production at $37.9 million. Compared to foodfish culture, baitfish culture is unique in the vast number of individual fish produced and the variety of sizes required by the market. In addition, the impact of competitive market forces plays a critical role in the baitfish industry. Demand for bait is seasonal, driven by regional customer preferences, and sensitive to weather conditions (Stone, 2000). Farmers monitor weekend weather forecasts for regions where their fish are sold to determine how many fish to harvest, grade, and harden in vats in anticipation of sales orders. For example, a warm winter means fewer days of ice fishing and a reduced market for minnows (Stone et al., n.d.)

Sources of baitfish include wild capture, extensive culture, and intensive culture. In the past, most baitfish were captured in the wild. In some areas, collecting small fish for bait is still legal, and commercial fishermen use seines or traps to harvest the fish. Farming fish for bait grew in response to shortages of wild-caught minnows in the 1930s and 1940s, as well as concerns over the possible depletion of wild stocks. Extensive culture, more common in northern states, is the practice of raising seasonal crops of fathead minnows or white suckers in shallow lakes. Fry are stocked in the spring and allowed to grow. The fish are raised on natural food alone. With this form of culture, the production yields are lower than those in intensive culture, which has a higher biomass within the production unit, but the costs incurred by the operator are also lower.

In 1934 the Michigan Department of Conservation began experimenting with minnow propagation (Stone, 2000). In the late 1940s through the 1970s, baitfish farms grew rapidly (Stone et al., 1997). Today about half of all baitfish are farm-raised (Stone, 2000). The first baitfish farms in Arkansas began in the late 1940s. In 1997 Arkansas had an estimated 27,800 acres under cultivation for baitfish (USDA, 2000). Most baitfish farm acreage produces golden shiners and fathead minnows (Stone et al., 1997). Golden shiners are the predominant species raised in Arkansas (Collins and Stone, 1999). Fathead minnows are the most common species raised in the North Central Region, which includes Illinois, Michigan, Minnesota, Ohio, South Dakota, and Wisconsin (Meronek et al., 1997). Goldfish are primarily raised in Arkansas and the southern part of the North Central Region (Gunderson and Tucker, 2000). Golden shiners are both wild-harvested and cultured in the North Central Region, while goldfish are only cultured (Gunderson and Tucker, 2000).

The production of farm-raised baitfish can help to minimize environmental impacts by reducing the demand for wild-caught baitfish. These fish are an integral part of the food chain for freshwater systems. Their decline could impact the entire ecosystem by reducing the number of forage fish. Also, the transfer of wild-caught baitfish from their native populations to other sites across the country raises concern about possible infiltration of non-native species.

#### *4.3.7.1 Production Systems*

Although culture practices vary with species and from farm to farm, most baitfish are raised in earthen ponds. Ponds used for golden shiners range in size from 5 to 20 acres, while ponds for fathead minnows are usually up to 10 acres (Stone, 2000). Ponds for goldfish are even smaller, with an average pond size of 2 acres. Water depth is relatively shallow, ranging from 2.5 to 6 feet to help farmers harvest fish without draining the ponds. Groundwater is used most often to fill ponds for baitfish culture. If surface water is used, farmers use fine-mesh, self-cleaning filters to prevent the introduction of wild fish into baitfish ponds. Golden shiners and fathead minnows are partially harvested from ponds during the year. Fish are baited into a corner and harvested by surrounding the fish with a seine. By the time the pond is emptied, the standing crop has been reduced to 25 to 50 pounds/acre.

#### *4.3.7.2 Culture Practices*

Golden shiners and goldfish have traditionally been propagated using either the wild-spawn method or the egg-transfer method (Stone, 2000). With the wild-spawn method, broodfish are stocked into newly filled ponds with aquatic vegetation in shallow water. Fish spawn freely on the vegetation, and then juveniles are either raised with their parents or transferred to another pond. In the wild-spawn method, fry are often vulnerable to predation by older generations of fish. Although fathead minnow growers generally use the wild-spawn method, most golden shiner and goldfish farmers use the egg-transfer method. In the latter method, spawning mats are used to collect eggs, and then the eggs are transferred to a rearing pond filled with a shallow layer of fresh well water (not filled to capacity) for incubation and hatching. Eggs hatch in 3 to 7 days.

Usually, eggs or fry are stocked into prepared ponds at higher densities, and when the juvenile fish are large enough, they are spread out into other ponds at lower densities. Juvenile fish can be stocked into ponds with adult fish once they are large enough to avoid being eaten. The growing season in the North Central Region is shorter (120 to 150 days) than that in Arkansas (180 days); therefore, the size attained by golden shiners and goldfish over a single growing season in the North Central Region is smaller (Gunderson and Tucker, 2000).

In preparation for stocking fry, ponds are fertilized to encourage the development of natural food. Golden shiners feed on zooplankton, but they also eat a wide variety of other animal and plant materials (Stone, 2000). Fathead minnows are primarily algae eaters, but they also eat zooplankton and insect larvae. Young goldfish feed primarily on zooplankton; as they age, they also feed on algae and detritus.

Feeding practices vary greatly among producers. Unlike in foodfish culture, the primary goal in baitfish production is not to grow the fish to market size as fast as possible; instead, producers manipulate the stocking density and feeding rate to produce a variety of sizes (Stone et al., 1997). Feeding rates for baitfish are determined by the market demand for various fish sizes. In Arkansas many farmers start feeding at 5 pounds/acre/day, then gradually increase to 10 or 15 pounds/acre/day. Most of the feed input to ponds is thought to contribute to the natural production of food organisms (Stone and Park, 2001, personal communication). Many baitfish farmers feed in one area of a pond, where aerators are placed, to attract fish for ease of harvest with seines. In the northern North Central Region, golden shiners are usually not fed prepared feed (Gunderson and Tucker, 2000).

Farmers also apply fertilizer to promote the growth of natural food. As a general rule, a single application of inorganic fertilizer for baitfish ponds should contain 3 to 4 pounds/acre of phosphorus (Stone et al., 1997). Organic fertilizers, such as vegetable meals, hay, and poultry litter, are normally used only for fry nursery ponds in combination with inorganic fertilizer. Fertilizer use has declined as farmers have switched to using prepared feeds, but natural food is still an important part of the baitfish diet (Stone et al., n.d.).

The biomass for baitfish in pond culture is low. Average yields for baitfish production are 350 pounds/acre for golden shiners and fathead minnows, and 790 pounds/acre for goldfish (Collins and Stone, 1999). In contrast, foodfish raised in ponds are stocked at approximately 6,000 pounds/acre.

#### *4.3.7.3 Water Quality Management Practices*

A common practice in Arkansas is to drain and pump water from pond to pond. The most common type of drain used in baitfish production ponds is the inside swivel drain (Stone et al., 1997). The swivel drain allows baitfish farmers to drain the pond from the top of the pond (the surface of the water) and minimize the release of solids during draining.

Water is transferred when ponds are drained to conserve water and reduce pumping costs. Drains are installed to transfer water between ponds, or diesel pumps are used to pump water from pond to pond. Boyd (1990) describes a method developed to reuse water on a large minnow pond in Arkansas. The farm installed pipes at the water level of adjacent ponds. When the pond is emptied, water is pumped into adjacent ponds and stored. After the pond is harvested, the cross pipes are opened, and the pond is refilled. Baitfish farmers in Arkansas routinely capture rainwater and prevent overflow from the ponds by maintaining pond water levels at least 6 inches below the overflow pipe. When a pond is emptied, water is often captured in a ditch and then transferred to another pond for reuse.

During the spring spawning season, a number of baitfish ponds are drained to make room for the new crop of fish (Stone et al., n.d.). A pond being prepared for fry is drained to adjacent ponds. After drying to ensure that organisms that could eat the small fry will not be present, the pond is filled to a depth of about 1 foot with well water. The well water is fertilized, and as the fry grow larger, water from the adjacent ponds is transferred back. Ponds are drained sequentially, so that old water from one pond can be used to top off ponds with new fry. (During incubation and hatching, these ponds contain only a shallow layer of fresh well water.) The old water has the advantage of containing natural foods for the young fry. Generally, this is the only time of year at which any discharge reaches receiving streams (Stone et al., n.d.). The volume of discharge is typically less than the volume of the pond because of water management practices that support the transfer and reuse of pond water.

Few data are available on water quality in commercial baitfish ponds or on effluents from these ponds; however, the impact is likely to be minimal. Baitfish production uses low biomass stocking densities. Also, current management practices within the industry reduce potential impacts of effluent discharges. Farmers seine by hand to prevent stirring up sediments because small baitfish are sensitive to muddy conditions. Farmers begin with a low biomass and lower the biomass density even further with partial harvests throughout the year. The combination of low biomass and reduced feed input prior to draining makes it likely that baitfish effluents will have lower solids concentrations than effluents from catfish ponds (Stone et al., n.d.). Also, it is likely that farmers' efforts to conserve water have also reduced effluent quantities.

### 4.3.8 Ornamental Fish

The culture of ornamental, or tropical, fish is primarily to supply animals for the home aquarium where fish are kept as a hobby or as pets. The ornamental fish industry is one of the two major non-food production sectors in the AAP industry; the baitfish industry is the other sector. Although many freshwater ornamental species are cultured, some examples are guppies *(Lebistes reticulates*), mollies (*Mollienesia* sp.), swordtails (*Xiphophorus* sp.), tetras (*Hemigrammus* sp.), gouramis (*Osphroneums, Sphaerichthys, Trichogaser* sp.), and goldfish (*Carassius auratus auratus*). More than 1,000 freshwater species in about 100 families are represented in the ornamental fish trade at any one time; however, only about 150 species are in great demand and account for the largest volume of trade (Chapman, 2000). Most ornamental fish currently produced in the United States are freshwater fish. Nearly 80% of the freshwater ornamental fish sold in the United States are raised in confinement, and the majority of those are raised in pond operations (Stoskopf, 1993). The production of marine ornamental fish is an emerging industry with few species regularly reproduced in captivity. Some of the most common species available from marine culture facilities include the clownfish (*Amphiprion* spp. and

*Premnas biaculeatus*), the neon goby (*Gobiosoma oceanops*), and the dottyback (*Psuedochromis* spp. and *Ogilbyina novaehollandiae*).

According to the 1998 Census of Aquaculture, there are 345 ornamental fish farm operations in the United States, which produce roughly $68 million in total sales (USDA, 2000). Florida, with 171 growers, dominates the domestic ornamental fish industry, with approximately $56 million in total sales, or 81% of the total sales in ornamental fish species in 1998. California, Arkansas, Indiana, and Hawaii also produce ornamental fish.

Ornamental fish culture may benefit wild ornamental populations by preventing destructive collection practices, which deplete wild populations and degrade natural habitat. The Asia Pacific region is the global center of marine diversity; it supports more species of coral and fish than any other region in the world (Holt, 2000). This region is home to 4,000 species of reef fish and more than one-third of the world’s coral reefs. In this region and throughout the tropics, natural populations of coral reef fish, which make up the majority of marine ornamental species, are increasingly threatened by development, dredging, coral collecting, and the live foodfish and aquarium fish trade (Holt, 2000). Many common collection methods, which include the use of dynamite and sodium cyanide, are destructive and cause damage to coral reef habitats. Loss of habitat reduces the area available for the settlement of new fish recruits.

#### *4.3.8.1 Production Systems*

Ornamental fish farming is characterized as an extensive culture (very low biomass densities) and often has two phases of production: a hatchery phase and a growout phase. Most breeding for ornamental fish takes place in recirculating systems, while the growout phase usually occurs in ponds. In many cases, ornamental fish farms are small businesses owned and operated by a family (Chapman, 2000). Farms often use a combination of both indoor and outdoor facilities for production. Indoor areas, usually built from modified greenhouses and wooden and steel sheds, are used primarily for breeding, hatching eggs, and raising larvae or fry. The remaining indoor area is used for holding, sorting, and shipping fish. The most common outdoor facilities are earthen ponds and concrete tanks. In Hawaii, broodstock of live-bearing ornamental fish are typically held in net cages in ponds, and then the juveniles are transferred to ponds for growout (JSA, 2000b). Net cages are small floating structures that allow water to flow through while retaining the confined animals (Stickney, 2000d). They are used for raising early life stages of various species, or sometimes to hold fish in advance of spawning. In Florida, live-bearer production is typically done in ponds.

*Pond Systems*

Although some ornamental fish are raised in recirculating systems, most are produced in outdoor earthen ponds (Watson and Shireman, n.d.). In Florida these ponds are almost all water-table ponds in sandy loams. Because the water table is so close to the surface, ponds can be created by digging out the appropriate area and letting the pond fill with water from the water table. The water level in the pond is dependent on the existing hydrology. In many areas, during dry seasons, well water is used to supplement the water table source. A typical outdoor pond in Florida is approximately 65 to 82 feet in length, 20 to 30 feet wide, and 5 to 6 feet deep. Farmers often cover outdoor ponds and tanks with nets to protect the fish from predators, or they use plastic to provide shade and maintain water temperatures, depending on the time of year (Chapman, 2000).

A typical growout pond (approximately 2,152 square feet) may be stocked with 10,000 to 80,000 fish from egg-laying parents or with around 200 live-bearing broodfish (Chapman, 2000). After 2 months, the live-bearing population in the pond can reach 30,000 fish. Growout ponds for juvenile freshwater ornamental fish are prepared for stocking by draining the pond after each production cycle and washing and preparing the bottom. After washing, the ponds are disinfected with hydrated lime to ensure that all predators are eliminated from the system. Although specific to individual species, some ponds remain in production unwashed for 1 to 2 years (Chapman, 2000). The ponds are fertilized to stimulate the growth of phytoplankton in the water. Organic fertilizers are used to sustain a release of nutrients over a longer period of time. Cottonseed meal is a common organic fertilizer used by ornamental fish producers. Inorganic fertilizers provide a short-term nutrient release and are often used to initialize phytoplankton growth. After the ponds are fertilized, they are filled with water and an algae bloom is allowed to develop to encourage the creation of a natural food source.

*Recirculating Systems*

Although recirculating systems are used primarily for the hatchery phase of ornamental production, producers are exploring opportunities to expand growout production, using technologies from recirculating systems (JSA, 2000b). Stocking densities are higher in recirculating systems than in ponds, approaching 15 fish/gallon without oxygen injection and 58 fish/gallon with oxygen injection. Water for facilities using recirculating systems is often treated internally with mechanical and biological filters (Chapman, 2000). Internal processes within recirculating systems include settling basins, baffles, screens, and upflow solids contact clarifiers to remove suspended and settleable solids. To break down organic wastes, some culturists use microbes in trickling filters and modified upflow clarifiers. To disinfect treated water, some culturists use ozone and/or ultraviolet light.

Ozone is also used to oxidize organic compounds. Fine suspended solids and other dissolved organics are stripped with dissolved air flotation or foam fractionation technology.

#### *4.3.8.2 Culture Practices*

With the exception of a few species like koi and goldfish, most ornamental fish are native to tropical regions of the world and cannot tolerate temperatures below 64 °F. Ornamental fish are relatively small in size, with a market weight between 0.1 and 1.4 ounces and length between 0.8 and 6 inches. Aquarium fish usually live from 6 to 10 years; however, some koi have been recorded as living as long as 70 to 80 years (Chapman, 2000).

Based on their reproductive cycles, freshwater ornamental fish are divided into egg layers and live-bearers. Egg-laying fish deposit their eggs on spawning mats or broadcast them for external fertilization. Live-bearing fish, such as guppies, release fully developed young that are ready to feed on their own.

Most egg layers are artificially bred in indoor hatcheries. Broodfish are paired in tanks or spawned together in large groups (Chapman, 2000). Fish are stimulated into breeding by using spawning mats and by manipulating the temperature, flow, pH, and hardness of the water. Culturists sometimes use hormones like human chorionic gonadotropin or carp pituitary extract, which are injected into individual fish to induce spawning. After spawning the eggs either are allowed to hatch where they are laid or are collected and placed in incubators. The larvae that hatch are pooled and transferred to rearing tanks or outdoor ponds. The fertilization and spawning of live-bearing fish is allowed to occur naturally in breeding ponds or tanks. In production, live-bearing parents are usually separated from their offspring to prevent cannibalism.

Many of the more popular and expensive marine ornamental fish, such as butterfly fish, angelfish, and wrasses, are difficult to raise in captivity. Clownfish, neon gobies, and dottybacks are easier to raise because they can change sex; therefore, a spawning pair is not needed. Clownfish have eggs that take several days to hatch, and they produce larvae that are large enough to feed on rotifers when they hatch. In captivity, gobies spawn regularly every 2 to 3 weeks and produce large eggs. Young can be raised on rotifers and zooplankton and, later, brine shrimp nauplii. Like gobies, dottybacks produce large larvae that grow quickly.

In general, it takes 3 to 6 months to produce market-ready fish. The typical survival rate for freshwater ornamental fish in a pond is 40% to 70%. Most losses in outdoor culture systems are due to predation, deterioration of water quality, and disease. Fish are harvested with fine seine nets, dip nets, and traps (Chapman, 2000). The process for harvesting ornamental fish differs from that for foodfish because the fish are individually selected and must be kept alive. Ornamental fish are sorted by hand, based on color and size. Mechanical graders are not yet available for the ornamental industry.

*Feed Management*

There is very little published information on the nutrition and feeding of ornamental fish. Most dietary knowledge has evolved from trial-and-error tests by individual farmers and a few studies in research laboratories (Chapman, 2000). Although most producers rely on a natural food sources for fish in outdoor ponds, these sources are sometimes supplemented with formulated feed. Fish raised in indoor tanks are fed commercial feed mixtures. Feed is delivered by hand or automatic feeder. Because of the small particle size of the feed and the low volume of feed used for the growout phase, feed is often allotted at a constant rate of 3% to 10% of fish biomass per day for freshwater ornamental fish (Chapman, 2000). Because the biomass for ornamental fish production is small, the feed input is also small.

*Health Management*

Parasites and bacteria are the two most common causes of infectious diseases in ornamental fish. The most common external parasites are ciliated protozoans, primarily *Ichthyophthirius multifiliis*, or “ich,” and *Trichodina.* Common treatments for external parasites include salt, formalin, copper sulfate, and potassium permanganate. The most prevalent infectious bacteria are in the aeromonad and columnaris groups. Common drugs used to treat bacterial infections are tetracycline, erythromycin, mitrofurazones, nalidixic acid, potassium permanganate, and copper sulfate (Chapman, 2000). Drugs are not often used in pond systems because of the high cost to treat a large volume of water. Drugs applied for ornamental culture are more commonly used in tanks for indoor recirculating systems (Watson, 2002, personal communication).

#### *4.3.8.3 Water Management Practices*

While there are few data in the literature on ornamental fish farm effluent characteristics, the impact from water discharged from ornamental fish production facilities is likely to be minimal. Assuming the average size of a growout pond is 2,152 square feet, with approximately 80,000 gallons of water, ornamental culture facilities typically discharge the volume of one pond, or less, per year (Watson, 2002, personal communication). Also, ornamental fish are extremely sensitive to water quality; therefore, water quality in the production system is constantly monitored by producers. Many producers are already implementing BMPs to reduce the impacts of effluents. For example, when ponds are drained, some facilities discharge water into settling basins, while others discharge into channels and ditches that run into surface waters. In Florida, ornamental fish farm effluents are regulated by the Florida Department of Agriculture and Consumer Services. The producer agrees to adhere to a set of BMPs, most of which deal with treatment of effluent prior to discharge (JSA, 2000b). When in compliance with Florida's BMP program, ornamental fish producers are issued an aquaculture certificate to verify their compliance. This program has a high compliance rate, estimated at 95% of the ornamental fish producers in Florida (Watson, 2002, personal communication). Because consumers and distributors often choose to buy fish only from certified aquaculture facilities, the demands of the market reinforce compliance with the BMP program.

### 4.3.9 Shrimp

Most commercial shrimp farms in the United States produce Pacific white shrimp (*Penaeus vannamei*), which were introduced from the Pacific coast of Central and South America, for a single annual crop (Iversen et al., 1993). According to the 1998 Census of Aquaculture (USDA, 2000), Texas is the leading producer of cultured shrimp in the United States, producing 3.7 million pounds/year with a value of $9.3 million. Hawaii, with 12 farms, produced 197,000 pounds with a value of $1.7 million. South Carolina, with six farms, produced approximately 43,000 pounds of shrimp annually. Overall, there are 42 shrimp farms in the United States that produce a total of 4.2 million pounds/year and generate sales of $11.6 million. Blue shrimp *(P. stylirostris*) from the Pacific coast of Central and South America and giant tiger prawn (*P. monodon*) from the western Pacific have also been introduced into the United States for shrimp farming.

#### *4.3.9.1 Production Systems*

Although shrimp can be raised in tanks, raceways, or ponds, most commercial facilities raise shrimp in levee ponds. Penaeid shrimp ponds rely on access to supplies of seawater. In general, shrimp farming in the United States takes place in coastal areas, primarily along estuary systems or waterways, such as tidal rivers or canals. A facility must be able to obtain seawater from the ocean, adjacent estuaries, or a reservoir. Pumping systems are used to transfer water to the ponds, and some facilities maintain reservoirs with supplemental supplies of seawater. Shrimp ponds usually have water gate inlets and outlets to fill and drain the pond. The gates are covered with screens to keep out unwanted predators and to prevent the escape of non-native cultured species to the receiving waters.

#### *4.3.9.2 Culture Practices*

In the wild, shrimp mate in the ocean. A single female can spawn 100,000 eggs or more at a time (Boyd and Clay, 1998). Within 24 hours of fertilization, the eggs hatch into larvae and begin feeding on plankton. The nauplius is the first larval stage. After approximately 12 days, the larval period ends and the young shrimp, now postlarvae, are carried on currents from the open ocean into nutrient-rich bays and estuaries. There they transform from organisms suspended in the water column into bottom-dwelling animals. Maturation from postlarvae to juveniles generally takes 4 to 5 months (Treece, 2000). In the late juvenile or early adult stage, the shrimp return to the ocean to mature and mate.

Culture for marine shrimp has three phrases—hatchery, nursery, and pond growout. Many shrimp producers rely on hatcheries that specialize in the production of postlarvae or juveniles for supplies of animals to stock their growout ponds. Shrimp hatcheries require relatively small tracts of land compared to growout facilities (Treece, 2000). Broodstock shrimp are harvested from the ocean and brought to the hatchery for sexual maturation and reproduction. Mated females harvested from the wild are allowed to spawn in a nauplii production facility. Some hatcheries prefer to control all production inputs; therefore, they harvest both males and females from wild stocks and quarantine them to ensure they are free of disease and other pathogens. The most important parameters for successful maturation of penaeid shrimp are constant temperature and acceptable levels of salinity, pH, light, and nutrition. Hatcheries rely on a readily available supply of high-quality seawater for successful shrimp maturation.

Shrimp are stocked in hatchery tanks at densities of 5 to 7 shrimp/10 square feet. The tanks are about 13 feet in diameter and are supplied with water through a flow-through system or a recirculating system (Treece, 2000). Most hatcheries now recirculate roughly 80% of the water to maintain better control over water quality (Treece, 2000). Once hatched, the young larvae (nauplii) are disinfected and evaluated for physical attributes. Nauplii with suitable physical characteristics are transferred to larval rearing tanks and stocked at densities ranging from 379 to 568 nauplii/gallon (Treece, 2000). At the postlarvae stage, shrimp are transferred from the larval rearing tank to a postlarvae-rearing/holding tank. Once the postlarvae have reached the PL8-18 stage (8 to 18 days old), they are usually sold to production farms for growout. Nursery ponds are smaller ponds used for an intermediate growout phase and to eliminate substandard juveniles. Not all farms use the nursery phase. Many farms stock postlarvae, either from the wild or from the hatchery, directly into growout ponds.

Climate plays an important role in shrimp production in the United States. Compared to tropical locations, the cooler climate in the continental United States limits outdoor shrimp culture to 9 months in southern regions of the country. Growout ponds are stocked in the early spring. Based on the characteristics of a typical facility from a 1998 report prepared for EPA, growout ponds are usually stocked at densities of 50,000 to 75,000 postlarvae/acre. Adult shrimp are harvested in the fall (September through

November) approximately 140 to 170 days after stocking (SAIC, 1998). Shrimp are usually harvested by draining the pond and collecting the shrimp in bags or containers on the outside of the pond at the end of the drainpipe. Shrimp can also be harvested by pumps that draw the shrimp out of the pond with a vacuum suction. Growout ponds remain dry throughout the winter. Most shrimp farmers manage bottom sediments by allowing the ponds to dry naturally, then mechanically tilling the pond bottoms.

*Feed Management*

In early spring growout ponds are filled with water from a nearby estuary. Inorganic fertilizer is added to the ponds to promote plankton growth. Postlarval shrimp feed on plankton and a commercial feed supplement for several weeks after stocking. Four to six weeks after stocking, the shrimp are large enough to receive pelleted feed. The shrimp are fed by broadcasting feed into the ponds with mechanical feeders. To prevent overfeeding, most marine shrimp farmers feed at least twice a day and use feeding trays to monitor consumption. Feed placed on the feeding trays is visually inspected ½ to 1 hour after being placed in the ponds to evaluate feed use. Feeding rates and quantity are determined by visual water quality, feeding tray assessments, and percent body weight increase (SAIC, 1998).

*Health Management*

Viruses frequently cause high mortalities in shrimp crops and limit shrimp farming production. More than 20 known viruses are associated with penaeid shrimp culture; however, only 4 of these pose a serious threat to the shrimp culture industry (Treece, 2000). The four disease-causing viruses that affect marine shrimp culture are infectious hypodermal and hematopoietic necrosis (IHHN) virus, taura syndrome virus (TSV), white spot syndrome virus (WSSV), and yellow head virus (YHV).

There are several theories on possible sources for shrimp viruses. These include entry to the facility through contaminated feed, infected broodstock or seed, and bird or animal transport. Two other potential sources are carrier organisms in ship ballast water and frozen seafood products (Browdy and Holland, 1998). Current treatment options for shrimp diseases are similar to traditional livestock disease treatment methods. Shrimp diseases are not harmful to humans due to the freezing and cooking processes typically conducted prior to consumption (Iversen et al., 1993). Facilities that do have an outbreak of disease dispose of the contaminated stock and water, and then sanitize the pond facilities. Ponds are chlorinated, dechlorinated, quarantined, and inspected before reuse (SAIC, 1998). Many shrimp facilities buy specific pathogen-free (SPF) or specific pathogen-resistant (SPR) shrimp to reduce disease outbreaks. Shrimp hatcheries are developing a new strain of *P. stylirostris* that is resistant to TSV and WSSV.

In addition to concern for the health of cultured species, there is concern for wild native populations, which can be infected by viruses carried out of an AAP facility through the discharge of pond effluent, processing plant wastewater, pond flooding, the escapement of cultured species, and the use of infected bait shrimp (SAIC, 1998). The spread of shrimp viruses is one of the most important problems limiting shrimp culture production worldwide (Browdy and Bratvold, 1998). Control of disease will depend on the development of biosecure production systems, which prevent pathogen transfer and establishment. Researchers at the Waddell Mariculture Center in South Carolina are exploring ways to create biosecure systems by identifying paths of pathogen transfer and evaluating existing technologies.

#### *4.3.9.3 Water Quality Management*

Shrimp farmers use aeration, water exchange, management of stocking densities, and feed management to improve water quality and support healthy stocks of shrimp. Shrimp production ponds are aerated to maintain sufficient levels of DO and to keep the water column well mixed. Shrimp farmers typically use more aeration per acre than finfish farmers because shrimp farmers must maintain sufficient oxygen levels on the pond bottom where the shrimp live. Good pond aeration also encourages natural processes within the pond to assimilate nutrients and wastes and to reduce total pollutant loads to receiving waters when pond water is discharged (Boyd, 2000).

After the shrimp are harvested in the fall, the ponds are drained and left to dry. This oxidizes the organic matter and reduces the likelihood of disease problems from growing season to growing season. Most shrimp facilities use surface water as a source and screen the inlets to prevent predators from entering the ponds. Because many of the shrimp grown in the United States are non-native species, escapement and disease are concerns for regulatory agencies. Outlets are screened to prevent escapement. Water is often reused by draining it into closed ditches, allowing sediments to settle, and then moving the water back into the ponds from the ditches.

In the past, water use in shrimp pond production was high, with average water exchange rates ranging from 8% to 23% of the pond volume per day to flush the pond system (Hopkins et al., 1993).

In a 1991 study, Hopkins et al. compared the effect of a typical exchange rate of 14% of the pond volume per day to the effect of a lower exchange rate of 4% on the growth and survival of *P. vannamei* stocked at 76 animals/square meter and found no difference in productivity (Table 4.3−9) (Hopkins et al., 1991). Hopkins et al. (1993) studied the effects of high water exchange at 25% and low water exchange at 2.5% on ponds stocked with *P. setiferus* at 4.1 postlarvae/square foot. Nutrient concentrations were higher in the pond with the lower exchange rate, but the total mass of pollutants discharged was lower. Growth and survival were good under both exchange conditions, with a higher production in the pond with the reduced exchange.

**Table 4.3–9. Water Quality of Inlet Water and Various Water Exchanges (Mean Values) of Shrimp Stocked at a Density of 4.1/Square Foot**

| *Water Exchange Treatment* | *Mean Size (lb)* | *Survival (%)* | *TSS (mg/L)* | *BOD (mg/L)* | *DO (mg/L)* | *Organic Solids (mg/L)* |
|---|---|---|---|---|---|---|
| Inlet water | N/A | N/A | 178.9 | 1.5 | N/A | 132.2 |
| Normal exchange (25% per day) | 0.035 | 81.9 | 183.3 | 8.5 | 5.4 | 122.5 |
| Reduced exchange (2.5% per day) | 0.040 | 79.5 | 196.2 | 14.7 | 5.0 | 115.4 |
| No exchange (0% per day) | 0.041 | 0.2 | 157.3 | 18.8 | 4.8 | 85.3 |

Source: Hopkins et al., 1991.

Currently, shrimp farmers rely on lower water exchange rates. Aeration is preferred over water exchange to enhance DO levels (Browdy et al., 1996). In the early 1990s Texas shrimp farms, under the requirements of more strict water quality and discharge regulations, initiated a shift in water use practices. Using semiclosed systems, farmers began reusing and recirculating water within the facility. In 1998, one Texas farm, Arroyo Aquaculture Association (AAA), produced more than 1.4 million pounds of shrimp on 345 acres, or approximately 4,000 pounds/acre, in a semiclosed system (Treece, 2000). The farm decreased its water use from 4,500 gallons/pound of shrimp produced in 1994 to 300 gallons/pound of shrimp produced in 1998 through 2000. Most of the water added is used to fill ponds and offset evaporation.

Shrimp farmers like AAA have also decreased their stocking densities and increased aeration to promote optimum conditions for shrimp production. AAA decreased its stocking density from 4.7 to 3.3 shrimp/square foot and increased its aeration from 8 to10 horsepower/acre (Fish Farming News, 2000). Research and industry practices have demonstrated that water exchange rates can be reduced without affecting shrimp production as long as DO levels are maintained.

#### *4.3.9.4 Effluent Characteristics and Treatment Practices*

The composition of pond effluents during water exchange, overflow after heavy rains, and initial stages of pond draining is similar to that of catfish pond water (Boyd and Tucker, 1998). Marine shrimp AAP facilities have two types of discharges: routine water exchange and water drained during harvest.

Shrimp pond effluents can have high concentrations of nutrients and suspended solids, high BOD, and low levels of DO. When discharged into receiving waters, effluents with high levels of suspended solids can cause turbidity, which can reduce light available for photosynthesis. Low DO levels can affect estuarine organisms in the receiving waters, and excessive nutrients can accelerate plankton growth, resulting in die-offs and increased BOD in receiving waters.

There is some evidence to suggest that effluent characteristics for marine shrimp ponds are similar to effluent characteristics for catfish farms (Boyd and Tucker, 1998). For example, as stocking densities increase, the quality of effluents deteriorates. In a study by Dierberg and Kiattisimkul (1996), data presented (Table 4.3−10) show average concentrations of water quality variables in effluent from shrimp (*P. monodon*) stocked at different rates. The quality of effluent declines for stocking densities above 3.7 shrimp/foot.

When shrimp ponds are drained, the effluent is almost identical in composition to pond water until about 80% of the pond volume has been released (Boyd, 2000). During the draining of the final 20% of the pond volume, concentrations of ($BOD_5$), TSS, and other substances increase because of sediment resuspension caused by harvest activities, crowding of agitated shrimp, and shallow and rapidly flowing water. The average $BOD_5$ and TSS concentrations often are about 50 milligrams/liter and 1,000 milligrams/liter, respectively (Boyd, 2000). The draining effluent contributes more to potential pollution than water exchange at 2%. Settling basins offer a treatment method for effluent released during shrimp harvest, especially for the highly concentrated final 20%. Settling basins or ponds remove coarse solids and the $BOD_5$ associated with them. Studies have shown that 60% to 80% of TSS and 15% to 30% of $BOD_5$ can be removed in a settling basin with only 6 to 8 hours of holding time (Teichert-Coddington et al., 1999). Settling basins also reduce TSS levels.

**Table 4.3–10. Composition of Discharge Waters from Ponds Stocked at Different Densities of *Penaeus Monodon***

| *Variable* | *Stocking Density (shrimp/ft$^2$)* | | | | |
|---|---|---|---|---|---|
| | ***2.8*** | ***3.7*** | ***4.6*** | ***5.7*** | ***6.5*** |
| Nitrite-nitrogen (mg/L) | 0.02 | 0.01 | 0.06 | 0.08 | 0.08 |
| Nitrate-nitrogen (mg/L) | 0.07 | 0.06 | 0.15 | 0.15 | 0.15 |
| Total ammonia nitrogen (mg/L) | 0.98 | 0.98 | 6.36 | 7.87 | 6.50 |
| Total nitrogen (mg/L) | 3.55 | 4.04 | 14.9 | 20.9 | 17.1 |
| Total phosphorus (mg/L) | 0.18 | 0.25 | 0.53 | 0.49 | 0.32 |
| Biochemical oxygen demand (mg/L) | 10.0 | 11.4 | 28.9 | 33.9 | 28.8 |
| Total suspended solids (mg/L) | 92 | 114 | 461 | 797 | 498 |
| Chlorophyll a (µg/L) | 70 | 110 | 350 | 460 | 350 |

Source: Dierberg and Kiattisimkul, 1996.

Based on the 1998 report for EPA, settling ponds are the method of water treatment most commonly used by shrimp facilities discharging effluent (SAIC, 1998). Based on the facilities monitored, some commercial farms discharge as much as 600 million gallons/year (MGY), while others report zero discharges. One facility has a 20-acre settling area where discharged pond water remains for 2 days before being discharged into receiving waters. Another facility uses weirs to allow discharged water to drop 10 feet before entering a drainage ditch. Many drainage ditches are designed as settling basins to trap solids from effluent discharged from ponds.

In addition to reusing water during production in a closed ditch system, AAA uses drainage ditches equipped with aerators to serve as settling basins for water discharged during harvest. This facility also uses weirs so that the water discharged drops 10 feet into the drainage ditch, helping to promote natural aeration and mixing. Drainage ditches are periodically monitored to ensure that the BOD levels are in compliance with the state standard of 6 milligrams/liter. Arroyo also uses screens on its effluent pipes to capture foam and prevent its transfer to receiving waters. Also, water drained from the ponds during the yearly harvest is collected and allowed to settle in empty ponds for 15 days before being released into the drainage ditches.

The Southern Star facility (Texas) has a constructed wetland area that is used to treat effluent from shrimp ponds. The wetland was constructed by building a dike around 100 acres of previously unused land adjacent to the facility. The wetland is designed to treat discharged wastewater and then filter recirculated water back to the ponds for reuse (SAIC, 1998).

Harlingen Shrimp Farms, located in Texas, is one of the largest shrimp farming operations in the United States. Pond effluent is usually discharged through water exchanges that begin 30 days after stocking the ponds, and all growout ponds are drained for harvesting 140 to 170 days after stocking. Routine water exchange rates of 10% to 20% occur until DO level fluctuations stabilize. Each pond is equipped with six to fifteen 8-inch pipes and one 35-inch gate for draining water during harvest (SAIC, 1998).

#### *4.3.9.5 Freshwater Prawn*

The Malaysian prawn (*Macrobrachium rosenbergii*), a freshwater prawn, has been cultured on a limited scale in the United States (KSU, 2002). The primary economic challenges associated with culturing shrimp in the United States are the availability of low-cost, high-quality feed; shorter growing seasons, with only one crop per year in some areas due to temperatures; the high cost of land and labor; high operating costs; foreign competition; and price fluctuations (Treece, 2000).

The Malaysian prawn spends part of its natural life cycle in saltwater. Adult shrimp migrate down rivers to estuaries to have their young. The prawns spend their early larval lives in brackish water, migrating to freshwater as juveniles and remaining there as adults (Iversen et al., 1993). The larvae feed by sight on zooplankton, worms, and larval stages of other aquatic invertebrates. Larvae undergo 11 molts before transforming into postlarvae. Transformation from newly hatched larvae to postlarvae requires 15 to 40 days, depending on food quality and quantity and temperature. After their metamorphosis to postlarvae, prawns change from living suspended in the water column to dwelling principally near the bottom (D'Abramo and Brunson, 1996a). Postlarvae can tolerate a range of salinities. They migrate to freshwater upon transformation, where they take on a bluish to brownish color as they change to the juvenile stage. Postlarvae are juveniles, but the common usage for the term *juvenile* is to describe freshwater prawns between postlarva and adult (D'Abramo and Brunson, 1996a).

*Production Systems*

As in penaeid shrimp production, most freshwater shrimp culture facilities use earthen ponds to produce shrimp. Ponds used for raising freshwater prawns have many of the same features as ponds used for the culture of channel catfish. Surface areas for growout ponds range from 1 to 5 acres, but some producers use larger ponds. Ponds are usually rectangular with a minimum depth of 2 to 3 feet at the shallow end and a maximum depth of 3.5 to 5 feet at the deep end (D'Abramo and Brunson, 1996b).

*Culture Practices*

As in penaeid shrimp culture, there are three phases of culture for freshwater prawns—hatchery, nursery, and pond growout. Many prawn producers purchase juveniles for the pond growout phase. Commercial hatcheries in Texas, California, and Mexico produce postlarvae and juveniles (D'Abramo and Brunson, 1996b).

Ponds are filled and then fertilized to provide natural food for the prawns and to create a phytoplankton bloom to shade out unwanted bottom plants. Juveniles are usually stocked at densities of 12,000 to 16,000 per acre. The length of the growout period depends on the water temperature of the ponds, but it is generally 120 to 180 days in the southern United States (D'Abramo and Brunson, 1996b). At the end of the growout season, prawns are harvested by seine or by draining the pond. For seining, the water volume is decreased by one-half before seining. During drain-down harvests, prawns are usually collected outside the pond levee as they travel through a drainpipe to a collecting device (D'Abramo and Brunson, 1996b). Some producers selectively harvest large prawns 4 to 6 weeks before the final harvest. After the harvest prawns are chilled and then marketed fresh on ice. They may be processed and frozen, or frozen whole for storage and shipment.

*Feed Management*

Juveniles stocked in growout ponds initially feed on natural pond organisms. As the juveniles grow to a weight of 0.011 pounds or greater, prawns are fed a manufactured feed. Channel catfish feed with 28% to 32% crude protein can be used for prawns. The feeding rate is determined by the mean weight of the population.

*Health Management*

Diseases do not appear to be a significant problem in freshwater prawn culture; however, as densities are increased, diseases are likely to be more prevalent (D'Abramo and Brunson, 1996b). Blackspot disease, also called shell disease, could affect freshwater shrimp. This disease is caused by bacteria that break down the outer skeleton.

*Water Characteristics and Effluent Treatment Practices*

Like catfish ponds, freshwater prawn ponds use aerators to maintain adequate DO levels and prevent thermal stratification. Farmers monitor dissolved levels in the bottom 1 foot of the pond water to make sure that DO concentrations do not fall below 3 parts per million. A common method in freshwater prawn culture is the use of full-time or nightly aeration. Farmers typically use 1 horsepower/acre (D'Abramo and Brunson, 1996b). Because standing crops rarely exceed 1,000 pounds/acre, this level of aeration is usually sufficient to prevent oxygen depletion. Some farmers use only emergency aeration as needed. Unlike marine shrimp production, there is no water exchange for freshwater prawn production. Nutrients in the pond are partially assimilated by pond processes (Boyd and Tucker, 1998).

There are very few data available in the literature describing the characteristics of effluent from freshwater shrimp ponds or effluent management practices associated with these ponds.

### 4.3.10 Crawfish

Red swamp crawfish (*Procambarus clarkii*) and white river crawfish (*Procambarus acutus acutus*) account for about 90% of all crawfish cultured in the United States (Davis, n.d.). Currently, crawfish represent the only crustacean species cultured on a large-scale basis in the United States (USDA, 1995). As a commercially available food source, crawfish can be traced back to New Orleans French Market records from the 1800s (LSU, 1999). A commercial fishery for wild crawfish was developed in the 1940s in the Atchafalaya River swamp in Louisiana, where crawfish are still harvested today. Because catches from the wild were unpredictable and driven by seasonal changes, an increase in consumer demand for a year-round supply eventually led to the development of a crawfish AAP industry in Louisiana (de la Bretonne and Romaire, 1990b).

In 1993 more than 59.5 million pounds of crawfish with a value of $26.7 million were produced in Louisiana on more than 143,000 acres of ponds operated by 1,618 producers (USDA, 1995). Production in Louisiana represents over 90% of the total U.S. farmed production for crawfish, 70% of which is consumed locally (de la Bretonne and Romaire, 1990a). In addition to Louisiana, some 21,000 acres of ponds are used for culturing crawfish in Texas; Mississippi, Maryland, South Carolina, North Carolina, Florida, Georgia, and California also have commercial crawfish farms. There are also some smaller producers in the midwestern and northeastern United States that culture crawfish for fish bait (Eversole and McClain, 2000).

#### *4.3.10.1 Production Systems*

Culture methods used to grow crawfish complement farm management plans by using marginal agricultural land, permanent farm labor, and farm equipment in the off-peak agricultural farming periods (de la Bretonne and Romaire, 1990b). There are two types of crawfish ponds: permanent ponds and rotational ponds (LSU, 1999). Permanent ponds are ponds that remain in the same location and have a continuous management plan applied year after year. Rotational ponds describe the practice of rotating the annual sequence of crops grown in a pond or rotating the physical location of the field in which crawfish are grown.

*Permanent Ponds*

Approximately half of the ponds in Louisiana are classified as permanent ponds (LSU, 1999). The three primary types of permanent ponds are single-crop crawfish ponds, naturally vegetated ponds, and wooded ponds. The typical culture cycle for permanent ponds is as follows (LSU, 1999):

| Time | Procedure |
|---|---|
| April–May | Stock 50 to 60 pounds of adult crawfish per acre (new ponds only) |
| May–June | Drain pond over a 2- to 4-week period |

| | |
|---|---|
| June–August | Plant crawfish forage or manage natural vegetation |
| October | Reflood pond |
| November–May/June | Harvest crawfish |
| May/June | Drain pond and repeat cycle without restocking crawfish |

Single-crop crawfish ponds are managed solely for the purpose of cultivating crawfish. Crawfish can be harvested 1 or 2 months longer because there is no overlap with planting, draining, or harvesting schedules for other crops. Naturally vegetated ponds usually refer to marsh impoundments and agricultural lands that are managed to encourage the growth of naturally occurring vegetation as a forage base for crawfish. High amounts of organic matter in the soil often lower the water quality, which decreases production. Though marsh ponds exist in Louisiana, they are not usually recommended for commercial production because of inconsistent yields. The last type of permanent pond is a wooded pond. Wooded ponds are built on heavy clay soils in forested areas (cypress-tupelo swamps) near drainage canals. Leaf litter provides the bulk of forage, but water quality is difficult to manage. While wooded ponds may provide advantages such as potential for waterfowl hunting, low initial start-up costs, and selective removal of unwanted vegetation, overall production per acre is usually lower than that for other management regimes (LSU, 1999).

*Rotational Ponds*

The most common crawfish-agronomic crop rotations are rice-crawfish-rice; rice-crawfish-soybeans; rice-crawfish-fallow; and field rotation. In rice-crawfish-rice rotations, rice and crawfish are double-cropped annually. A rice farmer can use the same land, equipment, pumps, and farm labor that are already in place. Farmers plant rice in a drained field (a shallow pond with a depth of roughly 18 inches) and then flood the field 6 to 8 weeks later. After the field has been flooded, crawfish are stocked to grow and reproduce. When the fields are drained in August to harvest the rice, crawfish burrow underground. Crawfish burrow when water temperatures become too warm and when oxygen levels are low. They can survive as long as their gills stay moist. After the grain is harvested, the remaining stubble is fertilized, flooded, and allowed to regrow (ratoon) (LSU, 1999). The ratoon crop is used as a forage base for crawfish. Crawfish are harvested between November and April; however, the harvest season is shortened in rotational ponds because ponds are usually drained in March or April to prepare fields to replant rice in the spring. Crawfish are harvested using baited traps. Harvesting crawfish is labor-intensive and accounts for nearly two-thirds of the production costs (LSU, 1999).

The following is a typical rotation schedule for rice-crawfish-rice rotations (LSU, 1999):

| Time | Procedure |
|---|---|
| March–April | Plant rice |
| June | At permanent flood (rice 8 to 10 inches high), stock 50 to 60 pounds of adult crawfish per acre |
| August | Drain pond and harvest rice (later in northern Louisiana) |
| October | Reflood rice fields |
| November–April | Harvest crawfish |
| March–April | Drain pond and replant rice |

In rice-crawfish-soybeans rotations, three crops are produced in 2 years. This rotation has the advantage of allowing for a longer crawfish harvest season than the rice-crawfish-rice rotation. The rice-crawfish-fallow rotation allows the farmer to leave the land fallow for a certain period of time to break the natural cycle of certain weeds and prevent overpopulation of crawfish. This is a common practice in southwest Louisiana. After several years in production, rotational ponds may develop stunted crawfish as a result of overpopulation in the pond. Some farmers relocate crawfish in stunted ponds by moving mature crawfish from the affected pond to stock a new pond that will be used in a crawfish-agronomic rotation. The affected pond is left dry during the part of the cycle during which crawfish would be harvested (LSU, 1999). When crawfish are produced with other crops through the rotational crop system, producers use the same amount of water they would need if they were raising only crawfish.

*Health Management*

Crawfish are sensitive to most chemicals. Four herbicides are approved for use in rice or soybean fields intended for use as crawfish ponds: Stam, Basagran, 2,4-D and Rodeo (LSU, 1999). The use of herbicides to control weeds is a common management tool for rice and soybean crop production. Farmers use broad-spectrum herbicides like 2,4-D as a pre-emergent treatment prior to planting rice to kill any native vegetation (weeds). Narrow spectrum herbicides like Rodeo are used to spot-treat post-emergent weeds. The mixture of herbicides, both broad-spectrum and narrow-spectrum, used to support rice and soybean growth is independent from crawfish production.

Of all insecticides available, only Malathion and Bt are labeled for use in crawfish ponds. Malathion is commonly used to control mosquitoes. There are no plant fungicides labeled for use in crawfish ponds or in fields intended for use as crawfish ponds. The frequency with which herbicides are used is unknown. Considering the potential to eliminate the crawfish crop plus the added expense of the chemicals, it is not likely that herbicides are used often; therefore, the impact on water quality would be negligible. If herbicides are used, farmers use them in association with their agricultural crops and use them sparingly to avoid building up chemical toxicities that could adversely affect crawfish.

Primary disease pathogens of crawfish include bacteria, fungi, protozoans, and parasitic worms; however, disease problems associated with current crawfish culture practices have been minor (LSU, 1999). In estimating variable costs of crawfish production for a 40-acre pond in southwestern Louisiana, herbicides are listed as a potential expense, but drugs to treat diseases are not included in the report (de la Bretonne and Romaire, 1990a). Using drugs to treat crawfish ponds for disease is not likely to be a common practice; however, if a disease outbreak does occur, this might result in a reduced crawfish crop for the season.

#### *4.3.10.2 Effluent Characteristics*

In a study conducted by the Southern Regional Aquaculture Center (Tucker, 1998) to characterize the quality of effluents from commercial crawfish ponds, samples were collected from 17 commercial ponds in south-central and southwest Louisiana. Three types of culture systems were selected: crawfish-rice field (rotational), single-crop crawfish (permanent), and wooded (permanent). Rice-field ponds included rice-crawfish double-cropping systems. Permanent crawfish ponds selected either were planted with rice or sorghum-sudan grass in early to late summer or were not planted with cultivated forages and had native aquatic and terrestrial plants.

DO concentrations in crawfish pond effluents ranged from 0.4 to 12.6 milligrams/liter. The concentration in effluent in fall (mean = 6.5 milligrams/liter) was higher than the concentration in winter (mean = 4.7 milligrams/liter), spring (mean = 4.9 milligrams/liter), and summer (mean = 4.3 milligrams/liter). Ponds with native vegetation had the lowest concentration of DO in effluents (mean = less than 3.5 milligrams/liter) because relatively high quantities of vegetative biomass depleted oxygen in the ponds.

Total solids concentration in the spring and summer ranged from 143 to 2,431 milligrams/liter (mean = 522 milligrams/liter), and total volatile solids ranged from 0 to 432 milligrams/liter (mean = 96 milligrams/liter). Effluents from ponds with native vegetation had significantly lower concentrations of total solids and total volatile solids in spring and summer (mean = 286 and 69 milligrams/liter, respectively) than in rice ponds (mean = 646 and 113 milligrams/liter) and sorgham-sudan grass ponds (mean = 578 and 92 milligrams/liter). Soluble reactive phosphorus concentrations ranged from 0.002 to 0.653 milligrams/liter (mean + 0.116 milligrams/liter), and total phosphorus concentrations ranged from 0.039 to 1.126 milligrams/liter (mean = 0.329 milligrams/liter).

Results from the study showed that concentrations of nutrients and solids in effluents in crawfish ponds were generally higher in the spring and summer. Effluent quality was poorest during the summer drainage period. The type and quantity of summer vegetation had a significant influence on the quality of water discharged from crawfish ponds. Ponds with native vegetation generally had lower concentrations of nutrients and solids than ponds with rice or sorghum-sudan grass. The presence of aquatic macrophytes in spring and summer in ponds with native vegetation increased nutrient uptake and reduced the level of suspended sediments. This study suggests that ponds with native vegetation are more likely to have better water quality.

#### *4.3.10.3 Current Effluent Treatment Practices Within the Industry*

As in other pond systems, the most important water quality concern in crawfish ponds is the level of DO. DO should be maintained above 3 milligrams/liter for optimal crawfish production (LSU, 1999). Problems with DO in crawfish AAP are compounded by the presence of large amounts of decomposing vegetation, which make typical remedies like emergency aerators ineffective (Eversole and McClain, 2000). Instead, crawfish farmers rely on preventive management measures such as the choice of forage type, the timing of flooding dates, the close monitoring of water quality conditions, and pond designs that divert flow to all areas of the pond. To improve levels of DO, some crawfish farmers use paddlewheel aerators coupled with diversion levees in the pond to improve circulation and maintain adequate DO levels (Eversole and McClain, 2000). Whereas feed management and the impacts of adding pelleted feed to the system are usually important water quality considerations for the culture of other species, feeding is not a regular practice in crawfish culture (Eversole and McClain, 2000). Instead, current production practices rely on a forage-based system. There are no feed management practices to recommend for this subcategory because the feed input is low and additional feed management practices would not likely have a significant impact.

Because farmers rely on soils to grow multiple crops like rice and soybeans in addition to crawfish, farmers using rotational crop systems in Louisiana, the region that accounts for 90% of the crawfish production in the United States, drain ponds slowly to prevent loss of soil. Ponds are also drained slowly to encourage crawfish to burrow into the pond bottom to start their reproductive cycle. There are some examples of crawfish farmers discharging water from crawfish ponds into siltation ditches and ponds prior to discharging the effluent into receiving surface waters like streams and rivers (Tetra Tech, 2002d). There is also cooperation with the NRCS to implement BMPs to minimize erosion and reduce the amount of nutrients and pesticides in effluent discharges (LSU, 1999). Examples of these practices include channel vegetation to improve turbidity problems, filter strips to reduce sediment in inflow and discharge water and help reduce soil erosion, and irrigation water management with planned flooding and draining to manage forage and crawfish.

BMP guidelines from NRCS also describe the positive environmental impacts of well-managed crawfish ponds (LSU, 1999). In many cases, flooded crawfish ponds benefit and improve the quality of the water entering and exiting fields by developing or restoring wetlands. Crawfish ponds provide more than 115,000 acres of man-made wildlife wetland habitat, benefiting waterfowl, wading birds, shorebirds, furbearers, reptiles, amphibians, and other invertebrate animals.

Although there is limited information about the quality of water discharged from either rotational ponds or permanent ponds, the impact of the volume of water discharged and the quality of the water discharged is likely to be minimal. First, crawfish production relies on the forage-based system for feeding, so feed management practices would not significantly impact water quality because the feed input is so low. Also, although DO levels are a concern, particularly as vegetation decays, crawfish farmers routinely check levels and use BMPs and technologies like mechanical aeration to maintain appropriate DO levels. Crawfish farmers also use siltation ditches to minimize the impact of discharge from crawfish ponds. Finally, when water is discharged from ponds, farmers release the water slowly to prevent the loss of valuable topsoil needed for productive agricultural crops and to encourage crawfish to burrow.

### 4.3.11 Lobster

The impoundment or pounding of the American lobster (*Homarus americanus*) in tidal lobster pounds is an important part of the lobster industry in Maine. Pounds are man-made tidal pools or impounded coves (Loughlin et al., 2000). They are flushed daily at high tide, replacing the holding area with fresh seawater. Pounds help lobster fishers and pound operators control the supply of lobsters to meet the market demand in the off-season when fishers are not harvesting wild catches. Although pounding is an important practice in Canada, according to the Maine Lobster Pound Association, Maine is the only state in the United States using this cultivation practice (Hodgkins, 2002, personal communication). There are 65 lobster pounds in Maine owned by 50 operators (Hodgkins, 2002, personal communication; Tetra Tech, 2002e).

In 2000, 57 million pounds of American lobster with a commercial value of more than $187 million were landed in Maine (Maine, 2002). Most wild-caught lobster harvests are shipped immediately to market, but some are held in pounds to extend their growth cycle. Tidal pounds in Maine hold about 5 million pounds, or approximately 10% of the total lobster landed in the state (Hodgkins, 2002, personal communication). In the colonial period, lobsters were considered poverty food, served daily to children, prisoners, and indentured servants (Gulf of Maine Aquarium, 2000). In today's market, the increased demand for lobster and the decline in wild lobster harvests has transformed lobster into a high-priced commodity, thereby encouraging the development of pounding.

#### *4.3.11.1 Production Systems*

For fall pounding, lobster fishers sell their catches of newly shed lobsters from September through November to pound keepers, who hold the shellfish in pounds (AII, 1989). Without aeration, lobsters are typically stocked 1 pound per square foot of bottom area. The average size of a lobster pound is 70,000 $ft^2$ (Hodgkins, 2002, personal communication; Tetra Tech, 2002e). From early September through April, the lobsters fill in their new larger shells with meat while the pound operators wait for a favorable market price. There are also shorter spring and summer pounding seasons with fewer lobsters. Spring pounding starts in May when the Canadian season opens, and spring-pounded lobsters are sold before they molt in July and August. From July to August soft shell lobsters are placed in pounds, where they harden and are sold. Summer pounding caters to the airfreight market (Tetra Tech, 2002e).

Lobsters are harvested using one of three methods: pumpers, dragging, or divers (Loughlin et al., 2000). Because of their speed and efficiency, airlift or hydraulic pumpers are considered the most cost-effective means of harvesting lobsters from a pound. With diver-operated pumpers, a diver works on the bottom, collecting lobsters and placing them into the end of the suction tube. Water flowing through the tube carries the lobsters to the surface. Dragging or seining is another common harvest method; however, lobsters are sometimes crushed or damaged when the work crew hauls the drag over the edge of the platform. Divers are also used to remove lobsters from pounds. They use a mesh bag to collect the lobsters. The bag is attached to a line that extends to the workstation. When the bag is full, the diver signals the crew to haul up the bag. Some pound owners drag their pounds until they recover about 80% of their lobsters; then they use divers to collect another 15%. The remaining lobsters are harvested when the pound is drained (Loughlin et al., 2000).

#### *4.3.11.2 Culture Practices*

*Feed Management*

Pound operators feed lobsters while they are in the pound. Most lobster pound facilities feed lobster freshly killed fish such as sculpin, pickled and smoked herring, and menhaden (Hodgkins, 2002, personal communication). Fresh or salted fish racks can also be used as a food source for lobsters. Operators generally use manufactured feed only when they need to apply medicated feed. The average feeding rate for Maine lobster pounds is approximately 70 pounds of fish per day per 5,000 lobsters (Hodgkins, 2002, personal communication; Tetra Tech, 2002e). Winter is the primary pounding season in

Maine. On average, lobsters are fed for 40 days within the winter pounding season. Feeding rates drop off when water temperatures drop below 40 °F. When water temperatures approach 32 °F, lobsters begin hibernating and do not consume food during this period. The summer and spring pounding seasons are shorter (1 to 2 months), with fewer lobsters and very few feeding days (Hodgkins, 2002, personal communication; Tetra Tech, 2002e).

*Health Management*

The three main diseases that affect lobsters are red tail, vibrio, and ciliated protozoan disease. Red tail (caused by *Gaffkemia*) is a fatal, infectious bacterial disease of lobsters that passes from one lobster to another through a break in the tail (Loughlin et al., 2000). Symptoms of red tail include inactive, weak, and lethargic lobsters; red tint under the tail; and a tendency in lobsters to remain near the shore (Loughlin et al., 2000). Red tail disease is present in an average of 5% to 7% of wild lobsters (Lobster Institute, 1995). If infected lobsters are placed in a pound and die, the live bacteria cells spread to other lobsters (Gulf of Maine Aquarium, 2000). Gram negative rod bacteria, such as *Vibrio*, are hard to detect and difficult to treat. To stop the spread of the bacteria to healthy lobsters, pounds prevent overfeeding and remove weak lobsters (Loughlin et al., 2000). Ciliated protozoan disease is fatal to lobsters, with mortality usually occurring in 1 to 2 months (Loughlin et al., 2000). As in red tail, the protozoan enters the lobster through a break or wound in the tail. The disease has no approved treatment and has shown up in more than a dozen pounds over the past 10 years (Loughlin et al., 2000).

Pound operators conduct an initial health screening of the lobsters before they are stocked into the pound to remove weak and sick animals. This practice reduces the frequency of disease in the pound. Pound operators also conduct periodic inspections using divers or a small hand drag to sample the pond and to screen out sick and dead lobsters (Loughlin et al., 2000).

When needed, pound keepers use medicated feed containing oxytetracycline (brand name Terramycin) to treat bacterial diseases like red tail. The frequency of use varies from facility to facility. On average, about half of the pound facilities use oxytetracycline in a pound season. Treatments with medicated feeds usually last 5 days before pound keepers switch back to regular feed, and pound keepers commonly use the drug for two cycles, or 10 days, in a pound season. Oxytetracycline is administered through medicated feed at approximately 6 to 8 pounds of feed per 1,000 pounds of lobster. As temperatures drop, feeding rates also decline to 3 to 5 pounds of feed per 1,000 pounds of lobster. Assuming an average facility holds 70,000 pounds of lobster, a facility would use roughly 3,850 pounds of medicated feed in a year. (For the entire industry, this would be approximately 127,050 pounds of medicated feed per year.)

The FDA regulates the use of medicated feed and requires lobster growers to apply a 30-day withdrawal period. Facilities must wait at least 30 days after feeding lobsters medicated feed before they remove lobsters from the pound to ensure that residues from the medication are flushed from the lobster before human consumption. Currently, oxytetracycline is the only FDA-approved medication for lobsters (Bayer, 2002, personal communication). Generally, this is the only drug used by lobster pound facilities.

### *4.3.11.3 Water Quality Management Practices*

Mechanical aeration enhances DO levels in lobster pounds. Approximately two-thirds of lobster pound facilities in Maine use mechanical aeration, especially in months with warmwater temperatures (Hodgkins, 2002, personal communication). Dams for the impoundment are built to the height of the mean low water mark with a notch at the mean low water mark. As incoming water flows through this notch at high tide, the increase in water velocity promotes water mixing inside the impoundment (Tetra Tech, 2002e). Pounds rely on tidal flushing to maintain the water quality in the impoundment. Currently, there are no existing control technologies in the industry to reduce discharge.

Although there is little information about the quality of water discharged from lobster pounds, the impact of the effluent is likely to be minimal. Currently, lobster pounds are found only in Maine, and they are not likely to expand to other states. This is a small industry subcategory that is site-specific to Maine. Based on a relatively low input of food and a limited number of feeding days, feed management BMPs are not likely to improve water quality in the system. Regular tidal flushing for all pounds and supplemental aeration for many pounds in Maine also help maintain water quality and DO levels. Finally, the industry is regulated by the FDA 30-day withdrawal requirement limiting the number of days that pound keepers can use medicated feed, so the impact from inputs of medicated feed into the system is likely to be minimal and is already regulated by another agency.

## 4.3.12 Molluscan Shellfish

Molluscan shellfish AAP systems are used to raise oysters, clams, mussels, and scallops. These animals are bivalves; that is, they have a soft body enclosed by two hard shells or valves. The valves are attached at a hinge and are held shut by a strong muscle. Most cultured molluscan shellfish are filter feeders that rely on phytoplankton and particulate detritus delivered by water currents as their food source (JSA, 2000c).

Oyster farming is practiced on the Atlantic, Gulf of Mexico, and Pacific coasts of the United States. In the United States, two species currently dominate the oyster culture industry: the Pacific or Japanese oyster (*Crassostrea gigas*) and the American oyster (*Crassostrea virginicia*). Oysters usually inhabit areas from low intertidal zone to approximately 45 feet deep, forming a reef-like mass on firm bottom. Depending on the geographic location, oysters take from 18 to 48 months to reach market size (JSA, 2000c).

Clam farming is widespread throughout the United States, particularly on the east coast. Two species dominate commercial production. The hard clam (*Mercenaria mercenaria*), also known as the quahog, hard-shelled clam, cherrystone clam, or little neck clam, is indigenous to the Atlantic and Gulf of Mexico coasts, with smaller populations present on the west coast. The hard clam prefers relatively protected areas that have stable sandy to muddy bottoms with small amounts of shell. Populations exist from the low intertidal zone to nearly 60 feet in depth. The second species of clam most often cultured in the United States is the Manila clam (*Tapes philippinarum*) on the Pacific coast. Manila clams are typically found in habitats similar to those of the hard clam, but they generally exist slightly higher in the intertidal zone in areas with a coarser substrate like gravel. As with the hard clam, Manila clams have short siphons (necks), and this limits the depth to which they can burrow. Like oysters, clams typically take from 18 to 48 months to reach market size. Two additional species may be produced commercially in the near future: the geoduck (*Panope abrupta*) on the west coast and the surf clam (*Spisula solidissima*) on the east coast.

Mussel farming is a relatively new sector in the United States. Three principal mussel species are cultivated: *Mytilus edulis* on the east coast and *M. galloprovincialis* and *M. trossulus* on the west coast. Mussels usually form dense aggregations, like reefs, from the low intertidal zone to 30 feet deep. These aggregations may be on hard substrate or stabilized muds or sands. Both species typically reach commercial size in 19 to 24 months.

Scallop farming, like mussel farming, is also a relatively new sector in the United States. Scallop culture is limited, and most commercial efforts have been confined to the bay scallop (*Argopecten irradians*). This species lives in shallow bays from Massachusetts through Florida and is often associated with beds of eelgrass (JSA, 2000c). Cultured scallops reach commercial size in 10 to 24 months There is also a growing interest in the northeastern United States in the sea scallop (*Placopecten magellanicus*), but currently these efforts are experimental. In Washington there is a project exploring the possibility of culturing the rock scallop (*Hinnites giganteus*).

Harvest data related specifically to the molluscan shellfish industry are very limited and inconsistent (Kraeuter et al., 2000). Shellfish production as reported by most states is not divided based on whether the shellfish are cultured or from a wild harvest fishery, and there is no consistency among states regarding reporting units. For example, some states report oysters by live weight and some in shucked meat weight. Based on data from the 1998 Census of Aquaculture (USDA, 2000), there are 535 molluscan shellfish farms in the United States—268 in the Southern Region, 150 in the Northeastern Region, 108 in the Western Region, 5 in the Tropical/Subtropical Region, and 4 in the North Central Region. Though it has fewer facilities, the Northeastern Region leads the country in revenue with approximately $26.7 million in total sales, followed by the Southern Region with $24.7 million in total sales.

#### *4.3.12.1 Production Systems*

Shellfish AAP activities vary widely throughout the United States. Different species are cultured in different regions and use a variety of culture systems. Determining what is actually AAP is a challenge (Kraeuter et al., 2000). On one end of the spectrum are managed wild fisheries, which rely on natural recruitment to reseed public beds. At the other end of the spectrum is intensive culture on privately owned tidelands. Beds are seeded with juveniles that began as larvae in a hatchery, raised in an upland nursery on cultured algae, transferred to a land-based nursery that relies on natural algae present in the water, and finally planted in some sort of growout system. Between these two ends of the spectrum are a range of other options with varying levels of control over the product being cultured.

Intertidal culture, or shallow-depth culture (less than 3 feet), is the most common bottom culture in the United States. Intertidal techniques vary and are dependent on the species being cultured. Clams, oysters, and mussels may be placed directly on the bottom in beds. Clams dig in, whereas oysters and mussels remain on the bottom surface. In clam culture, mesh is usually placed over the clams or they are placed in mesh bags to prevent predators from consuming the crop. Oysters and mussels are usually planted without protective devices; in Washington's Puget Sound, however, farmers sometimes use plastic mesh bags, which are attached to the bottom on a longline. Intertidal plantings of oysters and mussels can also be suspended above the bottom on racks, trays, longlines, or bags strung on lines or wrapped on pilings. These techniques usually suspend the crop 1 or 2 feet off the bottom and rely on tidal action to feed the animals and remove wastes.

Subtidal water column culture is used where tidal amplitudes are not sufficient to support intertidal beds or where the organisms do not require sediment. Scallops, mussels, and oysters are cultured in subtidal water column systems. Water column culture in deeper waters, or floating culture, uses either rafts or longlines attached to floats, or a tray or rack system. Tray systems require specialized diving or lifting gear for maintenance in deeper waters. Subtidal water column culture is less common in the United States because these systems require floats or rafts on the surface that create conflicts with competing recreation or commercial uses of the water surface or column, as well as concerns from upland owners regarding visual impact.

#### *4.3.12.2 Culture Practices*

The intensive culture of molluscan shellfish has five phases: food production, broodstock maintenance/conditioning, hatchery, nursery, and growout.

Bivalve hatcheries are used to condition (i.e., prepare for spawning) broodstock, spawn animals, and raise larvae. Food for conditioning broodstock, larval, and post-set bivalves consists of various forms of unicellular algae that are grown and added to the water for the bivalve to filter (Kraeuter et al., 2000). The production of algae is one of the most time-consuming and expensive parts of bivalve culture. There are two methods for producing phytoplankton for use as food for molluscan shellfish. The Wells-Glancey method involves filtering raw seawater to remove large diatoms and algae consumers, such as copepods, and enriching the filtrate to promote the growth of small diatoms and flagellates. This method is inexpensive, but it provides little control over the species cultured. The Milford method uses a single species of phytoplankton in bacteria-free or clean, but not contaminant-free, cultures. This method provides more control over algal growth, but the need to maintain cultures and sterile conditions increases the expense.

Broodstock are used to produce the gametes for the next generation. Most broodstock are maintained in field sites until they are to be conditioned, the process of gonadal maturation for spawning. The animals are brought into a hatchery where water temperatures can be controlled to manipulate spawning. Animals to be spawned are placed in tanks and slowly warmed, and then cultured algal food is added to the water. Tanks range in size from 150 to 500 gallons. This process is a batch culture, and water is typically exchanged every 2 days (Kraeuter et al., 2000). The conditioning phase takes approximately 6 to 8 weeks. A small hatchery may condition 50 to 100 animals, and a larger hatchery may condition up to 2,000 animals. Only algal food is added to the water during this phase.

With strip spawning, eggs or sperm are removed from the animal, and the eggs are fertilized and placed in a tank of filtered seawater. Mass or individual spawning is achieved by placing the animals in a seawater bath. In most instances, volumes of water used are small (usually less than 100 gallons) because hatcheries minimize the amount of water for which they need to control the water temperature. Once spawning begins, the eggs are retained in a dish, or a container for single spawning individuals. In mass spawning, fertilization takes place in a tray with animals. After the eggs hatch the larvae are fed algae beginning on the second day. Water is exchanged every 1 or 2 days. Some hatcheries use flow-through systems with screens to prevent the escape of larvae. The number of days in larval culture varies, but typically ranges from 14 to 20 days.

Setting is the process by which a bivalve grows a shell and changes from a planktonic, pelagic animal to a benthic animal. Though procedures vary from species to species, usually the animals are set and maintained with food inputs of cultured algae. Oysters may be set at the hatchery or moved to a remote site, where they are added to tanks that have been filled with bags of shell and filtered seawater and some unicellular algal food. The tanks are aerated. Setting can take 1 to 3 days, and individuals may remain in the tank for 1 to 3 weeks before they are placed in a field nursery. Clams, scallops, and mussels are all set by attaching to a substrate by their byssal threads. These animals are removed from the larval culture tanks and placed in downwellers (cylinders with a mesh bottom through which water is passed by pumping it in through the top), in bags of setting material, or in trays. Many of these methods continue to feed with unicellular algae for 1 to 2 weeks and then transition to a nursery culture.

Nurseries hold animals until they are ready to be planted in the substrate. The longer the larvae, or seed, can be raised in protected nursery systems, the higher the survival rate will be when they are planted in the final growout phase. As with the hatchery phase, the number of animals being cultured in a nursery is large, but the biomass is very small when compared to fish or crustacean culture (Kraeuter et al., 2000). Nurseries use two different culture methods: induced circulation and natural circulation. Induced circulation uses pumps, paddlewheels, or airlifts to move large volumes of water to create a flow so the bivalves can filter feed. For natural circulation, animals are placed in bags suspended in the water or on trays on the bottom, and natural circulation moves water over the animals to bring them food and remove waste. Animals are usually kept in a nursery until they are large enough to be planted. For most bivalve nurseries, the individuals increase in size from 1 to 10–20 millimeters (Kraeuter et al., 2000). The only significant addition to the production water in this phase is the freshwater used to wash the seed and flush the trays, upwellers, raceways, or sieves. Some nursery facilities also add cultured algae to the system, but costs limit this practice.

The growout phase is the last phase in bivalve culture. Some producers buy seed and focus only on growout. All growout techniques for bottom culture rely on naturally occurring food sources at the site. There are no feed management practices because there is no feed input.

*Feed Management*

Bivalve (molluscan) AAP is substantially different from other forms of AAP in that no food is added to the culture water during the growout phase (Kraeuter et al., 2000). Shellfish are grown out in the open, protected coastal waters. They feed by filtering large volumes of seawater through their gills and extracting natural phytoplankton present in estuaries. Depending on the species, size, water temperature, and other variables, volumes of water filtered can range from 20 to 80 gallons/day, per animal (Kraeuter et al., 2000). This demand at the growout stage for high volumes of water and physical space generally requires that molluscan shellfish are produced in the natural environment.

Although hatcheries and some nurseries add cultured algae to the water as a food source, the impact from this addition is not significant. The risk of nonindigenous microalgae grown for shellfish feed disrupting natural phytoplankton ecology is very low (Wikfors, 1999, personal communication). Cultured algae strains have been sheltered in artificial culture conditions. If they were to escape, they would most likely have lost most of their ability to compete with indigenous phytoplankton. Furthermore, there have been no examples of nonindigenous algal strains from shellfish hatcheries creating a bloom or even a low-level introduction in receiving waters.

*Health Management*

Drug and pesticide use in molluscan shellfish culture is very limited. The common industry practice is to maintain bacteria at low levels in the early stages of culture by sterilizing the water (Kraeuter et al., 2000). It is not economically feasible to use drugs to control disease in bivalves. If hatcheries use chlorine to clean tanks or sterilize seawater, these facilities are required to dechlorinate prior to discharge (Tetra Tech, 2001). Abalone culture is the only culture activity that uses spawning aids like hydrogen peroxide and L-Dopa to enhance settlement (Tetra Tech, 2001).

#### *4.3.12.3 Water Quality Management Practices*

The importance of bivalve filtration, or lack of filtration, in natural systems has been used as an argument for restoring the abundance of oysters in the Chesapeake Bay and the New York harbor through either AAP or natural reef restoration (Revkin, 1999; Zimmerman, 1998). Restoring this filter feeding population would increase DO and water clarity and remove nitrogen and phosphorus from the system through direct harvest (Newell and Ott, 1999). The ecological consequence of this current lack of filter feeders is significant. Rice et al. (1999) have estimated that the northern quahog (hard clam) could remove up to 167,000 pounds of nitrogen from the water column and that sustainable harvest of the population would completely remove 17,000 pounds of organic nitrogen annually. Another study found that an intensive mussel culture raft system increased the rate of energy flow, as well as nitrogen and phosphorus deposition and regeneration; but unlike fish farming, the mussel culture did not cause eutrophication by nutrient input (Rodhouse and Roden, 1987). Still another study proposes the use of mussels as a means to clean up eutrophied fjord systems in Sweden (Haamer, 1996).

Fertilizers used in hatcheries are not likely to affect receiving waters. The fertilizer mix used in shellfish hatcheries is designed to be deficient in nitrogen, the nutrient of most concern in coastal eutrophication (Wikfors, 1999, personal communication). Nitrogen is the limiting factor for phytoplankton growth. The standard hatchery operation involves growing algae to a density at which all nitrogen is assimilated by the microalgae and the algae stop growing.

The growout phase of molluscan shellfish production does not add food to the system. The bivalves rely on natural food found in coastal waters. In terms of a mass balance, materials are extracted from the estuary as they are converted into bivalve flesh and shell, or used for respiration (Kraeuter et al., 2000). Because there is no feed input, there are no feed management practices. Bivalve culture can actually result in the net removal of nitrogen, phosphorus, and other pollutants when crops are harvested and removed from the system (Kraeuter et al., 2000). Because bivalves filter nutrients out of the water, they do not pose a threat to water quality. EPA believes there is little, if any, impact on water quality; therefore, no current technologies or BMPs are being used by this industry subcategory.

### 4.3.13 Other Aquatic Animal Production (Alligators)

American alligators (*Alligator mississippiensis*) are raised in captivity primarily for their hides and meat. The leather is used to make luxury apparel items such as belts, wallets, purses, briefcases, and shoes. In the past the high value of these leather products led to extensive hunting of alligators in the wild. By the 1960s this exploitation, plus loss of habitat, had depleted many wild populations (Masser, 2000). Research into the life history, reproduction, nutrition, and environmental requirements of the American alligator, along with the rapid recovery of wild populations, led to the establishment of commercial farms in the United States in the 1980s. In 1996 wild harvest and farm-raised alligators from the United States supplied more than 240,000 hides to world markets. Approximately 83% of these hides were from alligator farms (Masser, 2000). States with licensed alligator farms are Alabama, Florida, Georgia, Idaho, Louisiana, Mississippi, and Texas.

The American alligator was once native to the coastal plain and lowland river bottoms from North Carolina to Mexico (Masser, 2000). The only other species of alligator (*A. sinensis*) is found in China and is endangered. Hunting alligators for their hides began in the 19$^{th}$ century. At the turn of the 20$^{th}$ century, the annual alligator harvest in the United States was around 150,000 animals. Overharvesting and habitat destruction depleted the wild population, and by the 1960s, most states had stopped allowing alligator hunting. To protect alligators from further exploitation, they were designated under the Endangered Species Act as endangered or threatened throughout most of their range, with the exception of Louisiana. Alligator populations recovered quickly, particularly in Louisiana, which had stopped legal harvesting in 1962 (Masser, 2000). Louisiana reopened limited harvesting of wild alligators in 1972, but the population continued to increase even with sustained harvesting. Most other southern states also experienced population increases after federal protection.

In 1983, under the CITES, the USFWS changed the designation for the American alligator to “threatened for reasons of similarity in appearance” (Masser, 2000). This classification means that the alligator is not threatened or endangered in its native range; however, the sale of its products must be strictly regulated so that the products of other crocodilian species that are endangered are not sold illegally as those of American alligators. Today, in addition to alligator farming, nuisance control is allowed in several southern states, and limited harvests from the wild are permitted in Louisiana, Texas, and Florida (Masser, 2000).

Alligators inhabit all types of fresh to slightly brackish aquatic habitats. Males grow larger than females, and growth and sexual maturity are dependent on climate and the availability of food (Masser, 2000). Along the Gulf coast, females usually reach sexual maturity at a length of 6.5 feet and an age of 9 to 10 years. As in other cold-blooded animals, maturation age is affected by temperature. Optimum growth occurs at temperatures between 85 and 91 °F (Masser, 2000). No apparent growth takes place below 70 °F, and temperatures above 93 °F cause stress and sometimes death.

In the wild, young alligators usually consume invertebrates such as crawfish and insects. As they grow, fish become a part of their diet. Adults consume mammals such as muskrats and nutria. Large adult alligators even consume birds and other reptiles, including smaller alligators (Masser, 2000). Females do not move or migrate over long distances once they have reached breeding age, and they prefer heavily vegetated marsh habitat. Males move extensively but prefer to establish territories in areas of open water.

#### *4.3.13.1 Production Systems*

Alligator farming uses a unique production system that is not easily categorized as either a pond system or a flow-through system. Alligator systems use more water than typical pond systems and less water than typical flow-through systems. Available literature suggests that pond-like systems, in the form of outdoor ponds and lagoons, are most often used for raising and maintaining breeding alligators for a source of eggs. Young alligators are typically raised for growout in indoor pens with shallow pools that use concrete tanks to hold the animals. Within the concrete tanks, water is usually pumped from a well and then heated before it is pumped into the pools of each pen. At some facilities, water in the indoor pools is completely drained and replaced daily or every other day to maintain good water quality (Coulson et al., 1995). Some facilities drain less frequently. Maintaining water temperature and minimizing heating costs are often major concerns of alligator farmers. Based on daily drainings, the production system could be described as a batch-like flow-through system with a daily exchange of water. When facilities drain less often, the system could be described as a pond with frequent drainings.

In an effort to reduce costs, some producers are using outside growout facilities (Masser, 2000). In this system, alligators are raised in indoor facilities for the first year of growth and then moved to outdoor fenced ponds. The alligators are fed a commercial diet during warm weather and are allowed to hibernate during cooler seasons. After about 2 years, the ponds are drained, usually during the winter, to facilitate handling and harvesting of the animals.

#### *4.3.13.2 Culture Practices*

The commercial production of alligators can be divided into three phases: management of adult alligators for breeding; egg collection, incubation, and hatching; and growout of juvenile alligators to market size. Alligator farmers must either purchase eggs or hatchlings from other producers or produce their own eggs. In Louisiana, Florida, and Texas, eggs and/or hatchlings can be taken from the wild under special permit regulations. Today, the primary source for eggs is wild populations; however, Louisiana law does not allow the sale of alligator eggs outside Louisiana.

Some farmers have completely integrated operations with their own breeding stocks, hatching facilities, nursery facilities, and growout houses, but most alligator farmers focus on only growout operations (Jensen, 2000, personal communication). This approach is also called ranching, an open-cycle system that does not maintain adult breeders or produce its own stock, similar to a cattle feedlot operation (Lane and King, 1996). With growout operations, hatchlings are purchased from a farm or ranch specializing in the production of hatchlings, usually from eggs collected from wild stocks. Most of the eggs used to produce hatchlings are collected on private lands, which provide a source of income to marsh landowners who, in turn, maintain and manage wetland habitat for the benefit of the alligator population. Egg collection from wild populations is regulated by state agencies that set site-specific quotas for the number of nests that may be harvested (Heykoop and Freschette, 1999). Hatchlings may also be available from state agencies that regulate wild populations. The wild population is a source of young stock for domestic populations, and in Louisiana, where a percentage of hatchlings is returned to the wild, the domestic population is a source of juveniles for the wild populations (Heykoop and Freschette, 1999).

The first phase, maintaining adult alligators and achieving successful and consistent reproduction, is extremely difficult and expensive (Masser, 1993a). Adult alligators that have been raised entirely in captivity or confinement behave differently from wild stock. Farm-raised alligators accept confinement and crowding as adults better than wild alligators. Also, adult alligators raised together tend to develop a social structure, adapt quicker, and breed more successfully than animals without an established social structure.

For the few farms that maintain breeding stocks or specialize in producing eggs, pens for adult alligators are built approximately 1 to 2 acres in size (Masser, 1993a). Pens must be carefully fenced to prevent the escape of the adult alligators. Breeding pen design, particularly the water ratio and configuration, is very important. The land area-to-water area ratio in the pen is approximately 3:1, and the shape of the pond maximizes the shoreline area with an ‘S’ or ‘Z’ shape. The depth of the breeding pond is at least 6 feet. Breeding ponds have dense vegetation around the pond to provide cover, shade, and nesting material. Alligators burrow into the pond banks if adequate shade is not provided. Stocking densities for adult alligators are approximately 10 to 20 animals per acre. The female-to-male ratio should be approximately 3:1.

Adult breeders should be disturbed as little as possible from February through August, during egg maturation, courting, and nesting. Nesting success in captive alligators has been highly variable. Wild versus farm-raised origin, pen design, density, the development of social structure within the group, and diet all affect nesting (Masser, 2000). Nesting rates for adult females in the wild averages around 60% to 70% with the most favorable habitat and environmental conditions. Nesting rates in captivity are usually much lower (Masser, 2000). Clutch sizes vary with the age and condition of the female, with larger and older females usually laying more eggs. Clutch size averages around 35 to 40 eggs and egg fertility varies from 70% to 95%. Survival of the embryo also varies from 70% to 95% and the hatching rate from 50% to 90%. Land costs, long-term care of adults, and low egg production contribute significantly to the cost of maintaining breeding stocks (Masser, 2000).

The method and timing of egg collection are very important; alligator embryos are very sensitive to handling from 7 to 28 days after the eggs are laid (Masser, 2000). Eggs should be collected in the first week or after the fourth week of natural incubation. When eggs are collected, they must be kept in the same position and not turned or rotated during handling. Compared with wild nesting, artificial incubation improves hatching rates because of the elimination of predation and weather-related mortality (Masser, 2000). The best hatching rates for eggs left in the wild are less than 70%, while hatching rates for eggs taken from the wild and incubated artificially average 90% or higher (Masser, 2000).

Eggs should be transferred into incubation baskets and placed in an incubator within 3 or 4 hours after collection. Eggs are completely surrounded with nesting material like grasses and other vegetation. The natural decomposition of the nesting materials helps with the breakdown of the eggshell. The incubation temperature is critical for the survival and development of the hatchlings. Temperature also determines the sex of the alligator. Temperatures of 86 °F or below produce females, and temperatures of 91 °F or above produce males. Temperatures much above or below these ranges result in high mortalities (Masser, 2000). After the alligators hatch, the hatchling are kept in the incubation baskets for the first 24 hours and then moved to small tanks heated to 86 to 89 °F. Maintaining 89 °F helps hatchlings absorb the yolk. Usually, hatchlings will begin to feed within 3 days. Once hatchlings are actively feeding, they can be moved into growout facilities.

A variety of growout facilities are used for raising alligators. Growout buildings are usually heavily insulated concrete block, wood, or metal buildings with heated foundations. They usually do not have windows. Most animals are kept in near or total darkness except during feeding and cleaning times. The concrete slab is lined with hot water piping or, sometimes, electric heating coils. A constant temperature is maintained by pumping hot water through the pipes. Covering about two-thirds of each pen is a pool of water about 1 foot deep at the drain. The bottom of the pool is sloped down toward the drain to facilitate cleaning. The remaining one-third of the pen area is above water and is used as a feeding area and basking deck (Masser, 1993b). Pens vary in size. In general, smaller pens are used for smaller alligators and larger pens are used as alligators grow. Usually, farmers construct several sizes of growout pens and reduce the density by moving the animals as they grow. Common stocking densities include 1 square foot/animal until the animal reaches 2 feet in length; 3 square feet/animal until the animal reaches 4 feet in length; and 6 square feet/animal until the animal reaches 6 feet in length.

