Merrimack Station
AR-1186

{DRAFT}

GUIDANCE

FOR EVALUATING THE

ADVERSE IMPACT OF COOLING WATER INTAKE STRUCTURES ON THE AQUATIC ENVIRONMENT:

SECTION 316(b) P.L. 92-500

U.S. Environmental Protection Agency
Office of Water Enforcement
Permits Division
Industrial Permits Branch
Washington, D.C.

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I. STATEMENT OF THE PROBLEM

The Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) require cooling water intake structures to reflect the best technology available for minimizing adverse environmental impact.

Cooling water intakes can adversely impact aquatic organisms basically in two ways. The first is entrainment, which is the taking in of organisms with the cooling water. The organisms involved are generally of small size, dependent on the screen mesh size, and include phyto- and zooplankton, fish eggs and larvae, shellfish larvae, and many other forms of aquatic life. As these entrained organisms pass through the plant they are subjected to numerous sources of damage. These include mechanical damage due to physically contacting internal surfaces of pumps, pipes and condensers; pressure damage due to passage through pumps; shear damage due to complex water flows; thermal damage due to elevated temperatures in condenser passage; and toxicity damage caused by the addition of biocides to prevent condenser fouling and other corrosives. Those organisms which survive plant passage potentially could experience delayed mortality when returned to the receiving water.

The second way in which intakes adversely impact aquatic life is through entrapment-impingement. This is the blocking of larger entrained organisms that enter the cooling water intake by some type of physical barrier. Most electric generating plants have screening equipment (usually 3/8" mesh} installed in the cooling water flow to protect downstream equipment such as pumps and condenser from damage or clogging. Larger organisms, such as fish which enter the system and cannot pass through the screens, are trapped ahead of them. Eventually, if a fish cannot escape or is not removed, it will tire and become impinged on the screens. If impingement continues for a long time period the fish may suffocate because the water current prevents gill covers from opening. If the fish is impinged for a short period and removed, it may survive; however, it may lose its protective slime and/or scales through contact with screen surfaces or from the high pressure water jets designed to remove debris from the screens. Delayed mortality to many species of fish following impingement may approach 100 percent. For some species of fish, the intake represents a double jeopardy situation where the same population will be subject to increased mortality through entrainment of eggs and larvae and additional mortality to juveniles and adults through impingement.

The data presently available on the magnitude of entrainment losses at existing electric generating stations, although just beginning to accumulate, reveals very large numbers of fish passing through some facilities. Results of one of these studies, conducted at the Detroit Edison plant on Lake Erie near Monroe, Michigan, indicate that 400-800 million fish larvae may have passed through that plant during April - August 1974. The fate of these larvae has not yet been determined, but the data from previous years indicate that some may have disintegrated during passage through the plant.

Other studies have shown that mortality may be high among fish larvae that pass through plant cooling systems[4, 38] due mainly to mechanical damage or shearing forces.[2,5] The circulating pump has been identified as the most likely site for mechanical damage.[4,5] Coutant and Kedl[39] in a simulation study have demonstrated that the condenser tubes are an unlikely site for mechanical damage to occur.

A large amount of data are available on the magnitude of entrapment-impingement losses at cooling water intakes. The data available on fish losses at Great Lakes cooling water intakes have been summarized by Edsall.[40] He reported the following losses:

> About 92,000 pounds of gizzard shad at the Ontario Hydro Lambton plant on the St. Clair River in 6 weeks during December 1971 - January 1972; 82,187 pounds (nearly 1.1 million individuals) at the Detroit Edison Company's plant on Lake Erie near Monroe, Michigan between April 1972 and March 1973, when the plant was operating at less than maximum capacity; 36,631 pounds (584,687 fish) at the Consumers Power Company's Palisades plant on Lake Michigan between July 1972 and June 1973, when the plant was operating at about 68 percent of its total capacity {the plant is now closed cycle); an estimated 1.2 million fish (no weight data given) at Commonwealth Edison's Waukegan (Illinois) plant on Lake Michigan between June 1972 and June 1973; 150,000 pounds of fish at the Ontario Hydro Pickering plant on Lake Ontario in April- June 1973; 659,000 fish (weight unavailable) at the Nine Mile Point plant generating unit number one on Lake Ontario during intermittent sampling from January - December 1973, representing an estimated total of about 5 million fish at unit one for that period; and about 67,950 pounds (929,000 fish) at Commonwealth Edison's Zion plant near Zion, Illinois, on Lake Michigan

during September - December 1973 and March - June 1974 when the monthly cooling water flow averaged only about 45 percent of the maximum capacity.

Approximately 14,000 fish of 44 species were impinged in 1974 at the Northern States Power Prairie Island Plant on the Mississippi River.[41] The Commonwealth Edison Company's Quad Cities Plant, also on the Mississippi River, impinged an estimated 1.8 million fish during 1974.[42]

The extent of fish losses of any given quantity needs to be considered on a plant-by-plant basis, in that the language of section 316(b) of P.L. 92-500 requires cooling water intakes to "minimize adverse environmental impact." Regulatory agencies should clearly recognize that some level of intake damage can be acceptable if that damage represents a minimization of environmental impact.

II. INTRODUCTION

This guidance manual describes the studies needed to evaluate the impact of cooling water intake structures on the aquatic environment and allow for determination of the best technology available for minimizing adverse environmental impacts The 1972 amendments to the Federal Water Pollution Control Act (P.L. 92-500) require in section 316(b) that:

> Any standard established pursuant to section 301 or section 306 of this Act and applicable to a point source shall require that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.

Sections 301 and 306 of the Act refer to the development of effluent limitations and dates for achievement of various standards of performance for existing and new sources of waste discharges. The steam-electric generating point source category is the largest user of cooling water in the United States and this guidance manual is directed primarily at this category. Other categories of point source dischargers such as iron and steel and petrochemicals for which intakes withdraw a major portion for cooling water would also require such a determination. This document is intended for use by the U.S. Environmental Protection Agency (EPA), State water pollution control agencies, industry, and members of the public who may wish to participate in such determinations.

The overall goal of conducting intake studies should be to obtain sufficient information on environmental impact to aid in determining whether the technology selected by the company is the best available to minimize adverse environmental impact. In the case of existing plants, this goal will be accomplished by providing reliable quantitative estimates of the damage that is or may be occurring and projecting the long-range effect of such damage to the extent reasonably possible. In the case of proposed intakes, reliable estimates of any future damage are to be obtained through the use of historical data, pre-operational models, and the operating experience of other plants.

General guidance is provided for the development, conduct, and review of surveys designed to determine and evaluate that portion of aquatic biota potentially involved with and subject to adverse environmental impact from cooling water intake structures. Guidance is also supplied for the analytical methodology needed to determine the extent and importance of aquatic environmental impacts. The environment-intake interactions in question are highly site specific and the decision as to best technology available for intake design, location, construction, and capacity must be made on a case-by-case basis.

Information is not provided on available intake technology. Such information is contained in the "Development Document for Best Technology Available for the Location, Design, Construction and Capacity of Cooing Water Intake Structures for Minimizing Adverse Environmental Impact," which also contains additional references on intake impacts. Information is also not provided on non-aquatic impacts of cooling water intake structures.

This document will be most useful in situations where siting and intake design have not been finalized; however, procedures to determine and evaluate the environmental impact of existing cooling water intakes are included.

Readers are cautioned not to depend too heavily on this manual. More specific advice as regards procedures and individual site evaluations will be available from the agency staff responsible for decision making and the biologists who best understand the area in question.

III. INFORMATION FLOW CHART

The development of 3l6(b) programs is a new procedure for many regulatory agencies and user groups. To assist in an orderly processing of data requirements for both existing and new cooling water intakes, flow charts have been developed (Figures 1, 2, and 3).

The process for evaluating existing intakes (Figure 1) is intended to be flexible so that the data requirements can be revised based on an agency determination of the potential for adverse impact and the availability of data on the plant's intake. It is expected that for some existing plants, sufficient data may already exist to make further studies unnecessary for a decision regarding best technology available. The process for new intakes (Figures 2 and 3) is more extensive because of requirements for data acquisition and models prior to site review and approval by the appropriate regulatory agency. Proper intake siting, in many cases, is the only way of minimizing adverse environmental impact. To obtain the necessary pre-siting perspective, the utilization of valid historical data and local knowledge is essential. A one- to three-year biological survey is required to obtain, in a preliminary fashion, the necessary data for assessment of environmental impact. A one-year survey is generally of limited value. However, in circumstances where substantial valid historical data can be presented and the intake can be represented as having low potential impact, a one-year survey may be acceptable. A decision as to the appropriate number of years of pre- operational data that are necessary will be made by the agency upon the submission of proposed study plans and their justification (see flow charts, Figures 2 and 3).

The type and extent of biological data appropriate in each case will be determined by the actual or anticipated severity or adverse environmental impact. Since the expected impact will vary, it is not expected that each case will require the same level of study.

A decision will be made at the outset by the agency as to whether the intake has high or low potential impact. Low potential impact intakes are generally those in which the volume of water withdrawn comprises a small percentage of the source water body segment and are located in biologically unproductive areas, or that have historical data showing no effect, or which have other considerations indicating reduced impact. High potential impact intakes will generally require extensive field surveys or models to elucidate potential total water body effects. New intakes will provisionally be considered high impact until data is presented in support of an alternate finding.