A common construction plan uses a 5,000-square foot building with an aisle down the middle and pens on either side. A 4-foot aisle creates pens that are approximately 14 feet wide. Pens are usually 13 feet long with a 3-foot concrete block separating individual pens from the aisle. Another popular building design is the single round house, a structure about 15 to 25 feet in diameter constructed as a single pen (Masser, 2000). Round houses have also been built from concrete blocks, or from a single section and roof of a prefabricated metal silo used for storing grain. The round concrete slab on which the house sits is sloped from the outer edge toward a drain in the center of the structure. The round house is filled with water so that approximately one-third of the floor is above the water level. Because they are single-pen units, round houses have the advantage of not disturbing alligators in other pens during feeding, cleaning, and handling operations.

The heating system, which consists of water heaters and pumps, is an important part of the growout facility. Warmwater is needed to heat the building, fill the pools, and clean the pens. Some heating systems have industrial-size water heaters, while other systems have flash-type heaters to heat water for cleaning and standard heaters to circulate warmwater through the slab. Thermostats regulate the temperature and circulation pumps. The temperature in growout pens must be between 86 and 88 °F for optimal growth (Masser, 2000).

Written approval and hide tags must be obtained from the appropriate state regulatory agency before any alligators may be harvested. Some states also require a minimum length of 6 feet at harvest. Alligators may be skinned only at approved sites. Skinning, scraping, and curing must be done carefully to protect the quality of the skin; hides that are cut, scratched, or stretched have a reduced value. Most hides are sold to brokers, who purchase and hold large numbers of hides and then sell them to tanneries for processing. A few larger farms sell directly to the tanneries, the best of which are in Asia and Europe.

*Feed Management*

In general, alligators in the wild consume a diet high in protein and low in fat. Early alligator producers manufactured their own feed using inexpensive sources of meat like nutria, beef cattle, horse, chicken, muskrat, fish, and beaver. Today, several feed mills are manufacturing pelleted alligator feed. Most farmers feed their animals only commercially available feed; however, some continue to feed the animals a combination of raw meats and commercial diets.

Feed is spread out on the deck in small piles to reduce competition. Typically, farmers feed alligators 5 times per week, although some may feed 6 or 7 days/week. The feeding rate is roughly 25% of the animal's body weight per week the first year; then the rate is gradually reduced to 18% of body weight as the animal approaches 3 years old or a length of 6 feet. Feed conversion efficiencies decrease as alligators grow larger. The food conversion ratio is between 2:1 and 3:1 (Masser, 2000). Monthly growth rates in alligators can be as high as 3 inches when the temperature is held at a constant 86 to 89 °F and they are fed a quality diet with minimal stress. Many producers grow hatchlings to 4 feet in 14 months, and some producers have grown alligators to 6 feet in 24 months (Masser, 2000).

*Health Management*

There is very little information available in the literature to characterize drug and pesticide use for alligator farming. No antibiotics are approved for use on alligators; therefore, any antibiotics needed must be obtained through a prescription from a veterinarian (Masser, 2000). Two antibiotics, oxytetracycline and virginiamycin, have been used by alligator producers and added to feed to fight bacterial infections (Masser, 1993b).

Alligators need clean water to maintain the quality of their skins. Poor water management can lead to brown spot disease, which scars the skin and reduces its value (Masser, 1993b). After pools are drained, veterinarians suggest that the refill water contain 1 to 2 milligrams/liter of chlorine to reduce bacteria and fungi (Schaeffer, 1990).

#### *4.3.13.3 Water Quality Management and Effluent Treatment Practices*

Raw wastewater from alligator production facilities closely resembles domestic wastewater. The major difference is that alligators tend to excrete approximately twice the amount of ammonia per body mass when compared to humans (Pardue et al., 1994). The concentrations of various alligator raw wastewater constituents are presented in Table 4.3–11.

Effluent treatment practices vary significantly from facility to facility. Most facilities use oxidation ponds or lagoons to treat effluent from the raising operations. In some cases, facilities have begun to experiment with the use of “package plants” to treat raw wastewater before it is recycled for cleaning purposes. These “plants” are small filtration units designed for the needs of individual facilities.

**Table 4.3–11. Pollutant Concentrations in Alligator Raw Wastewater**

| *Parameter* | *Concentrations (mg/L)* |
|---|---|
| Ammonia | 77.5 |
| Nitrate | 4.6 |
| TKN | 153.4 |
| Total phosphorus | 10.9 |
| Soluble phosphorus | 7.6 |
| $BOD_5$ | 452 |
| pH | 6.9 |
| Calcium | 13.4 |
| Magnesium | 5 |
| Sodium | 14.8 |
| Conductivity | 650 |
| Total solids | 379 |
| Volatile solids | 219 |

Source: Pardue et al., 1994.

## 4.4 TRENDS IN THE INDUSTRY

Based on an estimated increase in population in the United States from 270 million in 1998 to 310 million in 2015, it is likely that the U.S. demand for AAP products will continue to increase (Tomasso, 2002). The dependency of the United States on imported seafood might also be a factor in the future growth of AAP in this country. As world capture fisheries continue to decline and collapse, it is likely that AAP products will provide a source to meet the growing demand for fish products. Recently, American consumers have demanded more fresh seafood rather than canned or cured. If the trend toward fresh seafood continues, AAP will provide an important supply (Tomasso, 2002).

Despite an anticipated increase in demand for AAP products, the opportunities for expansion within the industry are limited by the demands of production systems. For pond systems, there are limited sites available with suitable land and water supplies for additional pond facilities. Increased profitability for production in pond systems will depend on improving efficiencies in farm management.

The expansion of flow-through systems is also limited by the availability of appropriate sites with suitable water sources. Development of this sector will depend on increased demand and its impact on profitability based on price. It is likely that conventional flow-through systems will be modified to some form of recirculating system or partitioned AAP system (Chen et al., 2002; Losordo and Timmons, 1994).

Recirculating systems have potential for expansion with continued research and technology development. There is a great deal of interest in recirculating systems because of their ability to reuse and recycle water. Although they are too expensive to use for the production of most species at this time, recirculating systems have the potential to expand in the future because they rely on smaller spaces for their facilities and use less water.

For net pen systems, limited nearshore sites are available for AAP, and net pens are not permitted in the Great Lakes. There are potentially an unlimited number of offshore sites, but the technology to support these offshore sites is expensive and not fully developed. This option is not likely to be developed in the near future while it is still less expensive to import salmon from other countries.

## 4.5 AQUATIC ANIMAL PRODUCTION SIZE CATEGORIES

In evaluating the detailed industry survey data related to facility annual production, EPA identified several variables distinguishing various types of facilities. CAAP facilities varied by type of facility operation (species and production system) and type of wastewater management (e.g., direct discharger, indirect discharger, no discharge/wastes applied to land on site). EPA identified annual production levels (by mass) at facilities based on the responses provided by individual facilities to the detailed industry survey. For the final regulation, EPA grouped facilities into two size categories:

- <100,000 pounds annual production
- ≥100,000 pounds annual production

For the purposes of estimating costs, loads, economic impacts, and non-water quality impacts (NWQIs), EPA used facility-level production and revenue data to project facilities that would meet the definition of a CAAP facility as defined in 40 CFR 122.24 and Appendix C to Part 122. The Small Business Administration's (SBA's) standard to determine a "small business" in the AAP industry is $750,000 annual revenues at the company level.

EPA used the results of the production rate thresholds to exclude facilities annually producing less than 100,000 pounds from the scope of the rule because the Agency anticipates that the technologies on which the options are based would not be economically achievable (and in some cases would be cost-prohibitive) for the facilities with the lowest production threshold (the smallest facilities).

## 4.6 INDUSTRY DEFINITION

The AAP industry includes sites that fall within the North American Industry Classification System (NAICS) codes 112511 (finfish farming and fish hatcheries), 112512 (shellfish farming), 112519 (other animal aquaculture), and part of 712130 (aquariums, part of zoos and botanical gardens). The first three groups (NAICS 112511, 112512, and 112519) have SBA size standards of $750,000, while the SBA size standard for NAICS 712l30 is $5.0 million. SBA sets up standards to define whether an entity is small and eligible for Government programs and preferences reserved for "small business" concerns. Size standards have been established for types of economic activity, or industry, generally under the NAICS. Refer to 13 CFR Part 121 for more detailed information. EPA uses these SBA size standards to conduct preliminary analyses to determine the number of small businesses in an industrial category and whether the proposed rule would have a significant impact on a substantial number of small entities.

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# CHAPTER 5
# INDUSTRY SUBCATEGORIZATION FOR EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS

The Clean Water Act (CWA) requires EPA to consider a number of different factors when developing effluent limitations guidelines. For example, when developing limitations that represent the best available technology economically achievable (BAT) for a particular industry category, EPA must consider, among other factors, the age of the equipment and facilities in the category, location, manufacturing processes employed, types of treatment technology to reduce effluent discharges, cost of effluent reductions, and non-water quality environmental impacts (Section 304(b)(2)(B) of the CWA, 33 U.S.C. 1314(b)(2)(B)). The statute also authorizes EPA to take into account other factors that the EPA Administrator deems appropriate and requires the BAT model technology chosen by EPA to be economically achievable, which generally involves considering both compliance costs and the overall financial condition of the industry. EPA used the best available data to take these factors into account in considering whether to establish subcategories. The Agency found that dividing the industry into subcategories leads to better-tailored regulatory standards, thereby increasing regulatory predictability and diminishing the need to address variations among facilities through a variance process. (See *Weyerhaeuser Co*. v. *Costle*, 590 F. 2d 1011, 1053 (D.C. Cir. 1978) for more detail.)

## 5.1 FACTOR ANALYSIS

EPA used published literature, site visit data, industry screener and detailed survey data, and EPA sampling data for the subcategorization analysis. Various subcategorization criteria were analyzed for trends in discharge flow rates, pollutant concentrations, and treatability to determine where subcategorization (segmentation) was warranted. EPA analyzed several factors to determine whether subcategorizing an industrial category and considering different technology options for those subcategories would be appropriate. For this analysis, EPA evaluated the characteristics of the industrial category to determine their potential to provide the Agency with a means to differentiate effluent quantity and quality among facilities. EPA also evaluated the design, process, and operational characteristics of the different industry segments to determine technology control options that might be applied to reduce effluent quantity and improve effluent quality. The factors associated with the aquatic animal production (AAP) industry that EPA assessed for the concentrated aquatic animal production (CAAP) point source category are as follows:

- Species
- System type

- Facility age
- Facility location
- Facility size
- Feed type and feeding rate
- Non-water quality environmental impacts
- Disproportionate economic impacts

EPA found the AAP industry is very diverse and that there are many unique aspects, depending on a combination of the facility characteristics listed above. Although most of the individual facilities in the AAP industry tend to have unique design and operational characteristics, EPA found that one factor, system type, captures the dominant differences between significant groups of CAAP facilities. The following sections show the basis for EPA's decisions relating to subcategorization.

### 5.1.1 System Type

There are several groups of AAP systems: ponds, flow-through systems, recirculating systems, net pens, bottom and off-bottom shellfish culture, shellfish hatcheries, aquariums, and other systems.

#### *5.1.1.1 Pond Systems*

Ponds are the most popular systems used to produce aquatic animals in the United States, with more than 2,800 commercial pond facilities (USDA, 2000) and numerous noncommercial ponds. Catfish, hybrid striped bass, shrimp, sport and game fish, ornamentals, and baitfish are all grown in pond systems. Pond systems use relatively large volumes of static water to grow aquatic animals. Most ponds used for producing aquatic animals range in size from less than 1 acre to more than 10 acres and typically have average depths of 3.5 to 6 feet. Once full of water, the ponds remain static in terms of water movement until rainfall events, operators add water, or operators drain the ponds for harvest or maintenance. Water might be added intentionally to make up for seepage or evaporative losses and to exchange water to maintain process water quality. Pond draining frequencies range from annually to every 10 years (or more). Ponds rely on natural processes to maintain water quality, using supplemental aeration when necessary and limiting the stocking density of the crop.

Most pond systems used for AAP are constructed to operate and function in the same general manner. Control of water entering the pond is the primary characteristic that distinguishes one type of pond system from another. Further subdividing pond systems into levee, watershed, and depression ponds accounts for most of these differences. Levee ponds are constructed by creating a dam or berm completely around an area of land. Soil is taken from the area to be enclosed to create the berms. Levee ponds are constructed above grade to give the operator almost complete control of water in the pond. Only rainwater falling directly onto the surface of the pond and the interior walls of the berms enters the pond without operator intervention. Pumping or otherwise conveying water from a surface water or groundwater source adds water to the pond.

Watershed ponds are constructed by creating a dam across a low-lying area of land to capture runoff during rainfall events. The pond can be shaped and a flat, sloping bottom created to make the watershed pond easy to manage for producing aquatic animals. Sizing the watershed to capture the right amount of water is a critical design feature of properly constructed watershed ponds. A general rule of thumb is about 10 acres of watershed for each 1 acre of pond. The key consideration is to capture enough rainfall and runoff to keep the pond full. Oversized contributing watersheds tend to add too much water to the pond and create excessive overflows, which are difficult to manage. Some watershed ponds are filled or topped off with well water in addition to the natural runoff.

Depression ponds are built similarly to levee ponds but are almost completely below grade. They are typically constructed in sandy soils to allow high groundwater tables to contribute water to the pond. To drain depression ponds, they must be pumped. Water levels are often difficult to control in depression ponds, so they are mostly constructed in areas of good-quality groundwater that is consistently near the surface.

Two sources of water are discharged from ponds—overflows during or following rainfall events and water from intentional draining for harvest or renovation. Many ponds are managed to capture as much rainfall (and runoff in the case of watershed ponds) as possible to minimize the need for pumping water to maintain water levels. Overflows sometimes occur. Because levee ponds are built above grade, the only source of overflow during storms is the rain actually falling onto the surface of the pond and interior berms. This contrasts to watershed ponds, where larger areas can contribute to the volume of storm water entering and possibly overflowing from ponds. These overflows are intermittent, depending on the frequency and intensity of storms and the capacity of the pond for storing additional water. Many watershed ponds serve as a sink for pollutants (primarily sediment) entering the ponds in the runoff water. The overflows typically contain dilute concentrations of pollutants.

Discharges from ponds also occur when the ponds are drained as part of the management strategy for the operation. Two predominant drainage strategies have been found among pond facilities—annual (or more frequent) draining and less frequent-than-annual draining. Annual draining is common among many parts of the AAP industry, including fingerling production for most species and production of shrimp, baitfish, hybrid striped bass, and many other species of foodfish and sport fish. Some of these discharges might drain into adjacent ponds for storage and reuse. Draining less than once a year is used by segments of the industry that can selectively harvest and restock with smaller fish or can almost completely harvest and then kill any remaining fish before restocking. The desire is to minimize water usage and pumping costs. Both drainage strategies result in large, mostly dilute volumes of water being discharged over several days. Because water remains in the ponds for long periods of time, some natural processing of the wastes in the ponds occurs.

### *5.1.1.2 Flow-through Systems*

Flow-through systems consist of raceways, ponds, or tanks that have constant flows of water through them. Flow-through systems are the second most popular production system in the United States, with more than 600 commercial and several hundred noncommercial facilities (USDA, 2000). Trout, salmon, and hybrid striped bass are examples of fish grown in flow-through systems. Flow-through systems are most commonly long, rectangular concrete raceways, but they also include tanks of various shapes made from fiberglass, concrete, or metal. Some flow-through systems use earthen ponds to culture aquatic animals.

In general, flow-through systems rely on flushing to maintain water quality, and the predominant management practices to maintain water quality are aeration, settling of solids in quiescent zones or in sumps, and maintenance of manageable stocking densities. Discharges from flow-through systems tend to be large in volume and continuous. When solids in tanks or raceways are collected and removed, these waste streams are usually higher in pollutant concentrations, including solids, nutrients, and biochemical oxygen demand than the water normally leaving the tank or raceway.

#### *5.1.1.3 Recirculating Systems*

Recirculating systems use a variety of processes to maintain production water quality and minimize water usage, including aeration, solids removal, biological filtration, and disinfection. Although a widely accepted formal definition for recirculating systems does not exist, these systems are generally distinguished by some form of engineered biological treatment that allows for extended water reuse. EPA uses the term “engineered” biological treatment to distinguish a recirculating system from a pond, which has a “natural” biological treatment process that allows for extended water reuse. Recirculating systems are gaining popularity in the United States as system design and management become better understood. Any species can be grown in a recirculating system, but tilapia and hybrid striped bass are the predominant species. The primary sources of wastewater are solids removal and overflow. Overflow water is generated when water is regularly added to the recirculating system. Solids are captured from the production water and discharged in a waste stream that is relatively low in volume and high in pollutant concentrations. The solids generated from flow-through and recirculating systems are similar in quality.

#### *5.1.1.4 Net Pens*

Net pens are floating structures in which nets are suspended into the water column in coastal waters and the open ocean. Net pen systems typically are located along a shore or pier or may be anchored and floating offshore. The most significant net pen operations are salmon net pens located in the northeastern and northwestern coastal areas of the United States. Salmon are grown for foodfish and as a source of smolts for ocean ranching using net pens. Water quality is maintained in net pens by the flushing action of tides and currents, and feed is added to the net pens.

Net pens are distinct from cages, which are generally relatively small structures with rigid frames covered with wire mesh or netting, used most often in freshwater environments (Stickney, 2002). Production in cages is very limited because of a lack of currents (tides).

#### *5.1.1.5 Floating and Bottom Culture*

Floating and bottom culture systems are used to grow molluscan shellfish in various coastal water environments. As in net pen culture, the flushing action of tides and currents helps to maintain water quality. Unlike fish produced in net pens, molluscan shellfish use naturally occurring food, the availability of which is also a function of the tides and currents. No feed is added to molluscan shellfish cultures in natural waters.

#### *5.1.1.6 Shellfish Hatcheries and Nurseries*

Shellfish hatcheries are used to condition (i.e., prepare for spawning) broodstock, spawn animals, and raise larvae. Food for conditioning broodstock, larval, and post-set bivalves consists of various forms of unicellular algae that are grown and added to the water for the bivalve to filter (Kraeuter et al., 2000). Shellfish nurseries hold animals until they are ready to be planted in the substrate. The longer the larvae, or seed, can be raised in protected nursery systems, the higher the survival rate will be when they are planted in the final growout phase. As with the hatchery phase, the number of animals being cultured in a nursery is large, but the biomass is very small when compared to fish or crustacean culture (Kraeuter et al., 2000).

Fertilizers used in hatcheries to grow algae are not likely to affect receiving waters. The fertilizer mix used in shellfish hatcheries is designed to be deficient in nitrogen, the nutrient of most concern in coastal eutrophication (Wikfors, 1999, personal communication). Nitrogen is the limiting factor for phytoplankton growth. The standard hatchery operation involves growing algae to a density at which all nitrogen is assimilated by the microalgae and the algae stop growing.

#### *5.1.1.7 Aquariums*

Aquariums are used to culture ornamental or tropical fish primarily for the home aquarium where fish are kept as a hobby or as pets. Public aquariums are AAP facilities that display a variety of aquatic animals to the public and conduct research on many different threatened and endangered aquatic species. EPA has determined, through the AAP screener and detailed surveys, that most aquariums are indirect dischargers. If these facilities discharge directly into waters of the United States, it is done only in emergency situations requiring rapid tank dewatering. These systems maintain low stocking densities and very clean, clear water to enhance the visual display of the animals. Discharges from aquariums are likely to be low in TSS and nutrients because of the low stocking densities.

#### *5.1.1.8 Other Facility Types*

Other AAP facilities encompass those facilities that do not fit well into the other categories. Alligator farming is a good example. Alligator farming typically uses a batch cycling of water through the facilities. The water in cement-lined basins, located in huts, is replaced every few days. Water is held for as long as possible (to minimize energy needed to maintain the correct temperature) and then discharged. Alligator farms therefore produce intermittent flows of concentrated effluents. Another production type that does not fit well into the other system descriptions is the crawfish pond. Although somewhat similar in appearance to other pond systems, crawfish ponds are shallow (typically less than 18 inches of water) and also managed for the forage crop that provides food for the growing crawfish. Water levels in crawfish ponds are managed by annual draining to promote reproduction in the pond.

### *5.1.1.9 Summary*

The characteristics that distinguish CAAP systems from each other are the relative amount of water used to produce a unit of product, the draining frequency, the general design of the facility, and the processes used to treat production water. Table 5.1−1 shows the relative amount of water used, the draining frequencies, and the processes used to treat water for some of the system types. Each of the system types has similar water use and management strategies, which produce wastewater flow rates and quality that are similar. Ponds produce infrequent discharges of overflow and drained water.

**Table 5.1−1. Comparison of Water Use, Frequency of Discharge, and Process for Maintaining Water Quality for CAAP Systems**

| *System* | *Water Use (gal/ lb production)*[a] | *Discharge Frequency* | *Water Quality Maintenance in System* |
|---|---|---|---|
| Ponds | 214 | Infrequent | Aeration, water exchange, natural physical, chemical, and biological processes |
| Flow-through<br>Coldwater species<br>Warmwater species | <br>6,490–63,300<br>32,900 | Continuous | Aeration, water exchange |
| Recirculating<br>Coldwater species<br>Warmwater species | <br>394<br>16 | Varies from infrequent to continuous | Clarifiers, biological filters, aerators |
| Net pen | N/A | N/A | Water exchange |

[a]Adapted from Chen et al., 2002.
Note: N/A = not applicable.

The quality of overflow water from ponds is typically equivalent to the quality in the pond, which must be sufficient for animal production. Drained water is similar to overflow water in quality but may contain elevated levels of solids and other pollutants at the beginning or end of the draining process. Flow-through systems produce a constant, high-volume quantity and nearly consistent quality effluent that is relatively low in pollutant concentrations. Changes in flow-through system effluent quality reflect changes in biomass and cleaning activities. Recirculating systems produce a small volume of effluent mostly made up of solids removed by process equipment in the system. Recirculating systems also produce overtopping water, which is system water displaced by make-up water added to maintain water quality and replace water lost in solids removal. Overtopping water may contain some suspended solids and is similar in quality to water discharged from settling basins. Net pens and shellfish culture discharge directly into the waters where they reside. Aquatic animals grown in net pens are fed by operators. Shellfish rely on natural food in the water and are not fed any additional food. Alligator systems are managed to discharge once every few days to keep the systems clean. The effluent is small in volume with relatively high levels of pollutants such as solids, biochemical oxygen demand, and nutrients. Crawfish effluents are infrequent when ponds are drained.

### 5.1.2 Species

EPA evaluated species as possible subcategories. The Agency's analyses indicated that species is not a significant factor in determining differences in production system effluent characteristics. For example, Hargreaves, et al., (2002) noted, "The ecological processes that affect effluent volume and quality are the same in all warmwater aquaculture ponds, whether they are used to grow baitfish in Arkansas or hybrid striped bass in North Carolina." EPA found similar results for other species. The management practices for a particular species dictate stocking densities, feed types, feeding rates and frequencies, and the overall management strategy. Species, however, does not appear to be a major determinant in the quality or quantity of effluent from a production system.

### 5.1.3 Facility Age

Facility age does not appear to be a significant factor in the quality or quantity of effluents from CAAP facilities of the same system type. EPA noted a range of facility ages during site visits. Important factors associated with facility age include the following:

- Newer facilities might be designed with equipment that enhances the production capabilities or ease of operation.
- Some older facilities might not have sufficient area for the installation of treatment technologies.
- Some older facilities might not be conducive to retrofits of technologies; for example, quiescent zones in raceways.

### 5.1.4 Facility Location

EPA did not find geographic location to be a significant factor in the determination of effluent quality. EPA was not able to find any geographic operational differences that occur in the CAAP industry to indicate significant differences in the quality of discharges.

### 5.1.5 Facility Size

EPA found facility size enables some operational economies of scale, but the Agency does not expect size to have a significant influence on effluent quality. EPA does expect that facility size will have a significant impact on the quantity of effluent. EPA evaluated facility size as a part of the economic analyses and found size to be an important determinant in the affordability of treatment options (see USEPA, 2004 for more information).

### 5.1.6 Feed Type and Feeding Rate

EPA found feed type and feeding rate to be important characteristics of CAAP facilities that identify differences in effluent quality. The following factors were evaluated:

- No food is added, as in the case of molluscan shellfish culture. Naturally occurring and created foods are the source of food for these species. Natural foods are produced by stimulating production with nutrients (fertilizers) and are used for larval diets for many species (e.g., catfish, hybrid striped bass, perch, and most sport fish) and as the primary diet for species like baitfish. The use of natural diets is primarily limited to pond systems, but natural diets are also used in some flow-through and recirculating systems.
- Prepared diets are used for the production of most species in CAAP facilities. These diets vary in the ingredients and relative proportions of fat, protein, and carbohydrates. The formulation of a diet can significantly influence the digestibility and uptake for a particular species.
- Feeding rates are a function of species, stocking density, temperature, and water quality.

Management objectives are a significant factor in feeding strategies. For example, game fish, grown for stocking enhancement in natural waters, are cultured with different management objectives than foodfish of the same species.

### 5.1.7 Non-water Quality Environmental Impacts

EPA evaluated the effects of various non-water quality environmental impacts (see Chapter 11 of this document), including the following:

- Energy use
- Solid waste generation and disposal
- Air emissions

### 5.1.8 Disproportionate Economic Impacts

The economic analysis evaluated the potential for disproportionate economic impacts of the rulemaking on various segments of the industry (USEPA, 2004).

### 5.1.9 Summary of Initial Factor Analysis

EPA did not find that the age of a facility or its equipment or the facility’s location significantly affected wastewater generation or wastewater characteristics; therefore, age and location were not used as a basis for subcategorization. An analysis of non-water quality environmental characteristics (e.g., solid waste and air emission effects) showed that those characteristics did not constitute a basis for subcategorization either.

Facility size (production rates) directly affects the effluent quality, particularly the quantity of pollutants in the effluent, and size was used as a basis for subcategorization because more stringent limitations would not be cost-effective for smaller AAP facilities. EPA also identified types of production systems (e.g., flow-through, recirculating, net pen) as a determinative factor for subcategorization due to variations in quantity and quality of effluents and estimated pollutant loadings. Based on the results of an initial evaluation, EPA determined that using the production system and facility size most appropriately subcategorizes the CAAP industry.

## 5.2 FINAL CATEGORIES

In the final rule, EPA requires limitations and conditions for two subcategories. Specifically, EPA requires new limitations and standards for facilities in the following CAAP subcategories: (1) flow-through and recirculating systems and (2) net pens. The final guidelines do not revise the existing definition of a CAAP as described in Chapters 1 and 2.

Minimum facility sizes used in subcategorization are based either on the current NPDES definition of a CAAP or at a higher level of production based on economic impacts. The NPDES definition sets the minimum frequency of discharge at 30 days/year and a minimum production level of 20,000 pounds/year for coldwater species (e.g., trout and salmon) and 100,000 pounds/year for warmwater species (e.g., catfish, hybrid striped bass, and shrimp). The following is a more detailed description of each subcategory based on its production processes and wastewater characteristics.

### 5.2.1 Flow-through and Recirculating Systems

For the flow-through and recirculating system subcategory, EPA is requiring all flow-through and recirculating facilities that produce at least 100,000 pounds/year of aquatic animals to be regulated by the same production-based effluent limitations guidelines.

### 5.2.2 Net Pen Systems

For the net pen system subcategory, EPA is requiring all facilities that produce at least 100,000 pounds/year of aquatic animals using net pens to be regulated by the same production-based effluent limitations guidelines.

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# CHAPTER 6
# WATER USE, WASTEWATER CHARACTERIZATION, AND POLLUTANTS OF CONCERN

## 6.1 WATER USE BY SYSTEM TYPE

The quantity of water required for aquatic animal production (AAP) depends on the type of production system and the facility's management practices. For AAP facilities, water is required to replace evaporative and seepage losses, to replenish oxygen, and to flush wastes from the system. Most AAP facilities are constructed to allow the operators at least some control over the water supply to the production units. There are a wide array of production systems, many unique in their layout and design. The unique characteristics of an individual system often take advantage of site-specific water supply characteristics.

Sources of culture water for AAP facilities include groundwater, springs, surface water, rainwater, municipal water, and seawater (Lawson, 1995). Many of these water sources require either the filtration or purification of before use (Wheaton, 1977a). Common problems with source water include insufficient dissolved oxygen (DO), heavy solids loads, and biological contaminants such as predator fish and insects.

Source water treatment systems are designed specifically to treat specific contaminants or problems with the source water before it is added to the culture system. Source water problems are usually specific to the water source. Groundwater lacks oxygen but is usually free of other pollutants and therefore only needs aeration before use. Surface waters may contain one or more of a variety of contaminants including solids loads, wild fish, parasites, waterborne predators, and disease organisms. Surface waters are often filtered with fine mesh screens to remove these contaminants before use (Wheaton, 1977a). The following subsections describe typical water use by production system type.

### 6.1.1 Pond Systems

The type of water supply for a pond system is primarily a function of the type of pond. Levee ponds are built with berms above grade to exclude surface water and allow the operator almost complete control of the water that enters the pond. Rainwater falling directly onto the surface of the pond and interior slopes of the berms is the only uncontrolled input of water to levee ponds; all other water is pumped or piped into the ponds.

Watershed ponds are constructed to capture water from a contributing watershed during storm events. Ideally, watershed ponds are constructed so that the contributing watershed provides good-quality water (free of sediment and other pollutants) and sufficient quantities of water to maintain adequate volumes throughout the year. The pond operator does not usually have much control over the runoff into the pond. Water is sometimes pumped or piped into watershed ponds to maintain pond volumes.

Depression ponds are constructed below grade, and most take advantage of groundwater seepage to maintain water levels in the pond. Depression ponds capture direct rainfall and some runoff, depending on the topography of the surrounding landscape. Water is sometimes pumped or piped into depression ponds to maintain pond volumes.

For many ponds the water supply is one or more wells located on-site at a facility. Some facilities rely on pumped or free-flowing water from surface water bodies such as lakes, streams, or coastal waters. Those relying on surface waters, however, must be careful not to introduce undesirable species or organisms into the culture ponds. To prevent this, water might need to be screened or filtered as it is pumped into the pond. Rainwater falling directly on the pond is also captured and can be a source for maintaining water levels, but most commercial AAP ponds cannot be filled with rainfall alone because rainfall events are sporadic.

Pond systems initially require a large supply of water to fill the ponds and then smaller amounts of water to regulate the water levels and compensate for seepage and evaporation. For example, a 10-acre pond with an average depth of 4 feet holds about 13 million gallons of water. Adding 3 inches of water to compensate for evaporation requires about 815,000 gallons of water in a 10-acre pond. Generally, ponds are drained infrequently; therefore, after initially filling the ponds, operators typically do not use large volumes of additional water. For those systems that rely on well water, water conservation and rainwater capture are important management tools to minimize pumping costs.

Pond system sizes vary depending on the species and lifestage (fingerlings versus food-size) raised and among facilities producing the same species. Typical pond sizes for catfish production vary from 7 to 15 acres of surface area and from 3 to 5 feet in depth (Hargreaves et al., 2002). Striped bass are cultured in ponds with an average size of 2 to 4 acres as fingerlings and then moved to growout ponds with 5 to 10 acres of surface area and a maximum depth of 6 feet (Hodson and Jarvis, 1990). Crawfish production ponds typically range in size from 10 to 20 acres (LSU, 1999).

Water use in pond systems varies based on the size and draining frequency of the pond. For example, a 10-acre catfish pond with a depth of 4 feet would contain about 13 million gallons of water, but the water would be used for an average of 6 years before being discharged (Boyd et al., 2000). Striped bass, shrimp, and crawfish production ponds are drained annually. Crawfish ponds usually are managed to a depth of about 8 to 10 inches of water, but water is exchanged throughout the harvest season (LSU, 1999). Water exchange can increase the water use in crawfish ponds to 651,800 gallons/acre/year (Lutz, 2001).

### 6.1.2 Flow-through Systems

Flow-through systems rely on a steady water supply to provide a continuous flow of water for production. As such, flow-through systems do not consume water but only flow water through production units for a relatively short period of time, typically less than an hour. The water is used to provide DO and to flush wastes from the system, producing a high volume of continuous discharge. Most flow-through systems use well, spring, or stream water as a source of production water. These sources are chosen to provide a constant flow with relatively little variation in rate, temperature, or quality.

Flow-through systems require high volumes of water. Water requirements for single-pass raceways can be as high as 30,000 to 42,000 gallons/pound production; however, this requirement can be reduced to 6,600 gallons/pound production using serial raceways (Hargreaves et al., 2002). Facilities with flow-through systems are found throughout the United States, wherever consistent quantity and quality of water are available. Flow-through systems are the primary method used to grow salmonid species such as rainbow trout. These species require high-quality coldwater with high levels of DO. Flow-through systems are therefore located where water is abundant, allowing farmers to efficiently produce these types of fish.

### 6.1.3 Recirculating Systems

Recirculating systems do not require large volumes of water because the culture water is continuously filtered and reused before it is discharged. System water volumes include the volume of the production units, filters, and reservoirs. The production water treatment process is designed to minimize water requirements, which leads to small-volume, concentrated waste streams as well as makeup water overflow. Waste streams from recirculating systems are typically a small but continuous flowing effluent. (Refer to Chapter 4, Section 4.2.3 for more information about internal treatment processes used in recirculating systems.) Facility operators typically rely on a supply of pumped groundwater from on-site wells or municipal water supplies. Most systems add makeup water (about 5% to 10% of the system volume each day) to dilute the production water and to account for evaporation, solids removal, and other losses. A recirculating production system operating at 10% added makeup water per day, may complete one water exchange every 10 days; a flow-through production system, on the other hand, might complete more than 100 volume exchanges per day (Orellana, 1992).

### 6.1.4 Net Pen Systems

Net pen systems rely on the water quality of the site at which the net pens are located. Open systems like net pen facilities can implement fewer practices than closed or semi-closed systems to control water quality parameters such as temperature, pH, and DO. Net pens and cages rely on tides and currents to provide a constant supply of high-quality water to the cultured animals and to flush wastes out of the system. The systems may be located along a shore or pier or may be anchored and floating offshore or in an embayment. Strict siting requirements typically restrict the number of units at a given site to ensure sufficient flushing to distribute wastes and prevent degradation of the bottom near the net pens.

### 6.1.5 Other Production Systems: Alligators

Alligator production systems use water primarily to provide resting pools and to clean the holding areas where alligators are kept. The amount of water used varies greatly between facilities depending on the cleaning frequency, pool depth, and water recirculating practices practiced at the facility. Water use estimates for the alligator industry varied between 0.5 and 2 gallons/alligator/day (Pardue et al., 1994; Shirley, 2002, personal communication).

## 6.2 WASTEWATER CHARACTERISTICS

Concentrated aquatic animal production (CAAP) facilities produce a variety of pollutants that may be harmful to the aquatic environment when discharged in significant quantities. The most significant of these pollutants are nutrients (nitrogen and phosphorus), total suspended solids (TSS), and biochemical oxygen demand (BOD). Each of these pollutants causes a variety of impacts on water quality or ecology in different bodies of water. Each type of production system produces different quantities and qualities of effluents, which are determined by the following:

- Amount and type of feed used for production
- Volume and frequency of discharge
- In-system treatment processes (including natural processes)
- Other inputs to the process water (such as drugs or pesticides).

The following subsections describe some of the production system wastewater characteristics.

### 6.2.1 Pond Systems

Characteristics of effluent from pond systems are influenced by the culture practices used to raise different species and the type of pond used. The composition of pond effluents during water exchange, overflow after heavy rains, and initial stages of pond draining is similar to that of pond water (Boyd and Tucker, 1998). Pond systems are unique because they are capable of assimilating wastes within the pond. Over time, natural processes within the pond lower the concentrations of nitrogen, phosphorus, and organic material. If water is retained in catfish ponds over a long enough period of time, biological, chemical, and physical processes remove some of the waste generated by fish. Some of the organic matter from phytoplankton production and fish waste is oxidized in the natural process of microbial decomposition (JSA, 2000). Total nitrogen (TN) levels in catfish pond waters are lowered as nitrogen is lost from the water column as organic matter when nitrogen particulates decompose on the bottom of the pond. Nitrogen is also lost from the water as a gas through denitrification and volatilization. Finally, total phosphorus (TP) concentrations in the water are lowered as phosphorus is lost to the pond bottom soils as particulate organic phosphorus and precipitates of calcium phosphates.

#### *6.2.1.1 Catfish*

In catfish ponds, the most important constituents of potential effluents are nitrogen, phosphorus, organic matter, and settleable solids (SS) (JSA, 2000). These materials are a direct or indirect product of feeds added to the ponds to promote rapid fish growth. Inorganic nutrients in fish waste stimulate the growth of phytoplankton, which, in turn, stimulate the production of more organic matter through photosynthesis. For both watershed and levee ponds, nitrogen and phosphorus compounds and organic matter are present in the pond water throughout the growout period, and they represent potential pollutants if discharged.

Table 6.2−1 shows effluent loadings for TSS, 5-day biochemical oxygen demand ($BOD_5$), TN, and TP from channel catfish ponds in Alabama. These data illustrate the influence of draining frequency on annualized effluent loadings. For example, TSS loads from levee foodfish production ponds, which are drained an average of once per 6.5 years, are about an order of magnitude lower than TSS loads from levee fry and fingerling ponds, which are drained once per year. Annual effluent loads in watershed ponds are about four times lower in the less frequently drained foodfish ponds than in fry and fingerling ponds.

**Table 6.2–1. Mass Discharge of TSS, $BOD_5$, TN, and TP from Channel Catfish Farms in Alabama**

| *Pond Type* | *Source of Effluent* | *TSS (lb/ac/yr)* | *$BOD_5$ (lb/ac/yr)* | *TN (lb/ac/yr)* | *TP (lb/ac/yr)* |
|---|---|---|---|---|---|
| *Fry and Fingerling Ponds Annual Draining* | | | | | |
| Levee ponds | Overflow | 58 | 7.9 | 4.5 | 0.48 |
| | Partial drawdown | 823 | 112.3 | 75.3 | 2.98 |
| | Final drawdown | 3,062 | 94.8 | 1.8 | 4.73 |
| | Total | 3,943 | 214.7 | 108.3 | 8.19 |
| Watershed ponds | Overflow | 232 | 31.5 | 9.82 | 1.94 |
| | Partial drawdown | 822 | 112.2 | 75.2 | 2.98 |
| | Final drawdown | 3,062 | 94.8 | 28.5 | 4.74 |
| | Total | 4,116 | 238.5 | 113.5 | 9.66 |
| *Foodfish Production Ponds Average 6 years Between Drainings* | | | | | |
| Levee ponds | Overflow | 58 | 7.8 | 4.5 | 0.48 |
| | Partial drawdown | 123 | 16.9 | 6.1 | 0.45 |
| | Final drawdown | 204 | 6.3 | 19.0 | 0.31 |
| | Total | 385 | 31 | 29.6 | 1.24 |
| Watershed ponds | Overflow | 738 | 50.9 | 15.8 | 3.15 |
| | Partial drawdown | 123 | 16.9 | 6.1 | 0.45 |
| | Final drawdown | 204 | 6.3 | 19.0 | 0.31 |
| | Total | 1,065 | 74.1 | 40.9 | 3.91 |

Source: Boyd et al., 2000.

### *6.2.1.2 Hybrid Striped Bass*

Effluents from hybrid striped bass ponds are similar to catfish pond effluents; however, hybrid striped bass facilities typically drain their ponds more frequently because they must be drained and completely harvested before restocking. To avoid draining the ponds, some farmers treat the ponds with a piscicide (a pesticide, such as Rotenone, used to kill fish) to eliminate remaining fish before restocking. Ponds are usually drained annually or biennially, depending on stocking size and production management.

In a study in South Carolina (Tucker, 1998), water samples were collected and analyzed from 20 commercial hybrid striped bass ponds (Table 6.2–2). To provide a broad representation of the industry, researchers included large and small operations, as well as ponds from both the coastal plain and piedmont areas of the state. Most of the commercial ponds sampled were freshwater ponds, but some saltwater ponds were also represented in the study. Water samples were collected from the surface and the bottom of each pond. Overall, the quality of effluents from hybrid striped bass ponds varied greatly from pond to pond. Concentrations of suspended solids, TN (including total ammonia), and BOD were the parameters that were most elevated relative to the source water and could potentially have the greatest impact on receiving bodies of water.

**Table 6.2–2. Means and Ranges for Selected Water Quality Variables from Hybrid Striped Bass Ponds in South Carolina**

| *Variable* | *Mean* | *Range* |
|---|---|---|
| Suspended solids (mg/L) | 49 | 0–370 |
| Volatile suspended solids (mg/L) | 29 | 0–135 |
| BOD (mg/L) | 11.5 | 1.4–64.4 |
| Kjeldahl nitrogen (mg/L) | 7.1 | 0–97.0 |
| Total ammonia (mg N/L) | 0.95 | 0.02–7.29 |
| Nitrite (mg N/L) | 0.07 | 0–2.94 |
| Nitrate (mg N/L) | 0.36 | 0–4.61 |
| TP (mg P/L) | 0.31 | 0–1.9 |
| Soluble reactive phosphorus (mg P/L) | 0.02 | 0–0.18 |

Source: Tucker, 1998.

### *6.2.1.3 Penaeid Shrimp*

There is some evidence to suggest that effluent characteristics for marine shrimp ponds are similar to effluent characteristics for catfish farms (Table 6.2–3), but that the final portion of effluent from marine shrimp ponds is higher in pollutant concentrations by 20% to 30% (Boyd and Tucker, 1998). For example, total annual TSS for shrimp ponds is about 5,000 pounds/acre and for catfish fingerling ponds about 4,000 pounds/acre. When shrimp ponds are drained for harvest, the effluent is almost identical in composition to pond water until about 80% of the pond volume has been released (Boyd, 2000). During the draining of the final 20% of the pond volume, concentrations of $BOD_5$, TSS, and other substances increase because of sediment resuspension caused by harvest activities, crowding of agitated shrimp, and shallow and rapidly flowing water. The average $BOD_5$ and TSS concentrations often are about 50 and 1,000 milligrams/liter, respectively (Boyd, 2000).

Although catfish ponds and shrimp ponds might have similar effluent characteristics, shrimp ponds are drained more frequently than food-size catfish ponds to facilitate harvest; therefore, the volume of water discharged from a shrimp farm is typically higher than the volume of water discharged from a catfish farm. Shrimp farms in the United States have responded to state regulatory concerns regarding the discharge of solids during draining and harvesting. In Texas, shrimp farms use drainage canals and large sedimentation basins to hold water on the farm and reuse the water in other ponds to minimize TSS in effluents. Most Texas facilities try to discharge during the winter, after harvests are complete and solids have had maximum time to settle (Tetra Tech, 2002b).

**Table 6.2–3. Average Concentrations and Loads of $BOD_5$ and TSS in a Typical Shrimp Farming Pond with a Water Exchange of 2% per day**

| *Type of Effluent* | *Concentration (mg/L)* | | *Load (lb/ac)* | |
|---|---|---|---|---|
| | ***$BOD_5$*** | ***TSS*** | ***$BOD_5$*** | ***TSS*** |
| Water exchange | 5 | 100 | 107 | 2,142 |
| Draining (first 80%) | 10 | 150 | 71 | 1,071 |
| Final draining | 50 | 1,000 | 89 | 1,785 |
| Total | – | – | 267 | 4,998 |

Source: Boyd, 2000.

South Carolina shrimp farmers also try to reuse water, when possible. Some South Carolina shrimp farms are holding water in harvested ponds and growing clams and other shellfish. The “treated” water is then slowly discharged after the shellfish are harvested (Whetstone, 2002 personal communication).

### *6.2.1.4 Other Species*

Tilapia ponds are drained to harvest fish, to adjust fish inventories, or to repair ponds. At the start of pond draining for harvest, pond water effluent characteristics can be expected to be similar to production water characteristics. However, fish harvest by seining stirs up sediments at the bottom of the pond. In fertilized tilapia ponds, sediments are likely to contain significant quantities of nitrogen and phosphorus. As draining and seining continue, effluent water quality can be expected to deteriorate (Tucker, 1998).

Although there are few data on ornamental fish farm effluent characteristics in the literature, the impact from water discharged from ornamental fish production facilities is likely to be minimal. Assuming the average size of a growout pond is 2,152 square feet with approximately 80,000 gallons of water, ornamental culture facilities typically discharge the volume of one pond, or less, per year (Watson, 2002 personal communication). There are also very few data available on water quality in commercial baitfish ponds or on effluents from these ponds. Baitfish production uses low biomass stocking densities. The combination of low biomass and reduced feed input before draining makes it likely that baitfish effluents will have lower solids concentrations than effluents from catfish ponds (Stone et al., n.d.).

There is limited information about the quality of water discharged from crawfish ponds for either rotational ponds or permanent ponds. Crawfish production relies on the forage-based system for feeding, so unlike other AAP systems that rely on pelleted feed, feed management practices will not significantly affect water quality because the feed input is so low. Also, although DO levels are a concern, particularly as vegetation decays, crawfish farmers routinely check levels and use best management practices (BMPs) and technologies, such as mechanical aeration, to maintain appropriate DO levels. Very few data are available on water quality within commercial ponds for other finfish production or on effluents from these ponds; however, the effluent is likely to be similar to the effluent from hybrid striped bass ponds.

### 6.2.2 Flow-through Systems

Effluents from flow-through systems can be characterized as continuous, high-volume flows containing low pollutant concentrations. Effluents from flow-through systems are affected by whether a facility is in normal operation or whether the tanks or raceways are being cleaned. Waste levels can be considerably higher during cleaning events (Hinshaw and Fornshell, 2002; Kendra, 1991).

Boardman et al. (1998) conducted a study after surveys conducted in 1995 and 1996 by the Virginia Department of Environmental Quality (VDEQ) revealed that the benthic aquatic life of receiving waters was adversely affected by discharges from several freshwater trout farms. Three trout farms in Virginia were selected to represent fish farms throughout the state. This study was part of a larger project to identify practical treatment options that would improve water quality both within the facilities and in their discharges to receiving streams.

After initial sampling and documentation of facility practices, researchers and representatives from VDEQ discovered that although pollutants from the farms fell under permit regulation limits, adverse effects were still being observed in receiving waters. Each of the farms was monitored from September 1997 through April 1998, and water samples were measured for DO, temperature, pH, SS, TSS, total Kjeldahl nitrogen (TKN), total ammonia nitrogen (TAN), $BOD_5$, and dissolved organic carbon (DOC).

Sampling and monitoring at all three sites revealed that little change in water quality between influents and effluents occurred during normal conditions at each facility (Table 6.2–4). The average concentrations of each regulated parameters (DO, $BOD_5$, TSS, SS, and ammonia-nitrogen ($NH_3$-N)) were below their regulatory limit at each facility; however, raceway water quality declined during heavy facility activity like feeding, harvesting, and cleaning. During these activities, fish swimming rapidly or employees walking in the water would stir up solids that had settled to the bottom. During a 5-day intensive study, high TSS values were correlated with feeding events. TKN and ortho-phosphate (OP) concentrations also increased during feeding and harvesting activities. Overall, most samples taken during this study had relatively low solids concentrations, but high flows through these facilities increased the total mass loadings.

**Table 6.2–4. Water Quality Data for Three Trout Farms in Virginia**

| Parameter | FARM A | | | FARM B | | | FARM C | | |
|---|---|---|---|---|---|---|---|---|---|
| | Inlet | Within Farm | Outlet | Inlet | Within Farm | Outlet | Inlet | Within Farm | Outlet |
| Flow (mgd) | 1.03–1.54[a] *(1.18)*[b] | | | 4.26–9.43 *(6.39)* | | | 9.74–10.99 *(10.54)* | | |
| DO (mg/L) | 9.2–14.2 *(10.6)* | 3.2–13.3 *(7.0)* | 5.7–9.5 *(8.5)* | 8.2–11.5 *(10.5)* | 5.8–10.8 (8.6) | 6.8–9.6 *(7.9)* | 9.4–10.6 *(10.5)* | 4.8–9.7 *(7.6)* | 7.2–9.4 *(8.1)* |
| Temperature (ºC) | 10.5–13 *(12.2)* | 11.5–15 *(13)* | 11–15.5 *(12.9)* | 6–12.5 *(9.7)* | 6–14 *(9.1)* | 5–16.5 *(11.4)* | 8.5–13.5 *(10.5)* | 8–14 *(11.0)* | 8.5–14 *(10.4)* |
| pH (SU) | 7.1–7.4 *(7.3)* | 7.0–7.4 *(7.2)* | 7.3–7.8 *(7.5)* | 7.3–7.6 *(7.5)* | 7.2–7.6 *(7.4)* | 6.9 | 7.3 | 7.1–7.6 *(7.3)* | 7.8 |
| TSS (mg/L) | 0–1.1 *(0.2)* | 0–30.4 *(3.9)* | 0.8–6 *(3.2)* | 0–1.8 *(0.5)* | 0–43.7 *(5.3)* | 1.5–7.5 *(3.9)* | 0–1.5 *(0.3)* | 0–28 *(7.1)* | 4.1–62 *(6.1)*[c] |
| SS (mg/L) | ND[d] | | 0–0.04 *(0.02)* | ND | | 0.01–0.08 *(0.04)* | ND | | 0.04–0.08 *(0.07)* |
| $BOD_5$ (mg/L) | 0–1.25 *(0.7)* | 0.5–3.9 *(1.5)* | 0.96–1.9 *(1.3)* | 0–1.4 *(0.5)* | 0.3–7.2 *(2.1)* | 0.6–2.4 *(1.2)* | 0–2.0 *(1.1)* | 0.4–7.5 *(2.5)* | 0.5–1.8 *(1.3)* |
| DOC (mg/L) | 0.93–4.11 *(2.1)* | 0.9–7.9 *(2.9)* | 1.5–2.4 *(1.9)* | 0.91–2.56 *(1.6)* | 1.2–8.1 *(2.7)* | 1.2–3.1 *(1.9)* | 1.1–2.7 *(2.0)* | 1.1–11.1 *(2.4)* | 1.5–3.8 *(2.3)* |
| $NH_3$-N (mg/L) | 0.6 | 0.2–1.1 *(0.5)* | 0.5–0.6 *(0.6)* | 0.2 | 0.06–1.1 *(0.5)* | 0.45 | 0.03 | 0.03–2.2 *(0.4)* | 0.02–0.17 *(0.1)* |

[a] When available the range of values has been reported
[b] The average is indicated using italics.
[c] Two outliers were discarded for calculation of mean.
[d] ND: Non-detect
Source: Boardman et al., 1998.

Table 6.2–5 describes the water quality data for two flow-through systems sampled as part of EPA's data collection efforts at CAAP facilities.

**Table 6.2–5. Flow-through Sampling Data**

| Parameter | Facility A | | | Facility B | | |
|---|---|---|---|---|---|---|
| | Inlet | OLSB[d] Effluent | Bulk Water Discharge | Inlet | OLSB Effluent | Final Effluent |
| BOD (mg/L) | ND (4)[a] | 56.0–185.0[b] (*125.70*)[c] | 3.50–4.20 (*3.85*) | ND (2) | 13 | ND (2) |
| Flow (mgd) | 192.4 | 0.914 | 91.4 | 2.481–2.777 | 0.017 | 2.481–2.777 |
| pH (SU) | 7.98–8.14 (*8.05*) | 6.11–6.58 (*6.43*) | 7.50–7.83 (*7.72*) | 7.73–8.06 (*7.93*) | 7.27 | 7.93–8.19 (*8.03*) |
| TP (mg/L) | 0.7–0.25 (*0.14*) | 8.32–11.10 (*9.81*) | 0.15–0.25 (*0.21*) | 0.02–0.03 (*0.03*) | 0.36 | 0.03–0.07 (*0.05*) |
| TSS (mg/L) | ND (4) | 44.0–78.0 (*63.0*) | ND (4) | ND (4) | 38 | ND (4) |

[a] ND: Non-detect, the minimum level is listed in parenthesis.
[b] When available the range of values has been reported.
[c] The average is indicated using italics.
[d] OLSB=Offline settling basin
Source: Tetra Tech, 2001a; Tetra Tech 2002a.

### 6.2.3 Recirculating Systems

Recirculating systems have internal water treatment components that process water continuously to remove waste and maintain adequate water quality. Overall, recirculating systems produce a lower volume of effluent than flow-through systems. The effluent from recirculating systems usually has a relatively high solids concentration in the form of sludge. The sludge is then processed into two streams—a more concentrated sludge and a less concentrated effluent (Chen et al., 2002). Once solids are removed from the system, sludge management is usually the focus of effluent treatment in recirculating systems.

In a study describing the waste treatment system for a large recirculating facility in North Carolina, Chen et al. (2002) characterize effluent at various points in the system (Table 6.2–6). Approximately 40% of the solid waste produced by this particular facility is collected in the sludge collector and composted. The remaining 60% of the solids are treated with two serial primary settlers (septic tanks) and then a polishing pond (receiving pond). Table 6.2–7 describes the water quality data for one recirculating system sampled as part of EPA's data collection efforts at CAAP facilities.

**Table 6.2–6. Water Quality Characteristics of Effluent at Various Points in the Waste Treatment System of Recirculating Aquaculture Systems at the North Carolina State University Fish Barn[a]**

| Parameter | TKN (mg/L) | $NH_3$-N (mg/L) | $NO_2$-N (mg/L) | $NO_3$-N (mg/L) | TP (mg/L) | $PO_4$-P (mg/L) | COD (mg/L) | TS (%) | TSS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| Primary settling 1 inflow | 50.3 | 2.96 | 5.35 | 109.0 | 28.6 | 5.98 | 1043 | 0.22 | 752 |
| Primary settling 2 | 47.5 | 2.42 | 31.17 | 78.5 | 22.7 | 11.50 | 690 | 0.18 | 364 |

| Parameter | TKN (mg/L) | $NH_3$-N (mg/L) | $NO_2$-N (mg/L) | $NO_3$-N (mg/L) | TP (mg/L) | $PO_4$-P (mg/L) | COD (mg/L) | TS (%) | TSS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| inflow | | | | | | | | | |
| Septic tank 2 outflow | 37.7 | 3.42 | 44.00 | 36.4 | 17.6 | 12.20 | 409 | 0.16 | 205 |
| Receiving pond effluent | 8.94 | 0.12 | 1.93 | 8.2 | 4.95 | 3.68 | 153 | 0.11 | 44 |

[a] Results are from sampling conducted 4 weeks after startup of the waste handling system. Flow from the system into the receiving pond for the sampling period was 15.5 cubic meter/day.
Source: Chen et al., 2002.
Note: $NO_2$-N = nitrite-nitrogen; $NO_3$-N = nitrate-nitrogen, $PO_4$-P = phosphate-phosphorous, COD = chemical oxygen demand, TS = total solids

### 6.2.4 Net Pen Systems

Although net pen systems do not generate a waste stream like other production systems, waste from the system can adversely affect water quality. The release of nutrients, reductions in concentrations of DO, and the accumulation of sediments under the pens or cages can affect the local environment through eutrophication and degradation of benthic communities (Stickney, 2002).

**Table 6.2–7. Recirculating System Sampling Data**

| Parameter | Facility C | |
|---|---|---|
| | Inlet | Discharge |
| BOD (mg/L) | ND (2)[a] | 35.0–48.0[b] (*42.0*)[c] |
| Flow (mgd) | 0.22 | 0.22 |
| pH (SU) | 7.8 | 6.97–7.25 (*7.15*) |
| TP (mg/L) | ND (0.01) | 8.58–10.50 (*9.32*) |
| TSS (mg/L) | ND (4) | 26.0–60.0 (*42.80*) |

[a] ND: Non-detect, the minimum level is listed in parenthesis.
[b] When available the range of values has been reported.
[c] The average is indicated using italics.
Source: Tetra Tech, 2001b.

### 6.2.5 Other Production Systems: Alligators

Wastewater from alligator production facilities is generated during the cleaning of production pens and when discharges are released from the building heating system. Wastewater characteristics from alligator farms are analogous to those of strong municipal wastewater (Pardue et al., 1994). Values for alligator farm wastewater constituents are shown in Table 6.2–8.

**Table 6.2–8. Alligator Wastewater Characteristics**

| *Parameter* | *Concentration (mg/L)* |
|---|---|
| $BOD_5$ | 452 |
| Total solids | 379 |
| Volatile solids | 219 |
| TP | 11 |
| Ammonia | 78 |
| Nitrate | 5 |
| TKN | 153 |
| pH | 6.9 (SU) |

Source: Pardue et al., 1994.

## 6.3 WATER CONSERVATION MEASURES

### 6.3.1 Pond Systems

Pond systems provide many opportunities to conserve water. Water conservation practices can be grouped into structural conservation measures and management conservation measures. Structural conservation measures are those measures that can be installed at the time the production pond is constructed or added at a later date. Structural water conservation measures include seepage reduction, building watershed ponds with watershed-to-pond area ratios of 10 or less, and maintaining vegetated levees. Ongoing management water conservation measures include maintaining storage volume, harvesting without draining, and reducing or eliminating water flushing (Hargreaves et al., 2002).

### 6.3.2 Flow-through Systems

Flow-through systems do not consume or hold water for long periods. Typically water in a flow-through system is in a production unit for less than an hour. The opportunities to use lower volumes of water in flow-through systems are usually limited and can involve substantial expense. Often, more fish can be grown in a flow-through system with a fixed inflow of water through increased stocking densities in production raceways, with additional oxygenation of the production water. Water use can also be maximized through the use of multi-pass serial raceways or tanks, which use re-oxygenated water passing through multiple raising units prior to discharge. Using water more efficiently allows flow-through system operators to reduce water use from high rates of 30,000 to 42,000 gallons/pound to much lower rates of 6,600 gallons/pound.

Facilities reusing multi-pass serial raceways must use active or passive aeration systems in order to maintain adequate DO concentrations in the culture water. Facilities with sufficient hydraulic head between raceways often use passive or gravity aeration systems to increase the air-water interface thereby increasing the DO content of the culture water (Wheaton, 1977b).

Facilities with insufficient head to passively aerate must use mechanical aeration systems to increase the DO content of the culture water. Mechanical aeration systems include liquid oxygenation systems and diffuser aerators. Liquid oxygen systems operate by adding liquid oxygen below the surface of the culture water. Diffuser aerators inject air or pure oxygen below the culture waters surface in the form of bubbles. As the bubbles pass through the water column oxygen is transferred across the air-water interface (Wheaton, 1977b).

### 6.3.3 Recirculating Systems

Recirculating systems are designed to conserve water by raising fish in small volumes of water, treating the water to remove waste products, and then reusing it (Rakocy et al., 1992). Normal stocking densities in recirculating systems vary from 0.5 to over 1 pound/gallon of culture water (Losordo and Timmons, 1994). Opportunities to conserve water in recirculating systems include operating all filter systems as efficiently as possible, increasing stocking densities, and reducing daily makeup water to less than 10%. These practices would not amount to significant reductions in water use and might not be achievable in most recirculating systems.

### 6.3.4 Other Production Systems: Alligators

Water conservation measures at alligator production systems have focused on reusing or recirculating cleaning water. Each alligator holding pen contains a shallow pool that accumulates waste products and must be cleaned regularly to remove the wastes and ensure good skin quality for the alligators. The pen-cleaning process takes place daily or every other day and causes the loss of a large amount of heated water (Delos Reyes, Jr. et al., 1996). Properly operating recirculating systems can reduce daily loss of heated water to as little as 5% (Delos Reyes, Jr. et al., 1996), but these systems are not commonly used in alligator production (Pardue et al., 1994; Shirley, 2002, personal communication).

## 6.4 POLLUTANTS OF CONCERN

### 6.4.1 Characterization of Pollutants of Concern

Four sources of data were reviewed to provide an initial assessment of the pollutants of concern (POC): (1) data from a sampling event at a flow-through facility; (2) data from a sampling event at a recirculating facility; (3) discharge monitoring report (DMR) data submitted to EPA from the EPA Regions; and (4) Permit Compliance System (PCS) data from an EPA database.

EPA used several criteria to identify the list of POCs. For the sampling data, the identification criteria were as follows: (1) raw wastewaters with analytes that had three or more reported values with an average concentration greater than 5 times the minimum level (ML) (ML is the level at which an analytical system gives recognizable signals and an acceptable calibration point); (2) raw wastewaters with analytes that had three or more reported values with an average concentration greater than 10 times the ML; and (3) treated effluents with analytes that had at least one reported value with an average concentration greater than 5 times the ML. The results for determining POCs are presented in Appendix C.

The first two criteria were applied to the same data (e.g., a raw wastewater from a sampling event) and were used as a measure to determine how a more stringent criterion (> 5 ML) contrasted with a less stringent criterion (> 10 ML) in determining an analyte as a pollutant of concern. In almost all cases, both criteria (> 5 ML and > 10 ML) produced the same results.

For the PCS and DMR data sets, the original data were first associated with a system type as defined by National Permit Discharge Elimination System (NPDES) permit information. Parameters with measurements in the DMR and PCS data without a value or with a value of zero were excluded from the data sets and assumed to be nondetectable. All other data were summarized by system type and analyte, with an analysis for the average sampling value, the maximum sampling value, the minimum sampling value, and the number of samples taken.

The PCS and DMR data, composed mainly of state and federal facilities and large commercial facilities that have NPDES permits, represent the best available information. One limitation of the data is the lack of information on pond systems. Generally, the pollutants identified in the DMR or PCS database are included in the list of POCs provided below.

The POCs that are currently indicated for the CAAP industry, based on the available data, include the following: conventional and nonconventional pollutants (ammonia, BOD, chemical oxygen demand (COD), chlorine, nitrate, nitrite, oil and grease, OP, pH, SS, TKN, TP, and TSS), metals (aluminum, barium, boron, copper, iron, manganese, selenium, and zinc), microbiologicals (*Aeromonas*, fecal *streptococcus*, and total coliforms), organic chemicals, and hexanoic acid.

### 6.4.2 Methodology for Selection of Regulated Pollutants

EPA selects the pollutants for regulation based on the POCs identified for each subcategory. Generally, a pollutant or pollutant parameter is considered a POC if it was detected in the untreated process wastewater at five times the minimum level in more than 10% of samples. The ML is a metric of the sensitivity of the analytic testing procedure to measure for a pollutant or pollutant parameter.

Monitoring for all POCs is not necessary to ensure that CAAP wastewater pollution is adequately controlled because many of the pollutants originate from similar sources (the feed), are associated with the solids, and are treated with the same pollutant removal technologies and similar mechanisms. Therefore, monitoring for one pollutant as a surrogate or indicator of several others can be sufficient in some cases.

Regulated pollutants are pollutants for which EPA establishes numerical effluent limitations and standards. EPA evaluated a POC for regulation in a subcategory using the following criteria:

- Not considered a volatile compound.
- Effectively treated by the selected treatment technology option.

- Detected in the untreated wastewater at treatable levels in a significant number of samples, e.g., generally five times the minimum level in more than 10% of the raw wastewater samples.

## 6.5 POLLUTANTS AND POLLUTANT LOADINGS

CAAP facility effluents can have high concentrations of nutrients, suspended solids, and BOD and low levels of DO. When discharged into receiving waters, effluents with high levels of suspended solids can cause turbidity, which can reduce light available for photosynthesis. Low DO levels can affect estuarine organisms in the receiving waters, and excessive nutrients can accelerate plankton growth, resulting in die-offs and increased BOD in receiving waters.

### 6.5.1 Sediments and Solids

Solids are the largest pollutant loading generated in CAAP facilities. Most pond systems, however, are managed to capture and hold solids in the pond, where the solids naturally degrade. Proper management of flow-through and recirculating systems captures most of the generated solids, which must then be properly disposed of. Many CAAP facilities with NPDES permits must control and monitor their discharge levels of solids. In Idaho, NPDES permits specify average monthly and maximum daily TSS limits that vary according to production and system treatment technology (USEPA, 2002).

Although some solids from CAAP facilities are land-applied, other solids leave the facility in the effluent stream and can have a detrimental effect on the environment. Suspended solids can degrade aquatic ecosystems by increasing turbidity and reducing the depth to which sunlight can penetrate, which decreases photosynthetic activity and oxygen production by plants and phytoplankton. If sunlight is completely blocked from bottom-dwelling plants, the plants stop producing oxygen and die. As the plants decompose, bacteria use up more of the oxygen and decrease DO levels further. Subsequently, low DO can cause fish kills. Decreased growth of aquatic plants also affects a variety of aquatic life that use the plants as habitat. Increased suspended solids can also increase the temperature of surface water because the particles absorb heat from the sunlight. Higher temperatures result in lower levels of DO because warmwater holds less DO than coldwater.

Suspended particles can abrade and damage fish gills, increasing the risk of infection and disease. They can also cause a shift toward more sediment-tolerant species, reduce filtering efficiency for zooplankton in lakes and estuaries, carry nutrients and metals, adversely affect aquatic insects that are at the base of the food chain (Schueler and Holland, 2000), and may harm fish development (Colt and Tomasso, 2001). Suspended particles reduce visibility for sight feeders and disrupt migration by interfering with a fish’s ability to navigate using chemical signals (USEPA, 2000). Finally, suspended particles cause a loss of sensitive or threatened fish species when turbidity exceeds 25 nephelometric turbidity units (NTUs) and a decline in sunfish, bass, chub, and catfish when monthly turbidity exceeds 100 NTUs (Schueler and Holland, 2000).

As sediment settles, it can smother fish eggs and bottom-dwelling organisms, interrupt the reproduction of aquatic species, destroy habitat for benthic organisms (USEPA, 2000) and fish spawning areas, and contribute to the decline of freshwater mussels and sensitive or threatened darters and dace. Deposited sediments also increase sediment oxygen demand, which can deplete DO in lakes or streams (Schueler and Holland, 2000).

Increased levels of suspended solids and nutrients have very different effects on aquatic plants. High levels of suspended solids can kill off desirable species, while elevated nutrient levels can cause too many plants to grow. In either situation, an ecosystem can be drastically altered by increases in these pollutants. As a result, it is important to maintain a balance in the levels of suspended solids and nutrients reaching waterbodies to reduce such drastic impacts on aquatic plants.

### 6.5.2 Nutrients

The two major nutrients found in CAAP discharges are nitrogen and phosphorus. Nitrogen from CAAP facilities is typically discharged nitrate, nitrite, ammonia, and organic nitrogen. Most of the nitrogen from these facilities is in the form of ammonia, which is not usually found at toxic levels in CAAP discharges. Some facilities with ponds and recirculating systems might also have high levels of nitrite. Organic nitrogen decomposes in aquatic environments into ammonia and nitrate. This decomposition consumes oxygen, reducing DO levels and adversely affecting aquatic life. Phosphorus is discharged from CAAP facilities in both the solid and dissolved forms. The dissolved form, however, poses the most immediate risk because it is available to plants.

Excess nutrients in receiving waters can lead to nutrient overenrichment which can then result in overgrowth of plants, murky water, low DO, fish kills, and depletion of desirable flora and fauna. In addition, the increase in algae and turbidity in drinking water supplies heightens the need to chlorinate drinking water. Chlorination, in turn, leads to higher levels of disinfection by-products that have been shown to increase the risk of cancer. Excessive amounts of nutrients can also stimulate the activity of microbes, such as *Pfiesteria piscicida* that may be harmful to human health (Grubbs, 2001).

#### *6.5.2.1 Nitrogen*

In CAAP facilities nitrogen can take many forms, although it is discharged mainly in the forms of ammonia, nitrate, and organic nitrogen. Organic nitrogen decomposes in aquatic environments into ammonia and nitrate. This decomposition consumes oxygen, potentially reducing DO levels and adversely affecting aquatic life. Ammonia can be directly toxic to aquatic life, affecting hatching and growth rates of fish. For example, when levels of un-ionized ammonia exceed 0.0125–0.025 milligrams/liter, growth rates of rainbow trout are reduced and damage to liver, kidney, and gill tissue may occur (IDEQ, n.d.). The proportion of total ammonia in the un-ionized form can vary with temperature and pH levels (IDEQ, n.d.). However, ammonia is not usually found at toxic levels in CAAP discharges.

Ammonia and nitrate may both be used by plants as a source of energy. However, the species of nitrogen available is largely dependent upon environmental conditions (e.g., availability of oxygen). Ammonia tends to bind to sediments and may be less available for plant uptake than nitrate, and large quantities of ammonia may be toxic to plants (Schlesinger, 1997). Nitrate is soluble in water and does not bind to particles, making them highly mobile (Kaufman and Franz, 1993). As a result, elevated levels of nitrate may cause increased plant and algae growth, particularly in estuarine or marine environments where nitrogen is generally a limiting nutrient. Nitrate is not usually found at toxic levels in CAAP effluents.

Some facilities with ponds and recirculating systems might have high levels of nitrite. High concentrations of nitrite can produce "brown blood disease" in fish. In this disease, the blood is unable to carry enough oxygen, leading to respiratory distress (Boyd and Tucker, 1998). As a result, fish may die of suffocation. However, according to EPA sampling data and technical literature, nitrite concentrations in CAAP facility effluents generally do not approach toxic levels.

#### *6.5.2.2 Phosphorus*

CAAP facilities release phosphorus in both the solid and dissolved forms. Although the solid form is generally unavailable, chemically some phosphorus may be slowly released from the solid form. However, the dissolved form is readily available and it poses the most immediate risk to the environment. Plants and bacteria require phosphorus in the dissolved form, generally as OP, for their nutrition (Henry and Heinke, 1996). The principle concerns associated with phosphorus in freshwater aquatic systems, however, are algal blooms and increased eutrophication (Hinshaw and Fornshell, 2002), which is an increase in levels of production in a water body (Wetzel, 2001). Eutrophication may result in decreased DO levels as bacteria decompose dead algae, consuming oxygen in the process. When DO concentrations fall below the levels required for metabolic requirements of aquatic biota, both lethal (e.g., fish kills) and sublethal effects can occur.

### 6.5.3 Organic Compounds and Biochemical Oxygen Demand

Organic matter is discharged from CAAP facilities primarily from feces and uneaten feed. Elevated levels of organic compounds contribute to eutrophication and oxygen depletion. This occurs because oxygen is consumed when microorganisms decompose organic matter. BOD is used to measure the amount of oxygen consumed by microorganisms when they decompose the organic matter in a waterbody. The greater the BOD, the greater the degree of pollution and the less oxygen available. When a sufficient level of oxygen is not available, aquatic species become stressed and might not eat well. Their susceptibility to diseases can increase dramatically, and some species might even die. Even small reductions in DO can lead to reduced growth rates for sensitive species.

### 6.5.4 Metals

Metals may be present in CAAP wastewaters for various reasons. They might be used as feed additives, occur in sanitation products, or result from deterioration of CAAP machinery and equipment. Many metals are toxic to algae, aquatic invertebrates, and fish. Although metals can serve useful purposes in CAAP operations, most metals retain their toxicity once they are discharged into receiving waters. EPA observed that many of the treatment systems used in the CAAP industry to remove solids provide substantial reductions of most metals. Because most of the metals are present in particulate form or bind to solid particles, they can be adequately controlled by controlling solids.

## 6.6 OTHER MATERIALS

CAAP facility effluents may also contain other materials, pathogens, drugs, chemicals, and pesticides. There is little evidence to suggest that the accumulation of wastes from net pen facilities is a source of human or environmental pathogens (Nash, 2003). Non-native species, if introduced to an area, have the potential to become invasive, outcompeting and threatening the survival of the native species. There is also the potential that introducing non-native species may introduce diseases against which native populations have no natural defenses. Potentially non-native species associated with CAAP facilities include Atlantic salmon, grass carp, shrimp, and tilapia (depending on the location of the facility).

Drugs, which include medicated feed, are added to the production facility to maintain or restore animal health, and they can be subsequently released into the waters of the United States. Some pesticides, such as copper sulfate, are used at CAAP facilities to remove algae and subsequently might be discharged to waters of the United States. More detailed information about pathogens, non-native species, and drugs/chemicals, as well as a discussion of their environmental impacts, is available in Chapter 7 of the Economic and Environmental Impact Analysis.

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# CHAPTER 7
# BEST MANAGEMENT PRACTICES AND TREATMENT TECHNOLOGIES CONSIDERED FOR THE CONCENTRATED AQUATIC ANIMAL PRODUCTION INDUSTRY

## 7.1 INTRODUCTION

EPA evaluated a variety of concentrated aquatic animal production (CAAP) industry best management practices (BMPs) and wastewater treatment technologies. BMPs are management strategies and practices that CAAP facility operators use to increase production efficiencies while reducing either the effluent volume or concentrations of pollutants in the effluent stream. Examples of BMPs include feed management, health management, and mortality removal. Wastewater treatment technologies are used at a facility to remove one or more pollutants from the effluent stream. For example, primary settling of solids is a technology used at a facility to capture solids from the facility's effluent. EPA evaluated a variety of treatment technologies and practices, including those presented in this chapter, as a part of the analyses used to support the development of the final regulation.

## 7.2 BEST MANAGEMENT PRACTICES

### 7.2.1 Feed Management

Feed is the primary source of pollutants to CAAP systems. Feed management recognizes the importance of effective, environmentally sound use of feed. Facility operators should continually evaluate their feeding practices to ensure that feed is consumed at the highest rate possible. For pond systems, pond biomass, though difficult to estimate accurately, can be helpful in determining how much feed to add to a particular pond. For all systems, observing feeding behavior and noting the presence of excess feed can be used to adjust feeding rates to ensure maximum feed consumption and minimal excess.

The primary operational factors associated with proper feed management are development of feeding regimes, based on the weight of the cultured species, and regular observation of feeding activities to ensure that the feed is consumed. This practice is advantageous because it decreases the costs associated with excess feed that is not consumed by the cultured species. Excess feed can degrade the quality of the production water by adding excess nutrients to the system. Facilities should also handle and store feed with care to prevent the breakdown of feed into fine particles. If fines are present in the feed, they should be removed and disposed of properly.

In pond systems, solids from the excess feed usually settle out and are naturally processed, along with feces from the aquatic animals. Although most of the dissolved and solids fractions from the uneaten feed are treated in the pond, some of the constituents can be released when water overflows from the pond or during draining. Too much excess feed can overwhelm natural processes in the pond and result in the discharge of higher pollutant loads.

There are a variety of practices that can be used to minimize wasted feed and optimize feed uptake by the aquatic animals. Facilities should use high-quality feed consistent with the nutritional needs of the cultured species to maximize feed consumption and conversion. The facility operator should know the feed requirements of the cultured species to accurately determine daily feed amounts. Facilities should use information including size of fish, water temperature, projected growth rates, and biomass in the system to determine appropriate feeding rates (Westers, 1995). Facilities should also store feed properly to maintain the nutrient quality and minimize humidity to prevent growth of molds or bacteria on feed.

In addition to the above practices, feed management practices for net pen facilities should monitor feeding rates using technologies such as underwater photography. Excess feed is the primary source of sediment accumulation beneath net pens, which can have an adverse effect on the benthic community.

### 7.2.2 Best Management Practices Plan

The BMP plan describes and documents management activities that are implemented at the CAAP facility to reduce the discharge of pollutants, including solids generated from feeding the aquatic animals. The BMP plan also documents practices and management activities such as those associated with the storage and use of drugs and pesticides, management and maintenance of solids containment systems, maintenance of the structural integrity of various system components, and any activities associated with feed management. Additionally, BMP plans include descriptions of record-keeping activities and training sessions for employees. The overall goal of the BMP plan is to document planning and implementation of operation and management activities that a facility uses to control the discharge of solids, nutrients, and chemicals such as drugs and pesticides. The BMP plan also shows regulatory authorities how facility personnel are preventing the accidental discharge of stored materials, trash, and dead aquatic animals.

### 7.2.3 Health Screening

During normal operations, health screening involves the periodic sampling of the cultured species, which are screened for diseases, parasites, and body weight. Health screening can be done periodically and involves using small seines, cast nets, or dip nets to collect a random sample. The samples are visually inspected for diseases and parasites, then weighed and returned to the culture system.

Health screening allows for the early detection of certain diseases and parasites, such as columnaris or trichodina, which would otherwise not be detected until the outbreak had spread through the cultured population. Most states have diagnostic services available to assist in screening aquatic animals and identifying potential problems. Measuring weight allows producers to evaluate general health, determine how well the crop is performing, and continually update feeding regimes so that the most efficient feed rates are used. Health screening can also reduce the use of medicated feeds by identifying diseases early in their development before catastrophic outbreaks occur.

### 7.2.4 Inventory Control

Inventory control refers to the ongoing management of the amount of aquatic animal biomass in a culture system. Accurate record-keeping and regular sampling to determine the average size of cultured species are important tools for estimating the amount of biomass in the production system. Higher biomass requires higher feed inputs, which could potentially lower the water quality by adding nutrients and reducing levels of dissolved oxygen (DO). Production systems with high biomass are subject to reduced growth rates, lower feed conversion ratios, and increased pollutant loadings from metabolic wastes. Information collected as part of inventory control helps the facility to develop cost-effective feeding regimes to promote optimal water quality.

### 7.2.5 Mortality Removal

Mortality of the cultured species in small numbers is a common occurrence in CAAP systems. Many of the mortalities float to the surface of the culture water and can be collected by hand or with nets. Mortality removal requires at least daily inspection of each culture unit to check for the presence of mortalities. Changes in operations should not be required because most producers complete at least one daily inspection of all production operations.

The timely removal of mortalities helps to prevent the spread of some diseases. Quickly removing mortalities before they start to decompose also reduces the introduction of excess nutrients into the system. There are no known disadvantages to the timely removal of mortalities; however, when facilities have large numbers of mortalities, removal might be more costly and require seines and crews similar to those used during harvest.

### 7.2.6 Net Cleaning

The regular cleaning of production nets helps to ensure the constant flow of water through the production area of the net pens. As the nets sit in the culture area, marine organisms attach to and grow on the nets, reducing the area of the openings. This reduction in area reduces the water flow through the net pens and the amount of DO available. Lack of water exchange due to a reduced open net area also increases the buildup of metabolic waste in the system.

### 7.2.7 Pond Discharge Management

The most significant determinant for effluent quality in pond systems appears to be frequency and duration of pond drainings. The longer the time interval between drainings, the lower the wastewater volume and pollutant loads being discharged primarily because of fewer discharge events.

Pond systems are characterized as systems with infrequent discharges of water that have been treated by natural processes in the pond. There are two types of discharge from ponds: unintentional discharges due to overflow events and intentional discharges related to production practices such as harvesting.

Intentional discharges vary in frequency with the type of pond, the species being produced, and operator preferences. Water may be intentionally discharged from ponds to facilitate harvests or to improve the quality of the water in the pond by flushing or exchanging the water with new water additions.

Discharge management applies practices to reduce the volume of water discharged and to improve the quality of water through in-pond processes. By managing the frequency of discharge and holding water between crops, natural processes in the pond can assimilate wastes in the system. Other practices and technologies, such as aeration and feed management, also enhance water quality in the system.

Reusing water for multiple crops reduces the effluent volume. Effluent volume can also be reduced by draining ponds only when necessary. When possible, facilities can construct ponds that do not have to be drained for harvest. Facilities may harvest fish by seining without partially or completely draining the pond unless it is necessary to harvest in deep ponds, restock, or repair pond earthwork.

Facilities may also design new ponds with structures that allow the ponds to be drained near the surface instead of from the bottom to improve the quality of the water drained. (Water from the bottom of the pond has more solids.) If necessary, facilities may install a swivel-type drain that can take in water from the surface and be lowered to completely drain the pond.

When ponds must be drained completely, it is recommended that the final 20% to 25% of the pond volume be discharged into a settling basin or held for 2 to 3 days to minimize suspended solids and then discharged slowly.

### 7.2.8 Rainwater Management

Ponds can be managed to capture and store precipitation and minimize the need for expensive pumped groundwater or surface water. By maintaining pond depths between 6 to 12 inches below the height of the overflow structure, about 160,000 to 325,000 gallons of storage capacity per surface acre of pond is available to capture direct rainfall and runoff from the pond walls. When more water is stored, less water is released through overflows and smaller amounts of potential pollutants are released. Capturing rainfall and reducing the amount of overflow reduces the need for pumping additional water into a pond to compensate for water lost to evaporation and infiltration. The capture of rainfall also reduces the amount of pollutants released into the waterways by extending the natural treatment processes that take place in the pond. This practice of preventing overflow by capturing rainwater is a common practice in many sectors within pond operations such as the catfish and baitfish industry. An additional benefit of this practice is that less energy is required for operating the facility.

For watershed ponds in larger watersheds, excess flows can be diverted away from the ponds. Diversions can be designed to provide sufficient water for the management of the pond and crop of fish while diverting excess water away from the pond. With less water flowing through the ponds during large runoff events, the overflow volume is reduced (Boyd et al., 2000).

There are little, if any, costs for this practice. The cost of energy and pump maintenance will be saved if water is not pumped into ponds to maintain water levels. The cost of adding more capacity by extending the height of drain structures should include pond design evaluations, materials to modify the structure, and labor to perform the modifications.

### 7.2.9 Siting

Siting is the preimplementation planning that should take place to ensure that a net pen system is located in an area of adequate flow. Net pens placed in areas without sufficient tidal flushing have an increased probability of sedimentation beneath the pens. Net pens should also be located in areas where they are protected from storm events and do not become a hazard to navigation.

### 7.2.10 Secondary Containment (Escape Control)

Secondary containment involves the use of a second set of containment netting around a net pen system. The secondary containment netting should be positioned to capture any fish that might escape the primary containment netting due to damage to the net pen system, which could occur because of a storm event or other structural failure.

Influent screening is also applicable to all systems using ambient water sources for culture water. Influent screening can prevent the escapement of the cultured animals into source water. Screening also ensures the removal of organisms such as wild fish and insects that can significantly reduce production through predation.

Many facilities also screen effluents to guard against the escapement of the cultured species into the receiving waters. Effluent screening may include the use of metal grates or screens with mesh sizes small enough to exclude the cultured species from the effluent stream or the use of disinfection techniques such as ozonation or UV disinfection to kill any of the cultured species before they are discharged to a receiving waterbody.

### 7.2.11 Solids Removal BMP Plan

A facility's solids removal BMP plan includes components designed to minimize the discharge of solids from the facility. The CAAP facility would provide written documentation of a solids removal BMP plan and keep necessary records to establish and implement the plan.

Evaluating and planning site-specific activities to control the release of solids from aquatic animal production (AAP) facilities is a practice currently required in several EPA regions as part of individual and general National Pollutant Discharge Elimination System (NPDES) permits (e.g., shrimp pond facilities in Texas, net pens in Maine, and flow-through facilities in Washington and Idaho). BMP plans in these permits require the facility operators to develop a management plan for handling removed solids and preventing excess feed from entering the system. The BMP plan also ensures planning for proper operation and maintenance of equipment, especially treatment control technologies.

### 7.2.12 Drug and Pesticide BMP Plan

The purpose of the drug and pesticide BMP plan is to document the proper use and storage of specific drugs and pesticides in the production facility (e.g., amount of the drugs and pesticides used, proper storage of chemicals, and proper identification of the disease or problem and selection of proper chemical). The plan also addresses practices to minimize the accidental spillage or release of drugs and pesticides. The CAAP facility is expected to provide written documentation of a BMP plan and keep necessary records to establish and implement the plan as well as to report use of investigational new animal drugs and extralabel drug use. Again, this tool is intended to be flexible; individual facilities are able to comply with the regulations by designing plans that address the unique needs of their facilities.

## 7.3 WASTEWATER TREATMENT TECHNOLOGIES

### 7.3.1 Aeration

Some discharges from ponds, especially those from bottom waters, might be low in DO or have sufficient biochemical oxygen demand (BOD) to be problematic in receiving waters. When DO is a problem, aeration of pond discharges can be used to increase DO levels and prevent receiving water problems. Discharges from ponds can be aerated by using mechanical or passive aeration devices before they are discharged into a receiving water body. For relatively shallow ponds that are easily mixed, aerating the pond to meet fish culture needs should be sufficient to prevent problematic discharges.

Mechanical aeration devices include paddlewheel aerators and other surface aerators that create surface agitation. Surface agitation increases the surface area available for oxygen transfer. For deeper ponds, aeration of the discharge as it leaves the pond might be more practical and efficient. Passive aeration systems use the energy generated by falling water to increase the air-water surface area. Passive aeration systems take many forms, including waterfalls, rotating brushes, and splash boards. Mechanical aeration devices used for effluent treatment should undergo the same inspection and maintenance procedures implemented for aeration devices used in production areas. Passive aeration devices should be inspected regularly to remove debris and ensure correct function of the device.

Mechanical aeration can be integrated at most pond production facilities because the facilities already own the necessary equipment to aerate the pond. Passive aeration systems require no energy inputs and have low maintenance inputs once they have been constructed. Passive aeration systems can also be used to convey discharges to the receiving water body, thus reducing the potential for erosion along earthen conveyance systems.