Figure 1. 316(b) FLOW CHART

EXISTING INTAKES

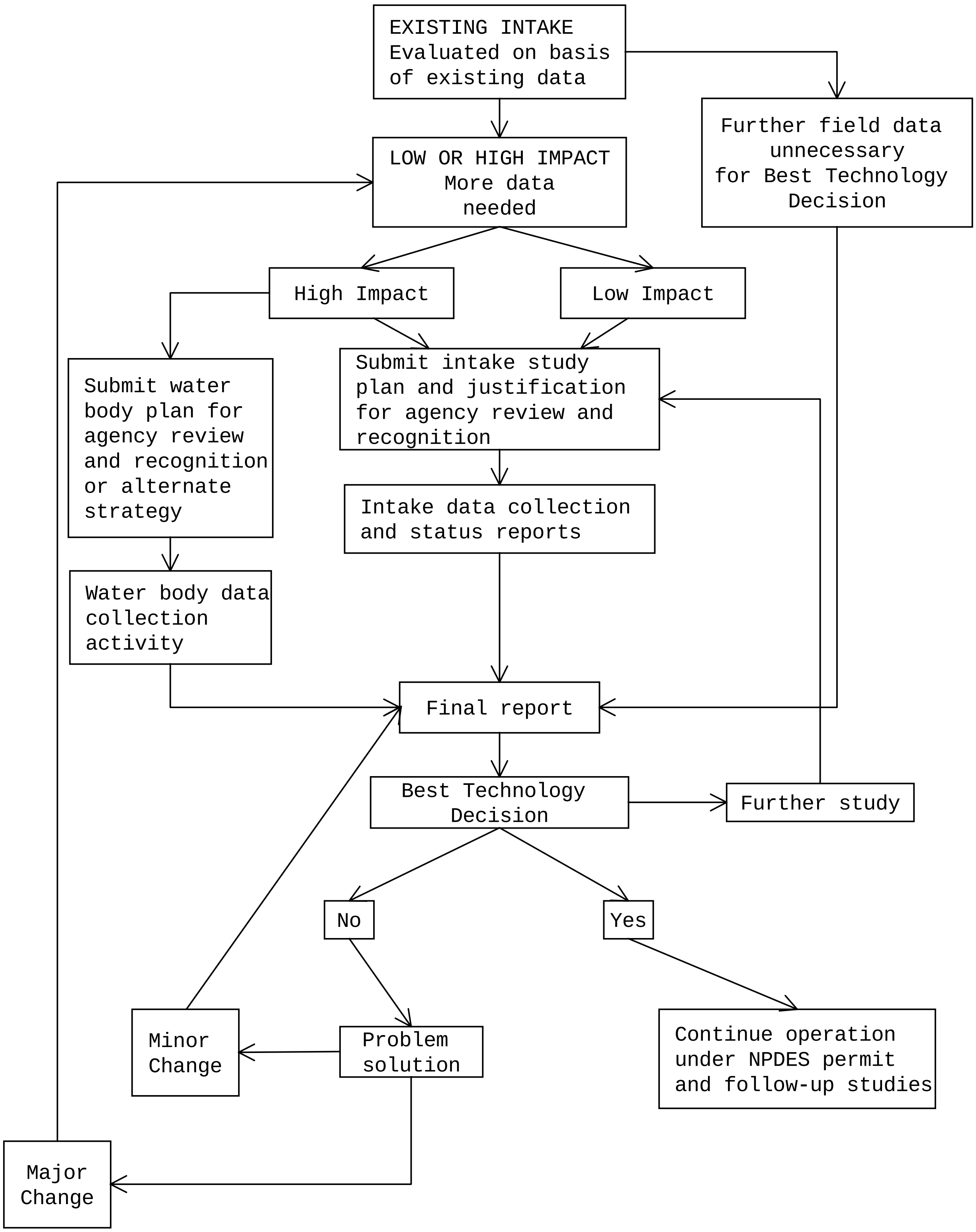


Figure 2. 316(b) FLOW CHART

NEW SOURCE INTAKES

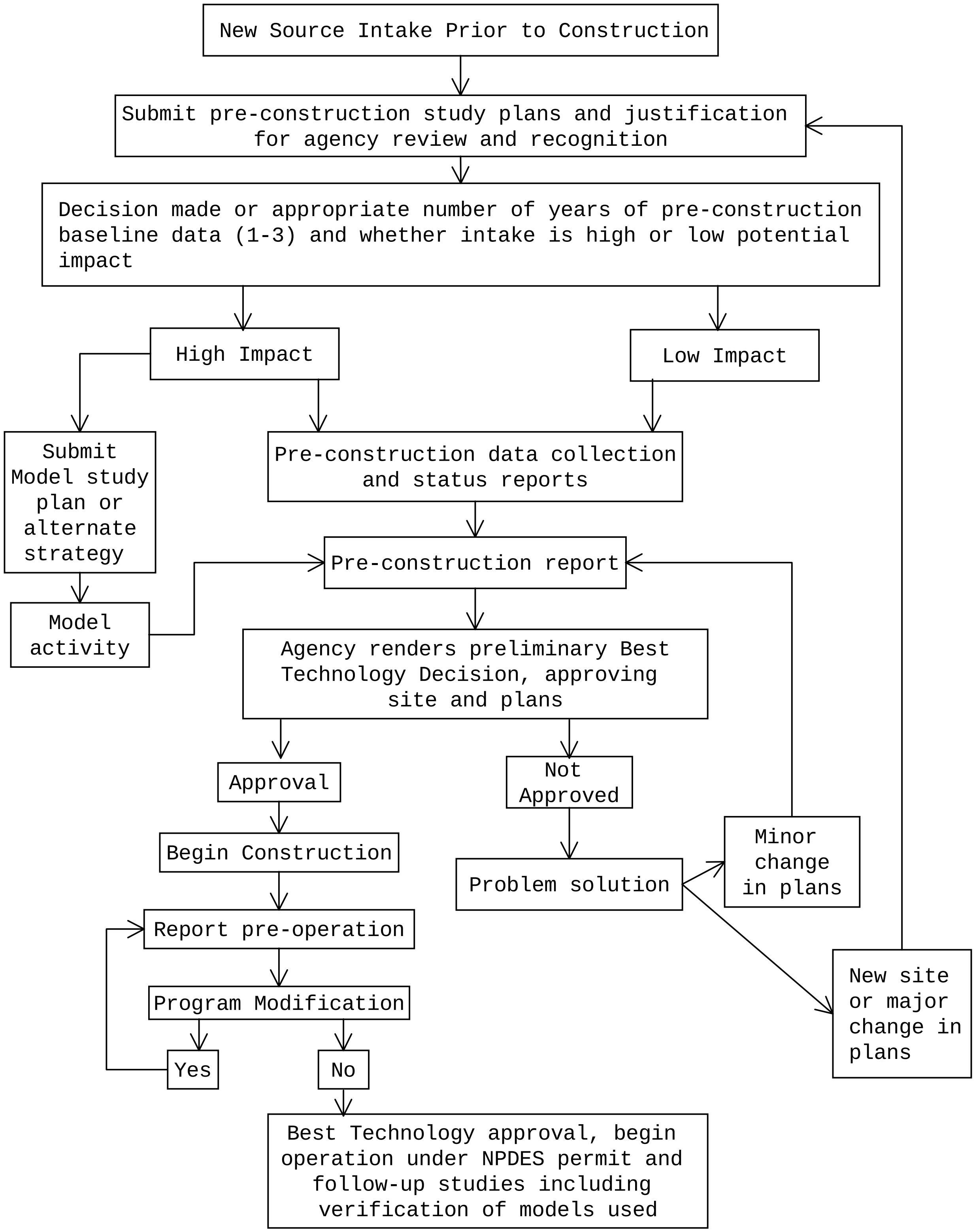
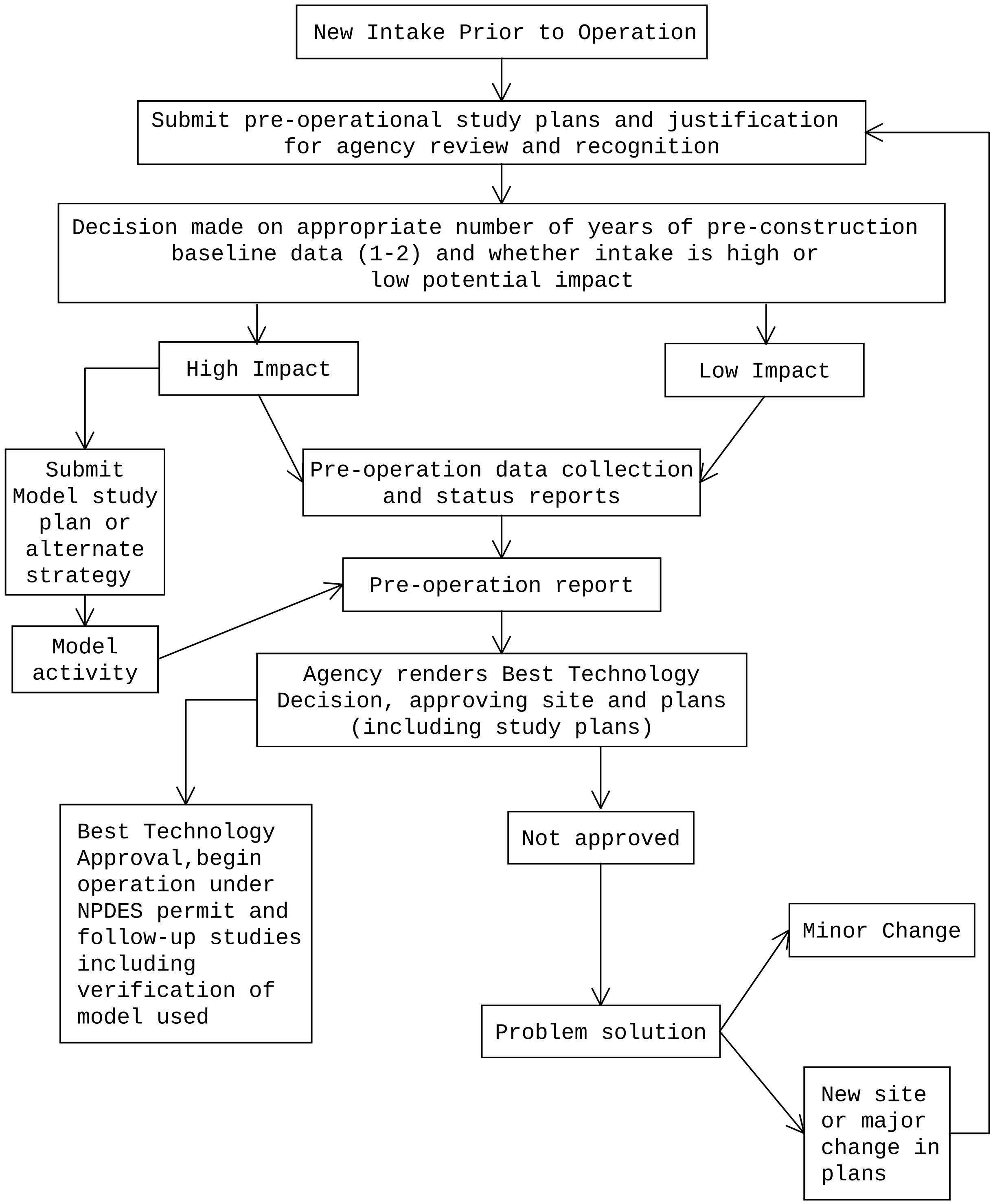


Figure 3. 316(b) FLOW CHART

NEW INTAKES (Not New Source)



The inclusion of several points in the flow chart for agency review and approval will ensure that all parties are in agreement as to the scope and specific details of work planned and will provide each party with a set of specific goals and schedules for completion. These review points should also ensure that studies address the important environmental and plant operational concerns of all parties, thereby resulting in timely and orderly completion. A further benefit from such review is that studies conducted throughout a water body segment can be coordinated so that methods utilized will result in a comparable data base. This uniform data base will allow for easier evaluation of any subsequent cumulative effect from all intakes operating on a water body.

IV. DECISION CRITERIA

Adverse aquatic environmental impacts occur whenever there will be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure. The critical question is the magnitude of any adverse impact. The exact point at which adverse aquatic impact occurs at any given plant site or water body segment is highly speculative and can only be estimated on a case-by-case basis by considering the species involved, magnitude of the losses, years of intake operation remaining, ability to reduce losses, etc. The best guidance that can be provided to agencies in this regard would be to involve professional resource people in the decision-making process and to obtain the best possible quantitative data base and assessment tools for evaluation of such impacts. The Development Document for 316(b)[47] is an essential reference for guidance in these evaluations.

Some general guidance concerning the extent of adverse impacts can be obtained by assessing the relative biological value of the source water body zone of influence for selected species and determining the potential for damage by the intake structure. For a given species, the value of an area is based on the following considerations:

1. principal spawning (breeding) ground;
2. migratory pathways;
3. nursery or feeding areas;
4. numbers of individuals present; and
5. other functions critical during the life history

A once-through system for a power plant utilizes substantially more water from the source water body than a closed recirculating system for a similar plant and thus would tend to have a higher potential impact. A biological value-potential impact decision matrix for best intake technology available could be:

BIOLOGICAL VALUE	COOLING WATER FLOW (Relative to Source Water Body Segment) HIGH	LOW
High	No	Questionable
Low	Questionable	Yes

(1) An open system large volume intake in an area of high biological value does not represent best technology available to minimize adverse environmental impact and will generally result in disapproval.

Exceptions to this may be demonstrated on a case-by-case basis where, despite high biological value and high cooling water flow, involvement of the biota is low or survival of those involved is high, and subsequent reduction of populations is minimal.

(2) Generally, the combination of low value and low flow most likely is a reflection of best technology available in location, design, and operation of the intake structure. Exceptions to this could involve significantly affected rare and endangered species.

(3) Other combinations of relative value-impact present the most difficult problems. In such circumstances, the biological survey and data analysis requires the greatest care and insight in accomplishing the impact evaluation upon which the judgement of best technology available is based. A case-by-case study is required and local knowledge and informed judgement are essential.

It is accepted that closed cycle cooling is not necessarily the best technology available, despite the dramatic reduction in rates of water used. The appropriate technology is best determined after a careful evaluation of the specific aspects at each site. A detailed discussion of available intake technology is contained in the 316(b) Development Document.[47]

Biological survey requirements suggested in this manual should provide a sufficient data base to provide insight as to the best location, design, construction, and capacity characteristics appropriate for achieving minimal total impact.

A stepwise thought process[47] is recommended for cases where adverse environmental impact from entrapment/impingement is occurring and must be minimized by application of best technology available:

> The first step should be to consider whether the adverse impact will be minimized by the modification of the existing screening systems.
>
> The second step should be to consider whether the adverse impact will be minimized by increasing the size of the intake to decrease high approach velocities.
>
> The third step should be to consider whether to abandon the existing intake and to replace it with a new intake at a different location and to incorporate an appropriate design in order to minimize adverse environmental impact.
>
> Finally, If the above technologies would not minimize adverse environmental impact, consideration should be given to the reduction of intake capacity which may necessitate installation of a closed cycle cooling system with appropriate design modifications as necessary.

Where environmental impact from entrainment must be minimized reliance must be placed primarily on flow reduction and intake relocation as remedial measures:

> Reducing cooling water flow is generally an effective means for minimizing potential entrainment impact. In fact, this may be the only feasible means to reduce impact of entrainment where potentially involved organisms are in relatively large concentration and uniformly distributed in the water column. Entrapment and impingement may also be lessened with lower flow as proportionally fewer animals will be subject to contact with the intake structure; water velocities associated with the structure can be reduced, enhancing probability of survival if impinged or of escape if trapped. Reduction of flow is accomplished primarily by an increase in condenser temperature rise or through recirculating cooling systems. When cooling water flow is reduced, however, elevated temperature or the effects of an auxiliary cooling system can increase the mortality rate of the organisms that are entrained.

Site location measures may prove effective in areas of discontinuous, temporal, or spatial occurrence {patchiness) of those species subject to entrainment (or entrapment/impingement).

Enhancing survival of organisms once entrained in the cooling water system generally appears to be the least effective means for avoiding adverse impact; however, operational regimes have been developed to decrease mortality of entrained species where heat, chlorine or both exert the predominant impact. Realistic laboratory studies can lead to optimal time-temperature regimes for survival. The effects of biocides can be reduced by intermittent and "split-stream" chlorination procedures. Mechanical methods for cleaning cooling system components where feasible can eliminate or reduce the need for biocides. The mechanical stress of entrainment is, in many cases, the critical factor in organism survival with the pump the site of major damage. At present, little can be done to minimize mechanical impact although potentially harmful effects may possibly be reduced by pump redesign which incorporates low RPM, low pressure and wide clearance characteristics. Reducing velocity changes, pressure, and turbulence in the piping system should prove helpful. Entrainment screening techniques such as leaky dams may have application in some circumstances. Regardless of beneficial measures taken, many fragile forms will not survive entrainment.

In summary, the location of a power plant or other cooling water use, coupled with the associated intake structure design, construction, and capacity results in a unique situation. While generalities may be useful, the optimal combination of measures effectively minimizing adverse impact on the biota is site and plant specific. The best technology available should be established on a case-by-case basis making full use of the kinds of information suggested for acquisition in this manual.

V. DEFINITIONS AND CONCEPTS

Adverse Environmental Impact

Adverse aquatic environmental impacts occur whenever there will be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure. The critical question is the magnitude of any adverse impact.

The magnitude of an adverse impact should be estimated both in terms of short term and long term impact with reference to the following factors:

(1) Absolute damage (# of fish impinged or percentage of larvae entrained on a monthly or yearly basis);

(2) Percentage damage (% of fish or larvae in existing populations which will be impinged or entrained, respectively);

(3) Absolute and percentage damage to any endangered species;

(4) Absolute and percentage damage to any critical aquatic organism;

(5) Absolute and percentage damage to commercially valuable and/or sport fisheries yield; or

(6) Whether the impact would endanger (jeopardize) the protection and propagation of a balanced population of shellfish and fish in and on the body of water from which the cooling water is withdrawn (long term impact).

Agency

This term refers to the Regional Administrator of the U.S. Environmental Protection Agency or the Directors of those State agencies authorized to issue NPDES permits.

Community

A community in general is any assemblage of populations living in a prescribed area or physical habitat; it is an organized unit to the extent that it has characteristics in addition to its individual and population components and functions as a unit through interacting metabolic transformations.

Critical Aquatic Organisms

Adverse environmental impact may be felt by many species in all trophic levels. A species need not be directly affected but nevertheless harmed due to loss of food organisms or other associated organisms in some way necessary for the well-being and continued survival of the population. It is not practicable to study all species that may be directly or indirectly harmed by intake structure operations.

The critical aquatic organisms concept is defined in the 316(b) Development Document.[47] Generally, 5 to 15 critical aquatic organisms will be selected for consideration on a case-by-case basis. Relative to environmental impact associated with intake structures, effects on meroplankton organisms, macroinvertebrates, and juvenile and adult fishes appear to be the first order problem. Accordingly, the selections of species should include a relatively large proportion of organisms in these categories that are directly impacted. Generally, because of short life span and population regeneration capacity, the adverse impact on phytoplankton and zooplankton species is less severe. It is suggested that, in addition to study of the selected species, the total phytoplankton and zooplankton communities be assessed to determine if the area under study is unique and important qualitatively or quantitatively. If preliminary sampling or prior data does not support special or unique value of these organisms at the site, phytoplankton and zooplankton species will generally not be selected.

The following guidelines are presented for selection of critical aquatic organisms for consideration in intake studies:

A. Critical aquatic organisms to be selected are those species which would be involved with the intake structure and are:

1. representative, in terms of their biological requirements, of a balanced, indigenous community of fish, shellfish, and wildlife;

2. commercially or recreationally valuable (e.g., among the top ten species landed -- by dollar value);

3. threatened or endangered;

4. critical to the structure and function of the ecological system (e.g., habitat formers);

5. Potentially capable of becoming localized nuisance species;

6. necessary, in the food chain, for the well-being of species determined in 1-4;

7. one of 1-6 and have high potential susceptibility to entrapment-impingement and/or entrainment; and

8. critical aquatic organisms based on 1-7, are suggested by the applicant, and are approved by the appropriate regulatory agencies.

B. Assumptions in the selection of critical aquatic organisms:

1. Since all species which are critical, representative, etc., cannot be studied in detail, some smaller number {e.g., 5 to 15) may have to be selected.

2. The species of concern are those most likely to be affected by intake structure, design, construction and operation.

3. Some species will be economically important in their own right, e.g., commercial and sport fishes.

4. Some of the species selected will be particularly vulnerable or sensitive to intake structure impacts or have sensitivities of most other species and, if protected, will reasonably assure protection of other species at the site.

5. Often, but not always, the most useful list would include mostly sensitive fish, shellfish, or other species of direct use to man, or to the structure or functioning of the ecosystem.

6. Officially listed "threatened or endangered species" are automatically considered "critical."

7. The species chosen may or may not be the same as those appropriate for a 316(a) determination dependent on the relative effects of the thermal discharge or the intake in question.

Cooling Water Intake Structure

The cooling water intake structure is the total structure used to direct water into the components of the cooling systems wherein the cooling function is designated to take place, provided that the intended use of the major portion of the water so directed is to absorb waste heat rejected from the process or processes employed or from auxiliary operations on the premises, including air conditioning.

Entrainment

The incorporation of organism into the cooling water flow is entrainment. There are two generally recognized types of entrainment: pumped entrainment --referring to those organisms that enter the intake and are pumped through the condenser, and plume entrainment -- referring to organisms that are incorporated into the discharge plume by the dilution water. Plume entrainment is not covered by section 316(b) but is part of the thermal discharge effect to be considered in conjunction with thermal effect demonstrations under section 316(a).

Entrapment-Impingement

The physical blocking of larger organisms by a barrier, generally some type of screen system in the cooling water intake. Entrapment emphasizes the prevention of escape of organisms and impingement emphasizes the collision of an organism with a portion of the structure.