Facilities with multi-pass serial raceways use active or passive aeration systems to maintain adequate DO concentrations in the culture water. Those facilities with sufficient hydraulic head between raceways tend to use passive or gravity aeration systems to increase the air-water interface, which in turn increases the DO content of the culture water (Wheaton, 1977).

Facilities with insufficient head between raceways use mechanical aeration systems to increase DO in the culture water. Recirculating systems also use mechanical aeration systems. Mechanical aeration systems include liquid oxygenation systems and diffuser aerators. Liquid oxygen systems add oxygen to the culture water under pressure to increase the efficiency of oxygenation. Diffuser aerators inject air or pure oxygen below the culture waters surface in the form of bubbles. As the bubbles pass through the water column, oxygen is transferred across the air-water interface (Wheaton, 1977).

Disadvantages of mechanical aeration systems include the energy and labor resources required to operate and maintain the aeration devices. Mechanical aerators should be operated and sited carefully to minimize the generation of suspended solids in the effluent.

### 7.3.2 Biological Treatment

Biological treatment involves the use of microorganisms to remove dissolved nutrients from a discharge (Henry and Heinke, 1996). Organic and nitrogenous compounds in the discharge can serve as nutrients for rapid microbial growth under aerobic (with oxygen) or anaerobic (with little or no oxygen) conditions. Biological treatment systems can convert approximately one-third of the colloidal and dissolved organic matter to stable end products and convert the remaining two-thirds into microbial cells, which can be removed through gravity separation.

Biological treatment operations are contained in tanks, lagoons, or filter systems. Most biological treatment systems are aerobic, meaning that they require free oxygen to maintain the microbial biomass necessary for effective treatment. Oxygen is usually supplied through diffusers in the bottom of the containment structure. In addition to providing oxygen, the diffusers ensure mixing of the discharge in the containment structure. After treatment, the discharge usually flows to polishing treatment operations before being discharged. Excess biomass from the containment structure is drained from the containment structure or captured in a settling device after the treated discharge leaves the biological treatment unit.

Biological treatment systems must have a constant supply of nutrient-rich water to keep the microorganism growth at its maximum potential. Aerobic biological systems also require supplemental oxygen systems to supply oxygen to the treatment system. In addition, biological systems in northern climates must be insulated from extremely cold conditions to remain effective throughout the winter. Biological treatment systems provide for the rapid conversion and removal of organic and nitrogenous pollutants in a small treatment volume. Biological treatment units also help to remove both fine and coarse solids as the discharge is settled.

Disadvantages of biological treatment systems include the cost associated with the continuous operation of these systems. Biological treatment systems are most effective when operated 24 hours/day and 365 days/year. Systems that are not operated continuously have reduced efficiency because of changes in nutrient loads to the microbial biomass. Biological treatment systems also generate a consolidated waste stream consisting of excess microbial biomass, which must be properly disposed. Operation and maintenance costs vary with the process used.

### 7.3.3 Constructed Wetlands

Constructed wetland treatment systems consist of shallow pools constructed on non-wetland sites with water at depths of usually less than 2 feet (Metcalf and Eddy, 1991; USEPA, 1996). Constructed wetlands provide substrate for specific emergent vegetation types such as cattail, bulrush, and reeds.

Constructed wetlands are designed to treat discharges through physical, chemical, and biological processes. The vegetation causes the discharge to flow slowly in a more serpentine manner, increasing the likelihood of solids settling. The vegetation also aids in the absorption of potential pollutants through plant and bacterial uptake, and it increases the oxygen level in the discharge flowing through it. Constructed wetland treatment systems can be designed to provide several different benefits, including treatment of the discharge through biological and chemical processes, temporary storage of discharges, recharge of aquifers, and reduction in discharge volume to receiving water bodies.

Constructed wetland treatment systems are most commonly used to provide a polishing or finishing step for discharge treatment operations. Newly constructed systems often require significant replanting of vegetation and backfilling of erosion damage. Once the system is operating properly, it should be inspected regularly to remove dead or fallen vegetation, check for erosion and channelization, and monitor sedimentation levels. Periodic harvest and proper disposal of the vegetation can also increase nutrient removal.

Constructed wetlands that have collected large amounts of sediment should be refurbished to ensure proper removal efficiencies and protect against the resuspension of collected solids. The section of the constructed wetland being refurbished should be taken offline for a period long enough to allow the removal of solids and regrowth of emergent vegetation. Solids removed from the wetland should either be land applied at agronomic rates or disposed using other sludge disposal methods.

Constructed wetlands have varying success in CAAP operations. Wetlands require large areas for treatment of relatively small volumes of water; therefore, facilities with limited available land for expansion are not able to use constructed wetlands. In many parts of the United States, constructed wetlands have seasonal differences in pollutant removal efficiencies. For example, in colder climates, constructed wetlands might discharge some dissolved nutrients during the colder season and become a sink for these pollutants during warmer months.

### 7.3.4 Injection Wells

Deep well injection is a wastewater disposal method by which wastewater is injected into a geologic layer beneath the earth's surface. EPA categorizes injection wells into five classes, based on the type of well and the waste disposed of. Class I and Class V wells are the only wells that may be used by CAAP facilities. Because of the costs associated with drilling and maintaining Class I wells, EPA assumes that most injection wells used by the

CAAP industry are Class V wells. Class V injection wells are defined as shallow wells such as septic systems and drywells used to place nonhazardous fluids directly below the land surface (USEPA, 2002b). Class V wells include technologically advanced wastewater treatment systems and simple waste disposal systems, such as septic systems and cesspools. These wells are usually shallow and depend on gravity to "inject" wastes below the earth's surface. Because Class V wells may be hydraulically connected to drinking water aquifers, they should be closely monitored to avoid contamination (USEPA, 2002a).

Class I injection wells are defined as municipal or industrial injection wells that inject wastewater below the lower most underground source of drinking water (USWD). To qualify as a USWD, the aquifer or part of it must or be able to supply a public water system (PWS) or contain water with less than 10,000 milligrams/liter of total dissolved solids, and not be exempted by EPA or state authorities from protection as a source of drinking water (USEPA, 2001).

### 7.3.5 Disinfection

Disinfection is a process by which disease-causing organisms are destroyed or rendered inactive. Most disinfection systems work in one of the following four ways: (1) damage to the cell wall, (2) alteration of the cell permeability, (3) alteration of the colloidal nature of the protoplasm, or (4) inhibition of enzyme activity (Henry and Heinke, 1996; Metcalf and Eddy, 1991).

Disinfection is often accomplished using bactericidal agents. The most common agents are chlorine, ozone ($O_3$), ultraviolet (UV) radiation, or disinfection with UV light. Chlorination, the use of chlorine, is the most common method of disinfection used in the United States. Applications of high concentrations of chlorine and ozone are used to disinfect the discharge stream. UV radiation disinfects by penetrating the cell wall of pathogens with UV light and completely destroying the cell or rendering it unable to reproduce.

Each disinfection system has specific operational factors related to its successful use, which might limit its appeal. Chlorine systems must have a chlorine contact time of 15 to 30 minutes, after which the discharge must in general be dechlorinated prior to discharge, depending on facility location and permit requirements. Chlorine systems may create byproducts, such as trihalomethanes, which are known carcinogens. Finally, the contact chamber must be cleaned on a regular schedule. Ozonation has limitations as well. Ozone must be generated on-site because its volatility does not allow it to be transported. On-site generation requires expensive equipment. UV radiation systems might have only limited value to dischargers without adequate total suspended solids (TSS) removal because the effectiveness of UV radiation systems decreases when solids in the discharge block the light. This system also requires expensive equipment with high maintenance costs to keep the system clean and replace UV bulbs.

Disinfection systems are beneficial because they render CAAP effluents free from active pathogenic organisms, regardless of their source. In addition, ozonation increases the DO content of the discharge stream and destroys certain organic compounds.

### 7.3.6 Flocculation/Coagulation Tank

Flocculation or coagulation tanks are used to improve the treatability of wastewater and to remove grease and scum from wastewater (Metcalf and Eddy, 1991). The purpose of wastewater flocculation is to cluster fine matter to facilitate its removal. These clusters are often referred to as “flocs.” The flocculation of wastewater by mechanical or air agitation increases the removal of suspended solids and BOD in primary settling facilities. For mechanical and air agitation, the energy input is commonly decreased so that the initially formed flocs will not be broken as they leave the flocculation facilities. Disadvantages associated with flocculation/coagulation tanks include high costs for maintenance and energy use.

### 7.3.7 Filters

A number of different filtration systems are available to treat CAAP effluents, including microscreen filters, multimedia filters, and sand filters. Filters are used to remove solids and associated pollutants from the wastewater stream. Because small-diameter solids and associated nutrients contained in CAAP industry effluents might be difficult to remove using only conventional (gravity) solids settling wastewater treatment operations, the use of filtration systems can efficiently increase the removal of these solids.

#### *7.3.7.1 Microscreen Filters*

Microscreen filters are commonly used filtration systems that consist of a synthetic screen of specific pore size that is used to remove solids from the effluent stream. Typical pore sizes for microscreen filters vary from 60 to 100 microns. Most microscreen filters operate by pumping the wastewater stream across the filter. Water passes through the screen and the solids are trapped on the surface of the screen, where they can later be flushed off to a solids holding unit for further treatment.

#### *7.3.7.2 Multimedia Filters*

Multimedia filters are pressurized or non-pressurized treatment units that contain filter media of at least two different materials. Wastewater flow is directed through a series of media (e.g., gravel and sand) using the coarse, larger sized media first to facilitate the removal of larger solids, then smaller sized media that are progressively less porous. At periodic intervals the flow of wastewater is stopped and the filters are backwashed (cleaned) by forcing clean water through the filter in the direction opposite the wastewater flow. The procedure removes the collected solids from the filter media and directs waste to either an additional treatment unit or to a solids holding structure.

#### *7.3.7.3 Sand Filters*

Sand filters can be pressurized or nonpressurized treatment units that contain sand. Sand filters are typically shallow beds of sand (24 to 30 inches) with a surface distribution system and an underdrain system (Metcalf and Eddy, 1991). The effluent is applied to the surface of the sand bed and the treated liquid is collected in the underdrain system. Most sand filters are buried underground.

### 7.3.8 Hydroponics

Hydroponics is a process in which fine solids and nutrients in discharges are removed through the culture of aquatic or terrestrial plants (Metcalf and Eddy, 1991; Van Gorder, 2001). After a concentrated waste has been screened to remove coarse solids, it is diverted through the hydroponics system. A hydroponics system functions by suspending the root system of a plant species in the discharge stream to allow for the uptake of nutrients and removal of fine solids. After the plants grow to their maximum size, they are harvested and replaced with new plants that will more effectively absorb nutrients.

Operational factors associated with hydroponic systems include the need for a constant supply of a nutrient-rich discharge to the hydroponics operation for the cultured plants, the harvesting of the cultured aquatic plants, and disposal of any unused biomass. Constant nutrient-rich discharge requirements make hydroponic systems most applicable to recirculating and flow-through production systems. The constant harvesting or removal of biomass requires the dedication of labor resources to these tasks. Hydroponic systems that use aquatic plants, such as water hyacinth, duckweed, or pennywort, to treat discharges must develop composting plans because the biomass generated by these species has no commercial value.

Limitations of hydroponic systems for intensive CAAP systems include the size of the hydroponics system needed to effectively treat the discharge stream and climatic conditions. A small intensive CAAP operation can provide sufficient nutrients for a large-scale hydroponics operation; however, a large hydroponic treatment in northern climates is limited by the infrastructure inputs needed to operate the system year-round. Most hydroponically grown plants cannot effectively grow year-round without being located inside a greenhouse. Also, it can be very difficult to control the nutrient content of effluents to meet the specific nutrient needs of the cultured plants.

Advantages of hydroponic systems include the removal of nutrients, such as phosphorus and ammonia, and economic benefits through the sale of crops such as lettuce.

### 7.3.9 Infiltration/Percolation Pond

Infiltration/percolation ponds allow for the simultaneous treatment and disposal of discharges by allowing them to gradually infiltrate the soils surrounding the basin. These ponds are constructed in soils with high hydraulic conductivity, allowing for the rapid infiltration of the wastewater into the soil (USEPA, 1996). Infiltration/percolation basins are designed with flat bottoms and without drainage structures. Evaporation is not considered to significantly increase the effectiveness of these basins.

Infiltration/percolation systems have few operational factors once they have been constructed. Before the ponds are constructed, soil tests must be conducted to ensure that the soils will have sufficient infiltration rates. Once operational, the basins should be inspected monthly to monitor water levels, check for soils accumulation, and determine whether any erosion of the banks has occurred. In some cases, it might be necessary to remove sediment and debris, and to till the basin bottom to preserve functionality.

All solids removed as part of an operation and maintenance program or in conjunction with a refurbishing effort should be treated in the same manner as solids from primary settling operations. The solids can be either be land applied at agronomic rates or disposed using other sludge disposal methods.

The primary advantage of these systems is the low operation and maintenance costs associated with their operation. Very few equipment or labor inputs are required after the construction of the systems; periodic brief inspection of the basin should be the only required operational task. Additional benefits of infiltration/percolation basins include the recharge of groundwater aquifers located below the basins and the absence of a discharge to a receiving water body.

Disadvantages of these systems include space availability for the basin and requirements for specific soil types with high hydraulic conductivities. Infiltration systems require a large surface area to successfully treat and dispose of large volumes of discharge. Another limitation of these systems is their long-term viability. Studies have shown the functional life of these systems is 5 to 10 years.

### 7.3.10 Oxidation Lagoons (Primary and Secondary)

Oxidation lagoons, also known as stabilization ponds, are usually earthen, relatively shallow wastewater treatment units used for the separation of solids and treatment of soluble organic wastes (Metcalf and Eddy, 1991). The basins are cleaned of solids as needed, which may be as long as once every 20 years. Oxidation ponds are used extensively in the wastewater treatment industry and are commonly used by the alligator industry for the treatment of wastewater generated during pen cleaning.

Oxidation lagoons are usually classified as aerobic, anaerobic, or aerobic-anaerobic (facultative) according to the nature of the biological activity in the pond. Aerobic and facultative lagoons require that oxygen be added to all or parts of the lagoon constantly; therefore, in order to reduce costs, most lagoons in the alligator industry are operated as anaerobic lagoons.

The primary advantages of oxidation lagoons for treatment of wastewater are the relative low costs of designing, constructing, and operating oxidation lagoons; the low technology requirements for the operators; and the demonstrated effectiveness of their use in treating similar effluents. Oxidation lagoons can also be operated without a discharge to surface waters through land application by spray irrigating water from the lagoon to prevent overflows.

Disadvantages of oxidation lagoons include the need to clean out accumulated solids; the potential odor emitted from the lagoon under normal operating conditions and during solids removal; and the inability of the lagoons to remove small-sized particles. The lagoon is designed to hold a fixed volume of solids and must be cleaned when the solids volume exceeds the design volume. Accumulated solids must be removed and properly disposed of through land application or other sludge disposal methods. Odors are a constant nuisance, and several methods are available to treat particularly bad odor problems. These solutions, however, tend to be costly and require additional equipment and operational resources.

### 7.3.11 Quiescent Zones

Quiescent zones are used in raceway flow-through systems where the last approximately 10% of the raceway serves as a settling area for solids. It is important to note that flow-through system raceways are typically sized according to loading densities (e.g., 3 to 5 pounds of fish per cubic foot), but the flow rate of water through the system drives the production levels in a particular raceway. Thus, EPA evaluated the impacts of placing quiescent zones in the lower 10% of raceways and found no adverse impacts on the production capacity of a facility (Hochheimer and Westers, 2002). The goal of quiescent zones and other in-system solids collection practices is to reduce the total suspended solids (and associated pollutants) in the effluent. Quiescent zone pollutant reductions were based on information supplied by industry representatives (Hinshaw, 2002, personal communication; Tetra Tech, 2002).

Quiescent zones usually are constructed with a wire mesh screen that extends from the bottom of the raceway to above the maximum water height to prohibit the cultured species from entering the quiescent zone. The reduction in the turbulence usually caused by the swimming action of the cultured species allows the solids to settle in the quiescent zone. Then the collected solids are available to be efficiently removed from the system. The quiescent zones are usually cleaned on a regular schedule, typically once per week in medium to large systems (Tetra Tech, 2002), to remove the settled solids. The Idaho BMP manual (IDEQ, n.d.) recommends minimal quiescent zone cleaning of once per month in upper raceways and twice per month in lower units. The settled solids must be removed regularly to prevent breakdown of particles and leaching of pollutants such as nutrients and BOD.

Quiescent zones placed at the bottom or end of each raising unit or raceway allow for the settling of pollutants, mainly solids, before the pollutants are discharged to other production units (when water is serially reused in several raising units) or receiving waters.

Quiescent zones increase labor inputs because of the regular removal of collected solids and maintenance of screens that exclude the culture species. Cleaning of the quiescent zones also creates a highly concentrated waste stream that should be treated before it is discharged into a receiving water body.

### 7.3.12 Sedimentation Basins

Sedimentation basins, also known as settling basins, settling ponds, sedimentation ponds, and sedimentation lagoons, separate solids from water using gravity settling of the heavier solid particles (Metcalf and Eddy, 1991). In the simplest form of sedimentation, particles that are heavier than water settle to the bottom of a tank or basin. Facilities with high levels of production and feeding rates clean the basins as often as once per month. Facilities with lower feeding rates clean less often, but at a minimum of once per year. Sedimentation basins are used extensively in the wastewater treatment industry and are commonly found in many flow-through aquatic animal production facilities. Most sedimentation basins are used to produce a clarified effluent (for solids removal), but some sedimentation basins remove water from solids to produce a more concentrated sludge. Both of these practices are used and are important in CAAP systems.

Settling in sedimentation basins occurs when the horizontal velocity of a particle entering the basin is less than the vertical (settling) velocity in the tank. When designing a sedimentation basin, settling properties of an effluent are determined, particularly the settling velocities, and the basins are sized to accommodate the expected flow through the basin. The length of the sedimentation basin and the detention time can be calculated so that particles will settle to the bottom of the basin.

Other design factors include the effects of inlet and outlet turbulence, short-circuiting of flows within the basin, solids accumulation in the basin, and velocity gradients caused by disturbances in the basin (such as those from solids removal equipment).

Proper design, construction, and operation of the sedimentation basin are essential for the efficient removal of solids. The basin must be cleaned at proper intervals to ensure the solids are removed at the designed efficiency.

The primary advantages of sedimentation basins for removing suspended solids from effluents from aquatic animal production systems are the relative low cost of designing, constructing, and operating sedimentation basins; the low technology requirements for the operators; and the demonstrated effectiveness of their use in treating similar effluents. In many CAAP systems, most of the solids from feces and uneaten feed are of sufficient size to settle efficiently in most moderately sized sedimentation basins. Many of the pollutants from CAAP operations can be partly or wholly removed with the solids captured in a sedimentation basin.

Disadvantages of a sedimentation basin include the need to clean out accumulated solids, the potential odor emitted from the basin under normal operating conditions, the odor produced by solids removed from the basin, and the inability of the basin to remove small-sized particles. Accumulated solids must be periodically removed and properly disposed of through land application or other sludge disposal methods. Odors are a constant nuisance, and several methods are available to treat particularly bad odor problems. These solutions, however, tend to be costly and require additional equipment and operational resources. System operators should attempt to minimize the breakdown of particles (into smaller sizes) to maintain or increase the efficiency of sedimentation basins. Existing CAAP systems might have limited available space for the installation of properly sized sedimentation basins.

Sedimentation basins do not function well in colder climates, where they are likely to freeze. The viscosity of water increases as its temperature decreases, which results in a decrease of the settling velocity of solids in the wastewater stream. Sedimentation basins designed for colder climates should include a safety factor to account for the longer detention times and inlet and outlet pipes should be located underwater to reduce the likelihood of freezing (Metcalf and Eddy, 1991).

### 7.3.13 Vegetated Ditches

A vegetated ditch is an excavated ditch that serves as a discharge conveyance, treatment, and storage system (USEPA, 1996). The vegetation layer aids in treating the discharge and reduces the susceptibility of the ditch banks and bottom to erosion. The length and width of the ditch are designed to allow for the slowing and temporary storage of the discharge as it flows toward the receiving water body. The walls of the ditch are excavated at an angle that supports the growth of a dense vegetation layer to enhance sedimentation and ensure against erosion.

Vegetated ditches are effective for treating wastewater discharges from CAAP facilities. They reduce the velocity of discharged water, which induces the settling of solids and associated pollutants by gravity. The vegetation ditch essentially traps pollutants such as suspended solids, settleable solids, and BOD and prevents them from being discharged into receiving waters. Depending on the porosity of the soil, a vegetated ditch might also allow wastewater to infiltrate the underlying soil as it flows along the channel.

Few operational factors are associated with using vegetated ditches. The main component of effective operation is proper design and construction of the ditch to ensure adequate vegetation and prevent scouring flows. Infiltration/percolation rates are a function of soil porosity and increase if the ditch is constructed in an area of high soil porosity. Vegetated ditches need to be maintained periodically to remove accumulated sediment for proper disposal and to maintain vegetation. Periodic harvest and proper disposal of the vegetation can also increase nutrient removal.

Disadvantages of vegetated ditches include lack of control over the treatment of the discharge. Furthermore, vegetated ditches have no backup system in the event of extremely high flow or during times when the vegetation needs to be reestablished.

### 7.3.14 Publicly Owned Treatment Works

Publicly owned treatment works (POTWs) are wastewater treatment plants that are constructed and owned by a municipal government for the purpose of treating municipal and industrial wastewater from homes and businesses within its borders and/or surrounding areas. A facility that discharges to a POTW is considered to be an “indirect” discharger because the facility’s wastewater is directed to a POTW for treatment before being discharged to surface water. Some CAAP facilities are indirect dischargers.

### 7.3.15 Solids Handling and Disposal

#### *7.3.15.1 Dewatering*

Dewatering is the physical process used to reduce the moisture content of sludge to make it easier to handle for transport, or prior to composting or incineration of the sludge. Several techniques are used to dewater sludge; some rely on natural evaporation, whereas others use mechanically assisted physical means such as filtration, squeezing, capillary action, vacuum withdrawal, and centrifugal separation (Metcalf and Eddy, 1991).

#### *7.3.15.2 Composting*

Composting is a process by which organic material undergoes biological degradation to a stable end product (Metcalf and Eddy, 1991). Approximately 20% to 30% of the volatile solids are converted to carbon dioxide and water. As the organic material in the sludge decomposes, the compost heats to temperatures in the range of 120 to 160 ºF, and pathogenic organisms are destroyed.

#### *7.3.15.3 Land Application*

Land application is the most common sludge disposal method in the CAAP industry (Chen et al., 2002). Land application of sludge is defined as the spreading of sludge on or just below the soil surface (Metcalf and Eddy, 1991). Application methods include using sprinklers and tank trucks to apply the sludge directly to the land. Sludge may be applied to agricultural land, forested land, disturbed land, and dedicated land disposal sites. In all of these cases, the land application is designed with the objective of providing further sludge treatment (Metcalf and Eddy, 1991). Sunlight, soil microorganisms, and dryness combine to destroy pathogens and other toxic organic substances present in sludge.

#### *7.3.15.4 Storage Tanks and Lagoons*

Manure, or sludge, from CAAP facilities has to be properly treated and disposed of. Storage tanks or storage lagoons are used to store untreated wastewater until the water can be treated or to store treated wastewater until it can be reused by the production system. Holding tanks, storage tanks, and surge tanks are used throughout the CAAP industry to hold untreated or treated wastewater.

## 7.4 TREATMENT TECHNOLOGIES OBSERVED AT EPA SITE VISITS

Table 7.4–1 describes the treatment technologies observed at the CAAP facilities that EPA visited as part of the Agency's data collection efforts.

**Table 7.4–1. Aquatic Animal Production Site Visit Summary**

| *State* | *Species* | *Production System* | *Treatment Technologies* |
|---|---|---|---|
| AL | Catfish | Ponds | Storage of runoff in reservoir, water management, erosion control, proper ditch construction |
| AL | Catfish | Ponds | Water management, erosion control, proper ditch construction |
| AL | Catfish | Ponds | Water management, riprap on pond banks, erosion control |
| AL | Catfish | Ponds | Water management, riprap on pond banks, erosion control |
| AL | Catfish | Ponds | Water management, riprap on pond banks, erosion control, drainage to natural wetland |
| AL | Catfish | Ponds | Water management, riprap on pond banks, erosion control, stairstep watershed ponds |
| AR | Baitfish | Ponds | Water management, erosion control |

| State | Species | Production System | Treatment Technologies |
|---|---|---|---|
| AR | Baitfish | Ponds | Water management, erosion control |
| AR | Baitfish | Ponds | Water management, erosion control |
| AR | Baitfish | Ponds | Water management, erosion control |
| AR | Baitfish | Ponds | Water management, erosion control |
| AR | Baitfish | Ponds | Water management, erosion control |
| CA | Salmon, steelhead | Flow-through | Settling pond |
| CA | Trout | Flow-through | No treatment |
| CA | Trout | Flow-through | Settling pond, constructed wetland |
| CA | Trout, salmon, steelhead | Flow-through | Infiltration pond |
| FL | Ornamentals | Flow-through tanks, low flow rate | Infiltration ditches |
| FL | Ornamentals | Ponds | Infiltration ditches |
| FL | Ornamentals | Ponds | Infiltration ditches |
| FL | Ornamentals | Ponds | Infiltration ditches |
| FL | Ornamentals | Ponds, recirculating systems | Infiltration ditches |
| FL | Ornamentals | Recirculating, flow-through tanks w/ low flow rate | Infiltration ditches |
| HI | Ornamentals | Flow-through | In-pond treatment |
| HI | Ornamentals, seaweed | Flow-through | Infiltration ditches |
| HI | Shrimp | Flow-through | In-pond treatment |
| HI | Shrimp | Flow-through | Settling ponds |
| HI | Shrimp, ornamentals, mullett, milkfish, red snapper | Flow-through | Infiltration ditches |
| HI | Tilapia, Chinese catfish | Net pen in pond | In-pond treatment |
| ID | Catfish, tilapia, alligators | Flow-through | Quiescent zone, gravel ditches, linear clarifiers, OLSB, full-flow settling |
| ID | Salmon/trout | Flow-through, recirculating | Biological treatment, linear clarifiers |
| ID | Tilapia | Flow-through, recirculating | Biological treatment ponds, full-flow settling |
| ID | Trout | Flow-through | Quiescent zones with OLSB |
| ID | Trout | Flow-through | Quiescent zones with OLSB |
| ID | Trout | Flow-through | Quiescent zones with OLSB |
| ID | Trout | Flow-through | Quiescent zones with OLSB |
| ID | Trout | Ponds, flow-through | Quiescent zones with OLSB |
| LA | Alligators | Other—alligator huts | 2-stage lagoon |
| LA | Crawfish | Ponds | In-pond treatment |

| ***State*** | ***Species*** | ***Production System*** | ***Treatment Technologies*** |
|---|---|---|---|
| LA | Crawfish | Ponds | In-pond treatment |
| LA | Crawfish | Ponds | In-pond treatment |
| LA | Hybrid striped bass | Ponds | In-pond treatment |
| LA | Tilapia | Recirculating system | Land application of solids |
| MA | Hybrid striped bass | Recirculating system | Primary settling, biological treatment, microscreen, ozonation, indirect discharge |
| MA | Tilapia | Recirculating | Plant production, constructed wetland |
| MD | Multiple | Recirculating system | Sand filters |
| ME | Brook trout, lake trout, splake | Flow-through | Settling pond |
| ME | Brook trout, landlocked salmon (coho, chinook) | Flow-through | Settling ponds |
| ME | Lobster | Other - pounds | None |
| ME | Salmon | Flow-through | Microscreen filters |
| ME | Salmon | Flow-through | Settling ponds |
| ME | Salmon | Net pens | Feed management, active feed monitoring |
| ME | Salmon, mussels | Net pens, off-bottom hanging culture (mussels) | Feed management, active feed monitoring |
| ME | Salmon - native endangered species | Flow-through | Settling ponds |
| ME | Salmon - native endangered species | Flow-through | Settling ponds |
| MI | Landlocked salmon | Flow-through | OLSB, quiescent zone, polishing pond |
| MI | Rainbow trout, brown trout | Flow-through | OLSB, quiescent zone, polishing pond |
| MN | Tilapia | Recirculating system | Lagoon, indirect discharge, composting |
| MO | Various warmwater species (including bluegill, catfish, paddlefish) | Ponds | Erosion control, water management, riprap |
| MS | Catfish | Ponds | In-pond treatment |
| MS | Catfish | Ponds | In-pond treatment |
| MS | Catfish | Ponds | In-pond treatment |
| NC | Crawfish | Ponds | In-pond treatment |
| NC | Hybrid striped bass, crawfish | Ponds | In-pond treatment |
| NC | Tilapia | Recirculating system | Solids particle trap |
| NC | Trout | Flow-through | Quiescent zones with OLSB |
| NC | Trout | Flow-through | Quiescent zones with OLSB |
| NC | Yellow perch, crab | Ponds, tanks | Settling pond |

| State | Species | Production System | Treatment Technologies |
|---|---|---|---|
| | shedding, catfish | | |
| NH | Marine species | Recirculating | Microscreen filter, solids settling tank, UV |
| NY | Tilapia | Recirculating | Holding pond—indirect discharge |
| PA | Hybrid striped bass | Flow-through | Full-flow settling |
| PA | Trout | Flow-through | Full flow settling |
| PA | Trout | Flow-through | OLSB |
| PA | Trout | Flow-through | Quiescent zone, OLSB, full-flow settling basin |
| TX | Shrimp | Ponds | Erosion control, water management, reuse, disease management, screening of effluent |
| TX | Shrimp | Ponds | Erosion control, water management, reuse, disease management, screening of effluent |
| TX | Shrimp | Ponds | Erosion control, water management, reuse, disease management, screening of effluent, constructed wetland |
| TX | Shrimp | Ponds | Erosion control, water management, reuse, disease management, screening of effluent, constructed wetland |
| UT | Trout | Flow-through | Quiescent zones, microscreen filter |
| VA | Tilapia, hybrid striped bass, yellow perch | Recirculating system | Indirect discharger to POTW |
| VT | Trout | Flow-through | Formalin detention pond, package plant for aerobic digestion for solids and phosphorus removal, chemical addition for phosphorus removal, full-flow polishing pond |
| WA | Molluscan shellfish - oysters | Flow-through, bottom culture | None |
| WA | Salmon | Flow-through, recirculating | Full-flow settling ponds in series |
| WA | Salmon | Net pens | Feed management |
| WA | Salmon | Net pens | Feed management |
| WA | Salmon | Net pens | Feed management |
| WI | Baitfish, various species of sport fish | Ponds | Erosion control, water management, discharge control (bottom drawing) |
| WI | Rainbow trout | Flow-through, earthen raceways | Riprap, erosion control, settling ponds, in pond settling |

Note: OLSB = Offline settling basin.

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# CHAPTER 8
# CONCENTRATIONS OF TOTAL SUSPENDED SOLIDS IN EFFLUENT

This section describes the data sources, data selection, data conventions, and statistical methodology used by EPA in evaluating achievable concentrations of total suspended solids (TSS) for the flow-through and recirculating subcategories. Although this chapter presents long-term averages, variability factors, and numeric limitations developed from effluent data, EPA decided not to establish national numeric effluent limitations for TSS, as explained in the preamble to the final rule. When EPA establishes national numeric limitations, EPA generally performs a more rigorous statistical and engineering review of the concentration data associated with the numeric limitations. For purposes of its evaluation of the TSS concentration data, however, EPA considers that these data were useful and of sufficient quality, and that the statistical analyses have provided reasonable results. Thus, EPA has provided information in this chapter about the long-term averages, variability factors, and numeric limitations for this data set. EPA considers these data and results to be valuable information that can be used by permit authorities in developing site-specific permits, although additional review of the data may be appropriate for that purpose.

Section 8.1 provides a brief overview of data sources (a more detailed discussion is provided in Chapter 3) and describes EPA's selection of episode data sets that were used in EPA's evaluation. Section 8.2 provides a more detailed discussion of the selection of the episode data sets for the configurations. Section 8.3 describes excluded data, and Section 8.4 presents the procedures for data aggregation. Section 8.5 describes the procedures for estimation of long-term averages, variability factors, and numeric limitations. Appendix D provides the listings for this chapter. Section 24.1 of the record for the final rule included most of the documents referenced in this chapter.

## 8.1 OVERVIEW OF DATA SELECTION AND CONFIGURATIONS

To develop the long-term averages, variability factors, and numeric limitations presented in this chapter, EPA used concentration data corresponding to the two options, A and B, described in the NODA, for the flow-through and recirculating subcategories. For purposes of evaluating the TSS discharges, EPA also combined the data from the two subcategories, and labeled the new set as the 'Combined subcategory.'

The TSS data for the analyses described in this chapter were collected from two sources: EPA's sampling episodes and self-monitoring data collected from EPA regional offices and EPA's Permit Compliance System (PCS), and submitted with comments on the proposal. These data are a subset of those described in Chapter 3. This chapter refers to the data from each facility in terms of ‘sampling episodes’ and ‘self-monitoring episodes.’ All of the data are presented in terms of gross values, that is, the values are not adjusted for TSS concentrations in the source water.

EPA considered the effluent discharges from different configurations associated with raceways and offline settling basins (OLSBs). Table 8.1–1 provides a brief description of each configuration. Figures 8.1–1 through 8.1–5 provide a graphical representation of each configuration.

**Table 8.1–1 Descriptions of Technology Configurations**

| ***Subcategory*** | ***Option*** | ***Configuration*** | ***Description*** |
|---|---|---|---|
| Flow-Through | A | 1A | Full flow settling basin effluent |
| | | 2A | OLSB effluent |
| | | 3A | Treated Raceway effluent |
| | | 4A | Combined OLSB and raceway effluent |
| | B | 1B | Full flow settling basin effluent |
| | | 2B | OLSB effluent |
| | | 3B | Treated Raceway effluent |
| | | 4B | Combined OLSB and raceway effluent |
| | N/A | 5 | Untreated raceway effluent |
| Recirculating | A | 6A | Solids treatment water |
| | | 7A | Overtopping water |
| | B | 6B | Solids treatment water |
| | | 7B | Overtopping water |
| Combined | A | 2A+6A+7A | Continuous |
| | B | 2B+6B+7B | Continuous |

The next section describes the episode and sample point selection for each configuration.

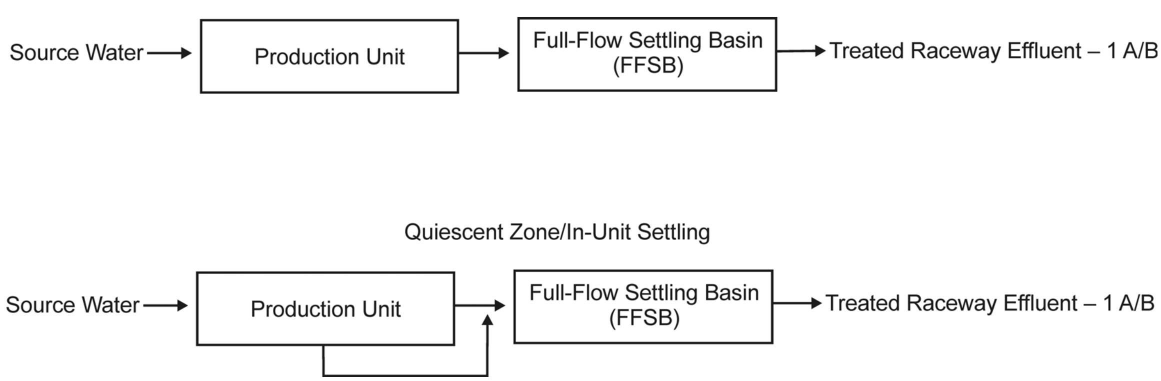



**Figure 8.1–1. Schematic of FFSB-FT Effluent Stream**

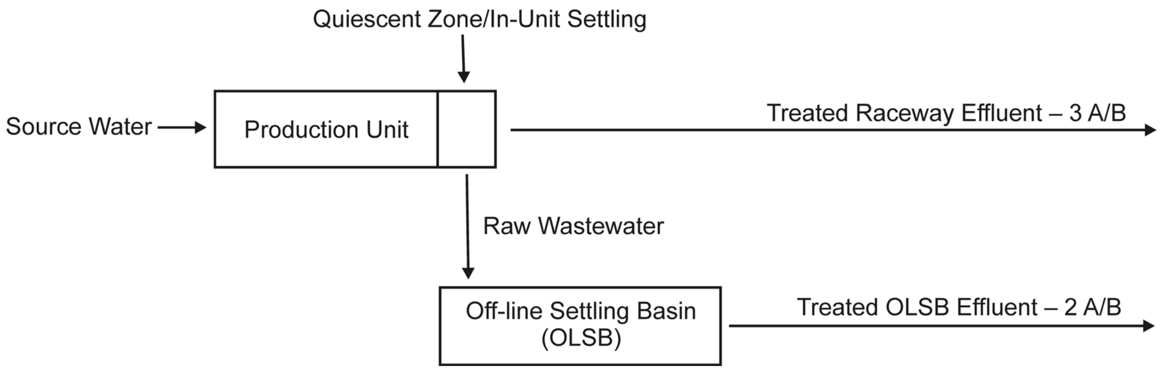
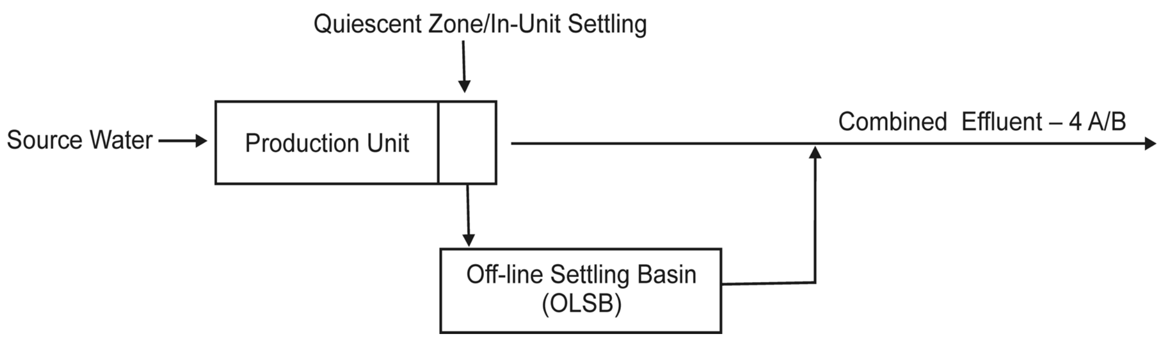


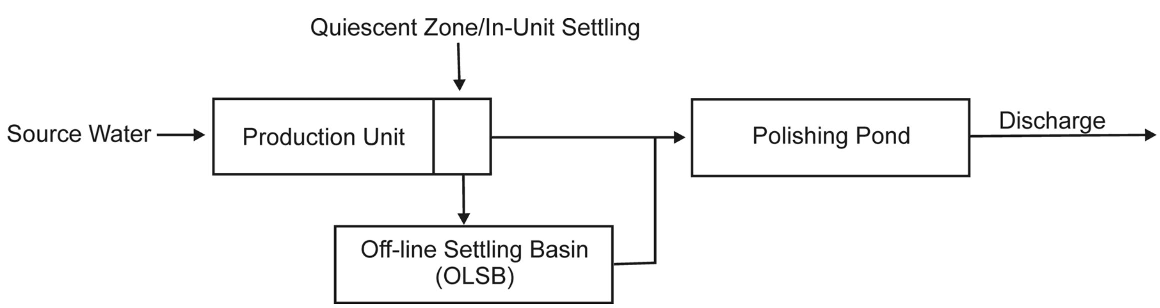

**Figure 8.1–2. Schematic of OLSB-Separate Effluent Stream**

**"4A" Classified Facility**




**"4B" Classified Facility**

**Facilities with Structural Technology**




**Or "A" Classified Facility + Feed Management**

**Figure 8.1–3. Schematic of OLSB-Combined Effluent Stream**

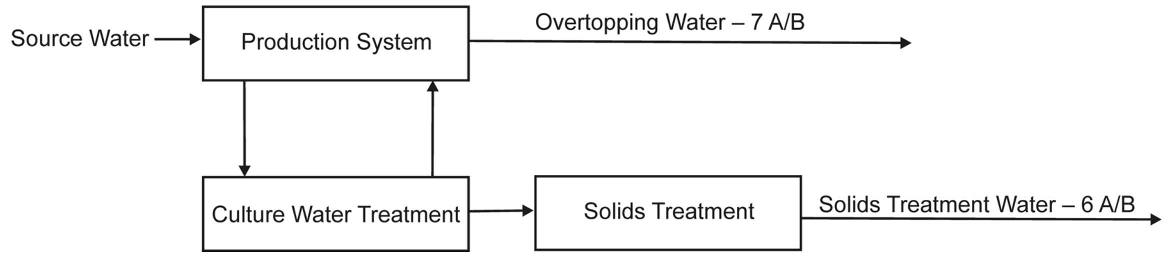



**Figure 8.1–4. Schematic of RAS-Separate Effluent Stream**

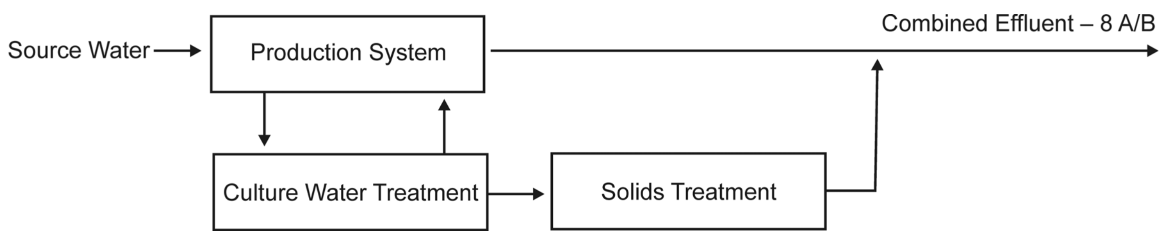



**Figure 8.1–5 Schematic of RAS-Combined Effluent Stream**

## 8.2 Episode Selection for Each Configuration

EPA qualitatively reviewed the data from the sampling episodes and self-monitoring episodes and then selected episodes to represent each configuration based on a review of the production processes and treatment technologies in place at each facility. The data are listed in *DCN 55101: All Data: Listing of Influent and Effluent TSS Concentration Data* (SAIC, 2004a) and electronically in SAIC, 2004b. Section 8.2 describes the episodes in more detail.

For its evaluations of the TSS concentrations for the final rule, EPA selected a subset of the data. The data from this subset are listed in Appendix C and electronically in SAIC, 2004c. Section 24.1 of the record identifies this subset as the 'Year 2001 Subset,' although the subset includes data from other years. First, this subset includes all of the EPA sampling data (episodes 6297, 6439, 6460, and 6495), because EPA had collected detailed information about the processes and treatment systems during the sampling episode. Second, the subset includes the self-monitoring data corresponding to the year 2001, because the questionnaire information allowed EPA to identify the configurations that were utilized by the facilities in 2001. Third, the subset includes the self-monitoring data considered in developing the proposed limitations (DMR01, DMR02, DMR03, and DMR04). The next section describes the data from the four EPA sampling episodes. The following section describes the self-monitoring data. When EPA had data from both its sampling episode and the facility's self-monitoring, EPA statistically analyzed the data from the sampling episode separately from the self-monitoring episode. This is consistent with EPA's practice for other industrial categories.

### 8.2.1 EPA Sampling Episodes

In calculating the numeric limitations, EPA used data from the four EPA sampling episodes: 6297, 6439, 6460, and 6495. If a facility had multiple production and treatment trains that EPA sampled separately, EPA has treated the data as if they were collected from different facilities because the trains were operated independently with different waste streams. In the documentation, the episode identifier is appended with a character, such as “A”, to indicate that the data are from one of the multiple trains. Table 8.2–1 summarizes the episode and sample point selections associated with each configuration of interest. This section describes the sample points selected from each episode for EPA’s evaluation of the TSS concentration data.

**Table 8.2–1 Summary of Episode and Sample Point Selection**

| *Subcategory* | *Episode* | *Option* | *Configuration* | *Influent* | *Effluent* |
|---|---|---|---|---|---|
| Flow-through | 6297A | B | 2B | SP-7 | SP-8 (dup SP-9) |
| | 6297B | B | 2B | SP-10 | SP-11 |
| | 6297C | B | 2B | SP-12 | SP-13(dup SP-14) |
| | 6297D | | NA[b] | SP-4 | N/A[c] |
| | 6297E | B | 3B | N/A[c] | SP-5 (dup SP-6) |
| | 6297F | B | 3B | N/A[c] | SP-2 (dup SP-3) |
| | 6297G | B | 4B | SP-7 | SP-8 (dup SP-9) and SP-5 (dup SP-6) |
| | 6297H | B | 4B | SP-10 | SP-11 with SP-5 (dup SP-6) |
| | 6297I | B | 4B | SP-12 | SP-13 (dup SP-14) and SP-2 (dup SP-3) |
| Recircu-lating | 6439A | A | 6A | SP-3 | SP-4 |
| | 6439B | B | 6B | SP-8 | SP-9 (dup SP-11) |
| | 6439C[f] | A | 7A | SP-2 | N/A[c] |
| Flow-Through | 6460A | A | 4A | N/A[c] | SP-7 and SP-9 |
| | 6460B | A | 3A | N/A[c] | SP-7 |
| | 6460C | A | 2A | SP-8 | SP-9 |
| | 6460D | B | 4B | SP-7, SP-8 | SP-10 (dup SP-11) |
| Flow-through | 6495A | A | 2A | SP-10 | SP-11 |
| | 6495B | B | 4B | Sp12 and SP-12A | SP-13 (dup SP-14) |

[a]When EPA collected duplicate samples, it assigned a different sample point designation than the sample point for the original sample. The parentheses identify the sample points for the duplicates.
[b]Although these sample points were not considered in developing the limitations and are labeled as “Not applicable” (NA), EPA used these data to review the overall performance at the facility. EPA has included these data in its data listings and summary statistics.
[c]N/A: for purposes of evaluating the configuration, this waste stream was not of interest or the data were not available.

#### *8.2.1.1 Episode 6297*

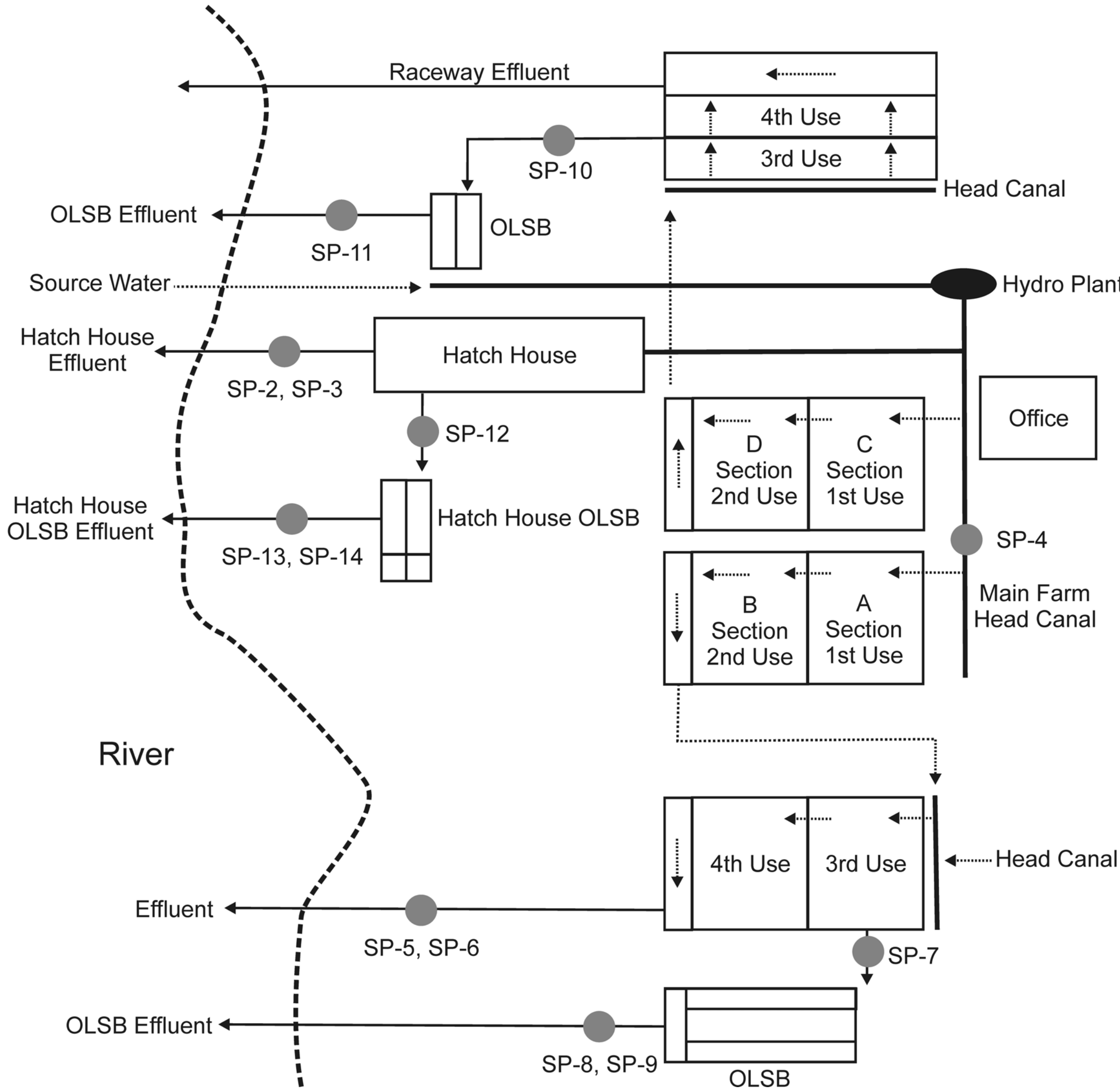
Episode 6297 was conducted on December 11 through December 16, 2000, in Buhl, Idaho, at the Box Canyon trout facility owned and operated by Clear Springs Foods, Inc. Box Canyon is the largest trout-producing raceway system in the United States and has an average annual production of some 8 million pounds. The facility includes a hatchery consisting of upwelling incubators; 20 raceways and four steel tanks for producing fry; 180 flow-through raceways for growout; and three OLSBs for solids collection. An overall schematic of the facility with the sample point locations is presented as Figure 8.2–1. Surface water from Box Canyon Spring is piped under the Snake River to Box Canyon at a rate of approximately 300 cubic feet per second (cfs). The water is diverted under the river through three steel pipes and through three turbines for electrical energy production. After passing through the turbines, the flow is split among the Blueheart, Eastman, and hatchery sections of the facility. Both the Blueheart and Eastman sections of the facility contain 90 concrete raceways holding approximately 10,000 fish per raceway. Automatic fish feeders are located above each raceway in four different locations. Automated feeding systems are used to feed the fish in the 180 raceways used for growout. All feeding in the hatchery is done by hand. Wastewater treatment operations at Box Canyon include quiescent zones, offline settling basins, and regular vacuuming of raceways. The quiescent zone at the terminal end of each raceway allows fecal material to settle before the raceway water is reused or discharged to the Snake River. Solids are removed from the quiescent zone by vacuuming. The vacuumed solids then flow by gravity to the designated OLSB for each section of the facility.

To evaluate the performance of the OLSBs, EPA considered data for the Eastman, Blueheart, and Hatch House OLSBs, labeled as *episodes 6297A*, *6297B*, and *6297C*, respectively. For comparison purposes, EPA considered data for the source water, which was labeled as *episode 6297D*. To evaluate the performance of the raceways, EPA considered data for the Eastman raceway (labeled as *episode 6297E*). EPA also considered effluent from the hatch house (labeled as *episode 6297F*). By mathematically combining data from different sample points, EPA considered three other configurations:

1. The Eastman raceway and its OLSB. This was labeled as episode *6297G*.
2. The Eastman raceway and the Blueheart OLSB. This was labeled as episode *6297H*.
3. The hatch house and its OLSB. This was labeled as episode *6297I*.

EPA also received self-monitoring data from the Box Canyon facility and has summarized that information in *Listings for Episode 6297: DMR Data, Summary Statistics, and Estimates* (SAIC, 2002a).[1] EPA also included these data with the self-monitoring data described in Section 8.2.2.1.

[1] In the record, EPA used the reported weekly flows to mathematically combine the data from different sample points. For the few cases where weekly flows were not reported, EPA used the average flow for the month. If a monthly average flow was also missing, then EPA used the maximum flow value reported for the month.




| Sampling Points | | | |
|---|---|---|---|
| SP-2 | Duplicate of SP-3 | SP-9 | Duplicate of SP-8 |
| SP-3 | Hatch House Effluent | SP-10 | OLSB Influent |
| SP-4 | Source Water | SP-11 | OLSB Effluent |
| SP-5 | Raceway Effluent | SP-12 | Hatch House OLSB Influent |
| SP-6 | Duplicate of SP-5 | SP-13 | Hatch House OLSB Effluent |
| SP-7 | OLSB Influent | SP-14 | Duplicate of SP-13 |
| SP-8 | OLSB Effluent | | |

**Figure 8.2–1. Schematic of Sampling Points and Facility for Episode 6297**

### *8.2.1.2 Episode 6439*

Episode 6439 was conducted at Fins Technology, LLC on April 23 through April 28, 2001 in Turners Falls, Massachusetts. Fins Technology, started in 1990 as AquaFuture, Inc, produces about 1 million pounds of hybrid striped bass per year in a recirculating system. It sells live and iced whole fish throughout the U.S. east coast and New England. A unique feature of this facility is its ability to grow hybrid striped bass from egg to foodfish in recirculating systems, all of which are located on-site. Fins Technology uses recirculating system technology to maintain water quality in the growing tanks for the hybrid striped bass. The facility adds less than 10% of the total system volume each day to offset water losses because of filter backwashes and to account for some of the inefficiencies in the recirculating system. Wastewater is generated from solids filtration equipment that maintains process water quality in the recirculating system. Solids are generated when the solids filters are backwashed throughout the day. Additional system overflow (overtopping) water is added to the waste stream and comes directly from the process tanks. Because the facility has claimed its process diagram as CBI, EPA is providing only a brief summary of the process at that facility in Figure 8.2–2.

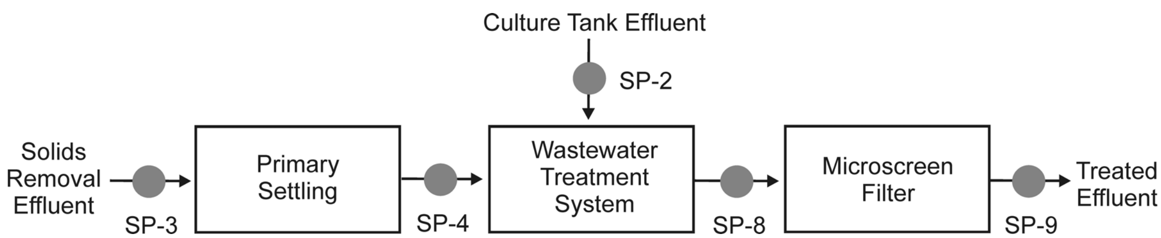



**Figure 8.2–2. Schematic of Sample points and Facility for Episode 6439**

To evaluate the solids treatment associated with recirculating systems, EPA evaluated the data from primary settling and wastewater treatment. The data associated with the two effluents are labeled as *episodes 6439A* and *6439B*. EPA also evaluated the data from the overtopping, and labeled these data as *episode 6439C*.

EPA notes that the facility had exceeded its permit limits during EPA's sampling episode. This facility is generally capable of complying with its permit limits of 50 milligrams/liter (daily maximum) and 30 milligrams/liter (monthly average), and therefore, EPA determined that the permit limits more accurately reflected normal operations. EPA also noted that the effluent from the polishing pond was more variable than EPA's experience with typical performance of polishing ponds.

### *8.2.1.3 Episode 6460*

Episode 6460 was conducted on August 24 through August 29, 2001, in Harrietta, Michigan, at the Harrietta Hatchery trout facility. Harrietta Hatchery is a Michigan Department of Natural Resources hatchery whose mission is to produce rainbow and brown trout for stocking into Michigan waters. Harrietta produces about 1.2 million trout annually. The trout are harvested from Harrietta's raceways when they are about 5 to 8 inches in length or about eight to ten fish to the pound. Figure 8.2–3 shows the process diagram for the facility associated with this episode. Harrietta uses well water at a rate of up to 5.5 million gallons per day from pumped and artesian wells that flow to the hatchery and 12 raceways. Wastewater treatment operations at the Harrietta Hatchery include the use of baffles, quiescent zones (sediment traps) in each raceway, a manure storage/settling pond, and a polishing pond. The outdoor growout system consists of 12 covered raceways grouped in three blocks of four. Water flows through each raceway in the block and is collected in a common trough, which is discharged either to an aeration shed or a polishing pond. At the downstream end of each raceway is a quiescent zone where solids settle and are easily vacuumed. The vacuumed solids are diverted into a manure collection/storage basin (or OLSB) adjacent to the polishing pond. A standpipe in each raceway can also be pulled to send water and solids to the OLSB. This OLSB has an intermittent discharge, typically weekly, and only occurred once during EPA's sampling episode (on August 27, 2001). To accommodate EPA's schedule, the facility discharged from the OLSB two days earlier than originally scheduled. (See *DCN 55209: Episode 6460 Concentration values of TSS reported on 8/27/2001* (SAIC, 2004d) for a schematic of the concentration levels through the facility on that day.)

To obtain one value for the combined discharges for each day, the Agency mathematically combined the data from the commingled raceway discharge and the OLSB discharge, and labeled them as *episode 6460A*. Because the OLSB discharged on only one day, the daily 'commingled values' for the other four days are based on only the raceway discharge. The discharge from one block of raceways, the OLSB, and polishing pond are labeled as *episodes 6460B, 6460C* and *6460D*, respectively.

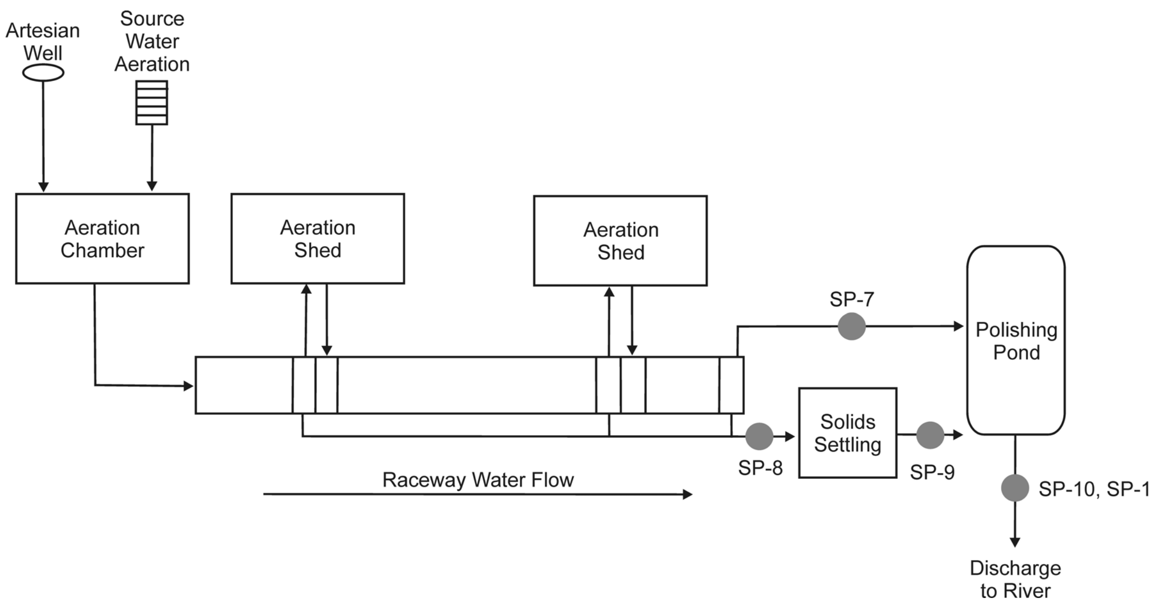



**Figure 8.2–3. Schematic of Sample points and Facility for Episode 6460**

### *8.2.1.4 Episode 6495*

Episode 6495 was conducted at the Huntsdale Fish Culture Station in Carlisle, Pennsylvania on March 24 through March 29, 2003. Huntsdale is owned by the Commonwealth of Pennsylvania and operated by the Pennsylvania Boat and Fish Commission. The facility's mission is to produce salmonid and warmwater fish for stocking into Pennsylvania waters. Species produced at the facility include brook trout

(*Salvelinus fontinalis*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), striped bass (*Morone saxtilits*), northern pike (*Esox lucius*), and muskellunge (Muskie) (*E. masquinongy*). Sampling at this facility focused on the flow-through salmonid grow-out production units within the facility.

As shown in Figure 8.2-4, the facility operates three sets of raceways and a hatchery for salmonid production. Source water is obtained from a combination of surface water and eight limestone springs located either on or adjacent to the facility. Average flow through the facility is approximately 8,000 gallons per minute. Spring water used by the facility averages 58 °F year-round. Due to drought conditions over the past two years, the average flow has dropped to about 5,000 gallons per minute, and the facility has had to rely on surface water sources for approximately 1,000 gallons per minute of its flow. The facility also operates 11 ponds for the production of warmwater species. The effluent conveyance system for these ponds is completely separate from the flow-through production system. The warmwater production system was not operating during the sampling episode.

Wastewater treatment operations at Huntsdale include the use of baffles and quiescent zones (sediment traps) in each raceway, a linear clarifier, and polishing pond. Approximately 11.5 million gallons per day of treated wastewater is discharged from the facility. Most of the production water from Huntsdale flows directly to a polishing pond before it is discharged into a ditch that conveys the water to Yellow Breeches Creek. Huntsdale personnel also use several best management practices (BMPs) that help to minimize the discharge of solids and reduce the need to use medicated feeds (antibiotic). The facility uses an extensive feed management program to optimize feeding and meet stringent production goals, which include numbers of individual fish within weight tolerance limits, at specific times of the year.

The daily data for the discharge from the OLSB are labeled as *episode 6495A*. The discharge from the commingled raceway and OLSB is labeled as *episode 6495B*.

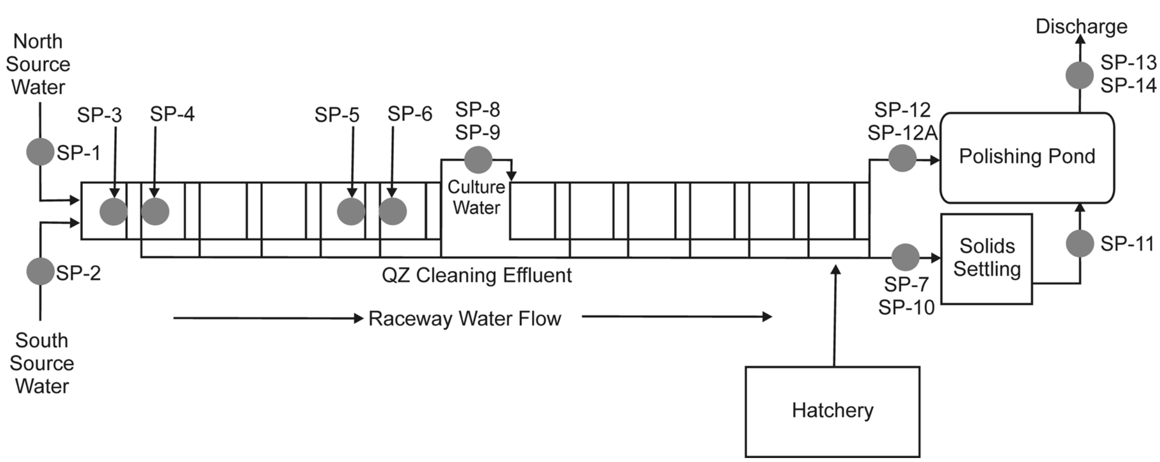



**Figure 8.2–4. Schematic of Sample Points and Facility for Episode 6495**

### 8.2.2 Self-Monitoring Data

In calculating the numeric limitations, EPA used self-monitoring data corresponding to the configurations described in Table 8.1–1. In the following sections and in the public record, EPA has masked the identity of the facilities for which it used self-monitoring data. Following the convention used for the proposal which included data from industry discharge monitoring reports (DMR), these episodes are identified only as DMRxx where "xx" is a two-digit number assigned to each self-monitoring episode. The following two sections describe the self-monitoring data considered for the proposal, and additional data incorporated into EPA's analyses after the proposal.

#### *8.2.2.1 Proposal DMR Data*

For the DMR episodes (DMR01, DMR02, DMR03, and DMR04) considered for the proposal, EPA identified the configurations using information from the facility NPDES permit and the responses to the open-ended question (question 10) in the AAP screener questionnaire, "What pollutant control practices do you use before water leaves your property?" After the proposal, EPA re-evaluated its use of these data. All of the self-monitoring data had been collected from 1996 through 1999, which was earlier than the base year, 2001, for the questionnaire. Thus, it is possible that the facility may have changed its operations sometime between 1996 and 2001. Thus, some or all of the self-monitoring data might have been generated by a different configuration than the one that EPA had identified for that facility. For this reason, EPA calculated the episode-specific long-term averages and variability factors from these data sets, but did not include them in the calculation of the configuration-specific long-term averages, variability factors, and numeric limitations. This section describes each of the four data sets in more detail.

For the four sets, EPA reviewed the NPDES permit information for each facility to determine the reporting requirements. The monitoring frequency was typically once per month or once per three months and the samples were typically 8-hour composite samples collected hourly or until five grab samples were collected. Because facilities report multiple parameters in a single report, multiple days are sometimes recorded as the monitoring period for all of the data. Based on the permit information, EPA assumed that each reported value was from a single 24-hour period. For purposes of the statistical analyses and data listings, EPA assumed that the sample date was the one associated with the "Monitoring from" date (starting date of the sampling) listed in the DMR. For purposes of listing the data, EPA assigned the sample point designation SP-1 to the effluent for each episode. The following paragraphs describe each facility.

The facility that provided the episode DMR01 data is the Virginia Department of Game and Inland Fisheries, Coursey Springs Fish Culture Station, Millboro, Virginia, a state fish hatchery that produces brook, brown, and rainbow trout for stocking in public trout streams. The facility uses about 11.5 million gallons per day of spring water and uses quiescent zones and full-flow settling for removing solids from the effluent stream.

The episode DMR02 data are from a state-owned trout production facility for stocking in public trout streams. The facility produces brook, brown, and rainbow trout in raceways. Effluents from the raceways flow into a two-stage settling pond for primary settling and secondary solids polishing. The system flow rate is about 2.8 million gallons per day.

Because the TSS data from DMR02 exceeded the monthly permit limit for one month, EPA excluded these data from the calculations for the configuration-specific long-term averages, variability factors, and numeric limitations.

The episode DMR03 data are from Virginia Department of Game and Inland Fisheries, Marion Fish Culture Station, Marion, VA, another state facility that produces trout, muskellunge, pike, and walleye for stocking in public waters. This facility separately samples its effluents from quiescent zones and a full-flow settling basin below the trout raceways. The facility then mathematically combines the two effluent data values to obtain one daily value for the facility. The facility uses about 2.0 million gallons per day for the trout production part of the operation.

The episode DMR04 data are from the Virginia Department of Game and Inland Fisheries, Buller Fish Culture Station, Marion, VA, a state-owned trout rearing station that produces trout for stocking in public waters. The facility samples its effluents from quiescent zones and a full-flow settling basin, separately, and then mathematically combines the results to obtain one daily value. The facility uses about 0.5 million gallons per day for the trout production.

#### *8.2.2.2 Post-Proposal DMR Data*

After the proposal, EPA evaluated TSS concentration data from an additional 51 facilities in the Year 2001 subset of effluent data. EPA obtained these data from EPA regional offices and EPA's Permit Compliance System (PCS), and submitted with comments on the proposal.

If a facility had multiple production and treatment systems or configurations, EPA has treated the data as if they were collected from different facilities because the trains are operated independently with different waste streams. In the documentation, the episode identifier is appended with a character, such as "A", to indicate that the data are from one of the multiple trains (e.g., DMR21A). In addition, each discharge point was assigned a different sample point number (e.g., SP-1, SP-2). For some facilities, EPA received data on the source water, and has designated the sample point to be 'SP-0.' (In the documentation, these data are sometimes identified as 'influent' data.)

In some cases, the reported monitoring frequency was once a month, but the actual sample date was not reported. Or, the monitoring frequency was not reported, but the daily maximum and monthly average values were identical for every month. In these two situations, for purposes of listing the data, EPA assumed that the sample had been collected on the first day of the month. Some other facilities reported the monitoring frequency to be once a week, but did not report the actual sample date. For those facilities, EPA assumed that the samples were collected every 7$^{th}$ day, starting with the 1$^{st}$ day of the month.

## 8.3 DATA EXCLUSIONS

In some cases, EPA did not use all of the data described in Section 8.2 in calculating the limitations. Other than the data exclusions described in this section, EPA has used the data from the episodes and sample points identified in Section 8.2.

EPA excluded the data for one sample (55949) of the influent during episode 6297 (sample point 12) because it was filtered before measuring the concentration levels. Instead, in its statistical analyses, EPA used the concentration data from another sample (55948) collected at approximately the same time at that sample point, but was not filtered prior to measuring the concentrations.

For the self-monitoring data, EPA compared each reported TSS concentration value to the permit's daily maximum limit. If the concentration value was greater than the limit, EPA excluded the value from its analyses. *DCN 55208: Year 2001 Subset: Comparison of Effluent Data to TSS Daily Maximum Limit in Permit* (SAIC, 2004e) identifies the values that have been excluded.

For two episodes, DMR19 and DMR61, some nondetected measurements were reported as 'zero,' instead of sample-specific detection limits. (See *DCN 55206: Year 2001 Subset: Listing of records with CONC=0 for TSS* (SAIC, 2004f).) Episode DMR19 had only one zero value, and it was for source water. Episode DMR61 had 12 effluent values, of which 8 were reported as 'zero.' EPA calculated episode-specific statistics for this data set, but excluded it from the calculation of configuration long-term averages, variability factors, and numeric limitations.

## 8.4 Data Aggregation

In some cases, EPA determined that two or more samples had to be mathematically aggregated to obtain a single value that could be used in other calculations. In some cases, this meant that field samples were averaged for a single sample point. In addition, for one facility, data were aggregated to obtain a single daily value representing the facility's influent or effluent from multiple sample points. Appendix C lists the data after these aggregations were completed and a single daily value was calculated. *DCN 55213: Year 2001 Subset: Unaggregated Data for Total Suspended Solids* (SAIC, 2004g) provides the unaggregated data.

In all aggregation procedures, EPA considered the censoring type associated with the data, as well as the measured values to be detected. In statistical terms, the censoring type for such data was NC. Measurements reported as less than some sample-specific detection limit (e.g., <2 milligrams/liter) were censored and were considered to be ND. In the tables and data listings in this document and the record for the rulemaking, EPA has used the abbreviations NC and ND to indicate the censoring types.

The distinction between the two censoring types is important because the procedure used to determine the variability factors considers censoring type explicitly. This estimation procedure modeled the facility data sets using the modified delta-lognormal distribution. In this distribution, data are modeled as a mixture of two distributions. Thus, EPA concluded that the distinctions between detected and nondetected measurements were important and should be an integral part of any data aggregation procedure. (See Appendix E for a detailed discussion of the modified delta-lognormal distribution.)

Because each aggregated data value was entered into the modified delta-lognormal model as a single value, the censoring type associated with that value was also important. In many cases, a single aggregated value was created from unaggregated data that were all either detected or nondetected. In the remaining cases with a mixture of detected and nondetected unaggregated values, EPA determined that the resulting aggregated value should be considered to be detected because TSS was measured at detectable levels.

This section describes each of the different aggregation procedures. They are presented in the order in which the aggregation was performed: filtrate samples, field duplicates, and multiple sample points.

### 8.4.1 Aggregation of Filtrate Samples

For SP-12 at episode 6297, the laboratory filtered the samples and processed the aqueous filtrate and filtered solids separately. As a result, for the classical/conventional analytes and the metals pollutants, the laboratory reported two results for each sample. The aqueous filtrate results were reported in weight/volume units (e.g., milligrams/liter), while the filtered solids were reported in weight/weight units (e.g., milligrams/kilogram). EPA aggregated the results as explained in the memorandum *Conversion of Aquaculture Data for Episode 6297* (DynCorp, 2002). *Listing of the Aquatic, Solid, and Combined Filtrate Data for Facility 6297* (SAIC, 2002b) provides the reported (unaggregated) and aggregated values.

### 8.4.2 Aggregation of Field Duplicates

During the sampling episodes, EPA collected a small number, about ten percent, of field duplicates. Field duplicates are two samples collected from the same sample point at approximately the same time, assigned different sample numbers, and flagged as duplicates for a single sample point at a facility. *DCN 55214: Year 2001 Subset: Individual Field Duplicate Sample Results for Total Suspended Solids* (SAIC, 2004h), provides the individual values for the field duplicates for the sample points identified in Table 8.2–1. (None of the self-monitoring episodes had more than one data value for any day, and thus, this step was not used for self-monitoring episodes.)

Because the analytical data from each duplicate pair characterize the same conditions at the same time at a single sample point, EPA aggregated the data to obtain one data value for those conditions by calculating the arithmetic average of the duplicate pair.

In most cases, both duplicates had the same censoring type. In these cases, the censoring type of the aggregate was the same as the duplicates. In the remaining cases, one duplicate was an NC value and the other duplicate was an ND value. In these cases, EPA determined that the appropriate censoring type of the aggregate was NC because TSS had been present in one sample. (Even if the other duplicate had a zero value,[2] TSS still would have been present if the samples had been physically combined.) Table 8.4–1 summarizes the procedure for aggregating the analytical results from the field duplicates. This aggregation step for the duplicate pairs was the first step in the aggregation procedures for both influent and effluent measurements.

[2] This is presented as a "worst-case" scenario. In practice, the laboratories cannot measure 'zero' values. Rather they report that the value is less than some level.

**Table 8.4–1. Aggregation of Field Duplicates**

| *If the Field Duplicates Are:* | *Censoring Type of Average is:* | *Value of Aggregate is:* | *Formulas for Aggregate Value of Duplicates:* |
|---|---|---|---|
| Both NC | NC | Arithmetic average of measured values | (NC1 + NC2)/2 |
| Both ND | ND | Arithmetic average of sample-specific detection limits | (DL1 + DL2)/2 |
| One NC and one ND | NC | Arithmetic average of measured value and sample-specific detection limit | (NC + DL)/2 |

NC - noncensored (or detected). ND - nondetected. DL - sample-specific detection limit.

### 8.4.3 Aggregation of Data Across Sample Points ("Flow-Weighting")

After field duplicates were aggregated, the data from each sample point in facilities with multiple sample points were further aggregated to obtain a single daily value representing the episode's influent or effluent.

In aggregating values across sample points, if one or more of the values were NC, the aggregated result was considered NC because TSS was present in at least one stream. When all of the values were ND, the aggregated result was considered to be ND. The procedure for aggregating data across streams is summarized in Table 8.4–2. The following example demonstrates the procedure at an episode with discharges on Day 1.

*Example of calculating an aggregated flow-weighted value:*

| Day | Sample Point | Flow (cfs) | Concentration (mg/L) | Censoring |
|---|---|---|---|---|
| 1 | Raceway | 1 | 50 | NC |
| 1 | OLSB | 100 | 10 | ND |

Calculation to obtain aggregated, flow-weighted value:

$$\frac{(100\ \text{cfs} \times 10\ \text{mg}/\text{L}) + (1\ \text{cfs} \times 50\ \text{mg}/\text{L})}{100\ \text{cfs} + 1\ \text{cfs}} = 10.4\ \text{mg}/\text{L}$$

Because one of the values was NC, the aggregated value of 10.4 milligrams/liter is NC.

**Table 8.4–2. Aggregation of Data Across Streams**

| *If the n Observations are:* | *Censoring Type is:* | *Formulas for Value of Aggregate* |
|---|---|---|
| All NC | NC | $\frac{\sum_{i=1}^{n} NC_i \times flow_i}{\sum_{i=1}^{n} flow_i}$ |
| All ND | ND | $\frac{\sum_{i=1}^{n} DL_i \times flow_i}{\sum_{i=1}^{n} flow_i}$ |
| Mixture of k NC and m ND (total number of observations is n=k+m) | NC | $\frac{\sum_{i=1}^{k} NC_i \times flow_i + \sum_{i=1}^{m} DL_i \times flow_i}{\sum_{i=1}^{n} flow_i}$ |

NC - noncensored (or detected). ND - nondetected. DL - sample-specific detection limit.

## 8.5 ESTIMATION OF THE NUMERIC LIMITATIONS

In estimating the numeric limitations, EPA first determined an average performance level that a facility with well-designed, well-operated model technologies (which reflect the appropriate level of control) would be capable of achieving. Second, EPA determined an allowance for the variation in TSS concentrations associated with well-operated systems. This allowance for variance incorporates all components of variability, including sampling and analytical variability. Variability factors assure that normal fluctuations in a facility's systems are accounted for in the limitations. By accounting for these reasonable excursions above the long-term average, EPA's use of variability factors results in limitations that are generally well above the actual long-term averages. If a facility operates its system to meet the relevant long-term average, EPA expects the facility will have discharges at or below the limitations.

The following sections describe the calculation of the configuration long-term averages and variability factors.

### 8.5.1 Calculation of Configuration Long-Term Averages

This section discusses the calculation of long-term averages by episode (episode long-term average) and by configuration within each subcategory and option (configuration long-term average). These averages were used to calculate the limitations.

First, EPA calculated the episode long-term average by using either the modified delta-lognormal distribution or the arithmetic average. Listing 8-2 in Appendix D lists the episode long-term averages. EPA has listed the arithmetic average (column labeled "Obs Mean") and the estimated episode long-term average (column labeled "Est LTA"). If

EPA used the arithmetic average as the episode long-term average, the two columns have the same value.

Second, EPA calculated the configuration long-term average as the median of the episode long-term averages from selected episode data sets that contained effluent data from the configuration. The median is the midpoint of the values ordered (ranked) from smallest to largest. If there is an odd number of values (with n = number of values), the value of the (n + 1)/2 ordered observation is the median. If there is an even number of values, the two values of the n/2 and [(n/2)+1] ordered observations are arithmetically averaged to obtain the median value.

For example, for subcategory Y configuration X configuration Z, if the four (n = 4) episode long-term averages are:

| Facility | Episode-Specific Long-Term Average |
|---|---|
| A | 20 mg/L |
| B | 9 mg/L |
| C | 16 mg/L |
| D | 10 mg/L |

the ordered values are:

| Order | Facility | Episode-Specific Long-Term Average |
|---|---|---|
| 1 | A | 9 mg/L |
| 2 | B | 10 mg/L |
| 3 | C | 16 mg/L |
| 4 | D | 20 mg/L |

and the configuration long-term average for configuration Z is the median of the ordered values (the average of the 2nd and 3rd ordered values): (10 + 16)/2 milligrams/liter = 13 milligrams/liter.

Listing 8-3 in Appendix D provides the *calculated* configuration long-term averages. After calculating the configuration long-term averages, EPA compared these values to the nominal quantitation limit of 4 milligrams/liter in EPA Method 160.2 used to measure TSS concentrations in effluent samples (see Appendix B). EPA has determined that some laboratories, under certain conditions, can measure to levels lower than the nominal quantitation limit. EPA has concluded that these results are quantitatively reliable, and therefore can be used to calculate long-term averages and variability factors. However, EPA also recognizes that not all laboratories consistently measure to these lower levels. To ensure the numeric limitations reflected “typical” laboratory reporting levels for approved methods in 40 CFR 136 for NPDES compliance monitoring of TSS discharges, EPA ensured that the configuration long-term averages had values equal to or greater than the nominal quantitation limit of 4 milligrams/liter. For configuration 3B (treated raceway effluent), the calculated configuration long-term average was 2.10 milligrams/liter. Because this value is less than 4 milligrams/liter, EPA substituted the value of 4 milligrams/liter as the configuration long-term average. For all other configurations, the calculated configuration long-term averages were equal to or greater than 4 milligrams/liter. Table 8.5–1 provides final configuration long-term averages that EPA considered in its evaluation of the TSS concentration data.

### 8.5.2 Calculation of Configuration Variability Factors

In developing the configuration variability factors used in calculating the numeric limitations, EPA first developed daily and monthly episode variability factors using the modified delta-lognormal distribution. Listing 8-2 in Appendix D lists the episode variability factors. Appendix E describes the estimation procedure for the episode variability factors using the modified delta-lognormal distribution.

After calculating the episode variability factors, EPA calculated the configuration daily variability factor as the *mean* of the episode daily variability factors for that configuration with the subcategory and option. Likewise, the configuration monthly variability factor was the mean of the episode monthly variability factors for that configuration in the subcategory and option. Listing 8-3 in Appendix D and Table 8.5–1 list the configuration variability factors.

### 8.5.3 Calculation of Numeric Limitations

EPA calculated each *daily maximum limitation* using the product of the configuration long-term average and the configuration daily variability factor. EPA calculated each concentration-based *monthly average limitation* using the product of the configuration long-term average and the configuration monthly variability factor. Table 8.5–1 provides the configuration long-term average, configuration daily variability factor, and the daily maximum limitation for each configuration.

**Table 8.5–1. Configuration Long-Term Averages, Variability Factors, and Numeric Limitations**

| *Subcategory* | *Option* | *Configuration* | *Configuration Long-Term Average (mg/L)* | *Configuration Variability Factors* | | *Limitations (mg/L)* | |
|---|---|---|---|---|---|---|---|
| | | | | *Daily* | *Monthly* | *Daily Maximum* | *Monthly Average* |
| Flow-through | A | 2A (OLSB) | 22.3 | 1.48 | 1.21 | 33.0 | 26.9 |
| | | 3A (Raceway) | 4.00 | -- | -- | -- | -- |
| | | 4A (Combined) | 9.54 | -- | -- | -- | -- |
| | B | 2B (OLSB) | 26.3 | 3.24 | 1.57 | 85.1 | 41.2 |
| | | 3B (Raceway) | 4.00 | 1.99 | 1.27 | 8 | 5 |
| | | 4B (Combined) | 4.17 | 1.06 | 1.02 | 4.44 | 4.26 |
| Combined | A | 2A+6A+7A (Continuous) | 22.3 | 1.48 | 1.21 | 33.0 | 26.9 |
| | B | 2B+6B+7B (Continuous) | 26.3 | 3.24 | 1.57 | 85.1 | 41.2 |

## 8.6 REFERENCES


DynCorp, 2002. *Memorandum: Conversion of Aquaculture Data for Episode 6297, from H. McCarty to C. Simbanin, July 24, 2002*.

SAIC (Science Applications International Corporation, Inc.). 2002a. *Listings for Episode 6297: DMR Data, Summary Statistics, and Estimates*. Reston, VA.

SAIC (Science Applications International Corporation, Inc.). 2002b. *Listing of the Aquatic, Solid, and Combined Filtrate Data for Facility 6297*. Reston, VA.

SAIC (Science Applications International Corporation, Inc.). 2004a. *DCN 55101: All Data: Listing of Influent and Effluent TSS Concentration Data*. Reston, VA.

SAIC (Science Applications International Corporation, Inc.). 2004b. *DCN 55107: Compact Disk with Data from DCN 55101*. Reston, VA.

SAIC (Science Applications International Corporation, Inc.). 2004c. *DCN 55207: Compact Disk with Data from Appendix C of the Technical Development Document*. Reston, VA.

SAIC (Science Applications International Corporation, Inc.). 2004d. *DCN55209: Episode 6460 Concentration values of TSS reported on 8/27/2001*. Reston, VA.

SAIC (Science Applications International Corporation, Inc.). 2004e. *DCN55208: Year 2001 Subset: Comparison of Effluent Data to TSS Daily Maximum Limit in Permit*. Reston, VA.

SAIC (Science Applications International Corporation, Inc.). 2004f. *DCN55206: Year 2001 Subset: Listing of records with CONC=0 for TSS*. Reston, VA.

SAIC (Science Applications International Corporation, Inc.). 2004g. *DCN 55213: Year 2001 Subset: Unaggregated Data for Total Suspended Solids*. Reston, VA.

SAIC (Science Applications International Corporation, Inc.). 2004h. DCN 55214: Year 2001 Subset: Individual Field Duplicate Samples Results for Total Suspended Solids. Reston, VA.

# CHAPTER 9
# COSTING METHODOLOGY

## 9.1 INTRODUCTION

EPA identified several potential regulatory options for the concentrated aquatic animal production (CAAP) industry. This chapter describes the methodology used to estimate engineering compliance costs associated with management practices EPA considered for the final regulatory option.

### 9.1.1 Approach for Estimating Compliance Costs

EPA traditionally develops either *facility-specific* or *model facility* compliance costs and pollutant loading reduction estimates. Facility-specific compliance costs and pollutant loading reduction estimates require detailed process and geographic information about facilities in an industry. These data typically include production, capacity, water use, wastewater generation, waste management operations (including design and cost data), monitoring data, geographic location, financial conditions, and any other industry-specific data that might be required for the analyses. EPA then uses each facility's information to estimate the cost of installing new pollution controls at that facility and the expected pollutant removals from these controls.

For the analyses that support the final regulation, EPA used a facility-specific approach for estimating compliance costs. EPA obtained detailed, facility-level information for a sample of potentially in-scope facilities through the detailed AAP survey (USEPA, 2002a). EPA analyzed the detailed survey information and determined the level of treatment currently in place at each facility (i.e., baseline). For each facility, EPA compared the specifications of the pollutant control technologies and management practices currently in place at the facility to technologies and BMPs that were found to meet the levels of pollutant removals specified for each regulatory option. EPA used data and layout information from the facility as the primary source to estimate the cost of any additional components that were not in place.

EPA developed a series of Microsoft Excel spreadsheets to serve as a computing platform for the cost and loadings analyses. The spreadsheets linked unit costs of the technologies or practices representing each regulatory option with facility attributes to derive a facility-specific cost estimate for compliance. The unit cost modules calculated an estimated cost of each required component based on estimates of capital expenses (which included elements such as engineering design, equipment, installation, one-time costs, and land) and annual operation and maintenance (O&M) expenses. Whenever possible, rate information for these estimates was taken from the facility's response to the detailed survey (e.g., hourly rates for employees). When this information was not provided, EPA used appropriate national or regional averages. For each facility, EPA applied combinations of technologies and BMPs, given the facility configuration characteristics (e.g., system type, size, and species). EPA did not cost for those components or parts of components for which the facility provided evidence that the technology or management practice is in place. EPA multiplied the costs estimates for each facility by its sample weight and then summed the weighted costs to determine estimates for national capital, one-time non-capital, and operation and maintenance costs.

### 9.1.2 Organization of the Cost Chapter

The following costing information is discussed in detail in this chapter:

- *Section 9.2* presents the structure of the cost model. EPA's cost model for the CAAP industry uses information about individual facilities to develop estimates of costs associated with the final regulatory option.
- *Section 9.3* discusses unit costs of BMPs, which include the components of the BMPs that compose the final regulatory option. The unit costs of BMPs contain formulas by which to calculate the costs associated with the final regulatory option based on the facility characteristics.
- *Section 9.4* summarizes the facility configurations, based on analysis of the detailed surveys. EPA's cost model relies on specific information about the species raised, culture system, pollutant inputs, and wastewater generation rates to accurately predict the costs associated with each regulatory option.
- *Section 9.5* discusses the sample weights that EPA used to estimate national costs.
- Section 9.6 summarizes the regulatory options that EPA considered.
- *Section 9.7* provides output data.
- *Section 9.8* describes the evolution and changes EPA made to the costing methodology since proposal.

## 9.2 COST MODEL STRUCTURE

EPA estimated the costs associated with regulatory compliance for each of the regulatory options it considered. The estimated costs of compliance to achieve the requirements being evaluated include initial capital costs, in some cases, as well as annual O&M and monitoring costs. EPA estimated compliance costs based on the lower cost between implementing BMPs or installing, operating, and maintaining control technologies when both have been shown to meet particular requirements.

To generate industry compliance cost estimates associated with each regulatory option for CAAP facilities, EPA developed a computer-based model made up of several individual cost modules. Figure 9.2–1 illustrates the structure of the cost model by showing that it consists of several components, which can be grouped into four major categories:

- Baseline facility configuration

- Unit cost of BMP
- Output data
- Weighting factors

Each module calculates costs and loading data for a specific BMP (e.g., feed management) based on facility characteristics. These weighted facility costs are then summed for each regulatory option and model facility. All costs were calculated in year 2001 dollars and then converted to present value during the economic analysis.

### 9.2.1 Facility Configuration

The facility configuration component of the costs model contains the characteristics of each surveyed facility based primarily on system type, species, annual production, and feed inputs. The facility configuration component also identifies the wastewater treatment and control practices currently in use at the facilities. These data were collected from the detailed survey and, if necessary, validated by contacting the facility.

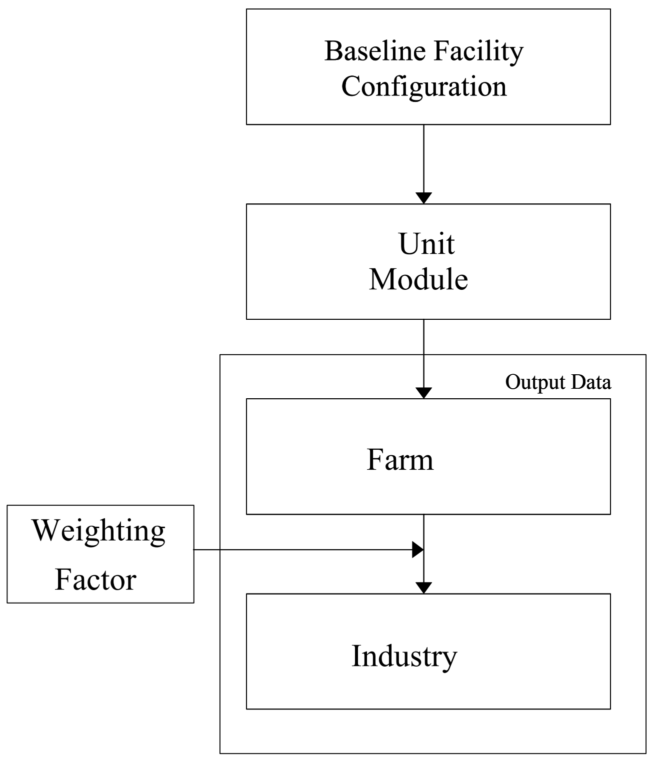



**Figure 9.2–1. Schematic of Cost Model Structure**

Input data to the facility configuration component include the following:

- Ownership
- Species produced
- Production method

- Pollutant control technologies and BMPs in place
- Cost—labor rates, feed, initial and annual cost of in-place technologies, other operation costs
- Average flow (daily) and variation in flow
- Estimates of annual production
- Feed information—annual amount, peak month

### 9.2.2 General Cost Assumptions

Whenever possible, EPA used specific costs supplied by the facility in their detailed survey response. However, when these data were not provided and unavailable for a specific facility, EPA made several general assumptions for the cost analysis approach:

- When the specific cost information was not furnished, EPA estimated state and, if necessary, regional averages from facilities with similar characteristics (e.g., ownership type, species, or system type) as a proxy.
- EPA assumed land costs to be $5,000/acre, which is in the high range of agricultural land.
- EPA applied the land costs as an opportunity cost for a facility when sufficient land was available for the technology system being considered.
- When sufficient land was not available for a particular technology system, EPA substituted technologies that would fit into the existing infrastructure at the particular facility.
- Daily activities are performed 6 days/week (312 days/year).

## 9.3 UNIT COST OF BMPS

A unit cost refers to the direct capital and annual costs for a particular practice. Cost modules calculate the costs for developing and maintaining these practices for a CAAP facility. Each cost module includes appropriate design of the technology based on the characteristics of the model facility and the specific regulatory option.

Estimates of capital, operation, and maintenance costs are based on information collected primarily from the AAP detailed survey. EPA also used data from the USDA 1998 Census of Aquaculture (USDA, 2000b), screener surveys, literature references, technical reports, EPA site and sampling visits, and estimates based on standard engineering methods of cost estimation (Hydromantis, 2001; Metcalf and Eddy, 1991). The following subsections describe each technology or BMP cost module that were considered as part of the regulatory options and specifically discuss the following:

- Description of practice
- Capital costs
- Operation and maintenance costs

### 9.3.1 Best Management Practices

#### *9.3.1.1 Best Management Practices Overall*

All of the options EPA evaluated included a requirement that all CAAP facilities develop BMP plans. The requirements and costs associated with the BMP plans were assumed to be equal for all species and culture systems.

*Description of Technology or Practice*

Evaluating and planning site-specific activities for the development of a facility-wide BMP plan, particularly with components to control the release of solids from CAAP facilities is a practice currently required in several EPA regions as part of individual and general National Pollutant Discharge Elimination System (NPDES) permits (e.g., shrimp pond facilities in Texas, net pens in Maine, and flow-through facilities in Washington and Idaho). BMP plans in these permits require the facility operators to develop a management plan for preventing excess feed from entering the system and removing solids from the effluent. The BMP plan also ensures planning for proper O&M of equipment, especially treatment control technologies. Implementation of the BMP plan results in a series of pollution prevention activities, such as ensuring that employees do not waste feed and planning for the implementation of other O&M activities, which are costed under each technology control or BMP.

In addition to providing an individualized overall strategy for CAAP facility operations to control the release of solids, BMP plans can be used at CAAP facilities to ensure that

- Facilities do not discharge spilled drugs or pesticides.
- Facilities do not release drugs or pesticides that are not used in compliance with FDA and FIFRA requirements.
- Facilities maintain the structural integrity of aquatic animal containment systems.

*Capital Costs: All System Types*

The capital costs for the BMP plan are based on the amount of managerial time required to develop a plan. The following components could be included in the plan:

- Operational components to prevent the discharge of blood, viscera, or transport water.
- Operational components to prevent the discharge of solid waste (e.g., feed bags, collected solids, culture unit cleaning solids, or mortalities).
- Operational components such as a description of pollution control equipment, feeding methods, preventative maintenance, and the layout and design of the facility.
- Description of critical structural integrity components that, if a failure occurs, would lead to the loss of the cultured animals, collected solids, or drug and pesticide storage systems.
- Description of cleaning of culture tanks/raceways and other equipment including how accumulated solids are removed and methods of disposal.

- Description of training for facility personnel to assure they understand the goals and objectives of BMPs and their role in complying with the goals and objectives of the BMP plan.
- Description of records maintenance for feed records, water quality monitoring, and final disposition of collected solids.
- The BMP plan should also include a statement that the plan has been reviewed and endorsed by the facility manager and the individuals responsible for the implementation of the plan (i.e., plan certification).

EPA Regional personnel and CAAP industry representatives (Fromm and Hill, 2002; MacMillan, 2002, personal communication) indicated that development of a BMP plan would take from about 4 hours for smaller facilities to at least 40 hours for larger facilities. EPA has assumed that about 40 hours would be required to develop a BMP plan. EPA assumed that the plan would be developed by the facility manager and would be revised or updated as needed or at least every 5 years upon permit renewal. The cost equation for plan development was as follows:

BMP plan costs = 40 hours * managerial labor rate

where BMP plan costs are in dollars and the managerial labor rate is the rate reported by the individual facility.

*Operation and Maintenance Costs: All System Types*

The O&M costs associated with the BMP plan included annual plan review of 4 hours each for the farm managers and general labor employees. EPA used the following formula to calculate costs associated with this monthly plan review:

BMP O&M costs = [(4 * general labor rate * No. of employees) + (4 * managerial labor rate * No. of managerial employees)]

where O&M costs are in dollars, the general and the managerial labor rates were the rates reported by the individual facility. Other implementation costs are included in the cost of specific unit technologies, such as the costs associated with maintaining quiescent zones.

Table 9.3–1 provides a summary of BMP plan development and annual O&M costs.

## Table 9.3–1. Estimated Costs for BMP Plan Development

| *Assumptions Used in Costing Labor Cost Elements—General Labor* | *Description* | *LOE* | *Cost Estimate* | *Reference* |
|---|---|---|---|---|
| BMP Plan Review—All facility staff to review the facility's BMP Plan at beginning of employment and at least annually thereafter. | BMP Plan Review—All facility staff to review the facility's BMP Plan at beginning of employment and at least annually thereafter. | Initial Plan review—4 hours | 4 hours * pay rate | Tetra Tech estimate based on observations at site visits and sampling events |
| | | Annual plan review—4 hours | 4 hours * pay rate | Tetra Tech estimate based on observations at site visits and sampling events |
| Labor Cost Elements —Managerial Labor | | | | |
| Facility Wide Best Management Practices (BMP) Plan Development—Facility management develop and maintain a facility wide BMP Plan that includes at minimum the following components:<br>Identification of all waste and wastewater streams within the facility<br>Identification of all wastewater and manure treatment/storage areas within the facility<br>Identification and standard operating procedures (SOPs) for all BMPs employed with the facility<br>Identification of managerial staff and their areas of responsibility | Facility Wide Best Management Practices (BMP) Plan Development—Facility management develop and maintain a facility wide BMP Plan. | Initial plan development—40 hours | 40 hours * facility management pay rate | R. McMillan, 2/22/03, Personal Communication |
| | BMP Plan Review—Facility management review the BMP Plan for updating at least annually. | Annual plan review—4 hours | 4 hours * facility management pay rate | |
| | Annual compliance check—8 hours/facility | Annual compliance check—8 hours/facility/year | 8 hours * facility management pay rate * once/year | |

### 9.3.2 Feed Management

Feed management is a management practice that was considered as part of Option 1 for all net pen operations and Option B for flow-through and recirculating systems.

#### *9.3.2.1 Description of Technology or Practice*

Feed management recognizes the importance of effective, environmentally sound use of feed. System operators should continually evaluate their feeding practices to ensure that feed placed in the production system is consumed at the highest rate possible. Observing feeding behavior and noting the presence of excess feed can be used to adjust feeding rates to ensure minimal excess (USEPA, 2002b).

An advantage of this practice is that proper feed management decreases the costs associated with the use of excess feed that is never consumed by the cultured species. Excess feed distributed to culture systems breaks down, and some of the resulting products remain dissolved in the receiving water. More important, solids from the excess feed usually settle and are naturally processed along with feces from the aquatic animals. In net pen systems, excess feed and feces accumulate under net pens, and if there is inadequate flushing this accumulation can overwhelm the natural benthic processes, resulting in increased benthic degradation.

The primary operational factors associated with proper feed management are development of precise feeding regimes based on the weight of the cultured species and constant observation of feeding activities to ensure that the feed offered is consumed. Other feed management practices include use of high-quality feeds, proper storage and handling (which includes keeping feed in cool, dry places; protecting feed from rodents and mold conditions; handling feed gently to prevent breakage of the pellets), and feeding pellets of proper size. Feed management is a practice required in net pen facility permits issued by EPA Regions 1 and 10 (USEPA, 2002b; USEPA, 2002c) and for flow-through and recirculating systems in Idaho and Washington.

#### *9.3.2.2 Capital Costs*

Because feed management does not require any capital improvements or additions to implement the practice, EPA assumed that no capital costs would be associated with the implementation of feed management.

#### *9.3.2.3 Operation and Maintenance Costs*

Observing feeding and keeping records to improve the estimation of delivering the right amounts of feed helps system operators to minimize wasted feed and adjust feeding rates as necessary. EPA estimated that implementing a feed management program at a facility would be site-specific, but would require the implementation of observation, record-keeping, and data review activities. The extra time required would be used to observe feeding behavior and perform additional record-keeping (amount of feed added to each rearing unit, along with records tracking the number and size of fish in the rearing unit). The record-keeping duties are documented by filling in a logbook. EPA assumed that observations of feeding behavior and equipment could be accomplished by observing feeding once per day, 312 days/year, based on information collected during site visits

(Tetra Tech, 2002a; Tetra Tech, 2002b). EPA assumed that the feed management (observing feeding behavior and record-keeping) would be performed by the person feeding and thus included labor costs for a general laborer. EPA also assumed that the farm manager already estimates the amount of feed needed for each daily feeding and performs other management duties related to feeding. EPA assumed that one key component of feed management would be for facilities to keep written records to document that the person feeding actually carries out the prescribed daily plan. Table 9.3–2 provides a summary of the labor costs elements and methods used to estimate the costs associated with feed management.

## Table 9.3–2. Estimated Costs for Feed Management

| *Assumptions Used in Costing Labor Cost Elements—General Labor* | *Description* | *LOE* | *Cost Estimate* | *Reference* |
|---|---|---|---|---|
| Initial Feed Measurements—Measure and record feed amounts to be distributed before being loaded into the distribution system. Facilities that feed by hand measure and record the amount of the feed to be distributed to each production area. | Hand Feeding Measurements and Records—Personnel measure feed for each production area before distribution. Feed from different production areas not be mixed prior to distribution. | Measurement and recording of feed—2 minutes/rearing unit/day | No. of rearing units * 2 minutes * general labor rate * 7 days/week * No. of active weeks | Tetra Tech estimate based on best professional judgment |
| Feeder Inspection—Visually inspect automatic and demand feeders weekly. Observe automated feeding systems during discharge to ensure proper operation. | Mechanical Inspection of Feeders—Facility personnel inspect all moving parts for proper function and normal wear. | Mechanical inspection of automated feeders —5 minutes/feeder/day | No. of Feeders * 5 minutes * general labor rate * 7 days/week * No. of active weeks | Tetra Tech estimate based on best professional judgment |
| | Visual Inspection of Feeding Operations—Facility observe each feeder in operation to ensure the feed is distributed when required, over the intended surface, and stop when required. | Observation of feeding activities (feeder operation 30 seconds, feeding observation 3 minutes, note taking 1.5 minutes)—5 minutes/production unit/day | No. of production units * 5 minutes * general labor rate * No. of active weeks | Tetra Tech estimate based on best professional judgment |
| | Feeder Repairs—Repair of any feeder that shows signs of malfunctioning as soon as feasible. | Facility specific | | |
| Feeder Calibration—Automated feeding systems calibrated prior to installation and then at least monthly to ensure accurate discharges of feed to the production system. | Initial Calibration—Upon installation, calibrate each feeder to ensure the proper volume or mass of feed is distributed with each operation. | Feeder specific | | |
| | Ongoing Calibration—Check the calibration on each feeder at least once/month or each time the feed size is changed. | Feeder specific | | |

| *Assumptions Used in Costing Labor Cost Elements—General Labor* | *Description* | *LOE* | *Cost Estimate* | *Reference* |
|---|---|---|---|---|
| Inventory Record-keeping—Staff keep detailed notes on the following information:<br>- Estimated number of cultured species<br>- Estimated biomass<br>- Production unit sampled<br><br>Inventory information entered in the facility's master records. This may be either a computer database system or hardcopy records | Record-keeping Activities—Inventory information calculated based on data collected in the field. Records at minimum include the estimated number of cultured species, estimated biomass, and date production unit sampled. | Staff record-keeping activities—10 minutes/rearing unit/week in use. | No. of units in use * 10 minutes * general labor rate * 0.5 * No. of consultations | Tetra Tech estimate based on best professional judgment |
| Feeding Observation—Facilities using automated feeding systems observe feeding in each production unit at least once/day and note any uneaten feed.<br><br>Staff observe feeding until all feed has been consumed or five minutes after feeding has ceased. | Automated Feeding Observations & Record-keeping—Facility personnel observe each automated feeder in operation once/day. Record-keeping at minimum includes information on feeder operation and feeding activity. | Observation of feeding activities (feeder operation 30 seconds, feeding observation 3 minutes, note taking 1.5 minutes)—5 minutes/production unit/day | No. of production units * 5 minutes * general labor rate * 7 days/week * No. of active weeks | Tetra Tech estimate based on best professional judgment |
| | Hand Feeding Observations & Record-keeping—Observe feeding unit until all feed has been eaten or five minutes after feeding ceases. Record observation. Record-keeping at minimum includes information on feeder operation and feeding activity. | Observation of feeding activities (feed distribution 30 seconds, feeding observation 3 minutes, note taking 1.5 minutes)—5 minutes/production unit/day | No. of production units * 5 minutes * general labor rate * 7 days/week * No. of active weeks | Tetra Tech estimate based on best professional judgment |

| ***Assumptions Used in Costing Labor Cost Elements—General Labor*** | ***Description*** | ***LOE*** | ***Cost Estimate*** | ***Reference*** |
|---|---|---|---|---|
| Feeding Record-keeping—Staff keep detailed notes on the following information:<br>- Amount of feed distributed<br>- Feeding time<br>- Feeding activity | Daily Record-keeping Activities—Record the daily feeding information in the field during feeding. Records at minimum include the amount of feed distributed, feed type, feeding time, and feeding activity. | **Note:** Should be completed during the field activities, no additional time required | | Tetra Tech estimate based on best professional judgment |
| At the end of each day, record feed information collected during the day in the facility's master records. This may be either a computer database system or hardcopy records. | Data Entry QC—Staff check at least 5% of the data entries to ensure the correct information has been entered. | Facility specific | | |
| Weekly Biomass Measurements—Staff conduct biomass measurements at least once/week. Samples are random and contain at least 10 samples to be weighed and measured. | Collection and Examination—Facility staff randomly collect samples from each production area to weigh and measure. The specimens are kept alive while waiting for examination so they can be returned to the production area. Facility staff record at minimum, the date and time of sampling, the production area sampled, number of specimens collected, and the length and weight of each specimen. | Collection and examination of samples—30 minutes/production unit<br>(sample collection setup—5 minutes, sample collection 3 minutes, sample examination 1 minute/sample, field note taking 10 minutes) | No. of production units * 30 minutes * general labor rate | Tetra Tech estimate based on best professional judgment |

| ***Assumptions Used in Costing Labor Cost Elements—General Labor*** | ***Description*** | ***LOE*** | ***Cost Estimate*** | ***Reference*** |
|---|---|---|---|---|
| Daily Water Quality Measurements—Water quality measurements collected each day to determine changes in culture water characteristics. Analytes include at minimum:<br>- Dissolved oxygen (DO)<br>- Temperature<br>- pH<br>- Ammonia | Daily Water Quality Measurements—Water quality measurements taken at points deemed appropriate by the facility manager. At minimum, water quality parameters measured where the water first enters the facility. | Water quality sampling and record-keeping—5 minutes/day. | 5 minutes/day * general labor rate * 7 days/week * No. of active weeks | Tetra Tech estimate based on best professional judgment |
| | Equipment Calibration—Facility staff record at minimum, date and time of sampling, the source sampled, and the result of each measurement. Calibrate all sampling equipment/the manufacturer's specifications. Note the results of these calibrations in a calibration log maintained for each piece of equipment. | Equipment calibration, and record-keeping—5 minutes/day. | 5 minutes/day * general labor rate 7 days/week * No. of active weeks | Tetra Tech estimate based on best professional judgment |

| *Assumptions Used For Costing Labor Cost Elements—Managerial Labor* | *Description* | *LOE* | *Cost Estimate* | *Reference* |
|---|---|---|---|---|
| Daily Feeding and Water Quality Data Review—Managers at least weekly review all feed and water quality data for the facility. | Weekly Data Review—Facility management review at least weekly the results of all feeding and water quality measurements. Additional review may be needed during significant weather events or disease outbreaks within the facility. | Weekly information review—0.25 hours/week | 0.25 hours * managerial labor rate * No. of active weeks | Tetra Tech estimate based on best professional judgment |
| | Staff Consultation—Facility management consult with staff as necessary to update feeding regimes and discuss water quality issues. | Staff consultation information—0.25 hours/consultation/week | 0.25 hours * managerial labor rate * No. of active weeks | Tetra Tech estimate based on best professional judgment |
| Weekly Biomass and Health Inspection Data Review—Managers review all weekly biomass and health inspection reports for problems. | Weekly Data Review—Facility management review at least biweekly the results of all biomass and health inspection data. Additional review may be needed during disease outbreaks within the facility. | Weekly information review—0.25 hours/week | 0.25 hours * managerial labor rate * No. of active weeks | Tetra Tech estimate based on best professional judgment |
| Feeding Regime Changes—Based upon the review of biomass and health inspections, changes to the upcoming feeding regimes can be made to obtain more efficient feeding results and insure the optimal health of the cultured species. | Feeding Regime Changes—Facility management modify the feeding regime as necessary to ensure optimal health of the cultured species. | Feeding regime changes—0.25 hours/change | 0.25 hours * managerial labor rate * No. of active weeks | Tetra Tech estimate based on best professional judgment |

### 9.3.3 Drug, Pesticide, and Feed Materials Spill Prevention Training and INAD and Extralabel Reporting

Drug, pesticide, and feed spill prevention training and INAD and extralabel reporting requirements were considered for all systems that reported using drugs or pesticides in the detailed survey. EPA assumed all requirements and costs associated with the drug and pesticide spill prevention training and INAD and extralabel reporting requirements to be equal for all species and culture systems.

*Materials Storage*

To address materials storage, facilities must ensure proper storage of drugs, pesticides, and feed in a manner designed to prevent spills that may result in the discharge of drugs, pesticides, or feed to waters of the United States. In the event that a spill of drugs, pesticides, or feed occurs that results in a discharge to waters of the United States, the owner or operator will provide an oral report of this to the permitting authority within 24 hours of its occurrence and a written report within 7 days. The report will include the identity of the material spilled and an estimated amount. Facilities must also implement procedures for properly containing, cleaning, and disposing of any spilled material. Many facilities may already have implemented practices that address these requirements.

*Discharge of INAD and Extralabel Drug Discharges*

Facilities that discharge drugs or pesticides that are used under the FDA INAD program or as a prescription from a licensed veterinarian may be discharging drugs or pesticides that have not been thoroughly reviewed for environmental impacts. This reporting alerts permitting authorities of discharges.

EPA does not anticipate that facilities will incur significant cost for this requirement. Facilities that use drugs as part of an INAD development are required to keep records that include information such as:

- Diagnosis
- Number of animals tested
- Route of administration
- Amount of drug used
- Number of treatments
- Other information specified in the experimental protocols

#### *9.3.3.1 Description of Technology or Practice*

The primary purpose of the drug, pesticide, and feed spill prevention training is to prevent the accidental discharge of drugs, pesticides, and feed used at CAAP facilities. The training should focus on practices used by facility staff to prevent spillage or other inadvertent releases of drugs, pesticides, and feed. The facility should document staff training. The INAD and extralabel drug reporting requirements allow the state to easily monitor the use of these drugs by facilities located within their boundaries.

### *9.3.3.2 Capital Costs*

The capital costs for the drug, pesticide, and feed spill prevention training and INAD and extralabel drug reporting requirements include the managerial time to become familiar with the requirements and to develop a training program for all staff on the applicable procedures at their facility.

EPA also computed costs for containment systems for liquid storage of drugs and pesticides, including 55-gallon drug storage and smaller containers. When costing these structures, EPA assumed the following:

- Liquid used in quantities of 55 gallons or greater are assumed to be stored in 55-gallon drums.
- Facilities using more than six 55-gallon drums per year were assumed to have drugs and pesticides delivered more than once per year, and therefore do not require storing more than three pairs of drums at a time.
- Facilities using pesticides in smaller amounts than 55-gallon drums were evaluated for containment storage using pesticide storage cabinets.

The storage-spill prevention system that was evaluated stores drums in a single unit or in pairs, up to three pairs high. For facilities that reported using less than 55 gallons, a smaller containment system was costed.

For facilities requiring storage of small amounts of pesticides, EPA costed facilities for pesticide storage using 12-, 30-, and 45-gallon pesticide cabinets.

### *9.3.3.3 Operation and Maintenance Costs*

The O&M costs for the drug and pesticide spill prevention training and INAD and extralabel reporting include managerial and general labor for annual training and reporting.

Details that explain the costing of the drug and pesticide spill prevention and reporting are presented in Table 9.3–3.

**Table 9.3–3. Drug and Pesticide Spill Prevention Training and INAD Reporting**

| ***Assumptions Used in Costing Labor Cost Elements—General Labor*** | ***Description*** | ***LOE*** | ***Cost Estimate*** | ***Reference*** |
|---|---|---|---|---|
| Drug and Pesticide Spill Prevention—The purpose of this training is to insure the proper use and storage of specific drugs and pesticides in the production facility. The training also addresses practices to minimize the accidental spillage or release of drugs or pesticides. | Staff Training—All facility staff attend training sessions lead by facility management as necessary to insure the proper use and storage of specific drugs and pesticides in the production facility. | Annual training—4 hours | Number of employees * 4 hours * general labor rate | Tetra Tech estimate based on best professional judgment |
| ***Assumptions Used in Costing Labor Cost Elements—Managerial Labor*** | ***Description*** | ***LOE*** | ***Cost Estimate*** | ***Reference*** |
| Drug and Pesticide Spill Prevention—The purpose of this training is to insure the proper use and storage of specific drugs and pesticides in the production facility. The training also addresses practices to minimize the accidental spillage or release of drugs or pesticides. | Management Training—Facility management develop a training program to be attended by facility staff as necessary to insure the proper use and storage of specific drugs and pesticides in the production facility. | Plan development—8 hours | 8 hours * managerial labor rate | Tetra Tech estimate based on best professional judgment |
| | Staff Training—Facility management lead training sessions attended by facility staff as necessary to insure the proper use and storage of specific drugs and pesticides in the production facility. | Annual training—4 hours | 4 hours * managerial labor rate | Tetra Tech estimate based on best professional judgment |
| INADs and Extralabel Requirements—Facility specific usage. | Facility management review and report the application to the appropriate agency as soon as possible after application. | Oral report—20 minutes | 20 minutes * managerial labor rate * No. of uses/year | Tetra Tech estimate based on best professional judgment |
| | Facility management file a written report of the application to the appropriate agency as soon as possible after application. | Written report—1 hour | 1 hour * managerial labor rate * No. of uses/year | Tetra Tech estimate based on best professional judgment |

### 9.3.4 Maintaining Structural Integrity

Maintaining structural integrity is applicable for all systems. Estimated costs for maintaining structural integrity can be found in Table 9.3–4.

#### *9.3.4.1 Description of Technology or Practice*

Practices to inspect the structural integrity of the critical components of the facility physical plant prevent the failure of the structure, resulting in the accidental or catastrophic release of pollutants from a CAAP facility. These critical components include culture system components (e.g., culture units, drains, nets, predator controls, settling basins, and biosolids storage areas), water supply conveyances, and wastewater treatment technologies. Facility personnel should evaluate systems to identify the critical components that require routine inspection.

#### *9.3.4.2 Capital Costs*

EPA estimates that practices to maintain structural integrity will not require any additional capital costs. EPA included costs for the identification of the critical components in the overall BMP plan development activities.

#### *9.3.4.3 Operation and Maintenance Costs*

For the purposes of estimating costs, EPA assumed the O&M costs to maintain the structural integrity practices include managerial and staff labor for routine inspections of the following critical components:

- Visual checks of each production unit
- Reporting failure of the structural integrity

## Table 9.3–4. Estimated Costs for Maintaining Structural Integrity

| ***Assumptions Used in Costing Labor Cost Elements—General Labor*** | ***Description*** | ***LOE*** | ***Cost Estimate*** | ***Reference*** |
|---|---|---|---|---|
| Maintenance of Structural Integrity—Staff inspect and document routine assessments of the structural integrity of the production systems. | Production Unit Inspection—Facility staff inspect each production unit weekly to ensure the integrity. | Visual checks of each unit—5 minutes/unit/week | No of production units * 5 minutes * general labor rate * 52 days/year | Tetra Tech estimate based on best professional judgment |
| ***Assumptions Used in Costing Labor Cost Elements—Managerial Labor*** | ***Description*** | ***LOE*** | ***Cost Estimate*** | ***Reference*** |
| Maintenance of Structural Integrity—Facility manager maintains oversight over all inspections of production units and other critical components to insure their integrity and insure the facility's compliance with any rules or regulations. | Failure Reporting—Facility management submit oral and written reports to the appropriate agency as soon as possible after the failure. | Oral Report—20 minutes once/year | 20 minutes * managerial labor rate * 1 report/year | Tetra Tech estimate based on best professional judgment |
| | | Written Report—1 hour once/year | 1 hour * managerial labor rate * 1 report/year | Tetra Tech estimate based on best professional judgment |

## 9.4 Facility Configurations

EPA defined individual facility characteristics based on information supplied in the detailed survey. Table 9.4–1 provides a summary of the facility counts for those facilities that responded to the detailed survey. This summary groups similar facilities by system type, production level, species, and ownership.

**Table 9.4–1. Facility Groupings by System-Ownership-Species**

**Flow-through Systems**

| Production | Species | Owner | Number of Facilities |
|---|---|---|---|
| >100,000 | Salmon | Commercial & Non-commercial | 13 |
| >100,000 | Striped Bass-Tilapia-Catfish-Other | Commercial & Non-commercial | 10 |
| >100,000 | Trout | Commercial | 13 |
| >100,000 | Trout | Non-commercial | 28 |
| | | Total | 64 |

**Recirculating Systems**

| Production | Species | Owner | Number of Facilities |
|---|---|---|---|
| >100,000 | Striped Bass-Salmon-Shrimp-Tilapia-Other | Commercial & Non-commercial | 7 |
| | | Total | 7 |

**Net Pen Systems**

| Production | Species | Owner | Number of Facilities |
|---|---|---|---|
| >100,000 | Salmon-Trout | Commercial | 8 |
| | | Total | 8 |

## 9.5 Sample Weighting Factors

In August 2001, EPA mailed approximately 6,000 screener surveys to aquatic animal production facilities. EPA received responses from 4,900 facilities, of which about 2,300 facilities reported that they produce aquatic animals. EPA based its proposed regulations on the data collected from the screener questionnaire.

Consistent with EPA's intentions described in the preamble to the proposed rule, EPA based its analyses for the final rule on data collected from the detailed questionnaire. The preamble described the detailed questionnaire (Hochheimer, 2003) and EPA's plans to recalculate estimates for costs and benefits associated with the proposed regulatory options. EPA reviewed the responses from the detailed questionnaire, performed follow-up activities on the detailed questionnaires resulting from inconsistencies or questions from an initial review of responses, and completed analyses of the data contained in these responses.

EPA used the screener responses to select a stratified random sample to receive the detailed questionnaire. Sample criteria were designed to primarily capture facilities that produce aquatic animals and are likely to be covered by the proposed rule. EPA also developed sample criteria to capture facilities that are out of scope (based on information in the screener survey) to validate its assumptions about the applicability of the proposed regulation. For example, the sample criteria includes facilities with ponds, which are out of scope in the proposed regulation, to confirm that additional regulations for ponds are unnecessary. The Technical Development Document (TDD), page A11, describes in detail the criteria and includes facilities that are in-scope and out of scope. The facilities selected met one of these criteria:

- Aquariums.
- Production includes alligators and total biomass exceeds 100,000 pounds.
- Production includes trout or salmon and total biomass exceeds 20,000 pounds.
- Predominant production method is ponds; predominant species is catfish; and total biomass exceeds 2,200,000 pounds.
- Predominant production method is ponds; predominant species is shrimp, tilapia, other finfish, or hybrid striped bass; and total biomass exceeds 360,000 pounds.
- Predominant production method is any method except ponds, and total biomass exceeds 100,000 pounds.

Applying these criteria resulted in 539 facilities from the screener questionnaire responses with these characteristics. EPA then classified the 539 facilities into 44 groups defined by facility type (commercial, government, research, or tribal), the predominant species, and predominant production. A sample was drawn from the 539 facilities ensuring sufficient representation of facilities in each of the 44 groups. The sample drawn consisted of 263 facilities. From these 263 facilities EPA excluded 11 facilities that were duplicates on the mailing list or, after revising production estimates, did not meet the production thresholds for a CAAP facility. Detailed questionnaires were finally sent to 252 facilities.

EPA received responses on 215 of the 252 questionnaires. A few responses contained information on more than one facility. Subsequently, EPA separated that information into several questionnaires so that a single questionnaire represented an individual facility. EPA also excluded data from 12 facilities that returned incomplete responses. Because these facilities would not have been subject to the proposed limitations, EPA did not ask for more information. After separating multiple responses and excluding incomplete responses, information is available from 205 facilities.

Because EPA selected the 205 facilities using a statistical design (see Appendix A of the Technical Development Document for more information), the responses allowed EPA to build a database to be used for estimating population characteristics reflecting the above criteria. For national (i.e., population) estimates, EPA applied survey weights to the facility responses that incorporate the statistical probability of a particular facility being selected to receive the detailed questionnaire and adjust for non-responses. (The response rate was about 80% for the detailed questionnaire. Appendix A of the proposed Technical Development Document addresses the nonresponse adjustments for the screener questionnaire.) In this case, a survey weight of 3 means that the facility represents itself and two others in the population.

## 9.6 REGULATORY OPTIONS CONSIDERED

For the final regulation, EPA decided to subject flow-through and recirculating systems to the same requirements and so included them in the same subcategory. EPA did not change the regulatory requirements for net pen systems. However, EPA considered two additional regulatory options for CAAP facilities:

- Option A—solids removal through treatment technologies and BMPs, facility BMP plan, BMP components to maintain the structural integrity of the aquatic animal containment system, and practices for minimizing the discharge of drugs and pesticides.
- Option B—additional solids removal through treatment technologies or feed management BMPs.

Table 9.6–1 illustrates the treatment technologies and BMPs for each proposed option by subcategory. All three options were evaluated for Best Practicable Control Technology Currently Available (BPT)/Best Available Technology Economically Achievable (BAT) regulatory options.

**Table 9.6–1. Treatment Technology and BMP Components of the Regulatory Options Evaluated**

<table>
<tr><th colspan="2" rowspan="2">Regulatory Option</th><th rowspan="2">Required BMPs and Technologies</th><th>Subcategory</th></tr>
<tr><th>Flow-through and Recirculating</th></tr>
<tr><td rowspan="6">Option B</td><td rowspan="5">Option A</td><td>Primary solids settling</td><td>X</td></tr>
<tr><td>BMP plan</td><td>X</td></tr>
<tr><td>Drug and pesticide BMP plan</td><td>X</td></tr>
<tr><td>Maintenance for the structural integrity of the containment system</td><td>X</td></tr>
<tr><td>Active feed monitoring</td><td></td></tr>
<tr><td></td><td>Solids polishing and compliance monitoring OR feed management plan</td><td>X</td></tr>
</table>

Note: "X" represents a required treatment technology or BMP component for an option.

EPA would allow facilities alternate compliance provisions for meeting the solids removal requirements for flow-through and recirculating. The first alternative requires specific numeric TSS limits (Table 9.6–2). These limits were determined for different discharge scenarios and levels of treatment options. The cost analysis included weekly monitoring and monthly reporting to show that a facility is meeting the requirements (see Section 9.4 for more details on the cost assumptions) for monitoring and reporting. The second alternative allows facilities to develop and implement a BMP plan that will achieve the numeric limits. The BMP plan and its implementation would then be used as the measure of compliance, in lieu of the weekly monitoring and monthly reporting. EPA believes that the alternate BMP plan approach could cost less than the monitoring and reporting approach. EPA does not believe that the BMP compliance alternative will cost any more than the estimated costs associated with the technology options described in this report. EPA performed additional cost analyses for the BMP plan alternative.

**Table 9.6–2. Summary of TSS Numeric Limits for Flow-through and Recirculating Systems**

| *System/Discharge Type* | *Maximum Daily (mg/L)* | *Maximum Monthly Average (mg/L)* |
|---|---|---|
| Flow-through; full flow and single discharge | 10 | 6 |
| Flow-through; offline settling, separate discharge | 69 | 55 |
| Recirculating; more than 100,000 pounds annual production | 50 | 30 |

## 9.7 RESULTS OF COST ANALYSIS

**Table 9.7–1. Summary of Cost Analysis by System-Ownership-Species Group**

**Flow-through Systems**

| *Production* | *Species* | *Owner* | *Number of Facilities* | *Land* | *Capital* | *One time Non-capital* | *Annual O&M* |
|---|---|---|---|---|---|---|---|
| >100,000 | Salmon | Commercial & Non-commercial | 15 | $ - | $6,760.62 | $9,982.60 | $57,402.49 |
| >100,000 | Striped Bass-Tilapia-Catfish-Other | Commercial & Non-commercial | 45 | $ - | $24,476.88 | $59,269.99 | $298,735.93 |
| >100,000 | Trout | Commercial | 52 | $ - | $16,278.87 | $34,031.19 | $227,039.89 |
| >100,000 | Trout | Non-commercial | 96 | $ - | $68,828.55 | $99,413.88 | $760,510.82 |

**Recirculating Systems**

| *Production* | *Species* | *Owner* | *Number of Facilities* | *Land* | *Capital* | *One time Non-capital* | *Annual O&M* |
|---|---|---|---|---|---|---|---|
| >100,000 | Striped Bass-Salmon-Shrimp-Tilapia-Other | Commercial & Non-commercial | 14 | $ - | $22,578.03 | $8,946.82 | $541,73.47 |

**Net Pen Systems**

| *Production* | *Species* | *Owner* | *Number of Facilities* | *Land* | *Capital* | *One time Non-capital* | *Annual O&M* |
|---|---|---|---|---|---|---|---|
| >100,000 | Salmon-Trout | Commercial | 19 | $ - | $ - | $4,080.85 | $69,799.02 |

## 9.8 CHANGES TO COSTING METHODOLOGY

### 9.8.1 Background

While the proposed regulatory options were under development, EPA performed several analyses and reviews to evaluate the options, including sharing drafts with stakeholders, small entity representatives (SERs), and technical experts. As specific elements of the proposed options were defined, EPA researched technical literature and studies and contacted technical experts to better quantify the compliance costs and the pollutant load removal efficiencies of the options. Throughout the option development process, EPA continued to modify the options to reflect new information as it became available. EPA developed and presented (to the Small Business Regulatory Enforcement Fairness Act (SBREFA) panel) a range of control technology and BMP options and estimated their compliance costs as part of the small business panel process.

EPA considered several technology options in its initial analysis. Some of these options resulted in a high cost in relation to revenues, and therefore EPA did not pursue those technologies further. For example, one option EPA considered, but did not pursue, was disinfection. EPA considered disinfection as an option to control pathogens present in effluents from solids collection and storage units at CAAP facilities, which might adversely affect human health. The economic impact of the estimated costs for disinfection was found to be high in proportion to revenues.

EPA performed several analyses, including economic and technical analyses, to evaluate the impacts of the proposed regulation on various sectors of the CAAP industry. As a result of the economic analyses, consultation with industry experts, and the deliberation of the Small Business Advisory Review Panel, production of aquatic animals in pond systems, lobster pounds, and aquariums, as well as the production of crawfish, molluscan shellfish in open waters, and alligators were no longer considered within the scope of the proposed regulation.

### 9.8.2 Modifications to Model Facility Methodology

EPA developed model facilities to reflect CAAP facilities with a specific production system, type of ownership, and often species. These model facilities were based on data gathered during site visits, information provided by industry members and their associations, and other publicly available information. EPA estimated the number of facilities represented by each model using data from the AAP screener survey (Westat, 2002), in conjunction with information from the USDA 1998 Census of Aquaculture (USDA, 2000b). EPA estimated costs for each model facility and then calculated industry-level costs by multiplying model facility costs by the estimated number of facilities required to implement the treatment technology or management practice in each model category.

Initially, EPA developed the production rate thresholds based on data from the 1998 Census of Aquaculture (USDA, 2000b). Instead of assuming one model facility for each of the three proposed subcategories, EPA used a minimum of six model facilities for each facility type in terms of ownership (e.g., commercial, government, research, tribal) and species size combination (e.g., fingerlings, stockers, food-size, trout, salmon, other) for better accuracy in its analyses. EPA applied these facility classifications to the screener survey data to derive the model facility characteristics that were used to support the proposed regulation. Final cost estimations for the proposed options are based on screener survey data. Commercial facilities are adjusted by a scaling factor, which is the ratio of commercial facilities in the 1998 Census of Aquaculture to the number of commercial facilities responding to the AAP screener survey.

Several SERs (Engle, 2002; Hart, 2002; Pierce, 2002; Vaught, 2002) questioned the ability of a model facility to capture the diversity of production sizes and operational differences among AAP facilities. EPA recognizes the diversity in the AAP industry; however, the Agency does not have site-specific data on each AAP facility. EPA used the best available data to make its estimates for the cost models, including AAP screener survey results, USDA Census of Aquaculture data, and technical input from producers and industry leaders. These data sources will be supplemented with the results of EPA's detailed survey in the final rule.

### 9.8.3 Net Pen Systems

Net pen systems are unique because their placement directly in the receiving water allows little opportunity for the treatment of effluents. Initially EPA targeted management practices that reduce feed inputs and uneaten feed in the development of options for net pen systems. After consulting with industry representatives and evaluating AAP screener survey data and existing NPDES permits, EPA found some net pen facilities currently using feed management practices. Thus, EPA determined the estimated cost of implementing feed management to be affordable.

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# CHAPTER 10
# POLLUTANT LOADING METHODOLOGY

## 10.1 INTRODUCTION

EPA identified several potential regulatory options for the concentrated aquatic animal production (CAAP) industry. To develop and evaluate these options, EPA used a computer spreadsheet model that estimates compliance costs and pollutant loadings for different combinations of the technologies and practices included in the regulatory options considered. Chapter 9 presents the costing methodology. This chapter describes the methodology used to estimate the pollutant loading reductions associated with installing and operating the pollutant control technologies and best management practices (BMPs) considered for the regulatory options.

### 10.1.1 Approach for Estimating Loadings

Consistent with EPA's intentions described in the preamble to the proposed rule, EPA based its analyses for the final rule on data collected from the detailed questionnaire. The preamble described the detailed questionnaire (Hochheimer, 2003) and EPA's plans to recalculate estimates for costs and benefits associated with the proposed regulatory options. EPA reviewed the responses from the detailed questionnaire, performed follow-up activities on the detailed questionnaires resulting from inconsistencies or questions from an initial review of responses, and completed analyses of the data contained in these responses.

For the analyses that support the final regulation, EPA used a facility-specific approach for estimating pollutant load reductions. EPA obtained detailed, facility-level information for a randomly-drawn, stratified sample of potentially in-scope facilities through the detailed AAP survey (USEPA, 2002a). The sample was taken from a group of screener surveys. EPA analyzed the detailed survey information and determined the level of treatment currently in place at each facility (i.e., baseline). For each facility, EPA evaluated the specifications of technologies and BMPs for each option that were used to determine regulatory compliance in comparison to the technologies in place at the facility. EPA used data from the facility to estimate the pollutant load reductions that would be expected from any components that were not in place.

Feed inputs to aquatic animal culture systems are the drivers of effluent quality discharged from CAAP facilities. Feed offered to the cultured species contributes to pollutant discharges in two ways. First, metabolic wastes and unmetabolized feed consumed by the cultured species are contained in the feces and urine. Pollutants contributed include organic solids (in the form of TSS and contribute to BOD), nutrients (i.e., nitrogen and phosphorus), and small amounts of metals and other compounds that are present in the feed. Second, uneaten feed settles, breaks down, and increases the pollutant load in the culture water. Depending on the culture and effluent treatment systems, some or all of the feed by-products can be discharged from a CAAP facility. For each in-scope facility that responded to the detailed survey, EPA estimated raw waste loads, baseline loads, and effluent loads for different regulatory option scenarios. All of the estimates are based on feed inputs to the systems.

EPA developed a series of Microsoft Excel spreadsheets to serve as a computing platform for the analysis. The spreadsheets linked feed inputs, unit pollutant load reductions of the technologies or practices representing each regulatory option, and facility attributes to derive a facility-specific load reduction estimate for compliance. For example, a pollutant load module was developed for feed management BMPs. Inputs, in the form of estimated pollutant loads, were customized for each individual facility using feed data supplied in the detailed survey. For each facility, EPA evaluated feed management strategies to enable the facility to meet narrative limits. EPA adjusted the total load reductions according to the layout of the individual facility, the technologies or practices currently in place. To check these estimates, EPA compared predicted loads and concentrations with discharge monitoring data that were available for some of the facilities. Finally, EPA multiplied the load reduction estimates for each facility by its sample weight and then summed the weighted load reductions to determine national estimates.

### 10.1.2 Organization of the Chapter

The following pollutant load reduction information is discussed in detail in this chapter:

- *Section 10.2* presents the structure of the load reduction model. EPA's load reduction model for the CAAP industry uses a facility specific approach to develop pollutant load reductions (from baseline loads) associated with each regulatory option.
- *Section 10.3* provides detailed background information on the contribution of feeds to pollutant loads (including constituents of feeds, feeding practices, and feed conversion ratios (FCRs)), the fate of feed in CAAP systems, and the method used to estimate raw pollutant loads.
- *Section 10.4* discusses unit load reduction modules, which are components of the treatment technologies that compose the regulatory options. Each treatment technology unit load reduction module contains formulas by which to calculate the pollutant load reductions associated with each regulatory option based on the facility characteristics.
- *Section 10.5* discusses a summary of the facility groupings, based on analysis of the detailed surveys. This section also provides estimates of raw and baseline pollutant loads from facilities.
- *Section 10.6* describes the estimates of pollutant loads from facilities when the regulatory options were applied.
- *Section 10.7* provides a summary of estimates for loads of other materials (i.e., metals, PCBs, drugs) that would be removed with solids.

## 10.2 LOADING MODEL STRUCTURE

EPA estimated the loading reduction associated with each of the regulatory options under consideration. EPA estimated loading reductions based on the implementation of control technologies that have known pollutant removal efficiencies and can achieve discharge limits for total suspended solids, as demonstrated by facilities in the CAAP industry.

To generate industry loading removals associated with each regulatory option for CAAP facilities, EPA developed a computer-based model made up of several individual treatment technology modules. Figure 10.2−1 illustrates the loading model and shows that it consists of several components, which can be grouped into five major categories:

- Feed input
- Baseline facility configuration
- Unit load reduction modules
- Output data—facility-specific pollutant load estimates and national pollutant load estimates
- Weighting factors

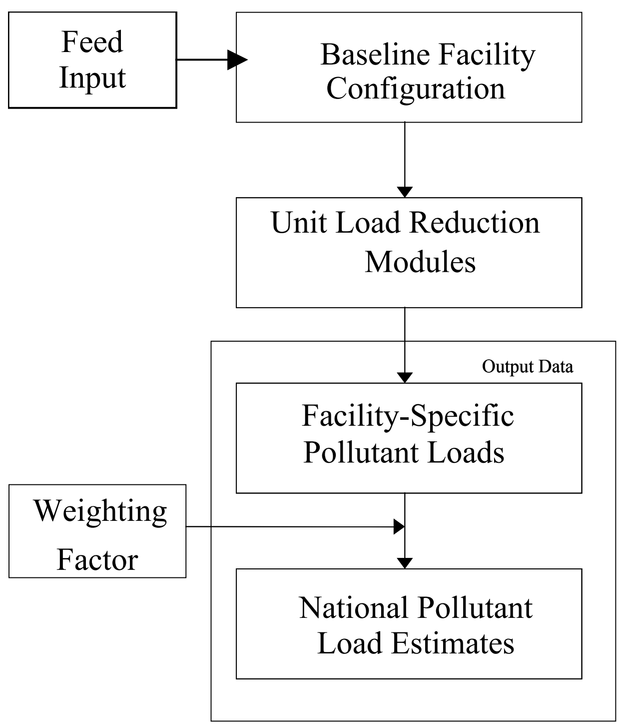


**Figure 10.2−1. Schematic of Loading Model Structure**

Since feed inputs are directly proportional to pollutant loads, annual feed use was first evaluated for each facility. Once a validated feed estimate was obtained, raw pollutant loads were calculated using known relationships between feed inputs and pollutant outputs. The configuration of each specific facility was analyzed and the characteristics matched to the pollutant reduction components of the specified options. Each unit load reduction module calculates loading reductions for a specific wastewater treatment technology (e.g., a primary settling basin or feed management) based on loading reductions for the specific facility characteristics. When sufficient information from the detailed survey were provided that enabled EPA to match facility-specific configurations to the desired regulatory outcome, a unit load reduction module was not evaluated (i.e., no costs or pollutant load reductions were assigned). For example, EPA assumed that facilities with quiescent zones and settling basins listed on the detailed survey had these technologies properly designed, installed, and operated. Thus, the facility would not bear a regulatory cost or contribute to national reductions in pollutants from primary settling. When possible, the facility's monitoring data were checked to confirm consistency with the regulatory limits. All of the unit load reductions were summed for a facility to estimate the farm-level pollutant load reductions. Weighting factors were then applied to the loading reductions to weight the reductions by the estimated percentage of operations that are similar to the specific facility. EPA summed these weighted facility reductions to estimate national load reductions resulting from the regulation.

### 10.2.1 Facility Configuration

The facility configuration part of the loading model sets up the characteristics of each unique facility, based primarily on system type, species, the combination of existing and final management practices and technologies, annual production, and feed inputs.

Input data to the model include the following:

- Data associated with feeding practices, including feeding in pounds/day and pollutant concentrations conversion factors associated with feed to estimate raw waste loads.
- Estimates of annual production.
- Average daily flow rates to each production unit and treatment component.
- Technologies and BMPs in place.
- Pollutant removals of technology options and BMPs.

### 10.2.2 Unit Load Reduction Modules

The unit load reduction modules contain the pollutant removal information for each component, BMP, or treatment technology contained in the regulatory options. The load reduction modules calculate the pollutant removals for the specific facilities, based on culture species and production system, using pollutant-specific removals for each of the regulatory options. The various load reduction factors are discussed in Section 10.5.

### 10.2.3 Output Data

Output data from the loading model provide estimates of baseline pollutant loadings discharged and incremental pollutant removals associated with each regulatory option for individual facilities and at a national level. Section 10.6 discusses the output data in more detail.

### 10.2.4 Weighting Factors

EPA's detailed industry survey was sent to a representative sample of the CAAP industry. Each sampled facility represents one or more facilities in the national population of CAAP facilities. The relationship between the sampled facility (which responded to the detailed survey) and the facilities it represents in the national population is characterized by a sample weighting factor. This weighting factor is used by EPA to scale its estimates from the sample population to the national population by multiplying an individual facility's sample weight and load estimates for pollutants. The sample weights are initially calculated when the stratified sample is drawn and then adjusted for non response in the surveys.

In August 2001, EPA mailed approximately 6,000 screener surveys to aquatic animal production facilities. EPA received responses from 4,900 facilities, of which about 2,300 facilities reported that they produce aquatic animals. EPA used the screener responses to select a stratified random sample to receive the detailed questionnaire. Sample criteria were designed to primarily capture facilities that produce aquatic animals and are likely to be covered by the proposed rule. EPA also developed sample criteria to capture facilities that are out of scope (based on information in the screener survey) to validate its assumptions about the applicability of the proposed regulation. For example, the sample criteria includes facilities with ponds, which are out of scope in the proposed regulation, to confirm that additional regulations for ponds are unnecessary. The Technical Development Document (TDD) for the proposed rule (USEPA, 2002b), page A11, describes in detail the criteria and includes facilities that are in-scope and out of scope. The facilities selected met one of these criteria:

- Aquariums.
- Production includes alligators and total biomass exceeds 100,000 pounds.
- Production includes trout or salmon and total biomass exceeds 20,000 pounds.
- Predominant production method is ponds; predominant species is catfish; and total biomass exceeds 2,200,000 pounds.
- Predominant production method is ponds; predominant species is shrimp, tilapia, other finfish, or hybrid striped bass; and total biomass exceeds 360,000 pounds.
- Predominant production method is any method except ponds, and total biomass exceeds 100,000 pounds.

Applying these criteria resulted in 539 facilities from the screener questionnaire responses with these characteristics. EPA then classified the 539 facilities into 44 groups defined by facility type (commercial, government, research, or tribal), the predominant species, and predominant production system type. A sample was drawn from the 539 facilities ensuring sufficient representation of facilities in each of the 44 groups. The sample drawn consisted of 263 facilities. From these 263 facilities EPA excluded 11 facilities that were duplicates on the mailing list or, after revising production estimates, did not meet the production thresholds described in the selection criteria for a CAAP facility. Detailed questionnaires were finally sent to 252 facilities.

EPA received responses on 215 of the 252 questionnaires. A few responses contained information on more than one facility. Subsequently, EPA separated that information into several questionnaires so that a single questionnaire represented an individual facility. EPA also excluded data from 12 facilities that returned incomplete responses. Because these facilities would not have been subject to the proposed limitations, EPA did not ask for more information. After separating multiple responses and excluding incomplete responses, information is available from 205 facilities.

Because EPA selected the 205 facilities using a statistical design (see Appendix A of the TDD, USEPA, 2002b, for more information), the responses allowed EPA to build a database to be used for estimating population characteristics reflecting the above criteria. For national (i.e., population) estimates, EPA applied survey weights to the facility responses that incorporate the statistical probability of a particular facility being selected to receive the detailed questionnaire and adjusted for non-responses. (The response rate was about 80% for the detailed questionnaire. Appendix A of the proposed Technical Development Document addresses the nonresponse adjustments for the screener questionnaire.) In this case, a survey weight of 3 means that the facility represents itself and two others in the population.

## 10.3 FEED INPUTS

### 10.3.1 Introduction

Food represents the fuel for a living organism, allowing it to live, grow, and reproduce. Food represents the input of energy to the aquatic animals; its main forms of energy are fats, carbohydrates, and proteins. All energy acquired through the ingestion of food is ultimately converted to wastes (in feces or by excretion), used in metabolic processes, or deposited as new body tissues (Jobling, 1994).

Jobling (1994) estimates that 20% to 35% of the ingested energy in aquatic animals is deposited as growth (i.e., new body tissue). Goddard (1996) states that up to one third (33%) of the content of feed used in intensive aquatic animal production may be indigestible and thus is excreted as feces, which may contain up to 30% of the dietary carbon and 10% of the consumed nitrogen. Chen (2000) estimates that up to 80% of feed input (on a dry weight basis) will not be used for growth and will eventually support metabolic processes or be wasted.

In most in-scope CAAP facilities, the aquatic animals being grown are carnivores (e.g., trout, salmon, striped bass) and omnivores (catfish and tilapia). Practical diets for these species are common and generally available to the facilities. However, there are many factors that contribute to the balance of growth, meeting metabolic needs, and producing wastes when feeding aquatic animals. These factors include many individual characteristics, as well as the interaction among the different factors. Some of the individual characteristics include:

- Species-specific factors—genetics, trophic level
- Diet—energy levels, form, feeding program, ingredients

- Environment—temperature, water quality, stressors

The combination of these factors can contribute to overall success at a CAAP facility in meeting its production goals and to the amount of waste produced. This combination of factors also results in variation among (and often within) facilities in terms of waste output. EPA attempted to account for some of this variation by using annual averages to describe feed inputs and pollutant outputs. EPA also grouped similar types of facilities (such as ownership-system type-species combination) when performing analyses. The following provides more detailed information about some of the sources of variation associated with feeds (and feeding) and the efficiency in which the aquatic animal uses the feed.

The aquatic animal producer has an economic incentive to observe that the feed introduced is fully utilized by the fish with little or no waste. Nevertheless, even under the most careful feeding conditions it is, from a practical point of view, difficult to eliminate feed waste completely (Cho et al., 1991). However, significant improvements in the utilization of feed have been realized during the last decade. Although feed waste cannot be determined accurately, it can be minimized by aiming at optimum rather than maximum production, along with other techniques available to the producer. This requires an awareness of important principles that can impact feed utilization by the fish.

Feeding of high energy diets is now a common practice for trout and salmon, which are carnivorous species. Omnivores (like catfish and some tilapia species), on the other hand, are fed lower-energy diets than carnivores. Diets of herbivores (such as tilapia and carp species) are even lower in energy. These herbivore fish require more bulk in their diet (which means they must be fed a higher percentage of their body weight on a daily basis to meet their energy and growth requirements) and a more-or-less continuous feed intake as they lack a stomach, but have a long gut.

Carnivores may use 44% of the feed calories for metabolism, 29% for growth, and 27% excreted, while herbivores use 37% for metabolism, 20% for growth, and a high 43% excretion. These are rule-of-thumb values; they depend on diets (especially low versus high energy), percent digestibility, and species. The capacity of different species of fish to utilize the energy contained in different nutrients varies greatly (DeSilva and Anderson, 1995). Also, the best performance occurs at a species optimum temperature.

Diets should provide required energy by means of fats and carbohydrates and spare the protein for metabolic needs, especially growth. This has two important facets; protein is the most expensive component of the diet and should not be used for energy, but rather for growing muscle (meat) and secondly this reduces the nitrogen waste.

Protein sparing is a good idea, but if the protein-to-energy ratio is tilted too much toward energy, feeding rate and efficiency are impaired. The goal, therefore, is to achieve the optimum protein-to-energy ratio, which is species dependent (Forster and Hardy, 2000).

The less protein is used as an energy source (i.e., as an aerobic substrate), the less nitrogen is excreted. For example, Johnsen and Wandsvik (1991) reported that using high energy diets have resulted in reduced nitrogen excretion by species up to 35%. Well balanced, high-energy diets have accomplished much in reducing nutrient wastes, as well as reductions in solid wastes. This fact is also reflected in major improvements in the efficiency of feeding, which is measured by feed conversion ratio (FCR) values. For instance, in Nordic countries, FCRs for species were over 2.0 in 1976, but only 1.0-1.1 in 1995 (Pearson and Black, 2000).

As an example, for optimum growth and efficiency of a feeding program, feeding levels should be adjusted when energy levels of the feed vary significantly. For low-energy diets, feeding levels should be increased and vice versa (Barrows and Hardy, 2001). Successful utilization of feed has physical and physiological aspects. Many factors play a role in the effectiveness of these two major functions and it is important for the aquatic animal producer to be aware of these.

The physical component, the capture and ingestion of the feed, depends on the fish's sensory capacities to locate food and their ability to capture, handle, and ingest food items. Once ingested, they depend on their physiological and biochemical capacities to digest, transfer, and utilize the ingested nutrients (Kestemont and Baras, 2001).

Because of the many factors controlling feed intake (appetite), the management of feeding and feed distribution is a very complex one (Guillaume et al., 2001). It is also important to properly distribute and time the availability of food for the fish. The activation of the feeding behavior (appetite) can be influenced by many factors such as:

- Aquatic animal health and stress
- Water quality, especially temperature and dissolved oxygen
- Whether the stomach is full or empty
- Time of day; diurnal responses
- Time of year; seasonal responses
- Rearing density
- Rearing unit characteristics, such as shape, depth, and flow pattern

With respect to the physiological/biochemical component affecting the utilization of the ingested feed, the following should be considered:

- Diet composition; the energy content, nutritional balance in particular with respect to the energy to protein ratio, digestibility of the ingredients, plant versus animal source ingredients, vitamins, minerals and additives.
- Carnivorous versus omnivorous/herbivorous species.
- Water quality, especially temperature, dissolved oxygen, as well as the buildup of ammonia and carbon dioxide in the rearing water.
- Overall fish health and stress.

Estimation of feed requirements may be relatively easy in theory, but estimates will seldom match the needs of the aquatic animals at a specific time, because of large variations in feed intake, both between days and over long periods of time (Alanärä et al., 2001; Guillaume et al., 2001). Often the most difficult part is accurately estimating the biomass to be fed. Feeding tables, formulae, etc. are guidelines, but in practice, daily observations are needed so any necessary adjustments can be made. Models that allow estimation of feed requirements are important for production plans, i.e., long-term planning of feed use. However, ultimately the best approach for producers is to develop their own feed budgets based on accurate records over the years. Ideally, feeding should be tuned to the aquatic animal's demand or appetite.

The act of feeding fish, according to DeSilva and Anderson (1995), is often considered to be the single most important element in aquatic animal production. One aspect of feeding, determining the optimum ration size, is one of the most difficult tasks in any aquatic animal production operation.

The facility operator may have to adjust the amount of feed based on specific requirements by the aquatic animals and, accordingly, select appropriate feed application and distribution relative to feeding schedules and methods.

### 10.3.2 Feed Conversion Ratio (FCR)

Feed conversion ratio (FCR) represents the ratio of feed fed to fish gain.

It is commonly used as a measure of the efficiency of a feeding program. Overall, the tendency among producers is to aim for fast and maximum growth, while showing less concern for FCRs and feed wastage. This approach is not necessarily the most economic one (Doupé and Lymbery, 2003).

In trout that grow normally, an FCR of 1.2 or less indicates that dietary energy requirements are met. For example, Barrows and Hardy (2001) state that the production of one kilogram trout requires between 3,740 and 3,960 kilocalories/kilogram of digestible diet. In practical terms, this corresponds to a feed containing about 4,000 kilocalories/kilogram diet, with a protein level of 42% and a dietary fat level of about 20%. The dietary requirements for trout, salmon, and catfish have been well studied and optimal diets (in terms of energy requirements) can be formulated. Other species have not been studied as extensively and optimal diets may not be available.

With higher energy feeds, FCRs of 1.0 or less are now routinely observed in salmon and trout farming. Anytime FCRs are significantly greater, then less of the feed input goes to growth and more is used to support metabolic processes and there is increased waste generation, intrinsically as well as extrinsically (wasted feed).

As stated earlier, many factors contribute to feeding efficiency. For example, the feeding method and feed availability can be shown to have significant effects on feeding efficiency, effluent quality, and growth.

Alanärä and Cripps (1991) report that demand feeding with unrestricted amounts of feed available resulted in an FCR of 1.49, while a restricted feeding strategy produced an FCR of 1.07. Interestingly, there was no significant difference in growth between these two groups. This seems to indicate either feed loss (feed not ingested) or over-indulgence with poor digestion (internal "loss"). Whether the waste was external (physical) or internal (physiological), the impact on effluent quality was significant. Total phosphorus output was reduced 45% from 10.2 to 5.6 grams/kilogram of fish. Total nitrogen was reduced 44% from 75.9 to 42.7 grams/kilogram of fish. But then, Äsgärd and Hillestad (1999) write that restricting feed below voluntary intake (satiation) can be a waste of resources. It is their opinion that the faster the growth the greater the amount of feed is converted to flesh, i.e., the lower the FCR. Aquatic animals, first of all, must meet their metabolic energy requirements. If feed intake only provides for this, no energy is left available for growth. As feed intake increases beyond metabolic energy requirements growth occurs until it reaches the maximum the animal is willing to consume. The preponderance of data show that optimum FCR and maximum growth do not coincide.

Eriksson and Alanärä (1990) report that fish (rainbow trout), when offered food in excess, grew larger than those on restricted feed. However, those on restricted feed converted their food much more efficiently than those feeding to excess, and as a result, the release of phosphorus and nitrogen was reduced by more than 50%.

Other studies showed that when rainbow trout were fed 75% of the maximum ration for feed intake and growth rate, the lowest FCRs were realized. Under this feeding program fish utilized feed more efficiently and released less nutrients into the effluent, but the overall weight gain was lower than in fish fed to satiation.

When feeding approaches satiation, fish slow down in their feeding activity, and unless the volume of introduced feed is reduced, the fish may not keep up with its capture, and feed may potentially be lost. Frequently fed fish (for example fingerlings) utilize their feed more efficiently than those fed less frequently. The benefit is lower FCR. As a rule of thumb, Barrows and Hardy (2001) recommend 1.0% body weight per feeding to ensure that, first of all, enough feed is offered that all fish have an opportunity to obtain feed, and secondly not too much feed is presented so their feeding action will remain high and the stomach is not over full. If fish gorge themselves, the feed may pass through the digestive system faster resulting in reduced nutrient absorption (higher FCR). This means the feed loss (nutrient loss) is indirect or internal, but it still contributes significantly to the various waste components, such as solids, BOD, nitrogen, and phosphorus.

Cho et al. (1991) mentions that under the most careful feeding conditions, it is still difficult to eliminate feed waste completely, but it can be minimized, i.e., to less than 5%, by aiming at optimum rather than maximum production. This requires the application of scientific feeding standards and sensible feeding practices and by using well-manufactured feeds of high water stability.

In 1991, Gowen et al., reported that food waste may account for as much as 20% of the total food fed and may account for 70% of organic carbon input in net pen culture of salmon. Pearson and Black (2000) report that current estimates of feed waste for salmonid net pen culture vary between 1% and 5%. This agrees with the statement by Riley (2001) that FCRs of 1.1 are now achievable in net pen operations by applying computer-operated pneumatic feeding systems, which allow precise control of the feeding operation and, subsequently, greatly reduces feed going to waste.

Hinshaw and Fornshell (2002) mention that feed waste varies from 1% to as high as 15% for trout raceway culture. Yet, intensive raceway culture offers greater opportunity for more accurate feeding programs than net pen culture. As a whole, today's trout industry in Idaho and North Carolina accomplish FCRs of 1.0 to 1.2 and keep feed wastes below 3.0% (Fornshell and Sloan, personal communication).

Immediate improvements in FCR and feed waste can be realized by simply offering the fish feed when they will use it most effectively and efficiently (Bergheim et al., 1991). As mentioned earlier, frequently fed fingerlings utilize their feed more efficiently, thus lowering the FCR and feed waste. Appetite returns in some carnivorous species, such as rainbow trout and eel, on the basis of stomach emptying time (Goddard, 1996).

It is important to understand that obtaining the highest weight gain and lowest FCR are separate goals; however, compromises can be made based on the goals of the hatchery program (Barrows and Hardy 2001). Optimizing both growth rate and FCR appears to be mutually exclusive. However, optimizing FCR benefits the environment, as it reflects low volumes of feed waste. It can also have an economic benefit.

### 10.3.3 FCR Analysis

EPA analyzed FCR data from many of the flow-through and recirculating system facilities that completed the detailed survey of the CAAP industry. The purpose of the FCR analysis was two fold:

1. FCRs were used to estimate and check the amount of feed used at each facility.
2. FCRs were used as a surrogate for estimating potential load reductions resulting from feed management activities.[1]

For those facilities that provided annual production and feed use data, EPA calculated an FCR estimate:

FCR = Feed Input/Facility Production

Where:

FCR = the annual feed conversion ration for the production system (pounds of feed per pound of aquatic animals produced)

Feed Input = annual feed use at the facility (pounds)

Facility Production = annual production of aquatic animals at the facility (pounds)

EPA was able to calculate FCRs for 69 flow-through and recirculating system facilities that responded to the detailed survey. EPA validated the feeding, production, and estimated FCRs by contacting each facility. For those facilities that were not able to supply accurate feed and/or production information, EPA randomly assigned an FCR. EPA attempted to capture and account for as much of the variation as possible when

[1] Note: EPA used FCR values as a means to estimate potential load reductions, not as a target to set absolute FCR limits for a facility or industry segment.

analyzing FCRs and in the random assignment process. For example, the production system, species, and system ownership (which are all known from the detailed surveys) were expected to influence feeding practices, so facilities were grouped according to these parameters. EPA included ownership as a grouping variable to account for some of the variation in production goals. Most commercial facilities that were evaluated are producing food-sized fish and generally are trying to maintain constant production levels at the facility; commercial facilities would tend to weigh maximum weight gain against FCR in determining their feeding strategy. Non-commercial facilities are generally government facilities that are producing for stock enhancement purposes. Production goals are driven by the desire to produce a target size (length and weight) at a certain time of year for release. Non-commercial facility feeding goals may not weigh as heavily on maximum growth. Some of the sources of variation, such as water temperature and age of the fish, were accounted for by evaluating distributions of the similar facility FCRs and using Monte Carlo simulations.

The process for the random assignment included:

- EPA grouped facilities by ownership, species, and production.
- FCRs were estimated for each facility with sufficient data and grouped.
- The distributions of grouped data were examined for possible outliers, which were defined as FCRs less than 0.75 or greater than 3.0. When extreme values were found and validated, they were removed from the grouping.[2] Some extreme values were updated based on validating information from the facility, and the updates were found to be within the range used for analysis.
- After removing outliers, the first and third quartiles were calculated for each grouping.[3]
- For each grouping, the target FCR was assumed to be the first quartile value.
- For the facilities with no FCR information, a random FCR between the first and third quartiles was assigned with a uniform distribution between the first and third quartile.[4]

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[2] Although these extremes may be possible and a function of production goals, water temperature, etc., EPA was not able to validate and model all of the factors contributing to the extreme FCR rates. Facilities excluded because of extreme values were not assigned a random FCR, but were found to have a documented reason for the extreme value. For example, one facility produced broodstock for stock enhancement purposes.

[3] The first quartile of a group of values is the value such that 25% of the values fall at or below this value. The third quartile of a group of values is the value such that 75% of the values fall at or below this value.

[4] The uniform distribution leads to the most conservative estimate of uncertainty; i.e., it gives the largest standard deviation. The calculation of the standard deviation is based on the assumption that the end-points of the distribution are known. It also embodies the assumption that all effects on the reported value, between a and b, are equally likely for the particular source of uncertainty. Detailed calculations are contained in the analysis spreadsheets located in the CBI record for this rulemaking (Tetra Tech, 2003a).

- For some categories there were not sufficient data to do the quartile analysis. In these cases, data from a similar category were used. Table 10.3−1 below summarizes the results of the quartile analysis.

**Table 10.3–1. Quartile Analysis**

| *Category* | *Number of Facilities* | *First Quartile—Third Quartile* |
|---|---|---|
| Commercial – Catfish – FT | <5 | |
| Commercial – Trout – FT | 36 | 1.12–1.48 |
| Government – Trout – FT | 57 | 1.19–1.60 |
| Research – Trout – FT | <5 | |
| Tribe – Trout – FT | <5 | 1.19–1.60 |
| Government – Salmon – FT | 24 | 1.00–1.31 |
| Commercial – Salmon – FT | 6 | 1.00–1.31 |
| Tribe – Salmon – FT | <5 | 1.00–1.31 |
| Commercial – Tilapia – FT | <5 | 2.10–2.21 |
| Commercial – Striped Bass – FT | <5 | 1.22–1.87 |
| Government – Other finfish – FT | <5 | |
| Government – Trout – Recirculating | <5 | 1.12–1.48 |
| Government – Salmon – Recirculating | <5 | 1.00–1.31 |
| Commercial – Striped Bass – Recirculating | <5 | 1.22–1.87 |
| Commercial – Tilapia – Recirculating | <5 | 2.10–2.21 |
| Commercial – Other finfish – Recirculating | <5 | |
| Commercial – Baitfish – Recirculating | <5 | |

### 10.3.4 Feed Inputs

EPA assumed the sources of pollutant loadings in CAAP facility production systems are the feed input and resulting metabolic wastes generated by the aquatic animals. The pollutant loadings calculated in the loading model were based on the feed input to the system and the feed-to-pollutant calculation, as described in 10.3.5.

Feed inputs to the model were typically obtained from the facility's response to the detailed survey. In these cases, the response from the detailed survey was checked and validated with the facility. In some cases, the facility was not able to provide accurate feed data and estimates were made by multiplying the specific facility production, which was determined by analysis of the detailed survey, by the facility-specific FCR:

Feed input = facility production * FCR

Where:

Facility production = the average yearly production at the facility (pounds)

FCR = the annual feed conversion ratio for the production system (pounds of feed per pound of fish produced) estimated using the procedure described in 10.3.3

If feed inputs were estimated using FCR values, EPA attempted to validate the estimates by contacting each facility. Table 10.3−2 provides a summary of the feed information, grouped by ownership, species, and system type.

**Table 10.3–2. Range of Feed Loads by System-Species-Ownership Grouping**

| *System* | *Species* | *Ownership* | *Number* | *Range (lb)* |
|---|---|---|---|---|
| Flow-through | Salmon | Commercial & Non-commercial | 13 | 112,200–1,178,480 |
| Flow-through | Striped Bass-Tilapia-Catfish-Other | Commercial & Non-commercial | 10 | 62,400–259,360 |
| Flow-through | Trout | Commercial | 13 | 42,700–750,000 |
| Flow-through | Trout | Non-commercial | 28 | 24,000–744,200 |
| Recirculating | Striped Bass-Salmon-Shrimp-Tilapia-Other | Commercial & Non-commercial | 7 | 132,000–7,206,700 |

### 10.3.5 Feed-to-Pollutant Conversion Factors

EPA only modeled pollutant generation at each facility as a function of feed inputs, which are the feed and associated metabolic wastes. EPA used values for the feed-to-pollutant conversion factors (Table 10.3−3) in the loading model to represent the range of values found in literature reviews (Hochheimer and Meehan, 2004).

**Table 10.3–3. Feed-to-Pollutant Conversion Factors**

| *Polluant* | *Conversion Factor* |
|---|---|
| BOD | 0.35 |
| TN | 0.0275 |
| TP | 0.005 |
| TSS | 0.25 |

Source: Hochheimer and Meehan, 2004.

EPA found studies that determine the pollutants associated with feeding fish are often done in controlled laboratory situations using tanks with static water. The feed-to-pollutant conversion factors vary somewhat by species and the constituents in the feed, so EPA used typical values found in the literature to represent some of this variability. For the purpose of estimating pollutant loadings, EPA assumed that all feed added to a production system is consumed and undergoes some metabolic conversion by the aquatic animals. Although feed conversion ratios greater than 1 indicate potentially uneaten feed, the amount of uneaten feed could vary considerably on a daily basis in a given production unit. Some of the factors that contribute to this variation are stress to the animals (e.g., changes in dissolved oxygen, spikes in production unit ammonia, unusual activity at the production facility, or a recent storm), water temperature, age of the aquatic animal, and the presence of disease. The mass of pollutants associated with unmetabolized feed are greater than those that are consumed and undergo the metabolic processes of the aquatic animals, so EPA used the more conservative value in the loading models.

EPA used the feed-to-pollutant conversion factors to estimate an untreated or "raw loading," which was used as the input to pollutant control technologies and BMPs. EPA calculated raw pollutant loadings by using the following equations:

Raw pollutant loading = annual feed input * feed-to-pollutant conversion factor

Where:

Raw pollutant loading = the pollutant load for each pollutant (i.e., TSS, BOD, TN, TP) in pounds/year

Annual feed input = the amount of feed distributed to the production system (pounds/year)

Feed-to-pollutant conversion factor = conversion of feed inputs into pollutant loadings (i.e., TSS, BOD, TN, TP) in pounds of pollutant per pound of feed

A summary of the raw waste load estimates is presented in Table 10.3–4.

**Table 10.3–4. Raw Waste Loads by Category**

| *System* | *Original Species* | *Ownership* | *Number* | *Range (lb)* | | | |
|---|---|---|---|---|---|---|---|
| | | | | *BOD* | *TN* | *TP* | *TSS* |
| Flow-through | Salmon | Commercial & Non-commercial | 13 | 39,270–412,468 | 3,086–32,408 | 561–5,892 | 28,050–294,620 |
| Flow-through | Striped Bass-Tilapia-Catfish-Other | Commercial & Non-commercial | 10 | 21,840–90,776 | 1,716–7,132 | 312–1,297 | 15,600–64,840 |
| Flow-through | Trout | Commercial | 13 | 14,945–262,500 | 1,174–20,625 | 214–3,750 | 10,675–187,500 |
| Flow-through | Trout | Non-commercial | 28 | 8,400–260,470 | 660–20,466 | 120–3,721 | 6,000–186,050 |
| Recirculating | Striped Bass-Salmon-Shrimp-Tilapia-Other | Commercial & Non-commercial | 7 | 46,200–2,522,345 | 3,630–198,184 | 660–36,034 | 33,000–1,801,675 |

## 10.4 Unit Load Reduction Modules

EPA evaluated several solids control strategies that are in use or could be used at flow-through, recirculating, and net pen facilities. These management strategies include:

- Feed management practices to achieve optimal feeding and prevent wasted feed. (Section 10.4.1).
- Active feed monitoring to ensure that feed offered to aquatic animals in net pen systems is consumed and not wasted (Section 10.4.2).

EPA developed unit load reduction modules that calculate the pollutant removal associated with a particular technology or practice for a CAAP facility. Each unit load reduction module contains a description of the technology or practice and the pollutant-specific removal efficiencies of the system component.

EPA used pollutant removal efficiencies for each of the TSS removal technologies and practices to determine pollutant load reductions that could be expected when a technology or practice is in place. These pollutant removal efficiencies were developed from a combination of data that were collected in the literature, facility monitoring data, and at EPA sampling events. By calculating load reduction efficiencies, EPA was able to directly estimate load reductions, without having to estimate loads from effluent concentrations and flow rates. EPA also compared its calculated estimates of loads and effluent concentrations for TSS with available monitoring and sampling data as a quality check (see Section 10.6 and Hochheimer and Escobar, 2004a; Hochheimer and Escobar, 2004b for details).

### 10.4.1 Feed Management

Feed management is a practice that was considered for all operations.

#### *10.4.1.1 Description of Technology or Practice*

Feed management recognizes the importance of effective, environmentally sound use of feed. System operators should continually evaluate their feeding practices to ensure that feed placed in the production system is consumed at the highest rate possible. Observing feeding behavior and noting the presence of excess feed can be used to adjust feeding rates to ensure minimal excess (USEPA, 2002c).

An added advantage of this practice is that proper feed management decreases the costs associated with the use of excess feed that is never consumed by the cultured species. Excess feed distributed to the production system increases the oxygen demand of the culture water and increases the solids loading to the treatment system. More important, solids from the excess feed usually settle and are naturally processed along with feces from the aquatic animals. In net pen operations, excess feed and feces accumulate under net pens, and if there is inadequate flushing, this accumulation can overwhelm the natural benthic processes and results in increased benthic degradation.

The primary operational factors associated with proper feed management are development of precise feeding regimes based on the weight of the cultured species and constant observation of feeding activities to ensure that the feed offered is consumed. Feed management is a practice required in net pen facility permits issued in EPA Regions 1 and 10 (USEPA, 2002c; USEPA, 2002d) and in Idaho and Washington flow-through system production facilities.

#### *10.4.1.2 Pollutant Removals: All Systems*

Pollutant removals associated with feed management result from better feed utilization and less wasted feed that is uneaten. Section 10.3.2 provides a detailed discussion on a variety of activities that facilities do to optimize feed utilization. Data are also presented in Table 10.3–1 that show ranges of feed conversion ratios (FCRs) for different facility groups (i.e., system type-species-ownership type) of CAAP facilities. EPA used this FCR data to estimate potential pollutant reductions at facilities with FCRs in the upper parts of the ranges for a facility group. It is important to reiterate that EPA used FCR values only as a means to estimate potential pollutant reductions, not as industry targets or regulatory requirements. EPA recognizes that it is possible for an individual facility to have greater than average FCRs for many reasons, even though the facility is practicing very efficient feed management. For example, a facility that has sub-optimal temperatures (either too high or too low) may have greater FCRs than a comparable facility with optimal, steady-state temperatures.

EPA evaluated feed management as a regulatory option for facilities that provided information on the detailed industry survey. The procedure EPA used involved facility-specific FCRs compared to a low FCR, which was estimated as the 25$^{th}$ percentile FCR value for the facility group. Many facilities provided sufficient data in their detailed industry survey responses to enable EPA to calculate an actual facility-specific FCR. Some facilities were not able to provide sufficient information to enable EPA to estimate a facility-specific FCR, so EPA developed a methodology for estimating one. EPA used a randomly assigned FCR (based on a uniform distribution for the range of reported FCRs in a facility group) as the facility estimate. If the facility's FCR (either randomly assigned or actual) was greater than 75% of the inter-quartile range and were not currently meeting the regulatory limits for their type of discharge configuration, then EPA assumed that the facility could benefit from feed management practices and would incur costs and pollutant load reductions. More details about this methodology are presented in Hochheimer and Escobar (2004c). EPA estimated the amount of feed conserved as:

$$\text{Feed conserved} = \text{Feed used for year 2001} * \left(1 - \frac{\text{Target FCR}}{\text{Actual or estimated FCR}}\right)$$

Where:

Target FCR = the FCR obtained with implementation of a feed management program

Actual FCR = the FCR as calculated based on information reported by the facility

Estimated FCR = the FCR estimated for a facility if the facility did not provide sufficient data to calculate one

Feed used for year 2001 = pounds of feed reported by the facility in the detailed survey or estimated by EPA (see Table 10.3–2)

EPA estimated pollutant load reductions using values presented in Table 10.3–3 and the equation:

Specific Pollutant Load Reduction = Feed conserved * Specific Pollutant Reduction Factor

Where:

Feed conserved = pounds of feed reduced at the facility by feed management practices

Specific Pollutant Reduction Factor = pounds of pollutant (i.e., TSS, TN, TP, BOD) reduced/pound of feed reduced

### 10.4.2 Active Feed Monitoring

Active feed monitoring was proposed as a management practice for all net pen facilities. Real-time feed monitoring is a proven technology that includes video monitoring, digital scanning sonar, upwelling systems, used by all of the facility operators who responded to the detailed survey to produce Atlantic salmon in net pen systems. Some type of remote monitoring equipment is operated during feeding to monitor for uneaten feed pellets as they pass through the bottom of the net. Active feed monitoring can also include monitoring of sediment of sediment quality beneath the pens, monitoring the benthic community beneath the pens, capture of waste feed and feces, or the adoption of good husbandry practices, subject to the permitting authority's approval. For the final rule, net pen facilities must develop practices to minimize the accumulation of uneaten food beneath the pens using active feed monitoring and management practices.