Estuary

An estuary is defined as a semi-enclosed coastal body of water which has a free connection with the open sea; it is thus strongly affected by tidal action and within it sea water is mixed {and usually measurably diluted) with fresh water from land drainage. It may be difficult to precisely delineate the boundary of estuarine and river habitats in the upper reaches of a fresh water river discharging into marine waters. The interface is generally a dynamic entity varying daily and seasonally in geographical location. In such cases, determination of habitat boundaries should be established by mutual agreement on a case-by-case basis. Where boundary determination is not clearly established, both estuary and river habitat biological survey requirements should be satisfied in a combined determination for environmental effects and best available technology for minimizing adverse impact.

Habitat Formers

Habitat formers are plants and/or animals characterized by a relatively sessile life state with aggregated distribution and functioning as:

1. a live and/or formerly living substrate for the attachment of epibiota;

2. either a direct or indirect food source for the production of shellfish, fish, and wildlife;

3. a biological mechanism for the stabilization and modification of sediments and contributing to processes of soil buildings;

4. a nutrient cycling path or trap; or

5. specific sites for spawning, and providing nursery, feeding, and cover areas for fish and shellfish.

High Potential Impact Intakes

High potential impact intakes are those located in biologically productive areas or where the volume of water withdrawn comprises a large proportion of the source water body segment or for which historical data or other considerations indicate a broad impact.

Impingement

See Entrapment-Impingement.

Lake

Any naturally occurring large volume of standing water occupying a distinct basin and, for purposes of this document, reservoirs and impoundments.

Low Potential Impact Intakes

Low potential impact intakes are those located in biologically unproductive areas and having low flow or having historical data showing no effect or for which other considerations indicate low impact. Plants with low capacity factors or with few remaining years of lifetime might be considered "low impact" despite their historical impact.

Macroinvertebrates

For the purposes of this document, the term macroinvertebrates may be considered synonymous with "aquatic macroinvertebrates" and are those invertebrates that are large enough to be seen by the unaided eye and can be retained by a U.S. Standard No. 30 sieve (0.595 mm. mesh opening).

Meroplankton

For the purposes of this document, meroplankton are defined as planktonic life stages (often eggs or larvae) of fish or invertebrates.

Oceans

The ocean habitat, for the purposes of this manual, is considered marine waters other than those water bodies classified as estuaries. This includes open coastal areas, embayments, fjords, and other semi-enclosed bodies of water open "to the sea and not measurably diluted with fresh water' from land drainage.

Two principal zones within the oceanic habitat potentially impacted are: (1) littoral zone --from high tide level to low tide level, and (2) neritic zone (near shore) --low tide level to the edge of the continental shelf.

Phytoplankton

Phytoplankton are the free-floating plants, usually microscopic algae, that photosynthetically fix inorganic carbon and are, therefore, primary producers in some aquatic environments.

Plankton

Plankton are essentially microscopic organisms, plant or animal, suspended in water which exhibit near neutral buoyancy. Because of their physical characteristics or size, most plankton organisms are incapable of sustained mobility in directions against water flow. Consequently, plankton drift more or less passively in prevailing currents.

Population

A population is generally considered to be comprised of individuals of the same species in a geographic area. Populations exhibit parameters such as mortality, natality, fecundity, intrinsic rate of increase, density, etc.

Primary Study Area

This includes the segment of the water body determined to be the area of potential damage. This concept is most pertinent to organisms subject to inner-plant passage, normally weakly motile or planktonic, and spatially subject to water body currents rather than possessing the ability to change location independent of water mass movements. Animals capable of large scale movements, i.e., migrant fishes, will move into this area periodically.

Rivers and Streams

A river or stream is a naturally occurring body of running (surface) water, with an unbroken, unidirectional flow, contained within a discrete channel. Reservoirs and/or impoundments, for the purposes of this document, will generally be viewed as lakes.

Secondary Study Area

The area within the water body segment outside the primary study area. Biota in this area directly affected by the intake structure may or may not be a significant component of the total population of indigenous species. For many species, particularly pelagic fishes, the total population may be spread over a wide geographical area. This area could be considered the secondary study area. However, other intake structures associated with cooling water uses, e.g., power plants, may also be impacting the population in these other areas. This may be considered in two ways:

1. consider the total population throughout the geographical range, estimate existing impacts, and determine to what extent the specific intake structure adversely impacts that portion of the population not already adversely stressed by sources outside the primary study area; or

2. consider only the population in the area of potential involvement and adjacent areas of occurrence not already impacted by an existing source of stress.

For example, when a number of intake structures are located within a water body such as the Hudson River, Ohio River, Long Island Sound, Western Basin of Lake Erie, Narragansett Bay, San Francisco Bay, etc., either of the two approaches may be taken to assess the impact of the structure under consideration. The total impact of all existing stresses may be weighed against the total population of biota studies and the adverse effects of the new stress added to existing stresses and assessed against impact to the total system. The alternative is to assign a section of the water body not already impacted by other intake structures and compare the segment of the community in the assigned area to the effect of the single structure concerned.

Threatened or Endangered Species

A threatened or endangered species 18 any plant or animal that has been determined by the Secretary of Commerce or the Secretary of the Interior to b. a threatened or endangered species pursuant to the Endangered Species Act of 1973, as amended.

Water Body Segment

A water body segment is a portion of a basin, the surface waters of which have common hydraulic characteristics (or flow regulation patterns) common natural physical, chemical, and biological processes, and which have common reactions to external stress, e.g., discharge of pollutants. Where they have been defined, the water body segments determined by the State Continuing Planning Process under section 303(e) of P.L. 92-500 apply.

Zone of Potential Involvement

The zone of potential involvement 1s considered the water mass surrounding the intake structure and likely to be drawn into the structure itself or into the associated cooling water system. This varies with time and is dependent on ambient water movements in the affected body of source water as modified by the influx of cooling water at the intake structure. It will be difficult to precisely define the limits of this zone of influence because of temporal and spatial variables. The zone of potential involvement always includes the primary study area and may include the secondary study area.

Zooplankton

True zooplankton are free-floating animals which have little or no ability for horizontal movement. They are thus carried passively along with natural currents in the water body.

VI. STUDY FORMAT

The studies submitted as support for a finding that the cooling water intake represents best technology available for a minimization of adverse environmental impact should be in the following format to facilitate agency review. At least two copies should be submitted.

1. Title page (plant name, water body, company, permit information, rate).

2. Table of contents.

3. An executive summary of 2-3 paragraphs (essence of material and conclusions).

4. Detailed presentation of methods used in data collection, analysis and/or interpretation when different from standard references.

5. Supportive reports, documents, and raw data. Data from the open literature need not be included so long as it is readily available.

6. Bibliographic citations to page number of cited text.

7. An interpretive, comprehensive narrative summary of the studies which will serve, in part, as the basis for the agency's decision. The summary should include a table of contents and may include table figures. Sources of data used in the summary should be cited to page number. The summary should include a clear discussion stating why the report shows (or does not show) that the water intake structure in question minimizes impact on the water resources and aquatic biota in the vicinity of the intake and throughout the water body segment.

8. An appendix listing the agencies and consultants conducting this or related work on the water body.

9. Reports generated in response to section 316(b) should be recorded and forwarded to the National Technical Information Service (NTIS) for recording and announcement. The folder, NTIS-PR-184, available from NTIS, U.S. Department of Commerce. Springfield, Virginia 22161 explains the procedure in detail.

It is the intention of the EPA to make the technical information submitted by industries is accordance with 3l6(b) available for use by other industries, scientists, and members of the public. This will be done initially by placing copies in the responsible EPA Regional Office library. A similar approach is also suggested for State agencies. In cases were demand for the demonstration materials exceeds the capability of an EPA or State agency library, the EPA Regional Administrator may also submit the materials to the NTIS so that the reports are available to the public in microfiche or hard copy form at the price of duplication. In the meantime, EPA is developing lists of plants with completed 3l6(b) demonstrations and will submit the plant name and an abstract of each study to NTIS.

It is also noted that the Atomic Industrial Forum has developed INFORUM, a data system which will extract and index information from reports submitted by utilities in accordance with sections 316(a) and (b). Questions should be referred to INFORUM at 1747 Pennsylvania Avenue, Washington D.C. 20006, telephone 202-833-9234.

VII. DETAILED STUDY REFERENCES

This document, of necessity, is generalized to provide an overall framework of guidance and conceptual approach. Six references are recommended which treat various aspects of the study requirements in more specific detail:

1. U.S. Environmental Protection Agency, Office of water & Hazardous Materials, Water Planning Division, September 30, 1974, Draft, 316(a) Technical Guidance on Thermal Discharges. (Revised draft to be published in 1976.)

2. U.S. Environmental Protection Agency. Office of Water & Hazardous Materials. Effluent Guidelines Division. April 1976 Development Document for Best Technology Available for the Location, Design, Construction, and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact.

3. Batelle Laboratories t Inc. t Environmental Impact Monitoring of Nuclear Power Plants -Source Book. Atomic Industrial Forum, Inc. August 1974. 810 p.

4. Aquatic Ecological Surveys. American Nuclear Society, F.W. Hinsdale, Illinois, Draft, October 1974.

5. <u>Entrainment:</u> Guide to steam electric power plant cooling system siting, design and operation for controlling damage to aquatic organisms. Amer. Nuc. Std. Publ. N18. -1974. Draft, July 1, 1974, 44 p. and appendices.

6. <u>Entrainment/Impingement:</u> Guide to steam electric power plant cooling system siting, design and operation for controlling damage to aquatic organisms at water intake structures. Amer. Nuc. Std. Publ. N18 -1974. Draft, September, 1974. 24 p. and appendix.

VIII. SITE DESCRIPTION

The following information is generally needed to fully describe the potential experiences of organisms which may be entrapped within intake structures, impinged on parts of the structure and/or entrained in the water mass taken in and circulated through the associated cooling water system. It is necessary to describe the full range of resultant physical chemical, and biological parameters of these experiences which could be encountered throughout the annual operation cycle. Information on daily and seasonal fluctuations is of special importance in those waters subject to wide variation in water quality at the specific site. Other data pertinent to the evaluation of environmental impact of the location or intake structure in question should be included even though not specifically listed.

The following data are required for adequate description of sites located in either fresh or marine water bodies:

1. Site location and layout

   A. Location of additional intake structures - Smaller scale map showing locations of intake structures, associated cooling water systems, and other pertinent discharges related to surrounding shore and water features in a 50-mile radius.