#### *10.4.2.1 Description of Technology or Practice*

The goal of active feed monitoring is to further reduce pollutant loadings associated with feeding activities. A variety of technologies could be used, including video cameras with human or computer interfaces to detect passing feed pellets, an acoustic or digital scanning sonar, or a simple air lift pump with its intake located at the bottom of the net. One example of a real-time monitoring system used a video monitor at the surface that is connected to an underwater video camera. An employee watches the monitor for feed pellets passing by the video camera and then stops feeding activity when a predetermined number of pellets (typically only two or three) pass the camera. EPA observed this technology at several Maine facilities during site visits (Tetra Tech, 2002b; Tetra Tech, 2002c).

#### *10.4.2.2 Pollutant Removals: All Systems*

EPA estimated that pollutant reductions associated with active feed monitoring could be about 5% or more for all pollutants. Since all of the in-scope net pen facilities that responded to the detailed industry survey indicated that they had a form of active feed management in place, EPA did not estimate any feed reductions for this technology as a result of the final regulation.

### 10.4.3 Drug Reporting and Material Storage

The drug reporting requirement is estimated to be equal for all species and culture systems and based on facility-specific drug usage.

#### *10.4.3.1 Description of Technology or Practice*

The purpose of the drug reporting requirement is to enable the permitting authority to become aware of the potential for releases of INAD and extralabel drugs under specific circumstances. The regulation also requires proper material storage including spill containment for all drugs or pesticides stored at the facility. EPA evaluated spill prevention training and chemical containment storage systems as ways facilities can meet the regulatory requirements.

#### *10.4.3.2 Pollutant Removals: All Systems*

Pollutant reductions for BOD, TN, TP, and TSS may occur as a result of implementation of a drug reporting/material containment requirement. Containment systems and spill clean-up procedures may help to reduce the discharge of materials (e.g., feed, drugs and pesticides) only. EPA did not estimate load reductions from this technology/practice.

### 10.4.4 Structural Integrity of the Containment System

All flow-through, recirculating, and net pen facilities are required to maintain the structural integrity of their production systems and wastewater treatment systems.

#### *10.4.4.1 Description of Technology or Practice*

Facilities can use regular inspections to ensure that critical structural components are in proper working order and will not fail under typical operating conditions. Adherence to this general requirement should prevent the release of materials including culture animals and collected biosolids.

#### *10.4.4.2 Pollutant Removals: All Systems*

The maintenance of the structural integrity of the containment system is to ensure proper operation to prevent failure and thus, a release of materials as a result of failure.

## 10.5 FACILITY GROUPINGS

EPA defined facility-specific models for flow-through and recirculating systems and evaluated facility groups that were based on system type, species, and ownership.

EPA analyzed each facility separately to determine the production systems used, species produced, and any other unique characteristics. Although facilities were all different, they could be grouped into several categories. Table 10.5−1 shows in-scope facility groupings by system type for those facilities analyzed in the detailed survey sample (unweighted) and the corresponding estimate for the in-scope national population (weighted[5]). Table 10.5−2 illustrates the in-scope sample and national estimates grouped by ownership. Table 10.5−3 shows the facilities grouped by location, which was defined by EPA region. Table 10.4−4 groups in-scope facilities by the species identified in the screener survey that was used to categorize the facility in the strata for the sample selection. Table 10.5−5

[5] The number of facilities in each of the weighted groupings may not sum to 240 because of rounding error.

shows the facilities grouped by the combination of system type-species-ownership. This grouping was used in many of the comparative analyses, such as those done for FCR.

**Table 10.5–1. Facility Groupings by System Type**

| *System Type* | *Weighted* | | *Unweighted* | |
|---|---|---|---|---|
| | *Number* | *%* | *Number* | *%* |
| Flow-through | 208 | 87 | 64 | 81 |
| Recirculating | 14 | 6 | 7 | 9 |
| Net Pens | 19 | 8 | 8 | 10 |
| Total | 240 | | 79 | |

**Table 10.5–2. Facility Groupings by Ownership**

| *Ownership* | *Weighted* | | *Unweighted* | |
|---|---|---|---|---|
| | *Number* | *%* | *Number* | *%* |
| Non-commercial | 139 | 58 | 43 | 54 |
| Commercial | 101 | 42 | 36 | 46 |
| Total | 240 | | 79 | |

| *Non-Commercial* | *Number* | *% of Total* | *Number* | *% of Total* |
|---|---|---|---|---|
| Federal | 33 | 14 | 10 | 13 |
| Army Corps | 3 | 1 | 1 | 1 |
| State | 103 | 42 | 32 | 40 |

**Table 10.5–3. Facility Groupings by Location**

| *EPA Region* | *Weighted* | | *Unweighted* |
|---|---|---|---|
| | *Number* | *%* | *Number* |
| EPA Region 1 | 34 | 13 | 12 |
| EPA Region 2 | 3 | 1 | <5 |
| EPA Region 3 | 14 | 6 | 5 |
| EPA Region 4 | 35 | 16 | 10 |
| EPA Region 5 | 14 | 6 | <5 |
| EPA Region 6 | 6 | 3 | <5 |
| EPA Region 7 | 4 | 2 | <5 |
| EPA Region 8 | 21 | 9 | 7 |
| EPA Region 9 | 48 | 20 | 16 |
| EPA Region 10 | 61 | 24 | 21 |
| Total | 240 | | 79 |

**Table 10.5–4. Facility Groupings by Sampled Species**

| *Species* | *Weighted* | | *Unweighted* |
|---|---|---|---|
| | *Number* | *%* | *Number* |
| Catfish-Other Finfish-Shrimp | 8 | 3 | 5 |
| Trout | 150 | 62 | 42 |
| Salmon | 64 | 27 | 21 |
| Striped Bass | 8 | 3 | 5 |
| Tilapia | 11 | 5 | 6 |
| Total | 240 | | 79 |

### Table 10.5–5. Facility Groupings by System-Ownership-Species

**Flow-through Systems**

| Production | Species | Owner | Number of Facilities |
|---|---|---|---|
| >100,000 | Salmon | Commercial & Non-commercial | 13 |
| >100,000 | Striped Bass-Tilapia-Catfish-Other | Commercial & Non-commercial | 10 |
| >100,000 | Trout | Commercial | 13 |
| >100,000 | Trout | Non-commercial | 28 |
| | | Total | 64 |

**Recirculating Systems**

| Production | Species | Owner | Number of Facilities |
|---|---|---|---|
| >100,000 | Striped Bass-Salmon-Shrimp-Tilapia-Other | Commercial & Non-commercial | 7 |
| | | Total | 7 |

**Net Pen Systems**

| Production | Species | Owner | Number of Facilities |
|---|---|---|---|
| >100,000 | Salmon-Trout | Commercial | 8 |
| | | Total | 8 |

EPA performed pollutants loadings analyses on 71 flow-through and recirculating systems. Each facility was analyzed individually to determine baseline configurations and baseline pollutant loads for TSS, BOD, TN, and TP. Table 10.5–6 summarizes the baseline loads that were estimated for each facility. EPA used the removal efficiency data for each treatment unit described in Section 10.4 to determine estimates for baseline loads. EPA checked these estimates with monitoring data when possible to verify the estimates (see Hochheimer and Escobar 2004d for more information).

### Table 10.5–6. Baseline Loads by Category

| System | Original Species | Ownership | Number | Range (lb) | | | |
|---|---|---|---|---|---|---|---|
| | | | | BOD | TN | TP | TSS |
| Flow-through | Salmon | Commercial & Non-commercial | 13 | 3,641–40,360 | 1,765–24,926 | 196–3,848 | 994–96,600 |
| Flow-through | Striped Bass-Tilapia-Catfish-Other | Commercial & Non-commercial | 10 | 2,342–21,981 | 1,706–6,669 | 296–1,157 | 8,120–34,732 |
| Flow-through | Trout | Commercial | 13 | 430–45,005 | 505–18,758 | 49–2,896 | 933–71,113 |
| Flow-through | Trout | Non-commercial | 28 | 504–205,513 | 604–18,726 | 98–3,029 | 2,760–146,795 |

| System | Original Species | Ownership | Number | Range (lb) | | | |
|---|---|---|---|---|---|---|---|
| | | | | BOD | TN | TP | TSS |
| Recirculating | Striped Bass-Salmon-Shrimp-Tilapia-Other | Commercial & Non-commercial | 7 | 2,772–228,900 | 3,321–90,669 | 537–14,666 | 15,180–331,508 |

## 10.6 LOAD REDUCTIONS AT REGULATORY OPTIONS

EPA's regulatory requirements for flow-through and recirculating systems include:

- Practices to control solids
- Facilities must maintain the structural integrity of production and wastewater treatment units. (No pollutant load reductions were estimated.)

EPA used its analysis of baseline conditions at each in-scope facility that responded to the detailed survey to estimate baseline discharge loads (see Table 10.5–1). EPA then applied a combination of treatment technologies and management practices to each facility as appropriate. Individual facility pollutant load reductions were scaled up to national pollutant load reductions by applying the appropriate weighting factor to the estimates for the individual facility and then summing across the facilities in the facility groups. Table 10.6–1 shows estimates of load reductions by facility group.

**Table 10.6–1. Estimated Pollutant Load After Implementation for In-Scope CAAP Facilities**

| System | Original Species | Ownership | Number | Range (lb) | | | |
|---|---|---|---|---|---|---|---|
| | | | | BOD | TN | TP | TSS |
| Flow- through | Salmon | Commercial & Non-commercial | 13 | 3,502–40,360 | 1,765–24,926 | 196–3,848 | 994–95,968 |
| Flow-through | Striped Bass-Tilapia-Catfish-Other | Commercial & Non-commercial | 10 | 2,342–21,981 | 1,596–6,669 | 277–1,157 | 8,120–34,732 |
| Flow-through | Trout | Commercial | 13 | 430–35,145 | 504–18,758 | 49–2,896 | 933–62,100 |
| Flow-through | Trout | Non-commercial | 28 | 504–205,513 | 604–16,147 | 98–2,936 | 2,760–146,795 |
| Recirculating | Striped Bass-Salmon-Shrimp-Tilapia-Other | Commercial & Non-commercial | 7 | 2,772–169,661 | 3,321–57,874 | 537–9,361 | 15,180–264,500 |

## 10.7 OTHER POLLUTANT LOADS

Metals may be present in CAAP effluents from a variety of sources. Some metals are present in feed (as feed additives), occur in sanitation products, or may result from deterioration of CAAP machinery and equipment. EPA has observed that many of the treatment systems used within the CAAP industry provide substantial reductions of most metals. Many of the metals present are readily adsorbed to solids and can be adequately controlled by controlling solids.

Most of the metals appear to be originating from the feed ingredients. Trace amounts of metals are added to feed in the form of mineral packs to ensure that the essential dietary nutrients are provided for the cultured aquatic animals. Examples of metals added as feed supplements include copper, zinc, manganese, and iron (Snowdon, 2003).

Estimated metals load reductions from in-scope facilities implementing the final rule are summarized in the table below. These load reductions were estimated as a function of TSS loads, using data obtained from four of the sampling episodes (Clear Springs–Box Canyon Facility, (Tetra Tech, 2001a); Harrietta Hatchery (Tetra Tech, 2002a), and Fins Technology (Tetra Tech, 2001b) and Huntsdale Fish Culture Station (Tetra Tech, 2003b)) performed for the proposed rule. For this analysis, EPA first assumed that non-detected sampled had half the concentration of the detection limit. From the sampling data, EPA calculated net TSS and metals concentrations at different points in the facilities. EPA then calculated metal to TSS ratios (in milligrams of metal/kilogram of TSS), based on net concentrations calculated above, and removed negative and zero ratios from the sample. Finally, basic sample distribution statistics were calculated to derive the relationship between TSS and each metal.

Estimated load reductions of PCBs from in-scope facilities were calculated as a percentage of TSS load reductions. Since the main source of PCBs at CAAP facilities is through fish feed, a conversion factor was calculated to estimate the amount of PCBs discharged per pound of TSS. EPA assumed that 90% of food fed was eaten, and that 90% of food eaten would be assimilated by the fish. By combining the amount of food materials excreted by fish (10% of feed consumed) with the 10% of food uneaten, EPA was able to partition the PCBs among fish flesh and aqueous and solid fractions. EPA estimated that 2 micrograms/gram[6] of feed would be contaminated with PCBs, and that 21% this load would be contained in the discharged TSS. Estimated loads of PCBs from CAAP facilities under this rule are presented below in Table 10.7−1.

EPA estimated the load of oxytetracycline discharged from in-scope CAAP facilities using data from EPA's Detailed Survey of the CAAP Industry and peer reviewed scientific literature. EPA first determined facility specific amounts of oxytetracycline used by each CAAP facility. For those facilities that reported using oxytetracycline, EPA evaluated their responses to the detailed survey to determine the amount, by weight, of medicated feed containing oxytetracycline and the concentration of the drug in the feed. EPA applied this conversion factor to the amount of oxytetracycline used at an individual

[6] 2 micrograms/gram feed is the FDA limit on PCB concentrations in fish feed.

facility coupled with the estimated load of TSS reduced by the regulation to estimate the facility level discharge of oxytetracycline in the solids. The facility level estimates were then multiplied by the appropriate weighting factors and summed across all facilities to determine the national estimate of pounds of oxytetracycline reduced from discharges as a result of the regulation.

**Table 10.7–1. Metals and Other Material Load Reductions Associated with TSS Reductions at In-Scope CAAP Facilities**

| *Pollutant* | *Total (lb)* | *Pollutant* | *Total (lb)* |
|---|---|---|---|
| TSS | 553,495 | Mercury | 0.03 |
| Aluminum | 395.84 | Molybdenum | 1.40 |
| Antimony | 0.25 | Nickel | 4.31 |
| Arsenic | 0.42 | Selenium | 1.48 |
| Barium | 49.63 | Silver | 0.11 |
| Beryllium | – | Thallium | 0.12 |
| Boron | 16.52 | Tin | 0.78 |
| Cadmium | 0.13 | Titanium | 5.40 |
| Chromium | 3.20 | Vanadium | 2.28 |
| Cobalt | 0.83 | Yttrium | 0.28 |
| Copper | 44.57 | Zinc | 457.60 |
| Iron | 1,298.57 | PCBs | 0.04 |
| Lead | 1.21 | Oxytetracycline | 1,030 |
| Manganese | 372.78 | | |

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# CHAPTER 11
# NON-WATER QUALITY ENVIRONMENTAL IMPACTS

Sections 304(b) and 306 of the Clean Water Act require EPA to consider non-water quality environmental impacts, including energy requirements, associated with effluent limitations guidelines and standards. In accordance with these requirements, EPA has considered the potential impacts of the regulation on solid waste generation, energy consumption, and air emissions. The estimates of these impacts for the concentrated aquatic animal production (CAAP) industry are summarized in Sections 11.1, 11.2, and 11.3.

## 11.1 SOLID WASTE

The regulatory option chosen for the final rule will reduce solid waste generation by approximately 2,300,000 pounds/year, mainly because feed management will reduce the solids loads entering the system. Solid wastes include sludge from sedimentation basins (primary settling) and from solids polishing technologies, such as microscreen filters. EPA assumed all solid wastes generated by the CAAP industry are nonhazardous. Federal and state regulations require CAAP facilities to manage solids to prevent release to the environment.

### 11.1.1 Sludge Characterization

Sludge harvested from settling basins, quiescent zones, or other solids capture technologies at CAAP facilities is similar to other types of animal manures. For example, Chen et al. (1996) provide a comprehensive review of the treatment and characteristics of CAAP sludge from recirculating systems. Table 11.1–1 shows the characteristics of sludge from a recirculating system that was captured from solids filter backwash after settling for 30 minutes. IDEQ (n.d.) also provides a summary of the nutrient content of fish manure, as shown in Table 11.1–2.

**Table 11.1–1. Characterization of CAAP Sludge**

| *Parameter* | *CAAP Sludge* | | |
|---|---|---|---|
| | *Range* | *Mean* | *Standard Deviation* |
| Total solids (TS) (%) | 1.4–2.6 | 1.8 | 0.35 |
| Total volatile solids (% of TS) | 74.6–86.6 | 82.2 | 4.1 |
| 5-day biochemical oxygen demand (mg/L) | 1,588–3,867 | 2,756.0 | 212.0 |
| Total ammonia nitrogen (N, mg/L) | 6.8–25.6 | 18.3 | 6.1 |
| Total kjeldahl nitrogen (as nitrogen, % of TS) | 3.7–4.7 | 4.0 | 0.5 |
| Total phosphorus (as phosphorus, % of TS) | 0.6–2.6 | 1.3 | 0.7 |
| pH | 6.0–7.2 | 6.7 | 0.4 |

Source: Reported in Chen et al., 1996.

**Table 11.1–2. Average Nutrient Content Measurements of Fish Manure from Various Treatment Systems**

| *Parameter* | *Raceways and Quiescent Zones* | *Settling Basins* | *Earthen Ponds* | *Dried Aged Manure* |
|---|---|---|---|---|
| % Total nitrogen | 7.06 | 4.18 | 0.86 | 1.01 |
| % Total phosphorus | 1.71 | 0.96 | 0.52 | NA |
| % Total potassium | 0.21 | 0.30 | 0.50 | NA |
| % Organic matter or volatile solids | 77.2 | 43.0 | 26.0 | 10.2 |

Source: Reported in IDEQ, n.d.
Note: NA = not available.

Naylor et al. (1999) compared fish manure with manure from beef, poultry, and swine. Overall, the nutrient composition of trout manure is similar to that of other animal manures (Table 11.1–3). Like livestock manure, the composition of fish manure is also highly variable due to differences in animal, age, feed, manure handling, and storage conditions.

**Table 11.1–3. Rainbow Trout Manure Compared to Beef, Poultry, and Swine Manures (Presented as Ranges on a Dry Weight Basis)**

| *Element* | *Fish* | *Beef* | *Poultry* | *Swine* |
|---|---|---|---|---|
| Nitrogen (%) | 2.04–3.94 | 1.90–7.8 | 1.3–14.5 | 0.6–10.0 |
| Phosphorus (%) | 0.56–4.67 | 0.41–2.6 | 0.15–4.0 | 0.45–6.5 |
| Potassium (%) | 0.06–0.23 | 0.44–4.2 | 0.55–5.4 | 0.45–6.3 |
| Calcium (%) | 3.0–11.2 | 0.53–5.0 | 0.71–14.9 | 0.4–6.4 |
| Magnesium (%) | 0.04–1.93 | 0.29–0.56 | 0.3–1.3 | 0.09–1.34 |

Source: Naylor et al., 1999.

### 11.1.2 Estimating Decreases in Sludge Collection

EPA estimates feed management will reduce raw loads of total suspended solids (TSS) within CAAP facilities by almost 500,000 pounds/year. After the final regulation is implemented, treatment technologies currently in place at CAAP facilities will capture about 276,000 fewer pounds of TSS each year than they do now because of the lower incoming loads. Table 11.1–4 shows the estimates of raw TSS loads and TSS captured in existing treatment technologies at CAAP facilities that would be in-scope for the final regulation. These estimates were calculated as part of the loadings analysis for the final regulatory option (see Chapter 10).

**Table 11.1–4. Impacts of the Final Regulatory Option on TSS**

| | *Raw TSS (lb/yr)* | *TSS Captured in Treatment Technologies (lb/yr)* | *TSS Released into the Nation's Waters (lb/yr)* |
|---|---|---|---|
| Baseline | 20,323,054 | 12,549,907 | 7,773,147 |
| Final regulatory option | 19,828,936 | 12,274,233 | 7,554,703 |
| Change from baseline | -494,118 | -275,674 | -218,444 |

EPA estimated the reduction in net sludge production, using the reduction in TSS and assuming sludge from CAAP facilities has a 12% solids content (IDEQ, n.d.):

Decrease in TSS captured in treatment technologies = 275,674 pounds/year

Decrease in sludge produced = 275,674 pounds/year * (1/0.12) = 2,297,284 pounds/year

EPA estimates that net sludge generation will decrease by approximately 2,300,000 pounds/year.

Net pen systems do not collect solids. Under general requirements for net pen systems, however, facilities must control discharges of solid waste and prevent discharge of water used for transport, which may contain blood and other wastes.

EPA assumed that collected solids will be land-applied as fertilizer at agronomic rates and therefore does not expect any adverse impacts due to solid waste to occur as a result of the regulation. For more information about the analysis, refer to Hochheimer and Escobar, 2004.

## 11.2 ENERGY

EPA estimates that implementing the final rule will result in a net decrease in energy consumption for CAAP facilities by approximately 43 kilowatt hours/year. The decrease is due to a reduction in the volume of sludge that will need to be pumped from raceways to solids settling ponds, therefore requiring less energy to pump it.

### 11.2.1 Estimating Decreases in Energy

EPA based its estimates for decreased energy requirements on estimated reductions in the volume of sludge generated due to implementation of the final regulation.

EPA calculated the decrease in net solids production based on the TSS load captured in treatment technologies and a 12% solids content in the sludge:

> Decrease in TSS captured in treatment technologies = 275,674 pounds/year
>
> Decrease in sludge pumped per year = 275,674 * (1/0.12) = 2,297,284 pounds/year

EPA then converted the pounds of sludge into a volume:

> 1 gallon = 8.4 pounds
>
> 275,674 pounds/year * (1 gallon/8.4 pounds) = 273,486 gallons/year

A ¾-horsepower Model 7CYG pump pumping at a rate of 60 gallons/minute would take 76 hours to pump the volume (the annual reduction in net sludge production):

> 273,486 gallons * (1/60 gallons/minute) = 4,558 minutes
>
> 4,558 minutes * (1 hour/ 60 minutes) = 76 hours

EPA then estimated the decrease in energy consumption to be 42.5 kilowatt hours/year:

> 0.75 horsepower * 746 watts/horsepower * 76 hours * 1 watt/1000 kilowatts = 42.5 kilowatt hours

### 11.2.2 Energy Summary

EPA estimates that implementing this rule will result in a net decrease in energy consumption for some CAAP facilities. The decrease is based on electricity currently used to pump sludge from wastewater settling units that would no longer need to be pumped under the final regulatory option.

EPA does not expect any adverse impacts to occur as a result of the decreased energy requirements for the regulation. For more information about the analysis, refer to Hochheimer and Escobar, 2004.

## 11.3 AIR EMISSIONS

EPA estimates that implementing the final rule will result in a net decrease of approximately 2,300 pounds/year in air emissions due to the volatilization of ammonia in solids generated at CAAP facilities.

Potential sources of air emissions from CAAP facilities include primary settling operations (e.g., settling basins and lagoons) and the land application of manure. Because the majority of emissions come from land application, EPA only estimated air emissions from land application of sludge.

CAAP sludge emits gases when it is spread on land as fertilizer. Air emissions are primarily generated from the volatilization of ammonia at the point the material is applied to land (Anderson, 2000). Additional emissions of nitrous oxide are liberated from agricultural soils when nitrogen applied to the soil undergoes nitrification and denitrification. Loss through denitrification depends on the oxygen levels of the soil to which manure is applied. Low oxygen levels, resulting from wet, compacted, or warm soil, increase the amount of nitrate-nitrogen released to the air as nitrogen gas or nitrous oxide (OSUE, 2000). A study by Sharpe and Harper (1997), which compared losses of ammonia and nitrous oxide from the sprinkler irrigation of swine effluent, concluded that ammonia emissions made a larger contribution to airborne nitrogen losses. Data for the CAAP industry are insufficient to quantify air emission impacts from the land application of manure; therefore, this analysis uses available information from similar industries and focuses on the volatilization of nitrogen as ammonia. The emission of other constituents is expected to be less significant.

### 11.3.1 Application Rate

The application rate affects the volatilization rate—if the amount of manure applied causes significant buildup of material on the field surface, causing a mulching effect, then the volatilization rate decreases. For the purposes of this analysis EPA assumed that the CAAP industry applies manure at agronomic rates or lower; applying at agronomic rates will not cause mulching.

### 11.3.2 Application Method

Manure application methods practiced by the CAAP industry include irrigation, surface application, and subsurface injection. EPA observed that applying solids as fertilizer for cropland at agronomic rates is a common industry practice. When agricultural land is adjacent to a CAAP facility, solids can be vacuumed directly from quiescent zones into a sprinkler system that land-applies the biosolids and water (IDEQ, n.d.).

Significant differences in the volatilization rate of ammonia result from the method used to apply manure (see Table 11.3–1). When manure is sprinkler-irrigated, a greater surface area from which the ammonia can volatilize is available, so the volatilization rate will be higher than from smaller surface areas.

**Table 11.3–1. Percent of Nitrogen Volatilizing as Ammonia from Land Application**

| *Application Method* | | *% Loss* [a] |
|---|---|---|
| Surface application | Broadcast (solid) | 15–30 |
| | Broadcast (liquid) | 10–25 |
| Subsurface injection | Broadcast (solid, immediate incorporation) | 1–5 |
| | Broadcast (liquid, immediate incorporation) | 1–5 |
| | Knifing (liquid) | 0–2 |
| Irrigation | Sprinkler irrigation (liquid) | 15–40 |

Source: MWPS, 1983.

[a] Percent of nitrogen applied that is lost within 4 days of application.

EPA assumed the final regulation would not change the method of land application used by any CAAP facilities. Based on this assumption, no significant change in the rate at which ammonia volatilizes is expected.

### 11.3.3 Quantity of Animal Waste

The movement of waste off-site changes the location of the ammonia released but not the quantity released. Land application is a common solid waste disposal method in the CAAP industry. Although the final regulatory option does not require land application of manure, for the purposes of estimating the maximum possible amount of emissions EPA assumed all captured solids would be land-applied. Because the final regulation is expected to decrease the amount of solid waste collected from CAAP facilities, the amount of ammonia released as air emissions is expected to decrease since the quantity of waste applied to cropland will decrease.

### 11.3.4 Calculation of Emissions

EPA estimated the decrease in ammonia emissions resulting from the implementation of the final regulation. The Agency assumed the ammonia content of solid waste from CAAP facilities was approximately 2.83% (Naylor et al., 1999). A factor of 30% was chosen as a conservative (high) estimate of the volatilization rate of ammonia from solids that are land applied. Table 11.3–2 shows estimates for the amount of solids generated, amount of ammonia contained in the solids, and the amount of amount that volatilizes before and after the regulation is implemented.

EPA calculated the ammonia content of the solid waste from CAAP facilities using the following equation:

Ammonia content = amount of solids collected by CAAP facilities * 2.83%

EPA used the following equation to calculate the ammonia volatilized during land application of the solids:

Ammonia volatilization = ammonia content * 30.0%

**Table 11.3–2. Ammonia Volatilization from CAAP Solids**

| | *Solids Collected (lb/yr)* | *Ammonia in Solids Collected (lb/yr)* | *Ammonia Volatilized (lb/yr)* |
|---|---|---|---|
| Baseline | 12,549,907 | 355,162 | 106,549 |
| Post-regulation | 12,274,233 | 347,361 | 104,208 |
| Change from baseline | -275,674 | -7,801 | -2,341 |

EPA does not expect any adverse air impacts to occur as a result of the final regulation. For more information about the analysis, refer to Hochheimer and Escobar, 2004.

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# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AAP | aquatic animal production |
| ADEM | Alabama Department of Environmental Management |
| ADFG | Alaska Department of Fish and Game |
| AETF | Aquaculture Effluents Task Force (JSA) |
| AFS | American Fisheries Society |
| APHIS | Animal and Planet Health Inspection Service (USDA) |
| BAT | Best Available Technology Economically Achievable |
| BCT | Best Control Technology for Conventional Pollutants |
| BGD | bacterial gill disease |
| BMPs | best management practices |
| BOD | biochemical oxygen demand |
| $BOD_5$ | biochemical oxygen demand measured over a 5-day period |
| BPJ | best professional judgment |
| BPT | Best Practicable Control Technology |
| CAAP | concentrated aquatic animal production |
| CAPDET | Computer-Assisted Procedure for the Design and Evaluation of Wastewater Treatment |
| CBI | Confidential Business Information |
| C-$BOD_5$ | carbonaceous biochemical oxygen demand measured over a 5-day period |
| CCVD | channel catfish virus disease |
| CFR | Code of Federal Regulations |
| CITES | Convention on International Trade of Endangered Species of Wild Fauna and Flora |
| COD | chemical oxygen demand |

| | |
|---|---|
| CTSA | Center for Tropical and Subtropical Aquaculture |
| CWA | Clean Water Act |
| CZMA | Coastal Zone Management Act |
| DMR | Discharge Monitoring Report |
| DO | dissolved oxygen |
| EEZ | Exclusive Economic Zone |
| ELGs | Effluent Limitations Guidelines |
| ERM | enteric redmouth |
| ERS | Economic Research Service (USDA) |
| ESC | enteric septicemia in catfish |
| FAO | Food and Agriculture Organization (United Nations) |
| FCR | feed conversion ratio |
| FDA | Food and Drug Administration |
| FDACS | Florida Department of Agriculture and Consumer Services |
| FDF | fundamentally different factor |
| FFS | full-flow settling |
| FR | Federal Register |
| FTE | full-time equivalent |
| HACCP | Hazard Analysis and Critical Control Points |
| HCG | human chorionic gonadotropin |
| ICR | Information Collection Request |
| IDEQ | Idaho Division of Environmental Quality |
| IHHN | infectious hypodermal and hematopoietic necrosis |
| INAD | investigational new animal drug |
| IPNV | infectious pancreatic necrosis virus |
| IRFA | Initial Regulatory Flexibility Analysis |
| ISA | infectious salmon anemia |
| JSA | Joint Subcommittee on Aquaculture |

| | |
|---|---|
| LTA | long-term average |
| LRP | low regulatory priority |
| MAS | motile *Aeromonas* septicemia |
| MDA | Maryland Department of Agriculture |
| MEPA | Massachusetts Environmental Policy Act |
| ML | minimum limit |
| MPRSA | Marine Protection Research and Sanctuaries Act |
| NAHMS | National Animal Health Monitoring System |
| NAICS | North American Industry Classification System |
| NASAC | National Association of State Aquaculture Coordinators |
| NASS | National Agricultural Statistics Service (USDA) |
| NMFS | National Marine Fisheries Service (Department of Commerce) |
| NOAA | National Oceanic and Atmospheric Administration (Department of Commerce) |
| NODA | Notice of Data Availability |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service (USDA) |
| NRDC | Natural Resources Defense Council |
| NSPS | New Source Performance Standards |
| NSTC | National Science and Technology Council |
| NTTA | National Technology Transfer and Advancement Act |
| NTU | nephelometric turbidity units |
| NWPCAM | National Water Pollution Control Assessment Model |
| NWQI | non-water quality impact |
| OLS | offline settling |
| OLSB | offline settling basin |
| O&M | operation and maintenance |
| OMB | Office of Management and Budget |
| PCB | polychlorinated biphenyl |

| | |
|---|---|
| PCS | Permit Compliance System |
| PGD | proliferative gill disease |
| POC | Pollutants of Concern |
| POTW | publicly owned treatment works |
| PSES | Pretreatment Standards for Existing Sources |
| PSNS | Pretreatment Standards for New Sources |
| PVC | polyvinyl chloride |
| QAPP | Quality Assurance Project Plan |
| QZ | quiescent zone |
| R&D | Research and Development |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RFA | Regulatory Flexibility Act |
| RHA | Rivers and Harbors Act |
| SAL | Special Activity License |
| SAP | Sampling and Analysis Procedures |
| SBA | Small Business Administration |
| SBAR | Small Business Advocacy Review Panel |
| SBREFA | Small Business Regulatory Enforcement Fairness Act of 1996 |
| SCC | Sample Control Center |
| SEQR | State Environmental Quality Review |
| SER | Small Entity Representative |
| SIC | Standard Industrial Classification |
| SIU | Significant Industrial User |
| SPF | specific pathogen-free |
| SPR | specific pathogen-resistant |
| SRAC | Southern Regional Aquaculture Center |
| SS | settleable solids |
| TAN | total ammonia nitrogen |

| | |
|---|---|
| TBT | tributyltin |
| TCI | The Catfish Institute |
| TDS | total dissolved solids |
| TKN | total Kjeldahl nitrogen |
| TL | total length |
| TN | total nitrogen |
| TOC | total organic carbon |
| TP | total phosphorus |
| TS | total solids |
| TSS | total suspended solids |
| TSV | taura syndrome virus |
| TVS | total volatile solids |
| USDA | United States Department of Agriculture |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey (Department of the Interior) |
| USFWS | United States Fish and Wildlife Service (Department of the Interior) |
| USTFA | United States Trout Farmer's Association |
| UV | ultraviolet |
| VDEQ | Virginia Department of Environmental Quality |
| VHS | viral hemorrhagic septicemia |
| WDF | Washington Department of Fisheries |
| WDOE | Washington Department of Ecology |
| WSSV | white spot syndrome virus |
| YHV | yellow head virus |

# Glossary

**Aeration:** The process of bringing air into contact with a liquid by one or more of the following methods: (1) spraying the liquid into the air, (2) bubbling air through the liquid, and (3) agitating the liquid to promote absorption of oxygen through the air-liquid interface.

**Aerobic:** Having or occurring in the presence of free oxygen.

**Agronomic rates:** The land application of animal wastes at rates of application that provide the crop or forage growth with needed nutrients for optimum health and growth.

**Algal bloom:** Sudden spurts of algal growth, which can affect water quality adversely and indicate potentially hazardous changes in local water chemistry.

**Aliquot:** A measured portion of a sample taken for analysis. One or more aliquots make up a sample.

**Anadromous:** Describes fish born in freshwater, descending into the sea to grow to maturity, and then returning to spawn in freshwater rivers and streams.

**Anaerobic:** Characterized by the absence of molecular oxygen, or capable of living and growing in the absence of oxygen, such as *anaerobic bacteria*.

**Analytes:** Chemical constituents analyzed as part of the aquatic animal production industry sampling episodes.

**Androgens:** Hormones used to invert the sex of female fry.

**Antifoulant:** Substance used to retard the growth of marine organisms on an object placed in the underwater marine environment.

**Aquaculture:** The production of aquatic plants and animals under controlled or semicontrolled conditions.

**Aquatic animal pathogen:** An organism that can cause disease outbreaks in aquatic animals.

**Aquatic animal production:** The production of aquatic animals under controlled or semicontrolled conditions.

**Baffle:** A device (such as a plate, wall, or screen) to deflect, check, or regulate the flow of water in a raceway.

**Benthic monitoring:** Monitoring conducted to ensure that degradation is not occurring under or around net pens.

**Best Available Technology Economically Achievable (BAT):** Technology-based standard established by the Clean Water Act (CWA) as the most appropriate means available on a national basis for controlling the direct discharge of toxic and nonconventional pollutants to navigable waters. BAT effluent limitations guidelines, in general, represent the best existing performance of treatment technologies that are economically achievable within an industrial point source category or subcategory.

**Best Control Technology for Conventional Pollutants (BCT):** Technology-based standard for the discharge from existing industrial point sources of conventional pollutants including BOD, TSS, fecal coliform, pH, oil and grease. The BCT is established in light of a two-part "cost reasonableness" test, which compares the cost for an industry to reduce its pollutant discharge with the cost to a POTW for similar levels of reduction of a pollutant loading. The second test examines the cost-effectiveness of additional industrial treatment beyond BPT. EPA must find limits, which are reasonable under both tests before establishing them as BCT.

**Best management practice (BMP):** A practice or combination of practices found to be the most effective, practicable (including economic and institutional considerations) means of preventing or reducing the amount of pollution generated.

**Best Practicable Control Technology Currently Available (BPT):** The first level of technology-based standards established by the CWA to control pollutants discharged to waters of the United States. BPT effluent limitations guidelines are generally based on the average of the best existing performance by plants within an industrial category or subcategory.

**Biochemical oxygen demand (BOD):** An indirect measure of the concentration of biodegradable substances present in an aqueous solution. Determined by the amount of dissolved oxygen required for the aerobic degradation of the organic matter at 20 °C. $BOD_5$ refers to the oxygen demand for the initial 5 days of the degradation process.

**Biocide:** Products added to other materials (typically liquids) to protect the other material from biological infestation and growth. Examples are well drilling fluid additives, cooling tower algaecides, products called slimicides, etc. The size of the biological organism a biocide controls is usually limited to single cell organisms and microscopic multicell organisms.

**Biomass:** All of the living material in a given area.

**Bivalves:** Animals characterized by a soft body enclosed by two hard shells or valves. The valves are attached at a hinge and are held shut by a strong muscle.

**Brackish water:** Mixed fresh and salt water.

**Broodstock:** A sexually mature group of a cultured species maintained solely for the production of eggs.

**Byssal threads:** Strong threadlike material used by some mussels to attach to their surroundings.

**Carotenoids:** Yellow or red pigments found in animal fat and some plants.

**Chemical:** Any substance that is added to a concentrated aquatic animal production facility to maintain or restore water quality for aquatic animal production and that might be discharged to waters of the United States.

**Chemical oxygen demand (COD):** A measure of the oxygen equivalent of the portion of organic matter that can be oxidized by a strong chemical oxidizing agent. This measure gives a better estimate of the total oxygen demand (as compared to BOD).

**Clean Water Act (CWA):** The Clean Water Act is an act passed by the U.S. Congress to control water pollution. It was formerly referred to as the Federal Water Pollution Control Act of 1972 or Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), 33 U.S.C. 1251 et. seq., as amended by: Public Law 96-483; Public Law 97-117; Public Laws 95-217, 97-117, 97-440, and 100-04.

**Cohort:** A group of like-species aquatic animals born in the same year.

**Concentrated aquatic animal production (CAAP) facility:** A hatchery, fish farm, or other facility that contains, grows, or holds aquatic animals in either of the following categories, or that the Director[1] designates as such on a case-by-case basis, and must apply for a National Pollutant Discharge Elimination System permit:

A. Coldwater fish species or other coldwater aquatic animals including, but not limited to, the Salmonidae family of fish (e.g., trout and salmon) in ponds, raceways, or other similar structures that discharge at least 30 days per year but does not include (1) facilities that produce less than 9,090 harvest weight kilograms (approximately 20,000 pounds) of aquatic animals per year and (2) facilities that feed less than 2,272 kilograms (approximately 5,000 pounds) of food during the calendar month of maximum feeding.

B. Warmwater fish species or other warmwater aquatic animals including, but not limited to, the Ameiuridae, Cetrachidae, and the Cyprinidae families of fish (e.g., respectively, catfish, sunfish, and minnows) in ponds, raceways, or similar structures that discharge at least 30 days per year, but does not include (1) closed ponds that discharge only during periods of excess runoff or (2) facilities that produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) of aquatic animals per year.

[1] The Regional Administrator or State Director, as the context requires, or an authorized representative. When there is no approved state program, and there is an EPA administered program, Director means the Regional Administrator. When there is an approved state program, "Director" normally means the State Director.

**Confidential Business Information (CBI):** Any information in any form received by EPA or its approved contractors from any person, firm, partnership, corporation, association, or local, state, or federal agency, or foreign government, that contains trade secrets or commercial or financial information; has been claimed as CBI by the person submitting it; and has not been determined to be non-CBI under the procedures in 40 CFR Part 2.

**Consent decree:** A legal document, approved by a judge, that formalizes an agreement reached between EPA and potentially responsible parties (PRPs) through which PRPs will conduct all or part of a cleanup action at a Superfund site, cease or correct actions or processes that are polluting the environment, or otherwise comply with EPA-initiated regulatory enforcement actions to resolve the contamination at the Superfund site involved. The consent decree describes the actions PRPs will take and may be subject to a public comment period.

**Conventional pollutants:** Pollutants typical of municipal sewage, and for which municipal secondary treatment plants are typically designed; defined by Federal Regulation [40 CFR 401.16] as BOD, TSS, fecal coliform bacteria, oil and grease, and pH.

**Daily discharge:** The discharge of a pollutant measured during any 24-hour period that reasonably represents a calendar day for purposes of sampling. For pollutants with limitations expressed in units of mass, the daily discharge is calculated as the total mass of the pollutant discharged during the day. For pollutants with limitations expressed in other units of measurement (e.g., concentration) the daily discharge is calculated as the average measurement of the pollutant throughout the day (40 CFR 122.2).

**Denitrification:** The chemical or biological reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen ($N_2$) or as an oxide of nitrogen ($N_2O$).

**Direct discharger:** A facility that discharges or may discharge treated or untreated wastewaters into waters of the United States.

**Dissolved oxygen (DO):** Oxygen dissolved in water by diffusion from the atmosphere and through the release into the water as a by-product of photosynthesis in aquatic plants; a water quality parameter.

**Drug:** Any substance, including medicated feed, that is added to a production facility to maintain or restore animal health and that subsequently might be discharged to waters of the United States.

**Effluent limitations guideline (ELGs):** Under the Clean Water Act, section 502(11), any restriction, including schedules of compliance, established by a state or the Administrator on quantities, rates, and concentrations of chemical, physical, biological, and other constituents that are discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean (Clean Water Act sections 301(b) and 304(b)).

**End-of-pipe treatment practices:** Technologies such as settling basins or microscreens that reduce discharge of pollutants after they have formed.

**Escapement:** The release of aquatic animals from a production facility to waters of the United States.

**Eutrophication:** A process in which the addition of nutrients (primarily nitrogen and phosphorus) to water bodies stimulates algal growth. This is a natural process, but it can be greatly accelerated by human activities.

**Excess feed:** Feed that is added to a production system, is not consumed, and is not expected to be consumed by the aquatic animals.

**Existing source:** For a categorical industrial user, any source of discharge, the construction or operation of which commenced prior to the publication of proposed categorical pretreatment standards under Section 307 of the Clean Water Act.

**Facility:** All contiguous property and equipment owned, operated, leased, or under the control of the same person or entity.

**Feed conversion ratio (FCR):** A measure of feeding efficiency that is calculated as the ratio of the weight of feed applied to the weight of the fish produced.

**Finfish:** A term used to delineate bony fishes from other aquaculture species such as crustaceans and molluscs.

**Fingerling:** Juvenile fish that are typically 2 to 6 inches long or weigh 2 to 60 pounds per 1,000 fish.

**Floating or bottom aquaculture system:** A system used for the production of molluscs and shellfish. The cultured species can be grown attached to or lodged in the substrate or suspended from strings or cages.

**Flow-through system:** A system designed for a continuous water flow to waters of the United States through chambers used to produce aquatic animals. Flow-through systems typically use either raceways or tank systems. Raceways are fed by nearby rivers or springs and are typically long, rectangular chambers at or below grade, constructed of earth, concrete, plastic, or metal. Tank systems are similarly fed and concentrate aquatic animals in circular or rectangular tanks above grade. The term does not include net pens.

**Foodfish:** Fish for human consumption, typically over 0.75 pound.

**Forage crop:** Crop planted to provide food for crawfish when the ponds are flooded in the fall; rice is a common forage crop.

**Frequency factors:** The regional compliance of animal feeding operations with best management practices associated with a nutrient management plan, facility upgrades, or strategies to reduce excess nutrients.

**Fry:** Young fish that are typically under 2 inches long or weigh less than 2 pounds per 1,000 fish.

**Groundwater:** Water in a saturated zone or stratum beneath the surface of land or water.

**Herbivore:** An animal that feeds on plants.

**Indirect discharger:** A facility that discharges or may discharge wastewaters into a publicly owned treatment works.

**Loading density:** The average stocking density of the culture species within the production system at maximum production levels.

**Long-term average (LTA):** For purposes of the effluent guidelines, average pollutant levels achieved over a period of time by a facility, subcategory, or technology option. LTAs were used in developing the effluent limitations guidelines and standards in the proposed regulation.

**Maximum monthly discharge limitation:** The highest allowable average of "daily discharges" over a calendar month, calculated as the sum of all "daily discharges" measured during the calendar month divided by the number of "daily discharges" measured during the month.

**Microbial decomposition:** The breakdown of complex molecules in either plant or animal matter by bacteria and fungi.

**Minimum level:** The level at which an analytical system gives recognizable signals and an acceptable calibration point.

**National Pollutant Discharge Elimination System (NPDES) permit:** A permit to discharge wastewater into waters of the United States issued under the National Pollutant Discharge Elimination System, authorized by section 402 of the Clean Water Act.

**National Pollutant Discharge Elimination System (NPDES) program:** The NPDES program authorized by sections 307, 318, 402, and 405 of the Clean Water Act. It applies to facilities that discharge wastewater directly to U.S. surface waters.

**Navigable waters:** Traditionally, waters sufficiently deep and wide for navigation by all, or specified vessels; such waters in the United States come under federal jurisdiction and are protected by certain provisions of the Clean Water Act.

**Net pen system:** A stationary, suspended, or floating system of nets or screens in open marine or estuarine waters of the United States. Net pen systems typically are located along a shore or pier or may be anchored and floating offshore. Net pens and cages rely on tides and currents to provide a continual supply of high-quality water to animals in production.

**New Source Performance Standards (NSPS):** Technology-based standards for facilities that qualify as new sources under 40 CFR 122.2 and 40 CFR 122.29. Standards consider that the new source facility has an opportunity to design operations to more effectively control pollutant discharges.

**Nonconventional pollutants:** Pollutants that are neither conventional pollutants nor priority pollutants listed at 40 CFR 401.15 and Part 423, Appendix A.

**Nonnative aquatic animal species:** An individual, group, or population of species found (1) to be outside its historical or native geographic range and (2) to threaten native aquatic biota determined and identified by the appropriate state authority or U.S. Fish and Wildlife Service. This term excludes species raised for stocking by public agencies.

**Non-water quality environmental impacts:** Deleterious aspects of control and treatment technologies applicable to point source category wastes, including, but not limited to, air pollution, noise, radiation, sludge, and solid waste generation, and energy used.

**North American Industry Classification System (NAICS):** System developed jointly by the United States, Canada, and Mexico to provide new comparability in statistics about business activity across North America.

**Ocean ranching:** The process of rearing smolts and releasing them into the wild (the ocean), from which they are later harvested.

**Omnivore:** An animal that feeds on both animal and vegetable substances.

**Outfall:** The mouth of the conduit drains and other conduits from which a facility effluent discharges into receiving waters.

**Pass through:** A discharge which exits the POTW into waters of the United States, or state of Washington, in quantities or concentrations which, alone or in conjunction with a discharge or discharges from other sources, is a cause of a violation of any requirement of the city's NPDES permit including an increase in the magnitude or duration of a violation.

**Pathogen:** A predatory or parasitic organism present in water or aquatic animals that, when discharged to waters of the United States, threatens disease in aquatic animals or humans.

**Pelagic:** Of, relating to, or living or occurring in the open sea.

**Permitting authority:** The agency authorized to administer the National Pollutant Discharge Elimination System permitting program in a state or territory.

**Phytoplankton:** Microscopic plants that serve as the plant food base for other organisms (zooplankton and larger animals) that are then consumed by fish. Phytoplankton is often referred to as the base of the food chain.

**Planktonic:** Relating to, being, or characteristic of plankton, a wide variety of plant and animal organisms that float or drift freely in water.

**Point source:** Any discernible, confined, and discrete conveyance from which pollutants are or may be discharged. See Clean Water Act section 502(14).

**Pollutant load:** The amount of a specific pollutant in a wastewater stream measured in mass units (pounds, kilograms).

**Pollutants of concern (POCs):** Pollutants commonly found in concentrated aquatic animal production facilities wastewaters. Generally, a chemical is considered a POC if it is detected in untreated process wastewater at five times a baseline value in more than 10 percent of the samples.

**Pond system:** An impoundment of water used for the production of aquatic animals. Pond systems are the most widely used production system in the aquatic animal production industry.

**Pretreatment standards for existing sources (PSES) of indirect discharges:** Under section 307(b) of the Clean Water Act, standards applicable (for this rule) to indirect dischargers that commenced construction prior to promulgation of the final rule.

**Pretreatment standards for new sources (PSNS):** Under section 307(c) of the Clean Water Act, standards applicable to indirect dischargers that commence after promulgation of the final rule.

**Protozoa:** Unicellular organisms that live individually or in small groups. Many kinds of protozoa are harmful to aquaculture animals. In some aquaculture systems, parasitic protozoa are the most important disease agents.

**Publicly owned treatment works (POTW):** A treatment works as defined by section 212 of the Clean Water Act, which is owned by a state or municipality (as defined by section 502(4) of the Clean Water Act). This definition includes any devices and systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature. It also includes sewers, pipes, and other conveyances, only if they convey wastewater to a POTW. The term also means the municipality, as defined in section 502(4) of the Clean Water Act, that has jurisdiction over the indirect discharges to and the discharges from such a treatment works.

**Quiescent zones:** Solids-collection zones placed at the end of a raceway tank to collect the settleable solids swept out of the fish-rearing area. They are the primary means for solids removal in flow-through raceways.

**Raceways:** Culture units in which water flows continuously, making a single pass through the unit before being discharged; these systems are also referred to as flow-through systems.

**Resource Conservation and Recovery Act (RCRA) of 1976:** (42 U.S.C. sections 6901 et seq.). RCRA regulates the generation, treatment, storage, disposal, or recycling of solid and hazardous wastes.

**Recirculating system:** A system that filters and reuses water in which aquatic animals are produced prior to discharge. Recirculating systems typically use tanks, biological or mechanical filtration, and mechanical support equipment to maintain high-quality water to produce aquatic animals.

**Seine:** A net with weights attached to the bottom and floats on the top that can be pulled from each end to enclose fish during harvest.

**Settleable solids:** Material heavy enough to sink to the bottom of a wastewater treatment tank.

**Sludge:** Settled sewage solids combined with varying amounts of water and dissolved materials that are removed from sewage by screening, sedimentation, chemical precipitation, or bacterial digestion.

**Smolt:** A young salmon ready for life in a saltwater environment.

**Sole proprietorship:** An unincorporated business owned by one person, who is entirely liable for all business debts. A sole proprietor files either IRS Schedule C (profit or loss from a business) or Schedule F (profit or loss from farming). This Schedule becomes part of the owner's Form 1040 (personal tax form).

**Spawning ground:** A specific site where fish lay their eggs.

**Standard industrial classification (SIC):** A numerical categorization system used by the U.S. Department of Commerce to catalogue economic activity. SIC codes refer to the products, or group of products, produced or distributed, or to services rendered by an operating establishment. SIC codes are used to group establishments by the economic activities in which they are engaged. SIC codes often denote a facility's primary, secondary, tertiary, etc. economic activities.

**Stockers:** Fish used for stocking public or private fishing areas that are typically more than 6 inches long or weigh 60 to 750 pounds per 1,000 fish.

**Total dissolved solids (TDS):** All material that passes the standard glass river filter; now called total filtrable residue. Term is used to reflect salinity.

**Total Kjeldahl nitrogen (TKN):** Water and wastewater analyte that indicates the sum of organic nitrogen and ammonia nitrogen in the matrix analyzed.

**Total nitrogen:** Sum of nitrate/nitrite and total Kjeldahl nitrogen.

**Total organic carbon (TOC):** The fraction of carbon covalently bound to organic molecules within a sample.

**Total suspended solids (TSS):** The weight of particles that are suspended in water. Suspended solids in water reduce light penetration in the water column, can clog the gills of fish and invertebrates, and are often associated with toxic contaminants because organics and metals tend to bind to particles. Differentiated from total dissolved solids by a standardized filtration process whereby the dissolved portion passes through the filter.

**Total volatile solids (TVS):** Those solids in water or other liquids that are lost on ignition of the dry solids at 550 °C.

**Turbidity:** A measure of light penetration in water. Produced by dissolved and suspended substances. The more dense these substances, the higher the turbidity.

**Volatile compound:** Any substance that evaporates readily.

**Wastewater treatment:** The processing of wastewater by physical, chemical, biological, or other means to remove specific pollutants from the wastewater stream, or to alter the physical or chemical state of specific pollutants in the wastewater stream. Treatment is performed for discharge of treated wastewater, recycle of treated wastewater to the same process that generated the wastewater, or reuse of the treated wastewater in another process.

**Zooplankton:** The animal portion of plankton, which makes up the primary and secondary food chains in most bodies of water and is generally passively floating, or weakly swimming, minute animal or plant life. Zooplankton generally feed on phytoplankton. In turn, zooplankton provide an important food source for larval fish and shrimp in aquaculture ponds.

# APPENDIX A
# SURVEY DESIGN AND CALCULATION OF NATIONAL ESTIMATES

# Appendix A
# Survey Design and Calculation of National Estimates

EPA has collected information from aquatic animal production by using a two-phase sample design with a questionnaire in each phase. A two-phase[1] sample design is a standard survey statistic technique (see, for example, Cochran (1977) or Kish (1965)). In the first phase of this design, information is collected from every unit (e.g., facility) in the sample. In the second phase, detailed information is collected from each unit in a second, smaller, sample. Typically, the first phase sample is used to classify the population for the second phase sample and this second sample is selected from the units in the first sample. Statistical inference can be made using the information from the second phase alone or in some combination of the first and second phases.

In the first phase conducted in August 2001, EPA sent a short screener questionnaire, entitled "Screener Questionnaire for the Aquatic Animal Production Industry" ("screener questionnaire," USEPA, 2001) to a list of 5939 possible aquatic animal production (AAP) facilities. This sample frame (list) is discussed in Section A.1 below. The screener questionnaire consisted of eleven questions to solicit general facility information, including confirmation that the facility was engaged in aquatic animal production, species and size category produced, type of production system, wastewater disposal method, and the total production at the facility in the year 2000. Section A.2 describes the census conducted in this first phase and the data analysis of the responses.

In the second phase conducted in June 2002, EPA selected 263 screener questionnaire respondents to receive the detailed questionnaire, "Detailed Questionnaire for the Aquatic Animal Production Industry," ("detailed questionnaire," USEPA, 2002). EPA designed this second questionnaire to collect detailed site-specific technical and financial information. The detailed questionnaire is divided into three parts. The first two parts collect general facility, technical, and cost data. The third part of the detailed questionnaire elicits site-specific financial and economic data. EPA sent each facility only the portions of each part that were relevant to the operations reported in the screener questionnaire. Section A.3 describes the sample selection criteria and estimation procedures from the responses from this second phase.

## A.1 SAMPLE FRAME

In 1998, the US Department of Agriculture (USDA) identified 4,028 aquaculture facilities in its Census of Aquaculture ("USDA Census"). Because their database was confidential and thus not available, EPA constructed a sampling frame from alternative sources consisting of data received from Dun & Bradstreet, augmented with supplemental sources of facilities. Attachment A-1 to this appendix summarizes the differences between the sample frames and other aspects of the two questionnaires.

EPA developed its initial list of facilities from the February 2001 version of the Dun & Bradstreet (D&B) database. D&B provided a list of 2,025 facilities whose primary,

[1] Some textbooks and journal articles refer to two-phase sampling as >double sampling.

secondary, or tertiary SIC codes related to AAP. The SIC codes included 0273 (animal aquaculture), 0279 (animal specialties), and 0921 (fish hatcheries and preserves). EPA found that the D&B database only contained half as many facilities as the USDA Census, 2,025 compared to 4,028. Although the size of the industry may have changed between 1998 (USDA Census) and 2001 (D&B), it was more likely that D&B did not include some facilities identified by the USDA. EPA then examined the total revenue of facilities in the D&B database, and found that it exceeded that of the Census by about 10%. Because both estimates of total revenue were about $1.0 billion, EPA concluded that the facilities not included in the D&B database probably were quite small.

In order to identify AAP facilities not identified by the D&B database, a number of secondary sources were identified and utilized. About 4,000 facilities were identified from supplemental sources. These included:

- An initial list of 2,241 facilities supplied by 24 state agencies such as Departments of Agriculture or Environmental Protection. These data varied considerably in quality and utility, including some lists that were incomplete and/or out of date.
- U.S. Fish and Wildlife Service
- The Internet, associations, and trade journals.
- EPA used its own list of 288 farms from which a subset of 121 new listings in 28 states was identified. EPA developed this list of 288 farms from its Permit Compliance System (PCS), Discharge Monitoring Reports (DMR), and other permit information. In addition, some additional facilities were added from a list of 30 facilities on EPA's site visit list.
- The frame was augmented with a list of public aquariums in the United States. These were identified largely through the Internet as well as data supplied by the American Zoo and Aquarium Association.

Identification and deletion of duplicate facilities (i.e., those appearing more than once on the list, perhaps with slightly different addresses or company names) was conducted both prior to and after mailing the questionnaires. In order to ensure that no active AAP facility would be inadvertently removed, only obvious duplicates were deleted prior to the mailing.

## A.2 SCREENER QUESTIONNAIRE (PHASE 1)

This section describes the screener questionnaire responses that were collected in Phase 1 of EPA's survey of the AAP industry. Section A.2.1 describes the sample design, which was a census of the industry, and the number of responses. Section A.2.2 describes the data analysis of the responses including the use of conversion factors; development of sample weights that adjust for non-response; and the estimation of national totals, national means, and their standard errors. While EPA has primarily relied on the Phase 2 data in developing the final rule, this Appendix describes Phase 1 because it was used to develop the proposed rule, and to select the Phase 2 sample.

### A.2.1 Sample Design: Census

In Phase 1, the screener questionnaires were mailed to all 5934[2] addresses on the frame. Because they were mailed to all facilities on the sample frame, the sample design for this phase is considered to be a 'census.' After the mailing, 53 unsolicited questionnaires were received that were not on the original mailing list. Many of these were from facilities that operated more facilities than the number of questionnaires that they received. In its data analyses and selection of the sample for the second phase, EPA considers these 53 facilities as if they were part of the original sample frame. Thus, the 'final' frame contained 5987 potential AAP facilities.

As of 8/8/02,[3] EPA had received 4199 completed,[4] 58 incomplete, and 75 blank questionnaires. EPA also had identified an additional 161 duplicate questionnaires (i.e., more than one questionnaire was sent to the same facility). For questionnaires returned by the delivery service, EPA attempted various data retrieval and searches to obtain a better mailing address. For 435 addresses, EPA was unsuccessful in finding better addresses, and thus, EPA assumed that these facilities did not exist (e.g., out of business). In addition, although they received a letter reminding them to return the questionnaire, 1064 facilities did not return their questionnaires and are considered to be 'non-respondents' in the statistical analysis presented in this appendix. (Five of the 1064 facilities returned a blank questionnaire and also are considered to be non-respondents.) Response rates can be calculated in various ways. One widely accepted method is to use the ratio of the number of returned questionnaires to the number of valid addresses. EPA was able to determine the number of valid addresses because the delivery service required recipients to sign a manifest. For the screener questionnaire, the number of valid addresses was 5552, that is, the remainder of the 5987 potential AAP facilities after subtracting the 435 addresses without a viable address. The response rate of 75.6 % is the ratio of the 4199 completed questionnaires to the 5552 valid addresses.

From the completed questionnaires, EPA identified 2329 facilities in the AAP industry. These facilities answered 'Yes' to question 1 which asked 'Do you produce (grow) aquatic animals (fish, shellfish, other aquatic animals) at this facility?'

### A.2.2 Data Analysis

Weighting the data allows inferences to be made about all eligible facilities, including those that did not respond to the questionnaire. Another advantage is that weighted

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[2] Elsewhere in this document and other record materials, EPA may have identified the total number of questionnaires as 5939; however, five were replacements of questionnaires with incomplete mailing labels. In some summaries, EPA includes the replacements as five new questionnaires.

[3] After this date, EPA received a small amount of additional screener information, which EPA reviewed and evaluated. However, because EPA primarily relied on data from the detailed questionnaire in developing the final rule, EPA did not incorporate the more recent screener information into the screener estimates presented in this appendix.

[4] The values in this appendix are upon a more recent version (8/8/02) of the screener database than the version used for Chapter 3. Thus, there are slight discrepancies between the values in that chapter and this appendix.

estimates have less biased variances than unweighted estimates (i.e., counts of the responses). Because of time constraints for the proposal, EPA was unable to incorporate these weighted results into its most analyses, such as economic achievability. However, EPA presented weighted results in Appendix A of the proposal TDD. These results also are provided in this appendix. This section presents its methodology for calculating the weighted results presented in Attachment A-3.

This section consists of three subsections. Section A.2.2.1 describes various conversion factors and their application in determining the biomass, predominant species, predominant production method, and total revenue at each facility. Section A.2.2.2 describes the sample weights that adjust for non-response. Section A.2.2.3 describes the application of these sample weights in developing national estimates (e.g., number of facilities with trout as their predominant species) and the standard errors of these estimates.

### *A.2.2.1 Use of Conversion Factors*

To simplify its data analyses, EPA determined the biomass, predominant species, and predominant production method for each facility, using various conversion factors in Attachment A-2. This section describes the use of the conversion factors and these determinations.

***Biomass***

For each size category, the screener questionnaire collected production in any of six units (pounds (live weight), number or count, live dry bushels, dozens, dollars sold, or other). To estimate the production at a facility, EPA converted all units into pounds using conversion factors from sources such as the USDA Census of Aquaculture, industry experts, internet sites about fish, and calls to aquaculture farms (see DCN 50070 in Section 10.3 of the proposal record). As shown in Tables A2.1 and A2.2 in Attachment A-2, the conversion factors depended on the species, the size category, and the reported units. When specific conversion factors were not available (for a minority of facilities), EPA used approximate conversion factors based on 1) the weight of food-size animals for the species, 2) an approximate weight ratio of food size to other size animals, and 3) approximate conversion factors from the reported unit into pounds. As an example of using the appropriate conversion factor in Table A2.1, if a facility produced 1,000 catfish of foodsize, the biomass of the catfish was calculated as

1,000 catfish x 1.5 pounds/catfish=1,500 pounds.

As another example, if a facility produced 1,000 whitefish of stocker size, the biomass was calculated using the conversion factor for whitefish of foodsize from Table A2.1 and the stocker size conversion factor from Table A2.2, as follows:

$1{,}000 \text{ whitefish}_{\text{stocker}} \times 2.5 \text{ pounds/whitefish}_{\text{foodsize}} \times 0.1418 \text{ whitefish}_{\text{foodsize}} / \text{whitefish}_{\text{stocker}} = 354.5$ pounds.

The *total biomass*, or total production, for a facility is the total weight in pounds across all size and species categories.

***Predominant Species***

To determine the predominant species, EPA calculated the biomass for each species reported by a facility. The species biomass was the total weight in pounds across all size categories for that species. EPA then selected the species with the largest biomass as the predominant species.

***Predominant Production Method***

In response to question 6 on the screener questionnaire, facilities could specify any of six different production methods (ponds, flow through systems, recirculating systems, net pens or cages, floating aquaculture, and other). However, the screener questionnaire requested species and production information separately from the production method. Thus, for facilities with multiple species, it was not possible to determine which production method was used for a particular species. Also, some facilities reported more than one production method. To assign a single production method to a facility's predominant species, EPA ordered the production methods from most common to least common among facilities with the same predominant species. Table A2.3 in Attachment A-2 presents this ordering of production methods. (As noted in the table, EPA used a slightly different ordering sequence for the data analyses presented in Attachment A-3, than it did for the sample selection for the detailed questionnaire.) As an example, *assume* a facility has catfish as the predominant species and uses both recirculating systems and flow through systems. From Table A2.3, the most common production method for facilities with catfish as the predominant species is ponds; however, ponds are not used at this facility. The second most common production method is flow through systems. Because this facility uses flow through systems, EPA would assume that these flow through systems are the predominant production method for catfish production at this facility.

***Total Revenue***

In response to question 5 of the screener questionnaire, facilities could report production in any of six units: pounds (live weight), number or count; live dry bushels; dozens; dollars sold; and other. Most facilities reported their total production in pounds, counts, or dollars. To convert the production units into dollars, EPA used the conversion factors in Table A2.4, in Attachment A-2, to estimate the number of facilities that would be subject to the proposed rule in three revenue classes: \$20,000-\$100,000; \$100,000-\$499,999, and >\$500,000.

As explained in the preamble to the proposed rule, in evaluating the screener questionnaire responses to question 5 (production), EPA used six production size categories that correspond with the revenue classifications used in the 1998 Census of Aquaculture (i.e., \$1,000-\$24,999; \$25,000 - \$49,999; \$50,000 - \$99,999; \$100,000 - \$499,999; \$500,000 - \$1,000,000; and >\$1,000,000). These classifications were used to develop model facilities representing these size ranges for each species evaluated. Because of the small numbers of facilities in some of the species and production method categories, EPA has not presented these results to protect confidential business information.

#### *A.2.2.2 Sample Weights*

This section describes the methodology used to calculate the base weights, non-response adjustments, and the final weights for the screener questionnaire. The sample weights accounted for different response rates and ineligible facilities. In conjunction with the conversion and predominant determinations described in the last section, the sample weights were used to calculate the national estimates presented in Attachment A-3.

The *base weight* is equal to 1.0 for all facilities because the screener questionnaire was sent to the entire sample frame (i.e., a census).

$$\textit{base weight} = 1.0 \qquad \text{(A-1)}$$

The number of returned questionnaires includes duplicate questionnaires, whether they were completed or not, but does not include questionnaires that were not deliverable. The non-response adjustment in effect spreads the weight associated with the non-responses (questionnaires not returned) across the responses. The non-response adjustment assumes that the fraction of duplicate addresses among those who responded is the same as the fraction among those who did not respond. Because different species tend to be located in different parts of the country, EPA decided to use the facility location as a basis for calculating the non-response rate. For states with 50 or more respondents, EPA defined the location of the facility as its state. For states with less than 50 respondents, EPA grouped the facilities into one stratum. (See Westat, 2002b, for a logistic regression that assessed which factors were significant predictors of non-response.) Within each stratum g, the non-response weight adjustment is the ratio of the number of facilities with valid addresses to the number that responded.

$$w_g = (non-response\ adjustment)_g = \frac{Number\ of\ valid\ addresses\ in\ stratum\ g}{Number\ of\ returned\ questionnaires\ in\ stratum\ g} \qquad \text{(A-2)}$$

The final screener weight $w_i$ for facility $i$ in non-response stratum $g$ can be written as:

$$w_i = (base\ weight) \times (Non-response\ adjustment) = 1.0 \times w_{g(i)} \qquad \text{(A-3)}$$

Where $w_{g(i)}$ is the non-response adjustment corresponding to the non-response stratum (g) associated with facility $i$.

Although the weight is applicable to all responding facilities, EPA is interested in only those facilities in AAP. For each non-response strata $g$, Table A.1 shows the number of valid addresses (excluding any duplicate addresses), the number of returned questionnaires, the screener weight, and the number of responding AAP facilities. The weights for the screener respondents ranged from 1.14 to 1.55.

As an example of the application of the screener weights, consider strata 1 which had 124 valid addresses and 93 returned questionnaires. The sample weight for all facilities in stratum 1 is:

$$w_1 = 1.0 \times \left( \frac{124}{93} \right) = 1.33$$

As shown in the last column, 56 of the 93 returned questionnaires are from AAP facilities. Then, using the sample weight, the estimated number of AAP facilities is 1.33 x 56 = 75 (rounded to an integer).

Using a non-response adjustment assumes that the fraction of facilities doing AAP is the same among the respondent and non-respondents. In its data analyses of the screener questionnaire responses, EPA has assumed that non-respondents have the same characteristics, proportionally, as the respondents. This is a common assumption used in survey estimation. However, if the non-respondents within a non-response adjustment stratum are different from the respondents, the survey estimates may be biased. There is considerable research into the area of non-response estimation (see, for example, Groves and Couper (1998)).

**Table A.1. Screener Weights and Number of Facilities by Non-Response (Location) Strata**

| *Non-Response (Location) Stratum* | *Number of Valid Addresses* | *Number of Returned Questionnaires* | *Screener Weight* $w_g$ | *Number of Responding AAP Facilities in the Stratum* |
|---|---|---|---|---|
| 1 (AK) | 124 | 93 | 1.333 | 56 |
| 2 (AL) | 162 | 111 | 1.459 | 74 |
| 3 (AR) | 450 | 323 | 1.393 | 164 |
| 4 (CA) | 316 | 249 | 1.269 | 144 |
| 5 (CO) | 65 | 52 | 1.250 | 30 |
| 6 (FL) | 524 | 410 | 1.278 | 125 |
| 7 (GA) | 155 | 118 | 1.314 | 69 |
| 8 (HI) | 163 | 105 | 1.552 | 50 |
| 9 (IA) | 67 | 57 | 1.175 | 31 |
| 10 (ID) | 109 | 92 | 1.185 | 59 |
| 11 (IN) | 68 | 55 | 1.236 | 29 |
| 12 (LA) | 246 | 182 | 1.352 | 119 |
| 13 (MA) | 323 | 218 | 1.482 | 114 |
| 14 (ME) | 100 | 73 | 1.370 | 50 |
| 15 (MI) | 107 | 85 | 1.259 | 51 |
| 16 (MO) | 74 | 65 | 1.138 | 44 |
| 17 (MS) | 220 | 163 | 1.350 | 121 |

| ***Non-Response (Location) Stratum*** | ***Number of Valid Addresses*** | ***Number of Returned Questionnaires*** | ***Screener Weight $w_g$*** | ***Number of Responding AAP Facilities in the Stratum*** |
|---|---|---|---|---|
| 18 (NC) | 261 | 194 | 1.345 | 123 |
| 19 (NE) | 117 | 86 | 1.360 | 35 |
| 20 (NY) | 116 | 93 | 1.247 | 53 |
| 21 (OH) | 70 | 58 | 1.207 | 35 |
| 22 (OK) | 68 | 55 | 1.236 | 31 |
| 23 (OR) | 99 | 74 | 1.338 | 55 |
| 24 (PA) | 75 | 64 | 1.172 | 44 |
| 25 (TX) | 308 | 254 | 1.213 | 122 |
| 26 (VA) | 114 | 90 | 1.267 | 40 |
| 27 (WA) | 217 | 162 | 1.340 | 102 |
| 28 (WI) | 226 | 171 | 1.322 | 98 |
| 29 (Other States) | 615 | 462 | 1.331 | 261 |
| Total | 5559 | 4214 | | 2329 |

#### *A.2.2.3 National Estimates and Standard Errors*

This section presents the general methodology and equations for estimating national totals, national means, and their standard errors, from the responses to the screener questionnaire.

Estimates of national totals were obtained for each characteristic and domain of interest by multiplying the reported value by the screener weight and by summing all weighted values for the facilities that belong to the domain of interest *k*:

$$\hat{y}_k = \sum_i w_i y_i I_{i \in k} \tag{A-4}$$

Where $I_{i \in k}$ is one if facility *i* is in domain *k* and zero otherwise. For example, if the domain of interest was ‘Facilities in Western USDA Region,’ $y_i$ was the trout production at each facility *i*, and $w_i$ was the screener weight for that facility, then $\hat{y}_k$ was the estimate of trout production for facilities in the Western USDA region.

Similarly, ratio estimates (for example, means and percentages) in a given domain *k* were obtained as a ratio of estimates of two total values. For example, the average trout production in the Western USDA region was the ratio of the estimate of trout production, $\hat{y}_k$ in that region, and the estimate of the number of facilities in that region producing trout, $n_k$:

$$\bar{y}_k = \frac{\hat{y}_k}{n_k} = \frac{\sum_i w_i y_i I_{i \in k}}{\sum_i w_i I_{i \in k}} \tag{A-5}$$

After calculating the national estimates, EPA calculated standard errors (s.e.) of its estimates using a jackknife replication method (Wolter, 1985). Under the jackknife replication method, a series of samples (called jackknife replicates) are selected from all responses (n). EPA created 100 replicates to obtain 99 degrees of freedom which EPA considered to be adequate for the statistical estimates while resulting in reasonably sized data files for the replicates. Each facility response was randomly assigned a number between 1 and 100. The first replicate used the responses from all facilities except those assigned to group 1. The other replicates were derived in a similar way by excluding the values for a different group each time. The replicate weights were used to adjust the replicate sample size for the missing group. That is, if there were 100 responses and 10 responses were randomly assigned to group r, then the replicate weight adjustment, $w_{(r)}$, was the ratio, 1.11, of the 100 responses in the full sample to the 90 responses (n(r)=90) in the replicate sample. In this way, a series of replicate weights were generated for each facility response, which together with the screener weight were used to calculate national estimates and averages:

$$\hat{y}_{k(r)} = \sum_i w_i w_{(r)} y_i I_{i \in k} \qquad \text{(A-6)}$$

$$\bar{y}_{k(r)} = \frac{\hat{y}_{k(r)}}{n_{k(r)}} = \frac{\sum_i w_i w_{(r)} y_i I_{i \in k}}{\sum_i w_i w_{(r)} I_{i \in k}} \qquad \text{(A-7)}$$

In order to illustrate how the sampling errors are calculated, let $\bar{y}$ be the weighted national average estimate of a characteristic y (e.g., average trout production at facilities that produce trout). If $\bar{y}_{(r)}$ is the corresponding estimate calculated using the facility responses for all groups except group r, then the estimated variance of $\bar{y}$ is given by the following formula:

$$\text{var}(\bar{y}) = \frac{99}{100} \sum_{r=1}^{100} \left( \bar{y}_{(r)} - \bar{y} \right)^2 \qquad \text{(A-8)}$$

where the summation extends over all 100 jackknife replicates that were formed from the screener responses. The standard error is then the square root of the variance:

$$s.e. = \sqrt{\text{var}(\bar{y})} \qquad \text{(A-9)}$$

In Attachment A.3, the tables provide various estimates and their standard errors. These standard errors can be used to compute 95 % confidence intervals around the estimate. These intervals are given by:

$$confidence\ interval = \bar{y} \pm (1.96 \times s.e.) \qquad \text{(A-10)}$$

## A.3 Detailed Questionnaire (Phase 2)

This section describes the detailed questionnaire that was distributed in Phase 2 of EPA's survey of the AAP industry. Section A.3.1 describes the sample design and sample selection for the detailed questionnaire based upon the responses to the screener questionnaire in Phase 1. Section A.3.2 describes the methods that EPA used in developing national estimates from the responses to the detailed questionnaire.

### A.3.1 Sample Design: Stratified Random Sample

After reviewing the results from the screener questionnaire, EPA decided that the information from the detailed questionnaire was needed for only a subset of the AAP facilities. Because the proposed rule is applicable only to concentrated aquatic animal production (CAAP) facilities, EPA was particularly interested in facilities, classified as either Commercial, Government, Research, or Tribal, and subject to the current NPDES regulations. (40 CFR 122.24 and Appendix C to Part 122.) According the NPDES regulations, CAAP facilities can be in either of two categories: cold water or warm water. The cold water species category includes ponds, raceways, or other similar structures which discharge at least 30 days per year but does not include: facilities which produce less than 9,090 harvest weight kilograms (approximately 20,000 pounds) per year of trout or salmon; and facilities which feed less than 2,272 kilograms (approximately 5,000 pounds) during the calendar month of maximum feeding. The warm water category includes ponds, raceways, or other similar structures which discharge at least 30 days per year but does not include: closed ponds which discharge only during periods of excess runoff; or facilities which produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) per year of any species except trout and salmon. Although EPA excluded ponds from the proposed rule, EPA determined that it needed additional information from facilities with ponds and large production volumes to evaluate whether EPA had appropriately excluded such facilities from the proposed rule. EPA also considered aquariums to assess concerns from interested parties, particularly with respect to drug and chemical use. EPA selected these based upon the facility name, responses to questions 4 and 5, and additional information from an industry trade association.

After considering these factors, EPA determined that it should sample facilities meeting one of the following six criteria:

1. Aquariums.

2. Production includes alligators and total biomass exceeds 100,000 pounds.

3. Production includes trout or salmon and total biomass exceeds 20,000 pounds.

4. Predominant production method is ponds; predominant species is catfish; and total biomass exceeds 2,200,000 pounds.

5. Predominant production method is ponds; predominant species is shrimp, tilapia, other finfish, or hybrid striped bass; and total biomass exceeds 360,000 pounds.

6. Predominant production method is any except ponds; and total biomass exceeds 100,000 pounds.

By applying these criteria, EPA identified 539 facilities with these characteristics from the screener questionnaire responses. In developing the sample selection criteria, EPA determined each facility's predominant species and predominant production method as explained in Section A.2.2.1, except that it excluded molluscan shellfish from its determination of the predominant species.[5] EPA then classified the 539 facilities into 44 strata which were defined by facility type (commercial, government, research, or tribal),[6] the predominant species, and predominant production.

In calculating the sample sizes, EPA used a common method for estimating sample sizes that is based upon the binomial distribution (see, for example, Cochran (1977)). The binomial distribution applies to situations where there are only two possible outcomes. For example, there are only two outcomes (yes or no) to a dichotomous question such as 'Does any of this water go to a publicly owned treatment works.' Because the assumption that 50 % of the respondents would answer "Yes" results in the largest possible variance for the binomial distribution and the largest possible sample size, EPA assumed that the probability of one outcome would be 0.5 (i.e., 50 % would select 'Yes' and 50 % select 'No.') This probability is written as 'p=0.5.' EPA used this probability (p=0.5) and its precision targets to derive the sample sizes. EPA's criteria for its sample can be summarized as follows:

1. For estimates for each stratum: a 95% confidence interval for p=0.5 is (0.2, 0.8); *and*

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[5] Before selecting the sample for the detailed questionnaire, EPA evaluated the impact of its 'approximate' conversion factors in the total biomass calculations described in Section A.2.2.1. Because it had identified facilities with production close to the cutoff for inclusion into the selected strata and expended additional effort to obtain more precise conversion factors, the use of approximate conversion factors had relatively little effect.

[6] Facility type was determined by the facility's response to question 4 of the screener questionnaire. If the facility type was missing (7 cases) or indicated as being 'Other,' EPA excluded these facilities from consideration for the detailed questionnaire.

2. For overall estimates (i.e., of the entire population meeting the criteria above): a 95% confidence interval for p=0.5 is (0.45, 0.55); *and*

3. No one facility unduly influences the overall estimate.

To achieve the desired precision, EPA determined that information should be collected from 263 of the 539 facilities in the 44 strata. For 34 strata with five or fewer facilities, EPA determined that a census was appropriate because of the relatively small sample sizes, and thus, selected the 163 facilities in those strata. (Of these 34 strata, 20 strata contained only one facility.) For the other 10 strata, EPA selected 200 of the 376 facilities. Table A.2 lists the variables defining each stratum, the number of facilities in the stratum ($N_h$), the number of facilities in the sample ($n_h$), and the sampling weight. The number of facilities are based on the responses to the screener questionnaire, without adjusting for non-response. As shown in Table A.2, the sampling weights are fairly consistent, ranging from 1.0 to 2.6. (Although aquariums and alligators are not listed in Table A.2, facilities selected for the sample included facilities that were aquariums and alligator farms.)

In selecting the sample for each of the 10 strata, EPA selected the first $n_h$ facilities in alphabetical order. Assuming that the information collected in the detailed questionnaire is not correlated with the alphabetical ordering of the facilities, the sample can be treated as a random statistical sample. By examining the production levels calculated from the screener questionnaire responses in each stratum, the sample appears to be representative of the population in each of the 10 strata (Westat, 2002c). After selecting the sample, EPA identified 8 of the 539 facilities as being duplicates of other facilities; however, they either were not selected for the sample or were only selected once. EPA also identified another facility that should have been excluded from consideration for the detailed questionnaire, because it did not meet the selection criteria. Although the facility was one of the 263 selected to receive the detailed questionnaire, it has been removed from the sample. EPA has concluded that the 262 remaining facilities in the sample will provide acceptable precision estimates for the 530 facilities.

**Table A.2 Sampling Strata for Detailed Questionnaire**

| ***Facility Type*** | ***Predominant Species*** | ***Predominant Production Method*** | ***Number of Facilities (based on Screener Responses)*** **$N_h$** | ***Number of Sampled Facilities*** **$n_h$** | ***Sampling Weight*** **$DQ_h=N_h/n_h$** |
|---|---|---|---|---|---|
| Commercial | Catfish | Flow through | <5 | all | 1.0 |
| | | Ponds | 50 | 20 | 2.5 |
| | Other | Flow through | <5 | all | 1.0 |
| | | Other | <5 | all | 1.0 |
| | | Ponds | <5 | all | 1.0 |
| | | Recirculating | <5 | all | 1.0 |
| | Trout | Flow through | 135 | 52 | 2.596 |
| | | Net pens | <5 | all | 1.0 |
| | Salmon | Flow through | 16 | 8 | 2.0 |
| | | Net pens | 10 | 7 | 1.429 |

| *Facility Type* | *Predominant Species* | *Predominant Production Method* | *Number of Facilities (based on Screener Responses)* $N_h$ | *Number of Sampled Facilities* $n_h$ | *Sampling Weight* $DQ_h=N_h/n_h$ |
|---|---|---|---|---|---|
| | | Recirculating | <5 | all | 1.0 |
| | Striped Bass | Flow through | <5 | all | 1.0 |
| | | Ponds | <5 | all | 1.0 |
| | | Recirculating | <5 | all | 1.0 |
| | Tilapia | Flow through | <5 | all | 1.0 |
| | | Recirculating | 12 | 7 | 1.714 |
| | Other Finfish | Flow through | <5 | all | 1.0 |
| | | Net pens | <5 | all | 1.0 |
| | | Ponds | 8 | 6 | 1.333 |
| | | Recirculating | <5 | all | 1.0 |
| | Baitfish | Recirculating | <5 | all | 1.0 |
| | Ornamentals | Flow through | <5 | all | 1.0 |
| | | Recirculating | <5 | all | 1.0 |
| | Shrimp | Flow through | <5 | all | 1.0 |
| | | Ponds | <5 | all | 1.0 |
| | | Recirculating | <5 | all | 1.0 |
| Government | Catfish | Flow through | <5 | all | 1.0 |
| | | Ponds | <5 | all | 1.0 |
| | Trout | Flow through | 157 | 61 | 2.574 |
| | | Other | <5 | all | 1.0 |
| | | Ponds | <5 | all | 1.0 |
| | Salmon | Flow through | 64 | 25 | 2.560 |
| | | Net pens | <5 | all | 1.0 |
| | | Recirculating | <5 | all | 1.0 |
| | Striped Bass | Ponds | <5 | all | 1.0 |
| | Other Finfish | Flow through | <5 | all | 1.0 |
| | | Ponds | 12 | 7 | 1.714 |
| Research | Catfish | Ponds | <5 | all | 1.0 |
| | Other | Recirculating | <5 | all | 1.0 |
| | Trout | Flow through | <5 | all | 1.0 |
| | Other Finfish | Recirculating | <5 | all | 1.0 |
| Tribal | Trout | Flow through | <5 | all | 1.0 |
| | Salmon | Flow through | 10 | 7 | 1.429 |
| | Other Finfish | Ponds | <5 | all | 1.0 |
| Totals | | | 537 | 263 | |

### A.3.2 Final Survey Weights

EPA used the information collected by the detailed questionnaires to re-estimate the costs and benefits associated with the proposed regulatory options and the NODA options. This section provides an overview of EPA's development of survey weights that were used in the final analyses. These final analyses are described elsewhere in this document and the EIA.

Weighting the data allows inferences to be made about all eligible facilities, not just those included in the sample, but also those not included in the sample or those that did not respond to the either the screener or detailed questionnaire.

For the final rule, EPA has applied survey weights that are slightly different than those used for the NODA which were adjusted for non-response within each sampling strata.[7] As a first cut, adjusting by sampling strata is a reasonable approach given the stratified sample design. Dividing the sample into many strata has the advantage that the true response probabilities are likely to be relatively constant within a strata, because the facilities have some of the same characteristics which might lead to similar types of behavior such as responding or not responding to the questionnaire. As a result, the non-response adjustment within each strata is likely to be close to the correct adjustment for all facilities in the strata. However, when the number of facilities in a strata is small, the calculated non-response adjustment factor is variable (or imprecise). The imprecision of the non-response adjustment will contribute variability to the estimates. If strata are combined (or "collapsed" as statisticians generally describe it) to create fewer strata with more facilities, the non-response adjustment factor in each strata will be more precise (the objective is to collapse strata which have similar probabilities of response). At the same time, the within-strata true response probabilities may differ more from the estimated value because the collapsed strata now include more different kinds of facilities. This difference contributes to bias in the survey estimates. Thus, there is a trade-off. After examining the sample sizes in the strata, EPA noted that many of the sampling strata have less than 10 facilities. For this reason, EPA determined that using collapsed strata, containing a larger number of facilities, to determine the non-response adjustments would be more appropriate than adjusting by strata as it had for the NODA analyses. Further, EPA used a stepwise logistic regression to determine which factors or 2-way interactions of factors were significant predictors of non-response. After combining Other, Baitfish, and Ornamentals into a general Other category, ownership (with Tribal and Research facilities collapsed into one group) was the only significant predicator of non-response. (Westat, 2004). This finding provided additional support for EPA's determination that ownership, rather than strata, should be used to adjust for non-response. The final weights and the NODA weights have a correlation of about 0.96, and thus, the results are similar, regardless of which set of weights are used.

Table A.3 shows the number of surveys sent and the number received by ownership category, excluding nine facilities that returned incomplete responses. As explained in the following paragraphs, EPA adjusted the response status in two situations.

First, for a few cases, the sampling frame listed facilities twice, and EPA has excluded the duplicate entry of each pair from the totals in this table. Generally, EPA did not send the duplicate questionnaire to the facility. For the one exception, for purposes of

[7] The NODA survey weights also included an adjustment for strata without any respondents. While such an adjustment is not necessary or correct, it has no effect on estimates of means and proportions and a relatively small effect on the estimate of totals, such as numbers of facilities in the population that potentially would be affected by a regulation. For the final survey weights, EPA has chosen a method that does not include this adjustment.

developing the final survey weights, EPA simplified the calculations by treating this single exception as a non-respondent.

Second, a few completed questionnaires contained information on more than one facility. Subsequently, EPA separated that information into several questionnaires so that a single questionnaire represented an individual facility. These questionnaires with multiple facility data resulted in eight additional facilities contributing relevant data to the detailed survey. However, for purposes of the costing analyses, for each original questionnaire, EPA combined the data values from the multiple facilities into a single value. EPA then applied the survey weight associated with the original questionnaire to that single, combined, value in using the data to calculate national estimates.

**Table A.3 Detailed Questionnaire: Response Rates**

| *Ownership Category* | *Number Sent* | *Number Received* | *Response Rate* ($R_{ownership}$) |
|---|---|---|---|
| Commercial | 134 | 107 | 0.79851 |
| Government | 102 | 97 | 0.95098 |
| Tribal or Research | 15 | 11 | 0.73333 |

The final detailed questionnaire weight $W_i$ for facility $i$ in stratum h and ownership category $g$ can be written as:

$$W_i = \frac{DQ_h}{R_{ownership}} \times w_i$$

(A-11)

where $DQ_h$ is the sampling weight from Table A.2; $R_{ownership}$ is the response rate from Table A.3; and $w_i$ is the screener weight from Table A.1 adjusted for non-response as in equation (A-3). EPA then used these adjusted survey weights to calculate national estimates as described in Section A.2.2.3. These estimates are presented elsewhere in this document and the record for the final rule.

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## ATTACHMENT A-1.
## COMPARISON OF USDA CENSUS OF AQUACULTURE AND EPA SCREENER QUESTIONNAIRE

| | *USDA Census of Aquaculture* | *EPA Screener Questionnaire* | *Difference* |
|---|---|---|---|
| **Primary Objective** | Economic description of the industry | Data for regulatory analysis | |
| **Year** | 1998 | 2000 | Two years |
| **Target Population** | All "aquaculture farms" from which aquaculture products were sold, or produced for restoration or conservation purposes during the census year (1998). | All "facilities" in the Aquatic Animal Production Industry which answer "Yes" to the question "Do you produce (grow) aquatic animals (fish, shellfish, or other aquatic animals) at this facility?" | EPA did not require that any products be sold for the farm to be included in its population. The USDA Census generally excluded farms that did not sell its products (e.g., state hatcheries). The USDA Census included "other aquaculture products" including algae. The EPA Screener excluded algae and non-animal products. While the USDA includes such farms, only 20 farms report algae and sea vegetables production (Table 19 in USDA (appears to be only about 20 farms in the USDA count. |
| **Frame Source** | Answered positively a 1997 Census of Agriculture question on whether there were "fish and other aquaculture products" in 1997. This list was supplemented by other USDA information and lists of State and Federal fish hatcheries. | A mailing list of 5988 facilities was constructed from Dun & Bradstreet, state lists, tribal information, aquaculture journals, various associations, the internet, and aquaculture facilities identified by respondents. The D&B SIC codes included: 0273 (animal aquaculture), 0279 (animal specialties), and 0921 (fish hatcheries and preserves). | Although constructed differently, it is difficult to say how the resulting lists of farms/facilities might differ. Both frames may miss some aquaculture farms or facilities. Total revenue of facilities in the D&B database exceeded that of the Census by about 10%. Both estimates of total revenue were about $1.0 billion. It was concluded that the facilities missed by D&B probably were quite small. |
| **Survey Design** | Census | Census | None. |
| **Frame Size** | Not available, assumed to be 4028 or more addresses based upon the reported number of farms. | 5988 addresses | Differences are due to how the frames were constructed, differences in the target population, or changes in the industry over time. |

| | ***USDA Census of Aquaculture*** | ***EPA Screener Questionnaire*** | ***Difference*** |
|---|---|---|---|
| **Instrument** | Mailed questionnaire augmented with telephone and personal interviews. Telephone calls and personal interviews were used to collect data from non-respondents. | Mailed questionnaire augmented with follow-up phone calls to clarify data. Reminder letters were sent to non-respondents. A limited effort was made to correct invalid addresses. | USDA had little non-response due to intensive follow-up of non-respondents. Screener results were weighted to adjust for non-response to calculate national estimates. |
| **Number of Respondents doing Aquaculture** | Apparently 4028, assuming no non-response due to non-response follow-up. Responses to some questions were imputed. | 2329 | Differences are primarily due to screener non-response as well as frame under-coverage for either questionnaire, changes in the industry over time, and inclusion of non-animal production in the USDA Census. |
| **Estimated Number of Aquaculture facilities nationally** | 4028 aquaculture farms | 3075 AAP facilities | Differences may be due to frame under-coverage for either questionnaire, changes in the industry over time, and inclusion of non-animal production in the USDA Census. |
| **Scope** | Collected detailed information relating to on-farm aquaculture practices, size of operation based on water area, production, sales, method of production, sources of water, point of first sale outlets, cooperative agreements and contracts, and aquaculture distributed for restoration or conservation purposes. | Collected information on the type of facility (commercial, Government, Tribal, etc.), quantities of animals produced in 2000 by species and size category, production methods used, whether water from the facility left the property and whether to a POTW and/or with an NPDES permit, and a description of pollution control practices. | Comparable values include production methods, species produced and some production information. |
| **Production Totals for Selected Species** | National estimate:<br>Catfish: 593 million pounds<br>Trout: 63 million pounds | Weighted national estimate:<br>Catfish: 637 million pounds<br>Trout: 121 million pounds | For catfish and trout, total screener production is somewhat larger than from the USDA Census. Screener estimates are based on unit conversion assumptions. Comparisons for other species would require additional assumptions. Differences may be due to changes over time and under coverage in the two frames. |

## ATTACHMENT A-2.
## CONVERSION FACTORS FOR SCREENER QUESTIONNAIRE RESPONSES

### Table A2.1. Biomass Calculations for Predominant Species: Pounds-to-Count Conversion Factors

| *Species Code1* | *SPECIES* | *SIZE (Size Category from Question 5 in the Screener)2* | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Foodsize (1)* | *Stockers (2)* | *Fingerlings (3)* | *Seed Stock (6)* | *Brood-stock (7)* | *Fry (4)* |
| 1 | Catfish | 1.5 | 0.18 | 0.0334 | | 4.31 | |
| 2 | Trout | 1 | 0.32 | 0.035 | | 2.5 | |
| 3 | Salmon | 5 | 0.32 | 0.035 | | 10 | |
| 4 | Striped Bass | 1.75 | 0.33 | 0.06 | | 5 | |
| 5 | Tilapia | 1.75 | 0.32 | 0.035 | | 2.5 | |
| 6 | Other Finfish (except as listed) | 1 | 0.32 | 0.035 | | 2.5 | |
| 6-15 | bass - smallmouth and largemouth | 2.00 | | | | | |
| 6-19 | Crappie | 1.13 | | | | | |
| 6-20 | Eel | 4.62 | | | | | |
| 6-24 | Paddlefish | 2.00 | | | | | |
| 6-26 | Perch | 0.59 | | | | | |
| 6-27 | Saugeye | 1.00 | | | | | |
| 6-29 | Sturgeon | 45.00 | | | | | |
| 6-30 | Sucker | 2.19 | | | | | |
| 6-31 | Sunfish (including bluegill and panfish) | 0.25 | | | | | |
| 6-33 | Walleye | 3.00 | | | | | |
| 6-34 | Whitefish | 2.50 | | | | | |
| 6-35 | Pike | 4.63 | | | | | |
| 6-69 | Shad (including threadfin) | 2.50 | | | | | |
| 6-71 | Charr | 2.00 | | | | | |
| 6-73 | Amberjack | 75.00 | | | | | |
| 6-74 | Bream | 0.33 | | | | | |
| 6-75 | Shell cracker | 0.50 | | | | | |
| 7 | Baitfish (except smelt) | 0.01 | | | | | |
| 7-48 | Smelt | 0.19 | | | | | |
| 8 | Ornamentals (except carp) | 0.01 | | | | | |
| 8-17 | Carp (includes koi, white amur) | 4.00 | | | | | |
| 9 | Shrimp | 0.0444 | | | 6.6E-06 | 0.1 | |
| 10 | Crawfish | 0.0444 | | | | 0.08 | |
| 11 | Other Crustaceans | 0.10 | | | | | |
| 12 | Molluscan shellfish | 0.10 | | | | | |
| 13 | Other (except as listed) | 1.00 | | | | | |
| 13-14 | Alligators (and caimen) | 13.00 | | | | | |
| 13-21 | Frogs and tadpoles | 0.13 | | | | | |
| 13-32 | Turtles | | | | | 3.5 | .03 |

## Table A2.2. Total Biomass Calculations: Foodsize-to-Other Sizes Conversion Factors (when not specified in Table A2.1)

| *Size Code from Question 5 in the Screener* | *Size* | *Food Size Multiplier* |
|---|---|---|
| 1 | Foodsize | 1.0000 |
| 2 | Stockers | 0.1418 |
| 3 | Fingerlings | 0.0214 |
| 4 | Fry | 0.0014 |
| 5 | Eggs | 0.00001 |
| 6 | Seed stock | 0.0001 |
| 7 | Brood size | 3.4247 |
| 8 | Other | 0.1000 |

## Table A2.3. Determination of Predominant Production Method: EPA's *Assumed* Hierarchy of Most to Least Common Production Method

| *Purpose* | *Predominant Species* | *Most Common to Least Common Production Method*[1] |
|---|---|---|
| Screener Questionnaire Data Analysis[2] (See Attachment A-3) | Catfish | Ponds, Flow through, Recirculating, Other |
| | Trout | Flow through, Recirculating, Ponds, Net Pens |
| | Salmon | Net pens, Flow through, Recirculating |
| | Striped Bass | Ponds, Recirculating, Flow through |
| | Tilapia | Recirculating, Flow through, Ponds |
| Detailed Questionnaire Sample Selection[3] | Catfish | Ponds, Flow through, Net pens, Recirculating, Other |
| | Trout | Flow through, Ponds, Recirculating, Other, Net Pens, Floating aquaculture |
| | Salmon | Flow through, Net pens, Recirculating, Ponds, Other, Floating aquaculture |
| | Striped Bass | Ponds, Flow through, Recirculating, Net pens, Other |
| | Tilapia | Recirculating, Flow through, Ponds, Net pens, Other, Floating aquaculture |
| | Other Finfish | Ponds, Flow through, Recirculating, Net pens, Other, Floating aquaculture |
| | Baitfish | Ponds, Flow through, Recirculating |
| | Ornamentals | Ponds, Recirculating, Flow through, Other, Net pens, Floating aquaculture |
| | Shrimp | Ponds, Recirculating, Flow through, Other, Net pens, Floating aquaculture |
| | Crawfish | Ponds, Net pens, Flow through, Recirculating, Other |
| | Other crustaceans | Recirculating, Flow through, Floating aquaculture, Ponds |
| | Other | Ponds, Recirculating, Other, Flow through, Net pens, Floating aquaculture |

[1] The production methods (e.g., Other) are from the choices provided in question 6 of the screener questionnaire.
[2] This hierarchy was based upon sources other than the screener questionnaire responses.
[3] This hierarchy is based upon a data analysis of the screener questionnaire responses. EPA acknowledges that floating aquaculture is unlikely to be used as a production method for certain species, and EPA plans additional review of these questionnaire responses.

**Table A2.4. Revenue Calculations: Prices for Species by Size[1]**

| *Species* | *Size* | *Prices* | *USDA Table (page)* [2] |
|---|---|---|---|
| Catfish | Foodsize | $0.74/lb | 8 (20) |
| | Stockers | $1.03/lb | 8 (21) |
| | Fingerlings/Fry | $1.66/lb | 8 (22) |
| | Brood Stock | $0.91/lb | 8 (19) |
| Trout | Foodsize | $1.06/lb | 9 (24) |
| | Stockers | $2.29/lb | 9 (25) |
| | Fingerlings | $162.16/1000 fish eggs | 9 (26) |
| Salmon | Foodsize (except Alaska) | $2.00/lb | [3] |
| | Foodsize (Alaska) | $0.23/lb | 12 (39) |
| | Fingerlings/Fry | $0.17/lb | 12 (40) |
| Striped Bass | Foodsize | $2.44/lb | 12 (34) |
| | Fingerlings/Fry | $0.26/lb | 12 (35) |
| Tilapia | Foodsize | $1.70/lb | 12 (41) |
| | Fingerlings | $0.11/fish | 12 (42) |

[1] EPA included *only* the listed species/size categories in its revenue calculations. Of those categories, EPA included only those responses that were reported in dollars sold, in pounds (applying the above conversion factors), or counts that could be converted to pounds using the conversion factors in Table A2.1.
[2] See USDA (2000).
[3] EPA adjusted the national average provided in Table 12 (p. 39) to obtain a value that did not include Alaska as follows:

(National total sales - Alaska sales)/(National total quantity - Alaska quantity)
= ($103,583,000 - $16,340,000)/(110,588,000 lbs - 70,129,000 lbs)
= $2.16/lb which EPA rounded to $2.00/lb

## ATTACHMENT A-3.
## NATIONAL ESTIMATES BASED ON SCREENER QUESTIONNAIRE

The following tables provide national estimates (i.e., adjusted for non-response) of the responses to the screener questionnaires. Each table presents estimates for different types (‘domains’) of facilities, such as facilities in each USDA region or facilities using each production method. The facility domains are shown in the left column. Within each domain, Tables A3.1 through A3.8 show the number of facilities, percent of facilities, and total aquatic animal production. The total aquatic animal production is the total production of all species across all facilities in the domain. In contrast, Table A3.9 shows the total production of only the species used to define the domain rather than all species.

In some tables in this attachment, EPA has not presented the totals, because some facilities were placed in more than one category. For example, Table A3.7 provides the number of facilities and their production for each production method. Thus, if a facility has ponds and flow-through systems, the facility and its production would be counted under both production methods.

### Table A3.1. USDA Region

| | *Number of Facilities* | | *Percent of Facilities* | | *Production (thousands of pounds)* | |
|---|---|---|---|---|---|---|
| ***Region*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** |
| NORTHEASTERN | 452 | 18 | 14.7% | 0.5% | 74,673 | 15,890 |
| SOUTHERN | 1393 | 30 | 45.3% | 0.7% | 820,946 | 112,800 |
| NORTH CENTRAL | 485 | 18 | 15.8% | 0.5% | 27,138 | 5,978 |
| WESTERN | 664 | 20 | 21.6% | 0.6% | 258,830 | 96,884 |
| TROPICAL | 80 | 9 | 2.6% | 0.3% | 7,382 | 4,088 |
| ALL | 3075 | 46 | 100.0% | | 1,190,000 | 150,200 |

### Table A3.2. Facility Type

| | *Number of Facilities* | | *Percent of Facilities* | | *Production (thousands of pounds)* | |
|---|---|---|---|---|---|---|
| ***Facility Type*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** |
| Commercial | 2384 | 44 | 77.5% | 0.9% | 1,060,000 | 146,700 |
| Government | 447 | 23 | 14.5% | 0.7% | 102,046 | 18,743 |
| Research | 67 | 9 | 2.2% | 0.3% | 1,738 | 724 |
| Tribal | 29 | 6 | 1.0% | 0.2% | 2,356 | 782 |
| Other | 147 | 14 | 4.8% | 0.4% | 20,762 | 5,266 |
| ALL | 3075 | 46 | 100.0% | | 1,190,000 | 150,200 |

## Table A3.3. Predominant Species[1]

| | *Number of Facilities* | | *Percent of Facilities* | | *Production, All Species (thousands of pounds)* | |
|---|---|---|---|---|---|---|
| ***Predominant Species*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** |
| Catfish | 739 | 29 | 24.0% | 0.9% | 613,627 | 103,700 |
| Trout | 707 | 30 | 23.0% | 0.9% | 98,373 | 19,398 |
| Salmon | 197 | 13 | 6.4% | 0.4% | 111,756 | 21,466 |
| Striped Bass | 91 | 11 | 3.0% | 0.3% | 17,788 | 5,538 |
| Tilapia | 129 | 14 | 4.2% | 0.4% | 12,599 | 3,843 |
| Other Finfish | 376 | 21 | 12.2% | 0.7% | 31,542 | 9,313 |
| Baitfish | 116 | 13 | 3.8% | 0.4% | 8,371 | 2,220 |
| Ornamentals | 173 | 13 | 5.6% | 0.4% | 8,800 | 2,465 |
| Shrimp | 54 | 8 | 1.7% | 0.3% | 11,702 | 4,620 |
| Crawfish | 38 | 7 | 1.2% | 0.2% | 629 | 310 |
| Other crustaceans | 15 | 5 | 0.5% | 0.1% | 160 | 129 |
| Molluscan shellfish | 274 | 17 | 8.9% | 0.5% | 139,231 | 97,493 |
| Other | 168 | 13 | 5.5% | 0.4% | 134,390 | 53,166 |
| ALL | 3075 | 46 | 100.0% | 0.0% | 1,190,000 | 150,200 |

[1] The predominant species is the species with the largest production at a facility. Each facility has only one predominant species.

## Table A3.4. Predominant Production Method

| | *Number of Facilities* | | *Percent of Facilities* | | *Production (thousands of pounds)* | |
|---|---|---|---|---|---|---|
| ***Predominant Production Method*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** |
| Ponds | 1561 | 38 | 50.8% | 1.0% | 763,380 | 109,500 |
| Flow through raceways, ponds, or tanks | 960 | 33 | 31.2% | 0.9% | 278,181 | 98,100 |
| Recirculating systems | 228 | 18 | 7.4% | 0.6% | 61,256 | 24,797 |
| Net pens or cages | 40 | 7 | 1.3% | 0.2% | 45,455 | 17,670 |
| Floating aquaculture or bottom culture | 233 | 17 | 7.6% | 0.5% | 37,564 | 11,463 |
| Other | 53 | 8 | 1.7% | 0.3% | 3,134 | 2,003 |
| ALL | 3075 | 46 | 100.0% | 0.0% | 1,190,000 | 150,200 |

## Table A3.5. Water Discharge Status to POTW[1]

| | *Number of Facilities* | | *Percent of Facilities* | | *Production (thousands of pounds)* | |
|---|---|---|---|---|---|---|
| ***Does water go to a POTW?*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** |
| Water leaves to POTW | 127 | 13 | 4.1% | 0.4% | 9,242 | 3,583 |
| Water leaves, not to POTW | 1981 | 39 | 64.5% | 1.0% | 1,030,000 | 142,400 |
| Water does not leave | 954 | 35 | 31.0% | 1.0% | 147,904 | 39,775 |
| No answer | 13 | 4 | 0.4% | 0.1% | 474 | 324 |
| ALL | 3075 | 46 | 100.0% | 0.0% | 1,190,000 | 150,200 |

[1] The responses in the table combine the answers to questions 7 and 8 in the questionnaire.

## Table A3.6. Water Discharge Status and NPDES Permits[1]

| | *Number of Facilities* | | *Percent of Facilities* | | *Production (thousands of pounds)* | |
|---|---|---|---|---|---|---|
| ***Does water go to a POTW?*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** |
| Water leaves, facility has NPDES permit | 541 | 27 | 17.6% | 0.8% | 278,103 | 98,129 |
| Water leaves, No NPDES permit | 1565 | 35 | 50.9% | 1.0% | 762,451 | 110,600 |
| Water does not leave | 954 | 35 | 31.0% | 1.0% | 147,904 | 39,775 |
| No answer | 14 | 5 | 0.5% | 0.1% | 511 | 324 |
| ALL | 3075 | 46 | 100.0% | 0.0% | 1,190,000 | 150,200 |

[1] The responses in the table combine the answers to questions 7 and 9 in the questionnaire.

## Table A3.7. Production Method[1]

| | *Number of Facilities* | | *Percent of Facilities* | | *Production (thousands of pounds)* | |
|---|---|---|---|---|---|---|
| ***Production Method*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** | ***Estimate*** | ***Standard error*** |
| Ponds | 1860 | 43 | 60.7% | 1.0% | 786,298 | 104,400 |
| Flow through raceways, ponds, or tanks | 1358 | 36 | 44.3% | 1.0% | 394,321 | 101,100 |
| Recirculating systems | 610 | 26 | 19.9% | 0.8% | 129,575 | 29,385 |
| Net pens or cages | 262 | 17 | 8.6% | 0.6% | 71,454 | 19,388 |
| Floating aquaculture or bottom culture | 248 | 16 | 8.1% | 0.5% | 38,315 | 11,296 |
| Other | 155 | 13 | 5.1% | 0.4% | 19,432 | 9,026 |

[1] If a facility reports using more than one production method, the facility is included in the table totals for each production method used. Therefore the sum of the column for the number of facilities is greater than the number of facilities represented by the data, and the same is true for the production numbers. Thus, the totals are not presented.

## Table A3.8. Species[1]

| | Number of Facilities | | Percent of Facilities | | Production, All Species (thousands of pounds) | |
|---|---|---|---|---|---|---|
| Species | Estimate | Standard error | Estimate | Standard error | Estimate | Standard error |
| Catfish | 901 | 30 | 29.3% | 0.9% | 637,211 | 99,896 |
| Trout | 818 | 28 | 26.6% | 0.8% | 120,600 | 23,065 |
| Salmon | 277 | 16 | 9.0% | 0.5% | 128,305 | 23,860 |
| Striped Bass | 155 | 13 | 5.1% | 0.4% | 24,817 | 6,168 |
| Tilapia | 178 | 15 | 5.8% | 0.5% | 24,005 | 7,236 |
| Other Finfish | 644 | 28 | 21.0% | 0.8% | 75,781 | 14,802 |
| Baitfish | 259 | 18 | 8.4% | 0.6% | 30,044 | 8,485 |
| Ornamentals | 267 | 19 | 8.7% | 0.6% | 24,031 | 7,881 |
| Shrimp | 73 | 10 | 2.4% | 0.3% | 12,957 | 4,623 |
| Crawfish | 83 | 9 | 2.7% | 0.3% | 12,353 | 6,430 |
| Other crustaceans | 24 | 6 | 0.8% | 0.2% | 293 | 170 |
| Molluscan shellfish | 303 | 18 | 9.9% | 0.6% | 140,308 | 96,204 |
| Other | 156 | 11 | 5.1% | 0.4% | 135,762 | 45,566 |

[1] If a facility produces more than one species, the facility is included in the table totals for each species produced. Therefore, the sum of the column for the number of facilities is greater than the number of facilities represented by the data, and the same is true for the production numbers. Each row provides the total production for all species at those facilities having the individual species in the left-hand column. See Table A3.9 for total production of just the individual species at those facilities.

## Table A3.9. Species[1]

| | Number of Facilities | | Percent of Facilities | | Production of Listed Species (thousands of pounds) | |
|---|---|---|---|---|---|---|
| Species | Estimate | Standard error | Estimate | Standard error | Estimate | Standard error |
| Catfish | 901 | 30 | 29.3% | 0.9% | 613,569 | 99,705 |
| Trout | 818 | 28 | 26.6% | 0.8% | 97,381 | 20,420 |
| Salmon | 277 | 16 | 9.0% | 0.5% | 112,514 | 23,443 |
| Striped Bass | 155 | 13 | 5.1% | 0.4% | 17,848 | 5,228 |
| Tilapia | 178 | 15 | 5.8% | 0.5% | 13,771 | 3,870 |
| Other Finfish | 644 | 28 | 21.0% | 0.8% | 26,888 | 6,317 |
| Baitfish | 259 | 18 | 8.4% | 0.6% | 10,781 | 2,975 |
| Ornamentals | 267 | 19 | 8.7% | 0.6% | 10,054 | 2,828 |
| Shrimp | 73 | 10 | 2.4% | 0.3% | 11,634 | 4,501 |
| Crawfish | 83 | 9 | 2.7% | 0.3% | 754 | 309 |
| Other crustaceans | 24 | 6 | 0.8% | 0.2% | 131 | 98 |
| Molluscan shellfish | 303 | 18 | 9.9% | 0.6% | 139,321 | 96,225 |
| Other | 156 | 11 | 5.1% | 0.4% | 134,324 | 45,584 |

[1] The total production is the production for the species listed in the left column. See Table A3.8 for the total facility production which includes production of all other species at the facilities producing that species in the left column.

## Table A3.10. For Selected Species, Number of Facilities by Predominant Production Method

| *Species* | *Predominant Production Method* | *National Estimate*[1] | *Responses* |
|---|---|---|---|
| **Catfish** | **Ponds** | 861.13 | 649 |
| | Flow Through & Not(Ponds) | 26.87 | 20 |
| | Recirculating & Not( Ponds or Flow Through) | ND | ND |
| | Other, Not(Ponds, Flow Through, or Recirculating) | ND | ND |
| | All systems | 900.91 | 679 |
| **Trout** | Flow Through | 735.07 | 569 |
| | Recirculating & Not(Flow Through) | 17.22 | 13 |
| | Ponds & Not(Flow Through or Recirculating) | 60.94 | 47 |
| | Net Pens & Not(Flow Through, Recirculating, or Ponds) | ND | ND |
| | Missing Production Information | ND | ND |
| | All systems | 818.40 | 633 |
| **Salmon** | Net Pens | 46.98 | 35 |
| | Flow Through & Not(Net Pens) | 219.25 | 166 |
| | Recirculating & Not(Net Pens or Flow Through) | ND | ND |
| | Other, Not(Net Pens, Flow Through, or Recirculating) | ND | ND |
| | All systems | 276.65 | 201 |
| **Shrimp** | Ponds | 55.57 | 42 |
| | Recirculating & Not(Ponds) | ND | ND |
| | Flow through & Not(Ponds or Recirculating) | ND | ND |
| | All systems | 72.53 | 55 |
| **Tilapia** | Recirculating | 119.42 | 90 |
| | Flow Through & Not(Recirculating) | 35.61 | 26 |
| | Ponds & Not(Recirculating or Flow Through) | ND | ND |
| | Missing Production Information | ND | ND |
| | All systems | 176.08 | 132 |
| **Sportfish (other Finfish)** | Ponds | 557.95 | 432 |
| | Flow Through & Not(Ponds) | 59.28 | 45 |
| | Recirculating & Not(Ponds or Flow Through) | 20.68 | 16 |
| | Other, Not(Ponds, Flow Through, or Recirculating) | 6.33 | 5 |
| | All systems | 644.24 | 498 |
| **Striped Bass/ Hybrid Striped Bass** | Ponds | 129.33 | 99 |
| | Recirculating & Not( Ponds) | 19.59 | 15 |
| | Flow through & Not(Ponds or Recirculating) | ND | ND |
| | Other & Not(Ponds, Recirculating, or Flow Through) | ND | ND |
| | All systems | 155.22 | 119 |
| **Alligator** | All systems | 41.12 | 31 |

[1] Sample sizes masked by ‘ND’ (‘Not Disclosed’) indicate there are five or fewer facilities for one or more of the production methods for that specie.

## Table A3.11. Estimated Number of Facilities Covered by the Proposed Rule[1]

| *Predominant Production Method* | *Species* | *Size* | *Revenue Classes* | | | |
|---|---|---|---|---|---|---|
| | | | *Class 1 ≥ $20,000 and <$100,000* | *Class 2 ≥ $100,000 and <$500,000* | *Class 3 ≥ $500,000* | *Total ≥ $20,000*[4] |
| Flow-through | Trout | Foodsize | 92 | 44 | 13 | 149 |
| | | Stockers | 139 | 131 | 39 | 309 |
| | Salmon | All with $ value | 44 | 52 | 38 | 133 |
| | Striped Bass | All with $ value | n/a[2] | ND[3] | ND | ND |
| | Tilapia | All with $ value | n/a | ND | ND | 9 |
| Recirculating | Striped Bass | All with $ value | n/a | ND | ND | ND |
| | Tilapia | All with $ value | n/a | 13 | 12 | 26 |
| Net Pens | Salmon | All with $ value | ND | ND | 19 | 32 |

[1] In the preamble to the proposed rule, EPA discusses six production size categories that correspond with the revenue classifications used in the 1998 USDA Census of Aquaculture (i.e., $1,000-$24,999; $25,000 - $49,999; $50,000 - $99,999; $100,000 - $499,999; $500,000 - $1,000,000; and >$1,000,000) to develop model facilities representing these size ranges for each species evaluated. Because small sample sizes for some revenue categories have small sample sizes, the national estimates are presented here. They are included in the non-public record as DCN50066CBI in Section 10.3.

[2] n/a: not applicable in the proposed rule

[3] ND: Sample sizes masked by 'ND' ('Not Disclosed') indicate there are five or fewer facilities for one or more of the classes in the production method/specie/size category

[4] Due to rounding, totals in this column may differ slightly from the sum of the numbers for the Classes.

# APPENDIX B
# ANALYTICAL METHODS AND NOMINAL QUANTITATION LIMITS

# APPENDIX B
# ANALYTICAL METHODS AND NOMINAL QUANTITATION LIMITS

The analytical methods described in this appendix were used to determine pollutant levels in wastewater samples collected by EPA at a number of aquatic animal production facilities (sampling efforts are described in Chapter 3). In developing the rule, EPA sampled aquatic animal production facilities to determine the levels of *Aeromonas*, ammonia as nitrogen, 5-day biochemical oxygen demand ($BOD_5$), chemical oxygen demand (COD), chloride, *E. coli*, *Enterococcus faecium*, fecal coliform, fecal streptococcus, 27 metals, *Mycobacterium marinum*, nitrate/nitrite, oil and grease (measured as hexane extractable material (HEM)), pH, settleable solids, semivolatile organics, sulfate, total chlorine, total coliform, total dissolved solids (TDS), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total orthophosphate, total phosphorus, total solids, total suspended solids (TSS), volatile organics, volatile residue, and whole effluent toxicity (WET). As explained in Chapters 2 and 8, EPA is regulating TSS for all facilties, and regulating total phosphorus and $BOD_5$ for some facilities.

Section B.1 of this appendix provides an explanation of nominal quantitation limits. Section B.2 describes the reporting conventions used by laboratories in expressing the results of the analyses. Section B.3 describes each analytical method and the nominal quantitation limits associated with each method.

## B.1 NOMINAL QUANTITATION LIMITS

The nominal quantitation limit is the smallest quantity of an analyte that can be reliably measured with a particular method, using the typical (nominal) sample size. The protocols used for determination of nominal quantitation limits in a particular method depend on the definitions and conventions that EPA used at the time the method was developed. Printouts in Section 10 of the proposal record list the nominal quantitation limit as a 'baseline value.'[1] The nominal quantitation limits associated with the methods addressed in this section fall into five categories.

1. The first category pertains to EPA Methods 1624, 1625, and 1664, which define the minimum level (ML) as the lowest level at which the entire analytical system must give a recognizable signal and an acceptable calibration point for the analyte. These methods are described in Section B.3.1.

2. The second category pertains specifically to metals, and is explained in detail in Section B.3.2.

[1] EPA used two different methods to analyze for ammonia as nitrogen and TKN, and only one method for the remaining pollutants of concern. The printout lists the nominal quantitation limit for the analytical method that was used most frequently for ammonia as nitrogen (Method 350.1) and TKN (Method 351.2).

3. The third category pertains to the remainder of the chemical methods (classical wet chemistry analytes) in which a variety of terms are used to describe the lowest level at which measurement results are quantitated. In some cases the methods date to the 1970s and 1980s when different concepts of quantitation were employed by EPA. These methods typically list a measurement range or lower limit of measurement. The terms differ by method and, as discussed in subsequent sections, the levels presented are not always representative of the lowest levels laboratories currently can achieve.

   For those methods associated with a calibration procedure, the laboratories demonstrated through a low-point calibration standard that they were capable of reliable quantitation at method-specified (or lower) levels. In such cases, these nominal quantitation limits are operationally equivalent to the ML (although not specifically identified as such in the methods).

   In the case of titrimetric or gravimetric methods, the laboratory adhered to the established lower limit of the measurement range published in the methods. Details of the specific methods are presented in Sections B.3.3 through B.3.19.

4. The fourth category pertains to all microbiological methods. This category pertains to the membrane filtration test and multiple tube fermentation procedures and are explained in detail in Section B.3.20.

5. The fifth category pertains to all whole effluent toxicity methods. The whole effluent toxicity methods are explained in detail in Section B.3.21.

## B.2 ANALYTICAL RESULTS REPORTING CONVENTIONS

Most of the analytical chemistry data were reported as liquid concentrations in weight/volume units (e.g., micrograms per liter [ g/L]), except for settleable solids data., which were reported in volume/volume units (e.g., milliliters per liter [mL/L]), and the pH data, which were reported in “standard units” (SU). In the case of solid samples such as sediments, the results were provided in weight/weight units (e.g., milligrams per kilogram [mg/kg]). Bacteriological data generated using membrane filtration techniques were reported as colony forming units (CFU) per 100 mL volume of sample or for data generated using multiple-tube fermentation techniques were reported as most probable number per 100 milliliters (MPN/100 mL). Whole effluent toxicity data endpoints measured were lethality in 50% of the organisms (LC50) for the fathead minnow and the *Ceriodaphnia*, growth in the larval fathead minnow and *Selenastrum*, and the number of offspring produced in the *Ceriodaphnia.*

The laboratories expressed results of the analyses either numerically or as not quantitated[2] for a pollutant in a sample. If the result is expressed numerically, then the

[2] Elsewhere in this document and in the preamble to the proposed rule, EPA may refer to pollutants as “not detected” or “non-detected.” This appendix uses the term “not quantitated” or “non-quantitated” rather than non-detected.

pollutant was quantitated[3] in the sample. For the non-quantitated results, for each sample, the laboratories reported a "sample-specific quantitation limit."[4] The sample-specific quantitation limit was used as a reporting limit for this industry. Two reporting examples are provided below.

<u>Example 1:</u> For a hypothetical pollutant X, the sample-specific quantitation limit is 10 g/L. When the laboratory quantitated the amount of pollutant X in the sample as being 15 g/L, the result would be reported as "15 g/L."

<u>Example 2:</u> For the hypothetical pollutant X, the sample-specific quantitation limit is 10 g/L. When the laboratory could not quantitate the amount of pollutant X in the sample, the result would be reported as "<10 g/L." That is, the analytical result indicated a value less than the sample-specific quantitation limit of 10 g/L. The actual amount of pollutant X in that sample is between zero (i.e., the pollutant is not present) and 10 g/L. If a pollutant is reported as non-quantitated in a particular wastewater sample, this does not mean that the pollutant is not present in the wastewater. It means that analytical techniques (whether because of instrument limitations, pollutant interactions, or other reasons) do not permit its measurement at levels below the sample-specific quantitation limit.

In its calculations, EPA generally substituted the reported value of the sample-specific quantitation limit for each non-quantitated result.

## B.3 ANALYTICAL METHODS

EPA analyzed all of the aquatic animal production facility wastewater samples using methods identified in Table B-1. (As explained in Section Z, EPA is proposing to regulate only a subset of these analytes.) Except for the volatile and semivolatile organics and total organic carbon, EPA used either EPA methods from *Methods for Chemical Analysis of Water and Wastes* (MCAWW) or the American Public Health Association's *Standard Methods for the Examination of Water and Wastewater*. EPA methods are identified in the sections that follow by their method number, e.g., EPA Method 1624. Methods from *Standard Methods for the Examination of Water and Wastewater* are prefaced by "SM." All of the chemical methods cited from Standard Methods (SM) are from the 18$^{th}$ edition; the biological methods cited from Standard Methods are from the 20$^{th}$ edition.

In analyzing samples, EPA generally used analytical methods approved at 40 CFR Part 136 for compliance monitoring or methods that had been in use by EPA for decades in support of effluent guidelines development. Exceptions for use of non-approved methods are explained in the method-specific subsections that follow. All EPA-proposed limitations or standards are based upon data generated by methods approved at 40 CFR Part 136.

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[3] Elsewhere in this document and in the preamble to the proposed rule, EPA may refer to pollutants as "detected." This appendix uses the term "quantitated" rather than detected.

[4] Elsewhere in this document and in the preamble to the proposed rule, EPA may refer to a "sample-specific quantitation limit" as a "sample-specific detection limit" or, more simply, as a "detection limit."

Each of the following sections states whether the method is listed at 40 CFR Part 136 (even if the pollutant was not proposed for regulation), provides a short description of the method, and identifies the nominal quantitation limit. Methods listed at 40 CFR Part 136 are approved for use in wastewater compliance monitoring under the NPDES process.

**Table B-1 Analytical Methods**

| | Method | CAS Number | Nominal Quantitation Limit | Unit |
|---|---|---|---|---|
| *Aeromonas* | 1605 | C2101 | 1 | CFU/100 mL |
| | 9260L | C2101 | 2 | MPN/100 mL |
| Ammonia as Nitrogen | 350.1 | 7664417 | 0.01 | mg/L |
| | 350.2 | 7664417 | 0.05 | mg/L |
| | 4500-$NH_3$ H | 7664417 | 0.02 | mg/L |
| $BOD_5$ | 405.1 | C003 | 2.0 | mg/L |
| *Ceriodaphnia Dubia* Chronic | 1002.0 | N/A | 100 | % |
| COD | 410.1 | C004 | 5.0 | mg/L |
| | 410.4 | C004 | 3.0 | mg/L |
| | 5220C | C004 | 50.0 | mg/L |
| Chloride | 325.1 | 16887006 | 1.0 | mg/L |
| | 325.3 | 16887006 | 1.0 | mg/L |
| | 4500$Cl^-$ B | 16887006 | 1.5 | mg/L |
| Dissolved Phosphorus | 365.2 | 14265442D | 0.01 | mg/L |
| *E. coli* | 1604 | 68583222 | 1 | CFU/100 mL |
| *Enterococcus Faecium* | 9230C | 68876788 | 100 | CFU/100 mL |
| Fathead Minnow | 1000.0 | N/A | 100 | % |
| Fecal Coliform | 9222D | C2106 | 1 | CFU/100 mL |
| Fecal Streptococcus | 9230C | C2107 | 1 | CFU/100 mL |
| | 9230B | C2107 | 2 | MPN/100 mL |
| HEM | 1664 | C036 | 5.0 | mg/L |
| Metals | 1620 | † | | |
| | 200.7 | † | | |
| | 200.9 | † | | |
| | 245.1 | † | | |

| | Method | CAS Number | Nominal Quantitation Limit | Unit |
|---|---|---|---|---|
| *Mycobacterium marinum* | 9260M | C2119 | 4 | CFU/100 mL |
| Nitrate/Nitrite | 353.1 | C005 | 0.01 | mg/L |
| | 353.3 | C005 | 0.01 | mg/L |
| | 4500-$NO_3$ E | C005 | 0.01 | mg/L |
| Oil and Grease | 5520E | C036 | 5.0 | mg/L |
| Orthophosphate | 365.2 | C034 | 0.01 | mg/L |
| pH | 150.1 | C006 | | SU |
| | 9045C | C006 | | SU |
| *Selenastrum* Growth Test | 1003.0 | N/A | 100 | % |
| Semivolatile Organics | 1625 | † | | |
| Settleable Solids | 2540F | N/A | 0.1 | mL/L |
| Sulfate | 375.3 | 14808798 | 10.0 | mg/L |
| | 375.4 | 14808798 | 1.0 | mg/L |
| Total Chlorine | Test Strip | 7782505 | 0.05 | mg/L |
| Total Coliform | 1604 | E10606 | 1 | CFU/100 mL |
| | 9221B | E10606 | 2 | MPN/100 mL |
| Total Dissolved Solids | 160.1 | C010 | 10.0 | mg/L |
| Total Kjeldahl Nitrogen | 351.2 | C021 | 0.5 | mg/L |
| | 351.3 | C021 | 1.0 | mg/L |
| | 4500-$N_{org}$ C | C021 | 0.02 | mg/L |
| Total Organic Carbon | 415.1 | C012 | 1.0 | mg/L |
| | Lloyd Kahn | C012 | 100 | mg/kg |
| Total Phosphorus | 365.2 | 14265442 | 0.01 | mg/L |
| Total Solids | 160.3 | C008 | 10.0 | mg/L |
| Total Suspended Solids | 160.2 | C009 | 4.0 | mg/L |
| Volatile Organics | 1624 | † | | |
| Volatile Residue | 160.4 | C030 | 10.0 | mg/L |

N/A There is no CAS Number for this analyte.† The method analyzed a number of pollutants

### B.3.1 EPA Methods 1624, 1625, and 1664 (Volatile Organics, Semivolatile Organics, and HEM)

Laboratories used EPA Methods 1624, 1625, and 1664 to measure volatile organics, semivolatile organics, and *n*-hexane extractable material (HEM). EPA Methods 1624, 1625, and 1664 are approved at 40 CFR Part 136.

These methods use the minimum level (ML) concept for quantitation of pollutants. The ML is defined as the lowest level at which the entire analytical system must give a recognizable signal and an acceptable calibration point for the analyte. When an ML is published in a method, the Agency has demonstrated that the ML can be achieved in at least one well-operated laboratory. When that laboratory or another laboratory uses that method, the laboratory is required to demonstrate, through calibration of the instrument or analytical system, that it can achieve pollutant measurements at the ML.

The nominal quantitation values are equal to the MLs listed in the methods for each analyte. The MLs for majority of volatile and semivolatile organics are 10 g/L, with a small number of higher values for pollutants that are more difficult to analyze. The ML for HEM determined by EPA Method 1664 is 5 mg/L.

### B.3.2 EPA Methods 1620, 200.7, 200.9, and 245.1 (Metals)

Laboratories used EPA Methods 1620, 200.7, 200.9, and 245.1 to measure the concentrations of 27 metals. While EPA Method 1620 is not listed at 40 CFR Part 136, it represents a consolidation of the analytical techniques in several 40 CFR 136-approved methods such as EPA Method 200.7 (inductively coupled plasma atomic emission (ICP) spectroscopy of trace elements) and Method 245.1 (mercury cold vapor atomic absorption technique). EPA Method 1620 was developed specifically for the effluent guidelines program. This method includes more metal analytes than are listed in the approved metals methods and contains quality control requirements that are at least as stringent as the approved methods. EPA Method 200.9 is not listed at 40 CFR Part 136, but represents a consolidation of the graphite furnace analytical methods approved at 40 CFR Part 136, such as EPA Methods 206.2 and 279.2.

EPA Method 1620 employs the concept of an instrument detection limit (IDL). The IDL is defined as "the smallest signal above background noise that an instrument can detect reliably." Data reporting practices for EPA Method 1620 analyses follow conventional metals reporting practices used in other EPA programs, in which values are required to be reported at or above the IDL. In applying EPA Method 1620, IDLs are determined on a quarterly basis by each analytical laboratory and are, therefore, laboratory-specific and time-specific.

Although EPA Method 1620 contains MLs, these MLs pre-date EPA's recent refinements of the ML concept described earlier. The ML values associated with EPA Method 1620 are based on a consensus reached between EPA and laboratories during the 1980s regarding levels that could be considered reliable quantitation limits when using EPA Method 1620. These limits do not reflect advances in technology and instrumentation since the 1980s. Consequently, the IDLs were used as the lowest values for reporting purposes, with the general understanding that reliable results can be produced at or above the IDL. The nominal quantitation values are the MLs listed in EPA Method 1620, except for two instances. The published ML for lead in EPA Method 1620 is 5 g/L for graphite furnace atomic absorption (GFAA) spectroscopy analysis. However, for the purposes of this effluent guideline study, EPA determined that it was not necessary for the laboratories to measure lead to such low levels, and permitted the analysis of lead by ICP spectroscopy. Consequently, the nominal quantitation limit for lead was adjusted to 50 g/L, the ML for the ICP method. Boron has an ML of 10 g/L, but historical information indicates that laboratories could not reliably achieve this low level. As a result, EPA only required laboratories to measure values at 100 g/L and above; this is the nominal quantitation limit used here.

### B.3.3 EPA Methods 350.1 and 350.2, and SM 4500H (Ammonia as Nitrogen)

Ammonia, as nitrogen, was measured using EPA Methods 350.1 and 350.2, and SM 4500H, all of which are approved at 40 CFR Part 136. Methods 350.1 and SM 4500H are automated methods using a continuous flow analytical system with a phenate/hypochlorite color reagent that reacts with ammonia to form indophenol blue that is proportional to the ammonia concentration. Method 350.2 utilizes either colorimetric, titrimetric, or electrode procedures to measure ammonia.

Method 350.1 has a lower measurement range limit of 0.01 mg/L. SM 4500H has a lower measurement range limit of 0.02 mg/L. Method 350.2 has a lower measurement range limit of 0.20 mg/L for the colorimetric and electrode procedures, and a lower measurement range limit of 1.0 mg/L for the titrimetric procedure.

### B.3.4 EPA Method 405.1 (Biochemical Oxygen Demand)

Biochemical oxygen demand ($BOD_5$) was measured using EPA Method 405.1, which is approved at 40 CFR Part 136. The sample and appropriate dilutions are incubated for five days at 20 C in the dark. The reduction in dissolved oxygen concentration during the incubation period is the measure of the biochemical oxygen demand.

The nominal quantitation limit for Method 405.1, which is expressed in the method as the lower limit of the measurement range, is 2 mg/L.

### B.3.5 EPA Methods 410.1 and 410.4, and SM 5220C (Chemical Oxygen Demand)

Chemical oxygen demand (COD) was measured using EPA Methods 410.1 and 410.4, and SM 5220C, all of which are approved at 40 CFR Part 136. Methods 410.1 and SM 5220C are titrimetric procedures designed to measure mid-level concentrations of COD and are associated with a nominal quantitation limit of 50 mg/L. Method 410.4 is a spectrophotometric procedure that measures COD and is associated with a nominal quantitation limit of 3 mg/L.

### B.3.6 EPA Methods 325.1 and 325.3, and SM 4500B (Chloride)

Chloride was measured using Methods 325.1 and 325.3, and SM 4500B, all of which are approved at 40 CFR Part 136. Method 325.1 is an automated colorimetric method that uses a ferricyanide reagent color for development. Method 325.3 is a titrimetric procedure that uses mercuric nitrate as the titrant. SM 4500B is also a titrimetric procedure, but it uses silver nitrate as the titrant.

Methods 325.1 and 325.3 measure concentrations greater than 1 mg/L, so the nominal quantitation limit is 1 mg/L. SM 4500B measures concentrations greater than 1.5 mg/L, so the nominal quantitation limit is 1.5 mg/L.

### B.3.7 EPA Methods 353.1 and 353.3, and SM 4500E (Nitrate/Nitrite)

Nitrate/nitrite was measured using EPA Methods 353.1 and 353.3, and SM 4500E, all of which are approved at 40 CFR Part 136. Method 353.1 is based on a colorimetric technique (i.e., adding reagents to a sample that form a colored product when they react with the nitrate/nitrite and measuring the intensity of the colored product). Method 353.1 uses hydrazine to reduce the nitrate ($NO_3$) present in the sample to nitrite ($NO_2$). Methods 353.3 and SM 4500E use granulated copper cadmium to reduce nitrate to nitrite. The nitrite is determined by reaction with sulfanilamide and coupling with N-(1-naphthyl)-ethylene diamine dihydrochloride to form a highly colored azo dye that is measured spectrophotometrically.

The nominal quantitation limit associated with Methods 353.1, 353.3, and SM 4500E is 0.01 mg/L.

### B.3.8 SM 5520E (Oil and Grease)

SM 5520E was used to measure oil and grease in the sediment samples from the aquatic animal production facilities because EPA Method 1664 is only applicable to aqueous samples. SM5520E is not approved at 40 CFR Part 136 because this method is applicable only to solid samples and not wastewater samples. SM 5520E is a gravimetric method in which the sediment is dried, the oil and grease is extracted with *n*-hexane, and the extract is weighed to obtain the concentration of oil and grease in the sample. The only difference between SM5520E and Method 1664 is the preparation of the sample for extraction. The solid sample is dried and magnesium sulfate added before extraction. There is no nominal quantitation limit associated with this method.

### B.3.9 EPA Methods 150.1 and 9045C (pH)

EPA Method 150.1 was used to analyze aqueous samples. Method 150.1 is approved at 40 CFR Part 136. Method 9045C, from *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), was used to analyze the sediment samples. Although Method 9045C is not approved at 40 CFR Part 136, it is approved for analyses of solid samples under the RCRA regulations at 40 CFR Part 261.

For Method 150.1, the pH of a sample is determined electrometrically using either a glass electrode in combination with a reference potential or a combination electrode. For Method 9045C, the sample is mixed with reagent water and the pH of the resulting aqueous solution is measured electrometrically.

There are no nominal quantitation limits for either Method 150.1 or 9045C.

### B.3.10 SM 2540F (Settleable Solids)

Settleable solids was determined by SM 2540F in the field by the samplers at the aquatic animal production facilities. SM 2540F is a volumetric method which uses an Imhoff cone. An Imhoff cone is filled to the 1-L mark with a well-mixed wastewater sample. The solids in the sample are allowed to settle in the cone for 45 minutes. The sample is agitated near the sides of the cone with a rod or by spinning and allowed to settle for an additional 15 minutes. The volume of the settleable solids in the cone is recorded as milliliters per liter (mL/L).

SM 2540F is approved at 40 CFR Part 136 under "residue-settleable." The method lists a lower limit of the measurement range of 0.1 mL/L; this value is also the nominal quantitation limit.

### B.3.11 EPA Methods 375.3 and 375.4 (Sulfate)

Sulfate was measured by EPA Methods 375.3 and 375.4, both of which are approved at 40 CFR Part 136. Method 375.3 is a gravimetric method that measures the amount of barium sulfate formed by reacting the sample with barium chloride. Method 375.4 measures the turbidity created by the insoluble barium sulfate in solution. A dispersant/buffer is added to the solution to aid in creating uniform suspension of the barium sulfate.

The nominal quantitation limit (also the lower limit of the measurement range) for Method 375.3 is 10 mg/L. The nominal quantitation limit for Method 375.4 is 1 mg/L.

### B.3.12 Test Strip Kit (Total Chlorine)

Total chlorine was determined by SenSafe™ total chlorine test strips in the field by the samplers at the aquatic animal production facilities. SenSafe™ total chlorine test strips range in sensitivity from 0.05 mg/L to 80 mg/L. The test strip from each sample is compared to a color chart to determine the result of the total chlorine.

### B.3.13 EPA Method 160.1 (Total Dissolved Solids)

Total dissolved solids (TDS) were measured by EPA Method 160.1, which is approved at 40 CFR 136 under "residue-filterable." Method 160.1 is a gravimetric method with a lower limit of the measurement range of 10 mg/L; this value is also the nominal quantitation limit.

### B.3.14 EPA Methods 351.2 and 351.3, and SM 4500C (Total Kjeldahl Nitrogen)

Total Kjeldahl nitrogen (TKN) was measured by EPA Methods 351.2 and 351.3, and SM 4500C, all of which are approved at 40 CFR Part 136. For Method 351.2, the sample is digested in a strong acid and a metal ion catalyst solution, taken to dryness, then reconstituted with an alkaline solution. The ammonia is the solution is determined by indophenol colorimetry using an automated continuous flow system. For Methods 351.3 and SM 4500C, the sample digestion is performed using a strong acid reagent with a metal ion catalyst. After the digestion period is complete, the solution is made alkaline and the ammonia in the digestate is distilled off into a borate buffer solution. Methods 351.3 and SM 4500C offer three different quantitation technique options for determining the ammonia concentration: titrimetric, iodide colorimetric, or $NH_3$ ion selective electrode.

The nominal quantitation limit (also the lower limit of the measurement range) for Method 351.2 is 0.1 mg/L. The nominal quantitation limit for Method 351.3 is 0.05 mg/L and the nominal quantitation limit for SM 4500C is 0.02 mg/L.

### B.3.15 EPA Method 415.1 and the "Lloyd Kahn" Procedure (Total Organic Carbon)

Total organic carbon (TOC) was determined by EPA Method 415.1 and the "Lloyd Kahn" procedure. Method 415.1 is a combustion (or oxidation) method with a lower limit of the measurement range is 1 mg/L; this value is also the nominal quantitation limit. The Lloyd Kahn procedure is similar to Method 415.1, but allows for a pyrolitic method that uses an elemental analyzer to determine carbon concentration. The nominal quantitation limit for the Lloyd Kahn procedure is 100 mg/kg.

Method 415.1 is approved at 40 CFR Part 136 and was used to analyze aqueous samples. However, this method only applies to aqueous samples. Therefore, the Lloyd Kahn procedure was used to analyze the solid samples. The Lloyd Kahn procedure applies only to solid samples and therefore is not approved at 40 CFR Part 136.

### B.3.16 EPA Method 365.2 (Dissolved Phosphorus, Total Orthophosphate, and Total Phosphorus)

Dissolved phosphorus, total orthophosphate and total phosphorus were measured by EPA Method 365.2, which is approved at 40 CFR Part 136. Total phosphorus represents all of the phosphorus present in the sample, regardless of form, as measured by the persulfate digestion procedure. Dissolved phosphorus results were obtained by filtering the sample prior to this step. Total orthophosphate represents the inorganic phosphorus ($PO_4$) in the sample determined by the direct colorimetric analysis procedure.

Method 365.2 is a colorimetric method and measures concentrations greater than 0.01 mg/L, which is also the nominal quantitation limit, for dissolved phosphorus, total orthophosphate, and total phosphorus.

### B.3.17 EPA Method 160.3 (Total Solids)

Total solids were determined by EPA Method 160.3, which is approved at 40 CFR Part 136 as “residue-total.” Method 160.3 is a gravimetric method with a lower limit of the measurement range of 10 mg/L; this value is also the nominal quantitation limit.

### B.3.18 EPA Method 160.2 (Total Suspended Solids)

Total suspended solids (TSS) were determined by EPA Method 160.2, which is approved at 40 CFR Part 136 as “residue-nonfiltrable.” Method 160.2 is a gravimetric method with a lower limit of the measurement range of 4 mg/L; this value is also the nominal quantitation limit.

### B.3.19 EPA Method 160.4 (Volatile Residue)

Volatile residue was determined by EPA Method 160.4, which is approved at 40 CFR Part 136. Method 160.4 is a gravimetric and ignition method with a lower limit of the measurement range of 10 mg/L; this value is also the nominal quantitation limit.

### B.3.20 EPA 1604 and SM 9221B, SM 9222D, SM 9230 B and 9230C, EPA 1605 and SM 9260L, SM 9260M (total coliform, fecal coliform, *E. coli*, fecal Streptococcus, *Enterococcus faecium, Aeromonas*, and *Mycobacterium marinum*)

Laboratories measured the densities of total coliform, fecal coliform, *E. coli*, fecal Streptococcus, *Aeromonas*, and *Enterococcus faecium* using membrane filtration methods specified in Standard Methods. EPA used multiple-tube fermentation procedures methods approved at 40 CFR Part 136 for ambient water for fecal coliform (SM9222D), fecal streptococcus (SM9230B and SM9230C), *Enterococcus faecium* (EPA Method 1106.1), total coliforms (EPA Method 1604 and SM9221B), and *E. coli* (EPA Method 1604). There are no 40 CFR Part 136-approved methods for *Aeromonas* or *Mycobacterium marinum*. For these microorganisms, EPA Method 1605 and SM 6260L was used for *Aeromonas*, and SM 9260M was used for *Mycobacterium marinum*.

1. **Total coliforms and *E. coli*** (EPA Method 1604 and SM 9221B). For EPA Method 1604, samples are filtered utilizing 0.45 μm filters, placed onto MI agar, and incubated for 24 ± 2 hours. Plates are read using ambient light and UV light to obtain total coliform and *E. coli* counts. Blue colonies are recorded as positive for *E. coli* and all colonies that fluoresce under UV light are recorded as total coliforms. Total coliforms were also measured by SM 9221B. Samples were inoculated into a presumptive medium (lauryl tryptose broth) and incubated. Tubes positive for growth and gas production were transferred into confirmatory media, brilliant green bile broth for total coliform. Tubes with growth and gas production in this media were recorded as positive.

2. **Fecal coliforms (9222D)**. Samples are filtered and placed onto mFC plates and incubated for 24 ± 2 hours in a water bath at 44.5°C ± 0.2 C. All blue colonies are considered positive for fecal coliforms.

3. **Fecal streptococcus (SM 9230 B and 9230C)**. Samples are filtered and placed onto mEnterococcus plates and incubated for 48 ± 3 hours for SM 9230C. All light and dark red colonies are considered positive for fecal streptococcus. For SM 9230B, samples were inoculated into a presumptive medium (azide dextrose broth) and incubated. Tubes positive for turbidity (growth) were confirmed by streaking onto bile esculin agar plates. All plates with typical growth were recorded as positive for fecal streptococcus.

4. ***Aeromonas* (EPA Method 1605 and SM 9260L)**. For EPA Method 1605, samples are filtered and placed onto ADA-V plates. All yellow colonies are isolated on nutrient agar and confirmed as *Aeromonas* if they are oxidase- and indole-positive and are able to ferment trehalose. *Aeromonas* densities were also determined by SM 9260L, followed by the confirmation steps in EPA Method 1605 to minimize false positive results. Samples were inoculated into a presumptive medium (TSB30) and

incubated. Tubes with growth were streaked onto ampicillin-detxtrin agar (ADA). All yellow colonies were isolated on nutrient agar and confirmed as Aeromonas if they were oxidase positive and were able to ferment trehalose. In addition to the biochemical confirmation, colony morphologies from ADA and nutrient agar were recorded and used to differentiate between *Aeromonas* and *Bacillus*.

5. ***Enterococcus faecium* (EPA Method 1106.1)**. Samples are filtered, placed onto mE agar, and incubated for 48 $\pm$ 3 hours. All filters with growth are transferred to EIA plates and incubated for an additional 20 minutes. All pink to red colonies on mE agar that produced a black or reddish brown precipitate on EIA agar are considered positive for *Enterococcus*. This effluent guideline study required that five positive colonies from each plate be submitted to biochemical identification to speciate and determine the levels of *Enterococcus faecium*.

6. ***Mycobacterium marinum* (SM9260M)**. Samples are screened for acid-fast bacteria prior to culturing. If acid-fast bacteria are present, the samples are decontaminated to remove organisms that may out-compete and overgrow the mycobacterium. After decontamination the samples are cultured in duplicate and incubated for 3-8 weeks at 37°C. Biochemical tests were then used to speciate the *Mycobacterium*.

The nominal quantitation limits are based on the actual sample volume filtered for the membrane filtration technique. The nominal quantitation limits for all the microbiological methods, except *Enterococcus faecium* and *Mycobacterium marinum*, are 1 CFU/100 mL. The nominal quantitation limit for *Enterococcus faecium* is 100 CFU/100 mL; the nominal quantitation limit for *Mycobacterium marinum* is 4 CFU/100 mL. For example, if a 100 mL volume is filtered, the nominal quantitation limit would be 1 CFU/100 mL. If a 10 mL volume is filtered, the nominal quantitation limit would be 10 CFU/100 mL.

Data were also generated using the most probable number (MPN) approach specified in Standard Methods. The MPN of each target organism per 100 milliliters was calculated based on the positive and negative results from the analysis of multiple replicates at multiple dilutions for each sample (see Table 9221.IV of Standard Methods). Based on the tables in Standard Methods, the nominal quantitation limit for the analytes analyzed by the multiple fermentation technique was 2 MPN/100 mL.

Table II at 40 CFR 136.3 specifies holding times of six hours for some pathogens. In collecting data supporting this rule, EPA measured counts in samples that had been retained longer than the six hours specified in Table II. In its data review narratives (located in Section 6.20 of the proposal record), EPA has identified those samples that were retained longer than eight hours at the laboratory (includes the six-hour holding time allotted for delivery to the laboratory plus an additional two hours at the laboratory). Standard Method 9221E, the 40 CFR Part 136 approved method for fecal coliform, states that "Water treatment and other adverse environmental conditions often place great stress on indicator bacteria, resulting in an extended lag phase before logarithmic growth takes place." EPA conducted a holding time study to assess potential changes in pathogen concentrations in effluents over time (i.e., 8, 24, 30, and 48 hours after sample collection). This study evaluated total and fecal coliforms, *Escherichia coli*, *Aeromonas* species, and fecal streptococci for the aquatic animal production facilities industrial effluents.

EPA conducted this holding time study for possible revisions to Table II. EPA notes that if the holding time can be extended to longer periods, overnight shipping of samples would be possible for compliance monitoring. However, EPA has not established any limitations and standards for these analytes. The report for the holding time study is located at DCN 62398 in Section 6.20 in the public record for the Notice of Data Availability (NODA).

#### *B.3.20.1 Holding Time Study*

When EPA conducted its own sampling episodes at the facilities, it exceeded the required holding time for sample samples. Although laboratories qualified to conduct total coliform, fecal coliform, and *E. coli* analyses might have been within driving distance of the facilities being evaluated, laboratories qualified to perform fecal streptococcus, *Aeromonas*, and *Enterococcus faecium* analyses generally were not available, because analysis for these analytes is more complex than coliform analyses. As a result, for most sampling episodes, EPA decided to ship samples overnight to a laboratory capable of performing all of the bacterial analyses. Because these samples would exceed the holding time requirements in 40 CFR 136, EPA performed a holding time study to evaluate the possible effects of analyzing samples at different holding times.

To determine whether or not the results for samples with longer holding times were consistent with results for samples analyzed within 8 hours (i.e., the time period consistent with 40 CFR 136 for compliance monitoring), for total coliforms fecal coliforms, *E. coli*, *Aeromonas*, fecal streptococcus, and *Enterococcus faecium* from CAAP facilities, EPA conducted a holding time study to evaluate sample concentrations at 8, 24, 30, and 48 hours after sample collection for wastewater effluent samples from two freshwater CAAP facilities. The study report , which contains results for all target bacteria, is DCN 62398 in Section 6.20 in the public record for the Notice of Data Availability (NODA).

Based on the results of this study, it appears that *Aeromonas* and fecal coliform samples from aquaculture effluents may not be analyzed beyong 8 hours after sample collection and still generate data comparable to those generate at 8 hours after sample collection. With these exceptions noted, fecal streptococcus samples may be analyzed at 30 hours; and total coliform, *E. coli*, *Enterococcus*, and *E. faecium* may be analyzed at 48 hours after sample collection and still generate data comparable to those generated within 8 hours of sample collection, provided the samples are held below 10°C and are not allowed to freeze. (Results of all samples analyzed are discussed in section 7.3 and Table 5 of the report.) Notwithstanding this conclusion, bacterial samples collected from concentrated aquatic animal production effluents should always be analyzed as soon as possible to comply with requirements at 40 CFR Part 136.

### B.3.21 EPA Methods 1003.0, 1000.0, and 1002.0 (*Selenastrum* growth test, Fathead Minnow Chronic, and *Ceriodaphnia Dubia* Chronic)

Whole effluent toxicity was measured using a suite of methods including the *Selenastrum* growth test (EPA Method 1003.0), the fathead minnow larval survival and growth test

(EPA Method 1000.0), and *Ceriodaphnia dubia* survival and reproductive test (EPA Method 1002.0). All three methods are listed in Table 1A at 40 CFR Part 136. Endpoints measured were lethality in 50% of the organisms (LC50) for the fathead minnow and the *Ceriodaphnia*, growth in the larval fathead minnow and *Selenastrum*, and the number of offspring produced in the *Ceriodaphnia.*

1. **Method 1003.0: *Selenastrum* growth test**. A population of the green algae, *Selenastrum capricornutum*, is exposed in a static system to a series of effluent concentrations for 96 hours. The response of the population is measured in terms of changes in cell density (cell counts per mL). The toxicity of the effluent is indicated by increases or decreases in algal growth in response to nutrients and toxicants, compared to a control group (unexposed) of algae.

   The test is run using a 50-mL aliquot of effluent solution in a 250-mL flask. The effluent solutions are 6.25%, 12.5%, 25%, 50%, and 100% effluent. Each effluent concentration is run in five replicates. Each flask is inoculated with 10,000 cells per mL and allowed to grow during a 96-hour time period. During this time, the flasks are swirled twice daily to homogenize the cells within the flasks to allow for optimum growth. After the 96 hours, cells are counted from each of the flasks by taking an aliquot and counting the cells under a microscope using an approved cell counting method.

2. **Method 1000.0: Fathead minnow chronic**. Larva of the fathead minnow, *Pimephales promelas*, are exposed to different concentrations of effluent for seven days in a static renewal system. Test results are based on survival and weight of the larvae. The toxicity of the effluent is indicated by changes in the survival rate and decreases in the growth of the larvae that survive the testing period, compared to a control group (unexposed) of larvae.

   The test is run using a 250-mL aliquot of effluent solution in a 500-mL beaker. The effluent solutions are 6.25%, 12.5%, 25%, 50%, and 100% effluent. Each effluent concentration is run in 4 replicates, each containing 10 minnows, with an initiation age of less than 24 hours old. Daily observations are made to record the number of surviving minnows when the effluent solution is renewed. At 96 hours the test is terminated, the final number of surviving minnows is recorded, and the surviving minnows are preserved in 70% ethanol, then dried and weighed. The survival of minnows at the different concentration levels is compared to the control group to determine if any statistical difference was observed and the results are reported as an LC50. The weight of the surviving minnows at the different concentration levels is compared to the control group to determine if any statistical difference was observed and the results are reported as the inhibition concentration with a 25% effect (IC25).

3. **Method 1002.0: *Ceriodaphnia dubia* chronic**. *Ceriodaphnia dubia* are exposed in a static renewal system to different concentrations of effluent until 60% of surviving control organisms have three broods of offspring. Test results are based on survival and reproduction. If the test is conducted properly, the surviving control organisms should produce 15 or more offspring in three broods.

The test is run using a 15-mL aliquot of effluent solution in a 30-mL beaker. The effluent solutions are 6.25%, 12.5%, 25%, 50%, and 100% effluent. Each effluent concentration is run in 10 replicates containing 1 female with an initiation age of less than 24 hours old. Daily observations are made to record the number of surviving organisms and the number of offspring when the effluent solution is renewed. When 60% of the surviving females produce 3 broods, the test is terminated. The survival of organisms at the different concentration levels is compared to the control group to determine if any statistical difference was observed and the results are reported as an LC50. The number of offspring produced by the surviving organisms at the different concentration levels is compared to the control group to determine if any statistical difference was observed and the results are reported as an IC25.

# APPENDIX C
## DAILY INFLUENT AND EFFLUENT DATA FOR TOTAL SUSPENDED SOLIDS

## Part 1a: Episodes for each Configuration

| *Subcategory* | *Option* | *Configuration* | *Episode* | *No. of data points* |
|---|---|---|---|---|
| Combined | A | 2A+6A+7A Continuous A | 6439A | 5 |
| | | | 6460C | 1 |
| | | | 6495A | 5 |
| Combined | B | 2B+6B+7B Continuous B | 6297A | 5 |
| | | | 6297B | 5 |
| | | | 6297C | 5 |
| | | | 6439B | 5 |
| | | | DMR06 | 12 |
| | | | DMR10 | 2 |
| | | | DMR12A | 49 |
| | | | DMR12B | 49 |
| | | | DMR15 | 43 |
| | | | DMR18 | 1 |
| | | | DMR21A | 48 |
| | | | DMR21B | 48 |
| | | | DMR21C | 48 |
| | | | DMR25A | 48 |
| | | | DMR25B | 48 |
| | | | DMR28 | 48 |
| | | | DMR31 | 43 |
| | | | DMR32 | 1 |
| | | | DMR34 | 20 |
| | | | DMR37 | 48 |
| | | | DMR38 | 11 |
| | | | DMR49 | 20 |
| | | | DMR54A | 48 |
| | | | DMR54B | 49 |
| | | | DMR59 | 9 |
| Flow-through | A | 2A OLSB A | 6460C | 1 |
| | | | 6495A | 5 |
| Flow-through | A | 3A Raceway A | 6460B | 5 |
| Flow-through | A | 4A Combined A | 6460A | 5 |
| | | | DMR01 | 19 |
| | | | DMR03 | 37 |
| | | | DMR04 | 34 |
| | | | DMR61 | 12 |
| Flow-through | B | 2B OLSB B | 6297A | 5 |
| | | | 6297B | 5 |
| | | | 6297C | 5 |
| | | | DMR06 | 12 |
| | | | DMR10 | 2 |

| ***Subcategory*** | ***Option*** | ***Configuration*** | ***Episode*** | ***No. of data points*** |
|---|---|---|---|---|
| | | | DMR12A | 49 |
| | | | DMR12B | 49 |
| | | | DMR15 | 43 |
| | | | DMR18 | 1 |
| | | | DMR21A | 48 |
| | | | DMR21B | 48 |
| | | | DMR21C | 48 |
| | | | DMR25A | 48 |
| | | | DMR25B | 48 |
| | | | DMR28 | 48 |
| | | | DMR31 | 43 |
| | | | DMR32 | 1 |
| | | | DMR34 | 20 |
| | | | DMR37 | 48 |
| | | | DMR38 | 11 |
| | | | DMR49 | 20 |
| | | | DMR54A | 48 |
| | | | DMR54B | 49 |
| | | | DMR59 | 9 |
| Flow-through | B | 3B Raceway B | 6297E | 5 |
| | | | 6297F | 5 |
| | | | DMR05 | 3 |
| | | | DMR06 | 12 |
| | | | DMR07 | 2 |
| | | | DMR08 | 9 |
| | | | DMR09 | 1 |
| | | | DMR10 | 16 |
| | | | DMR12A | 49 |
| | | | DMR13 | 2 |
| | | | DMR15 | 39 |
| | | | DMR17 | 1 |
| | | | DMR18 | 11 |
| | | | DMR19 | 4 |
| | | | DMR20 | 4 |
| | | | DMR21A | 48 |
| | | | DMR23 | 9 |
| | | | DMR25A | 48 |
| | | | DMR26 | 11 |
| | | | DMR27 | 2 |
| | | | DMR28 | 44 |
| | | | DMR29 | 3 |
| | | | DMR30 | 2 |
| | | | DMR31 | 44 |

| ***Subcategory*** | ***Option*** | ***Configuration*** | ***Episode*** | ***No. of data points*** |
|---|---|---|---|---|
| | | | DMR32 | 1 |
| | | | DMR34 | 7 |
| | | | DMR35 | 2 |
| | | | DMR36 | 4 |
| | | | DMR37 | 48 |
| | | | DMR38 | 12 |
| | | | DMR39 | 4 |
| | | | DMR42 | 3 |
| | | | DMR43 | 2 |
| | | | DMR44 | 1 |
| | | | DMR46 | 4 |
| | | | DMR47 | 2 |
| | | | DMR48 | 12 |
| | | | DMR49 | 43 |
| | | | DMR50 | 40 |
| | | | DMR51 | 7 |
| | | | DMR53 | 48 |
| | | | DMR54A | 48 |
| | | | DMR57 | 4 |
| | | | DMR58 | 1 |
| | | | DMR59 | 8 |
| | | | DMR60 | 9 |
| | | | DMR62 | 4 |
| Flow-through | B | 4B Combined B | 6297G | 5 |
| | | | 6297H | 5 |
| | | | 6297I | 5 |
| | | | 6460D | 5 |
| | | | 6495B | 5 |
| Recirculating | A | 6A RAS Solids A | 6439A | 5 |
| Recirculating | B | 6B RAS Solids B | 6439B | 5 |

## Part 1b: Configurations for each Episode

| *Episode* | *Subcategory* | *Option* | *Configuration* | *No. of data points* |
|---|---|---|---|---|
| 6297A | Combined | B | 2B+6B+7B Continuous B | 5 |
| | Flow-through | B | 2B OLSB B | 5 |
| 6297B | Combined | B | 2B+6B+7B Continuous B | 5 |
| | Flow-through | B | 2B OLSB B | 5 |
| 6297C | Combined | B | 2B+6B+7B Continuous B | 5 |
| | Flow-through | B | 2B OLSB B | 5 |
| 6297E | Flow-through | B | 3B Raceway B | 5 |
| 6297F | Flow-through | B | 3B Raceway B | 5 |
| 6297G | Flow-through | B | 4B Combined B | 5 |
| 6297H | Flow-through | B | 4B Combined B | 5 |
| 6297I | Flow-through | B | 4B Combined B | 5 |
| 6439A | Combined | A | 2A+6A+7A Continuous A | 5 |
| | Recirculating | A | 6A RAS Solids A | 5 |
| 6439B | Combined | B | 2B+6B+7B Continuous B | 5 |
| | Recirculating | B | 6B RAS Solids B | 5 |
| 6460A | Flow-through | A | 4A Combined A | 5 |
| 6460B | Flow-through | A | 3A Raceway A | 5 |
| 6460C | Combined | A | 2A+6A+7A Continuous A | 1 |
| | Flow-through | A | 2A OLSB A | 1 |
| 6460D | Flow-through | B | 4B Combined B | 5 |
| 6495A | Combined | A | 2A+6A+7A Continuous A | 5 |
| | Flow-through | A | 2A OLSB A | 5 |
| 6495B | Flow-through | B | 4B Combined B | 5 |
| DMR01 | Flow-through | A | 4A Combined A | 19 |
| DMR03 | Flow-through | A | 4A Combined A | 37 |
| DMR04 | Flow-through | A | 4A Combined A | 34 |
| DMR05 | Flow-through | B | 3B Raceway B | 3 |
| DMR06 | Combined | B | 2B+6B+7B Continuous B | 12 |
| | Flow-through | B | 2B OLSB B | 12 |
| | Flow-through | B | 3B Raceway B | 12 |
| DMR07 | Flow-through | B | 3B Raceway B | 2 |
| DMR08 | Flow-through | B | 3B Raceway B | 9 |
| DMR09 | Flow-through | B | 3B Raceway B | 1 |
| DMR10 | Combined | B | 2B+6B+7B Continuous B | 2 |
| | Flow-through | B | 2B OLSB B | 2 |
| | Flow-through | B | 3B Raceway B | 16 |
| DMR12A | Combined | B | 2B+6B+7B Continuous B | 49 |
| | Flow-through | B | 2B OLSB B | 49 |
| | Flow-through | B | 3B Raceway B | 49 |
| DMR12B | Combined | B | 2B+6B+7B Continuous B | 49 |
| | Flow-through | B | 2B OLSB B | 49 |

| *Episode* | *Subcategory* | *Option* | *Configuration* | *No. of data points* |
|---|---|---|---|---|
| DMR13 | Flow-through | B | 3B Raceway B | 2 |
| DMR15 | Combined | B | 2B+6B+7B Continuous B | 43 |
| | Flow-through | B | 2B OLSB B | 43 |
| | Flow-through | B | 3B Raceway B | 39 |
| DMR17 | Flow-through | B | 3B Raceway B | 1 |
| DMR18 | Combined | B | 2B+6B+7B Continuous B | 1 |
| | Flow-through | B | 2B OLSB B | 1 |
| | Flow-through | B | 3B Raceway B | 11 |
| DMR19 | Flow-through | B | 3B Raceway B | 4 |
| DMR20 | Flow-through | B | 3B Raceway B | 4 |
| DMR21A | Combined | B | 2B+6B+7B Continuous B | 48 |
| | Flow-through | B | 2B OLSB B | 48 |
| | Flow-through | B | 3B Raceway B | 48 |
| DMR21B | Combined | B | 2B+6B+7B Continuous B | 48 |
| | Flow-through | B | 2B OLSB B | 48 |
| DMR21C | Combined | B | 2B+6B+7B Continuous B | 48 |
| | Flow-through | B | 2B OLSB B | 48 |
| DMR23 | Flow-through | B | 3B Raceway B | 9 |
| DMR25A | Combined | B | 2B+6B+7B Continuous B | 48 |
| | Flow-through | B | 2B OLSB B | 48 |
| | Flow-through | B | 3B Raceway B | 48 |
| DMR25B | Combined | B | 2B+6B+7B Continuous B | 48 |
| | Flow-through | B | 2B OLSB B | 48 |
| DMR26 | Flow-through | B | 3B Raceway B | 11 |
| DMR27 | Flow-through | B | 3B Raceway B | 2 |
| DMR28 | Combined | B | 2B+6B+7B Continuous B | 48 |
| | Flow-through | B | 2B OLSB B | 48 |
| | Flow-through | B | 3B Raceway B | 44 |
| DMR29 | Flow-through | B | 3B Raceway B | 3 |
| DMR30 | Flow-through | B | 3B Raceway B | 2 |
| DMR31 | Combined | B | 2B+6B+7B Continuous B | 43 |
| | Flow-through | B | 2B OLSB B | 43 |
| | Flow-through | B | 3B Raceway B | 44 |
| DMR32 | Combined | B | 2B+6B+7B Continuous B | 1 |
| | Flow-through | B | 2B OLSB B | 1 |
| | Flow-through | B | 3B Raceway B | 1 |
| DMR34 | Combined | B | 2B+6B+7B Continuous B | 20 |
| | Flow-through | B | 2B OLSB B | 20 |
| | Flow-through | B | 3B Raceway B | 7 |
| DMR35 | Flow-through | B | 3B Raceway B | 2 |
| DMR36 | Flow-through | B | 3B Raceway B | 4 |
| DMR37 | Combined | B | 2B+6B+7B Continuous B | 48 |
| | Flow-through | B | 2B OLSB B | 48 |

| ***Episode*** | ***Subcategory*** | ***Option*** | ***Configuration*** | ***No. of data points*** |
|---|---|---|---|---|
| | Flow-through | B | 3B Raceway B | 48 |
| DMR38 | Combined | B | 2B+6B+7B Continuous B | 11 |
| | Flow-through | B | 2B OLSB B | 11 |
| | Flow-through | B | 3B Raceway B | 12 |
| DMR39 | Flow-through | B | 3B Raceway B | 4 |
| DMR42 | Flow-through | B | 3B Raceway B | 3 |
| DMR43 | Flow-through | B | 3B Raceway B | 2 |
| DMR44 | Flow-through | B | 3B Raceway B | 1 |
| DMR46 | Flow-through | B | 3B Raceway B | 4 |
| DMR47 | Flow-through | B | 3B Raceway B | 2 |
| DMR48 | Flow-through | B | 3B Raceway B | 12 |
| DMR49 | Combined | B | 2B+6B+7B Continuous B | 20 |
| | Flow-through | B | 2B OLSB B | 20 |
| | Flow-through | B | 3B Raceway B | 43 |
| DMR50 | Flow-through | B | 3B Raceway B | 40 |
| DMR51 | Flow-through | B | 3B Raceway B | 7 |
| DMR53 | Flow-through | B | 3B Raceway B | 48 |
| DMR54A | Combined | B | 2B+6B+7B Continuous B | 48 |
| | Flow-through | B | 2B OLSB B | 48 |
| | Flow-through | B | 3B Raceway B | 48 |
| DMR54B | Combined | B | 2B+6B+7B Continuous B | 49 |
| | Flow-through | B | 2B OLSB B | 49 |
| DMR57 | Flow-through | B | 3B Raceway B | 4 |
| DMR58 | Flow-through | B | 3B Raceway B | 1 |
| DMR59 | Combined | B | 2B+6B+7B Continuous B | 9 |
| | Flow-through | B | 2B OLSB B | 9 |
| | Flow-through | B | 3B Raceway B | 8 |
| DMR60 | Flow-through | B | 3B Raceway B | 9 |
| DMR61 | Flow-through | A | 4A Combined A | 12 |
| DMR62 | Flow-through | B | 3B Raceway B | 4 |

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

Subcategory=Flow-through -- Option=' ' -- Configuration=NA Not Applicable

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6297D | COLD | 1 | 12/11/2000 | | | | SP-4 | 4.00 | ND |
| 6297D | COLD | 2 | 12/12/2000 | | | | SP-4 | 4.00 | ND |
| 6297D | COLD | 3 | 12/13/2000 | | | | SP-4 | 4.00 | ND |
| 6297D | COLD | 4 | 12/14/2000 | | | | SP-4 | 4.00 | ND |
| 6297D | COLD | 5 | 12/15/2000 | | | | SP-4 | 4.00 | ND |

Subcategory=Flow-through -- Option=A -- Configuration=2A OLSB A

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6460C | COLD | 3 | 08/27/2001 | SP-9 | 38.00 | NC | SP-8 | 11800.00 | NC |
| 6495A | COLD | 1 | 03/25/2003 | SP-11 | 8.00 | NC | SP-10 | 91.00 | NC |
| 6495A | COLD | 2 | 03/26/2003 | SP-11 | 7.00 | NC | SP-10 | 92.00 | NC |
| 6495A | COLD | 3 | 03/27/2003 | SP-11 | 6.00 | NC | SP-10 | 62.00 | NC |
| 6495A | COLD | 4 | 03/28/2003 | SP-11 | 8.00 | NC | SP-10 | 29.00 | NC |
| 6495A | COLD | 5 | 03/29/2003 | SP-11 | 4.00 | ND | SP-10 | 25.00 | NC |

Subcategory=Flow-through -- Option=A -- Configuration=3A Raceway A

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6460B | COLD | 1 | 08/25/2001 | SP-7 | 4.00 | ND | | | |
| 6460B | COLD | 2 | 08/26/2001 | SP-7 | 4.00 | ND | | | |
| 6460B | COLD | 3 | 08/27/2001 | SP-7 | 4.00 | ND | | | |
| 6460B | COLD | 4 | 08/28/2001 | SP-7 | 4.00 | ND | | | |
| 6460B | COLD | 5 | 08/29/2001 | SP-7 | 4.00 | ND | | | |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

---------------------------------------- Subcategory=Flow-through -- Option=A -- Configuration=4A Combined A ----------------------------------------

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6460A | COLD | 1 | 08/25/2001 | SP7,SP9 | 4.00 | ND | | | |
| 6460A | COLD | 2 | 08/26/2001 | SP7,SP9 | 4.00 | ND | | | |
| 6460A | COLD | 3 | 08/27/2001 | SP7,SP9 | 31.68 | NC | | | |
| 6460A | COLD | 4 | 08/28/2001 | SP7,SP9 | 4.00 | ND | | | |
| 6460A | COLD | 5 | 08/29/2001 | SP7,SP9 | 4.00 | ND | | | |
| DMR01 | COLD | 1 | 05/02/1996 | SP-1 | 1.00 | NC | | | |
| DMR01 | COLD | 33 | 06/03/1996 | SP-1 | 2.00 | NC | | | |
| DMR01 | COLD | 67 | 07/07/1996 | SP-1 | 1.00 | NC | | | |
| DMR01 | COLD | 95 | 08/04/1996 | SP-1 | 1.00 | NC | | | |
| DMR01 | COLD | 127 | 09/05/1996 | SP-1 | 1.00 | NC | | | |
| DMR01 | COLD | 155 | 10/03/1996 | SP-1 | 5.00 | NC | | | |
| DMR01 | COLD | 246 | 01/02/1997 | SP-1 | 3.00 | NC | | | |
| DMR01 | COLD | 281 | 02/06/1997 | SP-1 | 1.00 | NC | | | |
| DMR01 | COLD | 307 | 03/04/1997 | SP-1 | 3.00 | NC | | | |
| DMR01 | COLD | 340 | 04/06/1997 | SP-1 | 1.00 | NC | | | |
| DMR01 | COLD | 371 | 05/07/1997 | SP-1 | 2.00 | NC | | | |
| DMR01 | COLD | 399 | 06/04/1997 | SP-1 | 1.00 | NC | | | |
| DMR01 | COLD | 523 | 10/06/1997 | SP-1 | 3.00 | NC | | | |
| DMR01 | COLD | 617 | 01/08/1998 | SP-1 | 2.00 | NC | | | |
| DMR01 | COLD | 677 | 03/09/1998 | SP-1 | 1.00 | NC | | | |
| DMR01 | COLD | 795 | 07/05/1998 | SP-1 | 1.00 | NC | | | |
| DMR01 | COLD | 1071 | 04/07/1999 | SP-1 | 2.00 | NC | | | |
| DMR01 | COLD | 1160 | 07/05/1999 | SP-1 | 2.00 | NC | | | |
| DMR01 | COLD | 1168 | 07/13/1999 | SP-1 | 1.00 | NC | | | |
| DMR03 | COLD | 1 | 02/06/1996 | SP-1 | 3.90 | NC | | | |
| DMR03 | COLD | 28 | 03/04/1996 | SP-1 | 5.50 | NC | | | |
| DMR03 | COLD | 58 | 04/03/1996 | SP-1 | 3.40 | NC | | | |
| DMR03 | COLD | 95 | 05/10/1996 | SP-1 | 4.00 | NC | | | |
| DMR03 | COLD | 120 | 06/04/1996 | SP-1 | 4.10 | NC | | | |
| DMR03 | COLD | 148 | 07/02/1996 | SP-1 | 3.10 | NC | | | |
| DMR03 | COLD | 176 | 07/30/1996 | SP-1 | 3.00 | NC | | | |
| DMR03 | COLD | 213 | 09/05/1996 | SP-1 | 5.60 | NC | | | |
| DMR03 | COLD | 242 | 10/04/1996 | SP-1 | 5.40 | NC | | | |
| DMR03 | COLD | 273 | 11/04/1996 | SP-1 | 2.40 | NC | | | |
| DMR03 | COLD | 302 | 12/03/1996 | SP-1 | 3.30 | NC | | | |
| DMR03 | COLD | 340 | 01/10/1997 | SP-1 | 3.20 | NC | | | |
| DMR03 | COLD | 368 | 02/07/1997 | SP-1 | 2.40 | NC | | | |
| DMR03 | COLD | 393 | 03/04/1997 | SP-1 | 5.00 | NC | | | |
| DMR03 | COLD | 424 | 04/04/1997 | SP-1 | 4.30 | NC | | | |
| DMR03 | COLD | 455 | 05/05/1997 | SP-1 | 4.00 | NC | | | |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