   B. Site Plan - Larger scale map with topographic and hydrographic data depicting specific location of structure in the water body. Data required includes:

      - Topographic details

      - Hydrological features (see U.S. Department of Commerce, National Ocean Survey Charts, where available), including depth contours

      - Water body boundaries

      - Affected water body segment

      - Location and description of other cooling water intakes in water body segment

      - Existing site with topographic and hydrological features as changed by proposed intake structure construction and operation (where applicable)

2. Meteorology (when hydrodynamic modeling is performed)

   - Air temperature, maximum, minimum, mean-monthly

   - Rainfall, monthly

   - Solar radiation kcal/m^2 /day {average/month for the annual cycle)

   - Wind speed and direction, prevailing winds identified as to seasonal patterns

   - Other relevant site specific data

3. Additional stresses on water body segment

   - Location of existing or planned point sources of potential adverse environmental impact

   - Summary of impacts associated with existing or future stresses (and citations to more extensive analyses, such as 316(a) demonstrations, impact statements. NPDES permits, etc.)

4. Cooling water intake structure

   A. Structure

   - Location with respect to cooling water system

   - Location in water body, horizontal and vertical (including skimmer walls)

   - Configuration including canals; and channels; detailed drawings

   - Capacity

   - Screening devices (behavioral and physical)

   - Fish by-pass and handling facilities

   - Average and maximum approach and thru-screen water velocities, by depth

   - Flow rates and frequency of occurrence correlated with load characteristics

   - Location, amount, and duration of recirculation water for deicing or tempering

   - Other relevant system-specific data

B. Pumps

- Design details (location in structure. configuration of blades, and housing)
- Revolutions per minute
- Number, capacities, and planned operating schedule
- Pressure regimes in water subjected to pumping
- Velocity shear stresses in pumping
- Sites of potential turbulence and physical impacts

C. Biocides

- Location of introduction in system
- Description and toxicity of biocide used
- Timing and duration of use
- Concentrations of biocide in various parts of cooling water system and receiving waters

D. Thermal experience

- Tabulation of annual ambient temperatures, thermal addition to cooling water of various operating capacities, and resultant time- temperature experience of organisms subjected to entrainment in cooling water system

E. Other relevant data on cooling water circulation system

- Dissolved gases
- Suspended solids and turbidity
- Other wastes and chemicals added
- Size of condenser tubes, heat exchanger components, water piping, siphon pits, etc.
- Maintenance procedures, use of heat treatment or deicing procedures

5. Plant Data

- Age and expected lifetime
- Capacity factor and percent of time at fractional loads
- History of intake model

IX. SOURCE WATER INVOLVEMENT

The physical interaction of the intake and the adjacent water body forms a base for assessment of biological impact by relating the behavior and motion of local organisms with the flow of water around the site and into the intake structure. To determine this involvement with the intake, it is desirable to identify the type or types of circulation which will be dominant in the water body, and to establish a program of monitoring currents and other relevant hydrological and physical parameters of the system. Predictive tools, such as computer models, are useful in assessment of impact, and for delineation of the area of potential damage. The approach outlined here is suggested for new plants having high potential impact when sufficient model accuracy is obtainable. The approach may be useful for other plants as well, as discussed in the impact assessment section below. The modeling program should be discussed with the Agency I advance of application and should include sensitivity analysis.

1. Hydraulic Features

The dominant modes of circulation in the water body are frequently identified in the literature and include channel flow, tidal and wind-driven currents, estuary or gravitational circulation, littoral drift, and others. The local currents (or velocity structure) can be modified by bathymetry and transient atmospheric conditions, and contain local features such as eddies; their importance can be modified by their effect on biological processes. It is also useful to identify interface zones if several current regimes or physical processes are evident. Large water withdrawals and discharges can be sufficient to modify existing hydraulic patterns enough to create new biological habitats.

A program of monitoring the currents and other relevant physical parameters is desirable for the study of source water involvement. Whenever possible, historical data should be used to identify the expected circulations and guide the selection of instrument stations, although as data comes in, a re-evaluation of the monitoring program is useful.

The relevant parameters are water current, speed and direction, wind speed and direction, tides or local water levels, temperature, and water density. Salinity data are important in an estuarine environment.

The spatial distribution of instrument stations is usually indicated by the circulation regime and local bathymetry, but is best organized to provide input to and verification data suitable for a predictive hydraulic model of the currents. Vertical spacing of instruments should be sufficient to identify any important depth variation in the circulation.

The use of a hydraulic model requires several other specific inputs to provide realistic prediction of currents in the area. Typical parameters include:

1. boundary geometry;
2. bottom topography;
3. bottom friction coefficients;
4. latitude of the area;
5. tides or water levels at open boundaries;
6. river flows;
7. temperature and salinity;
8. wind stress;
9. power plant cooling water flow rates; and
10. other point source flow rates.

A significant period of time (two weeks) might be chosen for a continuous (burst sampling) monitoring sequence to sense periodic variations in the circulation, and another program to sample changes on an annual (or longer) cycle. Careful recording of placement and start times is recommended.

The instruments chosen should be durable and resistant to fouling. The accuracy may be influenced by the scale of the parameters but for water level should generally be at least ± 0.01 ft. and, for current speed and direction, + .15 knots and ± 5.0° respectively. For temperature and salinity ± 0.1° C and ± 0.1 0/00 respectively can be expected. Special instrumentation for water current sensing may be necessary at threshold speeds.

An instrument calibration program is necessary to insure accuracy. Redundant marking of station locations and provision for recovery of unmarked instruments should be made.

Computer models as predictive tools represent the best available predictive tools and are useful in assessing water use and biological impact. Mathematical models solve the equations of water flow and are used to predict currents in the water body. Another model (of water quality) can be developed in tandem to solve the equation of mass flow and used to predict mass or concentrations of organisms under influence of the currents.

The selection of the appropriate model is guided by the circulation regime and the geomorphology of the water body. A number of mathematical models of tidal flow are available, and these can be extended to include channel flow. For example, the Leendertse 8, 9 type square-grid models for tidal currents and larvae transport have been used. Finite-element models are being developed for tidal circulation, and may have advantages in certain areas. For river-bay situations, the channel-junction model may have special advantages. Three-dimensional models such as those described in references 12,13, and 14 may be appropriate. A comprehensive summary of available models has been compiled by Gordon and Spaulding. The rationale for selection of the particular set of models should be justified by either emphasizing their suitability or by demonstrating a lack of other sufficient models.

Verification of model output should be made for both current and organism concentrations. Data from the monitoring survey are useful for verifying the current model while the biological sampling program may be used to verify the motion of organisms. Dye studies may also be useful in model verification.

Means for delineating study area and source water involvement may vary from intuitive judgments to highly sophisticated predictive models. The most logical measures, consistent with the local conditions should be determined.

2. Probability of Entrainment

The zone of potential involvement of the cooling water intake varies with species of organisms and time but the core concept is the determination of probability of entrainment. The predictive models are useful for mapping probability isopleths. This could be done by the simulation of drifters with the hydraulic model, or the spread of mass from point sources into the intakes with the concentration model. Drogue or dye studies could be used for verification. Drifters, drogues, or dye may, however, be poor analogs for the organisms in question. As a consequence, any study of this nature must be accompanied by justification that adequate adjustment is being made for differences in behavior between the organisms and their mechanical analogs.

A map of probability of entrainment would be useful in delineating the outline of the area of potential involvement by a rational analytical method. For example, the computer hydraulic model for currents could be used to simulate the flow of drogues in the region. A simulated release of drogues (several per hour) would be carried out until all drogues have either been entrained or have crossed the model boundaries and left the area. The ration of entrained drogues to the total gives the probability of entrainment. A repetition of this procedure for other release points gives a field distribution of probability.

An alternate method is to simulate mass transport from a field of points, wherein the ratio of mass entrained to the total released gives the probability. This method could be verified by use of dye studies.

In environments likely to exhibit density stratification, or in which the organisms stratify, it may be necessary to use multi-level sampling for all parameters, and consider stratification in the models chosen. Wind effects are more likely to be important in shallow water. The spatial changes in parameters in stratified systems are likely to be larger, so this must also be incorporated in a sampling program.

Obviously, models are highly desirable and the probability isopleth concept is a powerful analytical tool. However, the time and costs involved will not be justifiable in many situations.

X. BIOLOGICAL SURVEY REQUIREMENTS (NEW INTAKES)

The purpose of the biological survey is to provide a sufficient and valid data base for rational assessment of environmental impact related to the location, design, construction, and capacity of a cooling water intake structure, prior to a final siting decision.

Due to the possibility of extreme fluctuations in overall abundance of the species from year to year and shifts within a study area of its centers of abundance, several years study may be required. A term of three years is suggested as permitting an "exceptional" year to be detected and criticized on the grounds that events in so short a span cannot be understood in the context of long term trends. A period of 15 to 25 years is one in which many cyclic biological phenomena become evident, but a preliminary study of this length will be out of question, except as it can be gleaned from historical data. A one-year pre-operational study is generally of limited value but may be acceptable for preliminary agency determination's in situations where substantial historical data can be presented and the intake can be represented as having low potential impact.

Data collected must be sufficient to permit analysis and reduction to assessment criteria which will be useful in reaching a judgment on the existence and extent of an adverse impact suggested measures for data reduction and analysis, which are included in this manual, should be reviewed prior to developing a survey program.

Designation of species of the critical aquatic organisms to be studied is the first step in a sequence of operations for the subsequent biological survey. The species selected mayor may not be the same as the Representative Important Species designated in connection with demonstrations under section 316(a) of the Act. Differences would depend on the greater or lesser effect on such species of thermal discharges or intakes. Once species and source water involvement are known, the sampling methodology, survey study areas, and temporal characteristics of the survey can be determined to suit the organism selected, location, and characteristics of the intake structure. Each survey should be designed on a case-by-case basis recognizing the uniqueness of biota-site-structure interrelationships.

Biological surveys should be designed and implemented to determine the spatial and temporal variability of each of the important components of the biota that may be damaged by the intake. These surveys could include studies of mesoplankton, benthic fish, pelagic fish, benthic macroinvertebrates, phytoplankton, zooplankton, benthic infauna and boring and fouling communities where appropriate. Generally, the majority of critical aquatic organisms will be fish or macroinvertebrates.

Once the occurrence and relative abundance of critical aquatic organisms at various life stages has been estimated, it is necessary to determine the potential for actual involvement with the intake structure. An organism may spend only a portion of its life in the pelagic phase and be susceptible to entrainment. Migratory species may be in the vicinity of the intake for short segment of the annual cycle. Some species are subjected to intake structure effects during life history stages. For example, winter flounder larvae are found in the ichthyoplankton during their pelagic larval phase, and are susceptible to being entrained. During later life stages, as juveniles and adults, they are vulnerable to impingement. Both entrainment and impingement must be considered in subsequent impact assessment. Knowledge of the organism’s life cycle and determination of local water circulation patterns related to the structure are essential to estimating an individual species’ potential for involvement.

Once involvement is determined, actual effects on those organisms can be estimated. As a first order approximation, 100 percent loss of individuals impinged, entrapped, or entrained could be assumed unless valid field or laboratory data are available to support a lower loss estimate.

The final step is to relate loss of individuals to effects on the local population as impacted by intake structure location, design, construction and capacity. It is important to consider the means for data reduction and analysis in the early stages of survey design. Data must be amenable to biostatistical analyses, as utilized in arriving at the judgment for best available technology to minimize adverse environmental impact.

1. Sampling Design

It is necessary at the outset to clearly define the objectives of the sampling program and the area to be sampled. Quantitative sampling studies are designed to estimate numbers per unit and/or volume. The major considerations in these studies are:

- The dimension of the sampling unit. In general the smallest practical sampling unit should be used.

- The number of sampling units in each sample. The size of samples for a specified degree of precision can often be calculated if there is some preliminary sampling information. If not, preliminary sampling should be executed before extensive programs are developed.

- The location of sampling units in the sampling areas. Stratified random sampling is often preferable to simple random sampling. Strata can be unequal in area or volume, with sampling units allocated in proportion to the area or volume.

The survey effort should be intensive for at least the first year after which, based on first year results and historical data, lower effort programs could be justified. Survey data are usually of a time-series nature and, therefore, averages over time intervals within the series cannot be assumed independent. This situation limits the application of routine statistical procedures, Bartlett[17] and Quenoville.[18] Reference 19 is a recent example of the difficulties encountered when attempting to determine differences in portions of a time-series. The development of more powerful statistical methods for application to this type of data is necessary. It appears that only catastrophic impacts will be revealed to temporal comparisons of monitoring program data. Plant impact may be better revealed by spatial comparisons.

The discriminating power of surveys should be estimated prior to the implementation.

This can be done by design based on previously collected data at the site, or by assuming the variability of the system based on previous studies at similar sites. The expected discriminating power of the survey should be adequate for the purposes for which the data are intended.

2. Sampling Methodology

Recommendations on specific sampling protocol and methodology are beyond the scope of this document. The optimal methodology is highly dependent on the individual species studied coupled with site and structure characteristics. Some general guidelines are provided here. More specific details are provided in Reference 20.

Ichthyoplankton-Meroplankton Sampling

Sampling gear used should have known performance characteristics under the conditions in which it is to be used, or it will tested in comparison with a standard gear (such as the 60 cm. “bongo" net developed for purposes of ichthyoplankton sampling by the National Marine Fisheries Service MARMAP program).

When a new gear is introduced, data should be included on its efficiency relative to a standard gear. Gear should not be changed in the course of long-term investigations unless the comparative efficiencies of the old gear and the new can be satisfactorily demonstrated.

It is recognized that no sampling gear is, in practice, strictly quantitative and equally efficient in retaining different sizes of organisms.

A rationale for the choice of gear, mesh size, etc. should be developed for each sampling program. In most cases, lacking strong reasons to the contrary, adoption of a standard gear to permit comparisons with other investigations is recommended.

In general, replicate tows indicate that horizontal distribution of fish eggs and larvae and other planktonic organisms is uneven or patchy in character, and that vertical distribution not only of actively swimming forms but of eggs commonly shows some stratification. This typically varies over 24 hours due to the influence of water movement and changes in light intensity. Depth distribution of individual species of fish eggs may change during the course of development, and buoyancy may differ at different periods of the spawning season.

Night tows frequently produce larger catches and may show less variability than day tows for fish larvae in the same area. Both phenomena are related in part to differences in net avoidance under conditions of light and darkness. However, certain larvae may be altogether unavailable to the usual plankton sampling gear at some time of a diel cycle; for example, they may lie on or near the bottom by day, and migrate upward at night.

Night sampling must be considered in survey design as essential for an accurate picture of the numbers of ichthyoplankton actually present at a station, especially with regard to post- larvae and young juveniles. Sampling over the entire diel cycle should be conducted.

Characterization of the ichthyoplankton in a study area made exclusively from single tows at a series of stations is inadequate. Replication sufficient to show the typical variation between tows will be necessary, and it must be borne in mind that this may differ widely for different species, and may change over the course of a season. In reasonably homogeneous study areas, replicates can be taken at a subset of stations and the results applied to the rest. In certain circumstances, close to shore, or in the vicinity of the proposed intake, more rigorous error analysis is advisable, and this may require replication at each station. Determination of a suitable number of replicates will depend on characteristics at each site, and must be based on field studies. The most variable (patchy) of the critical species of ichthyoplankton under study at a given season will determine the number of replicates that are desirable.

Confidence limits for estimates of abundance must be based not only upon variation between tows at a given station, but must incorporate other sources of error, which include subsampling error (when aliquots of large samples are taken for lab analysis) and counting errors.

The ichthyoplankton-meroplankton sampling will generally re related to the impact of passing the organisms through the intake structure and associated cooling water system, i.e., entrainment.

Fishes and Macroinvertebrates

Sampling of fish and macroinvertebrates will be generally conducted in relation to the potential impact of entrapment and impingement. An exception would be juvenile and small fish of a size that would pass through intake screening rather than be caught upon such screens.

As previously noted, specific sampling methodology is detailed elsewhere.[20]

Some specimens taken from the screens may appear healthy; however, species-specific experiments with controls to assess the delayed mortality to these fish are required if less than 100 percent mortality is to be assumed.

Potential effects at proposed intake structures should make maximum use of existing data at operating structures to extrapolate involvement and mortality estimates to a new intake. Attention should be given to experiments which have statistically evaluated the effect of intake modifications on impingement-entrapment losses.

In cases where preliminary surveys indicate that the entrainment and entrapment-impingement losses may be high, it will be necessary to estimate the impact of these losses on the populations that will be involved. For each life stage susceptible to entrainment and/or entrapment-impingement, parameters necessary to adequately predict losses caused by power plant withdrawal include life stage duration, fecundity, growth and mortality rates, distribution, dispersal patterns, and intake vulnerability. These parameters can be either measured in the field or obtained from available literature. Estimates of equivalent adult stock loss on the basis of entrainment losses of immature forms requires a measure of natural mortality from immature to adult. For many if not most critical species, the natural mortality may be impossible to determine and the impact may have to be based on a reasonable judgment. Other data are required to project the long-term impact of the intake on the population and to include the population size, its age structure, and fecundity and mortality rates. These data can best be synthesized using mathematical models as discussed in section XII of this manual.

Zooplankton

Zooplankton sampling will generally be directed towards determination of entrainment impact. Zooplankton are essentially microscopic animals suspended in water with near neutral buoyancy. Because of their physical characteristics, most are incapable of sustained mobility in directions against water flow and drift passively in the currents.

In most cases, intake effects are of relatively short duration and confined to a relatively small portion of the water body segment because of short life span and regenerative capacity. Zooplankton, however, should not be dismissed from consideration without a preliminary assessment of the importance or uniqueness of the species' assemblage at the site.

Phytoplankton

Phytoplankton are free-floating green plants, usually microscopic in size, and are generally the main primary producers in the aquatic food web. Again, the potential cooling water intake structure impact on phytoplankton would be through entrainment. The short life-cycle and high reproductive capability of phytoplankters generally provides a high degree of regenerative capacity. In most cases, intake structure effects are of short duration and confined to a relatively small portion of the water body segment. Phytoplankton. however, should not be dismissed from consideration without a preliminary assessment of uniqueness or special importance of the species' assemblage at any particular site.

3. Follow-up Studies

Post-operational studies at new intakes will also be necessary in order to determine if the design, location, and operation, in fact, minimize adverse environmental impact and whether the model predictions utilized were realistic. Some suggestions for follow-up studies are available in section XI. However, the appropriate program at a new plant site should be determined in large part by the need for consistency with pre-operational study results.

XI. MONITORING PROGRAM (EXISTING INTAKES)

The study requirements necessary to evaluate losses of aquatic life at existing cooling water intakes can be considered in two separate steps. The first is assessment of the magnitude of the problem at each site through direct determination of the diel and seasonal variation in numbers, sizes and weights of organisms involved with operation of the intake. When losses appear to be serious, as a second step it may be necessary to conduct studies in the source water body if there is a need to evaluate such losses on a water-body-wide or local population basis. However, before requiring such studies it should be realized that the natural variability of biological systems, the difficulty of separating other stresses on population size, and difficulties in obtaining accurate and precise samples of the biota may mask the environmental impact from cooling water system operation. The magnitude of sampling variation is high and may range from 20 to 300 percent of the probable numbers.[36] Thus, effects of the intake structure often cannot be identified above this "background noise" unless they are considerably greater. For many species, adverse environmental impact may be occurring at levels below that which can be "seen" with the standard survey and analytical techniques. Such field studies therefore will be extensive and difficult to conduct, and will generally require several years of data collection, all without certainty of results. Such studies should not be required unless absolutely necessary for the best technology available decision and then only to address specific questions. Because of the above difficulties, it may be necessary to base a determination of adverse impact on professional judgment by experienced aquatic scientists.

In evaluating data from the following studies, it is often desirable to assume "worst case" conditions where all organisms which pass through the intake suffer 100 percent mortality. If the magnitude of the numbers precludes such an analysis, specific mortality estimates may be necessary.

The following study requirements are based in part on the recommendations contained in the reports of the Lake Michigan Cooling water Studies Panel’s and Lake Michigan Cooling Water Intake Committee:[45]

1. Sampling Program - Entrapment-Impingement

The objective of this sampling program is to document the magnitude of losses of fish life at operating cooling water intakes. Since it is possible to obtain a complete daily count of fish which are impinged by collecting the intake screen backwash material, this intensity of collection should be considered for application through one calendar year. The data which result will most accurately reflect the total annual loss by species. This approach does ignore possible delayed mortality to organisms involved with the intake structure but not impinged on the screens long enough to be killed. If total entrapment-impingement mortality is estimated by sampling from the screens, the sampling scheme must consider day-night and seasonal differences.