---------------------------------------- Subcategory=Flow-through -- Option=A -- Configuration=4A Combined A ----------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR03 | COLD | 484 | 06/03/1997 | SP-1 | 6.50 | NC | | | |
| DMR03 | COLD | 518 | 07/07/1997 | SP-1 | 4.10 | NC | | | |
| DMR03 | COLD | 546 | 08/04/1997 | SP-1 | 3.50 | NC | | | |
| DMR03 | COLD | 578 | 09/05/1997 | SP-1 | 1.70 | NC | | | |
| DMR03 | COLD | 611 | 10/08/1997 | SP-1 | 2.00 | NC | | | |
| DMR03 | COLD | 639 | 11/05/1997 | SP-1 | 2.40 | NC | | | |
| DMR03 | COLD | 667 | 12/03/1997 | SP-1 | 2.20 | NC | | | |
| DMR03 | COLD | 700 | 01/05/1998 | SP-1 | 3.10 | NC | | | |
| DMR03 | COLD | 730 | 02/04/1998 | SP-1 | 2.90 | NC | | | |
| DMR03 | COLD | 758 | 03/04/1998 | SP-1 | 3.20 | NC | | | |
| DMR03 | COLD | 788 | 04/03/1998 | SP-1 | 4.60 | NC | | | |
| DMR03 | COLD | 822 | 05/07/1998 | SP-1 | 2.60 | NC | | | |
| DMR03 | COLD | 854 | 06/08/1998 | SP-1 | 3.20 | NC | | | |
| DMR03 | COLD | 883 | 07/07/1998 | SP-1 | 2.40 | NC | | | |
| DMR03 | COLD | 913 | 08/06/1998 | SP-1 | 1.80 | NC | | | |
| DMR03 | COLD | 947 | 09/09/1998 | SP-1 | 3.90 | NC | | | |
| DMR03 | COLD | 977 | 10/09/1998 | SP-1 | 7.00 | NC | | | |
| DMR03 | COLD | 1008 | 11/09/1998 | SP-1 | 4.00 | NC | | | |
| DMR03 | COLD | 1036 | 12/07/1998 | SP-1 | 4.50 | NC | | | |
| DMR03 | COLD | 1070 | 01/10/1999 | SP-1 | 4.30 | NC | | | |
| DMR03 | COLD | 1100 | 02/09/1999 | SP-1 | 3.90 | NC | | | |
| | | | | | | | | | |
| DMR04 | COLD | 1 | 02/07/1996 | SP-1 | 1.70 | NC | | | |
| DMR04 | COLD | 28 | 03/05/1996 | SP-1 | 6.10 | NC | | | |
| DMR04 | COLD | 57 | 04/03/1996 | SP-1 | 4.50 | NC | | | |
| DMR04 | COLD | 87 | 05/03/1996 | SP-1 | 1.40 | NC | | | |
| DMR04 | COLD | 119 | 06/04/1996 | SP-1 | 1.60 | NC | | | |
| DMR04 | COLD | 147 | 07/02/1996 | SP-1 | 1.00 | NC | | | |
| DMR04 | COLD | 184 | 08/08/1996 | SP-1 | 2.10 | NC | | | |
| DMR04 | COLD | 212 | 09/05/1996 | SP-1 | 2.40 | NC | | | |
| DMR04 | COLD | 246 | 10/09/1996 | SP-1 | 1.90 | NC | | | |
| DMR04 | COLD | 275 | 11/07/1996 | SP-1 | 0.90 | NC | | | |
| DMR04 | COLD | 304 | 12/06/1996 | SP-1 | 1.00 | NC | | | |
| DMR04 | COLD | 336 | 01/07/1997 | SP-1 | 6.30 | NC | | | |
| DMR04 | COLD | 367 | 02/07/1997 | SP-1 | 9.60 | NC | | | |
| DMR04 | COLD | 426 | 04/07/1997 | SP-1 | 2.40 | NC | | | |
| DMR04 | COLD | 459 | 05/10/1997 | SP-1 | 2.90 | NC | | | |
| DMR04 | COLD | 490 | 06/10/1997 | SP-1 | 2.50 | NC | | | |
| DMR04 | COLD | 517 | 07/07/1997 | SP-1 | 3.30 | NC | | | |
| DMR04 | COLD | 547 | 08/06/1997 | SP-1 | 1.10 | NC | | | |
| DMR04 | COLD | 576 | 09/04/1997 | SP-1 | 0.90 | NC | | | |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

---------- Subcategory=Flow-through -- Option=A -- Configuration=4A Combined A ----------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR04 | COLD | 611 | 10/09/1997 | SP-1 | 1.50 | NC | | | |
| DMR04 | COLD | 639 | 11/06/1997 | SP-1 | 1.60 | NC | | | |
| DMR04 | COLD | 672 | 12/09/1997 | SP-1 | 1.50 | NC | | | |
| DMR04 | COLD | 756 | 03/03/1998 | SP-1 | 1.10 | NC | | | |
| DMR04 | COLD | 794 | 04/10/1998 | SP-1 | 6.40 | NC | | | |
| DMR04 | COLD | 820 | 05/06/1998 | SP-1 | 3.40 | NC | | | |
| DMR04 | COLD | 854 | 06/09/1998 | SP-1 | 4.20 | NC | | | |
| DMR04 | COLD | 882 | 07/07/1998 | SP-1 | 6.30 | NC | | | |
| DMR04 | COLD | 916 | 08/10/1998 | SP-1 | 2.20 | NC | | | |
| DMR04 | COLD | 939 | 09/02/1998 | SP-1 | 2.90 | NC | | | |
| DMR04 | COLD | 973 | 10/06/1998 | SP-1 | 1.60 | NC | | | |
| DMR04 | COLD | 1004 | 11/06/1998 | SP-1 | 1.70 | NC | | | |
| DMR04 | COLD | 1030 | 12/02/1998 | SP-1 | 1.50 | NC | | | |
| DMR04 | COLD | 1065 | 01/06/1999 | SP-1 | 1.60 | NC | | | |
| DMR04 | COLD | 1092 | 02/02/1999 | SP-1 | 0.60 | NC | | | |
| DMR61 | UNK | 612 | 01/01/2001 | SP-1 | 0.00 | NC | | | |
| DMR61 | UNK | 643 | 02/01/2001 | SP-1 | 1.00 | NC | | | |
| DMR61 | UNK | 671 | 03/01/2001 | SP-1 | 0.00 | NC | | | |
| DMR61 | UNK | 702 | 04/01/2001 | SP-1 | 5.00 | NC | | | |
| DMR61 | UNK | 732 | 05/01/2001 | SP-1 | 0.00 | NC | | | |
| DMR61 | UNK | 763 | 06/01/2001 | SP-1 | 0.00 | NC | | | |
| DMR61 | UNK | 793 | 07/01/2001 | SP-1 | 0.00 | NC | | | |
| DMR61 | UNK | 824 | 08/01/2001 | SP-1 | 6.00 | NC | | | |
| DMR61 | UNK | 855 | 09/01/2001 | SP-1 | 0.00 | NC | | | |
| DMR61 | UNK | 885 | 10/01/2001 | SP-1 | 0.00 | NC | | | |
| DMR61 | UNK | 916 | 11/01/2001 | SP-1 | 6.00 | NC | | | |
| DMR61 | UNK | 946 | 12/01/2001 | SP-1 | 0.00 | NC | | | |

---------- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ----------

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6297A | COLD | 1 | 12/11/2000 | SP8+9 | 70.00 | NC | SP-7 | 1000.00 | NC |
| 6297A | COLD | 2 | 12/12/2000 | SP8+9 | 44.00 | NC | SP-7 | 553.00 | NC |
| 6297A | COLD | 3 | 12/13/2000 | SP8+9 | 46.00 | NC | SP-7 | 1040.00 | NC |
| 6297A | COLD | 4 | 12/14/2000 | SP8+9 | 69.00 | NC | SP-7 | 1710.00 | NC |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6297A | COLD | 5 | 12/15/2000 | SP8+9 | 60.00 | NC | SP-7 | 363.00 | NC |
| 6297B | COLD | 1 | 12/11/2000 | SP-11 | 56.00 | NC | SP-10 | 1040.00 | NC |
| 6297B | COLD | 2 | 12/12/2000 | SP-11 | 68.00 | NC | SP-10 | 687.00 | NC |
| 6297B | COLD | 3 | 12/13/2000 | SP-11 | 74.00 | NC | SP-10 | 4.00 | ND |
| 6297B | COLD | 4 | 12/14/2000 | SP-11 | 72.00 | NC | SP-10 | 540.00 | NC |
| 6297B | COLD | 5 | 12/15/2000 | SP-11 | 78.00 | NC | SP-10 | 690.00 | NC |
| 6297C | COLD | 1 | 12/11/2000 | SP13+14 | 11.00 | NC | SP-12 | 4050.00 | NC |
| 6297C | COLD | 2 | 12/12/2000 | SP13+14 | 14.80 | NC | SP-12 | 707.00 | NC |
| 6297C | COLD | 3 | 12/13/2000 | SP13+14 | 9.80 | NC | SP-12 | 2020.00 | NC |
| 6297C | COLD | 4 | 12/14/2000 | SP13+14 | 11.60 | NC | SP-12 | 3360.00 | NC |
| 6297C | COLD | 5 | 12/15/2000 | SP13+14 | 8.40 | NC | SP-12 | 2830.00 | NC |
| DMR06 | COLD | 367 | 01/01/2001 | SP-1 | 31.10 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 398 | 02/01/2001 | SP-1 | 18.10 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 426 | 03/01/2001 | SP-1 | 11.90 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 457 | 04/01/2001 | SP-1 | 10.60 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 487 | 05/01/2001 | SP-1 | 12.50 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 518 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 548 | 07/01/2001 | SP-1 | 2.93 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 579 | 08/01/2001 | SP-1 | 12.80 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 610 | 09/01/2001 | SP-1 | 2.17 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 640 | 10/01/2001 | SP-1 | 6.08 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 671 | 11/01/2001 | SP-1 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 701 | 12/01/2001 | SP-1 | 66.70 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 367 | 01/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 374 | 01/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 398 | 02/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 405 | 02/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 426 | 03/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 433 | 03/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 457 | 04/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 487 | 05/01/2001 | SP-1 | 79.30 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 518 | 06/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 548 | 07/01/2001 | SP-1 | 78.70 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 579 | 08/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 610 | 09/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 671 | 11/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR10 | COLD | 692 | 11/22/2001 | | | | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR10 | COLD | 701 | 12/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR12A | COLD | 367 | 01/01/2001 | SP-1 | 10.60 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 374 | 01/08/2001 | SP-1 | 21.60 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 381 | 01/15/2001 | SP-1 | 4.70 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 388 | 01/22/2001 | SP-1 | 5.90 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 398 | 02/01/2001 | SP-1 | 39.20 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 405 | 02/08/2001 | SP-1 | 6.00 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 412 | 02/15/2001 | SP-1 | 12.60 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 419 | 02/22/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 426 | 03/01/2001 | SP-1 | 6.20 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 433 | 03/08/2001 | SP-1 | 5.40 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 440 | 03/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 447 | 03/22/2001 | SP-1 | 10.80 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 457 | 04/01/2001 | SP-1 | 4.70 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 464 | 04/08/2001 | SP-1 | 14.10 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 471 | 04/15/2001 | SP-1 | 14.70 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 478 | 04/22/2001 | SP-1 | 21.80 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 487 | 05/01/2001 | SP-1 | 11.70 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 494 | 05/08/2001 | SP-1 | 10.40 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 501 | 05/15/2001 | SP-1 | 10.00 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 508 | 05/22/2001 | SP-1 | 23.80 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 518 | 06/01/2001 | SP-1 | 13.20 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 525 | 06/08/2001 | SP-1 | 30.50 | NC | SP-0 | 5.40 | NC |
| DMR12A | COLD | 532 | 06/15/2001 | SP-1 | 18.10 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 539 | 06/22/2001 | SP-1 | 24.20 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 548 | 07/01/2001 | SP-1 | 5.20 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 555 | 07/08/2001 | SP-1 | 2.01 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 562 | 07/15/2001 | SP-1 | 16.50 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 569 | 07/22/2001 | SP-1 | 3.28 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 579 | 08/01/2001 | SP-1 | 2.23 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 586 | 08/08/2001 | SP-1 | 2.19 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 593 | 08/15/2001 | SP-1 | 3.44 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 600 | 08/22/2001 | SP-1 | 15.00 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 610 | 09/01/2001 | SP-1 | 16.80 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 617 | 09/08/2001 | SP-1 | 10.50 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 624 | 09/15/2001 | SP-1 | 8.64 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 631 | 09/22/2001 | SP-1 | 46.10 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 640 | 10/01/2001 | SP-1 | 10.10 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 647 | 10/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 654 | 10/15/2001 | SP-1 | 4.69 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR12A | COLD | 661 | 10/22/2001 | SP-1 | 15.00 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 671 | 11/01/2001 | SP-1 | 3.30 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 678 | 11/08/2001 | SP-1 | 49.00 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 685 | 11/15/2001 | SP-1 | 16.20 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 692 | 11/22/2001 | SP-1 | 3.04 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 699 | 11/29/2001 | SP-1 | 16.00 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 701 | 12/01/2001 | SP-1 | 3.90 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 708 | 12/08/2001 | SP-1 | 9.07 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 715 | 12/15/2001 | SP-1 | 41.00 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 722 | 12/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12B | COLD | 367 | 01/01/2001 | SP-2 | 10.60 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 374 | 01/08/2001 | SP-2 | 21.60 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 381 | 01/15/2001 | SP-2 | 4.70 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 388 | 01/22/2001 | SP-2 | 5.90 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 398 | 02/01/2001 | SP-2 | 39.20 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 405 | 02/08/2001 | SP-2 | 6.00 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 412 | 02/15/2001 | SP-2 | 12.60 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 419 | 02/22/2001 | SP-2 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 426 | 03/01/2001 | SP-2 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 433 | 03/08/2001 | SP-2 | 10.20 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 440 | 03/15/2001 | SP-2 | 30.30 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 447 | 03/22/2001 | SP-2 | 12.60 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 457 | 04/01/2001 | SP-2 | 15.90 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 464 | 04/08/2001 | SP-2 | 40.20 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 471 | 04/15/2001 | SP-2 | 11.90 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 478 | 04/22/2001 | SP-2 | 5.40 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 487 | 05/01/2001 | SP-2 | 19.20 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 494 | 05/08/2001 | SP-2 | 18.10 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 501 | 05/15/2001 | SP-2 | 8.80 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 508 | 05/22/2001 | SP-2 | 11.40 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 518 | 06/01/2001 | SP-2 | 5.20 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 525 | 06/08/2001 | SP-2 | 7.00 | NC | SP-0 | 5.40 | NC |
| DMR12B | COLD | 532 | 06/15/2001 | SP-2 | 29.90 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 539 | 06/22/2001 | SP-2 | 68.50 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 548 | 07/01/2001 | SP-2 | 9.70 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 555 | 07/08/2001 | SP-2 | 6.16 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 562 | 07/15/2001 | SP-2 | 38.40 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 569 | 07/22/2001 | SP-2 | 5.49 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 579 | 08/01/2001 | SP-2 | 3.70 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 586 | 08/08/2001 | SP-2 | 9.84 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR12B | COLD | 593 | 08/15/2001 | SP-2 | 9.57 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 600 | 08/22/2001 | SP-2 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 610 | 09/01/2001 | SP-2 | 23.40 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 617 | 09/08/2001 | SP-2 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12B | COLD | 624 | 09/15/2001 | SP-2 | 15.40 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 631 | 09/22/2001 | SP-2 | 20.90 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 640 | 10/01/2001 | SP-2 | 7.97 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 647 | 10/08/2001 | SP-2 | 7.92 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 654 | 10/15/2001 | SP-2 | 8.77 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 661 | 10/22/2001 | SP-2 | 20.30 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 671 | 11/01/2001 | SP-2 | 5.47 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 678 | 11/08/2001 | SP-2 | 14.50 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 685 | 11/15/2001 | SP-2 | 15.50 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 692 | 11/22/2001 | SP-2 | 15.50 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 699 | 11/29/2001 | SP-2 | 18.40 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 701 | 12/01/2001 | SP-2 | 14.30 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 708 | 12/08/2001 | SP-2 | 4.34 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 715 | 12/15/2001 | SP-2 | 16.70 | NC | SP-0 | 2.00 | ND |
| DMR12B | COLD | 722 | 12/22/2001 | SP-2 | 14.70 | NC | SP-0 | 2.00 | ND |
| | | | | | | | | | |
| DMR15 | COLD | 307 | 01/01/2001 | SP-1 | 29.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 314 | 01/08/2001 | SP-1 | 7.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 321 | 01/15/2001 | SP-1 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 338 | 02/01/2001 | SP-1 | 28.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 345 | 02/08/2001 | SP-1 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 352 | 02/15/2001 | SP-1 | 12.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 359 | 02/22/2001 | SP-1 | 29.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 366 | 03/01/2001 | SP-1 | 43.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 373 | 03/08/2001 | SP-1 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 380 | 03/15/2001 | SP-1 | 42.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 387 | 03/22/2001 | SP-1 | 4.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 427 | 05/01/2001 | SP-1 | 23.30 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 434 | 05/08/2001 | SP-1 | 8.20 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 441 | 05/15/2001 | SP-1 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 448 | 05/22/2001 | SP-1 | 16.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 458 | 06/01/2001 | SP-1 | 16.80 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 465 | 06/08/2001 | SP-1 | 19.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 472 | 06/15/2001 | SP-1 | 32.50 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 479 | 06/22/2001 | SP-1 | 18.80 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 488 | 07/01/2001 | SP-1 | 10.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 495 | 07/08/2001 | SP-1 | 10.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR15 | COLD | 502 | 07/15/2001 | SP-1 | 22.80 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 509 | 07/22/2001 | SP-1 | 16.80 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 519 | 08/01/2001 | SP-1 | 6.70 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 526 | 08/08/2001 | SP-1 | 5.70 | NC | SP-0 | 3.40 | NC |
| DMR15 | COLD | 533 | 08/15/2001 | SP-1 | 6.70 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 540 | 08/22/2001 | SP-1 | 7.00 | NC | SP-0 | 2.20 | NC |
| DMR15 | COLD | 550 | 09/01/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 557 | 09/08/2001 | SP-1 | 4.10 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 564 | 09/15/2001 | SP-1 | 5.70 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 571 | 09/22/2001 | SP-1 | 5.50 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 580 | 10/01/2001 | SP-1 | 3.40 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 587 | 10/08/2001 | SP-1 | 4.10 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 594 | 10/15/2001 | SP-1 | 8.40 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 601 | 10/22/2001 | SP-1 | 4.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 611 | 11/01/2001 | SP-1 | 11.80 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 618 | 11/08/2001 | SP-1 | 10.40 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 625 | 11/15/2001 | SP-1 | 5.80 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 632 | 11/22/2001 | SP-1 | 2.90 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 641 | 12/01/2001 | SP-1 | 24.20 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 648 | 12/08/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 655 | 12/15/2001 | SP-1 | 7.50 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 662 | 12/22/2001 | SP-1 | 2.30 | NC | SP-0 | 3.30 | NC |
| DMR18 | COLD | 374 | 01/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR18 | COLD | 398 | 02/01/2001 | | | | SP-0 | 2.20 | NC |
| DMR18 | COLD | 426 | 03/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR18 | COLD | 457 | 04/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR18 | COLD | 487 | 05/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR18 | COLD | 518 | 06/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR18 | COLD | 548 | 07/01/2001 | | | | SP-0 | 3.27 | NC |
| DMR18 | COLD | 579 | 08/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR18 | COLD | 600 | 08/22/2001 | | | | SP-0 | 7.50 | NC |
| DMR18 | COLD | 610 | 09/01/2001 | | | | SP-0 | 4.63 | NC |
| DMR18 | COLD | 654 | 10/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR18 | COLD | 671 | 11/01/2001 | | | | SP-0 | 7.77 | NC |
| DMR21A | COLD | 367 | 01/01/2001 | SP-1 | 23.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 374 | 01/08/2001 | SP-1 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 381 | 01/15/2001 | SP-1 | 60.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 388 | 01/22/2001 | SP-1 | 73.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 398 | 02/01/2001 | SP-1 | 32.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR21A | COLD | 405 | 02/08/2001 | SP-1 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 412 | 02/15/2001 | SP-1 | 25.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 419 | 02/22/2001 | SP-1 | 70.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 426 | 03/01/2001 | SP-1 | 49.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 433 | 03/08/2001 | SP-1 | 68.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 440 | 03/15/2001 | SP-1 | 49.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 447 | 03/22/2001 | SP-1 | 54.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 457 | 04/01/2001 | SP-1 | 44.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 464 | 04/08/2001 | SP-1 | 55.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 471 | 04/15/2001 | SP-1 | 40.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 478 | 04/22/2001 | SP-1 | 52.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 487 | 05/01/2001 | SP-1 | 50.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 494 | 05/08/2001 | SP-1 | 59.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 501 | 05/15/2001 | SP-1 | 50.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 508 | 05/22/2001 | SP-1 | 49.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 518 | 06/01/2001 | SP-1 | 50.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 525 | 06/08/2001 | SP-1 | 51.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 532 | 06/15/2001 | SP-1 | 70.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 539 | 06/22/2001 | SP-1 | 54.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 548 | 07/01/2001 | SP-1 | 70.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 555 | 07/08/2001 | SP-1 | 55.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 562 | 07/15/2001 | SP-1 | 79.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 569 | 07/22/2001 | SP-1 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 579 | 08/01/2001 | SP-1 | 71.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 586 | 08/08/2001 | SP-1 | 61.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 593 | 08/15/2001 | SP-1 | 55.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 600 | 08/22/2001 | SP-1 | 52.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 610 | 09/01/2001 | SP-1 | 69.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 617 | 09/08/2001 | SP-1 | 65.70 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 624 | 09/15/2001 | SP-1 | 57.50 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 631 | 09/22/2001 | SP-1 | 57.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 640 | 10/01/2001 | SP-1 | 82.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 647 | 10/08/2001 | SP-1 | 73.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 654 | 10/15/2001 | SP-1 | 31.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 661 | 10/22/2001 | SP-1 | 46.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 671 | 11/01/2001 | SP-1 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 678 | 11/08/2001 | SP-1 | 37.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 685 | 11/15/2001 | SP-1 | 49.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 692 | 11/22/2001 | SP-1 | 67.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 701 | 12/01/2001 | SP-1 | 38.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 708 | 12/08/2001 | SP-1 | 54.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR21A | COLD | 715 | 12/15/2001 | SP-1 | 39.30 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 722 | 12/22/2001 | SP-1 | 34.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 367 | 01/01/2001 | SP-2 | 50.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 374 | 01/08/2001 | SP-2 | 38.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 381 | 01/15/2001 | SP-2 | 36.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 388 | 01/22/2001 | SP-2 | 37.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 398 | 02/01/2001 | SP-2 | 22.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 405 | 02/08/2001 | SP-2 | 48.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 412 | 02/15/2001 | SP-2 | 33.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 419 | 02/22/2001 | SP-2 | 56.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 426 | 03/01/2001 | SP-2 | 31.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 433 | 03/08/2001 | SP-2 | 33.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 440 | 03/15/2001 | SP-2 | 43.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 447 | 03/22/2001 | SP-2 | 59.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 457 | 04/01/2001 | SP-2 | 48.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 464 | 04/08/2001 | SP-2 | 46.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 471 | 04/15/2001 | SP-2 | 34.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 478 | 04/22/2001 | SP-2 | 43.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 487 | 05/01/2001 | SP-2 | 35.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 494 | 05/08/2001 | SP-2 | 57.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 501 | 05/15/2001 | SP-2 | 33.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 508 | 05/22/2001 | SP-2 | 44.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 518 | 06/01/2001 | SP-2 | 33.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 525 | 06/08/2001 | SP-2 | 60.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 532 | 06/15/2001 | SP-2 | 68.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 539 | 06/22/2001 | SP-2 | 64.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 548 | 07/01/2001 | SP-2 | 60.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 555 | 07/08/2001 | SP-2 | 66.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 562 | 07/15/2001 | SP-2 | 53.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 569 | 07/22/2001 | SP-2 | 43.50 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 579 | 08/01/2001 | SP-2 | 46.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 586 | 08/08/2001 | SP-2 | 55.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 593 | 08/15/2001 | SP-2 | 37.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 600 | 08/22/2001 | SP-2 | 62.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 610 | 09/01/2001 | SP-2 | 56.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 617 | 09/08/2001 | SP-2 | 51.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 624 | 09/15/2001 | SP-2 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 631 | 09/22/2001 | SP-2 | 48.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 640 | 10/01/2001 | SP-2 | 47.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 647 | 10/08/2001 | SP-2 | 68.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR21B | COLD | 654 | 10/15/2001 | SP-2 | 62.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 661 | 10/22/2001 | SP-2 | 84.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 671 | 11/01/2001 | SP-2 | 46.50 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 678 | 11/08/2001 | SP-2 | 55.50 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 685 | 11/15/2001 | SP-2 | 35.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 692 | 11/22/2001 | SP-2 | 79.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 701 | 12/01/2001 | SP-2 | 59.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 708 | 12/08/2001 | SP-2 | 77.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 715 | 12/15/2001 | SP-2 | 41.00 | NC | SP-0 | 2.00 | ND |
| DMR21B | COLD | 722 | 12/22/2001 | SP-2 | 33.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 367 | 01/01/2001 | SP-3 | 11.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 374 | 01/08/2001 | SP-3 | 23.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 381 | 01/15/2001 | SP-3 | 16.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 388 | 01/22/2001 | SP-3 | 15.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 398 | 02/01/2001 | SP-3 | 20.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 405 | 02/08/2001 | SP-3 | 10.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 412 | 02/15/2001 | SP-3 | 12.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 419 | 02/22/2001 | SP-3 | 15.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 426 | 03/01/2001 | SP-3 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 433 | 03/08/2001 | SP-3 | 19.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 440 | 03/15/2001 | SP-3 | 15.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 447 | 03/22/2001 | SP-3 | 18.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 457 | 04/01/2001 | SP-3 | 13.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 464 | 04/08/2001 | SP-3 | 20.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 471 | 04/15/2001 | SP-3 | 14.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 478 | 04/22/2001 | SP-3 | 28.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 487 | 05/01/2001 | SP-3 | 12.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 494 | 05/08/2001 | SP-3 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 501 | 05/15/2001 | SP-3 | 17.50 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 508 | 05/22/2001 | SP-3 | 28.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 518 | 06/01/2001 | SP-3 | 8.60 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 525 | 06/08/2001 | SP-3 | 15.50 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 532 | 06/15/2001 | SP-3 | 21.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 539 | 06/22/2001 | SP-3 | 11.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 548 | 07/01/2001 | SP-3 | 11.80 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 555 | 07/08/2001 | SP-3 | 14.40 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 562 | 07/15/2001 | SP-3 | 13.50 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 569 | 07/22/2001 | SP-3 | 6.40 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 579 | 08/01/2001 | SP-3 | 8.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 586 | 08/08/2001 | SP-3 | 8.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR21C | COLD | 593 | 08/15/2001 | SP-3 | 8.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 600 | 08/22/2001 | SP-3 | 8.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 610 | 09/01/2001 | SP-3 | 8.60 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 617 | 09/08/2001 | SP-3 | 7.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 624 | 09/15/2001 | SP-3 | 7.40 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 631 | 09/22/2001 | SP-3 | 6.60 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 640 | 10/01/2001 | SP-3 | 9.20 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 647 | 10/08/2001 | SP-3 | 13.20 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 654 | 10/15/2001 | SP-3 | 2.90 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 661 | 10/22/2001 | SP-3 | 7.10 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 671 | 11/01/2001 | SP-3 | 4.80 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 678 | 11/08/2001 | SP-3 | 3.80 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 685 | 11/15/2001 | SP-3 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 692 | 11/22/2001 | SP-3 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR21C | COLD | 701 | 12/01/2001 | SP-3 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 708 | 12/08/2001 | SP-3 | 3.50 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 715 | 12/15/2001 | SP-3 | 3.80 | NC | SP-0 | 2.00 | ND |
| DMR21C | COLD | 722 | 12/22/2001 | SP-3 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR23 | COLD | 1 | 03/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR23 | COLD | 123 | 07/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR23 | COLD | 154 | 08/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR23 | COLD | 185 | 09/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR23 | COLD | 199 | 09/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR23 | COLD | 215 | 10/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR23 | COLD | 276 | 12/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR25A | COLD | 307 | 01/01/2001 | SP-1 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 314 | 01/08/2001 | SP-1 | 37.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 321 | 01/15/2001 | SP-1 | 34.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 328 | 01/22/2001 | SP-1 | 24.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 338 | 02/01/2001 | SP-1 | 22.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 345 | 02/08/2001 | SP-1 | 25.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 352 | 02/15/2001 | SP-1 | 16.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 359 | 02/22/2001 | SP-1 | 10.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 366 | 03/01/2001 | SP-1 | 29.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 373 | 03/08/2001 | SP-1 | 27.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 380 | 03/15/2001 | SP-1 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 387 | 03/22/2001 | SP-1 | 25.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 397 | 04/01/2001 | SP-1 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 404 | 04/08/2001 | SP-1 | 23.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR25A | COLD | 411 | 04/15/2001 | SP-1 | 31.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 418 | 04/22/2001 | SP-1 | 18.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 427 | 05/01/2001 | SP-1 | 23.30 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 434 | 05/08/2001 | SP-1 | 13.50 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 441 | 05/15/2001 | SP-1 | 22.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 448 | 05/22/2001 | SP-1 | 20.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 458 | 06/01/2001 | SP-1 | 37.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 465 | 06/08/2001 | SP-1 | 35.50 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 472 | 06/15/2001 | SP-1 | 40.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 479 | 06/22/2001 | SP-1 | 26.50 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 488 | 07/01/2001 | SP-1 | 38.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 495 | 07/08/2001 | SP-1 | 7.20 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 502 | 07/15/2001 | SP-1 | 30.70 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 509 | 07/22/2001 | SP-1 | 31.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 519 | 08/01/2001 | SP-1 | 38.50 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 526 | 08/08/2001 | SP-1 | 32.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 533 | 08/15/2001 | SP-1 | 56.50 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 540 | 08/22/2001 | SP-1 | 42.70 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 550 | 09/01/2001 | SP-1 | 31.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 557 | 09/08/2001 | SP-1 | 53.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 564 | 09/15/2001 | SP-1 | 40.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 571 | 09/22/2001 | SP-1 | 56.50 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 580 | 10/01/2001 | SP-1 | 51.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 587 | 10/08/2001 | SP-1 | 45.50 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 594 | 10/15/2001 | SP-1 | 38.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 601 | 10/22/2001 | SP-1 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 611 | 11/01/2001 | SP-1 | 44.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 618 | 11/08/2001 | SP-1 | 55.50 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 625 | 11/15/2001 | SP-1 | 63.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 632 | 11/22/2001 | SP-1 | 59.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 641 | 12/01/2001 | SP-1 | 64.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 648 | 12/08/2001 | SP-1 | 37.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 655 | 12/15/2001 | SP-1 | 64.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 662 | 12/22/2001 | SP-1 | 52.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 307 | 01/01/2001 | SP-2 | 30.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 314 | 01/08/2001 | SP-2 | 57.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 321 | 01/15/2001 | SP-2 | 43.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 328 | 01/22/2001 | SP-2 | 60.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 338 | 02/01/2001 | SP-2 | 52.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 345 | 02/08/2001 | SP-2 | 31.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR25B | COLD | 352 | 02/15/2001 | SP-2 | 42.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 359 | 02/22/2001 | SP-2 | 50.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 366 | 03/01/2001 | SP-2 | 72.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 373 | 03/08/2001 | SP-2 | 48.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 380 | 03/15/2001 | SP-2 | 37.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 387 | 03/22/2001 | SP-2 | 38.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 397 | 04/01/2001 | SP-2 | 49.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 404 | 04/08/2001 | SP-2 | 49.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 411 | 04/15/2001 | SP-2 | 40.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 418 | 04/22/2001 | SP-2 | 44.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 427 | 05/01/2001 | SP-2 | 31.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 434 | 05/08/2001 | SP-2 | 43.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 441 | 05/15/2001 | SP-2 | 38.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 448 | 05/22/2001 | SP-2 | 30.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 458 | 06/01/2001 | SP-2 | 59.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 465 | 06/08/2001 | SP-2 | 23.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 472 | 06/15/2001 | SP-2 | 37.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 479 | 06/22/2001 | SP-2 | 45.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 488 | 07/01/2001 | SP-2 | 37.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 495 | 07/08/2001 | SP-2 | 45.50 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 502 | 07/15/2001 | SP-2 | 42.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 509 | 07/22/2001 | SP-2 | 52.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 519 | 08/01/2001 | SP-2 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 526 | 08/08/2001 | SP-2 | 22.50 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 533 | 08/15/2001 | SP-2 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 540 | 08/22/2001 | SP-2 | 30.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 550 | 09/01/2001 | SP-2 | 28.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 557 | 09/08/2001 | SP-2 | 31.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 564 | 09/15/2001 | SP-2 | 37.30 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 571 | 09/22/2001 | SP-2 | 15.30 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 580 | 10/01/2001 | SP-2 | 33.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 587 | 10/08/2001 | SP-2 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 594 | 10/15/2001 | SP-2 | 36.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 601 | 10/22/2001 | SP-2 | 58.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 611 | 11/01/2001 | SP-2 | 64.30 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 618 | 11/08/2001 | SP-2 | 47.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 625 | 11/15/2001 | SP-2 | 52.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 632 | 11/22/2001 | SP-2 | 45.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 641 | 12/01/2001 | SP-2 | 73.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 648 | 12/08/2001 | SP-2 | 43.00 | NC | SP-0 | 2.00 | ND |
| DMR25B | COLD | 655 | 12/15/2001 | SP-2 | 66.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR25B | COLD | 662 | 12/22/2001 | SP-2 | 49.00 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 307 | 01/01/2001 | SP-1 | 26.60 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 314 | 01/08/2001 | SP-1 | 11.50 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 321 | 01/15/2001 | SP-1 | 10.10 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 328 | 01/22/2001 | SP-1 | 8.80 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 338 | 02/01/2001 | SP-1 | 10.70 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 345 | 02/08/2001 | SP-1 | 31.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 352 | 02/15/2001 | SP-1 | 20.80 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 359 | 02/22/2001 | SP-1 | 19.00 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 366 | 03/01/2001 | SP-1 | 13.10 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 373 | 03/08/2001 | SP-1 | 13.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 380 | 03/15/2001 | SP-1 | 6.10 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 387 | 03/22/2001 | SP-1 | 24.80 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 397 | 04/01/2001 | SP-1 | 31.50 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 404 | 04/08/2001 | SP-1 | 8.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 411 | 04/15/2001 | SP-1 | 13.10 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 418 | 04/22/2001 | SP-1 | 19.80 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 427 | 05/01/2001 | SP-1 | 9.60 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 434 | 05/08/2001 | SP-1 | 18.30 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 441 | 05/15/2001 | SP-1 | 14.90 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 448 | 05/22/2001 | SP-1 | 14.00 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 458 | 06/01/2001 | SP-1 | 49.10 | NC | | | |
| DMR28 | COLD | 465 | 06/08/2001 | SP-1 | 4.20 | NC | | | |
| DMR28 | COLD | 472 | 06/15/2001 | SP-1 | 20.90 | NC | | | |
| DMR28 | COLD | 479 | 06/22/2001 | SP-1 | 13.10 | NC | | | |
| DMR28 | COLD | 488 | 07/01/2001 | SP-1 | 55.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 495 | 07/08/2001 | SP-1 | 13.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 502 | 07/15/2001 | SP-1 | 11.70 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 509 | 07/22/2001 | SP-1 | 11.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 519 | 08/01/2001 | SP-1 | 11.60 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 526 | 08/08/2001 | SP-1 | 2.43 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 533 | 08/15/2001 | SP-1 | 14.70 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 540 | 08/22/2001 | SP-1 | 11.40 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 550 | 09/01/2001 | SP-1 | 2.34 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 557 | 09/08/2001 | SP-1 | 18.80 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 564 | 09/15/2001 | SP-1 | 14.40 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 571 | 09/22/2001 | SP-1 | 10.70 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 580 | 10/01/2001 | SP-1 | 33.90 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 587 | 10/08/2001 | SP-1 | 15.40 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 594 | 10/15/2001 | SP-1 | 20.10 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR28 | COLD | 601 | 10/22/2001 | SP-1 | 4.80 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 611 | 11/01/2001 | SP-1 | 10.70 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 618 | 11/08/2001 | SP-1 | 28.60 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 625 | 11/15/2001 | SP-1 | 9.72 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 632 | 11/22/2001 | SP-1 | 25.50 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 641 | 12/01/2001 | SP-1 | 18.50 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 648 | 12/08/2001 | SP-1 | 4.80 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 655 | 12/15/2001 | SP-1 | 17.60 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 662 | 12/22/2001 | SP-1 | 15.20 | NC | SP-0 | 2.00 | ND |
| | | | | | | | | | |
| DMR31 | COLD | 336 | 01/01/2001 | SP-1 | 18.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 343 | 01/08/2001 | SP-1 | 91.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 350 | 01/15/2001 | SP-1 | 45.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 357 | 01/22/2001 | SP-1 | 64.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 367 | 02/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR31 | COLD | 374 | 02/08/2001 | SP-1 | 87.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 381 | 02/15/2001 | SP-1 | 22.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 388 | 02/22/2001 | SP-1 | 41.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 402 | 03/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR31 | COLD | 409 | 03/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR31 | COLD | 426 | 04/01/2001 | SP-1 | 45.00 | NC | | | |
| DMR31 | COLD | 433 | 04/08/2001 | SP-1 | 44.00 | NC | | | |
| DMR31 | COLD | 440 | 04/15/2001 | SP-1 | 32.00 | NC | | | |
| DMR31 | COLD | 447 | 04/22/2001 | SP-1 | 46.00 | NC | | | |
| DMR31 | COLD | 456 | 05/01/2001 | SP-1 | 48.50 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 463 | 05/08/2001 | SP-1 | 30.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 470 | 05/15/2001 | SP-1 | 79.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 477 | 05/22/2001 | SP-1 | 81.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 487 | 06/01/2001 | SP-1 | 6.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 494 | 06/08/2001 | SP-1 | 45.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 501 | 06/15/2001 | SP-1 | 28.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 508 | 06/22/2001 | SP-1 | 20.50 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 517 | 07/01/2001 | SP-1 | 27.30 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 524 | 07/08/2001 | SP-1 | 58.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 531 | 07/15/2001 | SP-1 | 24.50 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 538 | 07/22/2001 | SP-1 | 21.50 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 548 | 08/01/2001 | SP-1 | 9.60 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 555 | 08/08/2001 | SP-1 | 12.50 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 562 | 08/15/2001 | SP-1 | 15.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 569 | 08/22/2001 | SP-1 | 16.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 579 | 09/01/2001 | SP-1 | 17.40 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR31 | COLD | 586 | 09/08/2001 | SP-1 | 11.10 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 593 | 09/15/2001 | SP-1 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 600 | 09/22/2001 | SP-1 | 25.30 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 609 | 10/01/2001 | SP-1 | 52.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 616 | 10/08/2001 | SP-1 | 36.70 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 623 | 10/15/2001 | SP-1 | 16.90 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 630 | 10/22/2001 | SP-1 | 12.20 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 640 | 11/01/2001 | SP-1 | 19.30 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 647 | 11/08/2001 | SP-1 | 63.30 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 654 | 11/15/2001 | SP-1 | 29.20 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 661 | 11/22/2001 | SP-1 | 8.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 670 | 12/01/2001 | SP-1 | 6.50 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 677 | 12/08/2001 | SP-1 | 21.30 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 684 | 12/15/2001 | SP-1 | 44.50 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 691 | 12/22/2001 | SP-1 | 5.40 | NC | SP-0 | 2.00 | ND |
| DMR32 | COLD | 457 | 07/01/2001 | | | | SP-0 | 52.00 | NC |
| DMR32 | COLD | 464 | 07/08/2001 | | | | SP-0 | 4.00 | NC |
| DMR32 | COLD | 549 | 10/01/2001 | SP-1 | 12.00 | NC | SP-0 | 25.00 | NC |
| DMR34 | COLD | 367 | 01/01/2001 | SP-1 | 48.30 | NC | | | |
| DMR34 | COLD | 374 | 01/08/2001 | SP-1 | 64.60 | NC | | | |
| DMR34 | COLD | 398 | 02/01/2001 | SP-1 | 92.80 | NC | | | |
| DMR34 | COLD | 405 | 02/08/2001 | SP-1 | 26.20 | NC | | | |
| DMR34 | COLD | 426 | 03/01/2001 | SP-1 | 33.80 | NC | | | |
| DMR34 | COLD | 440 | 03/15/2001 | SP-1 | 50.40 | NC | | | |
| DMR34 | COLD | 457 | 04/01/2001 | SP-1 | 45.10 | NC | | | |
| DMR34 | COLD | 464 | 04/08/2001 | SP-1 | 59.20 | NC | | | |
| DMR34 | COLD | 487 | 05/01/2001 | SP-1 | 34.90 | NC | | | |
| DMR34 | COLD | 494 | 05/08/2001 | SP-1 | 20.40 | NC | | | |
| DMR34 | COLD | 518 | 06/01/2001 | SP-1 | 82.40 | NC | | | |
| DMR34 | COLD | 525 | 06/08/2001 | SP-1 | 73.30 | NC | | | |
| DMR34 | COLD | 548 | 07/01/2001 | SP-1 | 35.40 | NC | | | |
| DMR34 | COLD | 555 | 07/08/2001 | SP-1 | 23.30 | NC | | | |
| DMR34 | COLD | 579 | 08/01/2001 | SP-1 | 19.20 | NC | SP-0 | 2.00 | ND |
| DMR34 | COLD | 586 | 08/08/2001 | SP-1 | 18.00 | NC | SP-0 | 2.00 | ND |
| DMR34 | COLD | 610 | 09/01/2001 | SP-1 | 14.80 | NC | SP-0 | 2.00 | ND |
| DMR34 | COLD | 617 | 09/08/2001 | SP-1 | 9.15 | NC | SP-0 | 2.00 | ND |
| DMR34 | COLD | 654 | 10/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR34 | COLD | 678 | 11/08/2001 | SP-1 | 18.80 | NC | SP-0 | 2.00 | ND |
| DMR34 | COLD | 701 | 12/01/2001 | SP-1 | 58.70 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR37 | COLD | 307 | 01/01/2001 | SP-1 | 19.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 314 | 01/08/2001 | SP-1 | 29.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 321 | 01/15/2001 | SP-1 | 23.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 328 | 01/22/2001 | SP-1 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 338 | 02/01/2001 | SP-1 | 19.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 345 | 02/08/2001 | SP-1 | 20.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 352 | 02/15/2001 | SP-1 | 18.50 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 359 | 02/22/2001 | SP-1 | 31.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 366 | 03/01/2001 | SP-1 | 30.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 373 | 03/08/2001 | SP-1 | 23.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 380 | 03/15/2001 | SP-1 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 387 | 03/22/2001 | SP-1 | 22.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 397 | 04/01/2001 | SP-1 | 48.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 404 | 04/08/2001 | SP-1 | 27.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 411 | 04/15/2001 | SP-1 | 30.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 418 | 04/22/2001 | SP-1 | 24.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 427 | 05/01/2001 | SP-1 | 17.30 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 434 | 05/08/2001 | SP-1 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 441 | 05/15/2001 | SP-1 | 24.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 448 | 05/22/2001 | SP-1 | 15.30 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 458 | 06/01/2001 | SP-1 | 19.30 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 465 | 06/08/2001 | SP-1 | 14.70 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 472 | 06/15/2001 | SP-1 | 22.70 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 479 | 06/22/2001 | SP-1 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 488 | 07/01/2001 | SP-1 | 18.70 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 495 | 07/08/2001 | SP-1 | 23.30 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 502 | 07/15/2001 | SP-1 | 32.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 509 | 07/22/2001 | SP-1 | 43.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 519 | 08/01/2001 | SP-1 | 36.70 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 526 | 08/08/2001 | SP-1 | 55.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 533 | 08/15/2001 | SP-1 | 25.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 540 | 08/22/2001 | SP-1 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 550 | 09/01/2001 | SP-1 | 28.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 557 | 09/08/2001 | SP-1 | 22.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 564 | 09/15/2001 | SP-1 | 28.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 571 | 09/22/2001 | SP-1 | 26.40 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 580 | 10/01/2001 | SP-1 | 21.30 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 587 | 10/08/2001 | SP-1 | 20.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 594 | 10/15/2001 | SP-1 | 37.50 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 601 | 10/22/2001 | SP-1 | 14.60 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR37 | COLD | 611 | 11/01/2001 | SP-1 | 10.80 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 618 | 11/08/2001 | SP-1 | 20.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 625 | 11/15/2001 | SP-1 | 18.80 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 632 | 11/22/2001 | SP-1 | 22.40 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 641 | 12/01/2001 | SP-1 | 18.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 648 | 12/08/2001 | SP-1 | 32.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 655 | 12/15/2001 | SP-1 | 13.50 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 662 | 12/22/2001 | SP-1 | 14.10 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 381 | 01/15/2001 | SP-1 | 14.60 | NC | SP-0 | 4.00 | NC |
| DMR38 | COLD | 419 | 02/22/2001 | SP-1 | 45.50 | NC | SP-0 | 4.10 | NC |
| DMR38 | COLD | 447 | 03/22/2001 | SP-1 | 56.60 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 471 | 04/15/2001 | SP-1 | 24.40 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 508 | 05/22/2001 | SP-1 | 17.50 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 539 | 06/22/2001 | SP-1 | 6.60 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 569 | 07/22/2001 | SP-1 | 5.52 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 607 | 08/29/2001 | SP-1 | 26.80 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 631 | 09/22/2001 | SP-1 | 11.60 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 668 | 10/29/2001 | SP-1 | 31.80 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 692 | 11/22/2001 | SP-1 | 52.50 | NC | SP-0 | 2.98 | NC |
| DMR38 | COLD | 729 | 12/29/2001 | | | | SP-0 | 2.40 | NC |
| DMR49 | COLD | 367 | 01/01/2001 | SP-1 | 21.80 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 374 | 01/08/2001 | SP-1 | 33.30 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 381 | 01/15/2001 | SP-1 | 14.80 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 388 | 01/22/2001 | SP-1 | 17.20 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 398 | 02/01/2001 | SP-1 | 14.90 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 405 | 02/08/2001 | SP-1 | 27.70 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 412 | 02/15/2001 | SP-1 | 49.00 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 419 | 02/22/2001 | SP-1 | 21.60 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 426 | 03/01/2001 | SP-1 | 23.70 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 433 | 03/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 440 | 03/15/2001 | SP-1 | 22.10 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 447 | 03/22/2001 | SP-1 | 31.60 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 457 | 04/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 464 | 04/08/2001 | SP-1 | 31.60 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 471 | 04/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 478 | 04/22/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 487 | 05/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 494 | 05/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 501 | 05/15/2001 | | | | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR49 | COLD | 518 | 06/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 525 | 06/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 532 | 06/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 548 | 07/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 555 | 07/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 562 | 07/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 579 | 08/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 586 | 08/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 593 | 08/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 610 | 09/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 617 | 09/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 624 | 09/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 640 | 10/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 647 | 10/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 654 | 10/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 661 | 10/22/2001 | | | | SP-0 | 2.00 | ND |
| DMR49 | COLD | 671 | 11/01/2001 | SP-1 | 11.10 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 678 | 11/08/2001 | SP-1 | 8.26 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 685 | 11/15/2001 | SP-1 | 15.00 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 692 | 11/22/2001 | SP-1 | 5.72 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 701 | 12/01/2001 | SP-1 | 15.80 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 708 | 12/08/2001 | SP-1 | 10.30 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 715 | 12/15/2001 | SP-1 | 16.30 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 722 | 12/22/2001 | SP-1 | 11.10 | NC | SP-0 | 2.00 | ND |
| | | | | | | | | | |
| DMR54A | COLD | 276 | 01/01/2001 | SP-1 | 36.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 283 | 01/08/2001 | SP-1 | 33.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 290 | 01/15/2001 | SP-1 | 18.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 297 | 01/22/2001 | SP-1 | 36.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 307 | 02/01/2001 | SP-1 | 17.50 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 314 | 02/08/2001 | SP-1 | 25.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 321 | 02/15/2001 | SP-1 | 27.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 328 | 02/22/2001 | SP-1 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 335 | 03/01/2001 | SP-1 | 32.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 342 | 03/08/2001 | SP-1 | 33.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 349 | 03/15/2001 | SP-1 | 29.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 356 | 03/22/2001 | SP-1 | 29.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 366 | 04/01/2001 | SP-1 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 373 | 04/08/2001 | SP-1 | 38.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 380 | 04/15/2001 | SP-1 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 387 | 04/22/2001 | SP-1 | 47.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR54A | COLD | 396 | 05/01/2001 | SP-1 | 48.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 403 | 05/08/2001 | SP-1 | 10.40 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 410 | 05/15/2001 | SP-1 | 42.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 417 | 05/22/2001 | SP-1 | 23.50 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 427 | 06/01/2001 | SP-1 | 44.70 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 434 | 06/08/2001 | SP-1 | 32.70 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 441 | 06/15/2001 | SP-1 | 52.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 448 | 06/22/2001 | SP-1 | 18.80 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 457 | 07/01/2001 | SP-1 | 9.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 464 | 07/08/2001 | SP-1 | 30.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 471 | 07/15/2001 | SP-1 | 14.30 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 478 | 07/22/2001 | SP-1 | 31.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 488 | 08/01/2001 | SP-1 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 495 | 08/08/2001 | SP-1 | 52.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 502 | 08/15/2001 | SP-1 | 19.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 509 | 08/22/2001 | SP-1 | 35.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 516 | 08/29/2001 | | | | SP-0 | 2.00 | ND |
| DMR54A | COLD | 519 | 09/01/2001 | SP-1 | 15.10 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 526 | 09/08/2001 | SP-1 | 18.80 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 533 | 09/15/2001 | SP-1 | 34.50 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 540 | 09/22/2001 | SP-1 | 48.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 549 | 10/01/2001 | SP-1 | 29.30 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 556 | 10/08/2001 | SP-1 | 37.30 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 563 | 10/15/2001 | SP-1 | 29.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 570 | 10/22/2001 | SP-1 | 3.60 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 580 | 11/01/2001 | SP-1 | 33.30 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 587 | 11/08/2001 | SP-1 | 19.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 594 | 11/15/2001 | SP-1 | 63.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 601 | 11/22/2001 | SP-1 | 19.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 608 | 11/29/2001 | | | | SP-0 | 2.00 | ND |
| DMR54A | COLD | 610 | 12/01/2001 | SP-1 | 30.70 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 617 | 12/08/2001 | SP-1 | 23.30 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 624 | 12/15/2001 | SP-1 | 4.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 631 | 12/22/2001 | SP-1 | 18.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 276 | 01/01/2001 | SP-2 | 50.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 283 | 01/08/2001 | SP-2 | 35.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 290 | 01/15/2001 | SP-2 | 45.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 297 | 01/22/2001 | SP-2 | 54.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 307 | 02/01/2001 | SP-2 | 47.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 314 | 02/08/2001 | SP-2 | 56.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR54B | COLD | 321 | 02/15/2001 | SP-2 | 42.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 328 | 02/22/2001 | SP-2 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 335 | 03/01/2001 | SP-2 | 51.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 342 | 03/08/2001 | SP-2 | 46.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 349 | 03/15/2001 | SP-2 | 90.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 356 | 03/22/2001 | SP-2 | 17.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 366 | 04/01/2001 | SP-2 | 27.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 373 | 04/08/2001 | SP-2 | 49.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 380 | 04/15/2001 | SP-2 | 19.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 387 | 04/22/2001 | SP-2 | 72.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 396 | 05/01/2001 | SP-2 | 62.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 403 | 05/08/2001 | SP-2 | 73.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 410 | 05/15/2001 | SP-2 | 40.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 417 | 05/22/2001 | SP-2 | 30.70 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 427 | 06/01/2001 | SP-2 | 84.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 434 | 06/08/2001 | SP-2 | 32.70 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 441 | 06/15/2001 | SP-2 | 98.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 448 | 06/22/2001 | SP-2 | 76.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 455 | 06/29/2001 | SP-2 | 43.00 | NC | | | |
| DMR54B | COLD | 457 | 07/01/2001 | SP-2 | 62.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 464 | 07/08/2001 | SP-2 | 52.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 471 | 07/15/2001 | SP-2 | 14.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 478 | 07/22/2001 | SP-2 | 92.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 488 | 08/01/2001 | SP-2 | 51.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 495 | 08/08/2001 | SP-2 | 40.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 502 | 08/15/2001 | SP-2 | 86.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 509 | 08/22/2001 | SP-2 | 51.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 516 | 08/29/2001 | | | | SP-0 | 2.00 | ND |
| DMR54B | COLD | 519 | 09/01/2001 | SP-2 | 22.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 526 | 09/08/2001 | SP-2 | 71.40 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 533 | 09/15/2001 | SP-2 | 36.50 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 540 | 09/22/2001 | SP-2 | 93.30 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 549 | 10/01/2001 | SP-2 | 75.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 556 | 10/08/2001 | SP-2 | 21.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 563 | 10/15/2001 | SP-2 | 37.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 570 | 10/22/2001 | SP-2 | 60.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 580 | 11/01/2001 | SP-2 | 3.80 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 587 | 11/08/2001 | SP-2 | 45.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 594 | 11/15/2001 | SP-2 | 43.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 601 | 11/22/2001 | SP-2 | 35.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 608 | 11/29/2001 | | | | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR54B | COLD | 610 | 12/01/2001 | SP-2 | 39.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 617 | 12/08/2001 | SP-2 | 26.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 624 | 12/15/2001 | SP-2 | 94.00 | NC | SP-0 | 2.00 | ND |
| DMR54B | COLD | 631 | 12/22/2001 | SP-2 | 19.50 | NC | SP-0 | 2.00 | ND |
| DMR59 | COLD | 367 | 01/01/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR59 | COLD | 398 | 02/01/2001 | SP-1 | 2.00 | ND | | | |
| DMR59 | COLD | 518 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 548 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 579 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 610 | 09/01/2001 | SP-1 | 3.48 | NC | SP-0 | 2.00 | ND |
| DMR59 | COLD | 640 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 671 | 11/01/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR59 | COLD | 701 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR62 | COLD | 1 | 09/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR62 | COLD | 31 | 10/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR62 | COLD | 62 | 11/01/2001 | | | | SP-0 | 2.00 | ND |
| DMR62 | COLD | 92 | 12/01/2001 | | | | SP-0 | 2.00 | ND |

Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6297E | COLD | 1 | 12/11/2000 | SP5+6 | 4.00 | ND | | | |
| 6297E | COLD | 2 | 12/12/2000 | SP5+6 | 4.00 | ND | | | |
| 6297E | COLD | 3 | 12/13/2000 | SP5+6 | 4.00 | ND | | | |
| 6297E | COLD | 4 | 12/14/2000 | SP5+6 | 4.00 | ND | | | |
| 6297E | COLD | 5 | 12/15/2000 | SP5+6 | 4.00 | ND | | | |
| 6297F | COLD | 1 | 12/11/2000 | SP2+3 | 4.00 | ND | | | |
| 6297F | COLD | 2 | 12/12/2000 | SP2+3 | 4.50 | NC | | | |
| 6297F | COLD | 3 | 12/13/2000 | SP2+3 | 4.00 | ND | | | |
| 6297F | COLD | 4 | 12/14/2000 | SP2+3 | 4.00 | ND | | | |
| 6297F | COLD | 5 | 12/15/2000 | SP2+3 | 4.00 | ND | | | |
| DMR05 | COLD | 367 | 01/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR05 | COLD | 671 | 11/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR05 | COLD | 685 | 11/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 367 | 01/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 398 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 426 | 03/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 457 | 04/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 487 | 05/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 518 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 548 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 579 | 08/01/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR06 | COLD | 610 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 640 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 671 | 11/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR06 | COLD | 701 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR07 | COLD | 457 | 07/01/2001 | SP-1 | 3.00 | NC | SP-0 | 2.00 | ND |
| DMR07 | COLD | 610 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR08 | COLD | 276 | 01/01/2001 | SP-1 | 7.60 | NC | SP-0 | 2.00 | NC |
| DMR08 | COLD | 307 | 02/01/2001 | SP-1 | 3.70 | NC | SP-0 | 2.00 | ND |
| DMR08 | COLD | 396 | 05/01/2001 | SP-1 | 3.00 | NC | SP-0 | 2.00 | ND |
| DMR08 | COLD | 457 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR08 | COLD | 488 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR08 | COLD | 519 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR08 | COLD | 549 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR08 | COLD | 580 | 11/01/2001 | SP-1 | 3.10 | NC | SP-0 | 2.00 | ND |
| DMR08 | COLD | 610 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR09 | COLD | 1 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.40 | NC |
| DMR10 | COLD | 367 | 01/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 374 | 01/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR10 | COLD | 398 | 02/01/2001 | SP-1 | 3.00 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 405 | 02/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR10 | COLD | 426 | 03/01/2001 | SP-1 | 2.80 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 433 | 03/08/2001 | SP-1 | 3.60 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 457 | 04/01/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 487 | 05/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR10 | COLD | 518 | 06/01/2001 | SP-1 | 3.40 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 548 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

----------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B -----------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR10 | COLD | 579 | 08/01/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 610 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR10 | COLD | 640 | 10/01/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 671 | 11/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 692 | 11/22/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR10 | COLD | 701 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| | | | | | | | | | |
| DMR12A | COLD | 367 | 01/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 374 | 01/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 381 | 01/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 388 | 01/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 398 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 405 | 02/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 412 | 02/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 419 | 02/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 426 | 03/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 433 | 03/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 440 | 03/15/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 447 | 03/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 457 | 04/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 464 | 04/08/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 471 | 04/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 478 | 04/22/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 487 | 05/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 494 | 05/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 501 | 05/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 508 | 05/22/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 518 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 525 | 06/08/2001 | SP-1 | 2.00 | ND | SP-0 | 5.40 | NC |
| DMR12A | COLD | 532 | 06/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 539 | 06/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 548 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 555 | 07/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 562 | 07/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 569 | 07/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 579 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 586 | 08/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 593 | 08/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 600 | 08/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 610 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 617 | 09/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

----------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B -----------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR12A | COLD | 624 | 09/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 631 | 09/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 640 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 647 | 10/08/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 654 | 10/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 661 | 10/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 671 | 11/01/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR12A | COLD | 678 | 11/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 685 | 11/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 692 | 11/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 699 | 11/29/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 701 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 708 | 12/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 715 | 12/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR12A | COLD | 722 | 12/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR13 | COLD | 32 | 01/01/2001 | SP-1 | 2.60 | NC | SP-0 | 0.10 | NC |
| DMR13 | COLD | 275 | 09/01/2001 | SP-1 | 1.20 | NC | SP-0 | 1.80 | NC |
| DMR14 | COLD | 1 | 11/01/2001 | | | | SP-0 | 44.70 | NC |
| DMR15 | COLD | 307 | 01/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 314 | 01/08/2001 | SP-1 | 2.50 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 321 | 01/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 338 | 02/01/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 345 | 02/08/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 352 | 02/15/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 359 | 02/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 366 | 03/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 373 | 03/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 380 | 03/15/2001 | SP-1 | 3.50 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 387 | 03/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 397 | 04/01/2001 | SP-1 | 4.30 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 404 | 04/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 411 | 04/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 418 | 04/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 488 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 495 | 07/08/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 502 | 07/15/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 509 | 07/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 519 | 08/01/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR15 | COLD | 526 | 08/08/2001 | SP-1 | 7.70 | NC | SP-0 | 3.40 | NC |
| DMR15 | COLD | 533 | 08/15/2001 | SP-1 | 5.70 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 540 | 08/22/2001 | SP-1 | 5.00 | NC | SP-0 | 2.20 | NC |
| DMR15 | COLD | 550 | 09/01/2001 | SP-1 | 6.20 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 557 | 09/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 564 | 09/15/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 571 | 09/22/2001 | SP-1 | 4.20 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 580 | 10/01/2001 | SP-1 | 4.60 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 587 | 10/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 594 | 10/15/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 601 | 10/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 611 | 11/01/2001 | SP-1 | 4.10 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 618 | 11/08/2001 | SP-1 | 3.00 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 625 | 11/15/2001 | SP-1 | 2.90 | NC | SP-0 | 2.00 | ND |
| DMR15 | COLD | 632 | 11/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 641 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 648 | 12/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 655 | 12/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR15 | COLD | 662 | 12/22/2001 | SP-1 | 3.00 | NC | SP-0 | 3.30 | NC |
| DMR17 | COLD | 397 | 08/01/2001 | SP-1 | 2.20 | NC | SP-0 | 4.00 | NC |
| DMR18 | COLD | 374 | 01/08/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR18 | COLD | 398 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.20 | NC |
| DMR18 | COLD | 426 | 03/01/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR18 | COLD | 457 | 04/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR18 | COLD | 487 | 05/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR18 | COLD | 518 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR18 | COLD | 548 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 3.30 | NC |
| DMR18 | COLD | 579 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR18 | COLD | 610 | 09/01/2001 | SP-1 | 5.80 | NC | SP-0 | 4.60 | NC |
| DMR18 | COLD | 654 | 10/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR18 | COLD | 671 | 11/01/2001 | SP-1 | 8.00 | NC | SP-0 | 7.80 | NC |
| DMR18 | COLD | 701 | 12/01/2001 | | | | SP-0 | 44.30 | NC |
| DMR19 | COLD | 336 | 01/01/2001 | SP-1 | 0.40 | NC | SP-0 | 0.00 | NC |
| DMR19 | COLD | 426 | 04/01/2001 | SP-1 | 0.70 | NC | SP-0 | 0.40 | NC |
| DMR19 | COLD | 517 | 07/01/2001 | SP-1 | 0.80 | NC | SP-0 | 1.00 | ND |
| DMR19 | COLD | 609 | 10/01/2001 | SP-1 | 0.60 | NC | SP-0 | 1.00 | ND |
| DMR20 | COLD | 215 | 01/01/2001 | SP-1 | 5.00 | NC | SP-0 | 5.00 | NC |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR20 | COLD | 274 | 03/01/2001 | SP-1 | 4.60 | NC | SP-0 | 1.40 | NC |
| DMR20 | COLD | 366 | 06/01/2001 | SP-1 | 2.30 | NC | SP-0 | 2.10 | NC |
| DMR20 | COLD | 427 | 08/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| | | | | | | | | | |
| DMR21A | COLD | 367 | 01/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 374 | 01/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR21A | COLD | 381 | 01/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR21A | COLD | 388 | 01/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR21A | COLD | 398 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR21A | COLD | 405 | 02/08/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 412 | 02/15/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 419 | 02/22/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 426 | 03/01/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 433 | 03/08/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 440 | 03/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR21A | COLD | 447 | 03/22/2001 | SP-1 | 2.50 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 457 | 04/01/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 464 | 04/08/2001 | SP-1 | 2.50 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 471 | 04/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR21A | COLD | 478 | 04/22/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 487 | 05/01/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 494 | 05/08/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 501 | 05/15/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 508 | 05/22/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 518 | 06/01/2001 | SP-1 | 4.30 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 525 | 06/08/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 532 | 06/15/2001 | SP-1 | 2.90 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 539 | 06/22/2001 | SP-1 | 2.90 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 548 | 07/01/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 555 | 07/08/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 562 | 07/15/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 569 | 07/22/2001 | SP-1 | 2.80 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 579 | 08/01/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 586 | 08/08/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 593 | 08/15/2001 | SP-1 | 2.90 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 600 | 08/22/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 610 | 09/01/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 617 | 09/08/2001 | SP-1 | 2.50 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 624 | 09/15/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 631 | 09/22/2001 | SP-1 | 2.90 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 640 | 10/01/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR21A | COLD | 647 | 10/08/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 654 | 10/15/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 661 | 10/22/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 671 | 11/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 678 | 11/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR21A | COLD | 685 | 11/15/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 692 | 11/22/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 701 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR21A | COLD | 708 | 12/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR21A | COLD | 715 | 12/15/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR21A | COLD | 722 | 12/22/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR23 | COLD | 1 | 03/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR23 | COLD | 123 | 07/01/2001 | SP-1 | 2.50 | NC | SP-0 | 2.00 | ND |
| DMR23 | COLD | 154 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR23 | COLD | 185 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR23 | COLD | 199 | 09/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR23 | COLD | 215 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR23 | COLD | 246 | 11/01/2001 | SP-1 | 2.00 | ND | | | |
| DMR23 | COLD | 260 | 11/15/2001 | SP-1 | 2.00 | ND | | | |
| DMR23 | COLD | 276 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 307 | 01/01/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 314 | 01/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 321 | 01/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 328 | 01/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 338 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 345 | 02/08/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 352 | 02/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 359 | 02/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 366 | 03/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 373 | 03/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 380 | 03/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 387 | 03/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 397 | 04/01/2001 | SP-1 | 2.80 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 404 | 04/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 411 | 04/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 418 | 04/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 427 | 05/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 434 | 05/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 441 | 05/15/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR25A | COLD | 448 | 05/22/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 458 | 06/01/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 465 | 06/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 472 | 06/15/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 479 | 06/22/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 488 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 495 | 07/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 502 | 07/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 509 | 07/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 519 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 526 | 08/08/2001 | SP-1 | 2.50 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 533 | 08/15/2001 | SP-1 | 2.80 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 540 | 08/22/2001 | SP-1 | 2.90 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 550 | 09/01/2001 | SP-1 | 2.90 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 557 | 09/08/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 564 | 09/15/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 571 | 09/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 580 | 10/01/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 587 | 10/08/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 594 | 10/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 601 | 10/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 611 | 11/01/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 618 | 11/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 625 | 11/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 632 | 11/22/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 641 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR25A | COLD | 648 | 12/08/2001 | SP-1 | 2.50 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 655 | 12/15/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR25A | COLD | 662 | 12/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR26 | WARM | 276 | 01/01/2001 | | | | SP-0 | 5.70 | NC |
| DMR26 | WARM | 283 | 01/08/2001 | SP-1 | 6.30 | NC | SP-0 | 4.30 | NC |
| DMR26 | WARM | 307 | 02/01/2001 | SP-1 | 5.80 | NC | SP-0 | 2.00 | ND |
| DMR26 | WARM | 314 | 02/08/2001 | SP-1 | 5.10 | NC | SP-0 | 2.00 | ND |
| DMR26 | WARM | 335 | 03/01/2001 | SP-1 | 5.30 | NC | SP-0 | 4.60 | NC |
| DMR26 | WARM | 342 | 03/08/2001 | | | | SP-0 | 4.30 | NC |
| DMR26 | WARM | 366 | 04/01/2001 | | | | SP-0 | 5.20 | NC |
| DMR26 | WARM | 373 | 04/08/2001 | | | | SP-0 | 4.20 | NC |
| DMR26 | WARM | 396 | 05/01/2001 | | | | SP-0 | 7.30 | NC |
| DMR26 | WARM | 403 | 05/08/2001 | SP-1 | 8.30 | NC | SP-0 | 11.00 | NC |
| DMR26 | WARM | 427 | 06/01/2001 | | | | SP-0 | 5.20 | NC |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR26 | WARM | 434 | 06/08/2001 | | | | SP-0 | 9.30 | NC |
| DMR26 | WARM | 457 | 07/01/2001 | | | | SP-0 | 5.40 | NC |
| DMR26 | WARM | 464 | 07/08/2001 | | | | SP-0 | 6.60 | NC |
| DMR26 | WARM | 488 | 08/01/2001 | SP-1 | 10.00 | NC | SP-0 | 2.00 | ND |
| DMR26 | WARM | 502 | 08/15/2001 | | | | SP-0 | 6.60 | NC |
| DMR26 | WARM | 526 | 09/08/2001 | SP-1 | 7.50 | NC | SP-0 | 3.60 | NC |
| DMR26 | WARM | 533 | 09/15/2001 | SP-1 | 9.60 | NC | SP-0 | 11.60 | NC |
| DMR26 | WARM | 580 | 11/01/2001 | SP-1 | 7.00 | NC | SP-0 | 3.90 | NC |
| DMR26 | WARM | 587 | 11/08/2001 | | | | SP-0 | 17.00 | NC |
| DMR26 | WARM | 610 | 12/01/2001 | SP-1 | 7.00 | NC | SP-0 | 14.10 | NC |
| DMR26 | WARM | 617 | 12/08/2001 | SP-1 | 5.00 | NC | SP-0 | 7.10 | NC |
| DMR27 | COLD | 1 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR27 | COLD | 154 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 367 | 01/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 374 | 01/08/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 381 | 01/15/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 388 | 01/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 398 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 405 | 02/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 412 | 02/15/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 419 | 02/22/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 426 | 03/01/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 433 | 03/08/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 440 | 03/15/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 447 | 03/22/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 457 | 04/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 464 | 04/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 471 | 04/15/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 478 | 04/22/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 487 | 05/01/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 494 | 05/08/2001 | SP-1 | 3.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 501 | 05/15/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 508 | 05/22/2001 | SP-1 | 4.30 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 548 | 07/01/2001 | SP-1 | 3.00 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 555 | 07/08/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR28 | COLD | 562 | 07/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 569 | 07/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 579 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 586 | 08/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

---------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ----------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR28 | COLD | 593 | 08/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 600 | 08/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 610 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 617 | 09/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 624 | 09/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 631 | 09/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 640 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 647 | 10/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 654 | 10/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 661 | 10/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 671 | 11/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 678 | 11/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 685 | 11/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 692 | 11/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 701 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 708 | 12/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 715 | 12/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR28 | COLD | 722 | 12/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR29 | WARM | 1 | 06/01/2001 | SP-1 | 7.00 | NC | SP-0 | 0.10 | NC |
| DMR29 | WARM | 93 | 09/01/2001 | SP-1 | 5.00 | NC | SP-0 | 3.00 | NC |
| DMR29 | WARM | 184 | 12/01/2001 | SP-1 | 6.00 | NC | SP-0 | 3.00 | NC |
| DMR30 | COLD | 1 | 03/01/2001 | SP-1 | 7.00 | NC | SP-0 | 25.00 | NC |
| DMR30 | COLD | 276 | 12/01/2001 | SP-1 | 8.00 | NC | SP-0 | 22.00 | NC |
| DMR31 | COLD | 336 | 01/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 343 | 01/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 350 | 01/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 357 | 01/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 367 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 374 | 02/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 381 | 02/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 388 | 02/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 402 | 03/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 409 | 03/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR31 | COLD | 426 | 04/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 433 | 04/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 440 | 04/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 447 | 04/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 456 | 05/01/2001 | | | | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

----------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B -----------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR31 | COLD | 463 | 05/08/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 470 | 05/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 477 | 05/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 487 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 494 | 06/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 501 | 06/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 508 | 06/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 517 | 07/01/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 524 | 07/08/2001 | SP-1 | 3.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 531 | 07/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 538 | 07/22/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 548 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 555 | 08/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 562 | 08/15/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 569 | 08/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 579 | 09/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 586 | 09/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 593 | 09/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 600 | 09/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 609 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 616 | 10/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 623 | 10/15/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 630 | 10/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 640 | 11/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 647 | 11/08/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR31 | COLD | 654 | 11/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 661 | 11/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 670 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 677 | 12/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 684 | 12/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR31 | COLD | 691 | 12/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR32 | COLD | 1 | 07/01/2001 | | | | SP-0 | 52.00 | NC |
| DMR32 | COLD | 8 | 07/08/2001 | SP-1 | 1.00 | ND | SP-0 | 4.00 | NC |
| DMR32 | COLD | 93 | 10/01/2001 | | | | SP-0 | 25.00 | NC |
| DMR33 | COLD | 1 | 10/01/2001 | | | | SP-0 | 50.20 | NC |
| DMR34 | COLD | 579 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR34 | COLD | 586 | 08/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR34 | COLD | 610 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR34 | COLD | 617 | 09/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR34 | COLD | 654 | 10/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR34 | COLD | 678 | 11/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR34 | COLD | 701 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR35 | COLD | 1 | 06/01/2001 | SP-1 | 2.20 | NC | SP-0 | 1.00 | ND |
| DMR35 | COLD | 93 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 1.00 | ND |
| DMR36 | COLD | 1 | 01/01/2001 | | | | SP-0 | 7.30 | NC |
| DMR36 | COLD | 60 | 03/01/2001 | | | | SP-0 | 5.80 | NC |
| DMR36 | COLD | 67 | 03/08/2001 | SP-1 | 8.60 | NC | SP-0 | 2.50 | NC |
| DMR36 | COLD | 121 | 05/01/2001 | SP-1 | 5.60 | NC | SP-0 | 2.00 | NC |
| DMR36 | COLD | 152 | 06/01/2001 | SP-1 | 5.60 | NC | SP-0 | 2.00 | NC |
| DMR36 | COLD | 213 | 08/01/2001 | SP-1 | 9.80 | NC | SP-0 | 2.00 | NC |
| DMR36 | COLD | 244 | 09/01/2001 | | | | SP-0 | 8.60 | NC |
| DMR36 | COLD | 335 | 12/01/2001 | | | | SP-0 | 9.40 | NC |
| DMR37 | COLD | 307 | 01/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 314 | 01/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 321 | 01/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 328 | 01/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 338 | 02/01/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 345 | 02/08/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 352 | 02/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 359 | 02/22/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 366 | 03/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 373 | 03/08/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 380 | 03/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 387 | 03/22/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 397 | 04/01/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 404 | 04/08/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 411 | 04/15/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 418 | 04/22/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 427 | 05/01/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 434 | 05/08/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 441 | 05/15/2001 | SP-1 | 2.90 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 448 | 05/22/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 458 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 465 | 06/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 472 | 06/15/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 479 | 06/22/2001 | SP-1 | 3.10 | NC | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR37 | COLD | 488 | 07/01/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 495 | 07/08/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 502 | 07/15/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 509 | 07/22/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 519 | 08/01/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 526 | 08/08/2001 | SP-1 | 2.80 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 533 | 08/15/2001 | SP-1 | 2.50 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 540 | 08/22/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 550 | 09/01/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 557 | 09/08/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 564 | 09/15/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 571 | 09/22/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 580 | 10/01/2001 | SP-1 | 2.50 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 587 | 10/08/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 594 | 10/15/2001 | SP-1 | 3.30 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 601 | 10/22/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 611 | 11/01/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 618 | 11/08/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 625 | 11/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 632 | 11/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR37 | COLD | 641 | 12/01/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 648 | 12/08/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 655 | 12/15/2001 | SP-1 | 2.70 | NC | SP-0 | 2.00 | ND |
| DMR37 | COLD | 662 | 12/22/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 86 | 01/15/2001 | SP-1 | 3.60 | NC | SP-0 | 4.00 | NC |
| DMR38 | COLD | 124 | 02/22/2001 | SP-1 | 2.00 | ND | SP-0 | 4.10 | NC |
| DMR38 | COLD | 152 | 03/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR38 | COLD | 176 | 04/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR38 | COLD | 213 | 05/22/2001 | SP-1 | 2.80 | NC | SP-0 | 2.00 | ND |
| DMR38 | COLD | 244 | 06/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR38 | COLD | 274 | 07/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR38 | COLD | 312 | 08/29/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR38 | COLD | 336 | 09/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR38 | COLD | 373 | 10/29/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR38 | COLD | 397 | 11/22/2001 | SP-1 | 2.00 | ND | SP-0 | 3.00 | NC |
| DMR38 | COLD | 434 | 12/29/2001 | SP-1 | 2.60 | NC | SP-0 | 2.40 | NC |
| DMR39 | COLD | 154 | 01/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR39 | COLD | 244 | 04/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR39 | COLD | 335 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR39 | COLD | 427 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.30 | NC |
| DMR40 | COLD | 1 | 07/01/2001 | | | | SP-0 | 103.00 | NC |
| DMR40 | COLD | 93 | 10/01/2001 | | | | SP-0 | 40.50 | NC |
| DMR42 | COLD | 367 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR42 | COLD | 548 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR42 | COLD | 640 | 11/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR43 | COLD | 1 | 11/01/2001 | SP-1 | 3.10 | NC | SP-0 | 5.90 | NC |
| DMR43 | COLD | 31 | 12/01/2001 | SP-1 | 7.10 | NC | SP-0 | 3.60 | NC |
| DMR44 | COLD | 1 | 06/01/2001 | SP-1 | 1.40 | NC | SP-0 | 1.00 | ND |
| DMR46 | COLD | 1 | 02/01/2001 | SP-1 | 1.60 | NC | SP-0 | 1.00 | ND |
| DMR46 | COLD | 121 | 06/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR46 | COLD | 182 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 1.00 | ND |
| DMR46 | COLD | 213 | 09/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR47 | COLD | 243 | 05/01/2001 | SP-1 | 6.00 | NC | SP-0 | 5.60 | NC |
| DMR47 | COLD | 304 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR48 | COLD | 276 | 01/01/2001 | SP-1 | 2.60 | NC | SP-0 | 2.00 | ND |
| DMR48 | COLD | 307 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.20 | NC |
| DMR48 | COLD | 335 | 03/01/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR48 | COLD | 366 | 04/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR48 | COLD | 396 | 05/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR48 | COLD | 427 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR48 | COLD | 457 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 3.30 | NC |
| DMR48 | COLD | 488 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR48 | COLD | 519 | 09/01/2001 | SP-1 | 5.80 | NC | SP-0 | 4.60 | NC |
| DMR48 | COLD | 549 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR48 | COLD | 580 | 11/01/2001 | SP-1 | 3.40 | NC | SP-0 | 5.20 | NC |
| DMR48 | COLD | 610 | 12/01/2001 | SP-1 | 6.00 | NC | SP-0 | 4.10 | NC |
| DMR49 | COLD | 367 | 01/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 374 | 01/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 381 | 01/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 388 | 01/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 398 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 405 | 02/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR49 | COLD | 412 | 02/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 419 | 02/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 426 | 03/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 433 | 03/08/2001 | SP-1 | 2.40 | NC | SP-0 | 2.00 | ND |
| DMR49 | COLD | 440 | 03/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 447 | 03/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 457 | 04/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 464 | 04/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 471 | 04/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 478 | 04/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 487 | 05/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 494 | 05/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 501 | 05/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 518 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 525 | 06/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 532 | 06/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 548 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 555 | 07/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 562 | 07/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 579 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 586 | 08/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 593 | 08/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 610 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 617 | 09/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 624 | 09/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 640 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 647 | 10/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 654 | 10/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 661 | 10/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 671 | 11/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 678 | 11/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 685 | 11/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 692 | 11/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 701 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 708 | 12/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 715 | 12/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR49 | COLD | 722 | 12/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR50 | COLD | 367 | 01/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 374 | 01/08/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 381 | 01/15/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

---------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ----------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR50 | COLD | 388 | 01/22/2001 | SP-1 | 2.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 398 | 02/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 405 | 02/08/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 412 | 02/15/2001 | SP-1 | 2.00 | NC | SP-0 | 1.00 | ND |
| DMR50 | COLD | 419 | 02/22/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 426 | 03/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 433 | 03/08/2001 | SP-1 | 2.00 | NC | SP-0 | 1.00 | ND |
| DMR50 | COLD | 440 | 03/15/2001 | SP-1 | 1.00 | ND | SP-0 | 5.00 | NC |
| DMR50 | COLD | 447 | 03/22/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 457 | 04/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 464 | 04/08/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 471 | 04/15/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 478 | 04/22/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 487 | 05/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 494 | 05/08/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 501 | 05/15/2001 | SP-1 | 2.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 508 | 05/22/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 518 | 06/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 525 | 06/08/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 532 | 06/15/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 539 | 06/22/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 548 | 07/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 555 | 07/08/2001 | SP-1 | 2.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 562 | 07/15/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | NC |
| DMR50 | COLD | 569 | 07/22/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 579 | 08/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 586 | 08/08/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 593 | 08/15/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 600 | 08/22/2001 | SP-1 | 2.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 607 | 08/29/2001 | SP-1 | 2.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 610 | 09/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 617 | 09/08/2001 | SP-1 | 2.00 | NC | SP-0 | 1.00 | ND |
| DMR50 | COLD | 624 | 09/15/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR50 | COLD | 701 | 12/01/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | NC |
| DMR50 | COLD | 708 | 12/08/2001 | SP-1 | 2.00 | NC | SP-0 | 1.00 | ND |
| DMR50 | COLD | 715 | 12/15/2001 | SP-1 | 2.00 | ND | SP-0 | 3.00 | NC |
| DMR50 | COLD | 722 | 12/22/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| | | | | | | | | | |
| DMR51 | COLD | 367 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR51 | COLD | 395 | 03/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR51 | COLD | 426 | 04/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR51 | COLD | 456 | 05/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR51 | COLD | 517 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR51 | COLD | 609 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR51 | COLD | 630 | 10/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| | | | | | | | | | |
| DMR53 | COLD | 307 | 01/01/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | NC |
| DMR53 | COLD | 314 | 01/08/2001 | SP-1 | 4.00 | NC | SP-0 | 3.00 | NC |
| DMR53 | COLD | 321 | 01/15/2001 | SP-1 | 4.00 | NC | SP-0 | 5.00 | NC |
| DMR53 | COLD | 328 | 01/22/2001 | SP-1 | 2.00 | NC | SP-0 | 3.00 | NC |
| DMR53 | COLD | 335 | 01/29/2001 | SP-1 | 3.00 | NC | SP-0 | 3.00 | NC |
| DMR53 | COLD | 338 | 02/01/2001 | SP-1 | 2.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 345 | 02/08/2001 | SP-1 | 7.00 | NC | SP-0 | 4.00 | NC |
| DMR53 | COLD | 352 | 02/15/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 359 | 02/22/2001 | SP-1 | 3.00 | NC | SP-0 | 2.00 | NC |
| DMR53 | COLD | 366 | 03/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 373 | 03/08/2001 | SP-1 | 5.00 | NC | SP-0 | 2.00 | NC |
| DMR53 | COLD | 380 | 03/15/2001 | SP-1 | 2.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 387 | 03/22/2001 | SP-1 | 2.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 397 | 04/01/2001 | SP-1 | 4.00 | NC | SP-0 | 2.00 | ND |
| DMR53 | COLD | 404 | 04/08/2001 | SP-1 | 5.00 | NC | SP-0 | 2.00 | ND |
| DMR53 | COLD | 411 | 04/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR53 | COLD | 418 | 04/22/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR53 | COLD | 427 | 05/01/2001 | SP-1 | 1.00 | ND | SP-0 | 2.00 | ND |
| DMR53 | COLD | 434 | 05/08/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | NC |
| DMR53 | COLD | 441 | 05/15/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 448 | 05/22/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 458 | 06/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 465 | 06/08/2001 | SP-1 | 2.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 472 | 06/15/2001 | SP-1 | 3.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 479 | 06/22/2001 | SP-1 | 4.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 488 | 07/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 495 | 07/08/2001 | SP-1 | 4.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 502 | 07/15/2001 | SP-1 | 3.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 509 | 07/22/2001 | SP-1 | 3.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 519 | 08/01/2001 | SP-1 | 3.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 526 | 08/08/2001 | SP-1 | 3.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 533 | 08/15/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 540 | 08/22/2001 | SP-1 | 8.00 | NC | SP-0 | 6.00 | NC |
| DMR53 | COLD | 550 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 557 | 09/08/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 564 | 09/15/2001 | SP-1 | 5.00 | NC | SP-0 | 1.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

---------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ----------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR53 | COLD | 571 | 09/22/2001 | SP-1 | 3.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 580 | 10/01/2001 | SP-1 | 1.00 | ND | SP-0 | 5.00 | NC |
| DMR53 | COLD | 587 | 10/08/2001 | SP-1 | 2.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 594 | 10/15/2001 | SP-1 | 5.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 601 | 10/22/2001 | SP-1 | 2.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 611 | 11/01/2001 | SP-1 | 6.00 | NC | SP-0 | 4.00 | NC |
| DMR53 | COLD | 618 | 11/08/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 625 | 11/15/2001 | | | | SP-0 | 1.00 | ND |
| DMR53 | COLD | 632 | 11/22/2001 | SP-1 | 6.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 641 | 12/01/2001 | SP-1 | 1.00 | ND | SP-0 | 1.00 | ND |
| DMR53 | COLD | 648 | 12/08/2001 | SP-1 | 3.00 | NC | SP-0 | 2.00 | NC |
| DMR53 | COLD | 655 | 12/15/2001 | SP-1 | 3.00 | NC | SP-0 | 1.00 | ND |
| DMR53 | COLD | 662 | 12/22/2001 | SP-1 | 5.00 | NC | SP-0 | 4.00 | NC |
| DMR54A | COLD | 276 | 01/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 283 | 01/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 290 | 01/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 297 | 01/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 307 | 02/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 314 | 02/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 321 | 02/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 328 | 02/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 335 | 03/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 342 | 03/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 349 | 03/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 356 | 03/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 366 | 04/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 373 | 04/08/2001 | SP-1 | 2.10 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 380 | 04/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 387 | 04/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 396 | 05/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 403 | 05/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 410 | 05/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 417 | 05/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 427 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 434 | 06/08/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 441 | 06/15/2001 | SP-1 | 2.50 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 448 | 06/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 457 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 464 | 07/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 471 | 07/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

------------------------------------------ Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ------------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR54A | COLD | 478 | 07/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 488 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 495 | 08/08/2001 | | | | SP-0 | 2.00 | ND |
| DMR54A | COLD | 502 | 08/15/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 509 | 08/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 516 | 08/29/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 519 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 526 | 09/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 533 | 09/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 540 | 09/22/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 549 | 10/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 556 | 10/08/2001 | SP-1 | 2.00 | NC | SP-0 | 2.00 | ND |
| DMR54A | COLD | 563 | 10/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 570 | 10/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 580 | 11/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 587 | 11/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 594 | 11/15/2001 | | | | SP-0 | 2.00 | ND |
| DMR54A | COLD | 601 | 11/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 608 | 11/29/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 610 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 617 | 12/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 624 | 12/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR54A | COLD | 631 | 12/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR56 | COLD | 1 | 10/01/2001 | | | | SP-0 | 50.00 | NC |
| DMR57 | COLD | 1 | 04/01/2001 | SP-1 | 2.10 | NC | SP-0 | 1.00 | ND |
| DMR57 | COLD | 198 | 10/15/2001 | SP-1 | 2.50 | NC | SP-0 | 1.00 | ND |
| DMR57 | COLD | 222 | 11/08/2001 | SP-1 | 2.20 | NC | SP-0 | 1.30 | NC |
| DMR57 | COLD | 245 | 12/01/2001 | SP-1 | 1.20 | NC | SP-0 | 0.80 | NC |
| DMR58 | COLD | 1 | 10/01/2001 | SP-1 | 1.50 | NC | SP-0 | 2.20 | NC |
| DMR59 | COLD | 367 | 01/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 518 | 06/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 548 | 07/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 579 | 08/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 610 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 640 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 671 | 11/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR59 | COLD | 701 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

---------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ----------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| DMR60 | COLD | 519 | 09/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR60 | COLD | 526 | 09/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR60 | COLD | 533 | 09/15/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR60 | COLD | 540 | 09/22/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR60 | COLD | 549 | 10/01/2001 | SP-1 | 3.10 | NC | SP-0 | 2.00 | ND |
| DMR60 | COLD | 556 | 10/08/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR60 | COLD | 580 | 11/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR60 | COLD | 610 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR60 | COLD | 617 | 12/08/2001 | SP-1 | 2.30 | NC | SP-0 | 2.00 | ND |
| DMR62 | COLD | 1 | 09/01/2001 | SP-1 | 2.20 | NC | SP-0 | 2.00 | ND |
| DMR62 | COLD | 31 | 10/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR62 | COLD | 62 | 11/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |
| DMR62 | COLD | 92 | 12/01/2001 | SP-1 | 2.00 | ND | SP-0 | 2.00 | ND |

---------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=4B Combined B ----------------------------------------

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6297G | COLD | 1 | 12/11/2000 | SP8+9,SP5+6 | 4.65 | NC | SP-7 | 1000.00 | NC |
| 6297G | COLD | 2 | 12/12/2000 | SP8+9,SP5+6 | 4.40 | NC | SP-7 | 553.00 | NC |
| 6297G | COLD | 3 | 12/13/2000 | SP8+9,SP5+6 | 4.42 | NC | SP-7 | 1040.00 | NC |
| 6297G | COLD | 4 | 12/14/2000 | SP8+9,SP5+6 | 4.64 | NC | SP-7 | 1710.00 | NC |
| 6297G | COLD | 5 | 12/15/2000 | SP8+9,SP5+6 | 4.55 | NC | SP-7 | 363.00 | NC |
| 6297H | COLD | 1 | 12/11/2000 | SP11,SP5+6 | 4.51 | ND | SP-10 | 1040.00 | NC |
| 6297H | COLD | 2 | 12/12/2000 | SP11,SP5+6 | 4.63 | ND | SP-10 | 687.00 | NC |
| 6297H | COLD | 3 | 12/13/2000 | SP11,SP5+6 | 4.69 | ND | SP-10 | 4.00 | ND |
| 6297H | COLD | 4 | 12/14/2000 | SP11,SP5+6 | 4.67 | ND | SP-10 | 540.00 | NC |
| 6297H | COLD | 5 | 12/15/2000 | SP11,SP5+6 | 4.73 | ND | SP-10 | 690.00 | NC |
| 6297I | COLD | 1 | 12/11/2000 | SP13+14,SP2+3 | 4.07 | ND | SP-12 | 4050.00 | NC |
| 6297I | COLD | 2 | 12/12/2000 | SP13+14,SP2+3 | 4.60 | NC | SP-12 | 707.00 | NC |
| 6297I | COLD | 3 | 12/13/2000 | SP13+14,SP2+3 | 4.06 | ND | SP-12 | 2020.00 | NC |
| 6297I | COLD | 4 | 12/14/2000 | SP13+14,SP2+3 | 4.08 | ND | SP-12 | 3360.00 | NC |
| 6297I | COLD | 5 | 12/15/2000 | SP13+14,SP2+3 | 4.04 | ND | SP-12 | 2830.00 | NC |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

---------------------------------------- Subcategory=Flow-through -- Option=B -- Configuration=4B Combined B ----------------------------------------
(continued)

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6460D | COLD | 1 | 08/25/2001 | SP10+11 | 4.00 | ND | SP7,SP8 | 4.00 | ND |
| 6460D | COLD | 2 | 08/26/2001 | SP10+11 | 4.00 | ND | SP7,SP8 | 4.00 | ND |
| 6460D | COLD | 3 | 08/27/2001 | SP10+11 | 4.00 | ND | SP7,SP8 | 9607.52 | NC |
| 6460D | COLD | 4 | 08/28/2001 | SP10+11 | 4.00 | ND | SP7,SP8 | 4.00 | ND |
| 6460D | COLD | 5 | 08/29/2001 | SP10+11 | 4.00 | ND | SP7,SP8 | 4.00 | ND |
| 6495B | COLD | 1 | 03/25/2003 | SP13+14 | 4.00 | ND | SP-12 | 4.00 | ND |
| 6495B | COLD | 2 | 03/26/2003 | SP13+14 | 4.00 | ND | SP-12 | 4.00 | ND |
| 6495B | COLD | 3 | 03/27/2003 | SP13+14 | 4.00 | ND | SP-12 | 4.00 | ND |
| 6495B | COLD | 4 | 03/28/2003 | SP13+14 | 4.00 | ND | SP-12 | 4.00 | ND |
| 6495B | COLD | 5 | 03/29/2003 | SP13+14 | 4.00 | ND | SP-12 | 4.00 | ND |

---------------------------------------- Subcategory=Recirculating -- Option=A -- Configuration=6A RAS Solids A ----------------------------------------

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6439A | WARM | 1 | 04/24/2001 | SP-4 | 86.00 | NC | SP-3 | 363.00 | NC |
| 6439A | WARM | 2 | 04/25/2001 | SP-4 | 118.00 | NC | SP-3 | 730.00 | NC |
| 6439A | WARM | 3 | 04/26/2001 | SP-4 | 110.00 | NC | SP-3 | 1030.00 | NC |
| 6439A | WARM | 4 | 04/27/2001 | SP-4 | 1010.00 | NC | SP-3 | 180.00 | NC |
| 6439A | WARM | 5 | 04/28/2001 | SP-4 | 84.00 | NC | SP-3 | 440.00 | NC |

---------------------------------------- Subcategory=Recirculating -- Option=A -- Configuration=7A RAS Overtopping A ----------------------------------------

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6439C | WARM | 1 | 04/24/2001 | | | | SP-2 | 38.00 | NC |
| 6439C | WARM | 2 | 04/25/2001 | | | | SP-2 | 45.00 | NC |
| 6439C | WARM | 3 | 04/26/2001 | | | | SP-2 | 49.00 | NC |
| 6439C | WARM | 4 | 04/27/2001 | | | | SP-2 | 55.00 | NC |
| 6439C | WARM | 5 | 04/28/2001 | | | | SP-2 | 44.00 | NC |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

Part 2: TSS(mg/L) Effluent and Influent Concentration Data

-------------------------------------- Subcategory=Recirculating -- Option=B -- Configuration=6B RAS Solids B --------------------------------------

| Episode | Warm or Cold | Sample Day | Sample Date | Effluent Sample Point | Effluent Concentration | Effluent Censor Type | Influent Sample Point | Influent Concentration | Influent Censor Type |
|---|---|---|---|---|---|---|---|---|---|
| 6439B | WARM | 1 | 04/24/2001 | SP9+11 | 44.00 | NC | SP-8 | 56.00 | NC |
| 6439B | WARM | 2 | 04/25/2001 | SP9+11 | 53.00 | NC | SP-8 | 58.00 | NC |
| 6439B | WARM | 3 | 04/26/2001 | SP9+11 | 61.00 | NC | SP-8 | 68.00 | NC |
| 6439B | WARM | 4 | 04/27/2001 | SP9+11 | 28.50 | NC | SP-8 | 30.00 | NC |
| 6439B | WARM | 5 | 04/28/2001 | SP9+11 | 46.50 | NC | SP-8 | 74.00 | NC |

If the Influent Sample Point is identified as SP-0, then the columns for Influent provide information about Source Water

# APPENDIX D
## SUMMARY STATISTICS AT EACH SAMPLE POINT FOR TOTAL SUSPENDED SOLIDS

Listing 8-1: Summary Statistics for TSS Daily Values (mg/L)

------------------------------------- -- Subcategory=Combined -- Option=A -- Configuration=2A+6A+7A Continuous A -------------------------------------

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALL | ALL | | 134.45 | 11 | 1 | 293.84 | 38.00 | 147.50 | 6.00 | 1010.00 | 4.00 | 4.00 |
| 6439A | SP-4 | WARM | 281.60 | 5 | 0 | 407.46 | 110.00 | 281.60 | 84.00 | 1010.00 | | |
| 6460C | SP-9 | COLD | 38.00 | 1 | 0 | | 38.00 | 38.00 | 38.00 | 38.00 | | |
| 6495A | SP-11 | COLD | 6.60 | 5 | 1 | 1.67 | 7.00 | 7.25 | 6.00 | 8.00 | 4.00 | 4.00 |

------------------------------------- -- Subcategory=Combined -- Option=B -- Configuration=2B+6B+7B Continuous B -------------------------------------

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALL | ALL | | 29.80 | 713 | 13 | 20.93 | 25.30 | 30.32 | 2.00 | 98.00 | 2.00 | 2.00 |
| 6297A | SP8+9 | COLD | 57.80 | 5 | 0 | 12.34 | 60.00 | 57.80 | 44.00 | 70.00 | | |
| 6297B | SP-11 | COLD | 69.60 | 5 | 0 | 8.41 | 72.00 | 69.60 | 56.00 | 78.00 | | |
| 6297C | SP13+14 | COLD | 11.12 | 5 | 0 | 2.39 | 11.00 | 11.12 | 8.40 | 14.80 | | |
| 6439B | SP9+11 | WARM | 46.60 | 5 | 0 | 12.07 | 46.50 | 46.60 | 28.50 | 61.00 | | |
| DMR06 | SP-1 | COLD | 17.99 | 12 | 1 | 19.09 | 12.20 | 19.44 | 2.17 | 66.70 | 2.00 | 2.00 |
| DMR10 | SP-1 | COLD | 79.00 | 2 | 0 | 0.42 | 79.00 | 79.00 | 78.70 | 79.30 | | |
| DMR12A | SP-1 | COLD | 12.89 | 49 | 3 | 11.63 | 10.40 | 13.60 | 2.01 | 49.00 | 2.00 | 2.00 |
| DMR12B | SP-2 | COLD | 14.81 | 49 | 1 | 12.21 | 11.90 | 15.08 | 2.10 | 68.50 | 2.00 | 2.00 |
| DMR15 | SP-1 | COLD | 14.07 | 43 | 0 | 10.85 | 10.00 | 14.07 | 2.20 | 43.00 | | |
| DMR18 | SP-1 | COLD | 2.00 | 1 | 1 | | 2.00 | | | | 2.00 | 2.00 |
| DMR21A | SP-1 | COLD | 52.61 | 48 | 0 | 14.11 | 52.00 | 52.61 | 23.00 | 82.00 | | |
| DMR21B | SP-2 | COLD | 49.05 | 48 | 0 | 13.87 | 47.50 | 49.05 | 22.00 | 84.00 | | |
| DMR21C | SP-3 | COLD | 11.68 | 48 | 1 | 6.59 | 11.40 | 11.89 | 2.00 | 28.00 | 2.00 | 2.00 |
| DMR25A | SP-1 | COLD | 34.75 | 48 | 0 | 14.78 | 33.00 | 34.75 | 7.20 | 64.00 | | |
| DMR25B | SP-2 | COLD | 42.89 | 48 | 0 | 12.69 | 42.50 | 42.89 | 15.30 | 73.00 | | |
| DMR28 | SP-1 | COLD | 16.56 | 48 | 0 | 10.60 | 13.60 | 16.56 | 2.34 | 55.20 | | |
| DMR31 | SP-1 | COLD | 34.08 | 43 | 0 | 22.74 | 28.00 | 34.08 | 5.40 | 91.00 | | |
| DMR32 | SP-1 | COLD | 12.00 | 1 | 0 | | 12.00 | 12.00 | 12.00 | 12.00 | | |
| DMR34 | SP-1 | COLD | 41.44 | 20 | 0 | 24.14 | 35.15 | 41.44 | 9.15 | 92.80 | | |
| DMR37 | SP-1 | COLD | 24.19 | 48 | 0 | 8.82 | 22.55 | 24.19 | 10.80 | 55.00 | | |
| DMR38 | SP-1 | COLD | 26.67 | 11 | 0 | 18.04 | 24.40 | 26.67 | 5.52 | 56.60 | | |
| DMR49 | SP-1 | COLD | 20.14 | 20 | 0 | 10.47 | 16.75 | 20.14 | 5.72 | 49.00 | | |
| DMR54A | SP-1 | COLD | 29.02 | 48 | 0 | 12.63 | 29.00 | 29.02 | 3.60 | 63.00 | | |
| DMR54B | SP-2 | COLD | 49.96 | 49 | 0 | 23.47 | 46.00 | 49.96 | 3.80 | 98.00 | | |
| DMR59 | SP-1 | COLD | 2.20 | 9 | 6 | 0.49 | 2.00 | 2.59 | 2.00 | 3.48 | 2.00 | 2.00 |

Listing 8-1: Summary Statistics for TSS Daily Values (mg/L)

---------------------------------------- -- Subcategory=Flow-through -- Option=A -- Configuration=2A OLSB A ----------------------------------------

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALL | ALL | | 11.83 | 6 | 1 | 12.91 | 7.50 | 13.40 | 6.00 | 38.00 | 4.00 | 4.00 |
| 6460C | SP-9 | COLD | 38.00 | 1 | 0 | | 38.00 | 38.00 | 38.00 | 38.00 | | |
| 6495A | SP-11 | COLD | 6.60 | 5 | 1 | 1.67 | 7.00 | 7.25 | 6.00 | 8.00 | 4.00 | 4.00 |

-------------------------------------- -- Subcategory=Flow-through -- Option=A -- Configuration=3A Raceway A ---------------------------------------

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALL | ALL | | 4.00 | 5 | 5 | 0.00 | 4.00 | | | | 4.00 | 4.00 |
| 6460B | SP-7 | COLD | 4.00 | 5 | 5 | 0.00 | 4.00 | | | | 4.00 | 4.00 |

-------------------------------------- -- Subcategory=Flow-through -- Option=A -- Configuration=4A Combined A --------------------------------------

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALL | ALL | | 3.06 | 107 | 4 | 3.35 | 2.40 | 3.03 | 0.00 | 31.68 | 4.00 | 4.00 |
| 6460A | SP7,SP9 | COLD | 9.54 | 5 | 4 | 12.38 | 4.00 | 31.68 | 31.68 | 31.68 | 4.00 | 4.00 |
| DMR01 | SP-1 | COLD | 1.79 | 19 | 0 | 1.08 | 1.00 | 1.79 | 1.00 | 5.00 | | |
| DMR03 | SP-1 | COLD | 3.69 | 37 | 0 | 1.25 | 3.50 | 3.69 | 1.70 | 7.00 | | |
| DMR04 | SP-1 | COLD | 2.70 | 34 | 0 | 2.07 | 1.80 | 2.70 | 0.60 | 9.60 | | |
| DMR61 | SP-1 | UNK | 1.50 | 12 | 0 | 2.54 | 0.00 | 1.50 | 0.00 | 6.00 | | |

---------------------------------------- -- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B ----------------------------------------

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALL | ALL | | 29.69 | 708 | 13 | 20.93 | 25.00 | 30.20 | 2.00 | 98.00 | 2.00 | 2.00 |
| 6297A | SP8+9 | COLD | 57.80 | 5 | 0 | 12.34 | 60.00 | 57.80 | 44.00 | 70.00 | | |
| 6297B | SP-11 | COLD | 69.60 | 5 | 0 | 8.41 | 72.00 | 69.60 | 56.00 | 78.00 | | |
| 6297C | SP13+14 | COLD | 11.12 | 5 | 0 | 2.39 | 11.00 | 11.12 | 8.40 | 14.80 | | |
| DMR06 | SP-1 | COLD | 17.99 | 12 | 1 | 19.09 | 12.20 | 19.44 | 2.17 | 66.70 | 2.00 | 2.00 |
| DMR10 | SP-1 | COLD | 79.00 | 2 | 0 | 0.42 | 79.00 | 79.00 | 78.70 | 79.30 | | |
| DMR12A | SP-1 | COLD | 12.89 | 49 | 3 | 11.63 | 10.40 | 13.60 | 2.01 | 49.00 | 2.00 | 2.00 |
| DMR12B | SP-2 | COLD | 14.81 | 49 | 1 | 12.21 | 11.90 | 15.08 | 2.10 | 68.50 | 2.00 | 2.00 |
| DMR15 | SP-1 | COLD | 14.07 | 43 | 0 | 10.85 | 10.00 | 14.07 | 2.20 | 43.00 | | |

Listing 8-1: Summary Statistics for TSS Daily Values (mg/L)

----------------------------------------- -- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -----------------------------------------
(continued)

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DMR18 | SP-1 | COLD | 2.00 | 1 | 1 | | 2.00 | | | | 2.00 | 2.00 |
| DMR21A | SP-1 | COLD | 52.61 | 48 | 0 | 14.11 | 52.00 | 52.61 | 23.00 | 82.00 | | |
| DMR21B | SP-2 | COLD | 49.05 | 48 | 0 | 13.87 | 47.50 | 49.05 | 22.00 | 84.00 | | |
| DMR21C | SP-3 | COLD | 11.68 | 48 | 1 | 6.59 | 11.40 | 11.89 | 2.00 | 28.00 | 2.00 | 2.00 |
| DMR25A | SP-1 | COLD | 34.75 | 48 | 0 | 14.78 | 33.00 | 34.75 | 7.20 | 64.00 | | |
| DMR25B | SP-2 | COLD | 42.89 | 48 | 0 | 12.69 | 42.50 | 42.89 | 15.30 | 73.00 | | |
| DMR28 | SP-1 | COLD | 16.56 | 48 | 0 | 10.60 | 13.60 | 16.56 | 2.34 | 55.20 | | |
| DMR31 | SP-1 | COLD | 34.08 | 43 | 0 | 22.74 | 28.00 | 34.08 | 5.40 | 91.00 | | |
| DMR32 | SP-1 | COLD | 12.00 | 1 | 0 | | 12.00 | 12.00 | 12.00 | 12.00 | | |
| DMR34 | SP-1 | COLD | 41.44 | 20 | 0 | 24.14 | 35.15 | 41.44 | 9.15 | 92.80 | | |
| DMR37 | SP-1 | COLD | 24.19 | 48 | 0 | 8.82 | 22.55 | 24.19 | 10.80 | 55.00 | | |
| DMR38 | SP-1 | COLD | 26.67 | 11 | 0 | 18.04 | 24.40 | 26.67 | 5.52 | 56.60 | | |
| DMR49 | SP-1 | COLD | 20.14 | 20 | 0 | 10.47 | 16.75 | 20.14 | 5.72 | 49.00 | | |
| DMR54A | SP-1 | COLD | 29.02 | 48 | 0 | 12.63 | 29.00 | 29.02 | 3.60 | 63.00 | | |
| DMR54B | SP-2 | COLD | 49.96 | 49 | 0 | 23.47 | 46.00 | 49.96 | 3.80 | 98.00 | | |
| DMR59 | SP-1 | COLD | 2.20 | 9 | 6 | 0.49 | 2.00 | 2.59 | 2.00 | 3.48 | 2.00 | 2.00 |

---------------------------------------- -- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ----------------------------------------

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALL | ALL | | 2.39 | 688 | 417 | 1.23 | 2.00 | 3.09 | 0.40 | 10.00 | 1.00 | 4.00 |
| 6297E | SP5+6 | COLD | 4.00 | 5 | 5 | 0.00 | 4.00 | | | | 4.00 | 4.00 |
| 6297F | SP2+3 | COLD | 4.10 | 5 | 4 | 0.22 | 4.00 | 4.50 | 4.50 | 4.50 | 4.00 | 4.00 |
| DMR05 | SP-1 | COLD | 2.00 | 3 | 3 | 0.00 | 2.00 | | | | 2.00 | 2.00 |
| DMR06 | SP-1 | COLD | 2.06 | 12 | 11 | 0.20 | 2.00 | 2.70 | 2.70 | 2.70 | 2.00 | 2.00 |
| DMR07 | SP-1 | COLD | 2.50 | 2 | 1 | 0.71 | 2.50 | 3.00 | 3.00 | 3.00 | 2.00 | 2.00 |
| DMR08 | SP-1 | COLD | 3.04 | 9 | 5 | 1.82 | 2.00 | 4.35 | 3.00 | 7.60 | 2.00 | 2.00 |
| DMR09 | SP-1 | COLD | 2.00 | 1 | 1 | | 2.00 | | | | 2.00 | 2.00 |
| DMR10 | SP-1 | COLD | 2.43 | 16 | 6 | 0.54 | 2.20 | 2.68 | 2.00 | 3.60 | 2.00 | 2.00 |
| DMR12A | SP-1 | COLD | 2.04 | 49 | 43 | 0.14 | 2.00 | 2.33 | 2.10 | 2.70 | 2.00 | 2.00 |
| DMR13 | SP-1 | COLD | 1.90 | 2 | 0 | 0.99 | 1.90 | 1.90 | 1.20 | 2.60 | | |
| DMR15 | SP-1 | COLD | 2.85 | 39 | 17 | 1.38 | 2.20 | 3.50 | 2.00 | 7.70 | 2.00 | 2.00 |
| DMR17 | SP-1 | COLD | 2.20 | 1 | 0 | | 2.20 | 2.20 | 2.20 | 2.20 | | |
| DMR18 | SP-1 | COLD | 2.98 | 11 | 7 | 2.01 | 2.00 | 4.70 | 2.40 | 8.00 | 2.00 | 2.00 |
| DMR19 | SP-1 | COLD | 0.63 | 4 | 0 | 0.17 | 0.65 | 0.63 | 0.40 | 0.80 | | |
| DMR20 | SP-1 | COLD | 3.23 | 4 | 1 | 1.90 | 3.45 | 3.97 | 2.30 | 5.00 | 1.00 | 1.00 |
| DMR21A | SP-1 | COLD | 2.36 | 48 | 9 | 0.41 | 2.30 | 2.45 | 2.00 | 4.30 | 2.00 | 2.00 |
| DMR23 | SP-1 | COLD | 2.08 | 9 | 7 | 0.17 | 2.00 | 2.35 | 2.20 | 2.50 | 2.00 | 2.00 |
| DMR25A | SP-1 | COLD | 2.14 | 48 | 27 | 0.26 | 2.00 | 2.33 | 2.00 | 2.90 | 2.00 | 2.00 |

Listing 8-1: Summary Statistics for TSS Daily Values (mg/L)

---------------------------------------- -- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ----------------------------------------
(continued)

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DMR26 | SP-1 | WARM | 6.99 | 11 | 0 | 1.74 | 7.00 | 6.99 | 5.00 | 10.00 | | |
| DMR27 | SP-1 | COLD | 2.00 | 2 | 2 | 0.00 | 2.00 | | | | 2.00 | 2.00 |
| DMR28 | SP-1 | COLD | 2.21 | 44 | 27 | 0.43 | 2.00 | 2.54 | 2.00 | 4.30 | 2.00 | 2.00 |
| DMR29 | SP-1 | WARM | 6.00 | 3 | 0 | 1.00 | 6.00 | 6.00 | 5.00 | 7.00 | | |
| DMR30 | SP-1 | COLD | 7.50 | 2 | 0 | 0.71 | 7.50 | 7.50 | 7.00 | 8.00 | | |
| DMR31 | SP-1 | COLD | 2.06 | 44 | 36 | 0.19 | 2.00 | 2.33 | 2.00 | 3.00 | 2.00 | 2.00 |
| DMR32 | SP-1 | COLD | 1.00 | 1 | 1 | | 1.00 | | | | 1.00 | 1.00 |
| DMR34 | SP-1 | COLD | 2.00 | 7 | 7 | 0.00 | 2.00 | | | | 2.00 | 2.00 |
| DMR35 | SP-1 | COLD | 2.10 | 2 | 1 | 0.14 | 2.10 | 2.20 | 2.20 | 2.20 | 2.00 | 2.00 |
| DMR36 | SP-1 | COLD | 7.40 | 4 | 0 | 2.14 | 7.10 | 7.40 | 5.60 | 9.80 | | |
| DMR37 | SP-1 | COLD | 2.28 | 48 | 11 | 0.33 | 2.20 | 2.37 | 2.00 | 3.30 | 2.00 | 2.00 |
| DMR38 | SP-1 | COLD | 2.25 | 12 | 9 | 0.51 | 2.00 | 3.00 | 2.60 | 3.60 | 2.00 | 2.00 |
| DMR39 | SP-1 | COLD | 2.00 | 4 | 4 | 0.00 | 2.00 | | | | 2.00 | 2.00 |
| DMR42 | SP-1 | COLD | 2.00 | 3 | 3 | 0.00 | 2.00 | | | | 2.00 | 2.00 |
| DMR43 | SP-1 | COLD | 5.10 | 2 | 0 | 2.83 | 5.10 | 5.10 | 3.10 | 7.10 | | |
| DMR44 | SP-1 | COLD | 1.40 | 1 | 0 | | 1.40 | 1.40 | 1.40 | 1.40 | | |
| DMR46 | SP-1 | COLD | 1.40 | 4 | 3 | 0.49 | 1.30 | 1.60 | 1.60 | 1.60 | 1.00 | 2.00 |
| DMR47 | SP-1 | COLD | 4.00 | 2 | 1 | 2.83 | 4.00 | 6.00 | 6.00 | 6.00 | 2.00 | 2.00 |
| DMR48 | SP-1 | COLD | 2.85 | 12 | 7 | 1.48 | 2.00 | 4.04 | 2.40 | 6.00 | 2.00 | 2.00 |
| DMR49 | SP-1 | COLD | 2.01 | 43 | 42 | 0.06 | 2.00 | 2.40 | 2.40 | 2.40 | 2.00 | 2.00 |
| DMR50 | SP-1 | COLD | 1.28 | 40 | 35 | 0.45 | 1.00 | 2.00 | 2.00 | 2.00 | 1.00 | 2.00 |
| DMR51 | SP-1 | COLD | 2.00 | 7 | 7 | 0.00 | 2.00 | | | | 2.00 | 2.00 |
| DMR53 | SP-1 | COLD | 2.88 | 48 | 15 | 1.75 | 2.50 | 3.64 | 2.00 | 8.00 | 1.00 | 2.00 |
| DMR54A | SP-1 | COLD | 2.03 | 48 | 41 | 0.09 | 2.00 | 2.19 | 2.00 | 2.50 | 2.00 | 2.00 |
| DMR57 | SP-1 | COLD | 2.00 | 4 | 0 | 0.56 | 2.15 | 2.00 | 1.20 | 2.50 | | |
| DMR58 | SP-1 | COLD | 1.50 | 1 | 0 | | 1.50 | 1.50 | 1.50 | 1.50 | | |
| DMR59 | SP-1 | COLD | 2.00 | 8 | 8 | 0.00 | 2.00 | | | | 2.00 | 2.00 |
| DMR60 | SP-1 | COLD | 2.16 | 9 | 7 | 0.37 | 2.00 | 2.70 | 2.30 | 3.10 | 2.00 | 2.00 |
| DMR62 | SP-1 | COLD | 2.05 | 4 | 3 | 0.10 | 2.00 | 2.20 | 2.20 | 2.20 | 2.00 | 2.00 |

---------------------------------------- -- Subcategory=Flow-through -- Option=B -- Configuration=4B Combined B ----------------------------------------

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALL | ALL | | 4.27 | 25 | 19 | 0.30 | 4.07 | 4.54 | 4.40 | 4.65 | 4.00 | 4.73 |
| 6297G | SP8+9,SP5+6 | COLD | 4.53 | 5 | 0 | 0.12 | 4.55 | 4.53 | 4.40 | 4.65 | | |
| 6297H | SP11,SP5+6 | COLD | 4.65 | 5 | 5 | 0.08 | 4.67 | | | | 4.51 | 4.73 |
| 6297I | SP13+14,SP2+3 | COLD | 4.17 | 5 | 4 | 0.24 | 4.07 | 4.60 | 4.60 | 4.60 | 4.04 | 4.08 |
| 6460D | SP10+11 | COLD | 4.00 | 5 | 5 | 0.00 | 4.00 | | | | 4.00 | 4.00 |
| 6495B | SP13+14 | COLD | 4.00 | 5 | 5 | 0.00 | 4.00 | | | | 4.00 | 4.00 |

Listing 8-1: Summary Statistics for TSS Daily Values (mg/L)

------------------------------------- -- Subcategory=Recirculating -- Option=A -- Configuration=6A RAS Solids A -------------------------------------

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALL | ALL | | 281.60 | 5 | 0 | 407.46 | 110.00 | 281.60 | 84.00 | 1010.00 | | |
| 6439A | SP-4 | WARM | 281.60 | 5 | 0 | 407.46 | 110.00 | 281.60 | 84.00 | 1010.00 | | |

------------------------------------- -- Subcategory=Recirculating -- Option=B -- Configuration=6B RAS Solids B -------------------------------------

| Episode | Sample Point | Warm or Cold | Episode Mean | Total Number Values | Number of ND | Obs Std Dev | Obs Median Value | Mean Value NC | Min Value NC | Max Value NC | Min Value ND | Max Value ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALL | ALL | | 46.60 | 5 | 0 | 12.07 | 46.50 | 46.60 | 28.50 | 61.00 | | |
| 6439B | SP9+11 | WARM | 46.60 | 5 | 0 | 12.07 | 46.50 | 46.60 | 28.50 | 61.00 | | |

Listing 8-2: Episode Long-Term Averages (mg/L) and Variability Factors for TSS
(with 3-significant digits)

------------------------------------- -- Subcategory=Combined -- Option=A -- Configuration=2A+6A+7A Continuous A -------------------------------------

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6439A | SP-4 | WARM | 5 | 0 | 5.05 | 1.05 | 282.0 | 273.0 | 388.0 | 6.65 | 2.33 | Y |
| 6460C | SP-9 | COLD | 1 | 0 | . | . | 38.0 | 38.0 | . | . | . | |
| 6495A | SP-11 | COLD | 5 | 1 | 1.97 | 0.14 | 6.60 | 6.61 | 1.58 | 1.48 | 1.21 | |

------------------------------------- -- Subcategory=Combined -- Option=B -- Configuration=2B+6B+7B Continuous B -------------------------------------

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6297A | SP8+9 | COLD | 5 | 0 | 4.04 | 0.22 | 57.8 | 58.1 | 13.0 | 1.63 | 1.19 | |
| 6297B | SP-11 | COLD | 5 | 0 | 4.24 | 0.13 | 69.6 | 69.7 | 8.96 | 1.34 | 1.11 | |
| 6297C | SP13+14 | COLD | 5 | 0 | 2.39 | 0.21 | 11.1 | 11.2 | 2.37 | 1.59 | 1.18 | |
| 6439B | SP9+11 | WARM | 5 | 0 | 3.81 | 0.29 | 46.6 | 47.1 | 13.8 | 1.87 | 1.26 | Y |
| DMR06 | SP-1 | COLD | 12 | 1 | 2.52 | 1.04 | 18.0 | 19.8 | 29.0 | 6.83 | 2.37 | |
| DMR10 | SP-1 | COLD | 2 | 0 | . | . | 79.0 | 79.0 | 0.424 | . | . | |
| DMR12A | SP-1 | COLD | 49 | 3 | 2.27 | 0.86 | 12.9 | 13.3 | 14.6 | 5.31 | 2.04 | |
| DMR12B | SP-2 | COLD | 49 | 1 | 2.45 | 0.73 | 14.8 | 14.9 | 12.8 | 4.25 | 1.81 | |
| DMR15 | SP-1 | COLD | 43 | 0 | 2.33 | 0.84 | 14.1 | 14.6 | 14.8 | 4.96 | 1.96 | |
| DMR18 | SP-1 | COLD | 1 | 1 | . | . | 2.00 | 2.00 | . | . | . | |
| DMR21A | SP-1 | COLD | 48 | 0 | 3.92 | 0.29 | 52.6 | 52.8 | 15.6 | 1.88 | 1.26 | |
| DMR21B | SP-2 | COLD | 48 | 0 | 3.85 | 0.29 | 49.1 | 49.1 | 14.4 | 1.87 | 1.26 | |
| DMR21C | SP-3 | COLD | 48 | 1 | 2.29 | 0.68 | 11.7 | 12.2 | 9.48 | 3.89 | 1.73 | |
| DMR25A | SP-1 | COLD | 48 | 0 | 3.45 | 0.48 | 34.7 | 35.3 | 18.1 | 2.74 | 1.47 | |
| DMR25B | SP-2 | COLD | 48 | 0 | 3.71 | 0.31 | 42.9 | 43.1 | 13.9 | 1.98 | 1.28 | |
| DMR28 | SP-1 | COLD | 48 | 0 | 2.62 | 0.65 | 16.6 | 17.0 | 12.4 | 3.70 | 1.68 | |
| DMR31 | SP-1 | COLD | 43 | 0 | 3.29 | 0.74 | 34.1 | 35.3 | 30.2 | 4.26 | 1.80 | |
| DMR32 | SP-1 | COLD | 1 | 0 | . | . | 12.0 | 12.0 | . | . | . | |
| DMR34 | SP-1 | COLD | 20 | 0 | 3.55 | 0.64 | 41.4 | 42.5 | 30.1 | 3.60 | 1.66 | |
| DMR37 | SP-1 | COLD | 48 | 0 | 3.13 | 0.33 | 24.2 | 24.2 | 8.26 | 2.05 | 1.30 | |
| DMR38 | SP-1 | COLD | 11 | 0 | 3.03 | 0.79 | 26.7 | 28.4 | 26.7 | 4.63 | 1.89 | |
| DMR49 | SP-1 | COLD | 20 | 0 | 2.88 | 0.52 | 20.1 | 20.4 | 11.5 | 2.95 | 1.52 | |
| DMR54A | SP-1 | COLD | 48 | 0 | 3.24 | 0.57 | 29.0 | 30.2 | 18.8 | 3.22 | 1.57 | |
| DMR54B | SP-2 | COLD | 49 | 0 | 3.77 | 0.60 | 50.0 | 52.0 | 34.1 | 3.36 | 1.61 | |
| DMR59 | SP-1 | COLD | 9 | 6 | 0.92 | 0.29 | 2.20 | 2.21 | 0.535 | 1.96 | 1.22 | |

Y in the Excluded column means that the data were not used for Listing 8-3

Listing 8-2: Episode Long-Term Averages (mg/L) and Variability Factors for TSS
(with 3-significant digits)

-- Subcategory=Flow-through -- Option=A -- Configuration=2A OLSB A --

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6460C | SP-9 | COLD | 1 | 0 | . | . | 38.0 | 38.0 | . | . | . | |
| 6495A | SP-11 | COLD | 5 | 1 | 1.97 | 0.14 | 6.60 | 6.61 | 1.58 | 1.48 | 1.21 | |

-- Subcategory=Flow-through -- Option=A -- Configuration=3A Raceway A --

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6460B | SP-7 | COLD | 5 | 5 | . | . | 4.00 | 4.00 | 0.0 | . | . | |

-- Subcategory=Flow-through -- Option=A -- Configuration=4A Combined A --

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6460A | SP7,SP9 | COLD | 5 | 4 | . | . | 9.54 | 9.54 | 12.4 | . | . | |
| DMR01 | SP-1 | COLD | 19 | 0 | 0.44 | 0.52 | 1.79 | 1.78 | 0.999 | 2.94 | 1.51 | Y |
| DMR03 | SP-1 | COLD | 37 | 0 | 1.25 | 0.34 | 3.69 | 3.70 | 1.31 | 2.09 | 1.31 | Y |
| DMR04 | SP-1 | COLD | 34 | 0 | 0.76 | 0.67 | 2.70 | 2.68 | 2.01 | 3.78 | 1.70 | Y |
| DMR61 | SP-1 | UNK | 12 | 0 | 1.30 | 0.87 | 1.50 | 5.35 | 5.69 | 5.18 | 2.01 | Y |

-- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B --

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6297A | SP8+9 | COLD | 5 | 0 | 4.04 | 0.22 | 57.8 | 58.1 | 13.0 | 1.63 | 1.19 | |
| 6297B | SP-11 | COLD | 5 | 0 | 4.24 | 0.13 | 69.6 | 69.7 | 8.96 | 1.34 | 1.11 | |
| 6297C | SP13+14 | COLD | 5 | 0 | 2.39 | 0.21 | 11.1 | 11.2 | 2.37 | 1.59 | 1.18 | |
| DMR06 | SP-1 | COLD | 12 | 1 | 2.52 | 1.04 | 18.0 | 19.8 | 29.0 | 6.83 | 2.37 | |
| DMR10 | SP-1 | COLD | 2 | 0 | . | . | 79.0 | 79.0 | 0.424 | . | . | |
| DMR12A | SP-1 | COLD | 49 | 3 | 2.27 | 0.86 | 12.9 | 13.3 | 14.6 | 5.31 | 2.04 | |
| DMR12B | SP-2 | COLD | 49 | 1 | 2.45 | 0.73 | 14.8 | 14.9 | 12.8 | 4.25 | 1.81 | |
| DMR15 | SP-1 | COLD | 43 | 0 | 2.33 | 0.84 | 14.1 | 14.6 | 14.8 | 4.96 | 1.96 | |
| DMR18 | SP-1 | COLD | 1 | 1 | . | . | 2.00 | 2.00 | . | . | . | |

Y in the Excluded column means that the data were not used for Listing 8-3

Listing 8-2: Episode Long-Term Averages (mg/L) and Variability Factors for TSS
(with 3-significant digits)

----------------------------------------- -- Subcategory=Flow-through -- Option=B -- Configuration=2B OLSB B -----------------------------------------
(continued)

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DMR21A | SP-1 | COLD | 48 | 0 | 3.92 | 0.29 | 52.6 | 52.8 | 15.6 | 1.88 | 1.26 | |
| DMR21B | SP-2 | COLD | 48 | 0 | 3.85 | 0.29 | 49.1 | 49.1 | 14.4 | 1.87 | 1.26 | |
| DMR21C | SP-3 | COLD | 48 | 1 | 2.29 | 0.68 | 11.7 | 12.2 | 9.48 | 3.89 | 1.73 | |
| DMR25A | SP-1 | COLD | 48 | 0 | 3.45 | 0.48 | 34.7 | 35.3 | 18.1 | 2.74 | 1.47 | |
| DMR25B | SP-2 | COLD | 48 | 0 | 3.71 | 0.31 | 42.9 | 43.1 | 13.9 | 1.98 | 1.28 | |
| DMR28 | SP-1 | COLD | 48 | 0 | 2.62 | 0.65 | 16.6 | 17.0 | 12.4 | 3.70 | 1.68 | |
| DMR31 | SP-1 | COLD | 43 | 0 | 3.29 | 0.74 | 34.1 | 35.3 | 30.2 | 4.26 | 1.80 | |
| DMR32 | SP-1 | COLD | 1 | 0 | . | . | 12.0 | 12.0 | . | . | . | |
| DMR34 | SP-1 | COLD | 20 | 0 | 3.55 | 0.64 | 41.4 | 42.5 | 30.1 | 3.60 | 1.66 | |
| DMR37 | SP-1 | COLD | 48 | 0 | 3.13 | 0.33 | 24.2 | 24.2 | 8.26 | 2.05 | 1.30 | |
| DMR38 | SP-1 | COLD | 11 | 0 | 3.03 | 0.79 | 26.7 | 28.4 | 26.7 | 4.63 | 1.89 | |
| DMR49 | SP-1 | COLD | 20 | 0 | 2.88 | 0.52 | 20.1 | 20.4 | 11.5 | 2.95 | 1.52 | |
| DMR54A | SP-1 | COLD | 48 | 0 | 3.24 | 0.57 | 29.0 | 30.2 | 18.8 | 3.22 | 1.57 | |
| DMR54B | SP-2 | COLD | 49 | 0 | 3.77 | 0.60 | 50.0 | 52.0 | 34.1 | 3.36 | 1.61 | |
| DMR59 | SP-1 | COLD | 9 | 6 | 0.92 | 0.29 | 2.20 | 2.21 | 0.535 | 1.96 | 1.22 | |

---------------------------------------- -- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ----------------------------------------

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6297E | SP5+6 | COLD | 5 | 5 | . | . | 4.00 | 4.00 | 0.0 | . | . | |
| 6297F | SP2+3 | COLD | 5 | 4 | . | . | 4.10 | 4.10 | 0.224 | . | . | |
| DMR05 | SP-1 | COLD | 3 | 3 | . | . | 2.00 | 2.00 | 0.0 | . | . | |
| DMR06 | SP-1 | COLD | 12 | 11 | . | . | 2.06 | 2.06 | 0.202 | . | . | |
| DMR07 | SP-1 | COLD | 2 | 1 | . | . | 2.50 | 2.50 | 0.707 | . | . | |
| DMR08 | SP-1 | COLD | 9 | 5 | 1.39 | 0.43 | 3.04 | 3.08 | 1.80 | 3.12 | 1.54 | |
| DMR09 | SP-1 | COLD | 1 | 1 | . | . | 2.00 | 2.00 | . | . | . | |
| DMR10 | SP-1 | COLD | 16 | 6 | 0.97 | 0.20 | 2.43 | 2.43 | 0.541 | 1.66 | 1.19 | |
| DMR12A | SP-1 | COLD | 49 | 43 | 0.84 | 0.12 | 2.04 | 2.04 | 0.147 | 1.34 | 1.08 | |
| DMR13 | SP-1 | COLD | 2 | 0 | . | . | 1.90 | 1.90 | 0.990 | . | . | |
| DMR15 | SP-1 | COLD | 39 | 17 | 1.17 | 0.40 | 2.85 | 2.84 | 1.32 | 2.64 | 1.42 | |
| DMR17 | SP-1 | COLD | 1 | 0 | . | . | 2.20 | 2.20 | . | . | . | |
| DMR18 | SP-1 | COLD | 11 | 7 | 1.42 | 0.59 | 2.98 | 3.06 | 2.39 | 4.22 | 1.74 | |
| DMR19 | SP-1 | COLD | 4 | 0 | -0.50 | 0.30 | 0.625 | 0.633 | 0.195 | 1.92 | 1.27 | |
| DMR20 | SP-1 | COLD | 4 | 1 | 1.32 | 0.43 | 3.23 | 3.33 | 2.08 | 2.90 | 1.57 | |
| DMR21A | SP-1 | COLD | 48 | 9 | 0.88 | 0.15 | 2.36 | 2.36 | 0.374 | 1.43 | 1.13 | |
| DMR23 | SP-1 | COLD | 9 | 7 | 0.85 | 0.09 | 2.08 | 2.08 | 0.179 | 1.31 | 1.08 | |

Y in the Excluded column means that the data were not used for Listing 8-3

Listing 8-2: Episode Long-Term Averages (mg/L) and Variability Factors for TSS
(with 3-significant digits)

--------------------------------------- -- Subcategory=Flow-through -- Option=B -- Configuration=3B Raceway B ---------------------------------------
(continued)

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DMR25A | SP-1 | COLD | 48 | 27 | 0.84 | 0.13 | 2.14 | 2.14 | 0.253 | 1.38 | 1.10 | |
| DMR26 | SP-1 | WARM | 11 | 0 | 1.92 | 0.24 | 6.99 | 7.01 | 1.73 | 1.71 | 1.21 | |
| DMR27 | SP-1 | COLD | 2 | 2 | . | . | 2.00 | 2.00 | 0.0 | . | . | |
| DMR28 | SP-1 | COLD | 44 | 27 | 0.91 | 0.19 | 2.21 | 2.21 | 0.396 | 1.62 | 1.16 | |
| DMR29 | SP-1 | WARM | 3 | 0 | 1.78 | 0.17 | 6.00 | 6.03 | 1.02 | 1.46 | 1.15 | |
| DMR30 | SP-1 | COLD | 2 | 0 | . | . | 7.50 | 7.50 | 0.707 | . | . | |
| DMR31 | SP-1 | COLD | 44 | 36 | 0.83 | 0.15 | 2.06 | 2.06 | 0.196 | 1.42 | 1.10 | |
| DMR32 | SP-1 | COLD | 1 | 1 | . | . | 1.00 | 1.00 | . | . | . | |
| DMR34 | SP-1 | COLD | 7 | 7 | . | . | 2.00 | 2.00 | 0.0 | . | . | |
| DMR35 | SP-1 | COLD | 2 | 1 | . | . | 2.10 | 2.10 | 0.141 | . | . | |
| DMR36 | SP-1 | COLD | 4 | 0 | 1.97 | 0.29 | 7.40 | 7.48 | 2.22 | 1.88 | 1.26 | |
| DMR37 | SP-1 | COLD | 48 | 11 | 0.85 | 0.13 | 2.28 | 2.28 | 0.319 | 1.38 | 1.12 | |
| DMR38 | SP-1 | COLD | 12 | 9 | 1.09 | 0.17 | 2.25 | 2.25 | 0.510 | 1.78 | 1.20 | |
| DMR39 | SP-1 | COLD | 4 | 4 | . | . | 2.00 | 2.00 | 0.0 | . | . | |
| DMR42 | SP-1 | COLD | 3 | 3 | . | . | 2.00 | 2.00 | 0.0 | . | . | |
| DMR43 | SP-1 | COLD | 2 | 0 | . | . | 5.10 | 5.10 | 2.83 | . | . | |
| DMR44 | SP-1 | COLD | 1 | 0 | . | . | 1.40 | 1.40 | . | . | . | |
| DMR46 | SP-1 | COLD | 4 | 3 | . | . | 1.40 | 1.40 | 0.490 | . | . | |
| DMR47 | SP-1 | COLD | 2 | 1 | . | . | 4.00 | 4.00 | 2.83 | . | . | |
| DMR48 | SP-1 | COLD | 12 | 7 | 1.32 | 0.43 | 2.85 | 2.88 | 1.60 | 3.07 | 1.51 | |
| DMR49 | SP-1 | COLD | 43 | 42 | . | . | 2.01 | 2.01 | 0.0610 | . | . | |
| DMR50 | SP-1 | COLD | 40 | 35 | 0.69 | 0.00 | 1.28 | 1.28 | 0.447 | 1.57 | 1.28 | |
| DMR51 | SP-1 | COLD | 7 | 7 | . | . | 2.00 | 2.00 | 0.0 | . | . | |
| DMR53 | SP-1 | COLD | 48 | 15 | 1.21 | 0.41 | 2.88 | 2.88 | 1.74 | 2.86 | 1.55 | |
| DMR54A | SP-1 | COLD | 48 | 41 | 0.78 | 0.08 | 2.03 | 2.03 | 0.0937 | 1.21 | 1.05 | |
| DMR57 | SP-1 | COLD | 4 | 0 | 0.66 | 0.33 | 2.00 | 2.03 | 0.679 | 2.02 | 1.30 | |
| DMR58 | SP-1 | COLD | 1 | 0 | . | . | 1.50 | 1.50 | . | . | . | |
| DMR59 | SP-1 | COLD | 8 | 8 | . | . | 2.00 | 2.00 | 0.0 | . | . | |
| DMR60 | SP-1 | COLD | 9 | 7 | 0.98 | 0.21 | 2.16 | 2.16 | 0.409 | 1.77 | 1.18 | |
| DMR62 | SP-1 | COLD | 4 | 3 | . | . | 2.05 | 2.05 | 0.100 | . | . | |

--------------------------------------- -- Subcategory=Flow-through -- Option=B -- Configuration=4B Combined B ---------------------------------------

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6297G | SP8+9,SP5+6 | COLD | 5 | 0 | 1.51 | 0.03 | 4.53 | 4.53 | 0.122 | 1.06 | 1.02 | |
| 6297H | SP11,SP5+6 | COLD | 5 | 5 | . | . | 4.65 | 4.65 | 0.0831 | . | . | |

Y in the Excluded column means that the data were not used for Listing 8-3

Listing 8-2: Episode Long-Term Averages (mg/L) and Variability Factors for TSS
(with 3-significant digits)

-------------------------------------- -- Subcategory=Flow-through -- Option=B -- Configuration=4B Combined B --------------------------------------
(continued)

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6297I | SP13+14,SP2+3 | COLD | 5 | 4 | . | . | 4.17 | 4.17 | 0.242 | . | . | |
| 6460D | SP10+11 | COLD | 5 | 5 | . | . | 4.00 | 4.00 | 0.0 | . | . | |
| 6495B | SP13+14 | COLD | 5 | 5 | . | . | 4.00 | 4.00 | 0.0 | . | . | |

-------------------------------------- -- Subcategory=Recirculating -- Option=A -- Configuration=6A RAS Solids A --------------------------------------

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6439A | SP-4 | WARM | 5 | 0 | 5.05 | 1.05 | 282.0 | 273.0 | 388.0 | 6.65 | 2.33 | Y |

-------------------------------------- -- Subcategory=Recirculating -- Option=B -- Configuration=6B RAS Solids B --------------------------------------

| Episode | Sample Point | Warm or Cold | # Obs | # NDs | mu | sigma | Obs Mean | Est. LTA | Est. STD | 1-Day V.F. | Monthly V.F. | Excluded |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6439B | SP9+11 | WARM | 5 | 0 | 3.81 | 0.29 | 46.6 | 47.1 | 13.8 | 1.87 | 1.26 | Y |

Y in the Excluded column means that the data were not used for Listing 8-3

Listing 8-3: Numeric Limitations for TSS (mg/L)
(with 3-significant digits)

| Subcategory | Option | Configuration | LTA | 1-Day V.F. | Monthly V.F. | Daily Limit | Monthly Limit |
|---|---|---|---|---|---|---|---|
| Combined | A | 2A+6A+7A Continuous A | 22.30 | 1.48 | 1.21 | 33.0 | 26.9 |
| Combined | B | 2B+6B+7B Continuous B | 26.30 | 3.24 | 1.57 | 85.1 | 41.2 |
| Flow-through | A | 2A OLSB A | 22.30 | 1.48 | 1.21 | 33.0 | 26.9 |
| Flow-through | A | 3A Raceway A | 4.00 | . | . | . | . |
| Flow-through | A | 4A Combined A | 9.54 | . | . | . | . |
| Flow-through | B | 2B OLSB B | 26.30 | 3.24 | 1.57 | 85.1 | 41.2 |
| Flow-through | B | 3B Raceway B | 2.10 | 1.99 | 1.27 | 4.17 | 2.67 |
| Flow-through | B | 4B Combined B | 4.17 | 1.06 | 1.02 | 4.44 | 4.26 |

Values are as calculated. See Chapter 8 for substitutions for Configuration 3B

# APPENDIX E:
# MODIFIED DELTA-LOGNORMAL DISTRIBUTION

# APPENDIX E:
# MODIFIED DELTA-LOGNORMAL DISTRIBUTION

This appendix describes the modified delta-lognormal distribution and the estimation of the episode long-term averages and variability factors used to calculate the limitations and standards.[1] This appendix provides the statistical methodology that was used to obtain the results presented in Chapter 8.

## E.1 BASIC OVERVIEW OF THE MODIFIED DELTA-LOGNORMAL DISTRIBUTION

EPA selected the modified delta-lognormal distribution to model pollutant effluent concentrations from the aquatic animals industry in developing the long-term averages and variability factors. A typical effluent data set from a sampling episode or self-monitoring episode (see Chapter 8 for a discussion of the data associated with these episodes) consists of a mixture of measured (detected) and non-detected values. The modified delta-lognormal distribution is appropriate for such data sets because it models the data as a mixture of measurements that follow a lognormal distribution and non-detect measurements that occur with a certain probability. The model also allows for the possibility that non-detect measurements occur at multiple sample-specific detection limits. Because the data appeared to fit the modified delta-lognormal model reasonably well, EPA has determined that this model is appropriate for these data.

The modified delta-lognormal distribution is a modification of the 'delta distribution' originally developed by Aitchison and Brown.[2] While this distribution was originally developed to model economic data, other researchers have shown the application to environmental data.[3] The resulting mixed distributional model, which combines a continuous density portion with a discrete-valued spike at zero, is also known as the delta-lognormal distribution. The delta in the name refers to the proportion of the overall distribution contained in the discrete distributional spike at zero; that is, the proportion of zero amounts. The remaining non-zero, non-censored (NC) amounts are grouped together and fit to a lognormal distribution.

EPA modified this delta-lognormal distribution to incorporate multiple detection limits. In the modification of the delta portion, the single spike located at zero is replaced by a discrete distribution made up of multiple spikes. Each spike in this modification is associated with a distinct sample-specific detection limit associated with non-detected (ND) measurements in the database.[4] A lognormal density is used to represent the set of

[1] In the remainder of this appendix, references to 'limitations' includes 'standards.'

[2] Aitchison, J. and Brown, J.A.C. (1963) The Lognormal Distribution. Cambridge University Press, pages 87-99.

[3] Owen, W.J. and T.A. DeRouen. 1980. "Estimation of the Mean for Lognormal Data Containing Zeroes and Left-Censored Values, with Applications to the Measurement of Worker Exposure to Air Contaminants." *Biometrics*, 36:707-719.

[4] Previously, EPA had modified the delta-lognormal model to account for non-detected measurements by placing the distributional "spike" at a single positive value, usually equal to the nominal method detection limit, rather than at zero. For further details, see Kahn and Rubin, 1989. This adaptation was used in

measured values. This modification of the delta-lognormal distribution is illustrated in Figure 1.

The following two subsections describe the delta and lognormal portions of the modified delta-lognormal distribution in further detail.

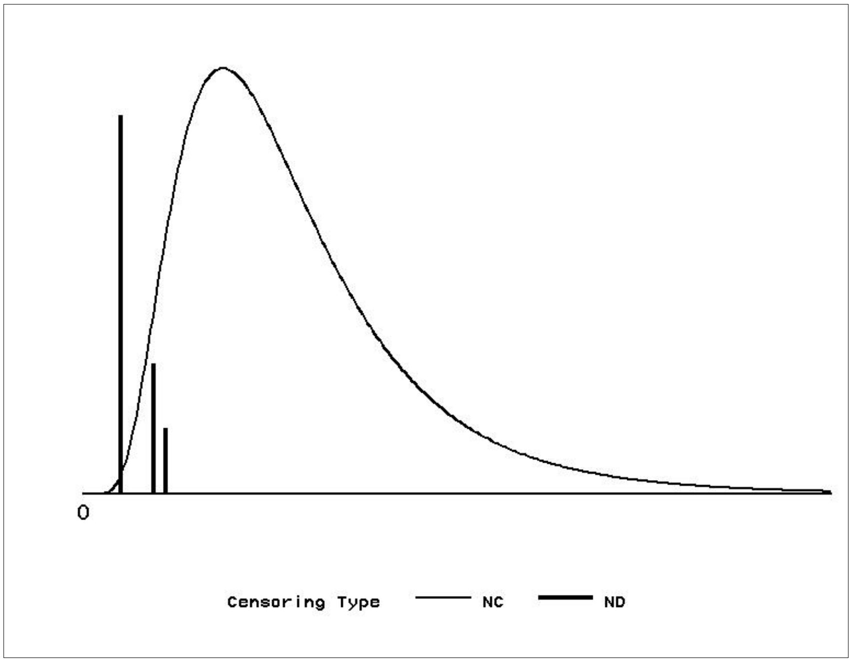


**Figure E-1. Modified Delta-Lognormal Distribution**

## E.2 Continuous and Discrete Portions of the Modified Delta-Lognormal Distribution

The discrete portion of the modified delta-lognormal distribution models the non-detected values corresponding to the k reported sample-specific detection limits. In the model, $\delta$ represents the proportion of non-detected values in the dataset and is the sum of smaller fractions, $\delta_i$, each representing the proportion of non-detected values associated with each distinct detection limit value. By letting $D_i$ equal the value of the $i^{th}$ smallest distinct detection limit in the data set and the random variable $X_D$ represents a randomly chosen non-detected measurement, the cumulative distribution function of the discrete portion of the modified delta-lognormal model can be mathematically expressed as:

$$\Pr\left(X_D \leq c\right) = \frac{1}{\delta} \sum_{i:D_i \leq c} \delta_i \qquad 0 < c \tag{E-1}$$

developing limitations and standards for the organic chemicals, plastics, and synthetic fibers (OCPSF) and pesticides manufacturing rulemakings. EPA has used the current modification in several, more recent, rulemakings.

The mean and variance of this discrete distribution can be calculated using the following formulas:

$$E(X_D) = \frac{1}{\delta} \sum_{i=1}^{k} \delta_i \, D_i \tag{E-2}$$

$$Var(X_D) = \frac{1}{\delta} \sum_{i=1}^{k} \delta_i \left(D_i - E(X_D)\right)^2 \tag{E-3}$$

The continuous, lognormal portion of the modified delta-lognormal distribution was used to model the detected measurements from the aquatic animals industry database. The cumulative probability distribution of the continuous portion of the modified delta-lognormal distribution can be mathematically expressed as:

$$\Pr\left[X_C \le c\right] = \Phi\left[\frac{\ln(c) - \mu}{\sigma}\right] \tag{E-4}$$

where the random variable $X_C$ represents a randomly chosen detected measurement, Φ is the standard normal distribution, and $\mu$ and $\sigma$ are parameters of the distribution.

The expected value, E($X_C$), and the variance, Var($X_C$), of the lognormal distribution can be calculated as:

$$E\left(X_C\right) = \exp\left(\mu + \frac{\sigma^2}{2}\right) \tag{E-5}$$

$$Var\left(X_C\right) = \left[E\left(X_C\right)\right]^2 \left(\exp\left(\sigma^2\right) - 1\right) \tag{E-6}$$

## E.3 Combining the Continuous and Discrete Portions

The continuous portion of the modified delta-lognormal distribution is combined with the discrete portion to model data sets that contain a mixture of non-detected and detected measurements. It is possible to fit a wide variety of observed effluent data sets to the modified delta-lognormal distribution. Multiple detection limits for non-detect measurements are incorporated, as are measured ("detected") values. The same basic framework can be used even if there are no non-detected values in the data set (in this case, it is the same as the lognormal distribution). Thus, the modified delta-lognormal distribution offers a large degree of flexibility in modeling effluent data.

The modified delta-lognormal random variable U can be expressed as a combination of three other independent variables, that is,

$$U = I_u X_D + (1 - I_u) X_C \qquad \text{(E-7)}$$

where $X_D$ represents a random non-detect from the discrete portion of the distribution, $X_C$ represents a random detected measurement from the continuous lognormal portion, and $I_u$ is an indicator variable signaling whether any particular random measurement, u, is non-detected or non-censored (that is, $I_u$=1 if u is non-detected; $I_u$=0 if u is non-censored). Using a weighted sum, the cumulative distribution function from the discrete portion of the distribution (equation 1) can be combined with the function from the continuous portion (equation 4) to obtain the overall cumulative probability distribution of the modified delta-lognormal distribution as follows,

$$\Pr(U \le c) = \sum_{i:D_i \le c} \delta_i + (1 - \delta)\,\Phi\left[\frac{\ln(c) - \mu}{\sigma}\right] \qquad \text{(E-8)}$$

where $D_i$ is the value of the $i^{th}$ sample-specific detection limit.The expected value of the random variable *U* can be derived as a weighted sum of the expected values of the discrete and continuous portions of the distribution (equations 2 and 5, respectively) as follows

$$E(U) = \delta E(X_D) + (1 - \delta) E(X_C) \qquad \text{(E-9)}$$

In a similar manner, the expected value of the random variable squared can be written as a weighted sum of the expected values of the squares of the discrete and continuous portions of the distribution as follows

$$E\left(U^2\right) = \delta E\left(X_D^2\right) + (1 - \delta) E\left(X_C^2\right) \qquad \text{(E-10)}$$

Although written in terms of U, the following relationship holds for all random variables, U, $X_D$, and $X_C$.

$$E\left(U^2\right) = Var(U) + [E(U)]^2 \qquad \text{(E-11)}$$

So using equation 11 to solve for Var(U), and applying the relationships in equations 9 and 10, the variance of *U* can be obtained as

$$\mathrm{Var}(U) = \delta\left(\mathrm{Var}(X_D) + [\mathrm{E}(X_D)]^2\right) + (1 - \delta)\left(\mathrm{Var}(X_C) + [\mathrm{E}(X_C)]^2\right) - [\mathrm{E}(U)]^2 \qquad \text{(E-12)}$$

## E.4 EPISODE ESTIMATES UNDER THE MODIFIED DELTA-LOGNORMAL DISTRIBUTION

In order to use the modified delta-lognormal model to calculate the limitations, the parameters of the distribution are estimated from the data. These estimates are then used to calculate the limitations.The parameters $\hat{\delta}_i$ and $\hat{\delta}$ are estimated from the data using the following formulas:

$$\hat{\delta}_i = \frac{1}{n}\sum_{j=1}^{n_d} I\left(d_j = D_i\right)$$
$$\hat{\delta} = \frac{n_d}{n} \qquad \text{(E-13)}$$

where $n_d$ is the number of non-detected measurements, $d_j$, $j = 1$ to $n_d$, are the detection limits for the non-detected measurements, $n$ is the number of measurements (both detected and non-detected) and I(…) is an indicator function equal to one if the phrase within the parentheses is true and zero otherwise. The "hat" over the parameters indicates that they are estimated from the data.

The expected value and the variance of the delta portion of the modified delta-lognormal distribution can be calculated from the data as:

$$\hat{E}\left(X_D\right) = \frac{1}{\hat{\delta}}\sum_{i=1}^{k} \hat{\delta}_i D_i \qquad \text{(E-14)}$$

$$\hat{V}ar\left(X_D\right) = \frac{1}{\hat{\delta}}\sum_{i=1}^{k} \hat{\delta}_i \left(D_i - \hat{E}\left(X_D\right)\right)^2 \qquad \text{(E-15)}$$

The parameters of the continuous portion of the modified delta-lognormal distribution, $\hat{\mu}$ and $\hat{\sigma}^2$, are estimated by

$$\hat{\mu} = \sum_{i=1}^{n_c} \frac{\ln\left(x_i\right)}{n_c}$$
$$\hat{\sigma}^2 = \sum_{i=1}^{n_c} \frac{\left(\ln\left(x_i\right) - \hat{\mu}\right)^2}{n_c - 1} \qquad \text{(E-16)}$$

where $x_i$ is the i^th detected measurement value and $n_c$ is the number of detected measurements. Note that $n = n_d + n_c$.

The expected value and the variance of the lognormal portion of the modified delta-lognormal distribution can be calculated from the data as:

$$\hat{E}\left(X_C\right) = \exp\left(\hat{\mu} + \frac{\hat{\sigma}^2}{2}\right) \quad \text{(E-17)}$$

$$\hat{V}ar\left(X_C\right) = \left[\hat{E}\left(X_C\right)\right]^2 \left(\exp\left(\hat{\sigma}^2\right) - 1\right) \quad \text{(E-18)}$$

Finally, the expected value and variance of the modified delta-lognormal distribution can be estimated using the following formulas:

$$\hat{E}\left(U\right) = \hat{\delta}\,\hat{E}\left(X_D\right) + \left(1 - \hat{\delta}\right)\hat{E}\left(X_C\right) \quad \text{(E-19)}$$

$$\hat{V}ar\left(U\right) = \hat{\delta}\left(\hat{V}ar\left(X_D\right) + \left[\hat{E}\left(X_D\right)\right]^2\right) + \left(1 - \hat{\delta}\right)\left(\hat{V}ar\left(X_C\right) + \left[\hat{E}\left(X_C\right)\right]^2\right) - \left[\hat{E}\left(U\right)\right]^2 \quad \text{(E-20)}$$

Equations 17 through 20 are particularly important in the estimation of episode long-term averages and variability factors as described in the following sections. These sections are preceded by a section that identifies the episode data set requirements.

Example:

Consider a facility that has 10 samples with the following concentrations:

| **Sample number** | **Measurement Type** | **Concentration (mg/L)** |
|---|---|---|
| 1 | ND | 10 |
| 2 | ND | 15 |
| 3 | ND | 15 |
| 4 | ND | 20 |
| 5 | NC | 25 |
| 6 | NC | 25 |
| 7 | NC | 30 |
| 8 | NC | 35 |
| 9 | NC | 35 |
| 10 | NC | 40 |

The ND components of the variance equation are:

$D_1 = 10, \hat{\delta}_1 = 1/10 D_2 = 15, \hat{\delta}_2 = 1/5 D_3 = 20, \hat{\delta}_3 = 1/10.$

Since $\hat{\delta}$ = 2/5, the expected value and the variance of the discrete portion of the modified delta-lognormal distribution are

$$\hat{E}\left(X_D\right) = \frac{1}{2/5}\left(\frac{1}{10}\times 10 + \frac{1}{5}\times 15 + \frac{1}{10}\times 20\right) = 15,$$

$$\hat{V}ar\left(X_D\right) = \frac{1}{2/5}\left(\frac{1}{10}\times(10-15)^2 + \frac{1}{5}\times(15-15)^2 + \frac{1}{10}\times(20-15)^2\right) = 12.5.$$

The mean and variance of the log NC values are calculated as

follows: $\hat{\mu} = \dfrac{\sum_{i=1}^{n_c}\ln\left(x_i\right)}{n_c} = \dfrac{\left(2\times\ln(25)+\ln(30)+2\times\ln(35)+\ln(40)\right)}{6} = 3.44$

$$\hat{\sigma}^2 = \frac{\sum_{i=1}^{n_c}\left(\ln\left(x_i\right)-\hat{\mu}\right)^2}{n_c-1} = \frac{\left(2\times\left(\ln(25)-3.44\right)^2\right)+\left(\ln(30)-3.44\right)^2+\left(2\times\left(\ln(35)-3.44\right)^2\right)+\left(\ln(40)-3.44\right)^2}{5} = 0.0376$$

Then, the expected value and the variance of the lognormal portion of the modified delta-lognormal distribution are

$$\hat{E}\left(X_C\right) = \exp\left(3.44+\frac{0.0376}{2}\right) = 31.779$$

$$\hat{V}ar\left(X_C\right) = [31.779]^2\left(\exp(0.0376)-1\right) = 38.695.$$

The expected value and variance of the modified delta-lognormal distribution are

$$\hat{E}(U) = \frac{2}{5}\times 15 + \left(1-\frac{2}{5}\right)\times 31.779 = 25.063$$

$$\hat{V}ar(U) = \frac{2}{5}\times\left(12.5+15^2\right)+\left(1-\frac{2}{5}\right)\times\left(38.695+31.779^2\right)-25.067^2 = 95.781.$$

### E.4.1 Episode Data Set Requirements

Estimates of the necessary parameters for the lognormal portion of the distribution can be calculated with as few as two distinct detected values in a data set. (In order to calculate the variance of the modified delta-lognormal distribution, two distinct detected values are the minimum number that can be used and still obtain an estimate of the variance for the distribution.)

If an episode data set for a pollutant contained three or more observations with two or more distinct detected concentration values, then EPA used the modified delta-lognormal distribution to calculate long-term averages and variability factors. If the episode data set for a pollutant did not meet these requirements, EPA used an arithmetic average to calculate the episode long-term average and excluded the dataset from the variability factor calculations (because the variability could not be calculated).

In statistical terms, each measurement was assumed to be independently and identically distributed from the other measurements of that pollutant in the episode data set.

The next two sections apply the modified delta-lognormal distribution to the data for estimating episode long-term averages and variability factors for the aquatic animals industry.

### E.4.2 Estimation of Episode Long-Term Averages

If an episode dataset for a pollutant mets the requirements described in the last section, then EPA calculated the long-term average using equation 19. Otherwise, EPA calculated the long-term average as the arithmetic average of the daily values where the sample-specific detection limit was used for each non-detected measurement.

### E.4.3 Estimation of Episode Variability Factors

For each episode, EPA estimated the daily variability factors by fitting a modified delta-lognormal distribution to the daily measurements for each pollutant. In contrast, EPA estimated monthly variability factors by fitting a modified delta-lognormal distribution to the monthly averages for the pollutant at the episode. EPA developed these averages using the same number of measurements as the assumed monitoring frequency for the pollutant. EPA is assuming that all pollutants will be monitored weekly (approximately four times a month).[5]

[5] Compliance with the monthly average limitations will be required in the final rulemaking regardless of the number of samples analyzed and averaged.

### *E.4.3.1 Estimation of Episode Daily Variability Factors*

The episode daily variability factor is a function of the expected value, and the 99th percentile of the modified delta-lognormal distribution fit to the daily concentration values of the pollutant in the wastewater from the episode. The expected value, was estimated using equation 19 (the expected value is the same as the episode long-term average).

The 99$^{th}$ percentile of the modified delta-lognormal distribution fit to each data set was estimated by using an iterative approach. First, the pollutant-specific detection limits were ordered from smallest to largest. Next, the cumulative distribution function, p, for each detection limit was computed. The general form, for a given value c, was:

$$p = \sum_{i:D_i \le c} \hat{\delta}_i + \left(1 - \hat{\delta}\right)\Phi\left[\frac{\ln(c) - \hat{\mu}}{\hat{\sigma}}\right] \qquad \text{(E-21)}$$

where Φ is the standard normal cumulative distribution function. Next, the interval containing the 99$^{th}$ percentile was identified. Finally, the 99$^{th}$ percentile of the modified delta-lognormal distribution was calculated. The following steps were completed to compute the estimated 99$^{th}$ percentile of each data subset:

Step 1 Using equation 21, k values of p at $c=D_m$, m=1,...,k were computed and labeled $p_m$.

Step 2 The smallest value of m (m=1,...,k), such that $p_m \ge 0.99$, was determined and labeled as $p_j$. If no such m existed, steps 3 and 4 were skipped and step 5 was computed instead.

Step 3 Computed $p^* = p_j - \hat{\delta}_j$ .

Step 4 If $p^* < 0.99$, then $\hat{P}99 = D_j$ else if $p^* \geq 0.99$, then

$$\hat{P}99 = \exp\left(\hat{\mu} + \hat{\sigma}\Phi^{-1}\left[\frac{0.99 - \sum_{i=1}^{j-1} \hat{\delta}_i}{1 - \hat{\delta}}\right]\right) \qquad \text{(E-22)}$$

where $\Phi^{-1}$ is the inverse normal distribution function.

Step 5 If no such m exists such that $p_m > 0.99$ (m=1,...,k), then

$$\hat{P}99 = \exp\left(\hat{\mu} + \hat{\sigma}\Phi^{-1}\left[\frac{0.99 - \hat{\delta}}{1 - \hat{\delta}}\right]\right) \qquad \text{(E-23)}$$

The episode daily variability factor, VF1, was then calculated as:

$$VF1 = \frac{\hat{P}99}{\hat{E}(U)} \qquad \text{(E-24)}$$

Example:

Since no such m exists such that $p_m > 0.99$ (m=1,...,k),

$$\hat{P}99 = \exp\left(3.44 + 0.194 \times \Phi^{-1}\left[\frac{0.99 - 0.4}{1 - 0.4}\right]\right) = 47.126.$$

The episode daily variability factor, VF1, was then calculated as:

$$VF1 = \frac{47.126}{25.067} = 1.880.$$

### *E.4.3.2 Estimation of Episode Monthly Variability Factors*

EPA estimated the monthly variability factors by fitting a modified delta-lognormal distribution to the monthly averages. These equations use the same basic parameters, μ and σ, calculated for the daily variability factors. Episode monthly variability factors were based on 4-day monthly averages because the monitoring frequency was assumed to be weekly (approximately four times a month).

Before estimating the episode monthly variability factors, EPA considered whether autocorrelation was likely to be present in the effluent data. When data are said to be positively autocorrelated, it means that measurements taken at specific time intervals (such as 1 day or 1 week apart) are related. For example, positive autocorrelation would be present in the data if the final effluent concentration of TSS was relatively high one day and was likely to remain at similar high values the next and possibly succeeding days. Because EPA is assuming that the pollutants will be monitored weekly, EPA based the monthly variability factors on the distribution of the averages of four measurements. If concentrations measured on consecutive weeks were positively correlated, then the autocorrelation would have had an effect on the estimate of the variance of the monthly average and thus on the monthly variability factor. Adjustments for positive autocorrelation would increase the values of the variance and monthly variability factor. (The estimate of the long-term average and the daily variability factor are generally only slightly affected by autocorrelation.)

EPA has not incorporated an autocorrelation adjustment into its estimates of the monthly variability factors. In some industries, measurements in final effluent are likely to be similar from one day (or week) to the next because of the consistency from day-to-day in the production processes and in final effluent discharges due to the hydraulic retention time of wastewater in basins, holding tanks, and other components of wastewater treatment systems. To determine if autocorrelation exists in the data, a statistical evaluation is necessary and will be considered before the final rule. To estimate autocorrelation in the data, many measurements for each pollutant would be required with values for equally spaced intervals over an extended period of time. If such data are available for the final rule, EPA intends to perform a statistical evaluation of autocorrelation and if necessary, provide any adjustments to the limitations.

Thus, in calculating the monthly variability factors for the proposal, EPA assumed that consecutive daily measurements were not correlated. In order to calculate the 4-day variability factors (VF4), EPA further assumed that the approximating distribution of $\overline{U}_4$, the sample mean for a random sample of four independent concentrations, was derived from the modified delta-lognormal distribution.[6] To obtain the expected value of the 4-day averages, equation 19 is modified for the mean of the distribution of 4-day averages in equation 25:

$$\hat{E}\left(\overline{U}_4\right) = \hat{\delta}_4' \, \hat{E}\left(\overline{X}_4\right)_D + \left(1 - \hat{\delta}_4'\right) \hat{E}\left(\overline{X}_4\right)_C \tag{25}$$

where $\hat{\delta}_4'$ denotes the probability of detection of the 4-day average, $\left(\overline{X}_4\right)_D$ denotes the mean of the discrete portion of the distribution of the average of four independent concentrations, (i.e., when all observations are non-detected values), and $\left(\overline{X}_4\right)_C$ denotes the mean of the continuous lognormal portion (i.e., when any observations are detected).

First, it was assumed that the probability of detection (δ) on each of the four days was independent of the measurements on the other three days (as explained in Section E.4.1, daily measurements were also assumed to be independent) and therefore, $\delta'_4 = \delta^4$. Because the measurements are assumed to be independent, the following relationships hold:

[6] As described in Section 8.4, when non-detected measurements are aggregated with non-censored measurements, EPA determined that the result should be considered non-censored.

$$\hat{E}\left(\overline{U}_4\right) = \hat{E}(U)$$
$$\hat{V}ar\left(\overline{U}_4\right) = \frac{\hat{V}ar(U)}{4}$$
$$\hat{E}\left(\left(\overline{X}_4\right)_D\right) = \hat{E}\left(X_D\right) \qquad \text{(E-26)}$$
$$\hat{V}ar\left(\left(\overline{X}_4\right)_D\right) = \frac{\hat{V}ar\left(X_D\right)}{4}$$

Substituting into equation 26 and solving for the expected value of the continuous portion of the distribution gives:

$$\hat{E}\left(\overline{X}_4\right)_C = \frac{\hat{E}(U) - \hat{\delta}^4\ \hat{E}\left(X_D\right)}{1 - \hat{\delta}^4} \qquad \text{(E-27)}$$

Using the relationship in equation 20 for the averages of 4 daily measurements and substituting terms from equation 25 and solving for the variance of the continuous portion of $\overline{U}_4$ gives:

$$\hat{V}ar\left(\overline{X}_4\right)_C = \frac{\frac{\hat{V}ar(U)}{4} + \left[\hat{E}(U)\right]^2 - \hat{\delta}^4\left(\frac{\hat{V}ar\left(X_D\right)}{4} + \left[\hat{E}\left(X_D\right)\right]^2\right)}{1 - \hat{\delta}^4} - \left[\hat{E}\left(\overline{X}_4\right)_C\right]^2 \qquad \text{(E-28)}$$

Using equations 17 and 18 and solving for the parameters of the lognormal distribution describing the distribution of $\left(\overline{X}_4\right)_C$ gives:

$$\hat{\sigma}_4^2 = \ln\left(\frac{\hat{V}ar\left(\overline{X}_4\right)_C}{\left(\hat{E}\left(\overline{X}_4\right)_C\right)^2} + 1\right)$$

and (E-29)

$$\hat{\mu}_4 = \ln\left(\hat{E}\left(\overline{X}_4\right)_C\right) - \frac{\hat{\sigma}_4^2}{2}$$

In finding the estimated 95$^{th}$ percentile of the average of four observations, four non-detects, not all at the same sample-specific detection limit, can generate an average that is not necessarily equal to $D_1$, $D_2$,..., or $D_k$. Consequently, more than k discrete points exist in the distribution of the 4-day averages. For example, the average of four non-detects at k=2 detection limits, are at the following discrete points with the associated probabilities:

| $i$ | $D_i^*$ | $\delta_i^*$ |
|---|---|---|
| 1 | $D_1$ | $\delta_1^4$ |
| 2 | $\left(3D_1 + D_2\right)/4$ | $4\delta_1^3\delta_2$ |
| 3 | $\left(2D_1 + 2D_2\right)/4$ | $6\delta_1^2\delta_2^2$ |
| 4 | $\left(D_1 + 3D_2\right)/4$ | $4\delta_1\delta_2^3$ |
| 5 | $D_2$ | $\delta_2^4$ |

When all four observations are non-detected values, and when k distinct non-detected values exist, the multinomial distribution can be used to determine associated probabilities. That is,

$$\Pr\left[\overline{U}_4 = \frac{\sum_{i=1}^{k} u_i D_i}{4}\right] = \frac{4!}{u_1!u_2!\ldots u_k!}\prod_{i=1}^{k}\delta_i^{u_i} \qquad \text{(E-30)}$$

where $u_i$ is the number of non-detected measurements in the data set with the $D_i$ detection limit. The maximum number of possible discrete points, $k^*$, for k=1,2,3,4, and 5 are as follows:

| k | k* | 1 | 1 |
|---|---|---|---|
| 2 | 5 | 3 | 15 |
| 4 | 35 | 5 | 70 |

To find the estimated 95th percentile of the distribution of the average of four observations, the same basic steps (described in Section E.4.3.1) as for the 99th percentile of the distribution of daily observations, were used with the following changes:

Step 1 Change $P_{99}$ to $P_{95}$, and 0.99 to 0.95.

Step 2 Change $D_m$ to $D_m^*$, the weighted averages of the sample-specific detection limits.

Step 3 Change $\delta_i$ to $\delta_i^*$.

Step 4 Change k to $k^*$, the number of possible discrete points based on k detection limits.

Step 5 Change the estimates of $\delta$, $\hat{\mu}$ ,and $\hat{\sigma}$ to estimates of $\delta^4$, $\hat{\mu}_4$ and $\hat{\sigma}_4^2$ respectively.

Then, using $\hat{E}\left(\overline{U}_4\right) = \hat{E}\left(U\right)$, the estimate of the episode 4-day variability factor, VF4, was calculated as:

$$VF4 = \frac{\hat{P}95}{\hat{E}\left(U\right)} \tag{E-31}$$

Example:

$$\hat{E}\left(\overline{U}_4\right) = 25.067$$

$$\hat{V}ar\left(\overline{U}_4\right) = \frac{95.781}{4} = 23.95$$

$$\hat{E}\left(\left(\overline{X}_4\right)_D\right) = 15$$

$$\hat{V}ar\left(\left(\overline{X}_4\right)_D\right) = \frac{12.5}{4} = 3.125$$

$$\hat{E}\left(\overline{X}_4\right)_C = \frac{25.067 - 0.4^4 \times 15}{1 - 0.4^4} = \frac{24.683}{0.974} = 25.331.$$

$$\hat{V}ar\left(\overline{X}_4\right)_C = \frac{23.95 + 25.067^2 - 0.4^4 \times \left(3.125 + 15^2\right)}{1 - 0.4^4} - 25.331^2 = 21.789$$

$$\hat{\sigma}_4^2 = \ln\left(\frac{21.789}{25.331^2} + 1\right) = 0.0334 \quad \hat{\delta}_4' = \hat{\delta}^4 = \left(\frac{2}{5}\right)^4 = 0.0256$$

$$\hat{\mu}_4 = \ln\left(25.331\right) - \frac{0.0334}{2} = 3.215.$$

$$\hat{P}95 = \exp\left(3.215 + 0.183 \times \Phi^{-1}\left[\frac{0.95 - 0.4^4}{1 - 0.4^4}\right]\right) = 33.683.$$

$$VF4 = \frac{33.683}{25.067} = 1.344.$$

### *E.4.3.3 Evaluation of Episode Variability Factors*

Estimates of the necessary parameters for the lognormal portion of the distribution can be calculated with as few as two distinct measured values in a data set (in order to calculate the variance); however, these estimates can be unstable (as can estimates from larger data sets). As stated in Section E.4.1, EPA used the modified delta-lognormal distribution to develop episode variability factors for data sets that had a three or more observations with two or more distinct measured concentration values.

To identify situations producing unexpected results, EPA reviewed all of the variability factors and compared daily to monthly variability factors. EPA used several criteria to determine if the episode daily and monthly variability factors should be included in calculating the option variability factors. One criteria that EPA used was that the daily and monthly variability factors should be greater than 1.0. A variability factor less than 1.0 would result in a unexpected result where the estimated 99$^{th}$ percentile would be less than the long-term average. This would be an indication that the estimate of $\hat{\sigma}$ (the log standard deviation) was unstable. A second criteria was that the daily variability factor had to be greater than the monthly variability factor. A third criteria was that not all of the sample-specific detection limits could exceed the values of the non-censored values. All the episode variability factors used for the limitations and standards met these criteria.

## E.5 REFERENCES

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