If a less than complete daily count over a year is utilized, daily sampling once every four days for one year is suggested as the lowest effort which will be acceptable from the standpoint of allowing for reliable loss projections reflective of the plant's operation. Both more and less intensive sampling approaches may also be justifiable based on apparent impact, intake data, spawning periods, and other site specific and seasonal considerations. The 4-day interval for sampling is based on observed variability in daily impingement losses.

For example, in a study of the Central Illinois Light Company's E.D. Edwards Plant on the Illinois River, numbers of fish impinged varied from 7,000 on July 18 to 500 on July 19. On August 23, 1,500 fish were impinged versus 30,000 fish on August 26. Not all plants exhibit such wide variations in numbers of fish impinged; however, until intensive sampling is completed at a site, total loss figures will be subject to question.

Collection of the samples can usually be accomplished by inserting collection baskets in the screen backwash sluiceway. These baskets should have a mesh size equal to or smaller than the intake screen mesh.

The following data should be collected during the sampling period:

A. Plant operating data required:

   1. Flow rate;

   2. Temperature (intake and discharge);

3. Time started, duration, and amount of warm water recirculated for intake deicing and thermal defouling;

4. Total residual chlorine contained in recirculated water during condenser chlorination;

5. Current velocity at intake(s) over the range of water volumes used in plant operation (representative measurements or calculated values may suffice);

6. Number of times screens are operated between sampling intervals;

7. Tidal stage (where appropriate) and flow;

8. Salinity (where appropriate); and

9. Dissolved oxygen if intake withdraws water from an area (or strata) of potentially low oxygen content;

B. Data required from biological collections:

1. Species, number, length, weight, and age group (young of the year, yearlings, or adults} collected from the screens or representative subsamples when numbers of individual species collected are very large. Subsampling approaches should be approved in advance by the Agency;

2. Representative samples of each species for determination of sex and breeding condition;

3. Numbers of naturally occurring dead fish in the area ahead of the intake screening system should be estimated; and

4. Periodically conduct a test to determine the recovery rate of fish impinged on the screen. This can be done by spiking the screen with tagged dead fish and determining the proportion that are recovered in the screen backwash sluiceway.

2. Sampling Program - Entrainment

The following section describes investigations necessary to determine effects of entrainment of phytoplankton, zooplankton, benthos, fish, and shellfish at existing cooling water intakes. Such studies should generally concentrate on fish and shellfish unless the phytoplankton, zooplankton, or benthos are uniquely important at the site in question.

Fish and Meroplankton

The potential for damage to fish or shellfish populations by entrainment depends on the number of organisms that pass through the condenser system and on conditions experienced during passage.

Overall objectives of the study are to determine the species and numbers of fish and shellfish eggs and larvae drawn into and discharged from the cooling systems and, if necessary, determine the immediate and delayed effects of cooling system passage on these organisms.

A pump system is acceptable as the primary sampling method, provided it does not damage fragile organisms, and pumps are easier to automate and quantify than systems in which sampling is done with nets suspended in the cooling water flow.

Diel sampling is recommended because the numbers of organisms, even in areas known to be good spawning and nursery areas, typically have low concentrations, and their distribution in time and space is usually either changing rapidly or patchy as a result of natural conditions. Therefore, adequate representation of these organisms can usually only be obtained with continuous sampling throughout a diel cycle.

The actual volume of water to be pumped to provide an adequate sample is dependent on the densities of fish eggs and larvae in the water surrounding the cooling system intake structure. The sample volume should therefore be determined based on the least dense species of concern. If no *a priori* source water density data exists, then as large a sample volume as can be handled will be necessary. Once information is developed on the least detectable density for species of concern, sample volumes may be adjusted accordingly. This point is extremely critical to acceptance of the resulting data. If the sample volume is too small the study will be biased and show fewer organisms involved with the structure than actually exist.

Sample locations in the intake system should be located immediately ahead of the intake screens and when less than 100 percent mortality is assumed, at a suitable point in the discharge system. When less than 100 percent is assumed, samples at intake and discharge should be from the same water mass. At each location one sampling point should be located near the surface, one near the bottom, and one at mid-depth. If uniform organism distribution can be demonstrated, one sampling depth may suffice.

Sampling should normally be conducted continuously at a frequency (e.g.. every fourth day of plant operation) allowing the estimation of annual numbers of organisms with a 95 percent confidence interval which is ± 50%. More frequent sampling may be desirable during peak spawning seasons.

Sampling should continue over at least one year. Sampling in subsequent years may be deemed necessary based on the results of the first year of study.

Macroinvertebrates

The primary concern regarding the effects of entrainment on macroinvertebrates is-does entrainment affect the rates of mortality, growth or reproduction? Specific objectives are to determine the kinds and numbers of organisms entrained, to assess the effect of entrainment on their survival and reproduction, and to describe the seasonal and diurnal patterns of entrainment. Pumped samples are acceptable provided the pump does not damage fragile organisms. A pump which will transfer small fish without harm is often satisfactory for zooplankton and benthos. Non-toxic material should be used throughout the sampling system.

Nets used to concentrate zooplankton and benthos from the pumped sample should be metered, or the pumping rate should be timed to provide an accurate determination of the volume filtered. Samples should be taken in duplicate. If no vertical stratification of organisms is documented, duplicate mid-depth or duplicate integrated samples may be taken.

Sampling sites should be established in the forebay, immediately ahead of the traveling screens, and as close as possibly to the point of discharge.

Samples should be carefully concentrated in non-toxic containers and inspected microscopically for mortality and damage as soon as possible after collection.

Samples should be collected in the forebay and at the discharge during a 24-hour period at least monthly. Duplicate samples should be taken every 3 to 4 hours during the 24 hour survey.

Phytoplankton

Phytoplankton are susceptible to entrainment and possible damage in cooling water systems such that rates of mortality, growth, reproduction, and primary production are-affected. Studies to determine those effects should involve microscopic examination, measurement of chlorophyll concentrations, measurement of rates of primary production, and observations of cell growth and division. In most cases, effects are of short duration and confined to a relatively small portion of the water body segment. Phytoplankton, however, should not be dismissed from consideration without a preliminary assessment of uniqueness or special importance of the species' assemblage at any particular site. Special sampling methodology can be found in reference 20.

Zooplankton

Zooplankton sampling will generally be directed towards determination of entrainment impact by an intake structure. Zooplankton are essentially microscopic animals suspended in water with near-neutral buoyancy. Because of their physical characteristics, most are incapable of sustained mobility in directions against water flow and drift passively in the currents.

In most cases, intake effects are of relatively short duration and confined to a relatively small portion of the water body segment because of short life span and regenerative capacity. Zooplankton, however, should not be dismissed from consideration without a preliminary assessment of the importance or uniqueness of the species' assemblage at the site.

3. Follow-up Studies

A follow-up monitoring program is also necessary at existing plants to determine whether the approved intake in fact minimizes environmental impact. In cases where an existing intake has been approved, it would be expected that the monitoring program could be on a reduced level from that noted above. However, where significant changes in intake location, design, construction, capacity, or operation have taken place, a program comparable to the pre-operational one should be followed.

XII. IMPACT ASSESSMENT

The goal of impact assessment is to analyze and reduce biological survey data to a form easily conceptualized and understood in the context of best available technology to minimize adverse environmental impact of intake structure location, design, construction, and capacity. The following approaches are suggested for use, although their application will not be appropriate in each case:

1. Biostatistical Analyses

In general, the minimum reduced raw sample data should include the arithmetic meant the standard error (or the standard deviation), and the sample size from which these calculations were made.

If a large number of measurements or counts of a variable (e.g., species) are made, the data may be summarized as a frequency distribution. The form or pattern of a frequency distribution is given by the distribution in numerical form (as in a frequency table). However, the data is more clearly evident in a diagram such as a histogram (i.e., a graph in which the frequency in each class is represented by a vertical bar). The shape of a histogram describes the underlying sampling distribution. Known mathematical frequency distributions may be used as models for the populations sampled in the study, and the frequency distributions from samples may be compared with expected frequencies from known models.

The spatial distribution of individuals in a population can be described in quantitative terms. In general, three basic types of spatial distribution have been described. They are: a random distribution, a regular or uniform distribution, and a contiguous or aggregated distribution. The spatial dispersion of a population may be determined by the relationship between the variance and the mean, as well as by other methods. In a random distribution, the variance is equal to the mean. The variance is less than the mean in a uniform distribution, and it is greater than the mean in a contiguous distribution. In general, a Poisson distribution is a suitable model for a random distribution, a positive binomial is an approximate model for a uniform distribution, and a negative binomial is probably the most often used, among possible models, for a contiguous distribution.

Temporal and spatial changes in density can be compared statistically. Significance tests for comparisons of groups of data may be parametric when the distributions of the parent populations are known to be normal or nearly normal, from previous experience or by deduction from the samples. Often, non-normal data may be transformed into data suitable for such testing. Otherwise, nonparametric tests for significance should be applied.

2. Predictive Biological Models

Models used to simulate currents (circulation models) and the dispersion of constituents (concentration models) are becoming more available for use in assessing impact. These models, when soundly-based conceptually, can usually be verified against hydrographic data and, therefore, represent an important tool for considering the influence of a power plant on its surroundings.

Diverse population and community models can be developed, but the assumptions on which they are based are difficult to test and the parameters difficult to estimate. Some important parameters depend on long time series of data (tens of years) and no level of effort can offset the requirement of time. These problems with biological models can sometimes be overcome by making “worse case” assumptions and estimates, but this course may tend to produce a plethora of models indicating potential disaster. Nevertheless, models are a means of integrating the available information and the subjective underlying assumptions about a problem in order to produce the most rational answer based on the inputs. In this regard, some models may serve an important role in assessing impact.

As previously noted, hydrodynamic models in theory can be used to predict the source of water drawn through a power plant intake structure. This is done by simulating the movement of drifters or the dispersion of a constituent originating at a particular point in the area modeled. The simulation is carried out for sufficient time for most of the material to be transported to the point of the assumed intake structure where it is considered entrained, or for the material to be transported sufficiently far away from the intake structure so that it has little chance of future entrainment. This procedure must be repeated or performed simultaneously) for numerous constituent origins and for numerous initial flow or tidal conditions. These results will provide isopleths of entrainment probabilities surrounding a proposed intake structure. The isopleths can be compared with the biological value zone to assure that the plant will not draw a high percentage of entrainable organisms from highly productive areas. Various intake locations may be considered to minimize impact. In practice, it might be very expensive to 'calculate the probability of entrainment isopleths (source area) of an intake structure because a large area may have to be modeled and considerable computer time expended.

For a given critical aquatic organism, it may be possible to use hydrodynamic models to estimate the percent reduction in annual recruitment resulting from entrainment of pelagic early life stages. When the source of pelagic eggs and/or larvae is known, the dispersion of this biological material around the study area and the consumption by a plant intake may be simulated, indicating the reduction in recruitment that will result. In this procedure, entrainment mortality 1s separated from natural mortality. If natural mortality is density dependent, the impact of power plant entrainment will be overestimated or underestimated when entrainment mortality is estimated separately from natural mortality.

The method described above for estimating the reduction in recruitment resulting from entrainment can only be applied, as stated, for closed systems. For the more common situation where some larvae are dispersed out of the modeled study area (area for which circulation and dispersion is simulated) additional assumptions are required. If it is reasonable to assume that once organisms have been transported out of the modeled study area they have a low probability of contributing to support of the adult population of the study area. Then the dispersion of organisms around the study area for a period of time equal to the length of the species' vulnerable pelagic phase can be simulated with and without the entrainment impact of a simulated power plant. By comparing the number of organisms remaining in the area, the reduction in recruitment to later stages of the life cycle may be estimated. This approach was used in reference 24. The approach ignores the possible impact of a reduction in the number of organisms dispersed outside the modeled study area and other supporting populations.

For open systems where pelagic entrainable organisms are dispersed out of a modeled study area, it is often necessary to consider the effect of a plant on biological material transported across the model boundaries and into the system. If sufficient information is available, the concentration of organisms at the boundaries may be input to the model as boundary conditions. Again, the situation with and without a plant intake could be simulated and the number or organisms remaining in the modeled study area could be compared in order to derive an estimate of the reduction in recruitment. The reduction in recruitment will change as the population of the modeled study area is reduced and becomes more dependent on the input of biological material across the boundaries

Hydrodynamic models are of little value for predicting the entrapment-impingement mortality rate suffered by populations. In the case of separate but similar intakes, this rate can be estimated after one is operational. Results may then be extrapolated to estimate the impact of additional intakes. Predictive models for entrapment-impingement are under development but have not yet been validated.

When the reduction in recruitment because of entrainment and the impingement mortality rates have been estimated for a critical aquatic organism, it is useful to assess the long-term impact on the local population. The dynamics of the population can be simulated by a compartment model with organisms distributed into compartments according to age. Each compartment is assumed to suffer non-power plant related mortality. Aging is simulated by advancing organisms to the next older compartment. Age-specific fecundity rates are used to determine the total biotic potential of the population. The recruitment to the youngest compartment is a function of total egg production. The effect of entrainment, entrapment, and impingement are incorporated by reducing the predicted recruitment by the appropriate proportion and adding age-(or size-) specific entrapment-impingement mortality to the age compartments. Computer simulations of the future dynamics of the population based on the compartment model with and without the plant can be compared

Such simulations require knowledge of the life table for the species being considered. Life table information for some species may be based on the literature. It may be possible to supplement this information with knowledge gained from field studies. The age- (or length-) fecundity function and the egg production-recruitment relationship must also be known. The latter may be of three forms: (1) recruitment as a linear function of egg production, (2) recruitment as a density dependent function of egg production,[3, 25] or (3) recruitment independent of egg production. The choice of the appropriate egg production-recruitment relationship and estimation of parameters must be based on the available historical information on the species. At least twenty years of data is probably required to make such a decision. In the absence of enough data, the assumption of a linear egg production-recruitment relationship is appropriate. Note that for a linear egg production-recruitment model, there is only a single equilibrium condition, and any plant related mortality is likely to disturb this equilibrium.

If the population is not isolated, exchange with other populations may be modeled. The results of mark and recapture experiments may be useful for estimating exchange rates.

The methods for assessing impact described in this section are useful but of unknown validity. Host assessments based on biological models have yet to be field verified. Development of predictive models for assessing impact should be encouraged but only after full consideration of the difficulties involved, the expense compared to the reliability of results, and the dangers of a 'worst case" analysis.

3. Community Response Parameters

The populations of all species in a given area or volume are defined as a community. Although the term "community" is considered a useful concept in delineating the group of interacting species in an area, it is believed to be a subjective entity. Thus, for specific studies and tests of hypothesis, the composition of the community must be strictly defined.

Community response parameters, such as changes in structure, have sometimes been studied and estimated by certain multi-variate classification techniques. Various measures of species diversity or association coefficients have also been employed to measure community response to perturbations.

In estimating community diversity, the most widely used indices are those based on information theory. When the sample of species abundances may be considered randomly taken from an ecological community or subcommunity, the Shannon index (also referred to as the Shannon-Wiener or Shannon Weaver Index) may be used. If the sample may not be considered a random set of species abundances taken from a larger species' aggregation of interest, then the Brillouin Index should be use. Either index may be computed with computational ease[46] and, in either case, the logarithmic base used must be stated.

The shortcomings of all existing indices of species' diversity and the biological phenomena which may influence these values should be recognized. References 28, 29, and 30 should be consulted for further explanation of diversity indices and their utility.

For the purposes at hand, the phrase “classification of communities” is utilized for processes that sort species into groups, and it includes both discrimination and clustering. In general, discrimination techniques begin with *a priori* conceptual distinctions or with data divided into *a priori* groups. Then one should proceed to develop rules which separate data into these *a priori* categories. Clustering techniques, on the other hand, use *a priori* selection of a measure of similarity, a criterion, and a class description to find inherent empirical structure in data, i.e., clusters. Clustering does not use an externally supplied label and involves finding derived data groups which are internally similar. A good review and summary of various discrimination and clustering procedures is provided in reference 31.

The aquatic environment can often be stratified in some way, such as by depth, substrate composition, etc. It is suggested that such stratification be done and that tables showing the frequency, or density, of each species at each environmental stratum be compiled. These tables are analogous to the distribution curves made in a gradient analysis, and are considered a natural and useful description for species association data. It is suggested that these tables be the basis for certain multivariate methods of data analysis for spatial and temporal variability, such as cononical variate analysis described in reference 33. In addition, for these data which now contain _a priori_ groupings, the linear discriminant function may also be successfully utilized for testing the differences among environmental strata using multiple measurement or counting data.

4. Biological Value Concept

The concept of establishing relative biological value zones in the water body segment impacted by a cooling water intake structure could be a useful approach in determining best technology available for intake design, location, and operation to minimize adverse environmental impact. The principal use of this concept is in delineating the optimal location within the water body for minimum impact on the biota potentially involved with the specific intake structure.

The essence of this concept is in establishing biological value of various zones for the water body segment (or other defined area) within which the intake structure is to be located. A judgment of value is made for the representative important species considering type of involvement with the intake (entrapment, impingement. entrainment) and the numbers of each which are adversely impacted. Results are summed up by species, seasonally or annually, and represented by graphical means to depict areas of the water body highly important to the species and, conversely, areas of low relative value, thus potentially, favorable intake structures.

Methodology. The following methodology for using the biological value concept is based on methods developed and utilized in community planning studies as described in reference 34.

Use of the biological value concept would require acceptance of the reasonableness of several basic premises:

1. There are areas of different concentrations of representative important species within the water body segment comprising potential sites for an intake structure.

2. Areas of biological concentrations can be expressed in terms of relative value to perpetuation of representative important species populations in the water body segment.

3. The area of zone of least biological value, expressed in relative terms of population densities, would be the optimal location for an intake structure in order to reduce adverse environmental impact.

This is not a precise method because of inexactness of differentiating relative value between species and difficulties in comparing importance of loss between eggs, larvae, and adults. Also, it is assumed that the adverse impact on the populations of critical aquatic organisms is significant to some degree and therefore, it is desirable to minimize this impact, thus giving importance, to best available intake locations.

If one can determine that one species is more important than another, one can weigh it in some way. If not, least concentrations of critical aquatic organisms in anyone location indicate its intrinsic suitability for intake structure location.[34]

A step-by-step procedure could include:

1. Select critical aquatic organisms; and

2. Divide water body segment into spatial compartments (use hydrological model).

For each species and spatial compartment:

1. Determine life stages potentially involved with intake and type of involvement (entrapment, impingement, entrainment);

2. Estimate numbers of organisms involved at representative times during the annual operation cycle;

3. Estimate numbers of those involved that are lost (determine percent survival or mortality of those entrained or impinged) on an annual basis;

4. Estimate conversion ratios to express eggs and larvae lost in terms of number of adults (this is a value judgment and assumes the loss of one egg is not as important to survival of the species as the loss of an adult};

5. Develop the data matrix for construction of the biological value level overlay charts (Table l);

6. Construct transparent overlays for each species on chart of water body segment. Areas of different impact in terms of organisms lost due to involvement with the intake structure could be color-coded; e.g., areas of most value could be dark gray; areas of least value, clear. Generally, three levels of value will suffice;

7. Superimpose overlays for all representative important species on chart to obtain compositive value, indicated by relative color, for all spatial compartments in the water body segment; and

8. Analyze graphic display of relative value and identify light-toned areas as most favorable intake sites, heavy areas as least favorable.

The methodology is intended to be flexible. Various shades of different colors could indicate comparative value between selected species or variations in density with depth. The value grades could be expressed in terms of their relation to populations of critical aquatic organisms in the overall water body to provide insight on importance of the specific segment studies to the whole system.

The biological value concept for analyzing survey data in the determination of best technology available to minimize adverse environmental impact appears to have the principal application in selection of the minimal impact zones for locating the intake structure. The usability of the concept is, of course, data-dependent. As noted, it is not precise, but at least integrates multiple factors and presents a defined indication of suitability for location of an intake structure in the affected water body segment.

Three-dimensional computer graphic techniques can also be applied to portray spatial and temporal distribution of biological data.[10, 35]

Time-series graphs can be useful in depicting the dynamic nature of occurrence and abundance of a designated species during the annual operating cycle of the intake structure. The principal application would appear to be in the determination of the optimal location of the intake structure. Also, graphic representations of the biologically predicted mathematical model output could assist in more clearly depicting intake structure impact on populations of Representative Important Species (RIS).

Table 1

Example Data Matrix

(SPECIES 1)

DATA SHEET

(SPATIAL COMPARTMENT [A])

TYPE OF INVOLVEMENT	Organisms Involved			% Lost (If assumed other than 100%)			Numbers Lost			Calculated Equivalent Adult Loss				Value Grade
	Eggs	Larvae	Adult	Eggs	Larvae	Adult	E.	L.	A.	E.	L.	A.	Total	I, II, III
Entrapment														
Impingement														
Entrainment														
Total Effect														

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